IMMINGHAM EASTERN RO-RO TERMINAL

Appendix 10.2 - Navigation Simulation Study (tracked)

Document Reference 8.4.10(b).1

PINS Reference – TR030007

November 2023

Document Information

Document Information		
Project	Immingham Eastern Ro-Ro Terminal	
Document Title	Appendix 10.2 - Navigation Simulation Study (tracked)	
Commissioned by	Associated British Ports	
Document ref	8.4.10(b).1	
Prepared by	IERRT Project Team	
Date	**Version**	**Revision Details**
11/2023	01	Deadline 6

HR Wallingford
Working with water

Style Definition: Normal (Web)

Project Sugar - ABP Humber - Immingham East Development

Navigation Simulation Study - July 2022

DJR6612-RT005-~~R04~~ R05-00

~~4 August 2022~~6 September 2022

Document information

Document permissions	Confidential - client
Project number	DJR6612
Project name	Project Sugar - ABP Humber - Immingham East Development
Report title	Navigation Simulation Study - July 2022
Report number	RT005
Release number	~~04~~05-00
Report date	~~4 August 2022~~6 September 2023
Client	Associated British Ports
Client representative	Oliver Peat
Project manager	Mike Parr
Project director	Dr Mark McBride

Formatted Table

Document history

Date	Release	Prepared	Approved	Authorised	Notes
6 Sep 2023	05-00	MPA	MMCB	MMCB	Minor revisions to track plots and run summaries
4 Aug 2022	04-00	MPA	MMCB	MMCB	Minor revisions
2 Aug 2022	03-00	MPA	MMCB	MMCB	Incorporating additional comment from client
1 Aug 2022	02-00	MPA	MMCB	MMCB	Revised following client comment
29 Jul 2022	01-00	MPA	MMCB	MMCB	Issued for comment

This unsigned document has not been formally checked and authorised for release. Until it has been reviewed and signed off by qualified technical staff within HR~~-~~ Wallingford, this document must not be considered complete or final.

Summary

As part of the development of Immingham Outer Harbour, ABP are considering additional RoRo berth capacity to the east of the Immingham lock entrance.

HR Wallingford have been supporting ABP and have previously conducted a series of navigation desk studies and real time navigation simulation studies in support of this work.

The work was undertaken between November 2021 and April 2022 and is described in detail in HR Wallingford's reports (References ~~1~~1 to ~~4),~~4), with a summary provided in Section ~~1.2~~1.2 of this report.

The work described in this report was an additional navigation simulation study that examined the effects on navigation of significant tidal effects, in the vicinity of the new infrastructure, that can occur in the upper lever of the water column during certain flood tides.

The study provided additional evidence to support the conclusions of the previous simulation work. Specifically, the following conclusions from the previous study remain valid, based on the additional runs conducted using a modified flow model and a 300°T orientation for the berths:

- The proposed berths are acceptable for safe manoeuvring of a 240m long RoRo vessel.
- Manoeuvres to and from the berths have been demonstrated in the most challenging tidal flows and with concurrent winds with up to a mean of 32.5 knots. On initial operations the berths should be limited to manoeuvres with wind speeds up to a maximum of 30 knots until confidence is developed in the operations of the particular vessels that will use the berths.
- The design width between the 2 new jetties, which is reduced to 120m between fender lines, remains practicable with an orientation of 300°T and considering the modified draught-averaged peak and mean spring flows.
- Manoeuvring operations at the berths will need to be supported by small, relatively agile and powerful tugs. The study found that 2 tugs of approximately 25m in length with at least 60t BP, will be required to maintain operations when the wind is above 25 knots. Although further sensitivity testing will be required to provide advice on the use of tugs in less severe conditions, as this will also depend on the occupation of adjacent berths, the strength and direction of the wind, type of vessel and state of the tide, it is expected that least one tug will be required in certain situations, particularly on a strong ebb with an adjacent moored vessel, when the wind is above 20 knots.
- Considering IOT, based on the additional runs using a modified flow model, the new infrastructure orientation and a 104m long tanker (with a deadweight of 6,535t), the following were concluded:
  - Navigation to and from the IOT6 and 8 jetties will not be adversely affected by the proposed size and location of the new RoRo infrastructure at an orientation of 300°T.
  - Existing manoeuvring practices will need to be updated, taking into account the new infrastructure and reduced sea room to the south of the IOT finger jetty. However, safe manoeuvring was demonstrated in peak spring flows and winds up to 30 to 35 knots.
  - Arrivals by vessels in their ballast state during strong south westerly winds will need to be restricted to a limit of 25 knots gusting to 30 knots. Arrivals above this limit may result in a hard landing. At low water there is potential for the new infrastructure to obstruct the flow which can create unusual flow patterns towards IOT8. Pilots and masters will need to be made aware of this effect.
  - Considering the size of the design vessel, it is considered likely that during southerly winds, a combination of sheltering and funnelling could increase the complexity of berthing at IOT6 and 8. This is a well understood effect and is experienced and managed by pilots elsewhere on the Humber.

Additionally:

- The runs indicated that departures from Berths 2 and 3 during the peak spring (7.2m range) ebb tides should be subject to a wind limitation of 25 to 30 knots, due to the reduced effectiveness of bow thrusters and the tugs. Berth 1 will be less constrained due to the additional manoeuvring space.
- A comparison between berth orientations of 300°T and 306°T during strong ebb flows confirmed the conclusion of the quasi-static force analysis, that the optimum orientation is 300°T.
- It should be noted that manoeuvring to and from the new infrastructure will be challenging particularly at the limiting conditions. Overall manoeuvres will require precise positioning of the vessel, tugs and their attitude to the tidal flow and the wind. Mitigating the inherent risks in these manoeuvring operations will require a robust training solution.

As the project develops it will be necessary to run more specific simulations to identify the detailed recommended procedures and limits for all classes of vessel, in a wider range of environmental conditions. This will be particularly important in developing appropriate limits for an initial operating capability.

Contents

Appendices

Tables

Figures

1 Introduction

1.1 Context

As part of the development of Immingham Outer Harbour, ABP are considering additional RoRo berth capacity to the east of the Immingham lock entrance.

HR Wallingford have been supporting ABP and have previously conducted a series of navigation desk studies and real time navigation simulation studies in support of this work.

The work was undertaken between November 2021 and April 2022 and is described in detail in HR Wallingford's reports (References ~~1~~1 to ~~4),~~4), with a summary provided in Section ~~1.2~~1.2 of this report.

The work described in this report was an additional navigation simulation study that examined the effects on navigation of significant tidal effects, in the vicinity of the new infrastructure, that can occur in the upper lever of the water column during certain flood tides.

1.2 Background

1.2.1 Part 1 Nov – Dec 2021

The initial navigation assessment studies used tidal data provided by ABP (Reference 6) to provide an understanding of the flows at Immingham East Harbour. Based on that data, the navigation desk and preliminary simulation based studies provided advice on the design, orientation and optimum dredged area for the proposed RoRo facility.

The flow data provided by ABP was also used to update and verify an HR Wallingford flow model for the area of Immingham East Harbour, which was required to be used in the navigation simulation work. This work is described in Reference ~~1.~~1.

1.2.2 Part 2 and 3 Dec 2021 – April 2022

The second part of the navigation assessment studies included the design, delivery and analysis of a full real time navigation study to understand the navigation operations of the proposed RoRo facility, and its effect on existing adjacent berths. The study was conducted in 2 stages, with the first using a 3 day navigation simulation session in December 2021 to investigate manoeuvring at the proposed development. This was followed by an additional short navigation simulation session in April 2022. This work is described in References ~~2~~2 and ~~3.~~3.

1.2.3 Part 4 – Jun 2022

Subsequently, it became clear that a significant tidal effect can occur in the upper lever of the water column during certain flood tides, in the vicinity of the new infrastructure.

Consequently, HR Wallingford were asked to:

- Consider the effect of new tidal data and make recommendations regarding the optimum orientation of the proposed infrastructure, based on analysis of the forces expected during manoeuvres at the berth;
- Recommend the additional real time navigation simulation work required;
- Produce a modified flow model representing the draught-averaged peak and mean spring flows.

Reference 4 covers this work, which concluded that:

- The optimum orientation of the RoRo berths at East Immingham outer harbour is 300°T/120°T;
- A real time navigation simulation study with the proposed orientation of 300°T/120°T should be used to check that the findings from earlier studies are not significantly affected by the new data;
- The study should include simulation runs which look at the sensitivity of berthing with the new orientation and with maximum flow speeds and variance of flow angles.

ABP commissioned HR Wallingford to undertake the additional real time navigational simulation study recommended, which is described in this report.

1.3 Aims and objectives

The real time navigation simulation study that is described in this report was designed to:

- Confirm that the conclusions regarding operations at the new infrastructure agreed during the Dec 2021 navigation study remained sound considering:
  - The RoRo facility orientated at 300°T/120°T;
  - Using draught- averaged flow models for peak and mean spring tides;
  - The limiting wind conditions established in Dec 2021 (NNE 30 to 35 knots and SW 30 to 35 knots);
  - A design vessel - 237 m Jinling RoRo model;
  - Towage provided by 24m 70t BP ASD tugs.
- Confirm that the conclusions regarding navigation to and from IOT 6 and 8 established in Dec 2021and April 2022 navigation study remined sound considering:
  - The RoRo facility orientated at 300°T/120°T;
  - Using draught- averaged flow models for peak and mean spring tides;
  - The limiting wind conditions established in Dec 2021 (NNE 30 to 35 knots and SW 30 to 35 knots);
  - A design vessel – 104m model of Thun Grace;
  - Towage provided by Spurn sands 10tBP twin screw work boat and a 45tBP ASD tug.

2 Simulator configuration

2.1 Berth layout

A new berth layout drawing for the RoRo infrastructure, orientated on 300°T/120°T, was prepared by Jacobs and provided to HR Wallingford by ABP (Reference ~~5).~~5). This is shown in Figure 2.1.

HR Wallingford prepared a new simulation configuration incorporating the details from the new layout drawing, as shown in Figure 2.2.

A further layout was produced with the new infrastructure at 306°T. The berths were rotated from the 300°T orientation around the north east corner of the pontoon closest to IOT8 (see Figure 2.1). The simulated infrastructure layout is shown in Figure 2.3.

The berths are numbered from north to south Berth 1, Berth 2 and Berth 3 (see Figure 2.1).

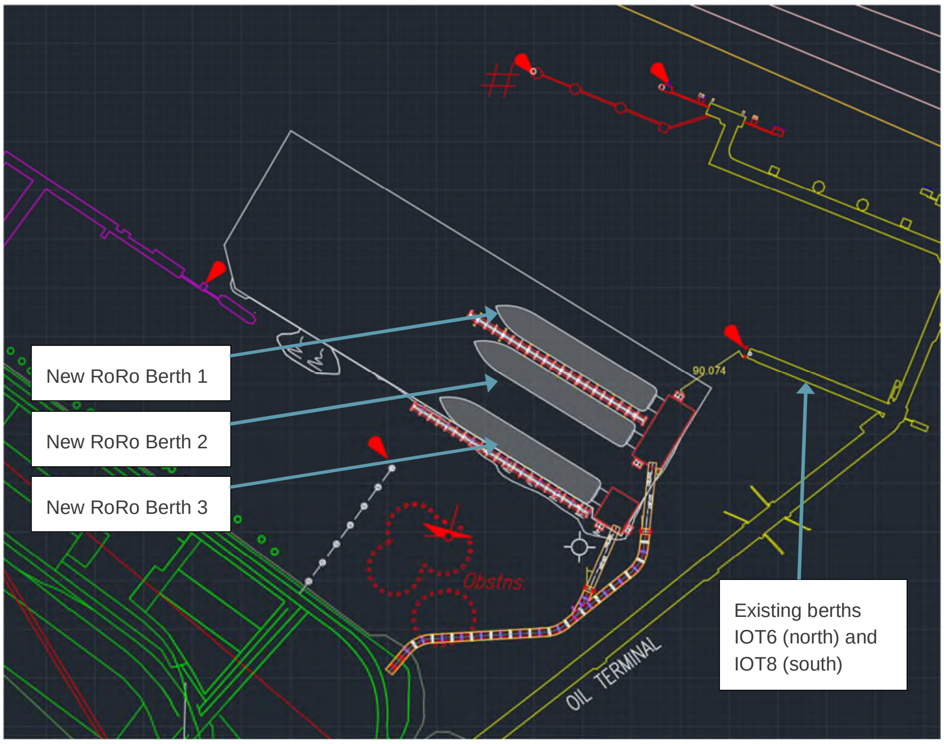

Figure 2.1: Detail from Jacobs drawing showing the new infrastructure at orientation 300°T/120°T

Source: Reference 48

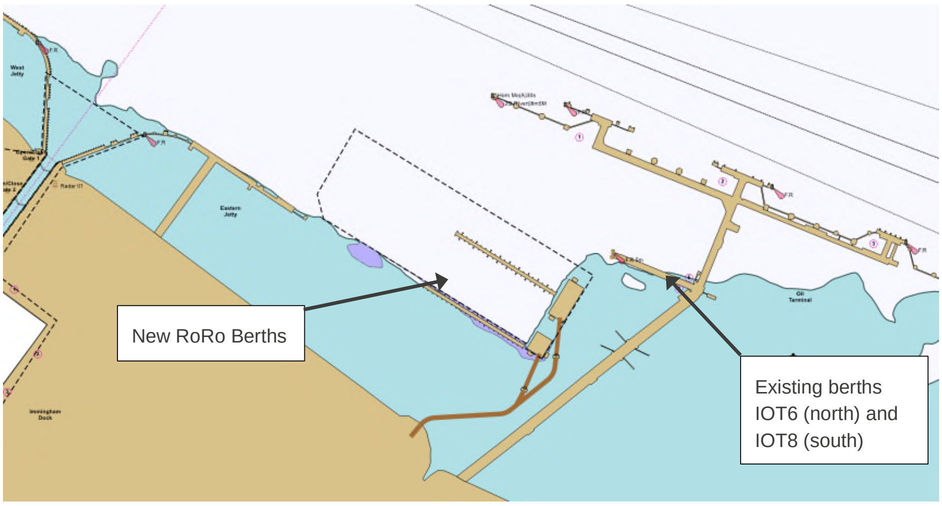

Figure 2.2: Simulator layout showing RoRo infrastructure at 300°T orientation

Figure 2.3: Simulator layout showing RoRo infrastructure at 306°T orientation

2.2 Environmental conditions

2.2.1 Wind and wave conditions

Wind and wave conditions were selected ,based on the same assumptions used in the previous studies.

