Northern Gateway Pipelines LP

Manoeuvring Study of Escorted Tankers to and from Kitimat

Real-time Simulations of Escorted Tankers bound for a Terminal at Kitimat

Part 1: Executive Summary

Final Report

FORCE Technology no. 108 – 29930 - ES Version 4.0

FORCE TECHNOLOGY

FORCE Technology

Project No. and Title of Report:

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Real-time Simulations of Escorted Tankers
for a Terminal at Kitimat

Executive Summary

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Northern Gateway Pipelines LP

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Date: January 19th 2010

Approved by:

B	Final	JCB	SSS		19-01-10
A	Draft	JCB			
Revision		***By***	***Checked***	***Approved***	***Date***

Keywords:
Manoeuvring Simulation Study with VLCC, Aframax and Suezmax tankers in ballast and loaded condition escorted by VSP (Voith Schneider Propulsion) tugs.

Classification:

☐ **Open**

☐ **Internal**

■ **Confidential**

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1. Introduction

This report summarizes the work carried out by FORCE Technology, Division for Maritime Industry, DMI, Lyngby, Denmark according to work order nos. WG-41145-08001 and WG-40322-22001 issued by Northern Gateway Pipelines LP (Northern Gateway).

Northern Gateway has initiated significant engineering, field work, and environmental and socio-economic assessments to support the proposed development of the Northern Gateway Pipelines Project that will include:

- A proposed oil export pipeline to transport oil from Strathcona County, Alberta (west of Bruderheim) to a new marine terminal located at Kitimat, British Columbia. The exported product will be shipped by tanker to Asia-Pacific and California markets.
- A proposed condensate pipeline to transport condensate from the Marine Terminal to Strathcona County, Alberta. The condensate will be imported by tankers from worldwide supply markets.

Two dedicated tanker berths are planned for the Kitimat Marine Terminal. Both berths will be used to load oil into tankers up to a Very Large Crude Carrier (VLCC) size, and either berth is capable of offloading condensate from tankers up to a Suezmax size.

The tankers will navigate from open sea and through confined coastal channels to the Kitimat Marine Terminal using one of several alternative routes. The primary routes are shown in Figure 1-1 and include:

- The North Route passes Haida Gwaii through Dixon Entrance and continues via Hecate Strait, Browning Entrance, Principe Channel, Nepean Sound, Otter Channel, Squally Channel, Lewis Passage, Wright Sound and Douglas Channel. This route is shown in purple
- The South Route passes through Queen Charlotte Sound and continues through Hecate Strait, Caamaño Sound, Campania Sound, Squally Channel, Lewis Passage, Wright Sound, and Douglas Channel. This route is shown in red

An alternative southerly route which bypasses Caamaño Sound going north in Hecate Strait along the western side of Banks Island to Browning Entrance is also considered viable, but this route (Browning Entrance) was not modelled at this time since the outer section is in open water.

Secondary routes which are currently in use and considered viable for some ship types under certain conditions were also assessed and include:

- Use of Whale Channel (orange)
- Use of Cridge Passage (yellow)

A south approach via Laredo Sound and Laredo Channel was investigated, but this route option is not considered viable for the design ships of this project.

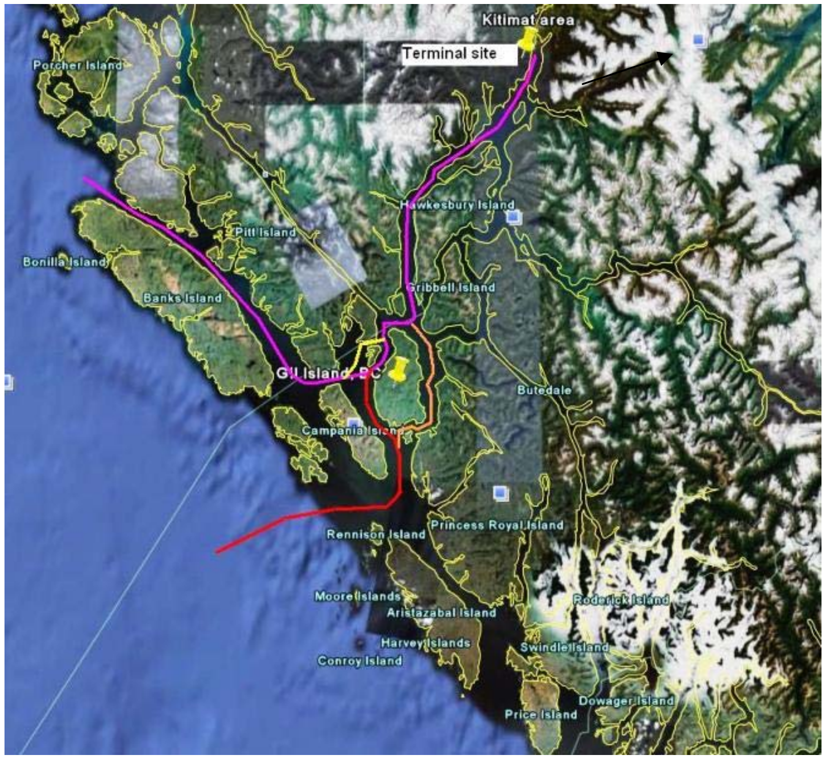


Figure 1-1 : Marine transportation route alternatives. Map source: Google Earth.

This report contains a brief overview of 4 phases of work completed over a calendar period of 3 years.

The work was conducted from 2006 to 2009 in the following phases:

- Fast-time simulation, 2006
- Real-time simulations, part 1, 2007
- Real-time simulations, part 2, 2008
- Real-time simulations, part 3, 2009
- Arrest simulations of tankers, 2009

1.1 Fast-time simulations

The objective of the simulations was to study the manoeuvring challenges between open sea and the proposed marine terminal and confirm that safe navigation of the route was viable prior to commencing the real-time simulations. The simulations were conducted as a desktop study using a computer simulation program where ships sail along pre-defined routes designed by pilots and master mariners. The advantage of this type of simulation is that a large number of sailings, covering long distances, can be conducted in a short period of time. A total of 36 fast-time simulations were performed.

1.2 Real-time simulations

Real-time (R-T) simulations were carried out on full-mission bridge simulators that used a mock-up of a ship's bridge located in the centre of a cylindrical projection screen on which graphical images of the route the ship was travelling were displayed. The full-mission simulators were equipped with real bridge instruments such as engine telegraph and communication equipment. The simulations were conducted with British Columbia Pilots navigating the simulated ships in real time along the routes described above.

This method of replicating the real navigation of a ship is a realistic and safe way to generate an overview of vessel performance and navigation information. The results from the simulations are highly reliable; FORCE Technology has more than 25 years of experience using this powerful tool in combination with use of accurate ship models. A total of 170 real-time runs with pilots conning the ships and experienced tug masters conning escort tugs were performed during 3 sets of simulations.

1.3 Participants in real-time simulations

During the first set of simulations performed over a period from January 3rd to January 13th 2007, the following individuals participated:

- Stan Turpin — Pilot, British Columbia Coast Pilots (BCCP)
- Allan Ranger — Pilot, British Columbia Coast Pilots (BCCP)
- Bengt Knape — Tug Master, Svitzer
- Jan O. Larsen — Tug Master, Svitzer
- Poul Jørgen Poulsen — Tug Master, Svitzer

Present during the simulations were Cynthia Hansen and Carlos Pardo, both Northern Gateway representatives.

FORCE Technology personnel: Catharine Steenberg participated as project manager and Capt. Christer Ström acted as instructor and advisor, interacting with the British Columbia Coast Pilots and the Svitzer Tug Masters during the simulations.

The second sets of simulations were performed in the period November 17th to 21st 2008 by:

- Allan Ranger — Pilot, British Columbia Coast Pilots (BCCP)
- Kevin Vail — Pilot, British Columbia Coast Pilots (BCCP)
- Bengt Knape — Tug Master, Svitzer
- Steffen Schultz — Tug Master and advisor, FORCE Technology

Marine Advisor Chris Anderson represented Northern Gateway and provided project-related input.

FORCE Technology personnel: Senior Naval Architect Jens Bay participated as project manager and Capt. Christer Ström acted as instructor and advisor, interacting with the British Columbia Coast Pilots and the Svitzer Tug Masters during the simulations.

The third sets of simulations were performed in the period March 23rd to 27th 2009 by:

- Kevin Vail — Pilot, British Columbia Coast Pilots (BCCP)
- Robert Lynch — Pilot, British Columbia Coast Pilots (BCCP)
- Bengt Knape — Tug Master, Svitzer
- Steffen Schultz — Tug Master and advisor, FORCE Technology

Marine advisor Chris Anderson represented Northern Gateway and provided project-related input.

FORCE Technology personnel: Senior Naval Architect Jens Bay participated as project manager and advisor, interacting with the British Columbia Coast Pilots and the Svitzer Tug Masters during the simulations.

2. Scope of work

The scope of work for the real-time simulations was to investigate the manoeuvring aspects of large tankers navigating from open sea to the Kitimat Marine Terminal. Three tanker sizes were examined: a 110,000 DWT Aframax, a 200,000 DWT Suezmax a 300,000 DWT VLCC and a 340,000 DWT VLCC.

2.1 Purpose and objectives

The overall objective of the full-mission simulation studies was to confirm that the proposed access routes can be safely navigated by the design ships and to identify navigation risks and possible risk mitigation solutions. Specific tasks included:

1. Investigate the manoeuvrability of three different tankers classes navigating from open ocean and through the confined channels leading to Kitimat under own power and in normal situations;

2. Confirm the navigability of the proposed routes for the three sizes of tanker between the Kitimat Marine Terminal and the open sea, under varying environmental conditions;

3. Investigate the viability of two large ships passing each other at locations with limited width;

4. Investigate the safety of ship transits in areas which have crossing traffic patterns;

5. Identify preliminary environmental limits for safe navigation;

6. Identify areas of difficult navigation;

7. Determine a safe and efficient speed profile for the routes;

8. Determine minimum speeds for navigation below which tug assistance is required;

9. Determine preliminary operational requirements for the escort tugs;

10. Develop preliminary operational criteria for berthing and un-berthing the tankers at the Kitimat Marine Terminal;

11. Determine the adequacy of the existing aids to navigation and assess the minimum requirements for additional aids to navigation in the confined channels;

12. Investigate emergency situations where the escort tug takes over the steering and speed control of the tanker.

3. Methodology

The methodology for the study consisted of the following elements:

- Fast-time simulation;
- Modelling the relevant parts of the BC coast;
- Modelling the three tanker sizes and the two tug boats;
- Determining relevant combinations of parameters for the simulation programs, and;
- Executing the simulation scenarios.

3.1 Fast-time simulation

A total of 36 scenarios were carried out with the Aframax and VLCC's in loaded and ballast condition. For a description of the mathematical models of the ships, reference is made to section 3.3.

The scenarios covered the VLCC and Aframax ships sailing from open sea following either the northern or the southern route to the terminal in the northern part of the Douglas Channel. The routes are shown in figure 3-1.

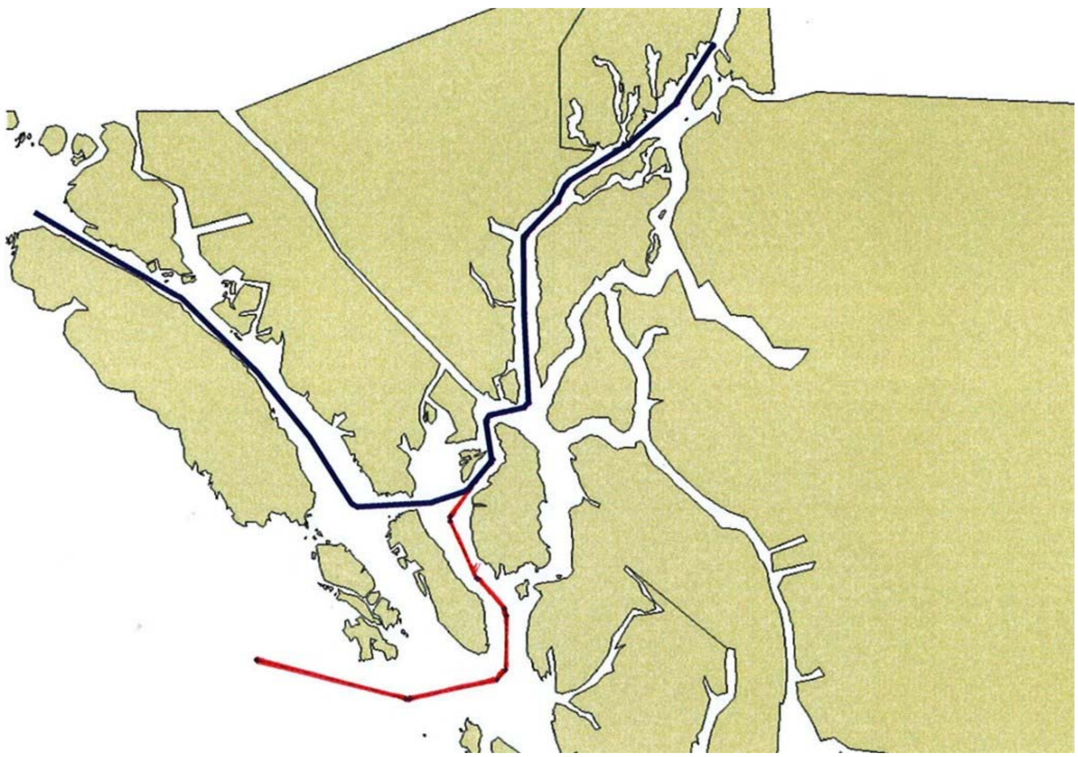


Figure 3-1: North (blue line) and South (red line) Route used for Fast-Time and Real-Time simulations

The North Route for the Confined Channel Assessment Area (CCAA), starts at Browning Entrance and continues through Principe Channel, Nepean Sound, Otter Channel, Squally Channel, Lewis Passage, Wright Sound and Douglas Channel. The South Route for the CCAA, starts at Caamaño Sound and continues through Campania Sound, Squally Channel, Lewis Passage, Wright Sound, and Douglas Channel.

3.2 Modelling of the Kitimat area

The relevant part of the BC coast that was modelled is shown in figure 3.2 below. The basis for the 2D (chart) and the 3D (visual) modelling used in the simulations were Canadian navigation charts of the area as well as electronic ECDIS charts. The charts were the foundation for generating the shore line, water depth and navigational markings.

The modelling of the Kitimat Marine Terminal was based on drawings and photos of a physical model provided by Enbridge Northern Gateway Pipelines LP. The new marine terminal will be located in the northern part of the Douglas Channel and about 3.5 nm south of the existing industrial facilities at the head of Kitimat Arm.

The environment model used in the full-mission simulations consisted of a detailed description of the shoreline and upland topography as well as a detailed description of the depths, wind, waves and current. The environment model for the fast-time simulations included land contours, water depth, wind, current and wave-definitions.

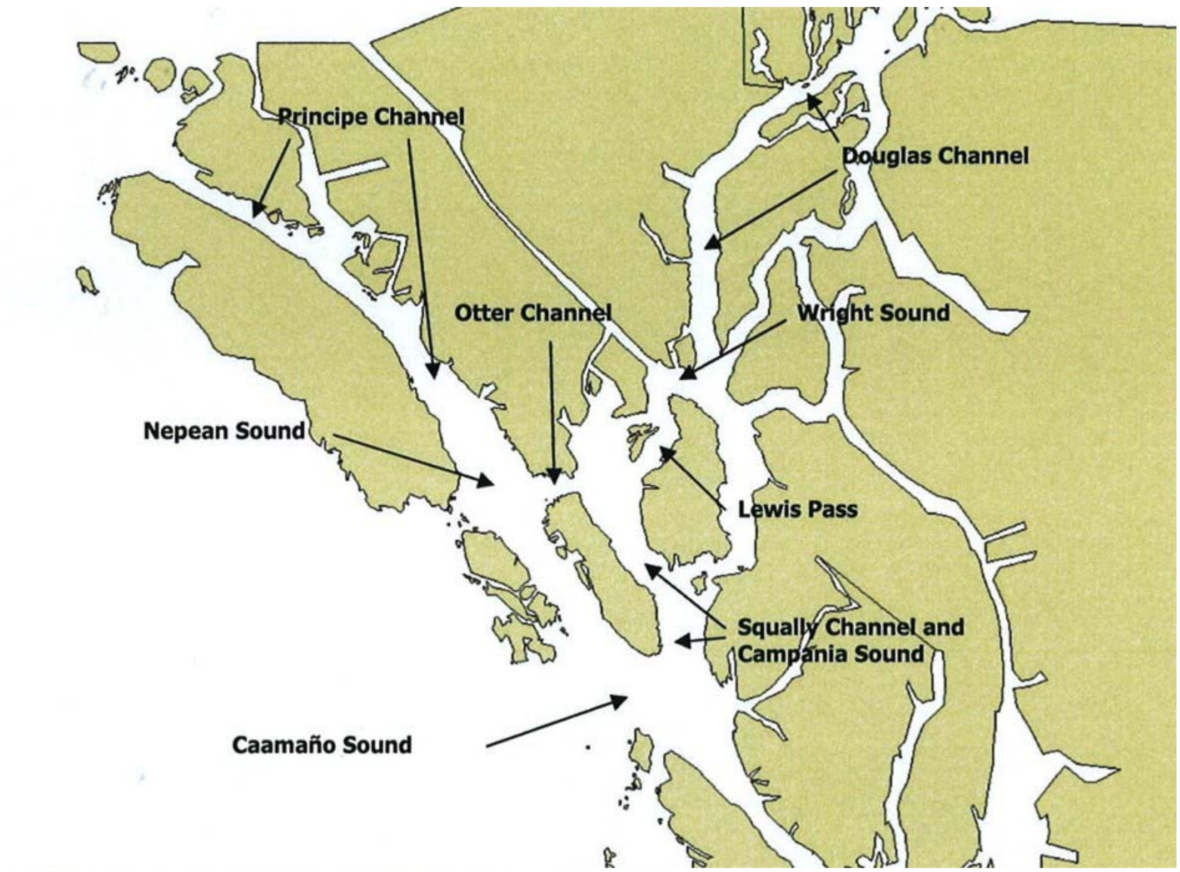


Figure 3-2: Overview of the approaches to Kitimat.

3.3 Modelling of the tankers and tugs

Modelling of tankers used in the simulator

Mathematical models of the Aframax, Suezmax, and VLCC tankers in ballast and loaded condition were generated using an in-house software package called Simflex Shipyard. Model details included:

- Force and moment of deep and shallow water hull hydrodynamic resistance
- Aerodynamic forces and moments originating from wind affecting the ship, calculated at 20 points along the ship hull
- Mean and low frequency wave drift loads by use of a linear diffraction program
- Visual model of the tankers
- Loads applied by tugs to the tanker either by pushing on the tanker hull or by pulling on towlines

Simflex Shipyard is a numerical simulation tool designed to generate ship models for the simulator and to predict the ships' manoeuvring characteristics. Simflex Shipyard includes a number of simulation methods based on a regression of FORCE Technology's large database of manoeuvring model tests results.

After generation of the project ship models, their manoeuvring performance was validated by plots of standard manoeuvres of real vessels and by internal test and validation by FORCE Technology captains.

The tankers used in the full-mission simulations were models of a 340,000 DWT VLCC, 300,000 DWT VLCC, 200,000 DWT Suezmax Tanker, and an 110,000 DWT Aframax tanker, all in loaded and ballast condition:

- Ship no. 3303 – 110,000 DWT Aframax tanker in ballast condition
- Ship no. 3267 – 110,000 DWT Aframax tanker in loaded condition
- Ship no. 3414 – 200,000 DWT Suezmax tanker in ballast condition
- Ship no. 3017 – 200,000 DWT Suezmax tanker in loaded condition
- Ship no. 3059 – 300,000 DWT VLCC tanker in loaded condition
- Ship no. 3242 – 300,000 DWT VLCC tanker in ballast condition
- Ship no. 3413 – 340,000 DWT VLCC tanker in ballast condition
- Ship no. 3219 – 340,000 DWT VLCC tanker in loaded condition

VLCC tankers are expected to arrive at the Kitimat Marine Terminal in ballast condition and depart in loaded condition. The Aframax and the Suezmax tankers may depart and arrive in both loaded and ballast condition. The tankers used for the fast-time simulations were 3303, 3267, 3413 and 3219. All ships for all simulations were modelled in 6 degrees of freedom.

Vessel specifications are provided below.

Project design ships Condition Ship No.	Aframax Ballast 3303	Aframax Loaded 3267	Suezmax Ballast 3414	Suezmax Loaded 3017	VLCC Ballast 3413	VLCC Loaded 3219	VLCC Ballast 3242	VLCC Loaded 3059
Displacement (m^3)	46386	105121	94462	212246	170200	373172	131127	344500
Length between Perpendiculars (m)	233.0	233.0	295.0	295.0	336.0	336.0	327.0	327.0
Length overall (m)	244.6	244.6	310.0	310.0	346.8	346.8	343.7	343.71
Breadth moulded (m)	42.00	42.00	47.0	47.0	60.5	60.50	56.4	56.40
Draught fore/aft (m)	5.0/7.0	13.1/13	8.0 / 10.0	19.1/19.1	9.0 / 11.0	21/21	8.0/10	21.8/21.8
Frontal wind Area (m^2)	1166.7	913	1374	876	1750	1060	1948	1060
Lateral wind area (m^2)	4676	3039	6043	2920	7724	4100	8867	4034

Table 3-1: Main particulars for the tankers used in this study.

Other ships were used to generate realistic scenarios with project design ships. The ships were controlled by the simulator Instructor / Operator or Pilot.

These ships included:

- Ship 3239 LNG tanker of 200,000 m^3 with 10 m draft
- Ship 3240 LNG tanker of 200,000 m^3 with 12 m draft
- Ship 3448 Ferry of 168 m length over all, with 4.7 m draft
- Ship 3315 LNG tanker of 216,000 m^3 with 9.34 m draft
- Ship 3355 LNG tanker of 202,000 m^3 with 12 m draft

Data for the traffic ships are shown in the table below:

Other Project ships Type Condition Ship No.	200K LNG Moss type Ballast 3239	200K LNG Moss type Loaded 3240	202K LNG Moss type Loaded 3355	216K LNG Membrane Ballast 3315	Ferry Loaded 3448
Displacement (m^3)	114035	142300	148 000	105 536	10 414
Length between Perpendiculars (m)	325.0	325.0	327.0	305.0	156.0
Length overall (m)	340.0	340.0	346.0	315.0	167.5
Breadth moulded (m)	51.30	51.30	51.00	50.0	24.7
Draught fore/aft (m)	10.0/10.0	12.0/12.0	12.0/12.0	9.34/9.34	4.73/4.68
Frontal wind Area (m^2)	1850	1850	1850	1510	525
Lateral wind Area (m^2)	10700	10000	10 000	7427	3139

Table 3-2 Main particulars for the traffic ships used in this study.

Modelling of tugs used in the simulator

The models of the VSP tugs used for escort and the ASD tugs used for berthing manoeuvres during the full-mission simulations were based on a generic tug model previously developed by FORCE Technology and confirmed as valid models by experienced tug masters.

The VSP tug model was further developed as a part of this study. Model tests were carried out, however, only bare hull tests, including propeller guard and fin, were completed. Model test data of interaction effect between hull and VSP units were provided by Voith Turbo Marine GmbH & Co.

The following tug models were used in the full-mission simulations:

- Ship no. 3421 VSP tug extended to 125 T BP, operated only by Tug Master
- Ship no. 3421 VSP tug reduced to 100 T BP, operated only by Tug Master
- Ship no. 3346 Svitzer Mars, ASD tug extended to 70 T BP, operated only by Tug Master
- Ship no. 3292 Svitzer Mars, ASD tug with 63 T BP, operated only by Tug Master
- Ship no. 9804, vector tugs with 60 T BP operated only by Tug Master and Pilots.

The choice to use VSP tugs for assessment of escort operations and ASD tugs for berthing manoeuvres was made in consultation with Northern Gateway and was based on a preliminary assessment that the VSP system is more effective for tethered tug escort work and meets the upper limits of IMO guidelines for required steering pull.

Vessel specifications for the tugs are provided in the below table.

Project tug Propulsion Ship No.	Ajax VSP 3421	Ajax VSP 3421	Svitzer Mars ASD 3346	Svitzer Mars ASD 3292
Displacement (m^3)	1268.3	1268.3	647.9	647.9
Length between Perpendiculars (m)	38.2	38.2	25.6	25.6
Length overall (m)	41.6	41.6	30.0	30.0
Breadth moulded (m)	15.9	15.9	11.0	11.0
Draught fore/aft (m)	6.8/6.8	6.8/6.8	4.60/4.60	4.60/4.60
Longitudinal centre of gravity (m)•	-0.55	-0.55	-0.80	-0.80
Vertical centre of gravity (m)•	2.6	2.6	-0.26	-0.26
Bollard pull – ahead (T)	100	125	70	63
Bollard pull – astern (T)	100	125	65	58

Table 3-3 Main particulars for the tugs used in this study.

Project Design ship: A full mathematical model that can be controlled as in the real environment, by the Pilots and the Masters.

Project Design ship: A semi-mathematical model / vector model that can be operated by the Instructor and Pilot during the exercise.

Apart from these ships, target ships such as smaller vessels, tugs and barges were also used. The target ships were controlled by the Simulator Instructor.

Target ship: A semi-mathematical model which can be operated as vector vessel by Instructor or Pilot.

3.4 Combination of environment parameters

Environment conditions:

The tested environmental conditions consisted of wind up to 50 (and occasionally 60) knots in the open areas such as Principe Channel and Caamaño Sound from the directions NW and SE. For areas such as Douglas Channel, Otter Channel, and Squally Channel, the wind speed was reduced to 40 (and occasionally 50) knots mainly blowing along the channels. The wind conditions were combined with either a spatially varying ebb or flood tide condition ranging from approximately 0.6 to 2.0 knots in the Douglas Channel and up to 3.0 knots in Principe Channel.

The wind and current conditions consisted of prevailing directions and directions considered as problematic for manoeuvring along the chosen route. The wind scenarios of NW and SE wind were modelled along with the current scenarios of ebb and flood tide. The wind and the current in the inland part of the area are dominated by mountains and the very deep channels. Therefore, in this area the current and the wind usually follow the direction of the channels.

Figure 3-3 provides an example of the current definition used.

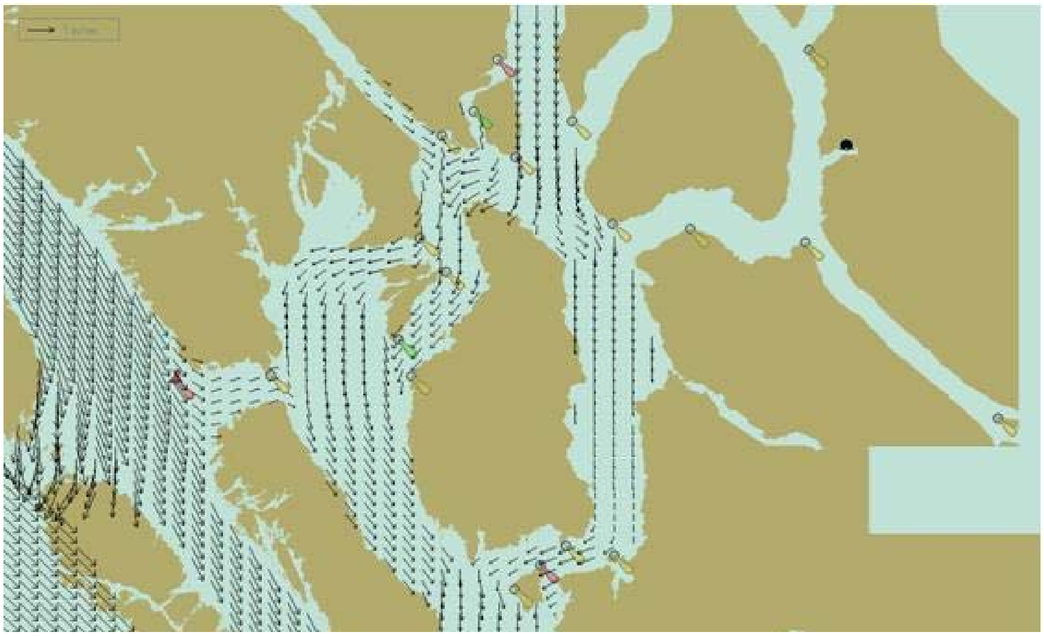


Figure 3-3 Ebb Current conditions in Wright Sound, Lewis Passage, Otter Channel, Whale Channel, Squally Channel and Nepean Sound

Figure 3-4 provides an example of the wind definition in the area:

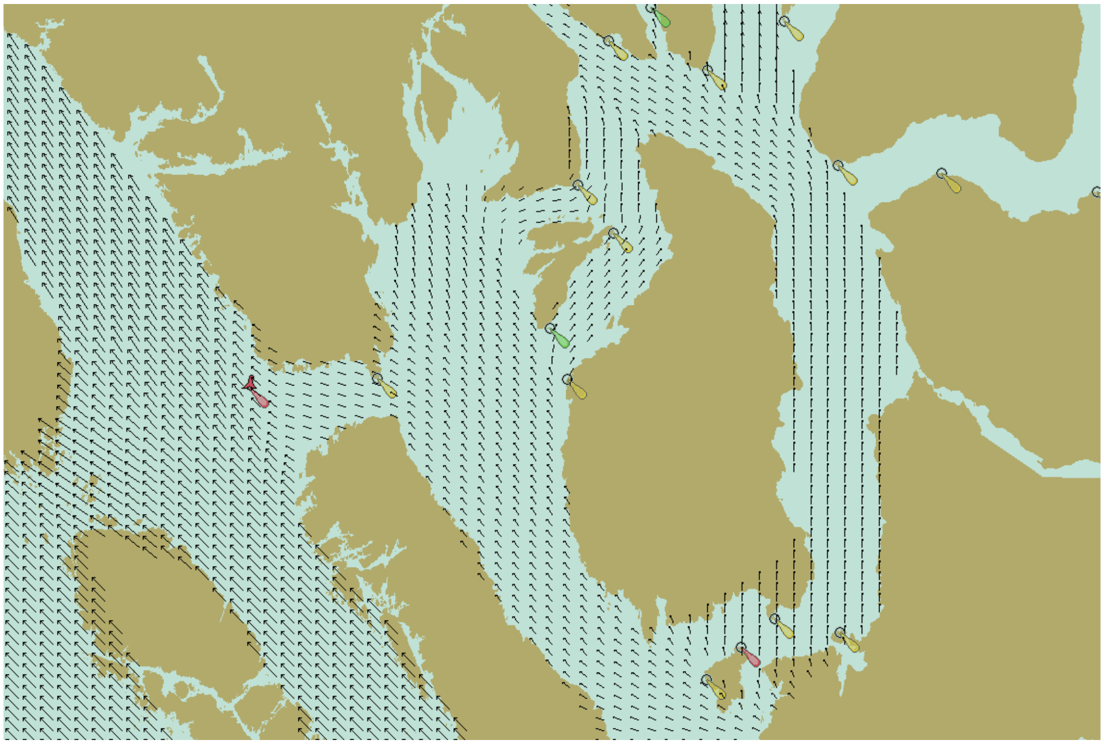


Figure 3-4 wind from SE around Gill Island and surrounding area. The arrows show the direction and speed of the wind at different locations with a prevailing wind from SE. Note: How the wind changes direction and speed due to the mountainous terrain.

3.5 Wave conditions

The wave forces acting on a ship were calculated in uni-directional irregular waves meaning that all wave components were assumed to propagate in the same direction. In the Kitimat simulations, wave heights in the confined channel areas ranged from 0.5 metres and up to 2.0 metres, and in the open sea areas, e.g. west of Caamaño Sound, the wave heights were up to 4 metres.

During the run, the simulator receives the following information from the Wave Generation Unit which gives real data and a picture for the area, including:

- Spectrum type
- Wave direction
- Mean water depth
- Wave period (Display purpose for User Defined)
- Significant wave height

The Simulator Operator/Instructor feeds in the following information at the beginning of each run:

Spectrum type, wave direction (degrees), height Hs (m) and period (sec.)

3.6 Simulation method

The initial fast-time simulations provided information on factors having the strongest influence on the tanker manoeuvrability, areas of particular interest and critical conditions for tanker manoeuvres. Output from the fast-time simulations was used as part of the definition for the scope of work for the real-time simulations.

The scope of work described in Section 2 formed the basis of the real-time simulations. For each simulation, parameters such as weather (combinations of wind, current and waves), ship types and sizes were modified to create different challenges.

Once a list of simulation runs was developed, the simulated sailings commenced. Adjustments and new scenarios were developed during each program session to address specific issues raised by the pilots or the client (such as assessing the viability of transits of Whale and Laredo Channels) and modifying the program to address the more critical (emergency response) scenarios.

After each sailing, the Pilots participated in a debriefing session where “run” evaluation reports were completed by the Pilots, which then formed the basis for a discussion between the Pilots, the FORCE Instructor and the Project Manager to assess run parameters and the Pilots’ observations on navigation viability.

3.7 Simulation scenarios

The simulation program comprises a number of scenarios that systematically test different combinations of specified parameters. The parameters in this study included:

- Ship types: tankers of approx. 110,000 DWT, 200,000 DWT and 340,000 DWT
- Loaded condition: ballasted or loaded
- VSP escort tug size: 100 t BP up to 125 t BP
- Geographic area: e.g. Principe Channel, Caamaño Sound, Otter channel, Wright Sound etc.
- Weather condition: Wind, current, waves, visibility, day/night light, traffic situation
- Direction of transit: inbound/outbound

Run list no.	Ship 1 no A	Type	Wind Knots	Current knots going	Waves height m	Wave periods	Direc. Going deg.	Day / Night	Visibility nm	Tugs # of BP in t	Pilot	Remarks
												All 100 runs are arrival
100	3413	VLCC bal	SW 6	0	1	8s	60	Day	good	4	Kevin	3 x 50 t tugs + 125 t VSP
100	3413	VLCC bal	SW 6	0	1	6s	210	Day	good	4	Kevin	3 x 50 t tugs + 125 t VSP
101	3413	VLCC bal	SSW 15	0.5 NNE	1	6s	210	Day	good	4	Bob	3 x 50 t tugs + 125 t VSP
102	3413	VLCC bal	SSW 30	0.5 NNE	1	8s	210	Day	good	4	Kevin	3 x 50 t tugs + 125 t VSP
103	3413	VLCC bal	NNE 30-50	1.0 SSW	2	8s	210	Day	good	4	Bob	3 x 50 t tugs + 125 t VSP
104	3413	VLCC bal	NNE 40	1.0 SSW	1	8s	60	Day	good	4	Kevin	3 x 50 t tugs + 125 t VSP

Table 3-4: Typical example of a run list from one (R-T) simulation session with weather conditions number of tugs used and assisted ship type.

Several thousand combinations can be produced when systematically combining all the parameters above. However, only a fraction of the combinations are tested because some combinations are irrelevant or very unlikely. For example, if it is already proven that a 340,000 DWT tanker can be controlled safely in wind speeds of 50 knots, there is no need to investigate the same situation in 40, 30 and 20 knot wind, as those speeds will be less of a challenge for the navigator conning the ship.

The VSP tug no. 3421 used during the tests in Lewis Sound was reduced to 90 t, 100 t and 110 t. This was done to find out how much steering was needed to control the escorted vessels.

3.8 Arrest simulations

Arrest simulations were performed in addition to the real-time simulations described above. Arrest simulations use two full-mission bridge simulators, one for the tanker and one for the escort tug. The simulators interact with one another providing real-time feedback to both operators. The purpose of these simulations was to investigate the stopping ability of tankers under their own power as well as with assistance of the escort tug. A total of 144 arrest runs were performed.

3.9 Simulation execution

Prior to each simulation study, a proposed list of runs was made. At the beginning of each week of simulation, this list was discussed with the participating Pilots, and necessary adjustments were made. Daily adjustments were also implemented as needed.

Each scenario was simulated, and after each run an evaluation form was filled out by the Pilot in command. At the same time, the FORCE Instructor showed a replay of the run and discussed the details with the Pilots. The evaluation form also included the Pilot's comments on the different questions asked and formed a valuable input for the later study conclusion.

At the end of each day, discussions between the Pilots, Enbridge representative(s) and FORCE personnel were held to sum up all the impressions and navigational issues that needed attention. Results from these discussions also formed part of the study conclusion.

Figures 3-5 through to 3-11 provide photographs from the 2008 and 2009 simulations, to give an impression of the physical appearance of the FORCE simulator system.

Figure 3-5 View from the simulator bridge on board a 200,000 dwt tanker. The terminal and a VLCC tanker along side can be seen left to centre

Figure 3-6 View from the simulator bridge showing the navigational equipment and control handles for the engine and rudder.

Figure 3-7 A tug master in front of one of the tug simulators used in the study. Note: On the visual view you can see the tow line that is connected from the tug's bow to the tanker's bow. This photo was taken in connection with a berthing manoeuvre close to the oil terminal.

Figure 3-8 View from a tanker showing visual view of assisting ASD (Azimuth Stern Drive) tug.

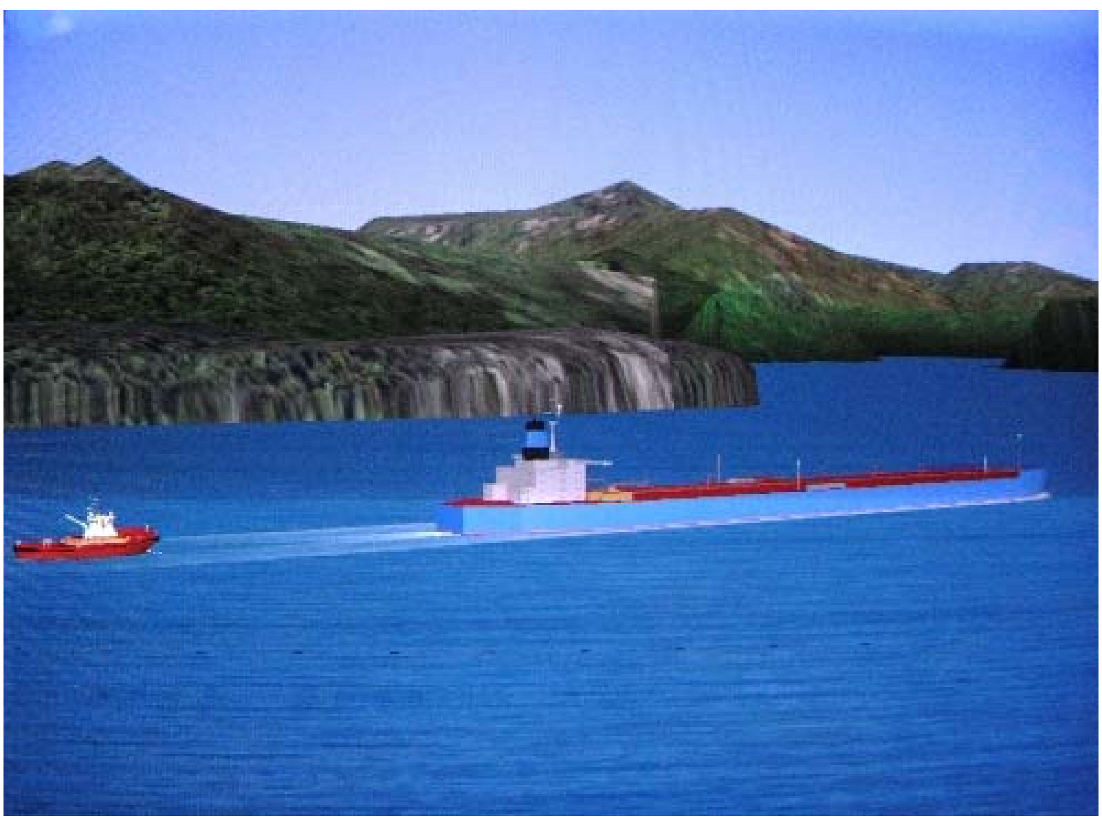


Figure 3-9 View of a loaded tanker and an escort tug in Douglas Channel.

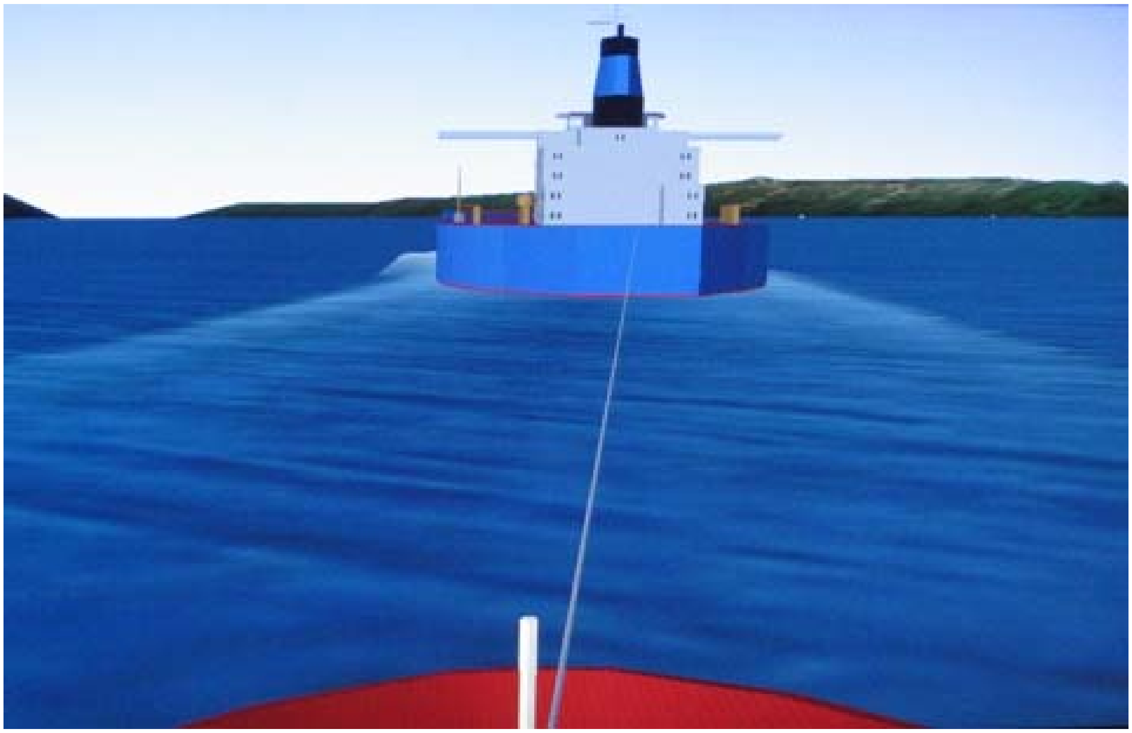


Figure 3-10 same as above, but seen from the escort tug.

Figure 3-11: A tug master towing in indirect escort mode on tug bridge "H" - a 360 degree field of view state of the art simulator.

4. Results

The results described below are presented to match the objectives described in Section 2.

4.1 Tankers' manoeuvring performance

One basis for the simulations was to test the manoeuvring capabilities of the tankers and tug boats.

A ship's manoeuvrability is evaluated from trial test results. There are 4 main characteristics that are of particular interest for this study. These are:

- Steering ability – shown by a zigzag test
- Turning ability
- Sensitivity to wind
- Stopping ability (by own power)

Steering ability

A ship's steering ability depends on the loading condition, hull shape, engine power, the propeller and the rudder. During the ship's sea trial, the steering ability is measured by performing a zigzag test. The test is typically performed at the ship's service speed which is a little lower than its maximum speed.

Figure 4-1 shows a 10-10 zigzag test for the three tankers involved in this study. The plots include the test for both loaded and ballasted condition.

The test is performed by commanding the rudder 10 deg. to port. When the ship has changed its course 10 deg. from its initial course, the rudder is commanded 10 deg. to starboard. When the ship has changed its course 10 deg. to starboard from its original course, the rudder is again commanded 10 deg. to port. The test typically continues until the ship had done two zigzags.

The test reveals if the ship is course stable or unstable. For tankers, it is normal that the ship is somewhat course unstable.

For the 3 tankers used in this study, the steering ability can be summarised as follows:

340, 000 dwt VLCC:

Ship 3219, loaded condition: The steering ability is slightly below average. It is somewhat course unstable, but normally not difficult to control.
Ship 3413, ballast condition: The steering ability is very good.

200,000 dwt tanker:

Ship 3017, loaded condition: The steering ability is about average. It is rather course unstable, but normally not difficult to control.
Ship 3414, ballast condition: The steering ability is very good. It's is marginally course stable and not difficult to control.

110,000 dwt tanker:

Ship 3267, loaded condition: The steering ability is about average. It is somewhat course unstable, but normally not difficult to control.
Ship 3303, ballast condition: The steering ability is very good. It's is marginally course stable and not difficult to control.

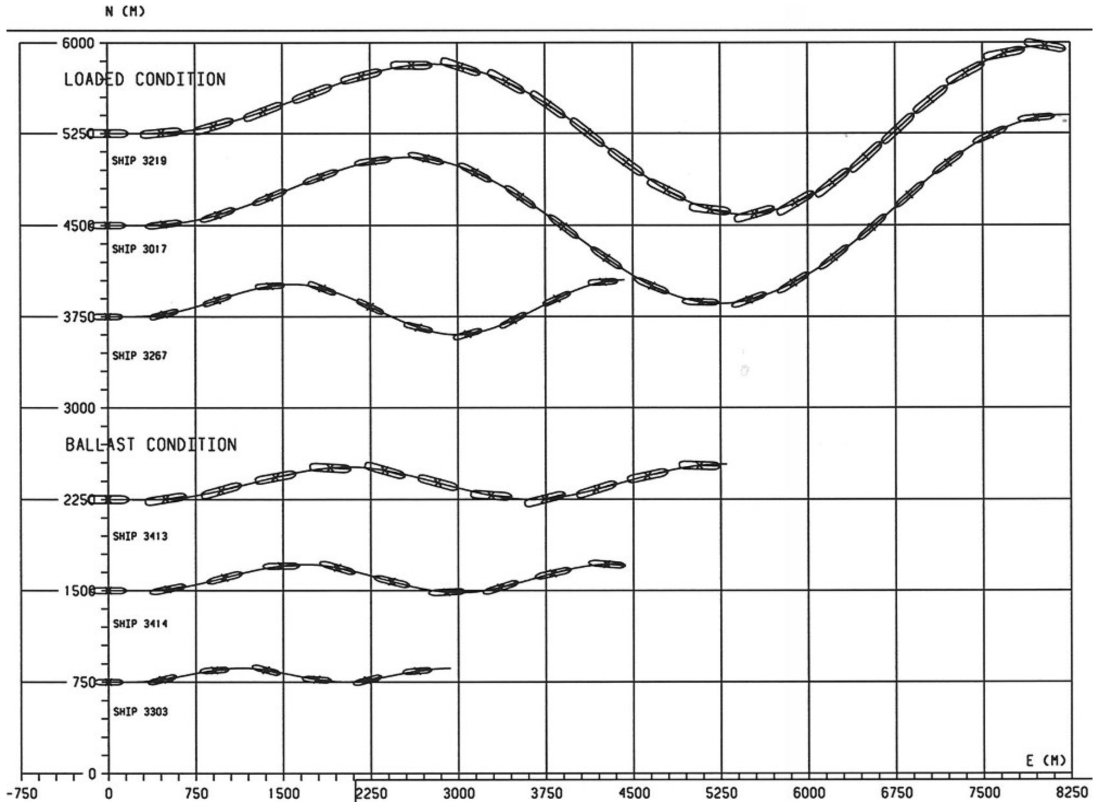


Figure 4-1: Comparison of tankers' steering ability in loaded and ballasted condition. The plot shows the so called 10-10 zigzag test.

Turning ability

A ship's turning ability also depends on the loading condition, hull shape, engine power, the propeller and the rudder. During the ship's sea trials, the turning ability is measured by performing a sharp turn at maximum rudder angle.

Figure 4-2 shows a hard to starboard turn test for the three tankers involved in this study. The plots include the test for both loaded and ballasted condition.

The test is performed by commanding the rudder 35 deg. to starboard while the engine is running at the maximum load. As the ship starts to turn, a great part of the ship's longitudinal speed is transferred into a transverse (drift) speed that due to the great resistance reduces the longitudinal speed significantly.

The primary parameters for this manoeuvre are:

- advance (of longitudinal movement)
- transfer (total width of the turning circle)
- speed reduction

For the 3 tankers used in this study, the turning ability can be summarised as follows:

340, 000 dwt VLCC:

Ship 3219, loaded condition: The turning ability is very good with a large speed loss
Ship 3413, ballast condition: The turning ability is about average with a large speed loss

200,000 dwt tanker:

Ship 3017, loaded condition: The turning ability is very good with a large speed loss.

Ship 3414, ballast condition: The turning ability is about average.

110,000 dwt tanker:

Ship 3267, loaded condition: The turning ability is good.

Ship 3303, ballast condition: The turning ability is normal.

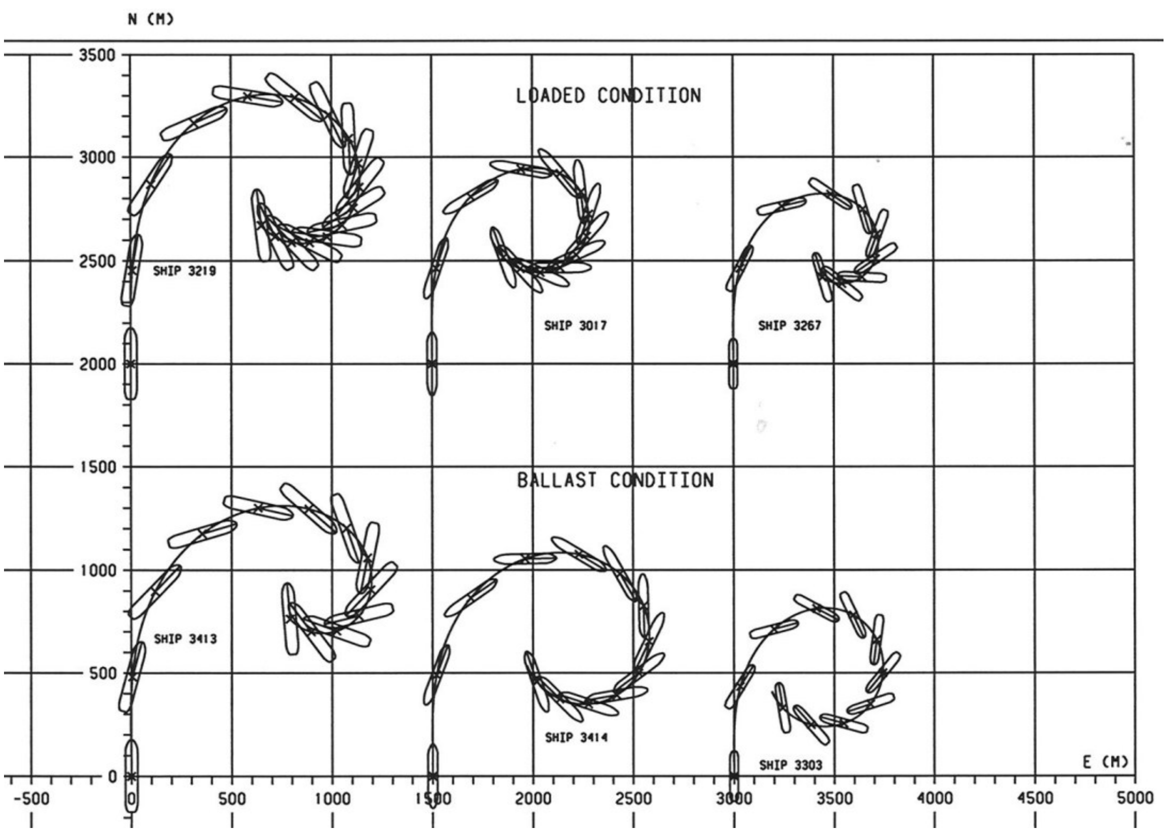


Figure 4-2: Comparison of tankers' turning ability in loaded and ballasted condition. The plot shows a hard a starboard turn test at full sea speed and engine going full ahead.

Figure 4-3 shows a hard to starboard turn at 10 knots. The shape of the turns is almost identical to that of full sea speed (see figure 4-2).

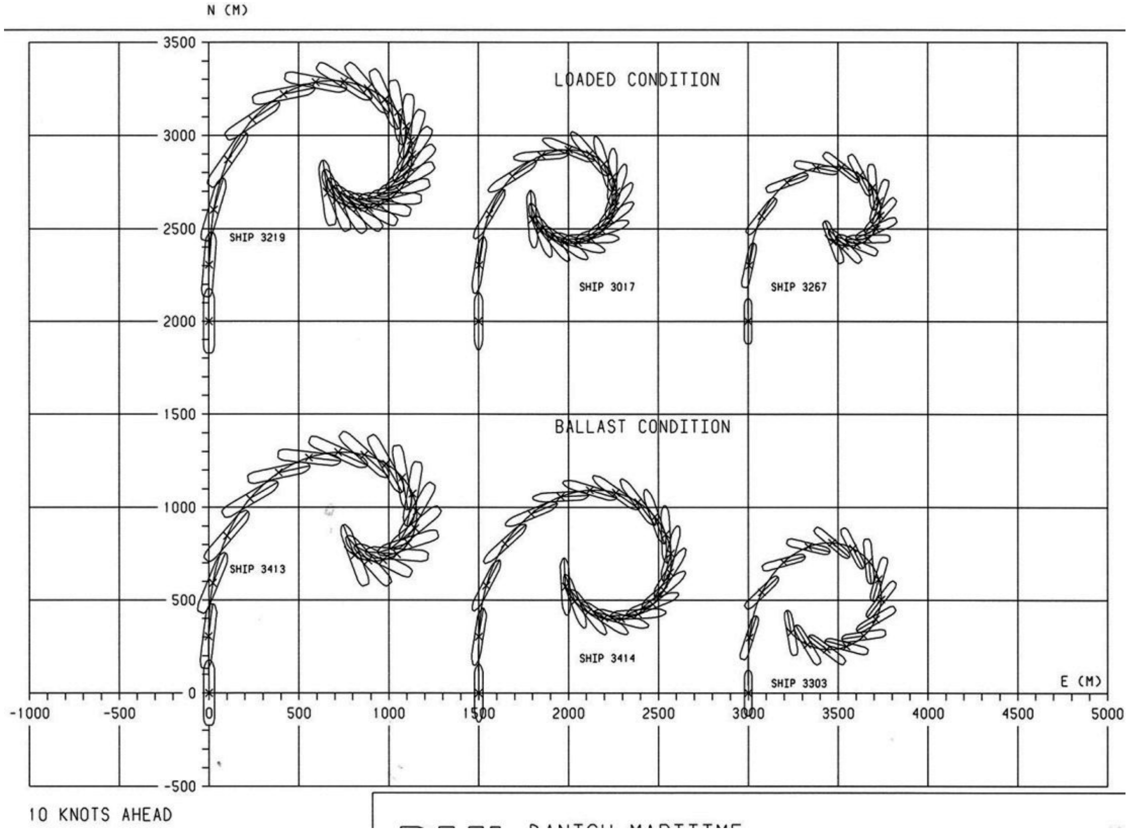


Figure 4-3: Comparison of tankers' turning ability in loaded and ballasted condition. The plot shows a hard a starboard turn test at 10 knots with engine going at RPM corresponding to 10 knots.

Transverse wind sensitivity

A ship's sensitivity to side wind can be measured by letting the ship steam at full speed with the rudder amid ship and the wind abeam. The ship's course change in e.g. 5 minutes will indicate the sensitivity, and a comparison can be made with other similar ships.

This manoeuvre is normally not performed during sea trials. Figure 4-4 shows the actual tankers' sensitivity.

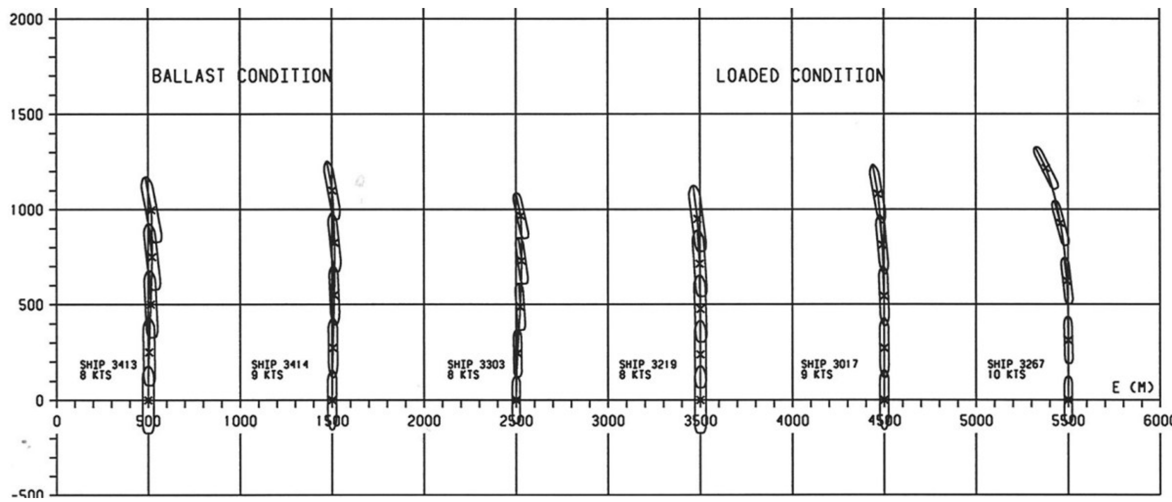


Figure 4-4: Comparison of tankers' sensitivity to 30 knots of wind on port side at ship speed of 8 to 10 knot. Note how the ships turn port into the wind!

Stopping ability

A ship's ability to stop is tested during the sea trials by letting the vessel steam at full speed and then ordering the engine full astern. This is done by first cutting off the fuel oil to the engine and then waiting for the engine to slow down to the RPM where it is safe (and possible) to start the engine in the reverse direction.

Because most tankers today are diesel driven with the propeller shaft directly coupled to the engine (with no clutch connection), the propeller will turn the engine for a while until the speed is reduced to the level where the engine can be reversed. That part of the stop manoeuvre is called a coasting stop. From that point on, when the engine is running in the reverse direction, it is actively stopping the ship until it has come to a full stop. The total distance the tanker has moved is considered the ship's stop distance.

In sea trials, the ship undergoes a so-called crash stop which means that the engine is ordered full astern. This manoeuvre can be destructive with damage to the engine, shaft bearings, foundation etc. That is why most mariners avoid this manoeuvre. A gentler stop where the engine is ordered half astern is considered a normal stop.

In Figure 4-5, the crash stop at 10 knots for the ships used in this study is shown, and Figure 4-6 shows a normal stop.

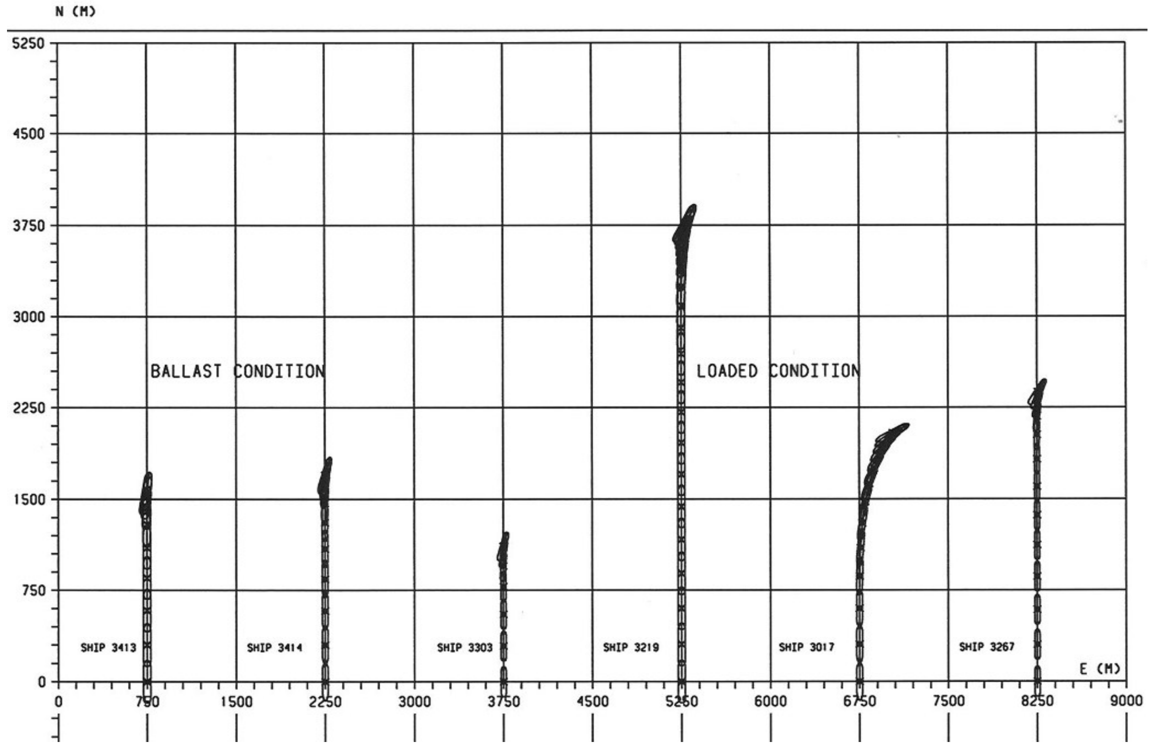


Figure 4-5: Comparison of tankers' emergency stop distances at 10 knots where the engine are running astern at full power.

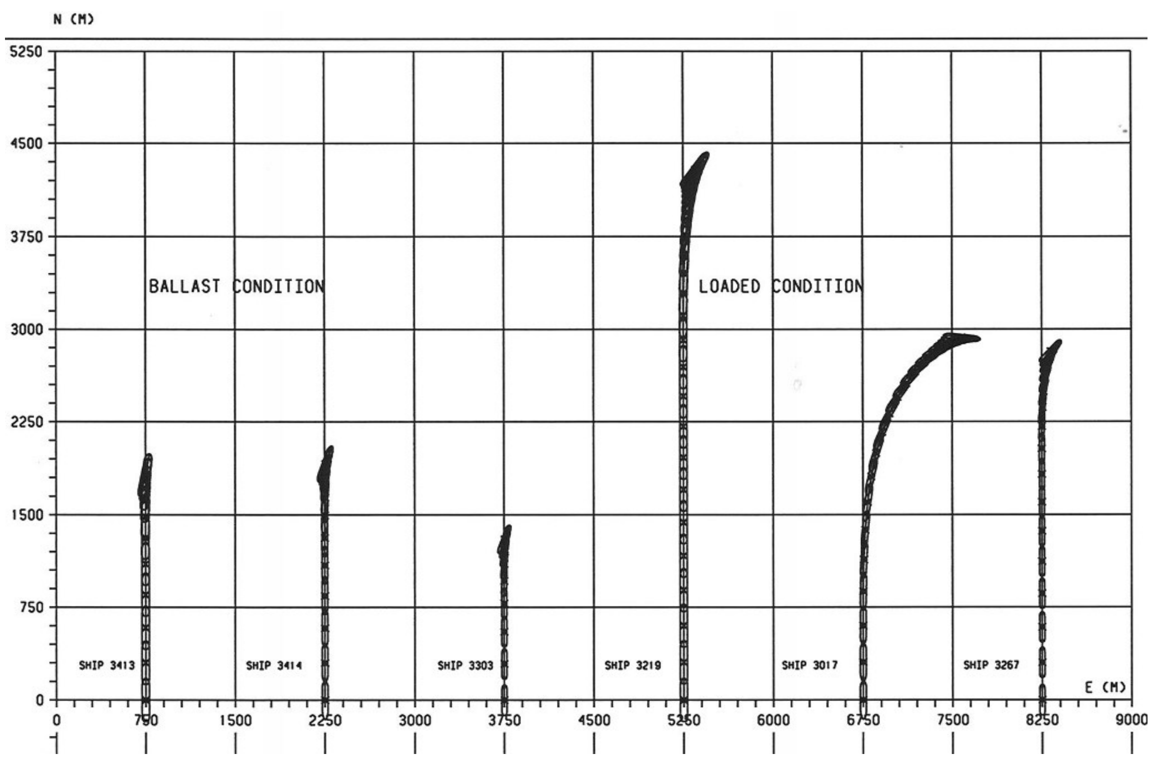


Figure 4-6: Comparison of tankers' normal stop distances at ship speed of 10 knot where the engine are running astern at 50 % power.