The two maximum wind conditions established for the study from the observations provided by ABP Humber were therefore as follows:

- SW winds up to 30 knots (about 12.5 m/s) with gusts up to 35 knots (about 17.5m/s);
- NE winds up to 30 knots (about 15 m/s) with gusts up to 35 knots (about 17.5m/s).

The proposed facilities at Immingham East will benefit from their sheltered location in the Humber and are not expected to experience significant wave activity, especially with regard to navigation of the size of vessels operating and those providing assistance at the new berths. Consequently, wave effects were not considered further.

2.2.2 Current and bathymetry

For the earlier navigation assessments, the currents at the site were represented based on a 2D, depth averaged model and depth averaged observed currents from an Acoustic Wave and Current Profiler (AWAC) located in the area (Reference 6).

Early indications from the ABP Humber Pilots were that the modelled flow directions were different to those they experienced in the estuary. Further discussions and investigations of the data showed that there was noticeable differences in current direction from the depth averaged to the near surface flows. Consistent three dimensional current effects (other than transient effects) may occur at the site for two reasons:

- The location of the berths on a bend in the estuary. Near surface flows would be expected to be directed towards the ‘outside’ of the bend, whereas near bed currents would more closely follow the channel;
- A longitudinal salinity gradient will enhance the near surface currents in the ebb direction and suppress them in the flood tide direction.

The balance of these effects, and their impact on currents experienced by the vessels, are likely to vary with the strength of the tidal currents, tidal level and seasonal effects on fresh water input to the estuary.

To overcome these issues a 3D flow model (using the TELEMAC-3D modelling system) was used to simulate the three dimensional current effects, including that of salinity. The 3D model used 6 layers with one at the surface, one at the bed and the remaining 4 at 25%, 50%, 75% and 90% of the distance above the bed.

The model was validated by running with the existing bathymetry and comparing with a portion of the AWAC data from November 2019, covering a set of spring tides. The current data was reanalysed to provide an average over the top 6m, which excluded the very top 1m and thus represents the top 7m of the observed currents, i.e. the part of the water column that will affect the project design vessel. The comparison of the observed currents and those from the upper layers of the model is shown in Figure 2.4.

The figure demonstrates the ability of the model to correctly replicate the variation in direction of the flood tide currents, as they move from 295°T to 315°T as the tide approached high water. The balance of high ebb currents to supressed flood tide currents was also simulated.

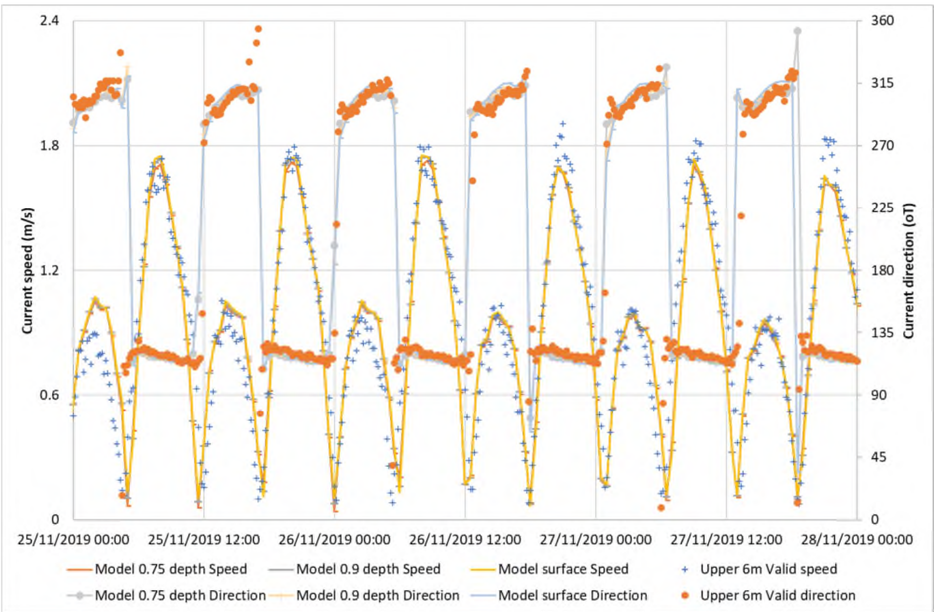

Figure 2.4: Comparison of observed and modelled currents in the upper water column

Following the successful data comparison, the model was updated to include the project infrastructure and the associated dredging to -9mCD at the berths to -6mCD at the site of the pontoons. The additional drag associated with the new piled elements of the berths was also added. The two pontoons were included as depressions in the water surface to the required pontoon draught. The updated model was run for two periods to provide input to the simulation, as follows:

- Tidal range of 6.5m representing a mean spring;
- Tidal range of 7.3m representing a peak spring tide.

To provide input to the simulation, currents from the 3D model results were averaged over the 7m draught of the project design vessel. Figure 2.5 and Figure 2.6 show snapshots of the simulated currents in the top 7m of the water column for the mean spring tide case. Currents at times of peak ebb current and peak flood are shown. Figure 2.7 and Figure 2.8 show equivalent results for the peak spring tide case.

Current magnitude and direction, water depth and bathymetry data were extracted from the model and input into the simulation on a grid with the following layout:

- Origin: 522,650mE, 413,700mN;
- Grid size: 5m;
- No. of columns and rows: 1,025 x 2,275;
- Rotation: 48.4° (measured anticlockwise from the x-axis).

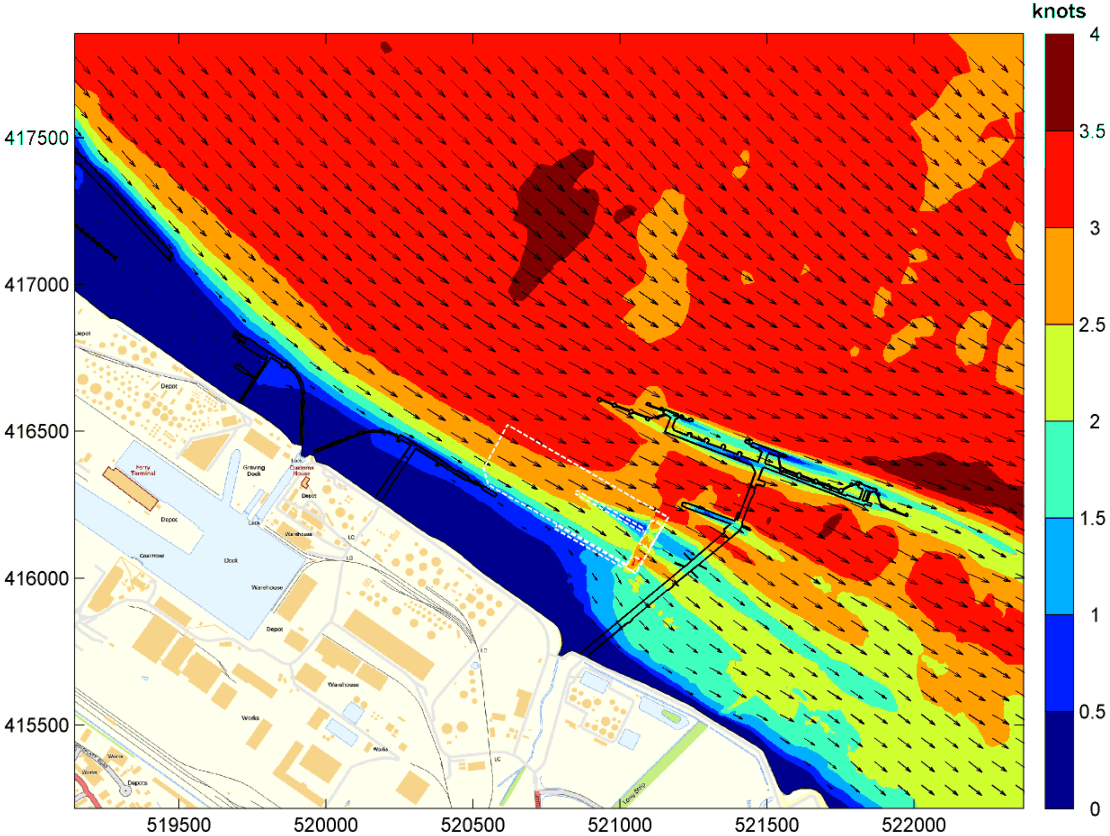

Figure 2.5: Modelled mean spring currents at time of peak ebb tide

Background contains OS data © Crown copyright (2022)

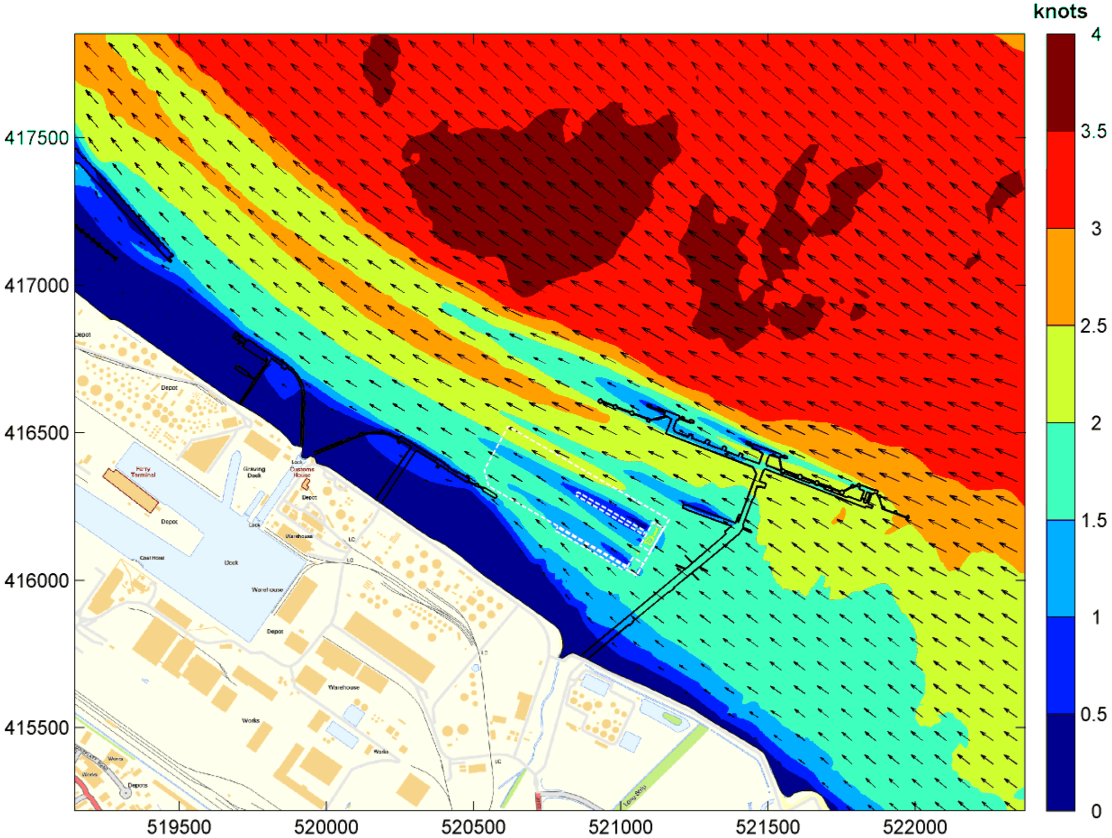

Figure 2.6: Modelled mean spring currents at time of peak flood tide

Background contains OS data © Crown copyright (2022)

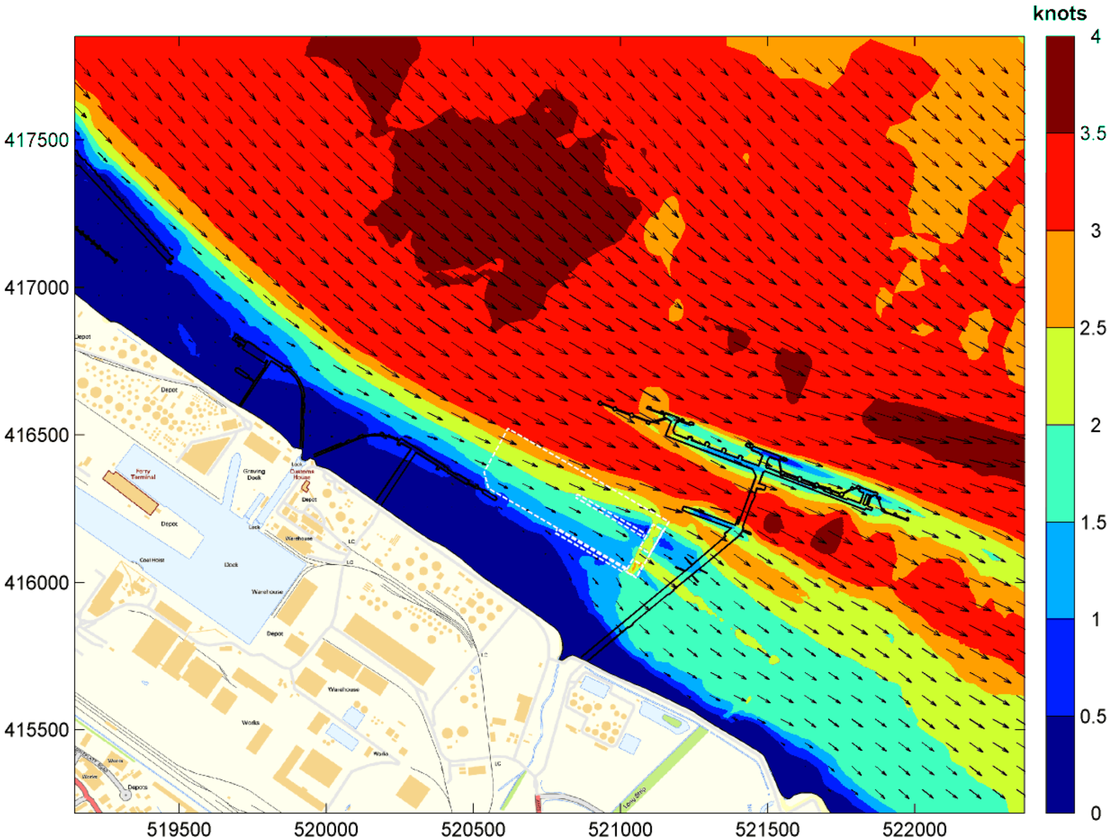

Figure 2.7: Modelled peak spring currents at time of peak ebb tide

Background contains OS data © Crown copyright (2022)

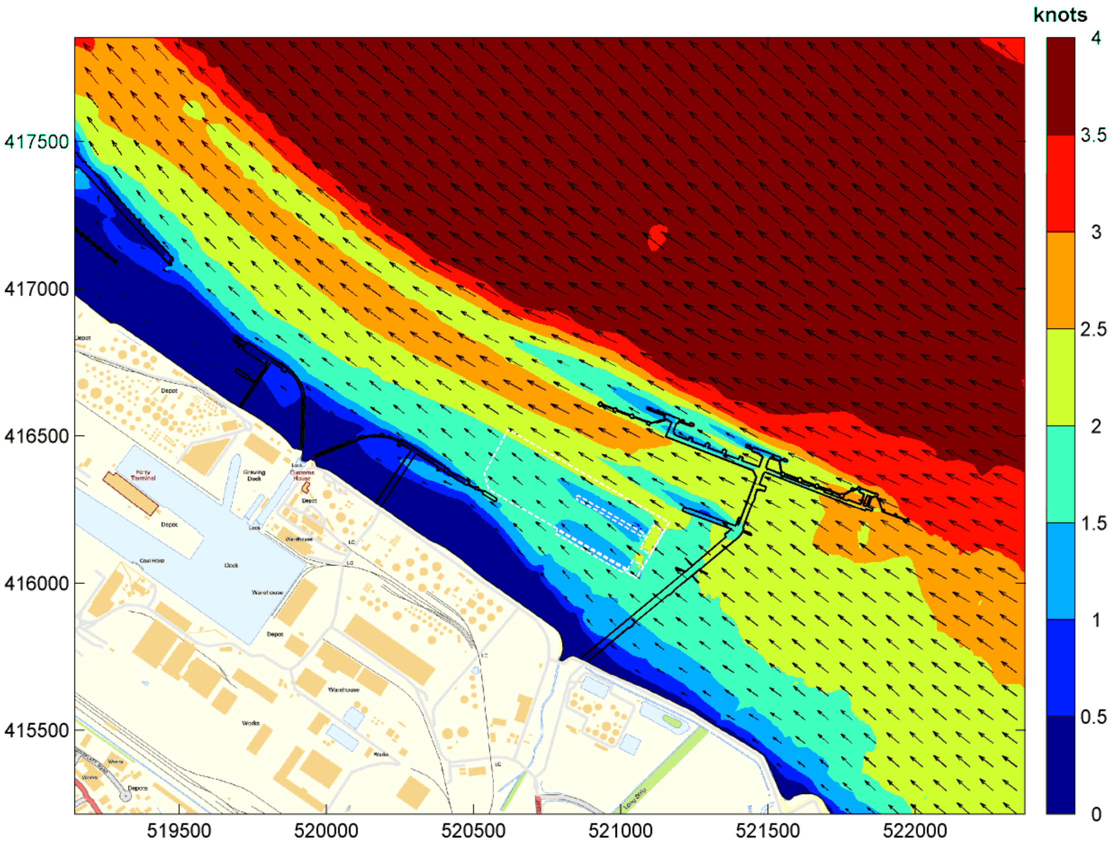

Figure 2.8: Modelled peak spring currents at time of peak flood tide

2.2.3 Current and bathymetry simulated

The bathymetry was represented in the simulator as shown in Figure 2.9, with the 10m contour in black.

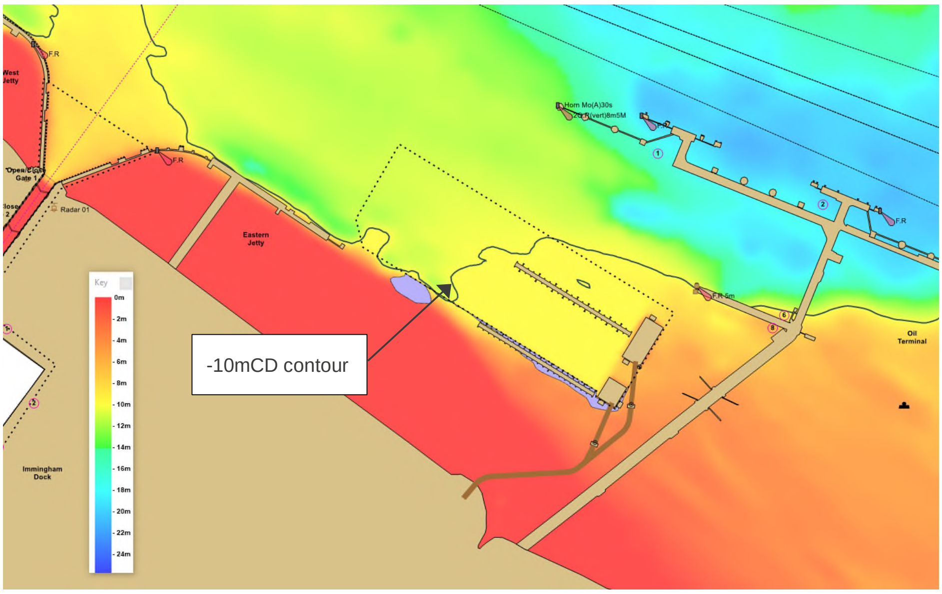

Figure 2.9: View of bathymetry as represented in the navigation simulation

The basis for selecting the critical point in a complex set of tidal cycles for the simulation is explained in further detail in Reference 4. In summary, a statistical analysis of the collected data was used to deduce the worst case point in each tidal cycle, based on a combination of flow direction and speed. The study concluded that there were 4 critical conditions to consider during the simulation as follows (with the numbers in brackets being the 7m draught-averaged AWAC recorded values for the tidal state described):

- Maximum flow during mean spring ebb – this represented the strongest flow during an ebb that would be regularly experience at the berth (119°T, 3.6 knots).
- Maximum flow during peak spring ebb – this represented the strongest ebb flow that would be seen over a year at the berth (122°T, 4.0 knots).
- Strong flow combined with strong variation of direction from 300°T during the mean spring ebb – this represented the most awkward flow based on strength and direction expected at the berth (307°T, 2.0 knots).
- Maximum flow with peak spring flood – this represented the strongest ebb flow that would be seen over a year at the berth (298°T, 2.2 knots).

In addition, there were 2 main tidal ranges considered in the simulation:

- Mean spring flow based on a range of 6.5m;
- Peak spring flow based on a range of 7.2m.

The peak spring flows were scaled by a factor of 1.15 to make a small correction for flow speed of the model compared with the AWAC data. This increased the maximum ebb flow rate from 3.5 knots to 4 knots at the AWAC buoy location.

Figure 2.10 to Figure 2.15 show the tidal characteristics of the peak and mean spring ranges as simulated.

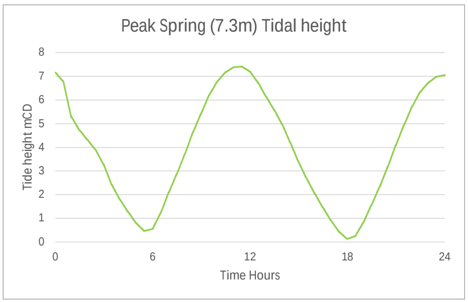

Figure 2.10: Peak spring tidal height as simulated

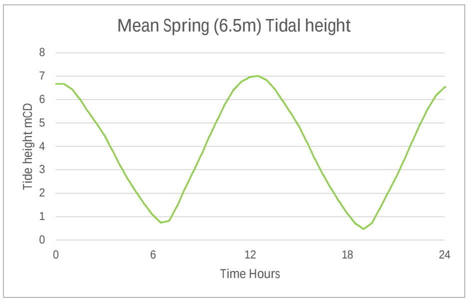

Figure 2.11: Mean spring tidal height as simulated

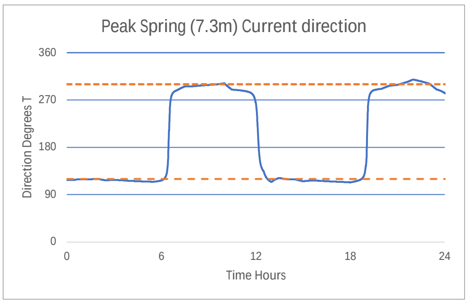

Figure 2.12: Peak spring current direction as simulated – with berth orientation 300°T/120°T shown as dashed orange line

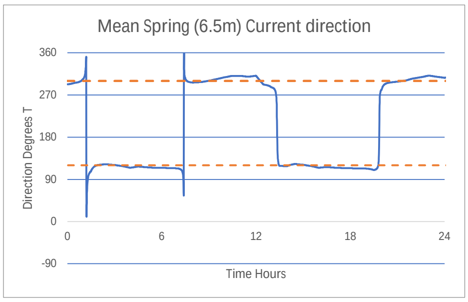

Figure 2.13: Mean spring current direction as simulated – with berth orientation 300°T/120°T shown as dashed orange line

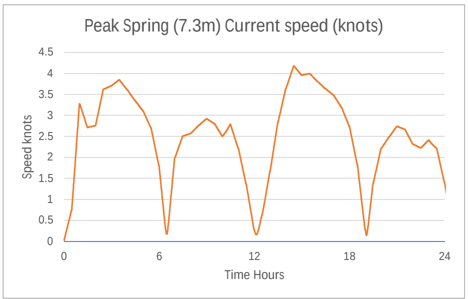

Figure 2.14: Peak spring current speed as simulated

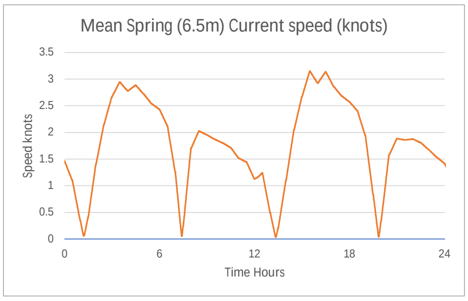

Figure 2.15: Mean spring current speed as simulated

The 7m draught-averaged flows are shown in Figure 2.16 to Figure 2.19. In these the red vertical line shows the point in the modelled tidal cycle that was deemed to be the closest in terms of variance from the orientation of the jetty and speed, to the measured values, and was therefore used during the simulations. As previously mentioned, the peak spring flow speed was scaled by a factor or 1.15 from the modelled magnitude to provide a better fit.