4.2 Navigational routes

Douglas Channel and the Kitimat area can be accessed from open sea via three alternative routes:

- A northern approach via Principe Channel
- A southern approach via Caamaño Sound
- A southern approach via Browning Entrance

The southern approach via Browning Entrance was not modelled at this time since the outer section is in open water.

Each of the approach areas are described below.

Northern Approach via Principe Channel and Otter Channel

The Principe Channel approach can be accessed either via Dixon Entrance north of Haida Gwaii or from the south via Hecate Strait. The Principe Channel approach can be sailed under the design ship's own power and steering in all weather conditions tested (up to 50 knots of wind) and by all three ship types tested, including the largest VLCC up to 340,000 DWT.

The Principe Channel approach is considered the "all-weather-safe-approach". The channel provides excellent protection from westerly winds and the swell from the Pacific Ocean. The smallest width in the Channel is 0.78 nm (1.43 km) which provides adequate room for manoeuvring a VLCC tanker in relatively deep natural water depths. The channel width in this and other channels along the route is well over a nautical mile and in some locations 3 to 4 nm wide.

Navigation of the full length of the channel routes (from Browning Entrance or Caamaño Sound to Kitimat terminal) was completed in the fast-time simulation model, and areas of more challenging navigation were selected for simulation on the FMBS.

The following simulation run sheets show examples of typical FMB simulations and include the "evaluation" notes of the Pilots who conducted the run and the "outcome" of the run assessed by FORCE Technology DMI.

Figure 4.2-1	Run No.: 101	Date: Mon Nov 17 2008	Page 1 of 1

Area: Entering Northern part of Principe Channel

Purpose:
Arrival Principe Channel with a ballasted VLCC 340.000 DWT. Test run. The vessel handled well throughout the passage.

Run execution:
Principe Channel with an inbound VLCC tanker of 340,000 DWT in ballast.
CPA to nearest shore or ground: 575 metres at start.
Engine and rudder command: Clear and accurate.
Tug command and response: Tug not used.
Objective of manoeuvre: Coming down Principe Channel from north heading for anchorage.

Basic info:	Weather:
Vessel involved: VLCC 3413 ballasted inbound Principe Channel Escort tugs involved: Tug not used in this run.	Current: NW going 1.0 knots Wind: SE 25 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.

Pilot evaluation:
Good approach clear of dangers.
Overall safety level 5 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

The tanker was handled well throughout the passage of Principe Channel. The situation was controlled.
Engine and rudder command: Within normal limits.

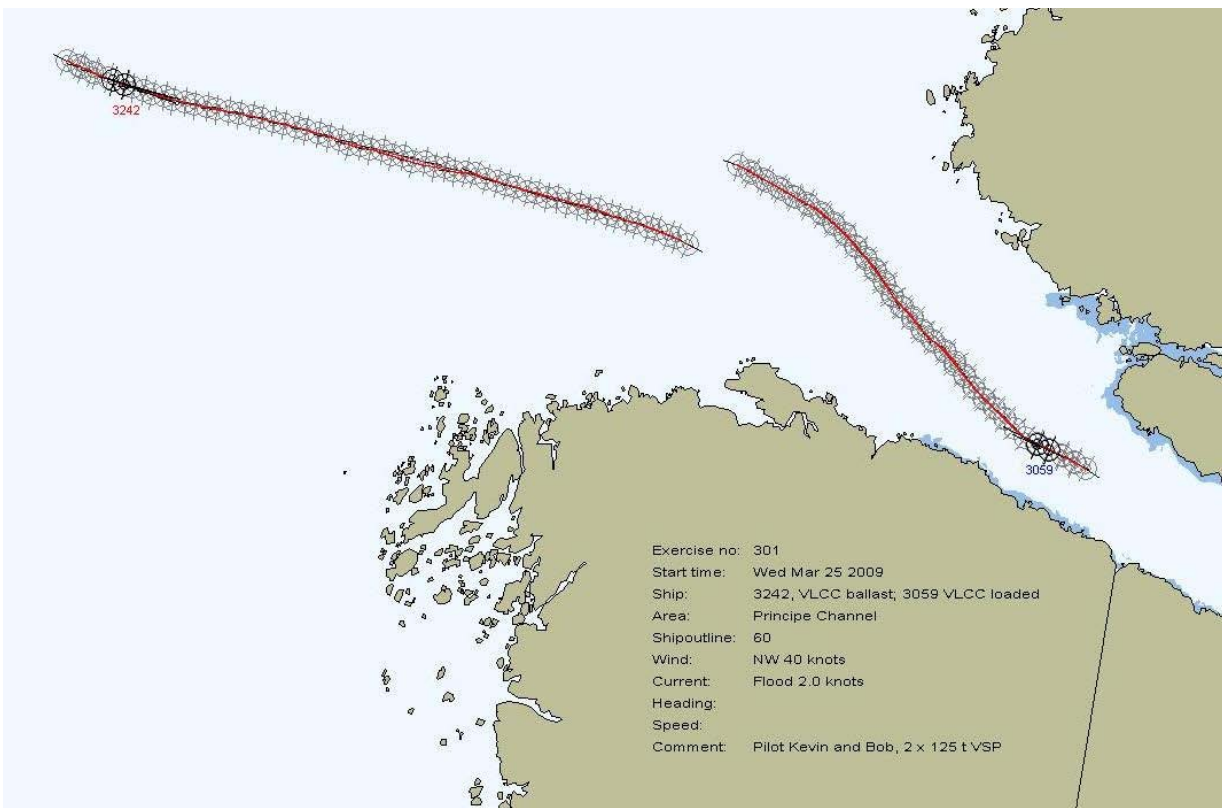
Figure 4.2-2	Run No.: 301	Date: Wed Mar 25 2009	Page 1 of 1

Area:
Arrival/departure northern part of Principe Channel at night time.

Purpose:
Two vessels passing each other north of Principe Channel under below-mentioned weather conditions.

Run execution:
Principe Channel with an inbound tanker of 300,000 DWT in ballast and an outbound tanker of 300,000 DWT loaded passing each other at northern part of Principe Channel.
CPA to other ships: 1 nautical mile
CPA to nearest shore or ground: NW bound vessel 990 metres to Banks Island at start and for SW bound vessel 1200 metres to Banks Island.
Engine and rudder command: Clear and accurate.
Tug command and response: Tugs standing by weren't required for any tasks.

Basic info: Night run. Vessels involved: 3242 VLCC ballasted inbound and 3059 VLCC loaded outbound. Escort tugs involved: 2 x 125 t VSP tugs	Weather: Wind: NW 40 knots Current: SE going 2.0 knots Visibility: good Waves: 1.5 metres 7.5 s



Pilot evaluation:
Pilot 3059: Tug wasn't required to perform any tasks. Safety level 4.
Pilot 3242: The sector at Deadmans Is. worked well. No concerns with meeting as simulated. Safety level 5. Good exercise.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
The tankers were handled well throughout the passage of Principe Channel. The situation was controlled with good communication to other traffic. Tugs were not used to assist in indirect towing mode during the passage. The sector lights at Deadmans Is. worked well.

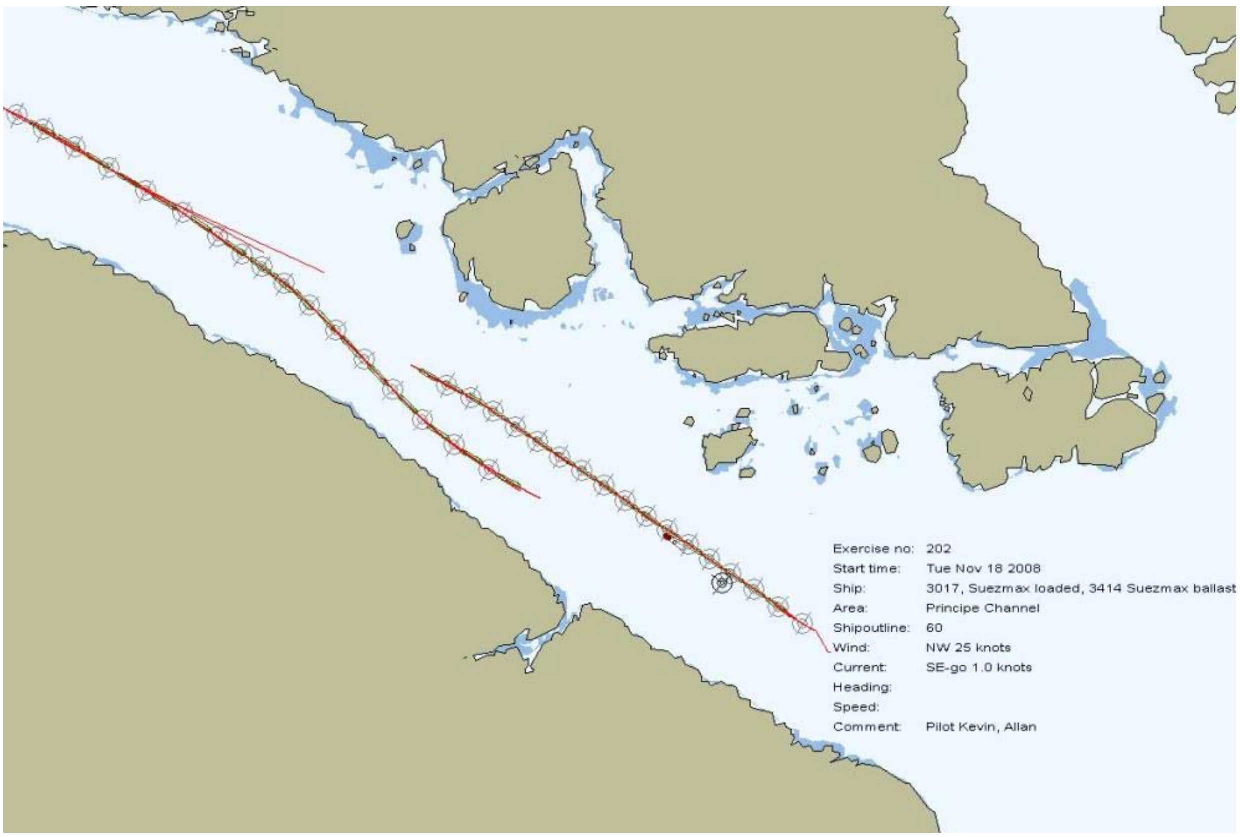
Figure 4.2-3	Run No.: 202	Date: Tue Nov 18 2008	Page 1 of 1

Area:
Navigating the narrowest area of Principe Channel: Passing Dixon Island

Purpose:
How much room is there for a loaded Suezmax outbound and a ballasted Suezmax inbound when passing each other at Dixon Island.

Run execution:
Principe Channel with an inbound tanker of 200,000 DWT in ballast and an outbound tanker of 200,000 DWT loaded passing each other off Dixon Island. The smallest width in the channel is 0.78 nm which should provide adequate room for two tankers passing each other.

Basic info:	Weather:
Vessel involved: 3017 Suezmax loaded outbound and 3414 Suezmax ballast inbound	Wind: NW 25 knots
Escort tugs involved: 2 x 125 t VSP tugs	Current: SE going 1.0 knots
	Visibility: good



Pilot evaluation:
Pilot 3017: Would not like to plan meeting at this point (un-necessary). Safety level 2.
Pilot 3414: Difficult to handle ship at 10 knots without using tug. Safety level 3.

Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
The tankers were handled well throughout the passage of Principe Channel. The situation was controlled with good communication to other traffic. Tugs were used to assist in indirect towing mode during the passage and with a maximum of 75% of power used. This was done to test the efficiency of the tugs. The manoeuvre could have been handled without the tugs assisting.

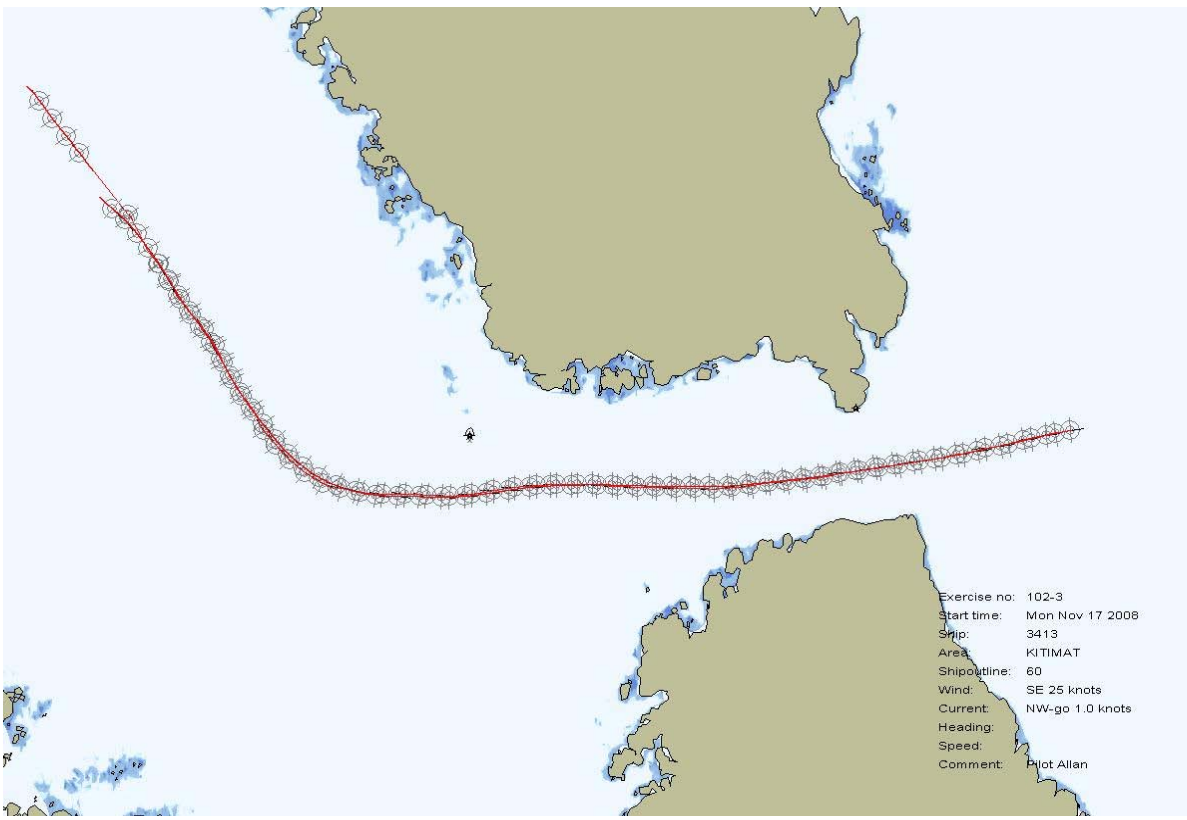
Figure 4.2-5	Run No.: 102-3	Date: Mon Nov 17 2008	Page 1 of 1

Area:
Navigating in Principe Channel and Otter Channel

Purpose:
A ballasted VLCC tanker navigating through the southern part of Principe Channel and entering Otter Channel

Run execution:
Southern part Principe Channel with an inbound tanker of 340,000 DWT in ballast turning to port into Otter Channel.

Basic info:	Weather:
Vessel involved: 3413 VLCC in ballast	Wind: SE 25 knots
Escort tugs involved: 1 x 90 t VSP tug	Current: NW going 1.0 knots
	Visibility: good



Pilot evaluation:

Vessel moved down south from Principe and proceeded for Otter Channel passage. No problem with passage.
Tug assisted with the turn into Otter Channel.
Good exercise.
Overall safety level 4 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
The tanker was handled well throughout the passage of Principe Channel. The situation was controlled. Tug was used to assist in indirect towing mode during the turn and passage with a maximum of 75% of power used. The tug was used to test its efficiency. The manoeuvre could have been done without the tug's assistance.

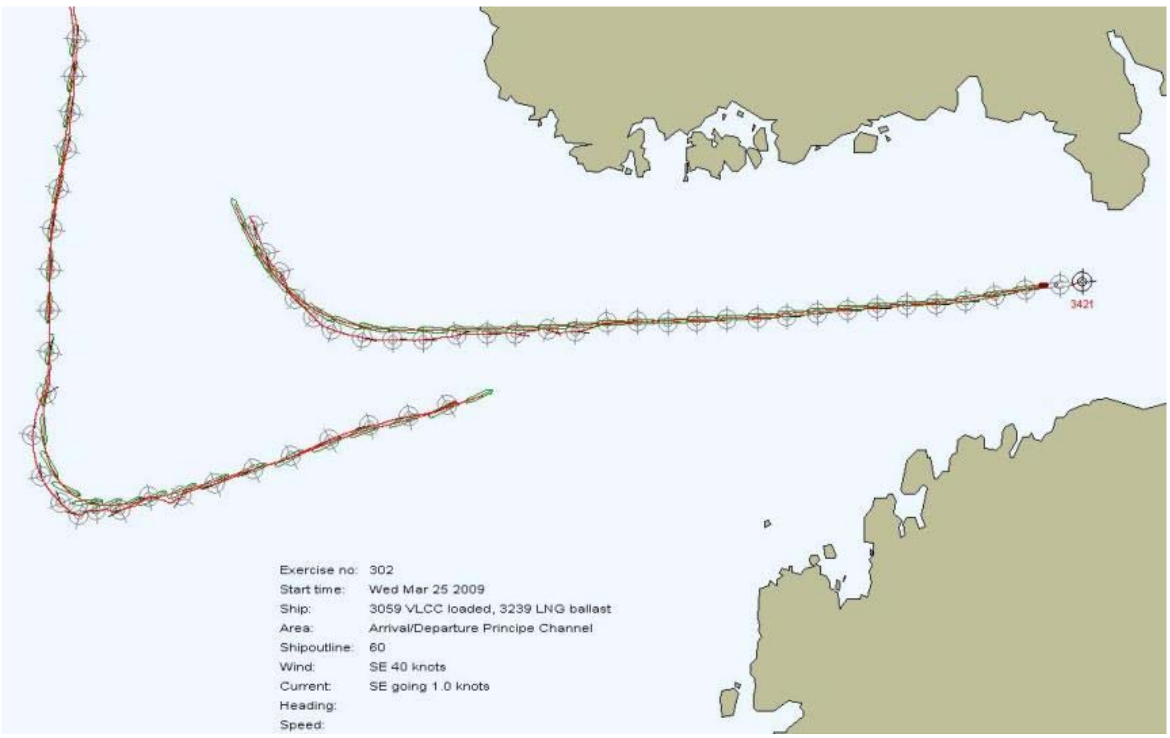
Figure 4.2-6	Run No.: 302	Date: Wed Mar 25 2009	Page 1 of 1

Area:
Otter Channel

Purpose:
Departure/Arrival Otter Channel with a loaded VLCC and a ballasted LNG. Both vessels had tugs standby.

Run execution:
CPA to other ships: 240 metres
CPA to nearest shore or ground: W bound vessel 1490 metres to Nepean Rk. and for E bound vessel 1700 metres to Nepean Rk.
Engine and rudder command: Clear and accurate and carried out in due time as expected for senior pilots.
Tug command and response: Fast response with maximum load on towing rope during the turns.

Basic info:	Weather:
Night run. Tanker speed: knots 10 Tug configuration: 2 x VSP 125 t BP (no. 3421) connected centre fairlead aft.	Current: SE going 1.0 knots Wind: NW 40 knots Waves: 1.5 metres 7.5 s Visibility: Good



Pilot evaluation:
Pilot 3239: Amazing amount of drift with the wind and a ballasted LNG tanker. Safety level 4.
Pilot 3059: Used the tug to make the turn at Nepean Rk. Safety level 4

Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

The vessels handled well throughout the passage without any concerns during passage. The assisting tug on the loaded VLCC was used to test the efficiency of tug. The manoeuvre could have been done without using the tug.

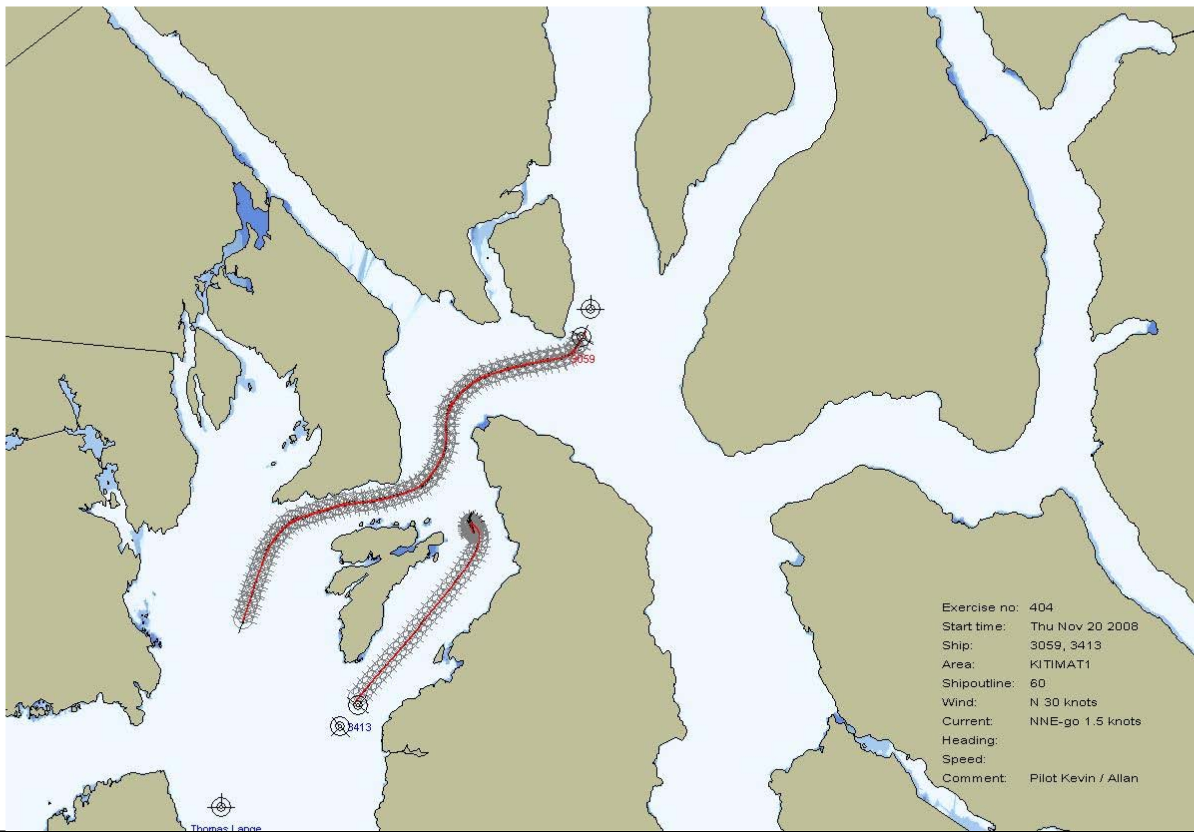
Figure 4.2-7	Run No.: 404	Date: Tue Nov 20 2008	Page 1 of 1

Area:
Transit in Lewis Passage and Cridge Passage. A loaded VLCC 300.000 DWT inbound and a ballasted VLCC 340.000 DWT outbound. Both vessels under escort towing.

Purpose:
Objective of manoeuvre: Two large VLCC will pass each other in Lewis Passage, but inbound tanker gets engine and rudder failure ("Black out").

Run execution:
CPA to traffic vessel when VLCC passing inbound VLCC: N/A
CPA to nearest shore or ground onboard outbound VLCC: 403 metres to Block Hd.
CPA to nearest shore or ground onboard inbound VLCC: 950 metres to Gil Island.

Basic info:	Weather conditions:
3059 Initial conditions VLCC outbound: Day run. Speed: knots 11.2, heading 256 at start. 3413 Initial conditions VLCC inbound: Day run. Speed: knots 10.7, heading 038 at start. Tug configuration: 2 x VSP 90 t BP connected to centre fairlead aft on each vessel.	Current: NNE going 1.5 knots Wind: N 30 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.



Pilot evaluation:
Pilot 3413: When coming through Lewis Passage, the tanker experiences engine/rudder failure. Safety level 3.
Pilot 3059: Due to rudder failure on other tanker, it was decided to use Cridge passage which is a good alternative route. Safety level 4.

Outcome:
Remarks: Due to failure onboard the inbound tanker the outbound tanker decides to use Cridge Passage which is a good alternative route. Pilot on tanker with engine and rudder failure succeeded in controlling the VLCC with the assistance of the 90 t VSP tug. Vessels handled well.

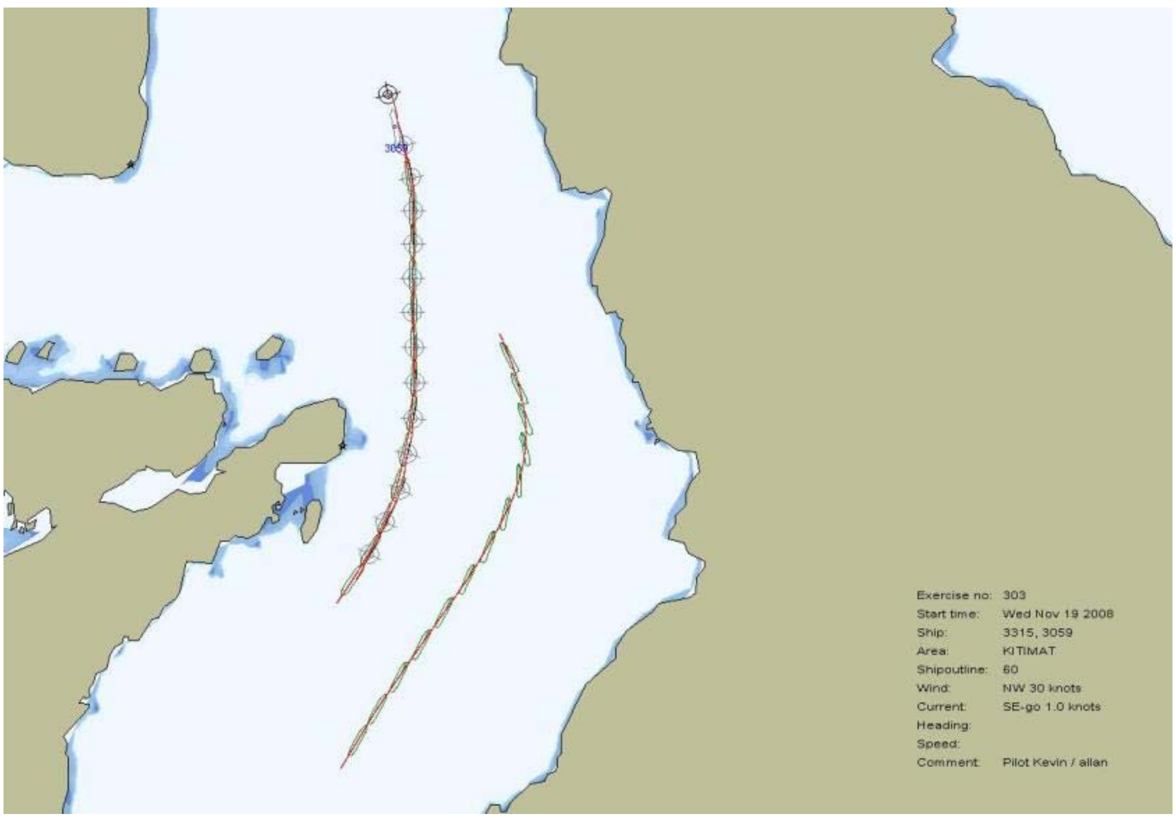
Figure 4.2-8	Run No.: 303	Date: Wed Nov 19 2008	Page 1 of 1

Area:
Two large vessels passing each other in Lewis Passage.

Purpose:
Transit in Lewis Passage with a loaded VLCC 300.000 DWT and a LNG Membrane type in ballast passing each other.

Run execution:
CPA to when VLCC passing LNG: 1130 metres.
CPA to nearest shore or ground onboard VLCC: 400 metres to Plover Pt.
CPA to nearest shore or ground onboard LNG: 950 metres to Gil Island.
Engine and rudder command: Clear and accurate and carried out in due time by the pilots.
Tug command and response: Fast response. Tug continually keeping tension on the towline.

Basic info:	Weather:
Initial conditions 3315 LNG 216.000 inbound: Day run. Speed: knots 9.8, heading 030 at start. Initial conditions 3059 tanker 300.000 outbound loaded: Day run. Speed: knots 11.5, heading 170 at start. Tug configuration: 2 x VSP 90 t BP connected to centre fairlead aft on each vessel.	Current: SE going 1.0 knots Wind: NW 30 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.



Pilot evaluation:

Pilot 3315: Had to increase turn rate to 15 degree/min. for this large vessel. Prefer to pass on straight course otherwise safe passing. Safety level 2.
Pilot 3059: Prefer also to pass on straight course. Safety level 4.

Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
The vessels handled well throughout the passage. Lesson learned: Wind age on these large VLCC is a consideration in all meeting situations.

Navigating Wright Sound

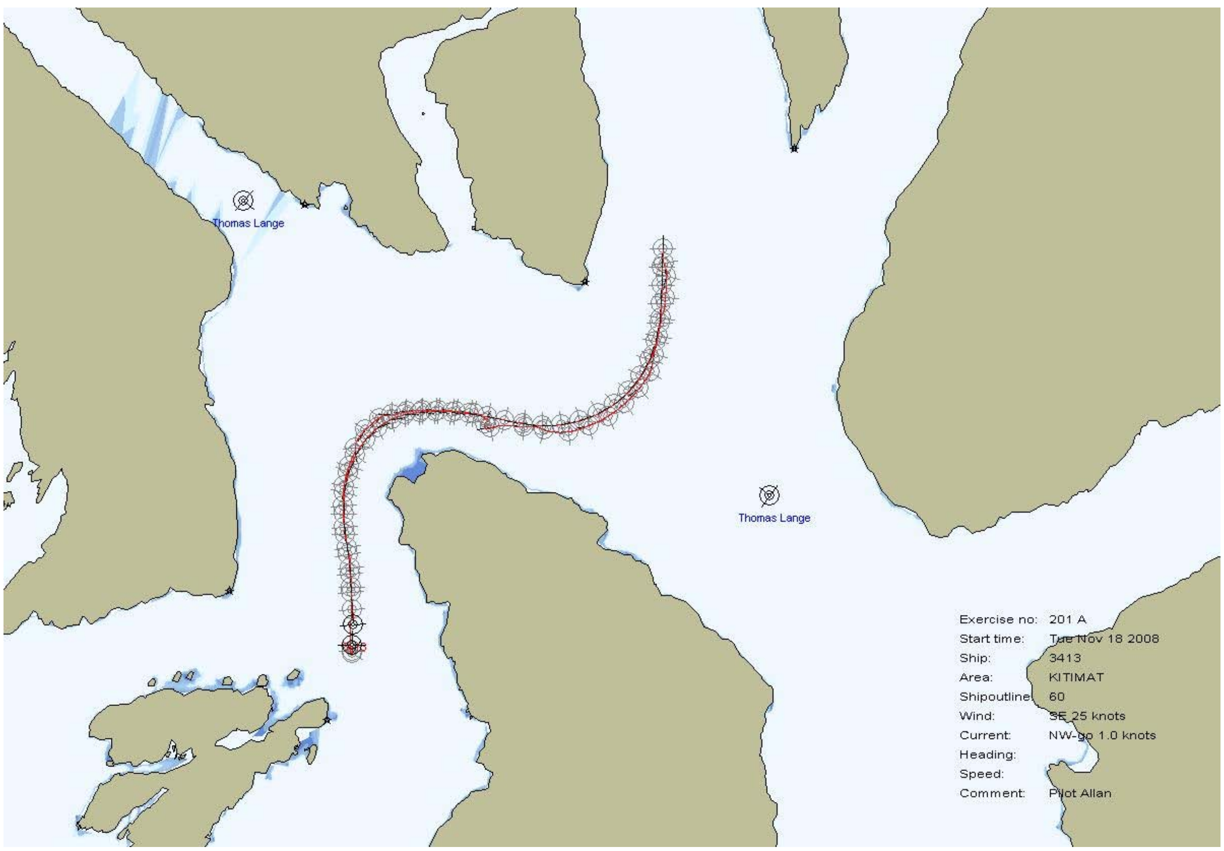
Figure 4.2-9	Run No.: 201 A	Date: Wed Jan 03 2007	Page 1 of 1

Area:
Wright Sound

Purpose:
Transit in Wright Sound. Escort towing of 3413 a ballasted VLCC 340.000 DWT

Run execution:
Coming from Lewis Passage into Wright Sound preparing for passage.
CPA to other ships: 1350 metres to nearest traffic ship.
CPA to nearest shore or ground: 630 metres at Turtle Pt.
Engine and rudder command: Clear and accurate.
Tug command and response: Fast response and accurate helm commands

Basic info:	Weather conditions:
Initial conditions: Day run. Speed: knots 11.5, heading 355 at start.	Current: NW going 1.0 knots
Tug configuration: 1 x VSP 125 t BP connected centre fairlead aft.	Wind: SE 25 knots
	Waves: 1.0 metres 8 s
	Visibility: 3-5 nm.