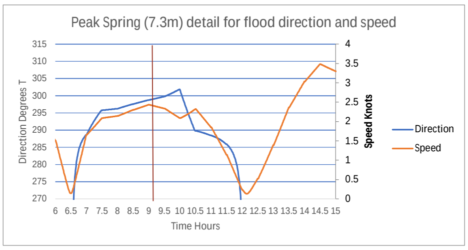

Figure 2.16: Peak spring flood for 7m draught-averaged flow model

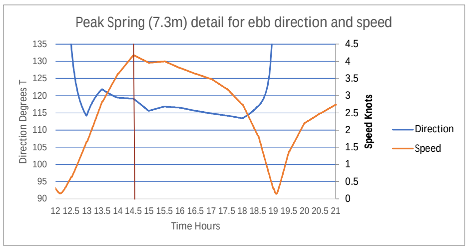

Figure 2.17: Peak spring ebb for 7m draught-averaged flow model

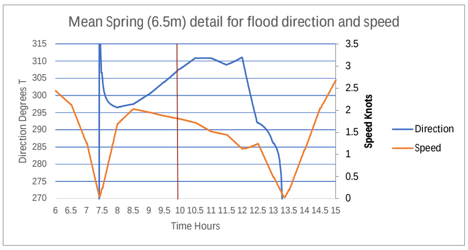

Figure 2.18: Mean spring flood for 7m draught-averaged flow model

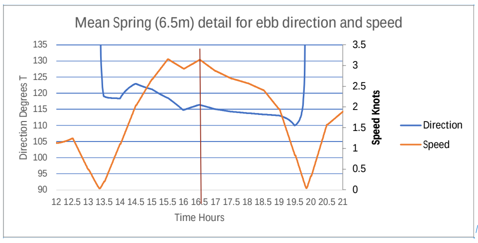

Figure 2.19: Mean spring ebb for 7m draught-averaged flow model

Commented [MP1]: Source file info: \\hrw-uk.local\projects\live\djr6612$\3_technical\Sim Flows\Mean and Peak Spring tidal curves for 7 m draught averaged flows.xlsx

With the RoRo berths aligned on 300°T, Figure 2.20 and Figure 2.21 show the flow vectors during peak spring flood for the period used in the simulation.

During the flood the flows are slightly setting towards Berth 2 and away from Berth 1.

During the ebb the flows between Berths 2 and 3 are generally parallel to the 300/120°T orientation of the berths, but there is some divergence away from Berth 1.

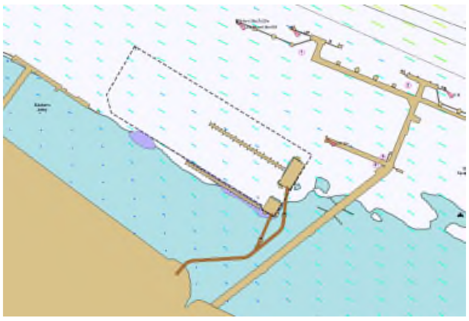

Figure 2.20: Peak spring flood flows as simulated

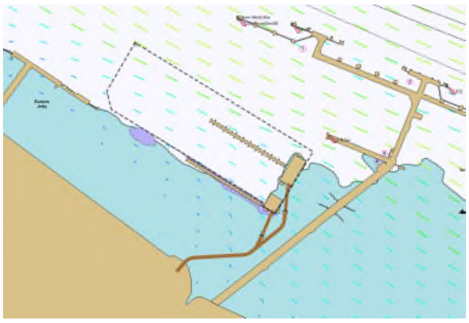

Figure 2.21: Peak spring ebb flows as simulated

Figure 2.22 and Figure 2.23 show the flow vectors during the mean spring flood for the period used in the simulation.

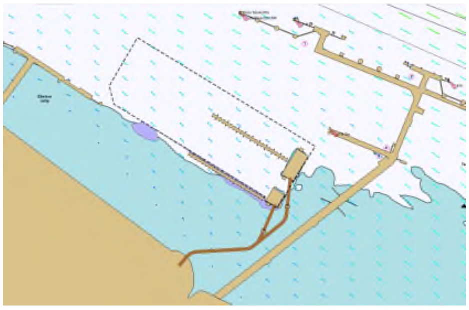

Figure 2.22: Mean spring flood flows as simulated

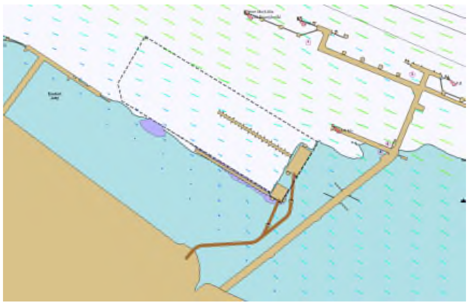

Figure 2.23: Mean spring ebb flows as simulated

An additional setup, with the berths orientated on 306°T/116°T, was created and used for 3 runs with ebb flow conditions. The current vectors are shown in Figure 2.24 and Figure 2.25, for the mean and peak spring conditions, respectively.

Figure 2.24: Mean spring currents - 306°T orientation

Figure 2.25: Peak spring currents - 306°T orientation

2.3 Design vessels

There were 3 design vessels used in this simulation study, which were also used in the previous work (References 2 and ~~3):~~3):

- 237m long RoRo ferry, for manoeuvres to the new berths;
- 104m long products tanker, based on the vessel 'Thun Grace', for manoeuvres to the adjacent IOT berths;
- 91.5m long tanker, based on the vessel 'Thames Fisher, for manoeuvres to the adjacent IOT berths, and used in just one run to repeat a manoeuvre from the study described in Reference 3.

A further design vessel was also considered, based on the Stena E-Flex Class vessel, but there was not sufficient data, or ship master experience available at the time of the study, for an adequate ship manoeuvring model verification process to be completed. Therefore the study continued to use the 237m long RoRo vessel, which is similar in size and was considered to provide a good representation for manoeuvring in the river Humber based on previous work undertaken for ABP.

The tanker ('Thun Grace') ship manoeuvring model was updated for the study to take into account wheelhouse poster and pilot card data that was provided by APT. In particular, this new information revealed a change in rudder type which was incorporated into the model. The rudder was upgraded from a standard spade rudder to a high lift rudder with a flap. The upgraded rudder offers improved manoeuvring and control performance throughout the speed range.

It was determined during the simulation session that the Pilots considered the ship manoeuvring model of the tanker to be more stable when turning and manoeuvring down-current. This will be further investigated by HR Wallingford and provides an opportunity to collect more data. Nevertheless, the ship manoeuvring model was conservative for the purposes of the study and the effect was managed such that it had no significance in terms of assessment of the new infrastructure's location and orientation.

The manoeuvring characteristics for the 237m RoRo ferry model that was used are provided in Table 2.1, with those for the 104m long products tanker, 'Thun Grace', shown in Table 2.2.

2.4 Tug support

2.4.1 Towage for 237m RoRo

For the simulation runs involving the 237m long RoRo vessel, which required tug support, a tug manoeuvring model of a 70tBP 2411 ASD tug, based on the tug 'Superman' was used, This had also been used extensively in previous simulation studies on this project. This model is fully described in Reference ~~2.~~2.

The tug model was controlled by a professional tug master from a separate tug bridge simulator that was integrated with the ship bridge simulator used for the design vessels.

2.4.2 Towage for 104m products tanker

For runs involving the 104m long products tanker, a ship manoeuvring model that was representative of the work boat, the 'Spurn Sands', was used. This had been used in the previous work and is fully described in Reference 2.

The work boat was restricted to 10tBP and could only be used to push. This vessel was centrally controlled by the Simulator Operator in response to the Pilot's commands.

Further tug support was made available using a 45tBP ASD tug, representative of the type of towage presently used at IOT in stronger winds. This tug was again operated by a professional tug master from a separate tug bridge simulator that was integrated with the ship bridge simulator. Details of this tug are available in Reference ~~4.~~4.

The same settings and considerations for tug control and effectiveness were as used in the previous studies, as described in References ~~2 and 3.~~2 and 3.

Table 2.1: Vessel characteristics for the 237 m RoRo design vessel

Characteristic	Unit	237m RoRo	
Ship type		RoRo	
Length overall	m	237.4	
Length between perpendiculars	m	233	
Beam overall	m	33	
Distance bridge to stern	m	74.5	
Draught forward	m	7	
Draught aft	m	7	
Block coefficient		0.634	
Displacement	t	35,000	
Propulsion			
Main engine type		2 x MAN BW 8S50ME-C9.5	
Engine power (total)	kW	23,600	
No. of propellers, type		2 x CPP	
Bow thrusters	t	65.6	
Stern thrusters	t	none	
Rudder type		Becker twisted flap	
Max rudder angle	°	65	
Manoeuvring engine order		**RPM**	**Speed (knots)**
Full Ahead		100	19.2
STOP		0	0
Full Astern		100	- 16.3
Windage			
Windage lateral	m²	6,200	
Windage frontal	m²	1,208	
Wind speed (knots)		**Beam wind force (t)**	
15		23	
20		40	
25		63	
30		90	

Table 2.2: Vessel characteristics for the 104m long products tanker design vessel (Thun Grace)

Characteristic	Unit	104m x 15m products tanker	
Ship type		Products tanker	
Length overall	m	103.46	
Length between perpendiculars	m	98.35	
Beam overall	m	15	
Distance bridge to stern	m	15	
Draught forward	m	3.5	
Draught aft	m	4.9	
Block coefficient		0.787	
Displacement	t	5,000	
Propulsion			
Main engine type		CAT MAK 6M25	
Engine power (total)	kW	2430	
No. of propellers, type		1 x CPP	
Bow thrusters	t	4	
Stern thrusters	t	none	
Rudder type		High lift with flap	
Max rudder angle	°	35	
Manoeuvring engine order		**RPM**	**Speed (knots)**
Full Ahead		100	13.3
STOP		0	0
Full Astern		100	- 8.0
Windage			
Windage lateral	m^2	894	
Windage frontal	m^2	190	
Wind speed (knots)		**Beam wind force (t)**	
15		3	
20		6	
25		9	
30		13	

Table 2.3: Vessel characteristics for the 91.5m long products tanker (Thames Fisher)

Characteristic	Unit	91.5m long products tanker	
Length overall	m	91.5	
Length between perpendiculars	m	85	
Beam overall	m	15.5	
Distance bridge to stern	m	20	
Draught forward	m	6	
Draught aft	m	6	
Block coefficient		0.76	
Displacement	t	6,000	
Propulsion			
Main engine type		Ruston 8RK270M	
Engine power (total)	kW	30,000	
No. of propellers, type		1 x CPP	
Bow thrusters	t	3.5	
Rudder type		Standard	
Max rudder angle	°	35	
Manoeuvring engine order		**RPM**	**Speed (knots)**
Full Ahead		160	12.0
STOP		0	0.0
Full Astern		125	-7.6
Windage			
Windage lateral	m²	436	
Windage frontal	m²	134	
Wind speed (knots)		**Beam wind force (t)**	
15		2	
25		4	
35		9	

3 Navigation simulation

3.1 Simulation session

The real time simulation session for this study was carried out over four days, from 11 to 14 July 2022 and a total of 55 additional simulation runs were conducted. During this session a series of simulation runs were performed using one ship and one integrated tug bridge simulators at HR Wallingford's UK Ship Simulation Centre. The simulators presented experienced pilots and tug masters the visual cues and other information, such as the coastline, aids to navigation and port infrastructure, which they would experience when approaching a marine terminal. In this way the essential features of the human input can be retained.

As previously mentioned, in addition to the two integrated and interactively controlled bridge simulators used, centrally controlled tugs/work boats were used to assist or provide additional realism to the simulation.

Ship manoeuvring models of the design ships and tugs were available so that the pilots and tug masters could operate the vessels realistic during manoeuvres. In each simulation comprehensive manoeuvring information was recorded so that the environmental limits and the optimal manoeuvring areas could be evaluated in support of the study.

An additional series of runs were completed on 02 August 2022 to ensure that some inconsistencies noted in the recording of the data did not affect the original findings of this study.

3.2 Simulation Team

The Simulation Team for the session was formed of personnel representing ABP Humber, Stena, APT, NASH Maritime, SMS Towage and HR Wallingford, as shown in Table 3.1.

Table 3.1: Composition of the Simulation Team 11 to 14 July

Company	Name	Role & dates attended
HR Wallingford	Dr Mark McBride (MMCB)	Project Director
	Mike Parr (MPA)	Project Lead
	Siobhan Vaughan (SHV)	Simulator Operator
ABP Humber	Joe Smith (JS)	ABP Humber Ops - 12-14 Jul
	Daniel Prutton (DP)	ABP Pilot First Class - 11-14 Jul
	Andy Russell (AR)	ABP Pilot First Class - 11-12 Jul
Stena	Geert Jan Feringa (GJF)	Master Stena (PEC) - 11-14 Jul
	Bert Broek (BB)	Master Mariner, Marine Safety Superintendent - 11,12,14 Jul
APT	Neal Keena (NK)	Marine Superintendent - 13 Jul
Nash Maritime	Nigel Basset (NB)	Consultant - 13 Jul
	Sam Anderson Brown (SAB)	Consultant - 13 Jul
SMS Towage	Gareth Bonner (GB)	Tug Master - 11-14 Jul

Additional technical support was provided by HR Wallingford personnel during the study, as required.

The Simulation Team agreed all assumptions outlined in this report before the start of the session and collectively determined the result of individual runs and the overall direction of the session.

The Simulation Team for the additional runs on 02 August are listed in Table 3.2.

Table 3.2: Composition of the Simulation Team for the additional runs on 02 August

Company	Name	Role
HR Wallingford	Dr Mark McBride (MMCB)	Project Director
	Mike Parr (MPA)	Project Lead
	Siobhan Vaughan (SHV)	Simulator Operator
	Ian Simpson (IS)	Master Mariner Pilot
	Gareth Bonner (GB)	Tug Master

3.3 Briefing and debriefing

The Pilots and Tug Masters were briefed on the simulation run conditions and objectives before each run. At the end of each run a debrief and discussion was used to capture their views, and those of any other members of the Simulation Team, the relevant aspects of which were recorded and are included in the discussion of results (see Section ~~4).~~4).

The discussion considered the events of the run and key conclusions, including any need for repeat runs or to alter the run schedule. Expertise from across the whole Simulation Team contributed to this important element of the study.

A daily summary discussion was held at the end of each simulation session day, in which the key conclusions arising from the simulation runs were agreed.

3.4 Grading of results

Each simulation run was graded by the Simulation Team as Successful, Marginal or Fail, according to the following evaluation criteria:

Successful

Standard manoeuvres:

- The ship remains under full control at all times without resorting to aggressive manoeuvring techniques;
- The ship stays within safe water areas with acceptable clearances to all port and other structures, and other berthed ships;
- Tugs are operating safely and within sustainable limits;
- For berthing manoeuvres, the ship ends the run alongside, or in such a position that lines would be ashore without appreciable difficulty, at zero speed, with an acceptable sway velocity and no appreciable yaw rate;
- For departure manoeuvres the ship exits smoothly, without risk of drifting onto port structures or other ships.

Emergency/failure situations:

- The ship is brought back under full control without encountering significant hazards, with the risk of only minor damage;
- The ship may leave the designated manoeuvring area boundaries, but still has acceptable under keel clearance and maintains acceptable clearances to other ships/structures throughout the recovery;
- Tugs are neither endangered nor asked to operate in an unsafe manner;
- The ship can be moved into safe, deep water or to a position suitable to anchor safely, where the equipment failure can be investigated / resolved.

Marginal

Standard manoeuvres:

- The Pilot considers the ship is at the limit of control during standard manoeuvres;
- The ship stays within the safe water area boundaries, but with unacceptable clearances;
- The ship clears all port structures, and other berthed ships, but with unacceptable clearances;
- Tugs are operating safely, but approaching their sustainable operating limits (e.g. being used at 100% power for more than 15 minutes);
- For approach manoeuvres, the ship ends up alongside, but may have a high approach velocity. The manoeuvre can be concluded, but minor damage may occur;
- On departure, the ship is manoeuvred off the berth but with some difficulty. The manoeuvre is completed with the potential for minor damage only.

Emergency/failure situations:

- The ship is at the limits of control during the recovery from the failure;
- The ship has marginal under keel clearance or marginal clearances to other ships/structures during the recovery;
- Tugs operate at the limits of safety;

- The ship is at the limits of controllability as it is moved into safe, deep water or to a position suitable to anchor safely, where the equipment failure can be investigated/resolved.

Fail — Standard manoeuvres:

- The Pilot loses control of the ship;
- The ship strays outside the safe water area boundaries and/or grounds;
- The ship either contacts, or has a near-miss with port structures and/or other berth ships;
- Tugs are required to operate in an unsafe manner, or exceed sustainable operating limits (e.g. being used at 100% power for more than 30 minutes);
- For approach manoeuvres, the ship cannot get alongside at all, or contacts the berth with sufficient force that severe damage may have occurred;
- On departure, the ship either cannot be manoeuvred off the berth, or encounters significant difficulty in manoeuvring, such that severe damage may have occurred.

Emergency/failure situations:

- The Pilot cannot regain control of the ship before the ship is endangered;
- The ship cannot be prevented from entering dangerously shallow water and/or grounds;
- The ship either contacts or has a near-miss with a known hazard, port structures, and/or other berth ships;
- Tugs are endangered or are asked to operate in an unsafe manner;
- The ship cannot be moved into safe, deep water or to a position suitable to anchor safely.

Aborted — The run was aborted for efficiency reasons, to save wasting any time, due to either:

- The initial manoeuvring strategy or approach/departure manoeuvre was deemed to be inappropriate right at the start, so the run would be bound to fail if continued; or,
- Because of the need to test aspects of the ship manoeuvring model.

3.5 Simulation run summary

Table 3.3). This detailed the set-up of the run including the vessel(s) used, the manoeuvre conducted, the tug configuration and the environmental conditions.

The additional runs conducted on 02 August are included as Runs 56 to 70.

Table 3.3: Simulation run summary

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
01	GJF	300°T	None	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	NNE 10	2.6 knots 121°T	Success
02	GJF	300°T	None	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	NNE 10	2.6 knots 121°T	Success
03	GJF	300°T	1 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	NNE ~~20 gusting 25~~22.5	2.6 knots 121°T	Success
04	GJF	300°T	1 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	SW ~~20 gusting 25~~22.5	2.6 knots 121°T	Success
05	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	NNE ~~25 gusting 30~~27.5	2.6 knots 121°T	Success
06	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	NNE ~~30 gusting 35~~32.5	2.6 knots 121°T	Success
07	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (6.4m)	SW ~~25 gusting 30~~27.5	2.6 knots 121°T	Success
08	GJF	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	SW ~~25 gusting 30~~32.5	2.6 knots 121°T	Fail
09	GJF	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	SW ~~25 gusting 30~~27.5	2.6 knots 121°T	Marginal
10	AR	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	SW ~~25 gusting 30~~27.5	2.6 knots 121°T	Success
11	DP	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	SW ~~30 gusting 35~~32.5	2.6 knots 121°T	Marginal
12	DP	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	SW ~~30 gusting 35~~32.5	2.6 knots 121°T	Marginal
13	AR	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	NNE ~~25 gusting 30~~27.5	2.6 knots 121°T	Success

Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
14	AR	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.4m)	NNE ~~30 gusting 35~~32.5	2.6 knots 121°T	Success
15	DP	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~20 gusting 25~~27.5	1.0 knots 301°T	Success
16	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~30 gusting 35~~32.5	1.0 knots 301°T	Aborted
17	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~20 gusting 25~~22.5	1.0 knots 301°T	Aborted
18	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~20 gusting 25~~22.5	1.0 knots 301°T	Aborted
19	GJF/ DP	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~20 gusting 25~~22.5	1.0 knots 301°T	Success
20	AR	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	SW ~~30 gusting 35~~32.5	1.0 knots 301°T	Success
21	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	NNE ~~25 gusting 30~~27.5	1.0 knots 301°T	Marginal
22	DP	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	NNE ~~25 gusting 30~~27.5	1.0 knots 301°T	Success
23	AR	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring - max. flood (7.25m)	NNE ~~30 gusting 35~~32.5	1.0 knots 301°T	Marginal
24	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 3	Peak spring - max. flood (7.25m)	NNE ~~30 gusting 35~~32.5	1.0 knots 301°T	Success
25	GJF	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Peak spring - max. flood (7.25m)	NNE ~~30 gusting 35~~32.5	1.0 knots 301°T	Success
26	DP	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Peak spring - max. flood (7.25m)	NNE ~~30 gusting 35~~32.5	1.0 knots 301°T	Success

Formatted ... [1]
Formatted ... [2]
Formatted ... [3]
Formatted ... [4]
Formatted ... [5]
Formatted ... [6]
Formatted ... [7]
Formatted ... [8]
Formatted ... [9]
Formatted ... [10]
Formatted ... [11]
Formatted ... [12]
Formatted ... [13]
Formatted ... [14]
Formatted ... [15]
Formatted ... [16]
Formatted ... [17]
Formatted ... [18]
Formatted ... [19]
Formatted ... [20]
Formatted ... [21]
Formatted ... [22]
Formatted ... [23]
Formatted ... [24]
Formatted ... [25]
Formatted ... [26]
Formatted ... [27]
Formatted ... [28]

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
27	N/A	300°T	2 x 70tBP	RoRo, 7m	Loss of engines and anchor hold test	Mean spring - max. ebb (6.4m)	W 30	2.6 knots 121°T	Success
28	DP	300°T	1 x 10tBP (not used)	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Mean spring LW+1 (6.4m)	NNE ~~15 gusting 20~~17.5	1.3 knots 306°T	Success
29	DP	300°T	1 x 10tBP	Tanker, ballast 4.2m (avg)	Departure from IOT8	Mean spring LW+1 (6.4m)	NNE ~~30 gusting 35~~22.5	1.3 knots 306°T	Success
30	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, laden 6m	Departure from IOT8	Mean spring LW+1 (6.4m)	NNE ~~30 gusting 35~~32.5	1.3 knots 306°T	Success
31	DP	300°T	1 x 10tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Mean spring LW+1 (6.4m)	NNE ~~30 gusting 35~~32.5	1.3 knots 306°T	Aborted
32	DP	300°T	1 x 45tBP	Tanker, laden 6m	Arrival to IOT8	Mean spring LW+1 (6.4m)	NNE ~~30 gusting 35~~32.5	1.3 knots 306°T	Aborted
33	DP	300°T	1 x 10tBP	Tanker, laden 6m	Arrival to IOT8	Mean spring LW+1 (6.4m)	No wind	1.3 knots 306°T	Aborted
34	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 1	Peak spring - max. flood (7.25m)	SW ~~25 gusting 30~~27.5	1.0 knots 300°T	Success
35	DP	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 1	Peak spring - max. flood (7.25m)	SW ~~25 gusting 30~~27.5	1.0 knots 300°T	Success
36	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, laden 6m	Departure from IOT8	Mean spring LW+1 (6.4m)	SW ~~30 gusting 35~~27.5	1.3 knots 306°T	Success
37	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, laden 6m	Departure from IOT8	Peak spring LW+1 (7.2m)	NNE ~~30 gusting 35~~32.5	1.5 knots 303°T	Success
38	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, laden 6m	Departure from IOT8	Peak spring LW+3 (7.2m)	NNE ~~30 gusting 35~~32.5	2.0 knots 301°T	Success
39	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	NNE ~~20 gusting 25~~22.5	1.5 knots 303°T	Success

Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt
Formatted: Font: 9 pt

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
40	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, laden 6m	Departure from IOT8	Peak spring LW+1 (7.2m)	NNE ~~20 gusting 25~~22.5	1.5 knots 303°T	Success
41	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	NNE ~~20 gusting 25~~32.5	1.5 knots 303°T	Success
42	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW ~~30 gusting 35~~32.5	1.5 knots 303°T	Marginal
43	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+3 (7.2m)	NNE ~~20 gusting 25~~32.5	2.0 knots 301°T	Success
44	GJF	306°T	None	RoRo, 7m	Departure from Berth 2	Peak spring - max. ebb (7.2m)	SW ~~10 gusting 15~~12.5	4.0 knots 119°T	Fail
45	DP	306°T	None	RoRo, 7m	Departure from Berth 2	Peak spring - max. ebb (7.2m)	SW ~~10 gusting 15~~12.5	4.0 knots 119°T	Fail
46	GJF	306°T	None	RoRo, 7m	Departure from Berth 2	Peak spring - max. ebb (7.2m)	SW ~~10 gusting 15~~12.5	4.0 knots 119°T	Success
47	JS	306°T	None	RoRo, 7m	Departure from Berth 2	Peak spring - max. ebb (7.2m)	SW ~~10 gusting 15~~12.5	4.0 knots 119°T	Fail
48	GJF	306°T	None	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (6.5m)	SW ~~10 gusting 15~~12.5	3.2 knots 118°T	Success
49	DP	300°T	None	RoRo, 7m	Departure from Berth 2	Peak spring - max. ebb (7.2m)	SW ~~10 gusting 15~~12.5	4.0 knots 119°T	Success
50	GJF	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean spring - max. ebb (7.2m)	SW ~~25 gusting 30~~27.5	4.0 knots 119°T	Success
51	DP	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring - max. ebb (7.2m)	NNE ~~30 gusting 35~~32.5	4.0 knots 119°T	Success
52	DP	300°T	1 x 10tBP 1 x 45tBP	Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW ~~30 gusting 35~~32.5	1.5 knots 303°T	Success