Pilot evaluation:
Overall safety level 4 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

The vessels handled well throughout the passage. The tug was used to assist in steering. This was done to test the efficiency of the tug.

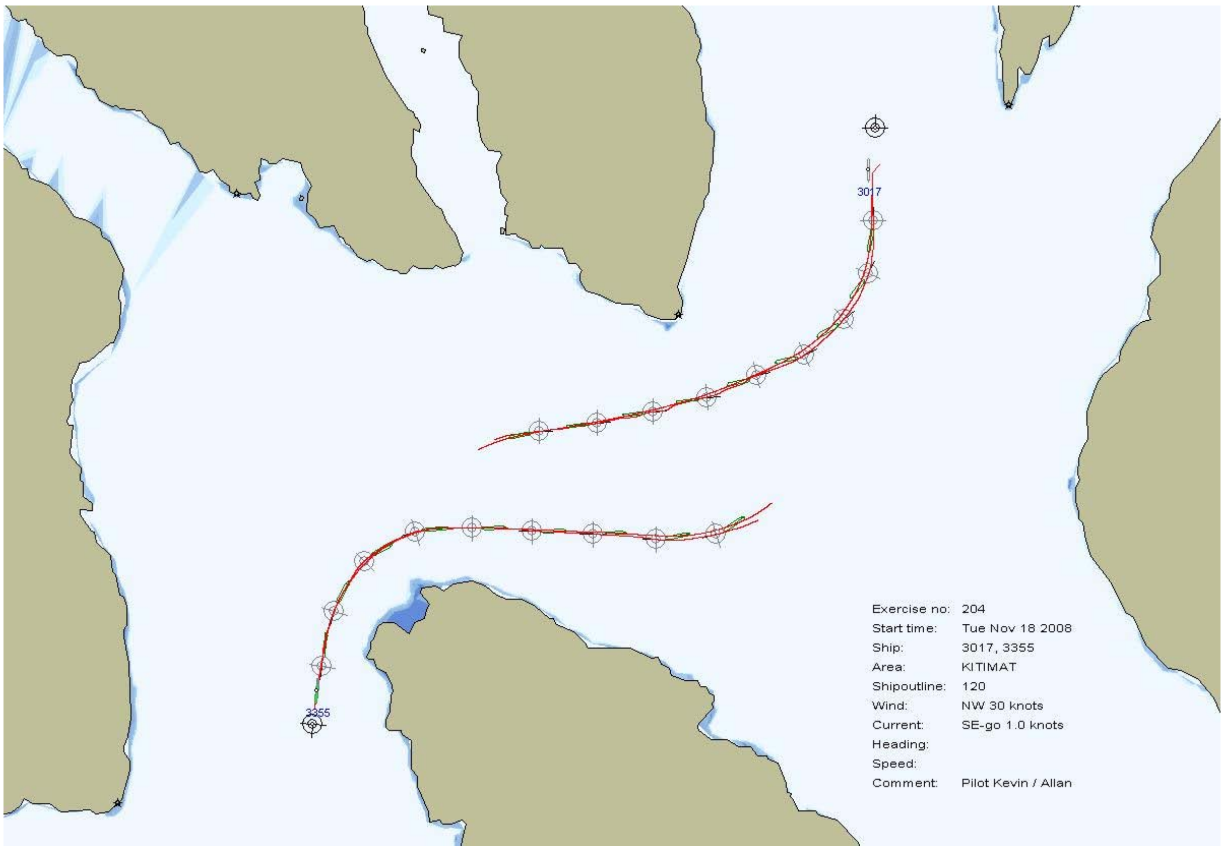
Figure 4.2-10	Run No.: 204	Date: Thu Nov 18 2008	Page 1 of 1

Area:
Arrival/Departure Principe Channel

Purpose:
Two tankers passing each other in Wright Sound.

Run execution:
Principe Channel with an inbound loaded LNG of 200,000 DWT and an outbound loaded Suezmax tanker of 200,000 DWT passing each other off Gill Island.

Basic info:	Weather:
Initial conditions Suezmax: Day run. Speed: knots 10.2, heading 180 at start. Initial conditions LNG: Day run. Speed: knots 12.6, heading 010 at start. Tug configuration: 2 x VSP 125 t BP connected to centre fairlead aft on each vessel	Current: SE going 1.0 knots Wind: NW 30 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.



Pilot evaluation:

Pilot 3017: Best place for two vessels to meet. Safety level 4
Pilot 3355: Good area to meet. Safety level 5.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

Everything went as planned, best place to meet in Wright Sound. The vessels handled well without any problems.

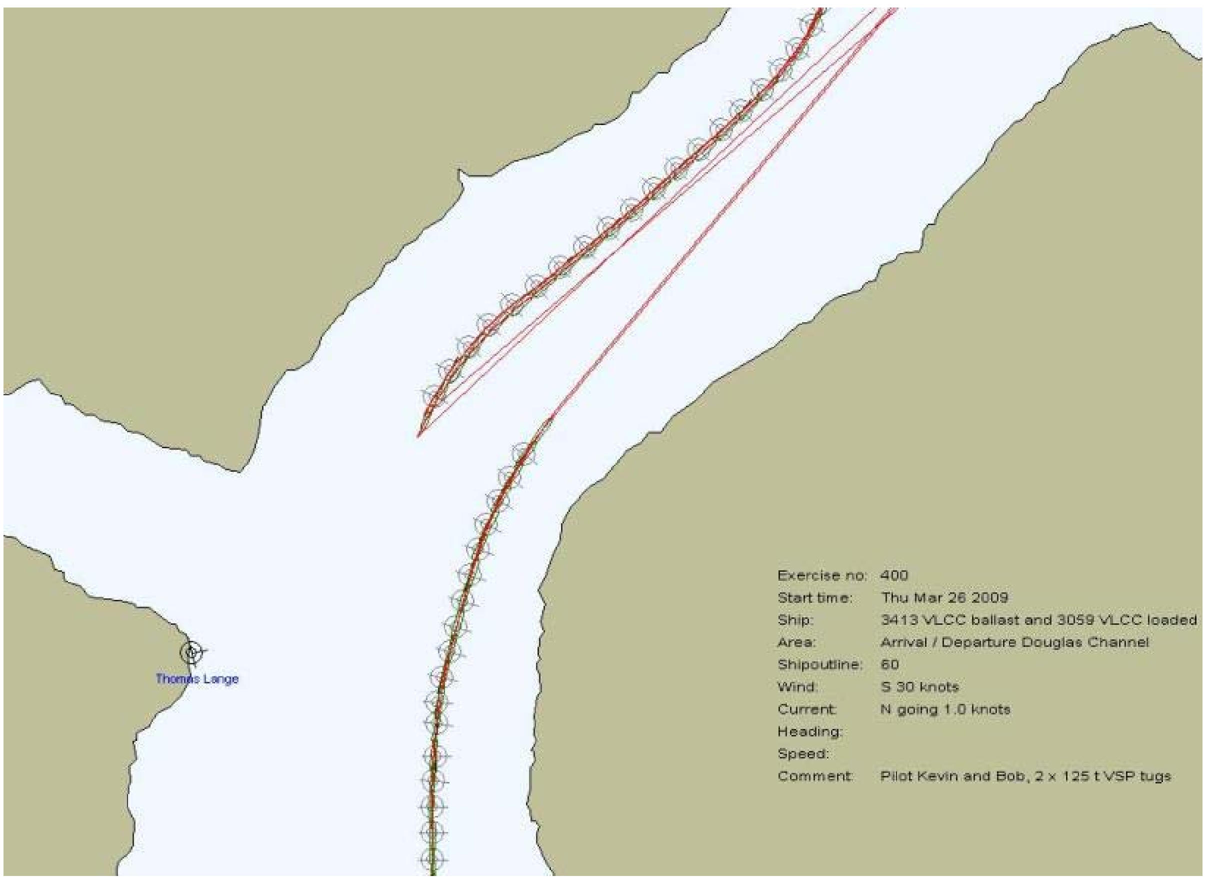
Figure 4.2-11	Run No.: 400	Date: Tue Mar 26 2009	Page 1 of 1

Area: Departure/Arrival Douglas Channel - escort towing with a loaded VLCC and a ballasted VLCC

Purpose:
Two vessels passing each other in the Douglas Channel under below-mentioned weather conditions.

Run execution:
CPA to other ships: 1120 metres.
CPA to nearest shore or ground: N bound vessel 650 metres to Hawkesbury Island and for S bound vessel 800 metres to Gertrude Pt.
Engine and rudder command: Clear and accurate.
Tug command and response: Tugs were not used during the passage, only standing by.

Basic info:	Weather conditions:
Initial conditions: Night run. 3413 VLCC ballasted, speed: knots 10, heading 000 and 3059 VLCC loaded, speed knots 10, heading 225 Tug configuration: 2 x VSP 125 t BP connected to centre fairlead aft on each tanker.	Current: N going 1.0 knots Wind: S 30 knots Waves: 0.5 metres 4 s Visibility: Good

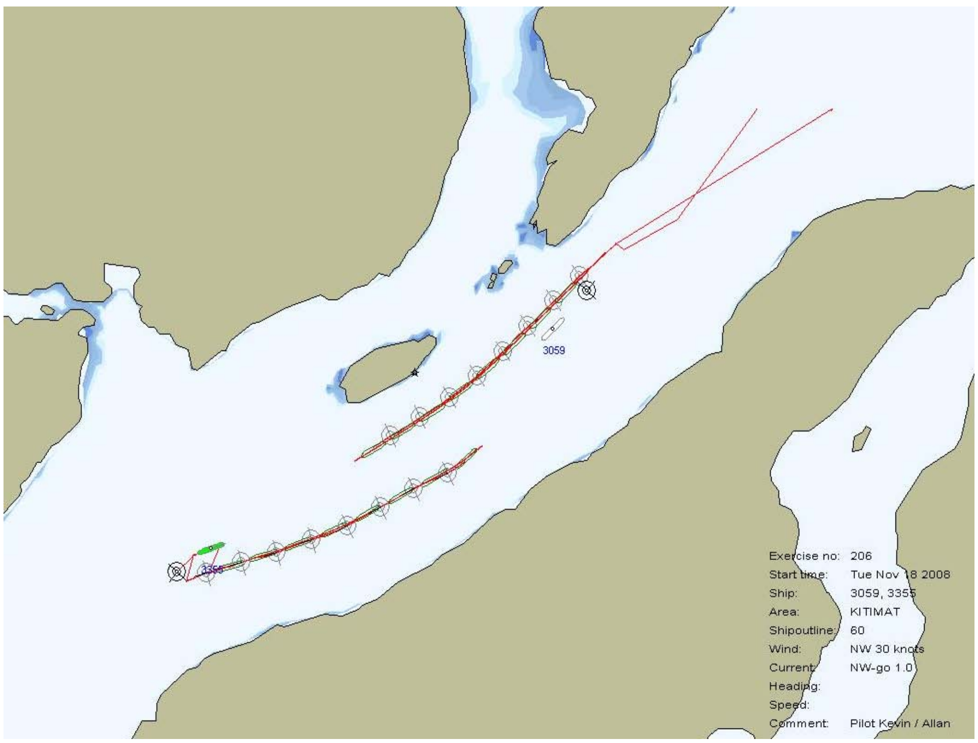


Pilot evaluation:
Pilot 3413: Good exercise. Safety level 4.
Pilot 3059: The new lights gave additional reference for judging the turns. Safety level 4.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
The vessels handled well throughout the passage. No problems with the turns in the Douglas Channel. There were no problems for two vessels to pass each other in the Douglas Channel, the situation was well controlled. The new proposed lights were very good.

Passing Emilia Island in Douglas Channel

Figure 4.2-12	Run No.: 206	Date: Tue Nov 18 2008	Page 1 of 1
Area: Douglas Channel			
Purpose: Passing of Emilia Island with a loaded VLCC 340.000 DWT and a loaded LNG Moss type			
Run execution: Douglas Channel at Emilia Island with a loaded outbound tanker of 300,000 DWT, meeting an inbound LNG tanker.			
Basic info: Initial conditions VLCC outbound: Day run. Speed: knots 10.2, heading 230 at start. Initial conditions LNG inbound: Day run. Speed: knots 13.0, heading 070 at start. Tug configuration: 2 x VSP 125 t BP connected to centre fairlead aft on each vessel.		Weather: Current: NW going 1.0 knots Wind: NW 30 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.	



Pilot evaluation:

Pilot 3059: Closer to Emilia Island than I would do under normal circumstances. Coming down from Kitimat fully loaded. Meet an LNG at Maitland, nearest passage distance between vessels 500 metres distance to closest shore 600 metres. Safety level 3.
Pilot 3355: Steaming upwards to Kitimat in Douglas. Meeting a loaded VLCC at closed point (Maitland). Passed in optimum position. Safety level 3.

Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

Communication is an important key to this meeting situation. The vessels handled well without any problems.

Final approach to the Kitimat Oil Terminal

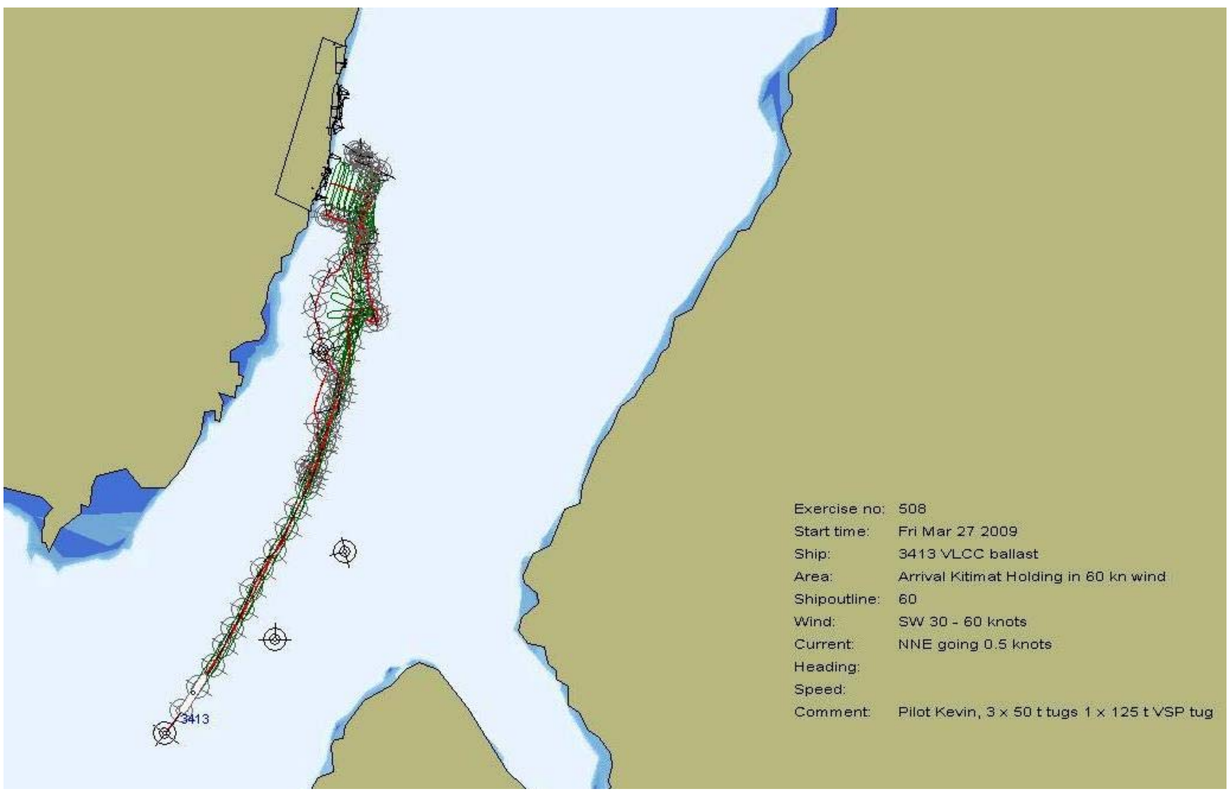
Figure 4.2-13	Run No.: 508	Date: Fri Mar 27 2009	Page 1 of 1

Area:
Arrival Kitimat with a ballasted VLCC

Purpose:
Tested holding the ship in position off the berth area in 60 knots of wind. Docking the vessel with starboard side alongside in 30 knots of wind.

Run execution:
CPA to other ships: N/A
CPA to nearest shore or ground: distance to shore south of the terminal 900 metres at start.
Engine and rudder command: Clear and accurate commands.
Tug command and response: Fast response and commands.

Basic info:	Weather conditions:
Initial conditions: Night run. Start speed: knots 6, heading 030 Tug configuration: 1 x VSP 125 t BP connected centre aft. One ASD tug 50 t BP connected centre lead fore and two ASD vector tugs 50 t BP free to push on ship side.	Current: NNE going 0.5 knots Wind: SSW 30 to 60 knots Waves: 0 metres Visibility: Good



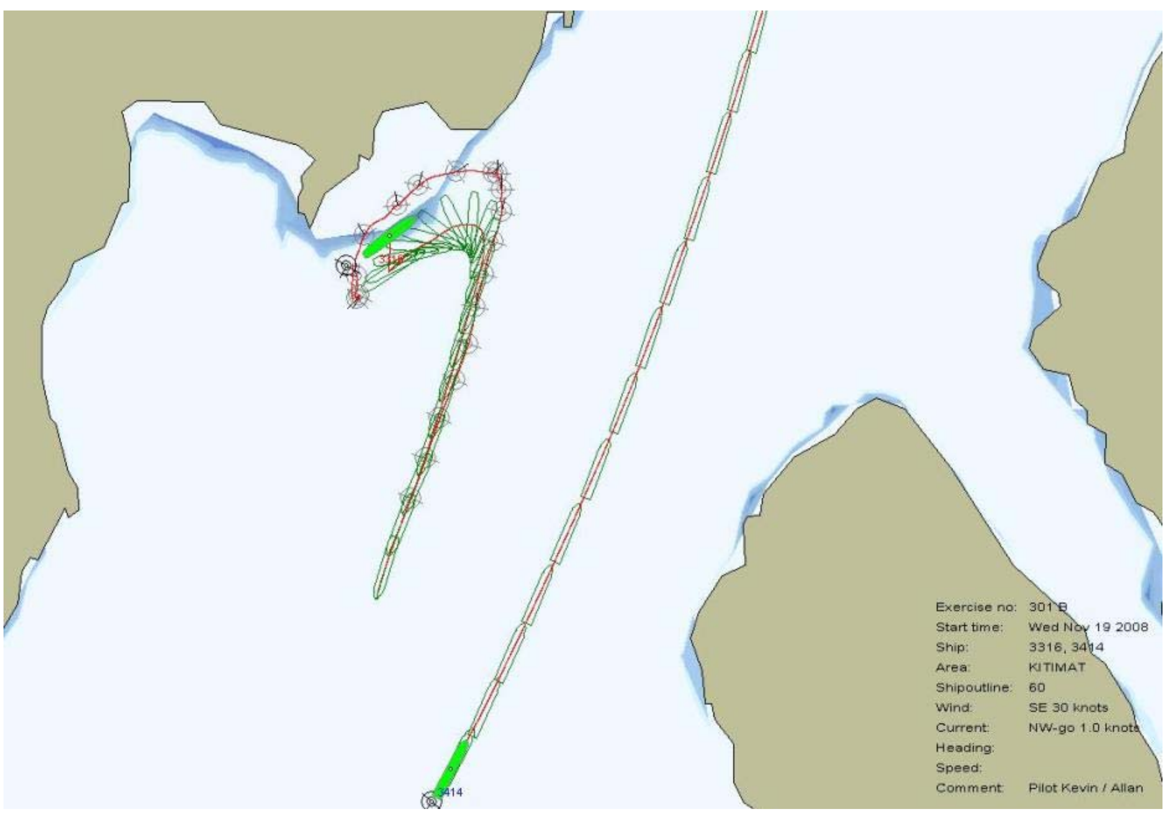
Pilot evaluation:
Tested holding the ship in position off the berth area in 60 knots of wind. Could be safely done as tested. Misjudged the sideways speed approaching the berth and should have slowed the approach from further off the berth.
Overall safety level 3 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

Could be safely done as tested. Tugs used with maximum power now and then.

Passing other tankers un-berthing from possible future LNG terminal

<table>
<tr><td>Figure 4.2-14</td><td>Run No.: 302</td><td>Date: Wed Nov 19 2008</td><td>Page 1 of 1</td></tr>
<tr><td colspan="4">Area:
Departure/arrival Kitimat escort towing with a ballasted Suezmax and a loaded LNG Moss type departing terminal.</td></tr>
<tr><td colspan="4">Purpose:
Two vessels passing each other in Douglas Channel south of Kitimat oil terminal, preparing for passage.
Passing un-berthing LNG tanker at proposed terminal south of the Kitimat oil terminal.</td></tr>
<tr><td colspan="4">Run execution:
CPA to when passing: 900 metres.
CPA to nearest shore or ground on board Suezmax: 550 metres to Clio Pt.
CPA to nearest shore or ground on board LNG: Departure
Engine and rudder command: Clear and accurate.
Tug command and response: Fast response and accurate helm commands.</td></tr>
<tr><td colspan="2">Basic info:
Initial conditions LNG outbound: Day run. Speed: knots 0.
Initial conditions Suezmax inbound: Day run. Speed: knots 5.0, heading 045 at start.
Tug configuration: 2 x VSP 90 t BP connected to centre fairlead aft on each vessel.</td><td colspan="2">Weather conditions:
Current: NW going 1.0 knots
Wind: SE 30 knots
Waves: 1.0 metres 8 s
Visibility: 3-5 nm.</td></tr>
</table>



<table>
<tr><td>Pilot evaluation:
Pilot 3414: Safety level 4.
Pilot 3316: Strong set to north with the south easterly wind. Safety level 5.
Rating 1= low, 3 = acceptable, 5 = high.</td></tr>
<tr><td>Outcome:
The run was completed safely and successfully.
Communication is an important key to this meeting situation. The vessels handled well without any problems.</td></tr>
</table>

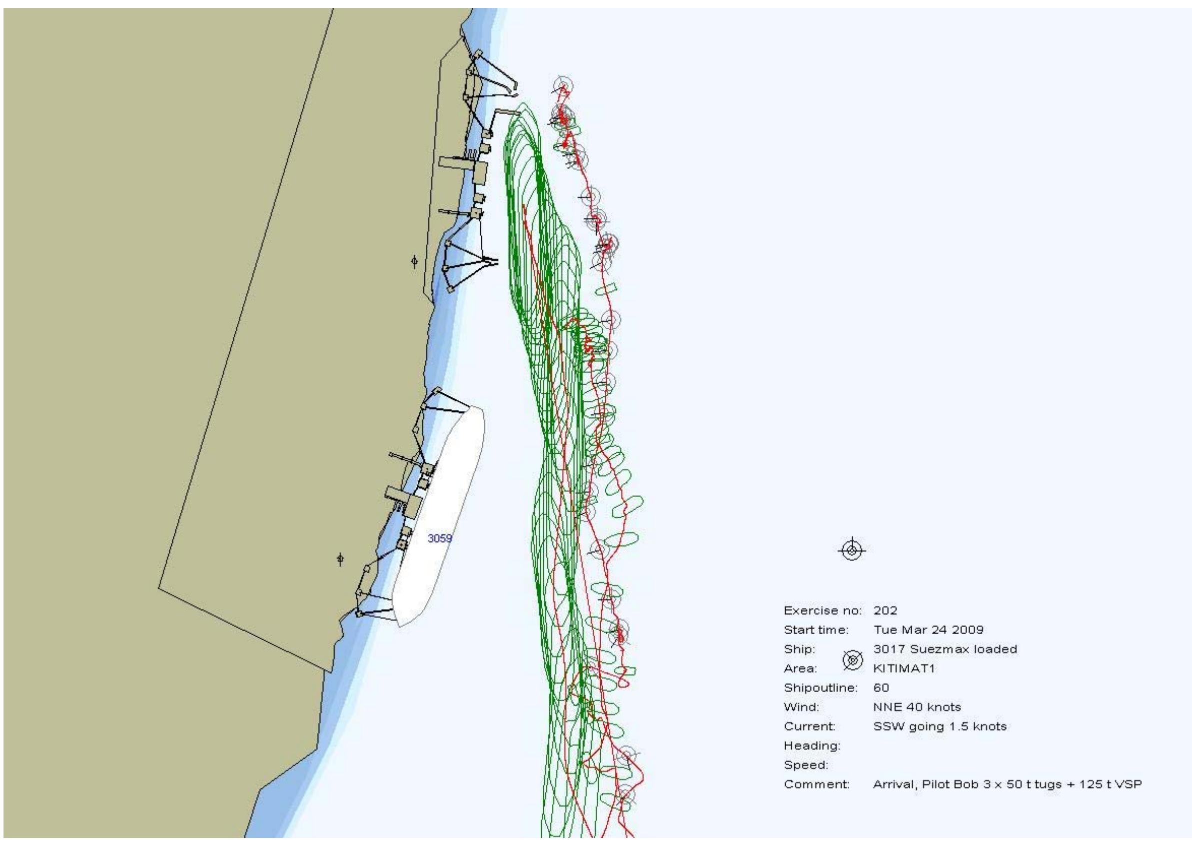
Figure 4.2-15	Run No.: 202	Date: Tue Mar 24 2009	Page 1 of 1

Area:
Arrival Kitimat with Suezmax in loaded condition

Purpose:
Heading north and passing the south berth at a safe distance with a vessel alongside and arrive at the North berth with port side alongside.

Run execution:
CPA to other ships: 90 metres.
CPA to nearest shore or ground: Distance to shore south of terminal 580 metres at start.
Engine and rudder command: Clear and accurate commands.
Tug command and response: Fast response with maximum 50% load on towing rope.

Basic info:	Weather conditions:
Initial conditions: Day run. Speed: knots 4, heading 000 Tug configuration: VSP 125 t BP connected centre aft. One ASD tug of 50 t BP connected centre lead for and two ASD vector tugs of 50 t BP free to push on ship side.	Current: SSW 1.5 knot Wind: NNE 40 knots Waves: 0 metres Visibility: Good



Pilot evaluation:
The approach was as planned and the tugs responded as anticipated except for a misunderstanding with a tug order. Overall safety level 4 out of max. 5.

Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
No problems were observed with this arrival. The vessel handled well throughout the arrival with the loaded VLCC alongside the South berth. Lesson learned: Exercise of tug commands is essential. Recommendation: Use “Clock method” for tug commands.

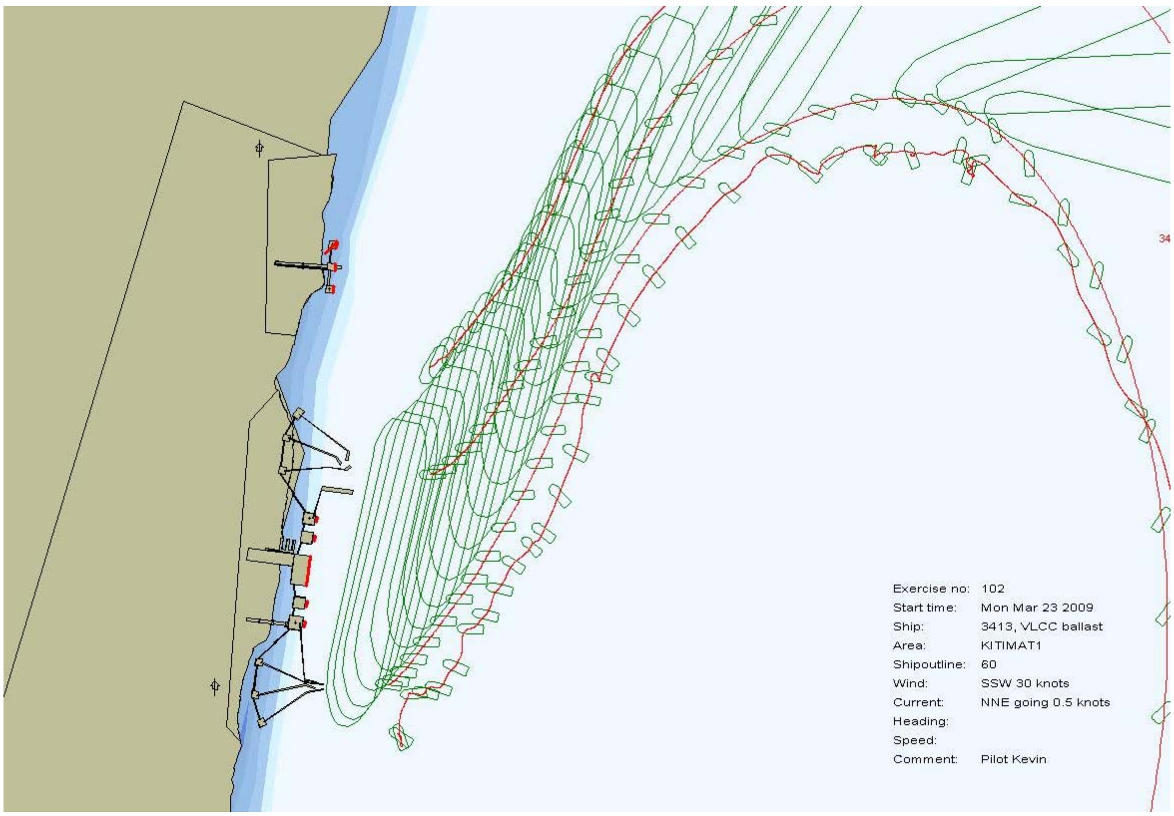
Figure 4.2-16	Run No.: 102	Date: Mon Mar 23 2009	Page 1 of 1

Area:
Arrival Kitimat with VLCC 3413 in ballast condition

Purpose:
Heading north and pass the berth at safe distance turn the vessel 180 degree to port and head the current and wind. Approach the North berth with starboard side alongside. Important to keep the speed down and stemming the wind.

Run execution:
CPA to other ships: N/A in this exercise.
CPA to nearest shore or ground: Distance to shore at start south of the terminal 850 metres.
Engine and rudder command: Clear and accurate according.
Tug command and response: Fast response, faster than expected.

Basic info:	Weather conditions:
Initial conditions: Day run. Start speed: knots 6, heading 030 Tug configuration: VSP 125 t BP connected centre aft. One ASD tug 50 t BP connected centre lead for and two ASD vector tugs 50 t BP free to push on ship side.	Current: NNE 0.5 knot Wind: SSW 30 knots Waves: 0 metres Visibility: Good



Pilot evaluation:
Close attention to stemming the wind and keeping approach speed down are important. Require good visibility. Even small wind on either bow caused significant force.
Overall safety level 4 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

No problems were observed with this passage or with the port turn. Keeping the vessel speed down is important.