Formatted ... [29]
Formatted ... [30]
Formatted ... [31]
Formatted ... [32]
Formatted ... [33]
Formatted ... [34]
Formatted ... [35]
Formatted ... [36]
Formatted ... [37]
Formatted ... [38]
Formatted ... [39]
Formatted ... [40]
Formatted ... [41]
Formatted ... [42]
Formatted ... [43]
Formatted ... [44]
Formatted ... [45]
Formatted ... [46]
Formatted ... [47]
Formatted ... [48]
Formatted ... [49]
Formatted ... [50]
Formatted ... [51]
Formatted ... [52]
Formatted ... [53]
Formatted ... [54]
Formatted ... [55]
Formatted ... [56]

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
53	GJF	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean flood (6.5m)	NNE ~~30 gusting 35~~32.5	1.6 knots 310°T	Success
54	DP	300°T	2 x 70tBP	RoRo, 7m	Arrival to Berth 2	Mean flood (6.5m)	SW ~~25 gusting 30~~27.5	1.6 knots 310°T	Success
55	GJF	300°T	2 x 70tBP	RoRo, 7m	Departure from Berth 2	Mean flood (6.5m)	SW ~~25 gusting 30~~27.5	1.6 knots 310°T	Success
56	IS	300°T	Nil	RoRo, 7m	Arrival to Berth 2	Peak ~~Spring Max Ebb~~spring max. ebb (7.2m)	NNE 10 (gusts added mid run)	2.5 knots 115°T	Success
57	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Arrival to Berth 2	Peak ~~Spring Max Ebb~~spring max. ebb (7.2m)	NNE 25 gusting 30	2.5 knots 115°T	Success
58	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Arrival to Berth 2	Peak ~~Spring Max Ebb~~spring max. ebb (7.2m)	SW 25 gusting 30	2.5 knots 115°T	Success
59	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring ~~Max~~max. flood (7.25m)	NNE 25 gusting 30	1.8 knots 304°T	Aborted
59A	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring ~~Max~~max. flood (7.25m)	NNE 25 gusting 30	1.8 knots 304°T	Success
60A	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Arrival to Berth 2	Peak spring ~~Max~~max. flood (7.25m)	SW 25 gusting 30	1.8 knots 304°T	Success
61A	IS	300°T	2 x ~~24~~11 ~~70t BP~~ ~~ASD~~70tBP	RoRo, 7m	Departure from Berth 2	Peak ~~Spring Max Ebb~~spring max. ebb (7.2m)	SW 25 gusting 30	2.5 knots 115°T	Success

Formatted ... [57]
Formatted ... [58]
Formatted ... [59]
Formatted ... [60]
Formatted ... [61]
Formatted ... [62]
Formatted ... [63]
Formatted ... [64]
Formatted ... [65]
Formatted ... [66]
Formatted ... [67]
Formatted ... [69]
Formatted ... [68]
Formatted ... [70]
Formatted ... [72]
Formatted ... [71]
Formatted ... [73]
Formatted ... [75]
Formatted ... [74]
Formatted ... [76]
Formatted ... [78]
Formatted ... [77]
Formatted ... [79]
Formatted ... [81]
Formatted ... [80]
Formatted ... [82]
Formatted ... [84]
Formatted ... [83]

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
62	IS	300°T	2 x ~~2411 70t BP~~ ASD70tBP	RoRo, 7m	Departure from Berth 2	Peak spring ~~Max~~max, flood (7.25m)	SW 25 gusting 30	1.8 knots 304°T	Success
63	IS	300°T	2 x ~~2411 70t BP~~ ASD70tBP	RoRo, 7m	Departure from Berth 2	Mean spring ~~Max~~max, flood (6.4m)	SW 25 gusting 30	1.7 knots 316°T	Success
64	IS	300°T	2 x ~~2411 70t BP~~ ASD70tBP	RoRo, 7m	Arrival to Berth 2	Mean spring ~~Max~~max, flood (6.4m)	SW 25 gusting 30	1.7 knots 316°T	Success
65	IS	300°T	1 x 10tBP 1 x 45tBP	~~Thun Grace~~Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW 30 gusting 35	1.6 knots 302°T	Fail
66	IS	300°T	1 x 10tBP 1 x 45tBP	Thames Fisher, ballast, 4.5m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW 25 gusting 30	1.6 knots 302°T	Success
67	IS	300°T	1 x 10tBP 1 x 45tBP	~~Thun Grace~~Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW 30 gusting 35	1.6 knots 302°T	Marginal
68	IS	300°T	1 x 10tBP 1 x 45tBP	~~Thun Grace~~Tanker, ballast 4.2m (avg)	Arrival to IOT8	Peak spring LW+1 (7.2m)	SW 25 gusting 30	1.6 knots 302°T	Success
69	IS	300°T	1 x 10tBP 1 x 45tBP	Thames Fisher, ballast, 4.5m (avg)	Arrival to IOT8	Peak spring LW+3 (7.2m)	NNE 25 gusting 30	1.9 knots 301°T	Success
70	IS	300°T	1 x 10tBP 1 x 45tBP	Thames Fisher, ballast,	Arrival to IOT8	Peak spring LW+3 (7.2m)	NNE 30 gusting 35	1.9 knots 301°T	Success

Formatted ... [85]
Formatted ... [86]
Formatted ... [87]
Formatted ... [89]
Formatted ... [88]
Formatted ... [90]
Formatted ... [92]
Formatted ... [91]
Formatted ... [93]
Formatted ... [95]
Formatted ... [94]
Formatted ... [96]
Formatted ... [99]
Formatted ... [97]
Formatted ... [98]
Formatted ... [100]
Formatted ... [103]
Formatted ... [101]
Formatted ... [102]
Formatted ... [104]
Formatted ... [107]
Formatted ... [108]
Formatted ... [105]
Formatted ... [106]
Formatted ... [109]
Formatted ... [112]
Formatted ... [110]
Formatted ... [111]
Formatted ... [113]
Formatted ... [114]
Formatted ... [115]
Formatted ... [116]

Run ID	Pilot	Berth angle	Tugs	Vessel and draught	Manoeuvre	Tide with range in brackets	Wind direction (from) and speed (knots)	Flows at berth (towards)	Outcome
				4.5m (avg)					

Formatted: Font: 9 pt

Formatted: Font: 9 pt

Formatted: Font: 9 pt

Formatted: Normal (Web), Space Before: 2 pt, After: 1 pt

3.6 Simulation track and data plots

The results of each navigation simulation run are available in the form of plots of the vessel tracks and graphs of key data parameters recorded during the run. These data are presented in Appendix ~~A.~~A.

The vessel data and track plots show:

- The position of the ship and the tugs at one minute intervals is indicated by a succession of black and blue vessel outlines. Red vessel outlines indicate the vessel's position every 10 minutes from the start of the run;
- The positions of port structures and aids to navigation;
- A north arrow;
- A scale bar;
- Seabed contours (bed levels in mCD).

The data graphs plot the variation of various key parameters against elapsed simulation time and graphs have been included for all vessels in all of the runs. These graphs are presented by vessel, starting with the ship, and then the independent tug (where applicable). The vessel ID is identified in the text block on the bottom right of each page.

The ship graphs comprise:

- Ship's under keel clearance(s) in metres and speed over the ground (knots). The data plotted in these UKC graphs does not take account of wave-induced ship motions;
- Speed (knots) and direction (°N) of the wind acting on the ship;
- Lateral wind force acting on the ship (tonnes);
- Ship's rate of turn (°/min) and heading in °N;
- Ship's course over the ground and drift angle in degrees;
- Ship's speed (over the ground and through the water) in knots, expressed in terms of longitudinal and lateral components relative to the ship's head;
- Ship's rate of turn (°/min);
- Ship's rudder angle (degrees);
- Ship's bow and/or stern thruster power (%);
- Number of ship's engine restarts.

Where there are no plots for a particular parameter, for example for bow thruster power, this indicates that the particular parameter was not relevant for the particular run or no bow thruster was available.

4 Discussion of results

4.1 General

The study benefited from having local Pilots, PEC holders, Tug Masters and representatives from the operations divisions of all of the interested parties that had been present for the previous studies. As such, they were familiar with the previous conclusions and the Simulation Team were able to quickly assimilate the changes for this study and build upon the previous work.

Initial runs were conducted using relatively benign conditions, to allow the Pilots and PECs to re-familiarise themselves with the simulator environment and the updated models.

Days 1, 2 and 4 focused on manoeuvres to and from the new RoRo berths using the 237m RoRo ship manoeuvring model.

Day 3 was used to facilitate ABP's colleagues at APT to witness manoeuvres to and from berth IOT8, using the updated ship manoeuvring model of the 'Thun Grace' products tanker, and the new flow models.

Overall, the rerunning of the simulations with the updated flow models provided significant further confidence in the conclusions determined in earlier studies.

4.2 Simulation run strategy and constraints

In order to maximise the effectiveness of the real time navigation simulation session, the conditions for testing were restricted to allow consistent testing of manoeuvres in the most challenging conditions at the most challenging berths.

It was acknowledged by the Simulation Team that further sensitivity testing will be required to provide advice on other berths and in less severe conditions. The manoeuvre, and particularly the requirement for tug support, will depend on the occupation of adjacent berths, the strength and direction of the wind, type of vessel and state of the tide.

Where, for expediency, a decision was made to constrain the scenario, it was taken such that the most challenging situation was tested, so producing the most conservative assessment in terms of the viability of the proposed infrastructure and navigational safety.

Consequently, the following were agreed:

- Focus on manoeuvres to and from Berth 2 (see Figure 4.1), as:
  - Berth 2 provides the most significant challenge in terms of flow strength, manoeuvring space at the berth, and precision of the initial swing;
  - Berth 1 provides a significantly more open approach and departure area, although the flows can be a little stronger and are aligned at more variance to the orientation of the berths;
  - Berth 3 has less flow speed in general, but is slightly more constrained by the proximity of vessels moored at Immingham West.

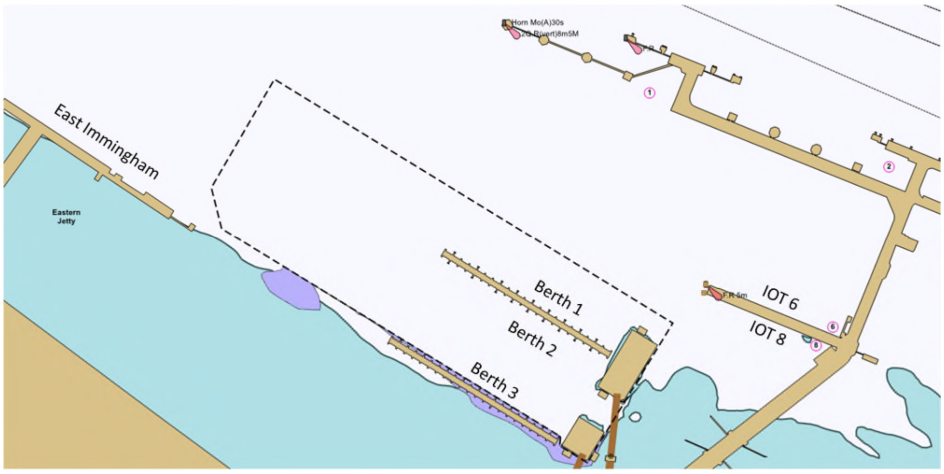

Figure 4.1: Berth layouts

- Limiting manoeuvring space:
  - All manoeuvres were completed with adjacent berths occupied by the largest design vessel for the berth. This ensured that the study was conservative, in that all manoeuvres were conducted in the least amount of space expected.
- Focus on the tidal conditions considered to be the most challenging (see Reference ~~4),~~4), so:
  - Maximum flow during mean spring ebb – this represented the strongest flow during an ebb that would be regularly experience at the berth (119°T, 3.6 knots);
  - Maximum flow during peak spring ebb – this represented the strongest ebb flow that would be seen over a year at the berth (122°T, 4.0 knots);
  - Strong flow combined with strong variation of direction from 300°T during the mean spring ebb – this represented the most awkward flow based on strength and direction expected at the berth (307°T, 2.0 knots);
  - Maximum flow with peak spring flood – this represented the strongest ebb flow that would be seen over a year at the berth (298°T, 2.2 knots).
- It was agreed to conduct manoeuvres with challenging wind conditions of 25 knots gusting 30 knots, up to a maximum of 30 knots gusting 35 knots. Consequently there was limited information regarding the specific limits for tug usage in more moderate conditions, which would need to be assessed in a separate study, if required.
- Wind sheltering would not be used during the study, so:
  - The forces experienced due to wind were not reduced on the basis of adjacent moored ships;
  - The conclusions regarding the viability of the infrastructure are conservative, so they do not provide the benefit of a reduction in wind speed due to sheltering, but the reduced space is represented;
  - The conditions where wind may funnel around the stern of other moored vessels, towards the IOT berths was discussed. It was recommended that the simulation represented the full effect of the wind, rather than reducing and increasing the speed. If this needs to be simulated for training purposes in due course, a more complex wind model would be needed to simulate the effect of funnelling and the associated yaw forces. This additional effort is usually only required where very limited manoeuvring space is available (less than a few metres), so it is not considered necessary in this case, given the space and tolerances for the manoeuvre to and from IOT.

4.3 237m RoRo – Peak and mean ebb flows

4.3.1 Arrivals

The runs using the updated flow models suggested no significant change to the conclusions from the previous work (Reference ~~2),~~2), that the manoeuvres to the new RoRo berths present a challenging and precise manoeuvre.

Pilots and PECs will need specific familiarisation training and initial supervision to ensure that vessels do not overly constrain other movements around Immingham. They will also need familiarisation training on the manoeuvring strategy required at the end of the initial swing, with wind and tide balanced, before commencing the astern manoeuvre towards the facility.

With ebb flows, it was concluded that the most efficient approach is for the vessel to manoeuvre significantly to the west of the IOT berths, with the current on the starboard bow helping to set it across towards the berth box, as shown in Figure 4.2.

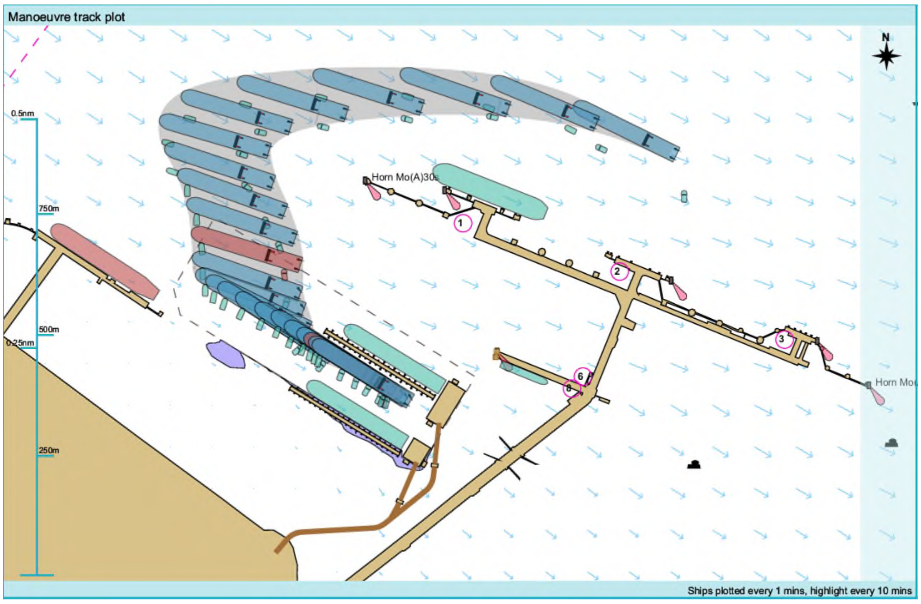

Figure 4.2: Arrival manoeuvre Run 6

It was demonstrated that the 237m RoRo was able to arrive safely at Berth 2 in mean and peak springs, with a mean wind of up to 32 knots setting on and off the berth (Runs 1 to 7).

There were 2 x 70tBP ASD tugs used as towage support in conditions when the wind was above 25 knots. It was found that there were significant amounts of reserve power available, suggesting that sensitivity testing in due course will reveal that on lower tidal ranges, fewer tugs might be required for similar wind.

As in the previous study, developing a suitable approach manoeuvre required patience and demonstrated the challenging nature of the manoeuvres in strong winds. This emphasises the requirement for further sensitivity development to develop procedures and the specific familiarisation training that will be required for Pilots an PECs that operate to these berths.

4.3.2 Departures

Once clear of the berthing fingers the most efficient and safe overall departure manoeuvre was the same as demonstrated in the previous work. That was to use the tide to assist a lateral manoeuvre to the north until clear of any risk of being set onto the Immingham East Jetty. Only once sufficiently clear should the manoeuvre ahead be commenced and then, continuing to use the current to assist lateral movement towards the main channel, as shown in Figure 4.3.

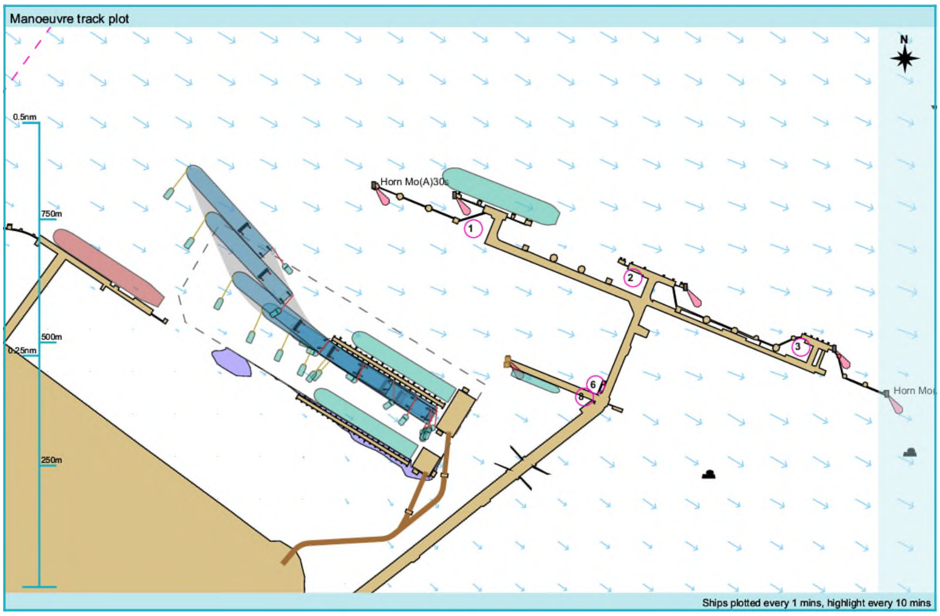

Figure 4.3: Departure using ebb current on port bow to assist departure

Departures from Berth 2 were achievable with the wind setting on and off the berth, up to a steady mean of 27.5 knots. However, at the upper limit, manoeuvring became more challenging (see Runs 08 to 14).

Runs 09 to 12 highlighted an issue that had been problematic during the previous study, with the stronger flows in the new flow model demonstrating the effect more acutely.

The problem involves departing the berths in strong ebbs flows, where the current is 3 knots or greater, such that the efficiency of bow thrusters and supporting towage is significantly reduced as the water speed increases.

As soon as the vessel is driven ahead into the flow, the efficiency is further reduced due to the increase of combined water speed, meaning that often the lateral lift provided by the bow thruster or tug reduces, and the vessel sets back onto the berth due to the wind.

Attempts to lift the bow into the tide, to assist lifting off the berth, were frustrated by the limited manoeuvring space caused by another vessel moored on the adjacent berth.

This issue with ebb flows and an onshore wind will also be similar for Berths 1 and 3.

It is expected that departing the berths with strong onshore winds above 25 knots, with a peak ebb flow, will not be achievable. It will be prudent to wait for the flow to reduce before departing.

Familiarisation training and procedures will need to be developed to highlight the dangers associated with ebb tide departures due to increased water flow. A similar effect can occur if the vessel accelerates too quickly in more moderate ebb flows, as the combined water speed will have a significant impact on the effectiveness of bow thruster and tug assistance.

4.4 237m RoRo – Mean flood flows

4.4.1 Arrivals

Initial arrival Runs 15 to 18 re-emphasised two issued that had been apparent in the previous study, as follows:

- The swing and setup for the flood arrival is more challenging to execute than the equivalent manoeuvre on the ebb. The recommended approach is to head towards Immingham East Jetty once clear of IOT. Then swing the stern to east to steady on the edge of the berthing box before making an astern manoeuvre to the berths (see Figure 4.4).
- Attempting to use the flood flow to manoeuvre laterally across the fairway towards the berthing box is potentially a slow manoeuvre, which would add to port congestion.
- The difficulty the Pilots had setting up the vessel for this manoeuvre (see Runs16 to 18) demonstrated the challenge and precision required for the approach to be effective. Refining this will require training and monitoring to ensure Pilots and PECs are prepared for it.
- During the swing there was always some redundant power available. The manoeuvre was always safe, but it is worth noting that repeated manoeuvres might lead to increased congestion at the terminal. ABP observed that the increased traffic volume will be managed by VTS and traffic management procedures, to maintain current levels of operability on adjacent berths.
- In northerly wind conditions the Pilot will need to be aware of being set too quickly down onto the Immingham East Jetty.

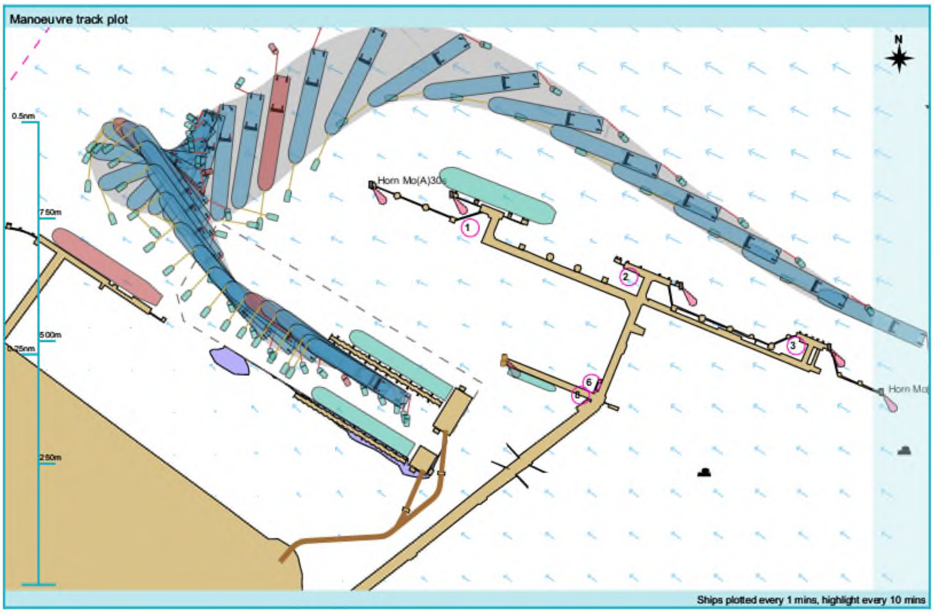

Figure 4.4: Run 19 approach showing preferred swing towards Immingham East and then stern to east

Arrivals to Berth 2 were conducted in conditions with the wind setting on and off the berth up to a mean of 32 knots, and with peak flows running along the berth.

Approaches to Berth 2 with the wind setting off were most challenging, once the mean wind speed exceeded 27.5 knots (Runs 20 to 25). It was deduced that moving the aft tug to operate in a position closer to the centre of balance for the vessel, enabled the vessel to be operated more effectively during approaches with strong winds.

4.4.2 Departures

Departures during the peak flood flow were demonstrated to be straightforward, with the wind setting on and off the berth up to a mean speed of 32.5 knots (see Runs 25 and 26).

4.5 237m RoRo vessel – Mean spring flood

The mean spring flood provides the maximum variance in terms of flow direction from the design orientation of the berth.

Runs 53 to 55 considered approaches and departures to and from Berth 2 with the mean spring model and a flood rate with the maximum set across the berth. At the end of Berth 2 the flow was setting 310°T at 1.6 knots.

Run 53 considered the situation with the wind setting off Berth 2 with a mean wind speed of 32.5 knots. The arrival was completed with no issues. It was concluded by the Simulation Team that the flow direction had little consequence when setting against the prevailing wind, and that a departure run in the same conditions was not required, although it should be included in any future sensitivity testing.

Run 54 and 55 considered the situation with the vessel approaching and departing the berth with wind and current setting onto the berth. Using 2 x 70tBP ASD tugs, the vessel was able to arrive and depart with little difficulty, although it was noted by the Pilot that with the wind strength approaching 30 knots the manoeuvre was close to its limits in combination with the tide. Further runs with winds of 30 knots gusting 35 knots would be advised as part of any future sensitivity testing for operating procedures.

4.6 237m RoRo vessel – Berths 1 and 3

Simulation runs were conducted to Berths 1 and 3 to demonstrate that there were no significant issues compared to the runs undertaken previously, due to the enhanced flow modelling (see Runs 24, 34 and 35).

Further simulations to Berths 1 and 3 are advised to establish more detailed operating limits and procedures and before initial operations begin. However, in general, the manoeuvres are similar or less challenging than approaches to Berth 2.

4.7 104m products tanker – IOT8

4.7.1 General

A total of 14 runs were conducted using the updated ship manoeuvring model of the 104m long products tanker, based on the 'Thun Grace'.