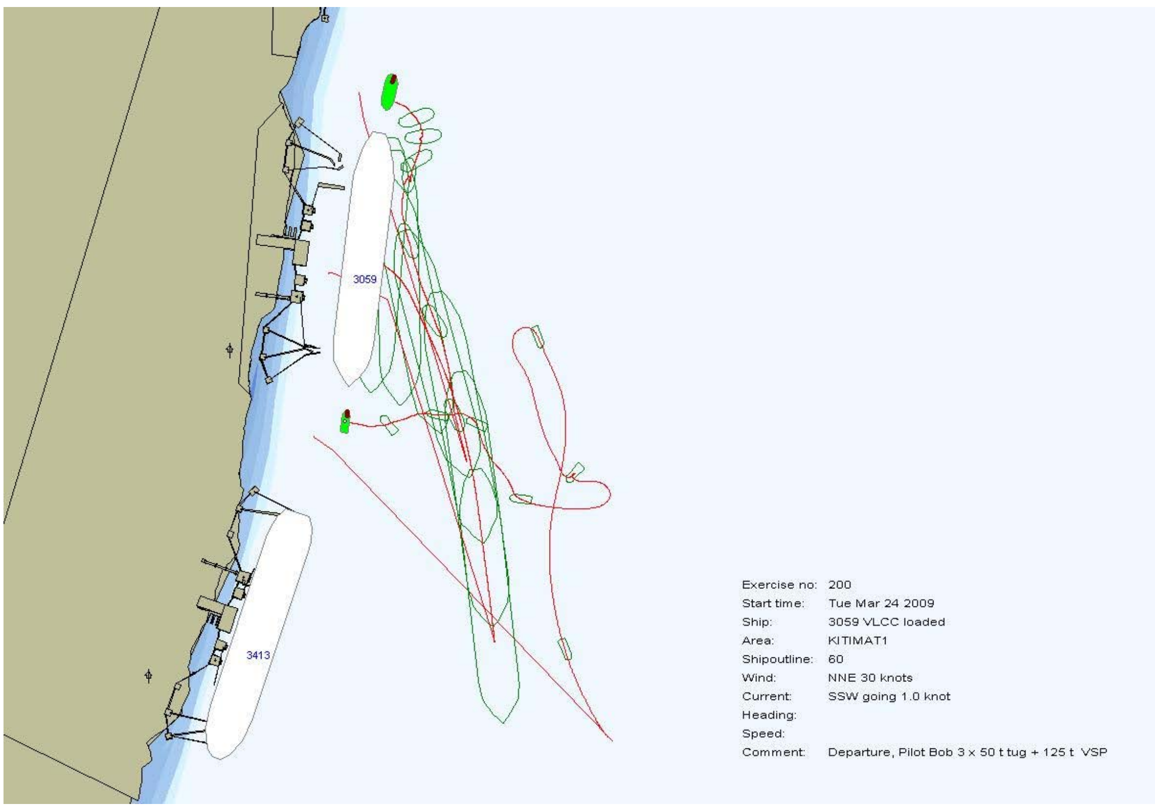
Figure 4.2-17	Run No.: 200	Date: Tue Mar 24 2009	Page 1 of 1

Area:
Departure Kitimat with loaded VLCC.

Purpose:
Departure from North berth by use of four tugs and pass the South berth pier at a safe distance and out into deeper water.

Run execution:
CPA to other ships: 180 metres
CPA to nearest shore or ground: 0 metres at departure.
Engine and rudder command: Clear and accurate commands.
Tug command and response: Fast response and clear commands.

Basic info:	Weather conditions:
Initial conditions: Day run. Speed: knots 0, heading 187 Tug configuration: VSP 125 t BP connected centre aft. One ASD tug 50 t BP connected centre lead for and two ASD vector tugs 50 t BP free to push on ship side.	Current: SSW 1.0 knot Wind: NNE 30 knots Waves: 0 metres Visibility: Good



Pilot evaluation:
With the available tug power, it is not anticipated any problems on departure.
Overall safety level 3 out of max. 5.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
No problems were observed with this departure. The vessel handled well throughout the un-berthing, with a loaded VLCC at South berth.

Southern Approach at Caamaño Sound

The approach via Caamaño Sound is the shortest and has the least travel time of all the approaches. The disadvantage is that the approach is poorly protected from winds and swells from the open ocean to the southwest. Therefore, this approach should only be used in moderate weather conditions. Navigation in wind speeds of up to 40 knots was managed without difficulty.

A concern with the Caamaño approach is that if an emergency occurs in heavy weather (wind above 40 knots combined with a difficult sea state) it may be difficult for an escort tug to hold the vessel or tow it out to sea due to the heavy swell that can occur in the area.

The following simulation run sheets show examples of typical FMB simulations and include the "evaluation" notes of the Pilots who conducted the run and the "outcome" of the run assessed by FORCE Technology DMI.

Figure 4.2-18	Run No.: 0606	Date: Mon Jan 08 2007	Page 1 of 1

Area:
Caamaño and into Campania Sound

Purpose:
A ballasted VLCC arrival from the Caamaño Sound and entering Campania Sound.

Run execution:
Caamaño Sound with an inbound tanker of 340,000 DWT in ballast turning port into Campania Sound in strong wind.

Basic info:	Weather:
Vessel involved: 3413 VLCC in ballast Escort tugs involved: 1 x 90 t VSP tug	Wind: SE 50 knots Current: NW going 1.0 knots Visibility: good

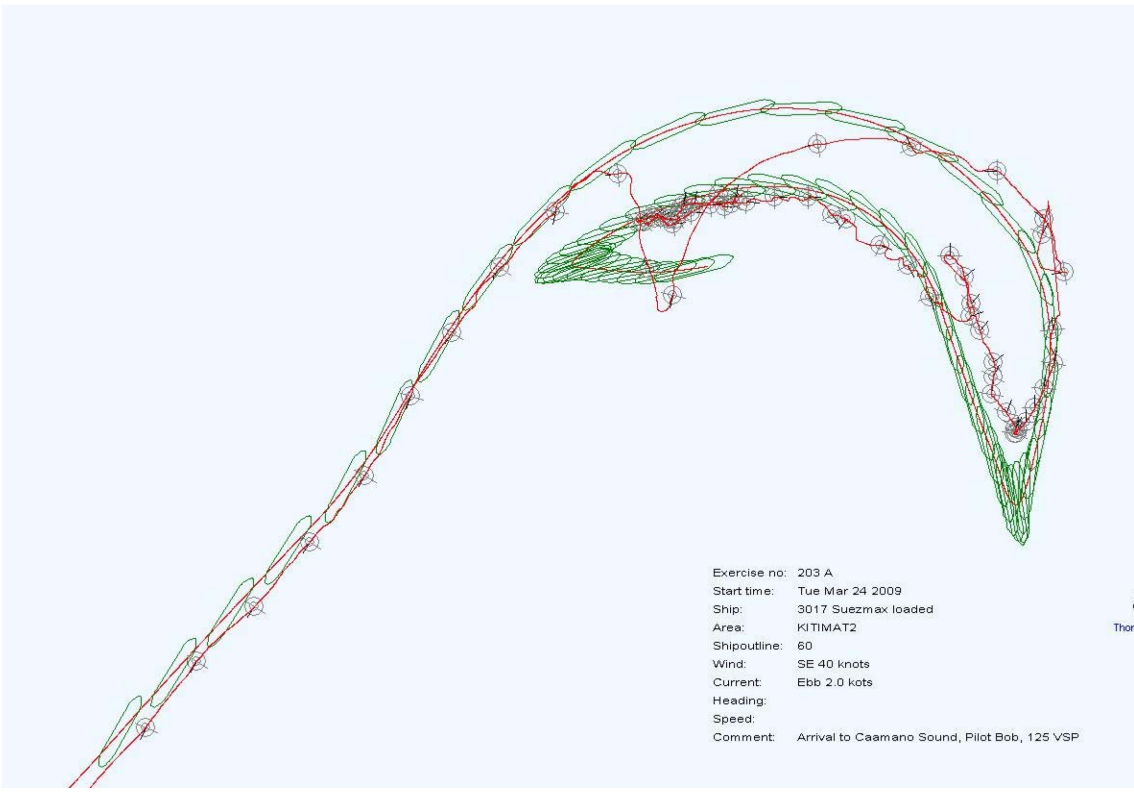
Pilot evaluation:

Approach should only be used in moderate weather conditions.
If an emergency occurs in heavy weather (wind above 30 knots combined with a difficult sea state) it may be difficult for an escort tug to hold the vessel or tow her out to sea due to the heavy swell that can occur in the area.

Outcome:
No problems were observed with this passage or with the turns. The vessel was handled well through the passage as expected. The vessel experienced 20 degree Leeway track and 3.0 knots cross track set. The pilot managed to keep track with maximum 20 - 25 degree rudder. The average rudder required during the run was 10 – 15 degree.

Figure 4.2-19	Run No.: 203 A	Date: Tue Mar 24 2009	Page 1 of 1

Area: Arrival from Hecate Strait to Caamaño Sound in escort towing mode with loaded Suezmax	
Purpose: Arrival from Hecate Strait in transit to Caamaño Sound with an escort tug. The tanker experienced an engine failure. The tug took over the control based on orders by the pilot.	
Run execution: CPA to other ships: N/A in this exercise. CPA to nearest shore or ground: 3.5 nautical miles to Ness Rock at start. Engine and rudder command: Clear and accurate. Tug command and response: Fast response with maximum load on towing rope.	
Basic info: Initial conditions: Day run. Speed: knots 10, heading 045 Tug configuration: VSP 125 t BP connected centre fairlead aft.	Weather conditions: Current: Ebb SE 2.0 knots Wind: SE 40 knots Waves: 4 metres 11 s Visibility: Good



Pilot evaluation: The wave conditions could contribute to the parting of the tow line in this situation. Overall safety level 3 out of max. 5 Rating 1= low, 3 = acceptable, 5 = high.
Outcome: After the engine failure, the tug was used to maintain and control the steering and act as brake for the tanker. The fibre towing rope might part in these weather conditions, especially if used for a longer time under full power and with significant wave heights of 4 metres. Tension winch is needed. Weather conditions were outside the normal transit conditions. It took about 20 minutes to slow down, control and start towing the tanker stern wise.

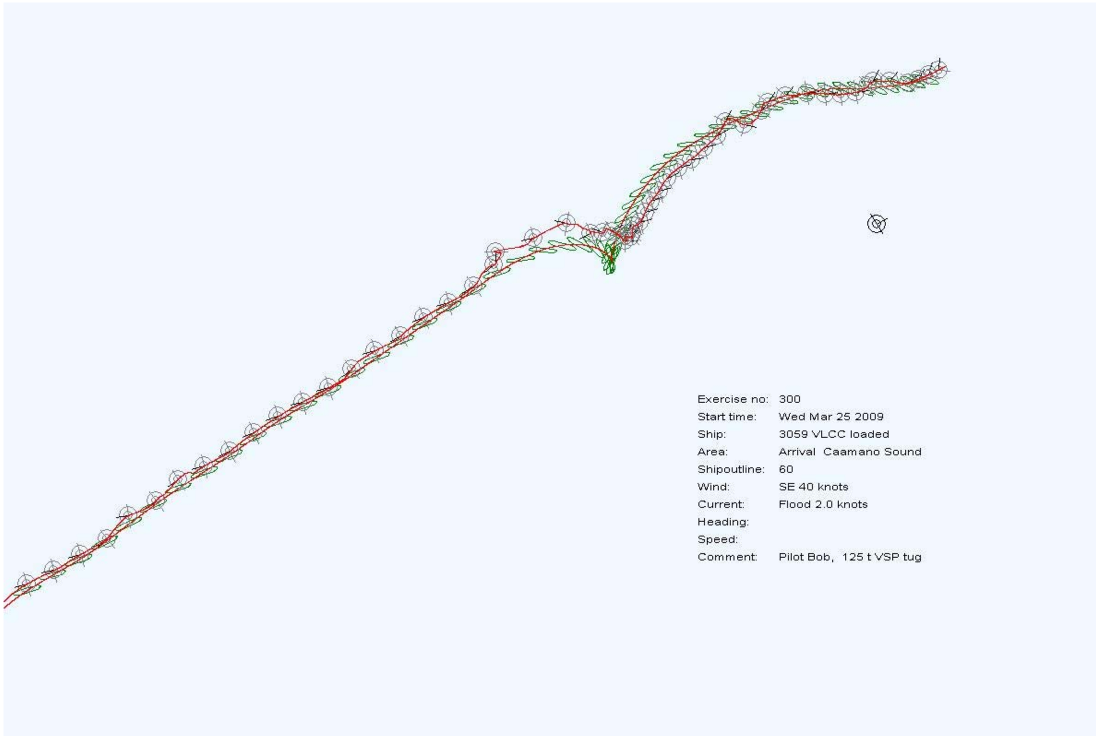
Figure 4.2-20	Run No.: 300	Date: Wed Mar 25 2009	Page 1 of 1

Area:
Arrival from Hecate Strait to Caamaño Sound in escort towing mode with loaded 300.000 DWT VLCC.

Purpose:
Arrival from sea in transit to Caamaño Sound with an escort tug. An engine failure occurred on the tanker.

Run execution:
CPA to other ships: N/A metres.
CPA to nearest shore or ground: 3.5 nautical miles to Ness Rock at start.
Engine and rudder command: Clear and accurate.
Tug command and response: Fast response with maximum load on towing rope.

Basic info:	Weather conditions:
Initial conditions: Night run. Speed: knots 10, heading 045 Tug configuration: VSP 125 t BP connected centre fairlead aft.	Current: NE going 2.0 knots Wind: SE 40 knots Waves: 4 metres 11 s Visibility: Good



Pilot evaluation:
It would be possible for the escort tug to control the tanker for a few hours but not to tow the tanker astern for the many hours it would take to get it into a sheltered area. The pilot felt it was a good exercise.
Overall safety level 3 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

After the engine failure, the tug was used to maintain and control the steering and act as brake for the tanker. A fibre rope will probably in these weather conditions break during use, especially if used with full load and without tension winch. Weather conditions were outside the normal transit conditions. It took about 18 minutes to stop the tanker and start sternway.

Figure 4.2-21	Run No.: 307	Date: Wed Nov 19 2008	Page 1 of 1
Area: Transit in Lewis Passage. Escort towing with a loaded VLCC 300.000 DWT and a ballasted VLCC 340.000 DWT.			
Purpose: Objective of manoeuvre: Passage of two escorted tankers in Lewis Passage.			
Run execution: CPA to other ships: 1.2 nautical miles. CPA to nearest shore or ground 500 metres to Gill Island.			
Basic info: Initial conditions: Night run. Speed: knots 10, heading 170 and 045 Tug configuration: 2 x VSP 125 t BP connected centre fairlead aft.		Weather conditions: Current: NW going 1.5 knots Wind: SSE 30 knots Waves: 1.0 metres 8 s Visibility: 3-5 nm.	

Pilot evaluation:

Pilot 3059: Outbound vessel got rudder failure and used about 7 min to stop, turn rate to port. Safety level 2.
Pilot 3413: Inbound went further east than comfortable. Meeting at this point in Lewis is not the best location. Safety level 2. Good exercise.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:

Remarks: The vessel handled well throughout the passage with limited room for safety navigation.

Navigating Squally Channel

<table>
<tr><td>Figure 4.2-22</td><td>Run No.: 0806</td><td>Date: Wed Jan 10 2007</td><td>Page 1 of 1</td></tr>
<tr><td colspan="4">Area:
Squally Channel</td></tr>
<tr><td colspan="4">Purpose:
Emergency run on NW course in Squally Channel</td></tr>
<tr><td colspan="4">Run execution:
When the ship had passed Ferny Hough Pt (Campania Is) the vessel's rudder froze in port 5 deg. The pilot used the escort tug as an emergency rudder and continued the passage. When the vessel was heading up in Lewis channel and had passed Williams Inlet, the vessel also experienced engine failure. Engine power was re-gained after approximately 15 minutes. The engine worked up to half ahead but the rudder failed, still frozen. One nm SW of Black fly pt (North Gill Island) the vessel again experienced engine black out. The vessel continued the escort into Wright Sound and when heading easterly, 0.8 nm north of Turtle pt., the vessel's speed was 3-4 knots with a northerly drift in the flood current. When the speed was reduced to 2 knots, the aft tug disconnected the line and was ordered to forward bow to make fast and continue to tow slowly at a course of 125 deg. N to counteract for the current setting. The pilot decided not to enter the Douglas Channel with present status, but to remain close or as close as possible to the present position and await repair.</td></tr>
<tr><td colspan="2">Basic info:
Ship 3413, 340.000 DWT in ballast condition:
The steering ability is very good.
Ship no. 3421 VSP tug extended to 125 T BP</td><td colspan="2">Weather:
Wind: SE 50 knots
Current: Flood 2 knots
Waves from SE</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Outcome:
The simulation went as expected, with the tug able to safely handle the VLCC both in the channels under way in indirect mode (more than 5 knots) and direct mode (less than 5 knots). The tug was also able to hold the VLCC in a proper position by slowly towing against the current, while awaiting the engine/rudder repair.</td></tr>
</table>

Navigating Whale Channel

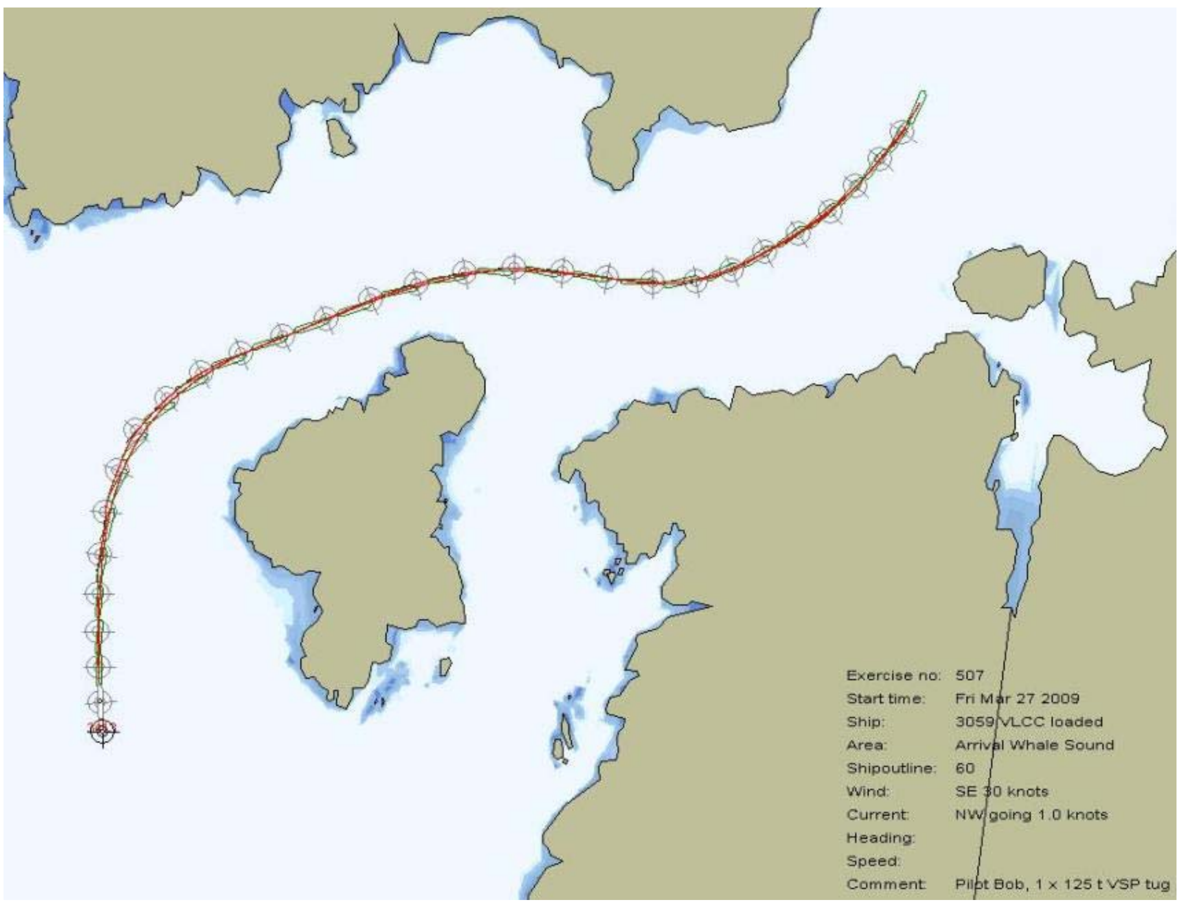
Figure 4.2-23	Run No.: 507	Date: Fri Mar 27 2009	Page 1 of 1

Area:
Escort Towing in Whale Sound with a loaded VLCC inbound.

Purpose:
The vessel passes Whale Sound and gets rudder break down, rudder locked in 35 degree to port and after 5 minutes the rudder was brought back to 0 degree position.

Run execution:
CPA to nearest shore or ground: 440 metres to Levy Pt.
Engine and rudder command: Clear and accurate.
Tug command and response: Tug was connected but not used during the passage

Basic info:	Weather conditions:
Initial conditions: Loaded VLCC. Day run. Speed: knots 9.5, heading 000 Tug configuration: 1 x VSP 125 t BP connected to centre fairlead aft on tanker.	Current: NW going 1.5 knots Wind: SE 30 knots Waves: None Visibility: Good



Pilot evaluation:
Passage through Whale Channel loaded posed no problems.
Overall safety level 4 out of max. 5
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
No real concerns with this transit.

Figure 4.2-24	Run No.: 402	Date: Tue Nov 20 2008	Page 1 of 1

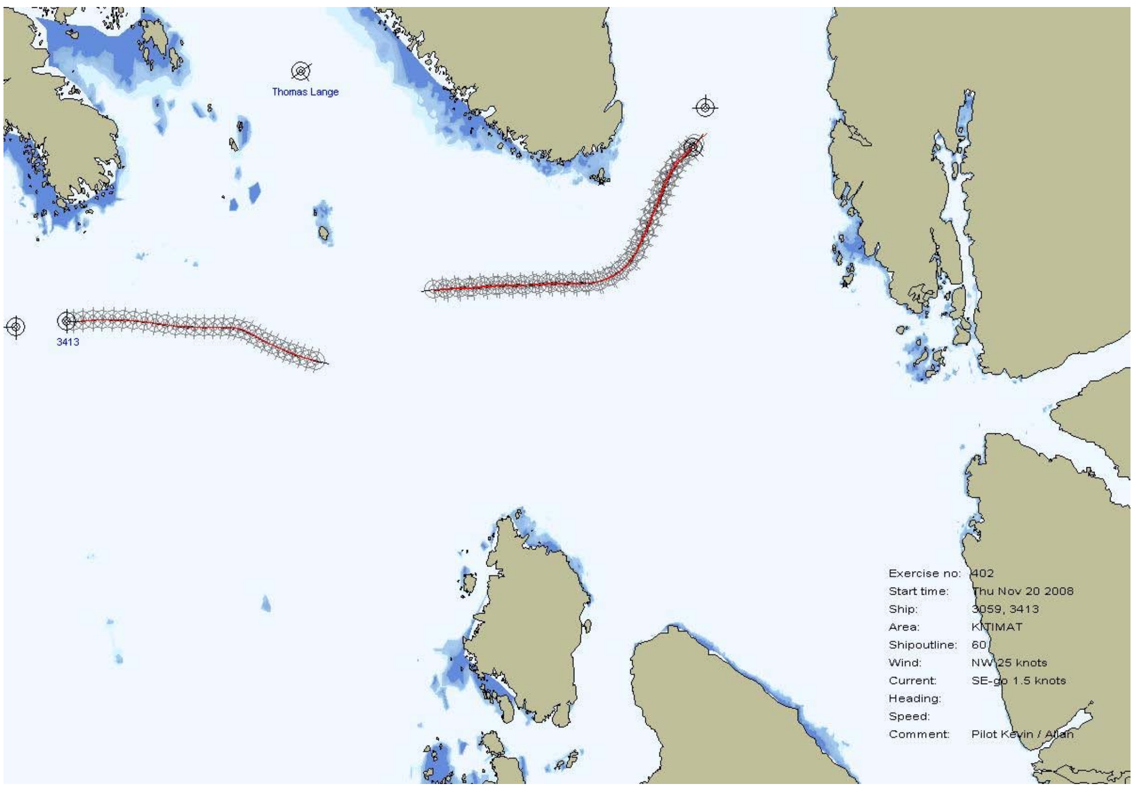
Area:
Transit in Caamaño Sound escort towing with a loaded VLCC 300.000 DWT and a ballasted VLCC 340.000 DWT

Purpose:
Two large VLCC passing each other in Caamaño Sound. Inbound tanker experiences rudder failure. The rudder locks at 15 degree to port.

Run execution:
Passages of two VLCC vessels in Caamaño Sound. The width of the Sound is between 2.5 and 4.5 nautical mile which leaves sufficient room for tanker movements in wind speeds up to the recommended maximum of 30 knots.
CPA to traffic vessel when VLCC passing inbound VLCC: 256 metres.
CPA to nearest shore or ground onboard southbound VLCC: 1650 metres to Alexander Is.
CPA to nearest shore or ground onboard inbound VLCC: 1063 metres to Cort Rk.

Basic info:
Initial conditions VLCC outbound: Day run. Speed: knots 9.8, heading 196 at start.
Initial conditions VLCC inbound: Day run. Speed: knots 10.5, heading 094 at start.
Tug configuration: 2 x VSP 90 t BP connected to centre fairlead aft on each vessel.

Weather conditions:
Current: SE going 1.5 knots
Wind: NW 25 knots
Waves: 1.0 metres 8 s
Visibility: 3-5 nm.



Pilot evaluation:
Pilot 3413: Inbound rudder frozen. Good exercise. Safety level 3.
Pilot 3059: Outbound towards Caamaño Sound. Safety level 3.
Rating 1= low, 3 = acceptable, 5 = high.

Outcome:
Inbound tanker frozen rudder 15 degree to port for more than one hour. Vessel continues and uses the escort tug to control the steering with a speed of 8 to 9 knots. The vessels handled well.

4.3 Passing of Two Tankers

One objective of the simulations was to determine the viability of two large ships, e.g. tankers, LNG carriers or other ships, passing one another at the following 5 locations:

1. From berth to passage of Clio Point (the terminal manoeuvring area)
2. From abeam Kersey Point (Maitland Island) to abeam Paisley Point
3. From abeam Turtle Point (Gil Island) to passage of Keld Point (Fin Island). See figure 4,7
4. From abeam Fanny Point through Otter Channel until abeam Fleishman Point
5. From abeam Wheeler Island to abeam Bush Island (southwest of Dixon Island)

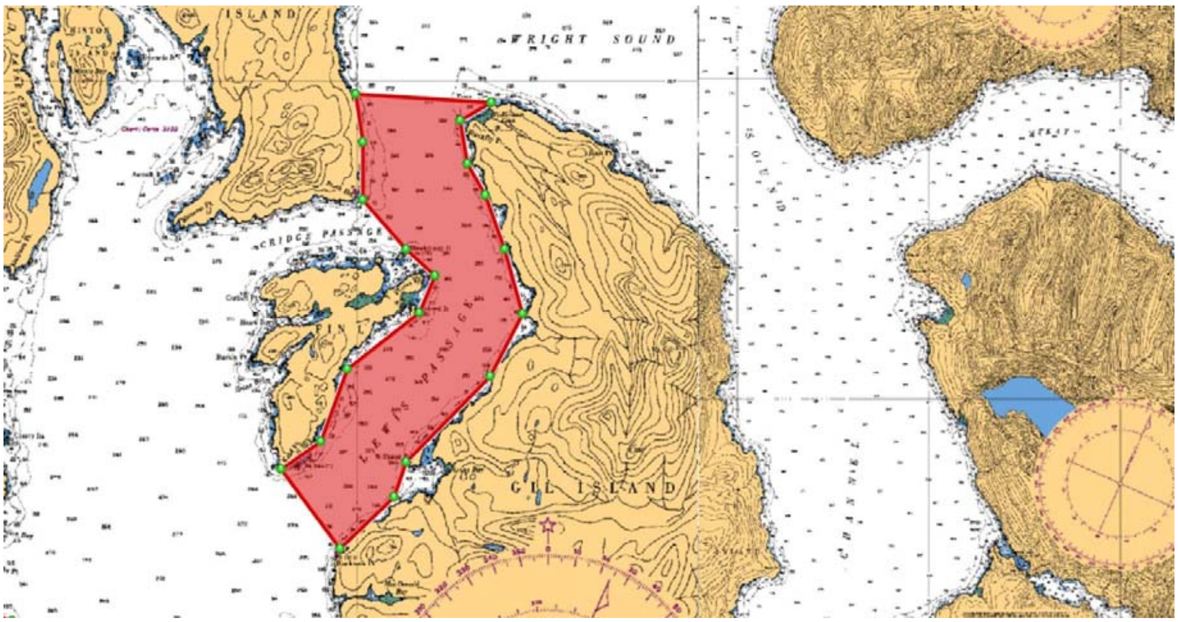


Figure 4.7: Lewis Passage an area with limited width, highlighted.

Referring to TERMPOL guidelines and other ship channel design guidelines such as the IALA, the International Association of Marine Aids to Navigation and Lighthouse Authorities, the minimum available channel width throughout the CCAA exceeds both guidelines' recommendations.

TERMPOL recommends a minimum channel width of 7 to 10 x the design ship beam. Other guidelines recommend 10 to 15 times ship beam. In the entire area from open sea to the terminal area there is well over 20 x ship beam.

While it is considered feasible to have ships pass in these locations, the Pilot evaluations noted that this would subject navigation to increased risk, and in normal practice, ships will pass in sections of the channel where the channel alignment is straight and has a wider cross section than those noted above.

Two ships meeting near location 1) close to the Kitimat Marine Terminal is not problematic as there is a large channel width that can accommodate ships arriving or departing from other terminals in the Port of Kitimat at the same time as a tanker is berthing/un-berthing at the Kitimat Marine Terminal.

4.4 Environment limits for safe navigation

All three tanker classes were successfully tested under their own power and steering, inbound and outbound, in straight sections and in channel bends and in wind speeds of 50 knots from the prevailing direction NW, W, SW and SE. In some cases wind speeds of 60 knots were tested. These conditions were modelled together with the current and wave conditions described below.

In general, the Pilots could handle the ships in 50 knots. However, they felt a safe upper limit of operation would be when the wind speed did not exceed 40 knots. Pilots will base their decisions for arrival or departure at the Kitimat Marine Terminal on long-term weather forecasts and real-time weather monitoring and will wait until the wind speeds are below 40 knots.

Tankers travelling in currents of up to 2.5 knots together with the wind conditions described above were found to be manoeuvrable. Currents in the areas studied are normally less than 2.5 knots with the majority of currents running parallel to the path of the tanker and therefore of minor concern.

Tugs were found to be able to handle the design tankers in waves of up to 4 metres significant height (Hs) outside Caamaño Sound together with the wind and current described above. However, inside Caamaño Sound, the pilots felt less comfortable navigating the 4 metre swell due to the difficulty of handling an emergency.

Waves in the confined channel areas were simulated to a maximum of 2 metres (Hs). Waves of this magnitude were not found to be challenging to the navigation of the tankers or tugs.

At the terminal, 1 to 1.5 metre waves are considered maximum. These waves are generated by the wind, have a short wavelength and therefore do not pose a challenge to the navigation of tankers or tugs.

4.5 Areas of challenging navigation

Seas outside Caamaño Sound can be challenging in bad weather (30 knots and above) due to the exposure to the open ocean to the southwest. The Sound is known to experience swell generated by south-westerly winds. Therefore, this entrance will only be used in moderate weather conditions.

The following inner channel areas are considered more challenging due to the need to navigate bends and/or reduced width. These areas include:

Principe Channel, a length of 2 nautical miles, from abeam Wheeler Island to abeam Bush Island (southwest of Dixon Island)

Otter Channel, a length of 4 nautical miles, from abeam Fanny Point through the Channel until abeam Fleishman Point

Lewis Passage, a length of 8 nautical miles, from abeam Turtle Point (Gill Island) to passage of Keld Point (Fin Island)

Douglas Channel, a length of 6 nautical miles, from abeam Kersey Point (Maitland Island) to abeam Paisly Point

In addition to the areas listed above, additional care is required in the navigation of Wright Sound on the northeast side of Gill Island where traffic density is higher and crossing traffic situations will be experienced.

It is noted that, at present, coverage of VHF communication and AIS data is limited in some areas from open sea to Kitimat due to "blind spots". Installation of radar stations will make transit of these areas safer. Otherwise the areas can be passed by slowing down.

4.6 Safe speed profile for tankers

The tankers' maximum recommended speed with an escort tug is estimated at 10 to 11 knots as that is the speed at which most escort tugs are designed to operate. Escort tug towing can be achieved at higher speeds with a purpose built tug.

Maximum safe speed throughout the confined channel areas from open sea to the Kitimat Marine Terminal is considered to be 10 to 12 knots. This provides a speed and time for tankers to complete safe and controlled manoeuvres.

When the tankers need to make a turn, the turn can be completed at rates of turn up to and exceeding 20 degrees per minute. However, it is considered preferable to keep the tankers' turning speed closer to a rate of 10 degrees per minute. With a ship speed of 10 knots, that will result in a turning radius of 1 nm. This is considered a smooth, safe and easy to control turn. There is a "reserve" rudder angle capacity, and there is adequate manoeuvring room on all channel bends to safely make this radius of turn.

4.7 Suggested speed for assistance tugs

The tanker will always be operated within the performance capabilities of the escort vessels taking into account speed, sea and weather conditions, navigational considerations and other factors that may change or arise during the escort transit.

As mentioned, the escort tugs assumed for this study were designed to safely operate in emergency manoeuvring mode at an optimal speed of 10 knots. At this speed, the tugs can perform the maximum steering pull they were designed for and keep a safe heeling angle. The heeling angle should typically not exceed 12 degrees.

The tugs' free running speed will be in the order of 15 knots, and the maximum speed for emergency operations should be less than 12 knots.

4.8 Berthing and un-berthing at the terminal

During all 3 real-time simulation sessions, several berthing and un-berthing manoeuvres were performed in different weather conditions with starboard and port side alongside.

Un-berthing

Departure from the oil terminal can be achieved safely in wind speeds of up to 40 knots, however, the Pilots would in such cases consider waiting until the wind has dropped to 30 knots.

The proposed procedure for un-berthing is to let the tugs pull the tanker parallel off the berth. As soon as the tanker is 2-3 ship beams off the berth, the Pilot will order ahead on the engine. After the tanker has picked up speed and is heading away from the shore, the forward tug (tug no. 1) and second tug (tug no. 2) on the ship side will be disconnected.

The escort tug aft (tug no. 3) is connected at all times and will follow the tanker all the way to open sea.

Berthing

The arrival manoeuvre will normally be done with the ship stemming the wind and current as it gives the Pilot the best control of the tanker.

In inflow winds, the strategy is to sail the tanker just north of the terminal, make a turn well off shore and slowly manoeuvre the tanker back towards the berth. See figure 4.2-16.

The tanker is assisted by at least one escort tug and 2 or 3 Cycloidal or ASD (Azimuth Stern Drive) tugs of approx. 50 t BP. This has shown to be sufficient and provides good safety margins with about 50% spare power capacity on the tugs.

In outflow winds, the berthing manoeuvre will be to navigate the tanker directly to the berth and at about 1 to 2 ship beams off the berth and parallel to it. Tugs will then push the tanker towards the berth.

Berthing was done safely in wind speeds of up to 40 knots, but it is anticipated that wind speed limits for berthing will be set below this value

4.9 Emergency manoeuvres

Different emergency manoeuvres were performed to test the capabilities of the escort tugs. The emergency situations included “black-outs” where the tankers lost all electrical and propulsion power and were therefore unable to steer.

Another type of emergency simulated included a situation where the rudder was locked at an angle due to a steering engine failure that could be caused by a hydraulic or an electrical malfunction.

In both the above emergency situations, the Pilot on the tanker ordered the escort tug to take over control of steering and speed. The time span from the start of the malfunction to the time where the tug was in position to assist was 1 to 2 minutes.

The emergency manoeuvres were all completed successfully. There was no instance of ship grounding, and the closest point of approach (to shore) was in the order of 250 metres.

4.10 Summary of arrest data

Arrest simulations were performed in addition to the real-time simulations described above. As for the real-time simulations runs, arrest simulations use two full-mission bridge simulators, one for the tanker and one for the tug escort. The simulators interact with one another providing real-time feedback to both vessel operators. The purpose of these simulations was to investigate the stopping ability of tankers under their own power as well as with assistance of the escort tug. The results are shown in Tables 4.1 and 4.2.

These simulations were carried out with a 100 ton bollard pull cycloidal (VSP) tug since this is the upper limit of design capacity for this type of propulsion system with current technology.

4.11 Arrest with ship engine and a 100 t BP VSP escort tug

The stop distance is set at 100% for arresting with ship engine only.

Speed 8 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	858	822	548
Suezmax ballast	724	580	398
Aframax ballast	580	386	305
VLCC loaded	2509	1786	948
Suezmax loaded	1262	1338	747
Aframax loaded	1106	690	445
In percentage	Approx 100%	Approx 75%	Approx 50%

Speed 12 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	3648	1556	1178
Suezmax ballast	1462	1184	893
Aframax ballast	1597	586	446
VLCC loaded	3988	3674	2099
Suezmax loaded	3478	2442	1626
Aframax loaded	2727	1247	1027
In percentage	Approx 100%	Approx 80%	Approx 60%

Table 4.1: Stop distances of 3 tanker types in ballast and loaded condition with an initial speed of 8 knots or 12 knots using ship engine only, tug only and both ship engine and tug. The tug had a bollard pull of 100 t.

4.12 Arrest with ship engine and a 125 t BP VSP escort tug

The stop distance is set at 100% for arresting with ship engine only.

Speed 8 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	858	689	455
Suezmax ballast	724	568	349
Aframax ballast	580	295	291
VLCC loaded	2509	1235	924
Suezmax loaded	1262	1273	719
Aframax loaded	1106	520	443
In percentage	Approx 100%	Approx 75%	Approx 50%

Speed 12 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	3648	1441	1178
Suezmax ballast	1462	1034	893
Aframax ballast	1597	524	446
VLCC loaded	3988	3199	2099
Suezmax loaded	3478	2311	1626
Aframax loaded	2727	1163	1027
In percentage	Approx 100%	Approx 80%	Approx 60%

Table 4.2: Stop distances of 3 tanker types in ballast and loaded condition with an initial speed of 8 knots or 12 knots using ship engine only, tug only and both ship engine and tug. The tug had a bollard pull of 125 t.

Two Voith Schneider tug (VSP) models were used for escorting the tanker and assisting the stop manoeuvres:

- Enhanced VSP tug of 125 t BP (Bollard Pull) and about 230 t steering pull
- VSP tug of 100 t BP (Bollard Pull) and about 180 t steering pull

A total of 144 runs were performed. All 72 combinations were repeated twice. The results presented in tables 4.1 and 4.2 are averages of the two runs for each combination.

4.13 Arrest with ship engine only

Arresting the tanker with its own engine at a speed of 8 knots shows that the time and the stopping distance needed is twice as long as if the tanker was stopped with own engine and the escort tug.

The relatively longer stopping distance at 12 knots occurs because the tanker's propeller is "wind milling" until the ship reaches about 8 knots. The tanker is performing a coasting stop before the engine can be reversed. The engine can be reversed between 7 to 8 knots depending on vessel type involved in the stop tests. This applies to tankers with a fixed pitch propeller directly coupled to a slow speed diesel engine which is the most common configuration.

4.14 Arrest with escort tug only

Stopping with tug only shows that the time and stopping distance for the tanker and escort tug is reduced from about 100% to 75% compared to stopping with the vessel's own engine only.

Stopping with the tug is more effective because the reversing power starts immediately independent of the tanker's speed.

Tug design and crew education and training are also factors that have to be taken into consideration.

The test results shown in tables 4.1 and 4.2 were achieved in an ideal situation with experienced tug captains.

5. Conclusions and Recommendations

The conclusions and recommendations presented in this report are based on the simulations completed to date and discussions with the Pilots, Tug Captains, Northern Gateway representatives and FORCE Instructors for the 110,000 DWT Aframax tanker, the 200,000 DWT Suezmax Tanker and the 340,000 DWT VLCC simulated under the tested environmental conditions.

The simulated wind, current and wave environment consisted of conditions considered at or near the upper limit for manoeuvring at open sea, confined channels and the terminal area.

5.1 Entering the Kitimat area from open waters

Entering the confined channels of the Kitimat area from the open sea can be done by the 2 main approaches, as follows:

- The north route approach via Principe Channel
- The south route approach via Caamaño Sound

Each of the approach areas are described below:

5.2 Approach via Principe Channel

The Principe Channel approach can be accessed either via Dixon Entrance north of Haida Gwaii or from the south via Hecate Strait. The Principe Channel approach can be safely navigated under the ship's own power and steering in all weather conditions tested (up to 50 knots of wind) and by all the ship types tested including the largest VLCC´s of up to 340,000 DWT.

This is considered an "all-weather-safe-approach". The channel gives excellent protection from westerly winds and the swell from the Pacific Ocean.

The results from section 4.2 show that it can be concluded that under the conditions simulated, the design vessels can safely and effectively navigate the Lewis Passage, Wright Sound, Douglas Channel as well as the terminal area.

5.3 Approach via Caamaño Sound

The direct approach via Caamaño Sound is the shortest and fastest route into Kitimat. The outer (seaward) approach section is unprotected from winds and swells from the open ocean to the southwest.

A concern expressed with the Caamaño Sound approach is that in heavy weather, if an emergency occurs, it may be difficult for an escort tug to hold the tanker or tow it out to sea because of the sea conditions that are experienced in winter months. Consequently, this approach will only be used during moderate weather conditions.

5.4 Passing and crossing ship traffic

One objective of the simulations was to determine the safety level when two large ships, e.g. tankers, meet one another at any of the narrower channel sections or in areas such as Wright Sound where crossing traffic is anticipated to be more frequent.

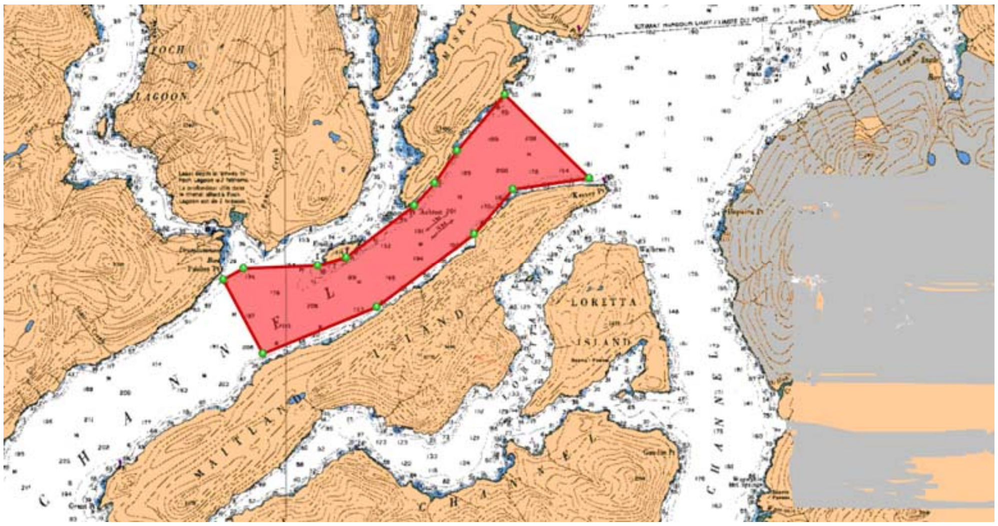


Figure 5-1 Example of area with limited width in Douglas Channel

The outcome of the simulation runs was that, in general, two large ships should avoid meeting at the following locations and particularly in severe weather conditions:

1) Principe Channel, a length of 2 nautical miles, from abeam Wheeler Island to abeam Bush Island (southwest of Dixon Island)

2) Otter Channel, a length of 4 nautical miles, from abeam Fanny Point through the Channel until abeam Fleishman Point

3) Lewis Passage, a length of 8 nautical miles, from abeam Turtle Point (Gill Island) to passage of Keld Point (Fin Island)

4) Douglas Channel, a length of 6 nautical miles, from abeam Kersey Point (Maitland Island) to abeam Paisley Point

In addition to the narrow areas listed above, additional care is required in the navigation of Wright Sound on the northeast side of Gill Island where traffic density is higher and crossing traffic situations will be experienced.

It was noted that current coverage of VHF communication and AIS data are limited in some areas from open sea to Kitimat due to “blind spots”. Repeater stations should be installed at strategic locations to solve this problem.

Consensus from discussions with the Pilots is that the meeting of two large ships at locations 1), 2), 3), and 4) should, in general, be avoided, particularly during severe (wind 30 knots or above) weather conditions. The reason for this restriction is that the margins for safe navigation are limited in case of an emergency situation where the engine is lost or the rudder is locked at an angle different from “mid ship”. According to the pilots, the meeting of ships at these locations can easily be avoided through:

1) Proper planning and pilot to pilot communication
2) Use of a VTS service in the area
3) Use of AIS data of other ships' movements

With the use of the above three tools, it is not considered to be problematic for tankers to manoeuvre through areas 1), 2), 3) and 4).

5.5 Berthing and un-berthing manoeuvres

Arrival to the Kitimat Marine Terminal can be achieved safely in wind speeds of up to 40 knots with the assistance of at least one escort tug and 2 or 3 cycloidal or ASD tugs of 50 t BP.

Arrivals and departure from the oil terminal has been simulated in wind speeds of up to 40 knots, however, it is anticipated that in practice limiting wind speeds for berthing and un-berthing operations will be set below this value.

5.6 Emergency manoeuvres

Safe handling of emergency situations was an important part of the simulations. All emergency situations tested were handled within reasonable safety margins.

It is important to keep in mind that the emergency situations described rarely occur, but that it is necessary for the Pilots and Tug Masters to rehearse these situations on a regular basis in order to be prepared in case an incident actually occurs.

Proper training of Pilots and especially Tug Masters is essential for a generally safe operation.

The results from all the simulated emergency manoeuvres were that the escort tugs of 100 t BP (and 180 t steering pull) and 125 t BP (and 230 t steering pull) were able to take control of the tanker within an acceptable time frame. The Pilots have indicated a preference for tugs of the maximum bollard pull to respond to emergency manoeuvres on the largest loaded design ship.

5.7 Recommendations for additional aids to navigation

After the simulations in 2006, the pilots discovered that there was a need for additional navigation aids or for changes to the existing navigation aids.

The pilot's recommendations for extra markings were applied in the simulations in 2008 and 2009 and, in general, improved safe navigation.

5.8 Prospective vessel holding area

Suggested holding area for vessels passing through the inner portion of Caamaño Sound en-route to Kitimat would be a position bounded by and slightly south of Alexander Is, Dunkers Pt and Wall Is, the total diameter of the holding area being approximately 5 nm and holding vessels can stem into the wind and/or current in either direction.

A short-term holding area for vessels southbound in Principe Channel en-route to Kitimat via Otter Sound is located between Nepean Sound and Estefan Sound just before entering Otter Channel. In this area, the prevailing winds are NW or SE, and the current NW flooding or SE ebbing which is the same direction as the channel alignment. The holding and steaming distance against the wind and the current drift is approximately 5 nm, and the turning circle is approximately 1.5 nm.

A holding area for vessels coming from the north through Principe channel is the area NW of Anger Island at Anger anchorage. The anchorage area is narrow and with a maximum distance to the shore side of 2.0 nm. The anchorage area currently has no marking or range lights and is considered a viable anchorage in fair to moderate weather conditions. This holding area would also require a tug in attendance at all times.

An alternative holding area is the area N/NW of Banks Is before entering Principe Channel. In this area, it is also possible to anchor, if the weather permits, in 2 – 3 shackle deep water. However, anchoring would be a poor alternative as a tug would have to be in constant attendance. This area is well-known for strong currents and abrupt weather changes.

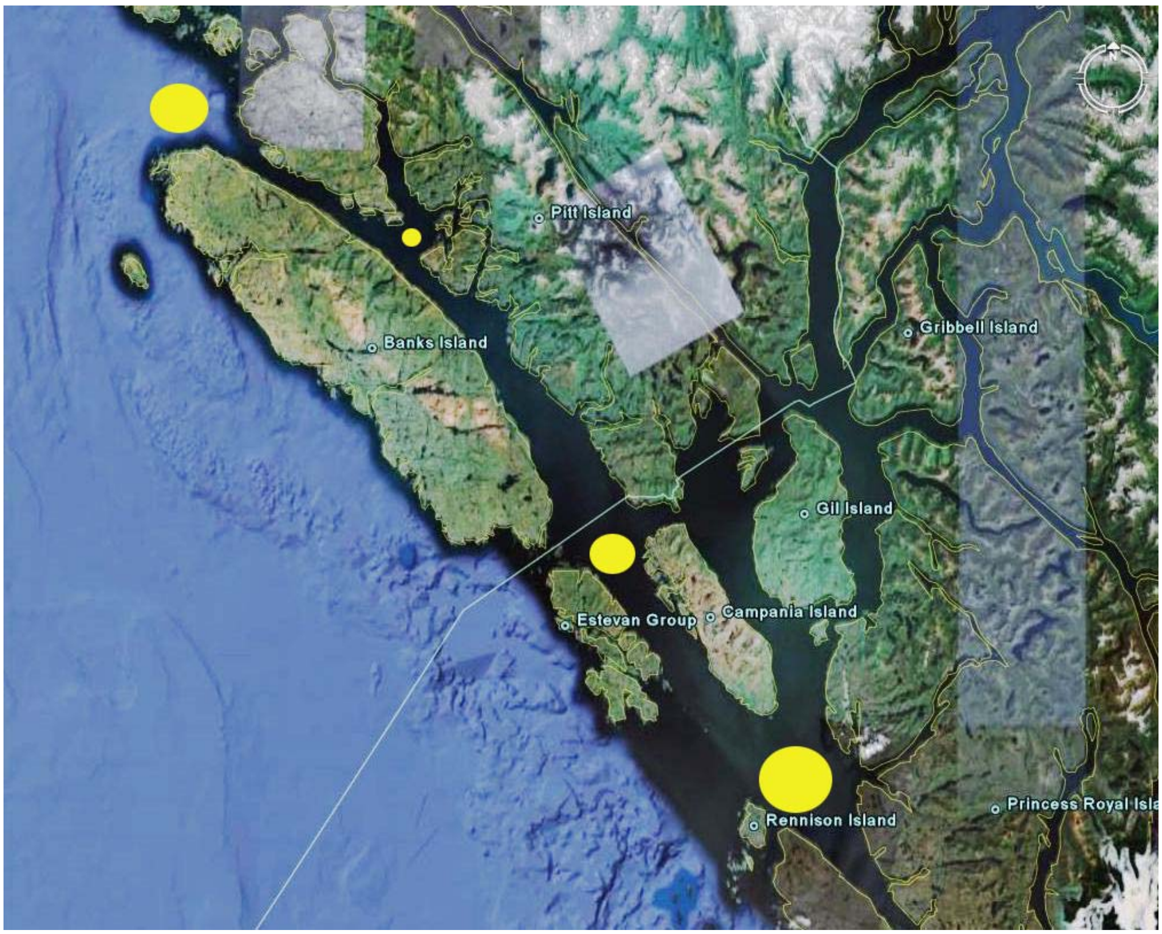


Figure 5-2 Map of prospective four holding areas for tankers. Source: Google Earth. Holding area north of Banks Island (top), Anger Island (top centre), Neapean Sound (bottom centre) and Caamaño Sound north of Alexander Island (bottom)

6. References

Ref/1/ Manoeuvring Study of Tankers to Kitimat. Real-time Simulations of Tankers passing Different Routes to and from Oil Terminal at Kitimat. FORCE Technology Report no 2006180

Ref/2/ GEM report: Marine Physical Environment Report TR-ASL-008: GEM Oceanography Program, January to April 2006

Ref/3/ GEM report: Marine Physical Environment Report TR-ASL-002: Ocean Currents

Ref/4/ GEM report: Marine Physical Environment TR-ASL-001: Meteorology Review from Historical Data

Ref/5/ Fast-time Simulations of Tankers passing Different Routes to and from Oil Terminal at Kitimat

Ref/6/ Introduction to Physical Oceanography". Robert H. Stewart. Department of Oceanography, Texas A&M University. Copyright 1997-2005.

Enbridge Gateway Pipeline

Maneuvering Study of Escorted Tankers to and from Kitimat

Real-time Simulations of Escorted Tankers bound for a Terminal at Kitimat

Part 2: Main Report

FORCE Technology no. 108 – 29930 – main. **Version 1.0**

FORCE Technology

Project No. and Title of Report:	

FORCE Technology no. 108-29930-main

Maneuvering Study of Escorted Tankers to and from Kitimat.

Real-time Simulations of Escorted Tankers
bound for a Terminal at Kitimat

Part 2: Main report, version 1.0

Client: Northern Gateway Pipeline	***Client's Ref.:*** Chris Anderson
Author(s): Naval Architect, M.Sc. Jens Bay and Master Mariner Steffen Schultz	***Date:*** June 29th, 2010 ***Approved by:***

A	Final	SSS/JCB	JCB		29-06-10
Revision	***Description***	***By***	***Checked***	***Approved***	***Date***

Keywords: Maneuvering Simulation Study with VLCC, Aframax and Suezmax tankers in ballast and loaded condition. The tankers were escorted by a 90 to 125 t bollard pull (BP) tug from open sea to oil terminal south of Kitimat.	***Classification:*** ☐ **Open** ■ **Internal** ☐ **Confidential**

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1 Introduction

This report contains a detailed description the work carried out by FORCE Technology, Division for Maritime Industry, DMI, Lyngby, Denmark according to work order nos. WG-41145-08001 and WG-40322-22001 issued by Enbridge Gateway Pipelines (Northern Gateway).

The reports include all simulations carried out in 2007, 2008 and 2009 and includes both Fast-Time and Real-Time simulation studies.

Northern Gateway has initiated significant engineering, field work, and environmental and socio-economic assessments to support the proposed development of the Northern Gateway Pipelines Project that will include:

- A proposed oil export pipeline to transport oil from west of Bruderheim, Alberta to a new marine terminal located at Kitimat, British Columbia. The exported product will be shipped by tanker to Asia-Pacific and US west coast markets.
- A proposed condensate pipeline to transport condensate from the Marine Terminal to Bruderheim, Alberta. The condensate will be imported by tankers from worldwide supply markets.

Two dedicated tanker berths are planned for the Kitimat Marine Terminal. Both berths will be used to load oil into tankers up to a Very Large Crude Carrier (VLCC) size, and either berth is capable of offloading condensate from tankers up to a Suezmax size.

The tankers will navigate from open sea and through confined coastal channels to the Kitimat Marine Terminal using one of several alternative routes. The primary routes are shown in Figure 1-1 and include:

- The North Route passes Haida Gwaii through Dixon Entrance and continues via Hecate Strait, Browning Entrance, Principe Channel, Nepean Sound, Otter Channel, Squally Channel, Lewis Passage, Wright Sound and Douglas Channel. This route is shown in purple

- The South Route passes through Queen Charlotte Sound and continues through Hecate Strait, Caamaño Sound, Campania Sound, Squally Channel, Lewis Passage, Wright Sound, and Douglas Channel. This route is shown in red

An alternative southerly route which bypasses Caamaño Sound going north in Hecate Strait along the western side of Banks Island to Browning Entrance is also considered viable, but this route (Browning Entrance) was not modeled at this time since the outer section is in open water.

Secondary routes which are currently in use and considered viable for some ship types under certain conditions were also assessed and include:

- Use of Whale Channel (orange)
- Use of Cridge Passage (yellow)

A south approach via Laredo Sound and Laredo Channel was investigated, but this route option is not considered viable for the design ships of this project.

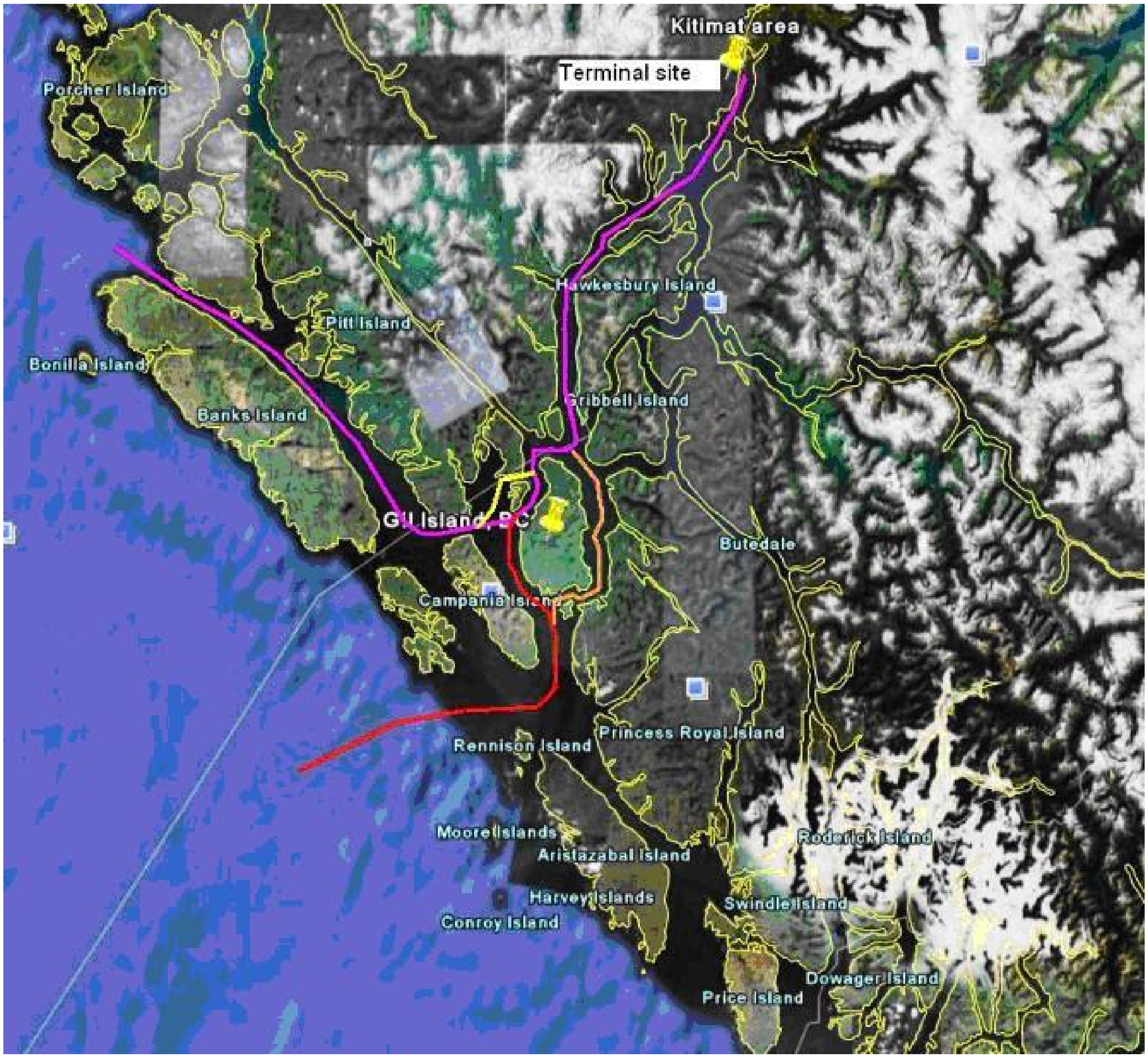


Figure 1.1 Marine transportation route alternatives. Map source: Google Earth.

This report contains a detailed overview of 5 phases of work completed over a calendar period of 3 years. The work was conducted from 2006 to 2009 in the following phases:

- Fast-time simulation, 2006
- Real-time simulations, part 1, 2007
- Real-time simulations, part 2, 2008
- Real-time simulations, part 3, 2009
- Arrest simulations of tankers, 2009

List of participants in the simulations can be seen in appendix G.

2 Purpose and objectives during the complete study

The overall objective of the fast-time and full-mission simulation studies was to confirm that the proposed access routes can be safely navigated by the design ships and to identify navigation risks and possible risk mitigation solutions. Specific tasks included:

1. Investigate the maneuverability of three different tanker classes navigating from open ocean and through the confined channels leading to Kitimat under own power and in normal situations.
2. Investigate the viability of two large ships passing each other at locations with limited width;
3. Investigate the safety of ship transits in areas which have crossing traffic patterns;
4. Identify preliminary environmental limits for safe navigation;
5. Identify areas of difficult navigation;
6. Determine a safe and efficient speed profile for the routes;
7. Determine minimum speeds for navigation below which tug assistance is required;
8. Determine preliminary operational requirements for the escort tugs;
9. Develop preliminary operational criteria for berthing and un-berthing the tankers at the Kitimat Marine Terminal;
10. Determine the adequacy of the existing aids to navigation and assess the minimum requirements for additional aids to navigation in the confined channels;
11. Investigate emergency situations where the escort tug takes over the steering and speed control of the tanker.

2.1 Fast-time (FT) simulations

The initial fast-time simulations provided information on factors having the strongest influence on the tanker maneuverability, areas of particular interest and critical conditions for tanker maneuvers. Output from the fast-time simulations was used as part of the definition for the scope of work for the real-time simulations

The objective of the FT simulations was to study the maneuvering challenges between open sea and the proposed marine terminal and provide an initial assessment of the navigation of the routes and to provide input to the planning of and identification of focus areas for the following real-time simulations.

The simulations were conducted as a desktop study using a computer simulation program where ships sail along pre-defined routes designed by pilots and master mariners. The advantage of this type of simulation is that a large number of sailings, covering long distances, can be conducted in a short period of time.

A total of 36 scenarios were carried out with the Aframax and VLCC's in loaded and ballast condition. For a description of the mathematical models of the ships, reference is made to section 4.5.

The scenarios covered the VLCC and Aframax ships sailing from open sea following either the northern or the southern route to the terminal in the northern part of the Douglas Channel. The routes are shown in figure 2.1. For more detailed results see section 6.

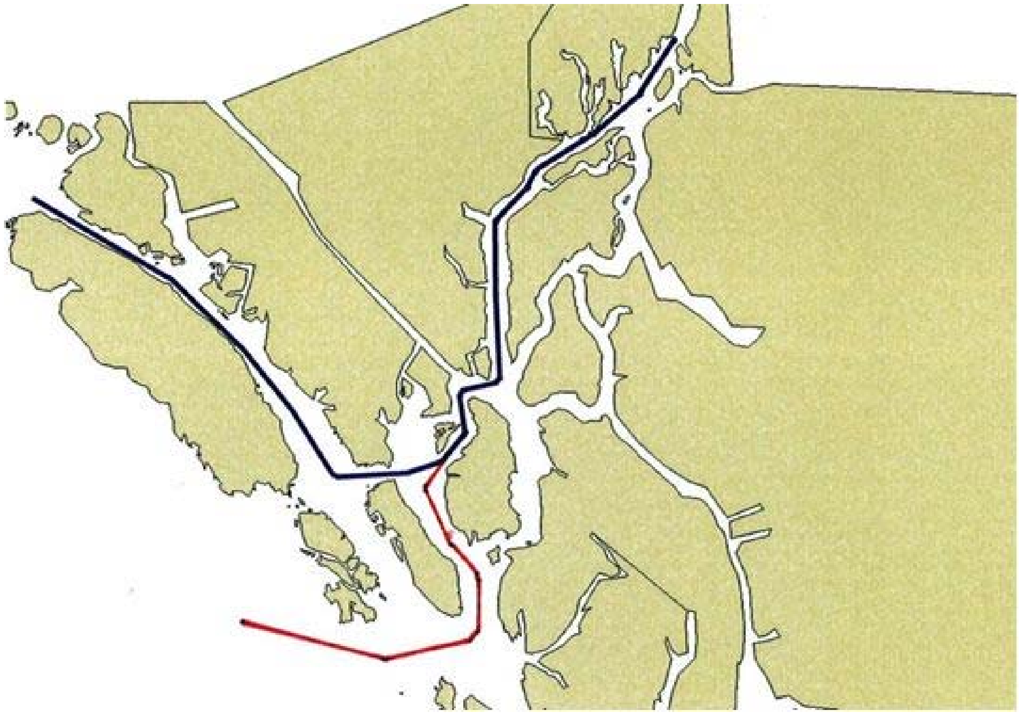


Figure 2.1 North (blue line) and South (red line) Route used for Fast-Time and Real-Time simulations

- The North Route for the Confined Channel Assessment Area, starts at Browning Entrance and continues through Principe Channel, Nepean Sound, Otter Channel, Squally Channel, Lewis Passage, Wright Sound and Douglas Channel.
- The South Route for the Confined Channel Assessment Area, starts at Caamaño Sound and continues through Campania Sound, Squally Channel, Lewis Passage, Wright Sound, and Douglas Channel.

2.2 Real-time (RT) simulations

The scope of work for the real-time simulations was to investigate the maneuvering aspects of large tankers navigating from open sea to the Kitimat Marine Terminal. Four tanker sizes were examined:
An 110,000 DWT Aframax, a 200,000 DWT Suezmax, a 300,000 DWT VLCC and a 340,000 DWT VLCC.