The purpose of the runs was to assess whether or not the additional rotation of the new infrastructure to 300°T made any significant difference to safe manoeuvring operations at IOT. The 104m tanker was used in the previous study and had been found to be difficult to manoeuvre during the swing in towards the berth. So the updated ship manoeuvring model was used in this case, and it was tested for verification purposes immediately before the start of the simulation session and was found to be more representative in that manoeuvre.

During the simulation session, it was noted that when manoeuvring down-tide, the vessel was turning significantly more slowly than would normally be expected in reality, so this was investigated by the Simulation Team in Runs 31 to 33.

It was deduced that the forces on the vessel during the turn when manoeuvring down-current were not initially well represented in the simulation, due to the ship model maintaining too much lateral stability. The tactical diameter of the ship model was similar to the real ship's tactical diameter in still water, but the experience of Pilots in a flood flow is that the vessel maintains a high rate of turn once the rudder has been applied.

As previously mentioned, this effect will be investigated further by HR Wallingford and it provides HR Wallingford and ABP an opportunity to source some data for further study, including PPU data for some real manoeuvres.

For the purposes of this study, the Simulation Team agreed that the ship manoeuvring model was conservative, as it was turning outside the expected path, and therefore provided a more challenging assessment of the approach. It was found to be possible to manage the effect during the runs, so that it had no bearing on the outcome of the manoeuvres within the restricted space between the new infrastructure and IOT jetties.

4.7.2 Simulation runs

The simulation runs demonstrated similar operational limits to those concluded from the previous work (Reference 3), as follows:

- Navigation to and from the IOT6 and 8 berths are not expected to be adversely affected by the proposed size and location of the new RoRo infrastructure at an orientation of 300°T.
- Existing manoeuvring practices will need to be updated, taking into account the new infrastructure and reduced sea room to the south of the IOT finger jetty. However, safe manoeuvring was demonstrated in peak spring flows and winds up to 30 to 35 knots.
- At low water there is potential for the new infrastructure to obstruct the flow which can create unusual flow patterns towards IOT8. Pilots and masters will need to be made aware of this effect.
- Considering the size of the design vessel, it is considered likely that during southerly winds, a combination of sheltering and funnelling could increase the complexity of berthing at IOT6 and 8.
- Towage support for the manoeuvres will not need to be adjusted from what is qualitatively considered current practice, so:
  - All manoeuvres to be assisted by the work boat ('Spurn Sands');
  - Additional towage should be considered in manoeuvres in winds above 25 knots.

4.7.3 Runs 42 and 52

Run 42 was initiated as the penultimate run on Day of the simulation session, and was the 14th run completed by the Pilot on that day, so fatigue may have played a part in the run result. In addition, the conditions for the run were challenging:

- Flood flow at low water with a slight set towards IOT due to the current flowing around the pontoons associated with the new infrastructure;
- Wind setting onto IOT at a steady 32 knots.

At minute 20 into the run, at 30m from the end of the IOT jetty, the Pilot applied 30° of starboard rudder in error. This resulted in the stern turning rapidly towards the berth. Despite applying power and opposite helm, the Pilot was unable to avoid a hard landing on IOT8 (see Figure 4.5).

The details of the run were reviewed the following day, and it was agreed to re-run the approach, which was achieved in Run 52 (see Figure 4.6). This run shows that the approach with a strong combined southerly set onto the berth can be controlled safely.

In the debrief for Run 52, it was noted that the approach would have been better if the Pilot had taken an even more southerly approach to the berth, using a line closer to the edge of the berthing box.

In conditions when there is a strong southerly wind setting to the north, it is considered appropriate for vessels approaching IOT8 to take a line which is no closer than 25m (1.5 beam widths) from another vessel moored on Berth 1. This line will make it more straightforward to manage approaches to IOT and should be included as advice to Pilots if the new infrastructure is developed.

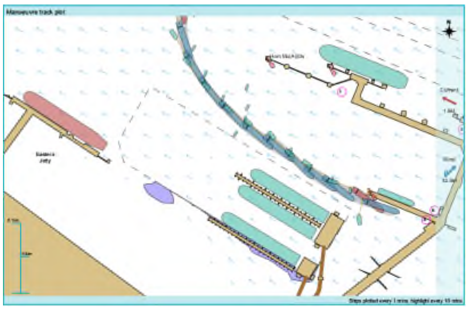

Figure 4.5: Run 42 simulation track plot

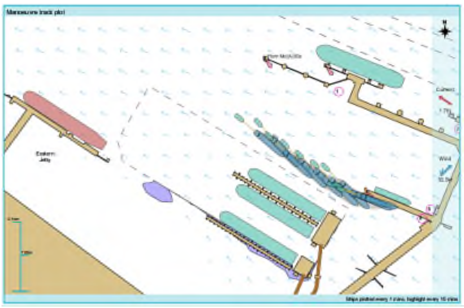

Figure 4.6: Run 52 simulation track plot

On 02 August additional runs were conducted considering the Thun Grace tanker arrival to IOT8 in south westerly conditions.

It was not possible during those runs (Runs 65 and 67) to create a situation where the Thun Grace did not land heavily in strong south westerly winds above 30 knots. This is considered to be consistent with previous experience of operations with similar size takers in strong on-berth winds. It is challenging to hold the bow up-wind using their own power and so they need small, specific towage of about 10t to 15tBP, to support the operations. Larger tugs are not suitable for such small ships as their power delivery overwhelms the manoeuvre and they can therefore be more of a hinderance than a help.

The findings support the results of the previous navigation simulation study (see Reference ~~3),~~3), which examined manoeuvres of the slightly smaller, 91.5m long, Thames Fisher tanker. This concluded that it would be unlikely to attempt to berth that ship in an on-berth wind stronger than 30 knots, and so identified the limiting conditions as south westerly 25 knots ~~gutsing~~gusting to 30 knots.

The runs showed that the Thun Grace could be berthed in south westerly winds of 25 knots gusting to 30 knots, when supported by Spurn Sands work boat (10tBP) and a 45tBP ASD tug, without causing a heavy landing (see Run 68).

4.8 Consideration of 306°T orientation

During the course of the study there was some discussion about the option of orientating the berth to the flood flow direction to 306°T. HR Wallingford previously stated that the statistical analysis shows that an orientation of 300°T represents the best compromise, particularly because the ebb flows are much stronger and so would set across a berth orientated on 306°T at a more challenging angle.

Nevertheless, 5 departure runs were carried out with the berth orientated at 306°T in Runs 44 to 47, which were all conducted on a peak spring ebb. All of these runs were considered to be failures, even with the wind set at a relatively low steady speed of 12.5 knots. Using mooring lines as springs and the vessel's own power, the Pilots were unable to manoeuvre out of the berth safely, during the maximum flow conditions.

Run 48 was conducted with a mean spring ebb tides. In this case the Pilot was able to manoeuvre clear of the berth, but with 10 to 15 knots of wind, the manoeuvre was considered to be particularly challenging, particularly when compared to Runs 49 and 50, with the berth orientated at 300°T.

4.9 Total power failure

Run 27 was carried out as a test to check that the anchoring ability of the ship manoeuvring model was operating as intended. It was conducted to the west of the IOT main jetty in a peak ebb flow and with 30 knots of wind setting towards the infrastructure. The run was primarily an internal check, but it was recorded because there had been discussions regarding possible mitigation measures in certain emergency scenarios.

At a time in the run which was considered to represent the most onerous time for a ship-board equipment failure, so when the vessel was passing 200m from the end of IOT1 , a total power failure on the ship was simulated. The tidal flows were at their strongest at this point and there will be minimal sheltering from the prevailing wind, so the forces setting the ship towards the infrastructure were expected to be at their greatest. This is a situation that can happen within current operational practice, and it was agreed that the primary mitigation at this point would be to use the ship's anchor.

At the point that the total power failure was initiated, tugs were slipped and the vessel's anchor was released. The vessel slowed from 2.5 knots to almost stopped in less than 1 ship's length, as would be expected in practice.

It should be noted that there are additional parameters that need to be included for this to be a true evaluation of the situation, but it indicated that the anchoring response of the design vessel is likely to be similar to that of vessels currently operating in a similar manner to and from Immingham.

5 Conclusions

The study provided additional evidence to support the conclusions of the previous simulation work. Specifically, the following conclusions from the previous study remain valid, based on the additional runs conducted using a modified flow model and a 300°T orientation for the berths:

- The proposed berths are acceptable for safe manoeuvring of a 240m long RoRo vessel.
- Manoeuvres to and from the berths have been demonstrated in the most challenging tidal flows and with concurrent winds with up to a mean of 32.5 knots. On initial operations the berths should be limited to manoeuvres with wind speeds up to a maximum of 30 knots until confidence is developed in the operations of the particular vessels that will use the berths.
- The design width between the 2 new jetties, which is reduced to 120m between fender lines, remains practicable with an orientation of 300°T and considering the modified draught-averaged peak and mean spring flows.
- Manoeuvring operations at the berths will need to be supported by small, relatively agile and powerful tugs. The study found that 2 tugs of approximately 25m in length with at least 60t BP, will be required to maintain operations when the wind is above 25 knots. Although further sensitivity testing will be required to provide advice on the use of tugs in less severe conditions, as this will also depend on the occupation

of adjacent berths, the strength and direction of the wind, type of vessel and state of the tide, it is expected that least one tug will be required in certain situations, particularly on a strong ebb with an adjacent moored vessel, when the wind is above 20 knots.

- Considering IOT, based on the additional runs using a modified flow model, the new infrastructure orientation and a 104m long tanker (with a deadweight of 6,535t), the following were concluded:
  - Navigation to and from the IOT6 and 8 jetties will not be adversely affected by the proposed size and location of the new RoRo infrastructure at an orientation of 300°T.
  - Existing manoeuvring practices will need to be updated, taking into account the new infrastructure and reduced sea room to the south of the IOT finger jetty. However, safe manoeuvring was demonstrated in peak spring flows and winds up to 30 to 35 knots.
  - Arrivals by vessels in their ballast state during strong south westerly winds will need to be restricted to a limit of 25 knots gusting to 30 knots. Arrivals above this limit may result in a hard landing. At low water there is potential for the new infrastructure to obstruct the flow which can create unusual flow patterns towards IOT8. Pilots and masters will need to be made aware of this effect.
  - This is a well understood effect and is experienced and managed by pilots elsewhere on the Humber.

Additionally:

- The runs indicated that departures from Berths 2 and 3 during the peak spring (7.2m range) ebb tides should be subject to a wind limitation of 25 to 30 knots, due to the reduced effectiveness of bow thrusters and the tugs. Berth 1 will be less constrained due to the additional manoeuvring space.
- A comparison between berth orientations of 300°T and 306°T during strong ebb flows confirmed the conclusion of the quasi-static force analysis, that the optimum orientation is 300°T.
- It should be noted that manoeuvring to and from the new infrastructure will be challenging particularly at the limiting conditions. Overall manoeuvres will require precise positioning of the vessel, tugs and their attitude to the tidal flow and the wind. Mitigating the inherent risks in these manoeuvring operations will require a robust training solution.

As the project develops it will be necessary to run more specific simulations to identify the detailed recommended procedures and limits for all classes of vessel, in a wider range of environmental conditions. This will be particularly important in developing appropriate limits for an initial operating capability.

6 References

1. HR Wallingford, “Project Sugar – ABP Humber – Immingham East Development – Design review and navigation studies” , Report no. DJR6612-RT001-00-04,10 Dec 2021.
2. HR Wallingford, “Project Sugar – ABP Humber – Immingham East Development – Navigation simulation study Dec 2021”, Report no. DJR6612-RT002-03-00, 04 Aug 2022.
3. HR Wallingford, “Project Sugar – ABP Humber – Immingham East Development – Navigation simulation study Apr 2022”, Report no. DJR6612-RT003-02-00, 04 Aug 2022.
4. HR Wallingford, “Project Sugar – ABP Humber – Immingham East Development – Quasi-static force assessment”, Report no. DJR6612-RT0004-01-00, 08 Jul 22.
5. Jacobs, ”Jetty Arrangements”, Drawing B2429400-JAC-00-ZZ-M2-ZZ-0003, received 26 May 2022.
6. ABPmer, ”Nordic AWAC deployment Hydrodynamic Study”, R3354, 04 Jul 22.

Appendices

A Simulation track and data plots

HR Wallingford
Working with water

HR Wallingford is an independent engineering and environmental hydraulics organisation. We deliver practical solutions to the complex water-related challenges faced by our international clients. A dynamic research programme underpins all that we do and keeps us at the leading edge. Our unique mix of know-how, assets and facilities includes state of the art physical modelling laboratories, a full range of numerical modelling tools and, above all, enthusiastic people with world-renowned skills and expertise.We design smarter, more resilient solutions across both the natural and built environment to help everyone live and work more sustainably with water.

HR Wallingford Ltd, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381, email info@hrwallingford.com
www.hrwallingford.com