As the project's design tanker size of 320,000 DWT was not available in the FORCE library it was decided to use both a 300k and 340k tanker to cover the characteristics of a 320k tanker.

RT simulations were carried out on full-mission Bridge simulators that used a mock-up of a ship's bridge located in the centre of a cylindrical projection theatre on which graphical images of the route the ship was travelling were displayed. The full-mission simulators were equipped with real bridge instruments such as engine telegraph, radars, echo sounder and communication equipment.

The simulations were conducted with BC Coast Pilots navigating the simulated ships in real-time along important sections of the routes described above.

This method of replicating the real navigation of a ship is a realistic and safe way to generate an overview of vessel performance and navigation information. The results from the simulations are highly reliable; FORCE Technology has more than 25 years of experience using this powerful tool in combination with use of accurate ship models.

A total of 170 real-time runs with pilots conning the ships and experienced tug masters conning escort tugs were performed during 3 sets of simulations.

2.3 Real-time Part 1

This part covers the real-time simulations carried out during January 2007.

The objective of the full-mission simulation study was:

- Confirm the navigability of the proposed routes (north and south) for the 3 tanker types between the Kitimat terminal and open water under varying environmental conditions;
- Identify environmental limits during navigation;
- Identify challenging navigational areas and mitigation strategies;
- Determine a safe and efficient speed profile;
- Determine minimum speeds for navigation, below which tug assistance is required;
- Determine the adequacy of the existing navigational aids and assess the requirement for additional aids in the confined channel assessment area as a minimum;
- Determine the operational requirements of escort tugs; Develop operational criteria for berthing and un-berthing the vessel at the terminal

The primary purpose of this study was to evaluate and assess the navigability of the proposed routes (north and south) for the 3 tanker sizes between the Kitimat terminal and open water under varying environmental conditions.

A VSP escort tug with 125 TBP was used as escort assistance from open water to the terminal and also for assistance with the final berthing of the tanker. Close to the terminal three additional tugs were used to bring the tanker along side. These consisted of two ASD tugs of 60 t BP, and one vector tug of 60 t BP.

The number and size of tugs to be used at the terminal for berthing and un-berthing the tankers will depend on the tanker size and weather conditions. However, during the simulation of berthing and un-berthing maneuvers the three 60 t tugs turned out to be able to handle with safety margins all weather conditions tested as well as all tanker sizes

The evaluation and assessment included identifying environmental limits, challenging navigational areas, minimum speeds for navigation, operational requirements for the escort tug, and requirements for navigational aids.

A total of 76 simulations were completed during the simulation session from 3rd to 13th January. The simulation program comprised of three different types of simulation scenarios using different simulator setups also described in section 5.

- Arrival/Departure simulations. Navigating tankers through selected areas along the routes
- Emergency simulations. Navigating tankers assisted by an escort tug through selected areas along the route in emergency scenarios
- Terminal simulations. Navigating tankers to and from the terminal including berthing/un-berthing maneuvers assisted by tugs.

Arrival / Departure Simulations

The first seven days focused on the arrival/departure simulations with the VLCC (ship no. 3219 and 3413), the Suezmax tanker (ships no. 3017 and 3414), and the Aframax tanker (ships no. 3303 and 3267) in ballast and loaded condition.

The simulations covered the areas of Caamaño Sound (19 simulation of which 11 simulations covered defining the point of no return), Nepean Sound and Otter channel (10 simulations), Wright Sound and Lewis Passage (16 simulations).

The simulations were completed in upper environmental operating limits for navigation. During day seven only a few simulations were completed as preparation of the pilots for the coming emergency simulations.
The remaining time was used on making the necessary changes in the simulator setup for simulating with interactive tugs.

Emergency Simulations

A total of 17 emergency simulations were completed on day eight and nine with the VLCC in ballast and loaded condition (ships no. 3219 and 3413) and the Suezmax tanker in loaded condition (ship no. 3017). During the emergency simulations the tankers were assisted by a VSP escort tug with 125 T BP.
The simulations covered the areas of Caamaño Sound, Otter Channel and Nepean Sound, Wright Sound and Lewis Passage and Douglas Channel off Maitland Island.
The emergency simulations covered different scenarios of rudder and engine failure, rudder jamming, break of towing line, and loss of communication.
The simulations were stopped when the pilot had recovered from the emergency with full control of the ship and the situation.

Terminal Simulations

A total of 14 terminal simulations were completed on day ten and eleven. For the terminal simulations the VLCC (ship no. 3219 and 3413) and the Suezmax tankers (ship no. 3017 and 3414) were used in both ballast and loaded condition. The tankers were assisted by one VSP tug and three ASD tugs distributed on three manned simulators and one vector tug operated by instructor or pilot.
The arrival simulations to the terminal were started approximately one nm from the terminal with the VSP tug connected aft. The other ASD tugs and the vector tug were connected when requested by the pilot. The simulations were stopped when the tankers were aligned at the berth within approximately a ship's beam to the berth.

In between each simulation a debriefing session was completed by all participants. By the end of day eleven, the main conclusions were discussed and mutually agreed by all tug masters, pilots, and representatives from Enbridge Pipelines. The conclusions are presented in section 6 and 10 of this report.

All the simulations were completed in environmental conditions considered as the upper limit. The wind conditions covered two scenarios with wind from NW and SE in open water. The wind changed direction and speed in the inland waters due to the mountains. The wind speed was generally in the interval of 40 to 50 knots and on a few occasions even up to 60 knots.

The current conditions covered ebb and flood scenarios and the current speed was generally set to approximately 2 knots. The waves are generally wind generated in the inland waters with wave periods from 4s to 6s and wave heights of maximum 2 m. In open water such as Caamaño Sound the waves are swell waves with long wave periods of up to around 15 s and generally very high. Please see section 4 for a more detailed description of the environmental conditions used for the simulations.

2.4 Real-time Part 2

This part covers the real-time simulations carried out during November 2008.

The present simulation study has investigated more closely the operational conditions for escort tugs, limiting environmental conditions and emergency situations.

The objective of the second full-mission simulation study was to:

- Investigate all possible routes in and out of the area leading to Kitimat.
- This would include navigation in Whale Channel, Laredo Sound and Channel and other routes.
- Investigate two ships passing on opposite course.
- Determine the safety levels when using 90 t contra 125 t Bollard Pull VSP Escort tugs.

The primary purpose of this study was to evaluate and assess the navigability of the proposed routes (Principe, Caamaño and Laredo) for the 3 tanker sizes between the Kitimat terminal and open water under varying environmental conditions.

A VSP tug with 125 T BP and a smaller of 90 t BP was used to assess tug escort assistance and emergency maneuvers from open water to the terminal. The evaluation and assessment included identifying environmental limits, challenging navigational areas, and meeting of 2 large tankers at 5 locations with limited width, operational requirements for the escort tug, and requirements for navigational aids.

A total of 49 simulations were completed during the one week of simulation. The simulation program comprised of three different types of simulation scenarios using different simulator setup.

- Arrival/Departure simulations. Navigating tankers through selected areas along the routes.
- Emergency simulations. Navigating tankers by steering or controlling speed using an escort tug through selected areas along the route involving emergency scenarios.
- Meeting and crossing traffic situations at selected locations with limited width along the way to Kitimat.

Arrival / Departure Simulations

During the 5 days of simulations, the exercises were distributed in the follows areas:

1 run in Principe Channel, North end
1 run in Principe Channel at Dixon Island
4 runs in Principe Channel at Anger Island
4 runs in Otter Channel
1 run in Caamaño Sound
1 run in Laredo Channel
2 runs in Whale Channel, South end
5 runs in Lewis Pass
1 run in Cridge Passage
4 runs in Wright Sound including crossing traffic
3 runs in Douglas Channel at Emilia Island
2 runs at the terminal area

Except for some test runs on the first day all the other simulation was done as two ship simulation where a meeting or crossing scenario was included.

Emergency Simulations

An important part of this study was to investigate how different emergency scenarios would develop and to what extent an escort tug could assist a tanker such that the tanker in an emergency could be stopped and held in a given safe position and avoid contact with the rocky bottom. The purpose of these simulation scenarios was also to evaluate how well the escort tug performed and how long time it would take to get the emergency situation under control. In addition the distance to risk objects such as other ships and the shore line could be measured and evaluated to judge the safety level of such an event.

The emergency scenarios included:

- “Black out” where the ship lost engine and rudder control
- Rudder failure, where the rudder locked in a fixed angle

The following runs included emergency: Run no. 203 “black out”, 301 “black out”, 307 Rudder failure (both tankers), 401 rudder failure (both tankers), 402 rudder failure (fixed at port 15 deg), 402-2 “black out”, 402-2 rudder failure (fixed at port 15 deg), 404 rudder failure, 405 “black out”.

In all the emergency scenarios the escort tug took over the control of the tanker’s movement based on orders from the pilot on board the tanker.

Meeting scenarios

Another important part of the study was to investigate traffic situations where two tankers could potentially meet each other on different locations along the way from open sea to the oil terminal at Kitimat.

In a previous study in 2007 (the first set of Real-Time simulations) 5 locations had been identified as potentially “one way traffic only” those and other locations were assessed for viability during this study with two ships passing at the most narrow point. See locations in section 6.2.

2.5 Real-time Part 3

The simulations in March 2009 investigated more closely the operational conditions for escorted tankers limiting environmental conditions, berthing and un-berthing at the terminal and emergency situations in open sea and inshore areas.

The objective of this simulation study was to:

- Perform and investigate berthing and un-berthing scenarios with focus on safety aspect and identify environmental limits for those operations;
- Investigate meeting situations in Douglas Channel with two VLCC tankers;
- Determine the operational limits of the escort tugs performing emergency towing in open sea;
- Determine the operational difference between escort tugs with 90 t BP, 100 t BP, 110 t BP and 125 TBP in connection with emergency steering of a loaded VLCC;

The primary purpose of this study was to evaluate maneuvers close to the terminal in Kitimat and handling of emergency situations.

This included berthing and un-berthing of VLCC tankers in weather conditions with wind speeds up to 60 knots and current up to 1.5 knots flooding and ebbing. Furthermore, the study included some meeting situations with two tankers in Douglas Channel as well as emergency towing of tankers in open sea outside the Caamaño approach.

Finally emergency steering with two size's of escort tugs were performed in Lewis passage with the purpose of investigating the performance of a 90 t to a 125 t bollard pull VSP tug.

A total of 51 single simulations were completed during the simulation session from March 23rd to 27th, 2009. The simulation program comprised of three different types of simulation scenarios using different simulator setup.

- Arrival/Departure simulations. Navigating tankers through selected areas along the routes
- Emergency simulations. Navigating tankers with intervention usage of an escort tug through selected areas along the route under emergency scenarios
- Meeting situations at locations with the least channel width along the way to Kitimat.

Arrival / Departure Simulations

During the 5 days of simulations, the exercises were distributed in the follows areas:

2 runs in Principe Channel
6 runs in Caamaño Sound
1 run in Whale Channel
21 runs in Lewis Pass
4 runs in Wright Sound
2 runs in Douglas Channel at Emilia Island
12 runs at the terminal area

Except for some test runs the first day of simulation, all the other simulation was done as two ship simulation where a meeting or crossing traffic scenario was included.

Emergency Simulations

An important part of this study was to investigate how different emergency scenarios would develop. The emergency scenarios included:

- “Black out” where the ship lost engine and rudder control
- Rudder failure, where the rudder locked in a fixed angle

The following runs included emergency: Run no. 403 to run no. 506 B rudder failure (fixed at port 35 deg.).

In all the emergency scenarios the escort tugs took over the control of the vessel’s movement based on orders from the pilot. The purpose of these simulation scenarios was to evaluate how well the escort tug performed and how long it would take to get the emergency situation under control. In addition the distance to risk objects such as other ships and the shore line could be measured and evaluated to judge the safety level of such an event.

Meeting scenarios

Another important part of the study was to investigate traffic situations where two large vessels meet each other on different spots along the way from open sea to the oil terminal at Kitimat.

In a previous study in 2007 five locations had been identified as narrower channel sections where pilots would prefer to avoid meeting situations. Those and other locations were tested with two ships passing at the most narrow point. Details on this subject can be seen in section 6.0.

2.6 Arrest simulations

Arrest simulations were performed in addition to the real-time simulations described above. Arrest simulations use two full-mission bridge simulators, one for the tanker and one for the escort tug. The simulators interact with one another providing real-time feedback to both operators. The purpose of these simulations was to investigate the stopping ability of tankers under their own power as well as with assistance of the escort tug. A total of 144 arrest runs were performed.

The overall objective of this simulation study in September 2009 was to investigate the tug arrest properties for 3 types of tankers. The study included:

- Recording of stopping distance
- Recording of transfer distance
- Time to stop the vessel

The arrest maneuvers were performed for 3 different cases for each ship type:

- Arrest using ship engine only
- Arrest using escort tug only
- Arrest using ship engine and escort tug

All tests were performed at an initial speed of 8 and 12 knots.

The simulations were carried out using the following tankers in ballast and loaded condition:

- 110.000 Dwt Aframax Tanker
- 200.000 Dwt Suezmax Tanker
- 340.000 Dwt VLCC

Two Voith Schneider tug (VSP) model was used for escorting the tanker.

- VSP tug of 125 t BP (Bollard Pull) and about 230 t steering pull
- VSP tug of 100 t BP (Bollard Pull) and about 180 t steering pull

According to OCIMF tankers above 50.000 DWT shall be fitted with a strong point of 200 t SWL. If the tankers are below 50.000 DWT they shall be fitted with a strong point of 100 t SWL.

For results see section 6 and appendix A.

3 Simulation Methodology

In this section is described the methodology used in both the Fast Time and Real Time simulations

3.1 Fast Time Simulations

The fast-time simulations are the first step of an investigation of the viability of using tankers to safely transport condensate and oil to and from Kitimat.

The Fast Time simulations are executed by use of the following tool.

3.1.1 Numerical Navigator

The FORCE Technology fast-time simulator is based on the PC-based simulator Simflex Navigator. The mathematical models for vessels and environment are the same as used in the real-time simulators, both full-mission and part-task simulators. This ensures that the response of the ship models the state-of-the-art within ship simulators.

Normally, the vessel is controlled by the navigator by means of normal control equipment (rudder, engine telegraph, etc.) and running in real-time. However, in fast-time mode the numerical navigator controls the vessel and the simulator is running as fast as the computer allows. This enables a huge number of simulations to be completed within a relatively short period of time depending on the length of the track. Once the fast-time simulations have been set up it is relatively easy to perform a large number of runs in various environmental conditions and various channel or harbour layouts.

3.1.2 Numerical Navigator - Methodology

The numerical navigator controls the ship. The numerical navigator has been developed to behave as representative navigators who have slight variations in preferences for e.g. position and timing for wheel over points and how to use the rudder for controlling the stopping of a turn before entering the next leg.

It follows a pre-defined track plan, which might include straight legs, wheel over-line, waypoints and curved tracks with a given turn rate. The track-plan furthermore includes a desired speed over ground. Human errors or misjudgment are included as a random function with a given standard deviation to obtain a number of tracks that are different and to obtain a track envelope.

Observations and corrective actions are done at discrete time intervals at a given typical interval, given as a mean time interval with a corresponding standard deviation. The rudder is controlled by the autopilot and the numerical navigator commands the autopilot with heading commands during straight legs and rate of turn commands during turning.

A speed controller adjusts the speed to match the speed over ground from the plan. If the ship is not able to keep the planned track and the maximum rudder angle is used, the handle setting is increased stepwise until the desired heading is reached.
Then the handle setting is decreased stepwise again until the target speed is reached. The planned track has a higher priority than the planned speed.

The time series logged during the simulations are afterwards analyzed statistically with the in-house developed program Replay. The statistical analysis provides information on e.g. controllability of the vessel, use of rudder, distances to certain structures, valuable for decision-making.

3.1.3 Numerical Navigator – Planned Track

In this study, man-made plans of two routes were made for the fast-time simulations. An example of a planned track for one of the routes, which consists of straight lines and a curved section, is shown in the table below.

The plan is defined by a series of waypoints. Each waypoint has a specified position, point type, desired rate of turn, desired heading, desired course, desired speed and a safety factor (a number between 0 and 1) which defines the need to stay close to the planned track. In this study, since the need to follow the plan closely is crucial, the safety factor is constant during the simulations.

The point types are defined as follows:

0. Starting point
1. Straight line point
2. Turning point
4. Ending point

Origin	49	0	0.000	N	135	0	0.000	W						
	X				Y				Point Type	ROT (rad/s)	Heading (rad)	Course (rad)	Speed (m/s)	Safety Factor
WAYPOINT	53	39	350.000	N	130	28	500.000	W	0	0	2.09954	2.09954	5.14444	1
WAYPOINT	53	31	640.010	N	130	6	397.337	W	1	0	2.09954	2.09954	5.14444	1
WAYPOINT	53	31	523.465	N	130	6	102.152	W	2	0.00276	2.34003	2.34003	5.14444	1
WAYPOINT	53	31	411.092	N	130	5	795.131	W	1	0	2.34003	2.34003	5.14444	1
WAYPOINT	53	24	602.975	N	129	54	99.105	W	2	0.00274	2.46376	2.46376	5.14444	1
WAYPOINT	53	24	506.103	N	129	53	946.248	W	1	0	2.46376	2.46376	5.14444	1
WAYPOINT	53	18	402.268	N	129	45	860.024	W	2	0.002935	2.5546	2.5546	5.14444	1
WAYPOINT	53	18	326.821	N	129	45	765.455	W	1	0	2.5546	2.5546	5.14444	1
WAYPOINT	53	12	139.796	N	129	39	040.390	W	2	-0.004625	1.5015	1.5015	5.51556	1
WAYPOINT	53	11	843.819	N	129	38	381.467	W	1	0	1.50173	1.50173	5.14444	1
WAYPOINT	53	12	195.178	N	129	26	848.436	W	2	-0.002444	1.21462	1.21462	4.11556	1
WAYPOINT	53	12	249.864	N	129	26	181.658	W	1	0	1.21462	1.21462	4.11556	1
WAYPOINT	53	13	167.771	N	129	21	893.407	W	2	-0.002438	0.692474	0.692474	4.11556	1
WAYPOINT	53	13	454.986	N	129	21	32.272	W	1	0	0.692322	0.692322	4.11556	1
WAYPOINT	53	15	753.891	N	129	17	740.234	W	2	-0.004585	6.12751	6.12751	5.11556	1
WAYPOINT	53	16	226.891	N	129	17	364.092	W	1	0	6.12759	6.12759	4.11556	1
WAYPOINT	53	19	608.319	N	129	18	151.383	W	2	0.004007	1.33322	1.33322	5.11556	1
WAYPOINT	53	20	398.880	N	129	17	635.823	W	1	0	1.33319	1.33319	4.11556	1
WAYPOINT	53	21	057.412	N	129	12	754.536	W	2	-0.0047765	6.22159	6.22159	6.11556	1
WAYPOINT	53	21	517.733	N	129	11	781.305	W	1	0	6.22159	6.22159	4.11556	1
WAYPOINT	53	30	0.034	N	129	12	399.942	W	2	0.00228	6.26554	6.26554	4.11556	1
WAYPOINT	53	30	48.849	N	129	12	402.818	W	1	0	6.26536	6.26536	4.11556	1
WAYPOINT	53	36	894.996	N	129	12	404.502	W	2	0.0046925	0.743777	0.743777	5.11556	1
WAYPOINT	53	37	342.880	N	129	12	218.836	W	1	0	0.743861	0.743861	4.11556	1
WAYPOINT	53	40	347.888	N	129	7	403.348	W	2	-0.00368	0.417853	0.417853	4.11556	1
WAYPOINT	53	40	565.432	N	129	7	89.207	W	1	0	0.417776	0.417776	4.11556	1
WAYPOINT	53	41	881.588	N	129	6	041.958	W	2	0.004035	0.980252	0.980252	3.60111	1
WAYPOINT	53	42	242.197	N	129	5	641.614	W	1	0	0.980252	0.980252	3.60111	1
WAYPOINT	53	45	686.625	N	128	56	573.330	W	2	-0.00565622	0.841367	0.841367	4.11556	1
WAYPOINT	53	45	788.955	N	128	56	303.201	W	1	0	0.841367	0.841367	4.11556	1
WAYPOINT	53	49	457.295	N	128	49	024.100	W	2	-0.00422	0.540919	0.540919	3.60111	1
WAYPOINT	53	49	700.716	N	128	48	587.133	W	1	0	0.540919	0.540919	3.60111	1
WAYPOINT	53	54	985.616	N	128	42	899.882	W	4	0	0.540796	0.540796	3.60111	1

Table 3.1 Plan for "Numerical Navigator" for passage of Route 2 in wind from NW and flood current.

The two routes that were simulated are shown in figure 3.1 and figure 3.2.

Route 1:	Caamaño Sound Squally Channel Lewis pass Wright Sound Douglas Channel	Route 2:	Principe Channel Nepean Sound Otter Channel Lewis pass Wright Sound Douglas Channel.

The routes as shown in Figure 3.1 and 3.2 are aiming at the vessels centre line being in the middle of the channels. The speed is chosen at 10 knots when being in either Caamaño Sound or Principe Channel and varies between 7 and 8 knots when being in more sheltered areas. The choice of vessel speed is based on what is believed to be a worst case scenario but also being in a range where it is possible to use an escorting tug. With a speed of i.e. 7 to 8 knots the vessel has less maneuverability, less squat, and larger drift angle due to wind and current than compared to larger speeds. Due to the environmental conditions with strong following or opposing wind and current and also beam wind and current as in the Caamaño Sound, it was necessary to prepare individual plans for each of the simulated scenarios.

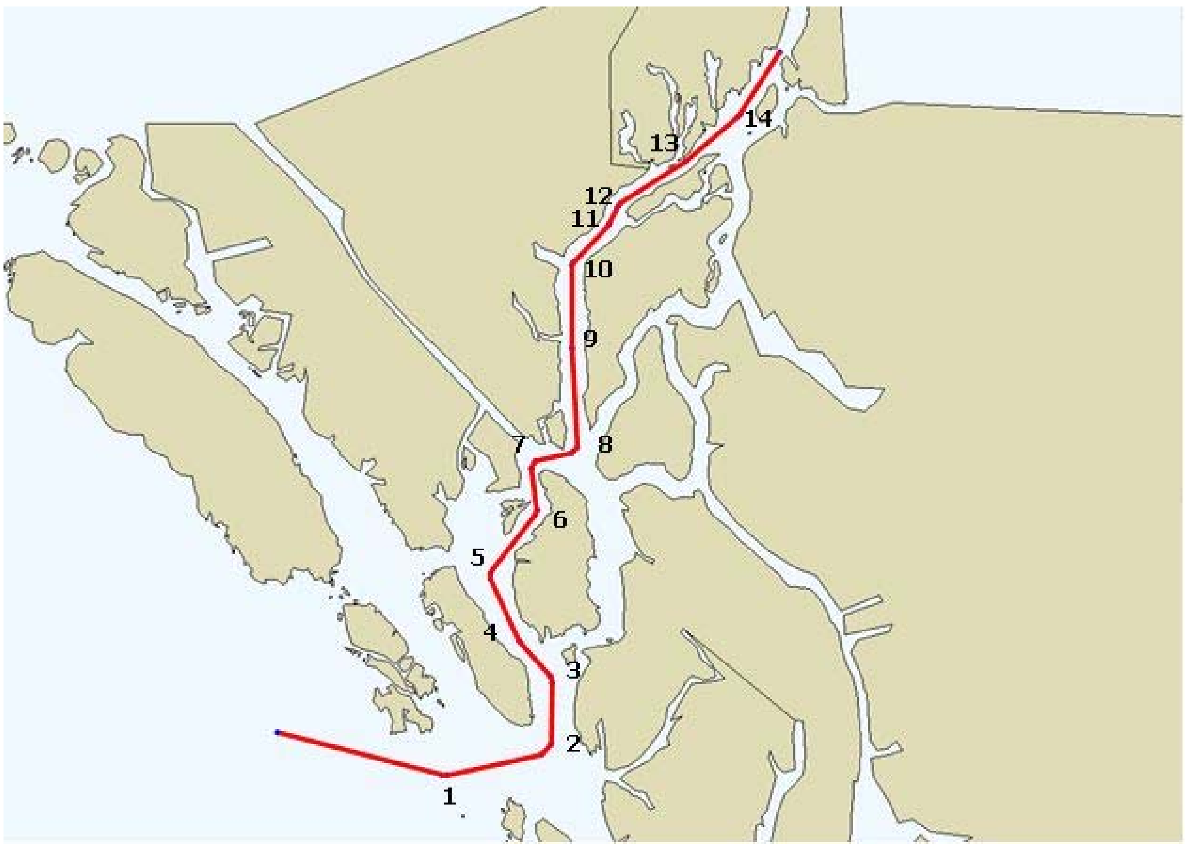


Figure 3.1 Route 1, Numbering of Turns

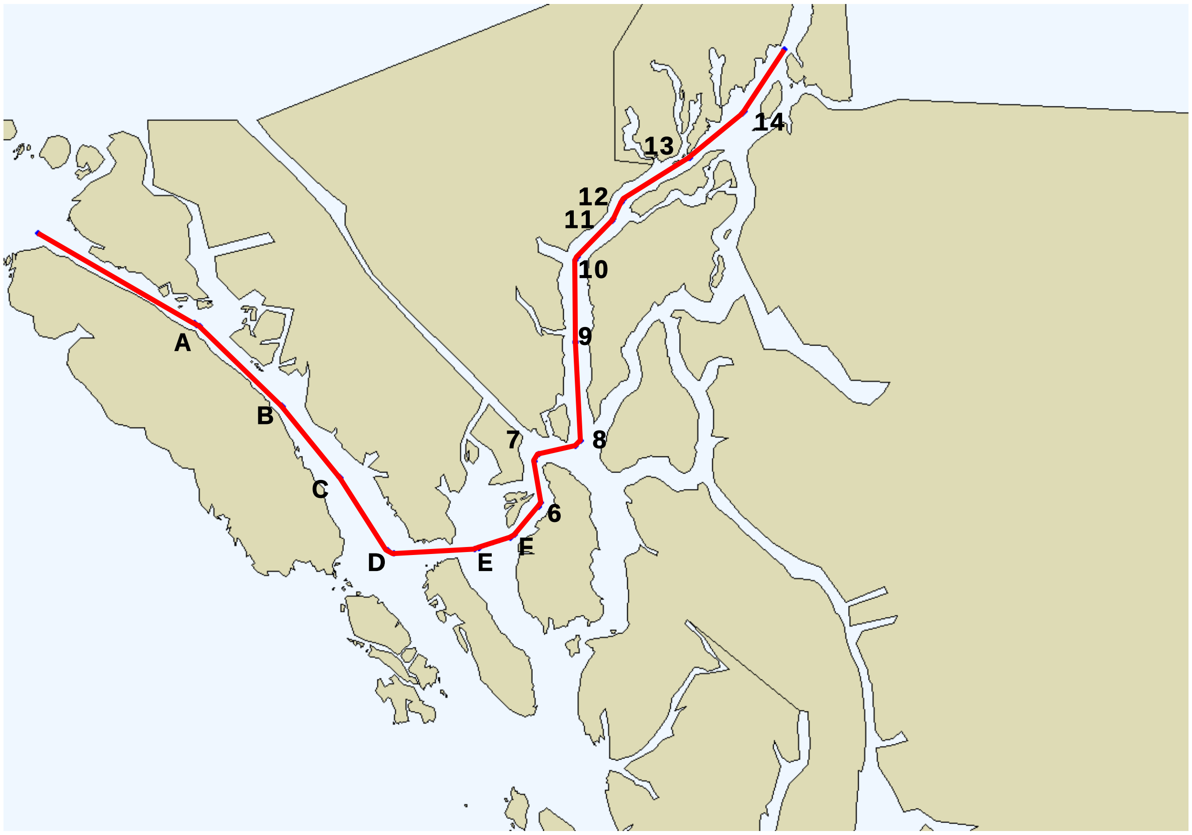


Figure 3.2 Route 2, Numbering of Turns

3.2 Real time-time Simulation method

The initial fast-time simulations provided information on factors having the strongest influence on the tanker maneuverability, areas of particular interest and critical conditions for tanker maneuvers. Output from the fast-time simulations was used as part of the definition for the scope of work for the real-time simulations.
The fast-time simulations were followed by full-mission simulations where especially operational conditions for escort by tugs, limiting environmental conditions, emergency situations, operational conditions for berthing and un-berthing at the terminal, and adequacy of existing navigational aids were investigated more closely.

The scope of work described in Section 3.1 formed the basis of the real-time simulations. For each simulation, parameters such as weather (combinations of wind, current and waves), ship types and sizes were modified to create different challenges.

Once a list of simulation runs was developed, the simulated sailings commenced. Adjustments and new scenarios were developed during each program session to address specific issues raised by the pilots or the client (such as assessing the viability of transits of Whale and Laredo Channels) and modifying the program to address the more critical (emergency response) scenarios.

After each sailing, the Pilots participated in a debriefing session where "run" evaluation reports were completed by the Pilots, which then formed the basis for a discussion between the Pilots, the FORCE Instructor and the Project Manager to assess run parameters and the Pilots' observations on navigation viability.

3.2.1 Simulation scenarios

The simulation program comprises a number of scenarios that systematically test different combinations of specified parameters. The parameters in this study included:

- Ship types: tankers of ranging from 110,000 to 340,000 DWT
- Loaded condition: ballasted or loaded
- VSP escort tug size: 100 t BP up to 125 t BP
- ASD escort tug size: 60 t BP
- Vector tug of 60 t BP
- Geographic area: e.g. Principe Channel, Caamaño Sound, Otter channel, Wright Sound etc.
- Weather condition: Wind, current, waves, visibility, day/night light, traffic situation
- Direction of transit: inbound/outbound

Run list No.	Ship 1 no A	Type	Wind Knots	Current knots going	Waves height m	Wave period s	Direc. Going deg.	Day / Night	Visibility Nm	Tugs # of BP in t	Pilot	Remarks
												All 100 runs are arrival
100	3413	VLCC bal	SW 6	0	1	8s	60	Day	Good	4	Kevin	3 x 50 t tugs + 125 t VSP
100	3413	VLCC bal	SW 6	0	1	6s	210	Day	Good	4	Kevin	3 x 50 t tugs + 125 t VSP
101	3413	VLCC bal	SSW 15	0.5 NNE	1	6s	210	Day	Good	4	Bob	3 x 50 t tugs + 125 t VSP
102	3413	VLCC bal	SSW 30	0.5 NNE	1	8s	210	Day	Good	4	Kevin	3 x 50 t tugs + 125 t VSP
103	3413	VLCC bal	NNE 30-50	1.0 SSW	2	8s	210	Day	Good	4	Bob	3 x 50 t tugs + 125 t VSP
104	3413	VLCC bal	NNE 40	1.0 SSW	1	8s	60	Day	Good	4	Kevin	3 x 50 t tugs + 125 t VSP

Table 3.2 typical example of a run list from one (R-T) simulation session with weather conditions number of tugs used and assisted ship type.

Several thousand combinations can be produced when systematically combining all the parameters shown in table 3.2 above. However, only a fraction of the combinations are tested because some combinations are irrelevant or very unlikely. For example, if it is already proven that a 340,000 DWT tanker can be controlled safely in wind speeds of 50 knots, there is no need to investigate the same situation in 40, 30 and 20 knot wind, as those speeds will be less of a challenge for the navigator conning the ship.

The VSP tug (no. 3421) used during the tests in Lewis Sound was reduced to 90 t, 100 t and 110 t. This was done to find out how much steering was needed to control the escorted vessels.

3.2.2 Simulation execution

Prior to each simulation study, a proposed list of runs was made. At the beginning of each week of simulation, this list was discussed with the participating Pilots, and necessary adjustments were made. Daily adjustments were also implemented as needed.

Each scenario was simulated, and after each run an evaluation form was filled out by the Pilot in command. At the same time, the FORCE Instructor showed a replay of the run and discussed the details with the Pilots. The evaluation form also included the Pilot's comments on the different questions asked and formed a valuable input for the later study conclusion. See section 10.

At the end of each day, discussions between the Pilots, Enbridge representative(s) and FORCE personnel were held to sum up all the impressions and navigational issues that needed attention. Results from these discussions also formed part of the study conclusion.

Pictures from the 2008 and 2009 simulations give an impression of the physical appearance of the FORCE simulator system can be seen in appendix B.

3.3 Arrest simulation

Arrest simulations were performed in addition to the real-time simulations described above. As for the real-time simulations runs, arrest simulations use two full-mission bridge simulators, one for the tanker and one for the tethered escort tug. The simulators interact with one another providing real-time feedback to both vessel operators. The results are shown in section 6.3.

These simulations were carried out with a 100 ton bollard pull Cycloidal (VSP) tug since this is the upper limit of design capacity for this type of propulsion system with current technology and is also within the current design limit (200 t) for the ships' tow point.

3.3.1 Basis for arrest test

In order to be able to make a direct comparison between the 3 tanker types all stop tests were carried in the same manner under the following conditions:

- Calm weather with no wind.
- No current.
- No waves.
- Water depths greater than 100 metres.
- No influence from Squat.

3.3.2 Assumptions

All tankers were fitted with a long stroke directly coupled (to a fixed pitch propeller) reversible diesel engine.

All stop tests begin at 12 knots or 8 knots. When commanding full astern on the tanker the propeller would be wind milling, until the speed of the tanker were down to about 7 to 8 knots. At this speed the engine revolutions were about 25 RPM and the engine could be reversed.

This means that for all exercises starting with a speed of 12 knots the vessels will use a couple of minute before the main engine is able to reverse. From 12 knots to about 7 to 8 knots the ship is performing a coasting stop where only the resistance on the hull is reducing the speed.

When the tug was ordered to stop the tanker the breaking power was obtained almost immediately. In reality execution of orders given can take longer time depending on the tug crew, training and weather circumstances. Also the time from the tankers engine stopped (only runs with tug only arrest) until the navigator recognizes that an emergency condition exists is not considered in these tests.

3.3.3 Definition

The advance (stop distance) and the transfer distance are defined in the figure 3.1 below.
The distances are recorded from the time the engine and/or the tug are commanded astern.

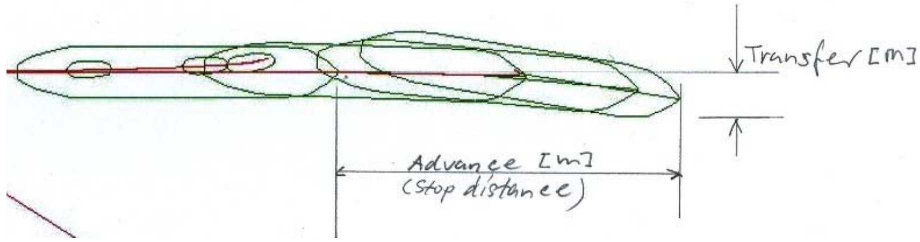


Figure 3.3 Definition of Advance and Transfer distances

4 Modelling

The methodology for the study consisted of the following elements:

- Modeling the relevant parts of the BC coast;
- Modeling three tanker sizes and two tug boats;
- Determining relevant combinations of parameters for the simulation programs,
- Executing the simulation scenarios;

4.1 Modeling of the Kitimat area

The relevant part of the BC coast that was modeled is shown in figure 4.1. The basis for the 2D (chart) and the 3D (visual) modeling used in the simulations were Canadian navigation charts of the area as well as electronic ECDIS charts. The charts were the foundation for generating the shore line, water depth and navigational markings.

The new marine terminal at Kitimat will be located in the northern part of the Douglas Channel. See figure 4.3. Arrival at the terminal goes from open water and through various channels either from Browning Entrance through Principe Channel, Otter Channel, Wright Sound, and Douglas Channel up to the terminal or from Caamaño Sound, through Squally Channel, Wright Sound and again Douglas Channel up to the terminal.

The environment model used in the full-mission simulations consists of a detailed description of the shoreline and topography, a detailed description of the depths, wind, waves, and current charts based on nautical charts and previous surveys.

The environment model used in the full-mission simulations consisted of a detailed description of the shoreline and upland topography as well as a detailed description of the depths, wind, waves and current. The environment model for the fast-time simulations included land contours, water depth, wind, current and wave-definitions.

Figure 4.1 View from the visual model

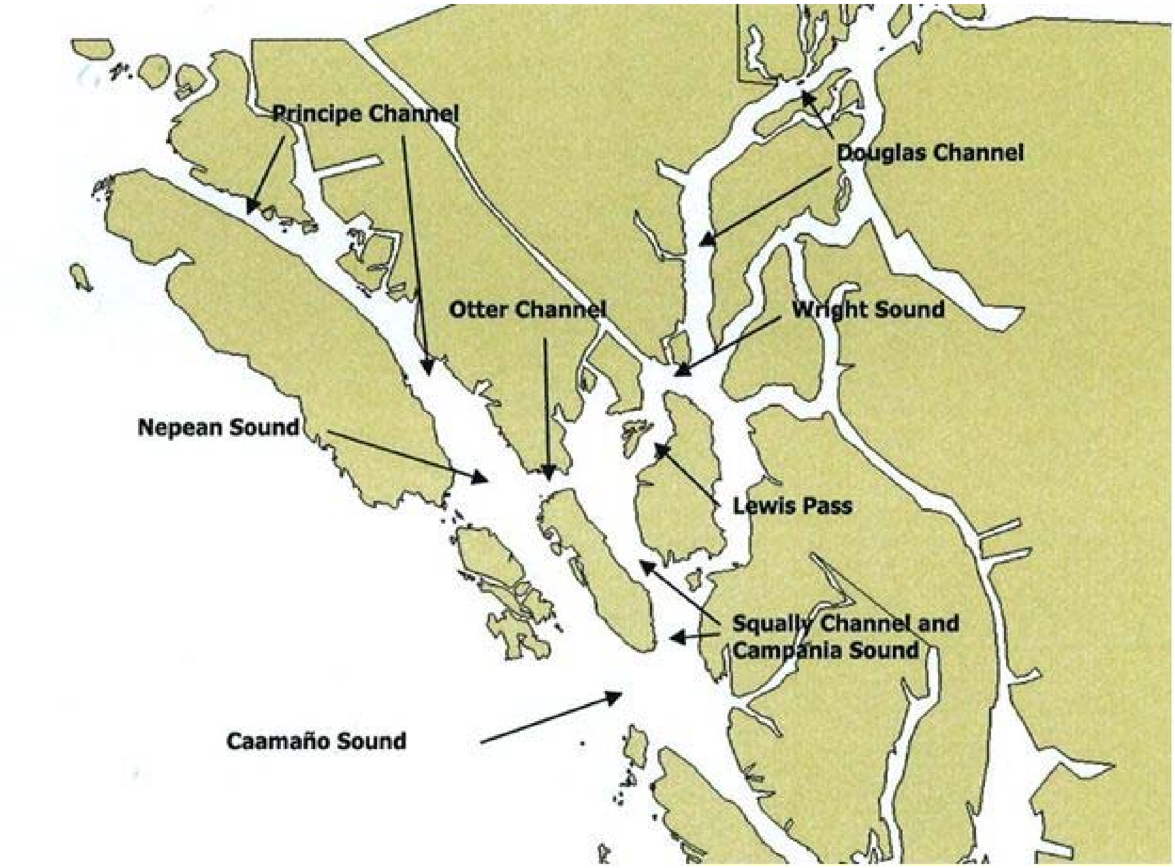


Figure 4.2 Overview of the approaches to Kitimat.

The shoreline and the topography were generated based on data downloaded from www.geobase.ca - a portal offering high-quality geospatial data for all of Canada. With a high lateral and horizontal resolution of the data it was possible to generate both shoreline and topography for the area model of Kitimat to a level where details in the landscape were visually recognizable for the pilots in the full-mission simulator. A screen download from the simulator is shown in figure 4.1.

The depths in the area vary from small depths along the shoreline that increase rapidly with the distance to the shoreline and reach as much as 250 m in some channels. Based on bathymetry data provided by Canadian Hydrographic Service (CHS) a depth chart was generated and implemented in the area model.

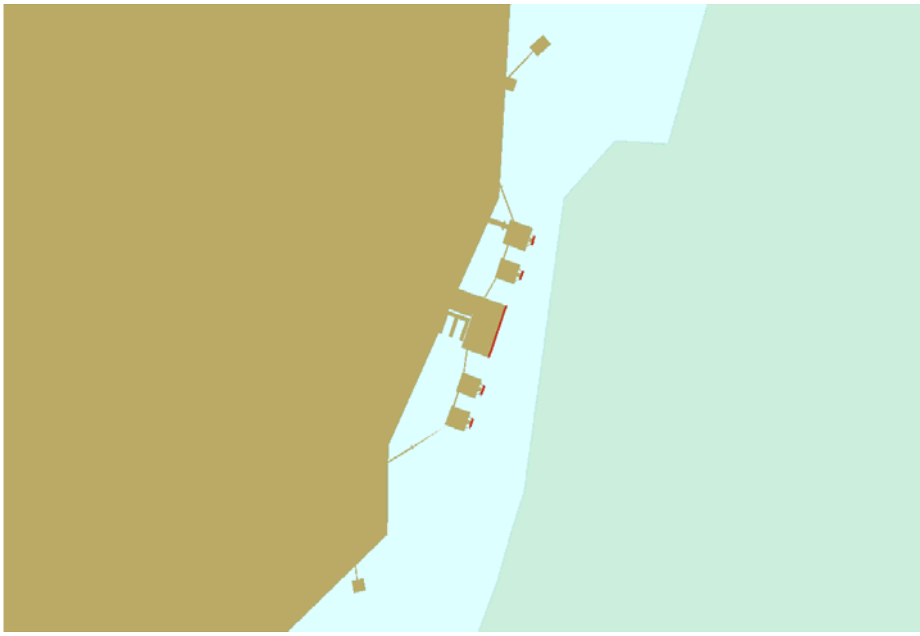


Figure 4.3 2D (chart) view of proposed terminal at Kitimat used in the simulation.

Figure 4.4 2D overview of simulation area with lights and buoys

4.2 Wind definitions

The predominant wind directions in the area are SE and NW. During winter time the average wind comes from SE and in the summer time it comes from NW. Ref/4/ shows that the highest wind speeds occur during fall and winter and the lowest during summer.

Inland wind speeds are reduced with approximately 35% compared to the average wind speeds at open sea. For the highest wind speed the reduction is around 50%. For the two modeled wind scenarios the wind speed in open water such as Caamaño sound and in the Principe Channel is around 40 knots.

For inland water navigation wind speeds of 40 knots were simulated with gusts up to 60 knots.

The wind runs mostly along the channels. However, there are islands in the area, such as Campania Island that are not high enough to deflect the wind. The wind patterns for the NW and SE wind conditions are showed in Appendix H.

The definition of wind speeds used in the simulator are based on wind-tunnel tests and are converted to a uniform wind speed at 10 meters height, which is the normal meteorological definition. This wind speed may be different from the impression of the wind speed which the captain gets from his observation of the wind indicator depending on the vertical location of the wind indicator. This is often positioned high up in the mast. Also it is the most normal human reaction to notice the peak value of the meter. A more detailed description is given in Appendix E and H.

Environment conditions

The tested environmental conditions consisted of wind up to 50 (and occasionally 60) knots in the open areas such as Principe Channel and Caamaño Sound from the directions NW and SE. For areas such as Douglas Channel, Otter Channel, and Squally Channel, the wind speed was reduced to 40 (and occasionally 50) knots mainly blowing along the channels.

The wind conditions were combined with either a spatially varying ebb or flood tide condition ranging from approximately 0.6 knots at the terminal berths to 2.0 knots in the Douglas Channel and up to 3.0 knots in Principe Channel.

The wind and current conditions consisted of prevailing directions and directions considered as problematic for maneuvering along the chosen route. The wind scenarios of NW and SE wind were modeled along with the current scenarios of ebb and flood tide. The wind and the current in the inland part of the area are dominated by mountains and the very deep channels. Therefore, in this area the current and the wind usually follow the direction of the channels.

4.3 Current definitions

The current in the area depends strongly on wind direction and speed, tide, and time of year. Previous technical reports based on surveys, Ref/2/ and Ref/3/ show that the current patterns in the area are very complex with stratified currents of rather different direction and speed. I.e. the average surface current runs towards open sea whereas the depth current runs towards inland waters.

According to Ref/2/ the currents in the area are characterized by typical flow speeds of about 0.3 knots to 0.6 knots at the surface. The highest surface currents were measured in the outer seaward parts of the area including Campania Sound, Caamaño Sound and Principe Channel, while Kitimat Arm of northern Douglas Channel appears to have lower surface currents.

The maximum current speeds for the flood tide condition were 3.0 knots in Principe Channel reducing to 0.6 knots in Douglas Channel. For the ebb tide condition the current speeds were 3.0 knots in Principe channel and from 1.0 knot in the northern part of the Douglas Channel to 2.0 knots in the southern part of Douglas channel.

The maximum ebb surface current measured in the inland part of the area east of Principe Channel is 1.6 knots in the northern part of Whale channel. In this area the flood current is maximum 1.3 knots.

For the present study, the ebb and flood current conditions were modeled as a depth-averaged spatially varying current given by the speed and the direction. The ebb tide flows in a SE direction along the outer coast. If there is outflow in Douglas Channel (ebb tide), there will be a SE flow through Principe Channel and at the south end of Grenville Channel. The flood tide runs NW along the outer coast. It reverses in the channels where there is an island large enough to delay the north-going flood. Therefore the current direction to the west of the islands is NW during the flood. Also the flood current runs north past the west entrance of Otter Channel and north through Principe Channel. The flood tide sets to the west through Otter Channel except on small tides where it tends to go to the east on the flood. In the model description, the current is running towards west in Otter Channel.
The current speeds used during the exercises are described in the list of runs either as a factor multiplied to the current pattern definition or as a fixed value in knots.

The description of the current patterns for the Kitimat area was generated on the information provided by Ref/2/ the nautical charts and information from British Colombia Coast Pilots. The nautical charts were used at the locations on which Ref/2/ had no available information. In other areas in which Ref/2/ the nautical charts had no available information, the current description was based on the experience and knowledge of the local pilots. The final descriptions of the ebb current and flood current conditions were reviewed by the pilots and are shown in Appendix I.

4.4 Wave conditions

The wave forces acting on a ship were calculated in uni-directional irregular waves meaning that all wave components were assumed to propagate in the same direction. In the Kitimat simulations, wave heights in the confined channel areas ranged from 0.5 meters and up to 2.0 meters, and in the open sea areas, e.g. west of Caamaño Sound, the wave heights were up to 4 meters.

During the run, the simulator receives the following information from the Wave Generation Unit which gives real data and a picture for the area, including:

- Spectrum type
- Wave direction
- Mean water depth
- Wave period (Display purpose for User Defined)
- Significant wave height

The Simulator Operator/Instructor feeds in the following information at the beginning of each run:

Spectrum type, wave direction (degrees), height Hs (m) and period (sec.)

4.5 Modeling of the tankers and tugs

Modeling of tankers used in the simulator

Mathematical models of the Aframax, Suezmax, and VLCC tankers in ballast and loaded condition were generated using an in-house software package called Simflex Shipyard. Model details included:

- Force and moment of deep and shallow water hull hydrodynamic resistance
- Aerodynamic forces and moments originating from wind affecting the ship, calculated at 20 points along the ship hull
- Mean and low frequency wave drift loads by use of a linear diffraction program
- Visual model of the tankers
- Loads applied by tugs to the tanker either by pushing on the tanker hull or by pulling on towlines

Simflex Shipyard is a numerical simulation tool designed to generate ship models for the simulator and to predict the ships' maneuvering characteristics. Simflex Shipyard includes a number of simulation methods based on a regression of FORCE Technology's large database of maneuvering model tests results.

A more detailed documentation of the ships models used can be seen in appendix F.

After generation of the project ship models, their maneuvering performance was validated by plots of standard maneuvers of real vessels and by internal test and validation by FORCE Technology captains.

The tankers used in the full-mission simulations were models of tankers, ranging from 110.000 DWT to 340.000 DWT all in loaded and ballast condition:

- Ship no. 3303 – 110,000 DWT Aframax tanker in ballast condition
- Ship no. 3161 – 110,000 DWT Aframax tanker in loaded condition
- Ship no. 3267 – 110,000 DWT Aframax tanker in loaded condition
- Ship no. 3414 – 200,000 DWT Suezmax tanker in ballast condition
- Ship no. 3017 – 200,000 DWT Suezmax tanker in loaded condition
- Ship no. 3059 – 300,000 DWT VLCC tanker in loaded condition
- Ship no. 3242 – 300,000 DWT VLCC tanker in ballast condition
- Ship no. 3413 – 340,000 DWT VLCC tanker in ballast condition
- Ship no. 3219 – 340,000 DWT VLCC tanker in loaded condition

VLCC tankers are expected to arrive at the Kitimat Marine Terminal in ballast condition and depart in loaded condition. The Aframax and the Suezmax tankers may depart and arrive in both loaded and ballast condition. The tankers used for the fast-time simulations were 3303, 3267, 3413 and 3219. All ships for all simulations were modeled in 6 degrees of freedom.

Vessel specifications are provided below.

Project design ships Condition Ship No.	Aframax Ballast 3303	Aframax Loaded 3267	Aframax Loaded 3161	Suezmax Ballast 3414	Suezmax Loaded 3017	VLCC Ballast 3413	VLCC Loaded 3219	VLCC Ballast 3242	VLCC Loaded 3059
Displacement (m^3)	46386	105121	95250	94462	212246	170200	373172	131127	344500
Length between PP (m)	233.0	233.0	233.0	295.0	295.0	336.0	336.0	327.0	327.0
Length overall (m)	244.6	244.6	244.6	310.0	310.0	346.8	346.8	343.7	343.71
Breadth moulded (m)	42.00	42.00	42.00	47.0	47.0	60.5	60.50	56.4	56.40
Draught fore/aft (m)	5 / 7	13.1/13	12 / 12	8 / 10	19.1/19.1	9 / 11	21 / 21	8 /10	21.8/21.8
Frontal wind Area (m^2)	1166.7	913	959	1374	876	1750	1060	1948	1060
Lateral wind area (m^2)	4676	3039	3295	6043	2920	7724	4100	8867	4034

Table 4.1 Main particulars for the tankers used in the study.

Other ships were used to generate realistic situations in meeting, passing and crossing scenarios with project design ships. The ships were controlled by the simulator Instructor / Operator or Pilot.

These ships included:

- Ship 3239 LNG tanker of 200,000 m^3 with 10 m draft
- Ship 3240 LNG tanker of 200,000 m^3 with 12 m draft
- Ship 3448 Ferry of 168 m length over all, with 4.7 m draft
- Ship 3315 LNG tanker of 216,000 m^3 with 9.34 m draft
- Ship 3355 LNG tanker of 202,000 m^3 with 12 m draft
- Ship 3316 LNG tanker of 216.000 LNG Q flex tanker with 12 m draft
- Ship 3224 Bulker 125.000 DWT with 16 m draft

Data for the traffic ships are shown in the table:

Other Project design ships Condition Ship No.	LNG Ballast 3239	LNG Loaded 3240	LNG Loaded 3355	LNG Ballast 3315	Ferry Loaded 3448	Bulker Loaded 3224	LNG Loaded 3316
Displacement (m^3)	114035	142300	148 000	105 536	10 414	145000	139073
Length between Perpendiculars (m)	325.0	325.0	327.0	305.0	156.0	265.0	305.0
Length overall (m)	340.0	340.0	346.0	315.0	167.5	285.0	315.0
Breadth moulded (m)	51.30	51.30	51.00	50.0	24.7	43.0	50.0
Draught fore/aft (m)	10/10	12/12	12/12	9.34/9.34	4.73/4.68	16/16	12/12
Frontal wind Area (m^2)	1850	1850	1850	1510	525	910	1380
Lateral wind area (m^2)	10700	10000	10 000	7427	3139	2726	6666

Table 4.2 Main particulars for the traffic ships used in this study.

Modeling of Tugs used in the simulator

The basis for the generation of the ASD tugs is a generic ASD tug model previously developed by FORCE Technology. The generic ASD tug model is based on a large number of model tests carried out using our PMM (Planar Motion Mechanism) in order to define the relevant and important properties of an ASD tug. The model tests comprised bare hull tests with and without thrusters' interaction.

Likewise, a generic VSP tug model was developed as a part of this study. Similar PMM model tests were carried out, however only bare hull tests, including propeller guard and fin, were completed. Model test data of interaction effect between hull and VSP units were kindly provided by Voith Turbo Marine GMbH & Co.

The mathematical tug models contained:

- Description of Ships Mass, Inertia, Time Constants
- Deep-Water Hydrodynamics
- Shallow-Water Hydrodynamics
- Aerodynamic Forces (derived from our database of wind tunnel tests)
- Wave-Induced Motions (based upon 3D panel sea keeping code)
- Thrusters loss due to waves (based on operator experience)

Based upon the generic ASD and VSP tugs listed in table 4.3 mathematical models of the tugs were produced.

The ASD tugs have been used in previous studies and through these studies they have been validated thoroughly by external tug masters. The VSP tug was validated by a very experienced tug master during a one-day validation session held on 19th December 2006 prior to the simulations.

The validation session especially emphasized the escorting capabilities of the tug. The same tug master also participated in the actual simulation program.

The models of the VSP tugs used for escort and the ASD tugs used for berthing maneuvers during the full-mission simulations were based on a generic tug model previously developed by FORCE Technology and confirmed as valid models by experienced tug masters.

The following tug models were used in the full-mission simulations:

- Ship no. 3421 VSP tug extended to 125 T BP, operated only by Tug Master
- Ship no. 3421 VSP tug reduced to 100 T BP, operated only by Tug Master
- Ship no. 3346 Svitzer Mars, ASD tug extended to 70 T BP, operated only by Tug Master
- Ship no. 3292 Svitzer Mars, ASD tug with 63 T BP, operated only by Tug Master

- Ship no. 9804, vector tugs with 60 T BP operated by Pilots and Tug Master.

The choice to use VSP tugs for assessment of escort operations and ASD tugs for berthing maneuvers was made in consultation with Northern Gateway and was based on a preliminary assessment that the VSP system is more effective for tethered tug escort work and meets the upper limits of IMO guidelines for required steering pull.

Vessel specifications for the tugs are provided in the below table.

Project tug Propulsion Ship No.	Ajax VSP 3421	Ajax VSP 3421	Svitzer Mars ASD 3346	Svitzer Mercur ASD 3292
Displacement (m^3)	1268.3	1268.3	647.9	647.9
Length between Perpendiculars (m)	38.2	38.2	25.6	25.6
Length overall (m)	41.6	41.6	30.0	30.0
Breadth moulded (m)	15.9	15.9	11.0	11.0
Draught fore/aft (m)	6.8/6.8	6.8/6.8	4.60/4.60	4.60/4.60
Longitudinal centre of gravity (m)•	-0.55	-0.55	-0.80	-0.80
Vertical centre of gravity (m)•	2.6	2.6	-0.26	-0.26
Bollard pull – ahead (T)	100	125	70 - 50	63 - 50
Bollard pull – astern (T)	100	125	65 - 50	58 - 50

Table 4.3 Main particulars for the tugs used in this study.

Project Design ship: A full mathematical model that can be controlled as in the real environment, by the Pilots and the Masters.

Apart from these ships, target ships such as smaller vessels, tugs and barges were also used. The target ships were controlled by the Simulator Instructor.

Target ship: A semi-mathematical model which can be operated as vector vessel by Instructor or Pilot.

5 Simulator Set-up

The full-mission simulations were carried out at the premises of FORCE Technology. The simulation facility at FORCE Technology consists of seven individual simulators, which can be coupled together, each controlling its own ship whether tankers or fully modeled tugs. During the simulation session four different simulator configurations were used depending on whether focus was put on the tanker operations or on the tug operations.

A: Tanker on Bridge A with 360 deg field of view
(main focus on tug escorting operations)

B: Tanker on Bridge B with 120 deg field of view
(main focus on tug escorting operations)

C: Tug on Bridge H with 360 deg field of view
(main focus on vessel maneuvering/escort operations)

D: Tug on Bridge G with 120 deg field of view
(main focus on vessel maneuvering/escort operations)

The above-mentioned simulator configurations comprised one or more of the following bridges, which are also depicted in figure 5.1

- A full bridge tug or tanker mock-up, 360 deg. Horizontal field of view (HFOV) (Bridge A)
- A full bridge tug or tanker mock-up, 360 deg. Horizontal field of view (HFOV) (Bridge H)
- A full bridge tanker mock-up, 120 deg. HFOV (Bridge B)
- A full bridge tanker mock-up, 120 deg. HFOV (Bridge C)
- Two auxiliary tug cubicles (Bridge F and G)
- An Instructor/Operator Control Centre (OCC)

Details of the simulation bridges are described in the sections below.

When two or more simulators were connected to each other, (configuration A and C), information was exchanged through the network on e.g. position, speed, heading, fender and hawser force, etc. at every time step. The updating frequency of the simulations was 4 Hz, thus, giving a time step of 0.25 seconds.

The simulators were operated from the Operator Control Centre, from where the operator could set-up up each simulation, start and stop the simulations and interact by e.g. changing the environment if required during the simulations.

All the tug bridges were equipped with control handles for both ASD tugs and VSP tugs with a layout of the bridges made in a way that the control handles for both types of tugs were present at all times. Hence, no time for changing control handles between the simulations was necessary when changing type of simulated tug.

The control handles for the VSP tugs were identical on all three tug bridges. The layout of the handles consisted of a wheel controlling the steering pitch, a lever controlling the speed pitch and of the four buttons giving the possibility to select between 40%, 80%, 90%, and 100% engine revolutions. The handle layout was developed in cooperation with Bosch/Rexroth, supplier to Voith Turbo Marine GmbH & Co.

The handle layout for the ASD tugs consisted of two thrust control handles for control of the azimuth propellers.

The Tanker and the tugs were shown on the visual screen on all bridges together with the surroundings (mountains, navigational marks, terminal structures, etc.). When sailing, the ship models moved over the screens in real time scale, so that response times, motions, etc. were correct. The horizon rolled and pitched according to the maneuver-induced motions of the ships.

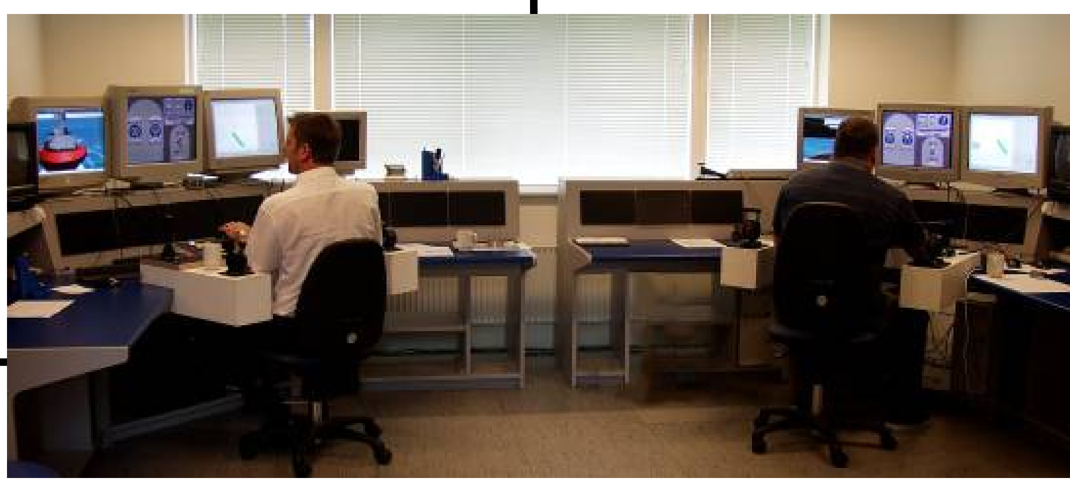
All runs were logged in order to be able to replay second by second what happened during the runs. When each simulator run had been completed, the pilot, the tug captains, client's representatives and the DMI instructor had a debriefing session discussing the aspects of the run, in order to conclude on the simulation.

It was requested to simulate with a fourth tug for the terminal operations. This was done in a simplified manner by using a "vector tug" approach. The vector tug was controlled from the tanker bridge. When the vector tug was used the pilot gave his orders to an assisting tug operator, who fed in the desired thrust and relative heading. The vector tug was a tractor tug of 60 Tons Bollard Pull (TBP) and included features such as speed and heading dependence, and ship-ship interaction from wash effect.

Tug or Tanker bridge, 360º

Tanker Bridge, 120º HFOV and pan function.

Instructor station.



Auxiliary tug Bridges.

Figure 5.1 Conceptual display of full mission tug simulator set-up.

5.1 Full-Bridge tug or Tanker Mock-up

The full-bridge tug or tanker mock-up was installed in the simulator centre (Bridge A) which provided a 360º horizontal view from the wheelhouse.

Depending on the ship type to be simulated the bridge was equipped with the following propulsion controls:

1. Two Aqua-master handles for control of the azimuth propellers on the ASD tugs
2. One set of controls for speed pitch and steering pitch for the VSP tugs
3. Handles controls for speed and rudder on tanker

The set-up for the tankers was:

- Berthing display
- Radar
- Conning Display
- View selection panel
- Handles controls for speed and rudder

The set-up for an ASD or VSP tug is shown in 5.2 the set-up comprises (clockwise from lower left)

- Aqua-Master thrust control handles
- Radar/conning display
- VSP control handles (in front of tug captain)
- Berthing display, see figure 5.3
- Winch control handles

The winch could be controlled either by hand or by a foot pedal. The conning display showed the status of thruster direction for both type of tugs, pitch, engine power and rpm.

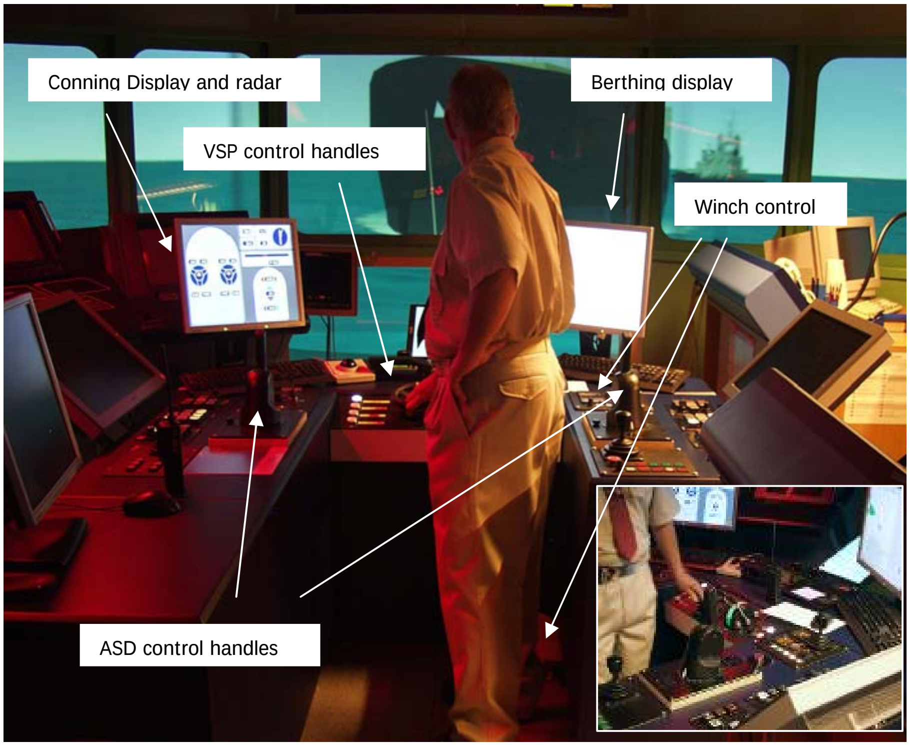


Figure 5.2 ASD and VSP tug bridge layout at Bridge A. Configuration (B and C) Lower right corner shows a close up of the handles for both ASD and VSP tugs.

The berthing display

Figure 5.3 showed an overview of the tanker and tugs' position with zooming and scrolling functions. The grey area to the right displayed details such as:

- speed
- heading
- turn rate
- depth under keel (DUK)
- relative wind speed, and direction
- wave amplitude and direction
- fender force or hawser force
- line length
- angle between tug and LNG Carrier
- heave
- roll
- heel
- constant tension command
- winch speed command

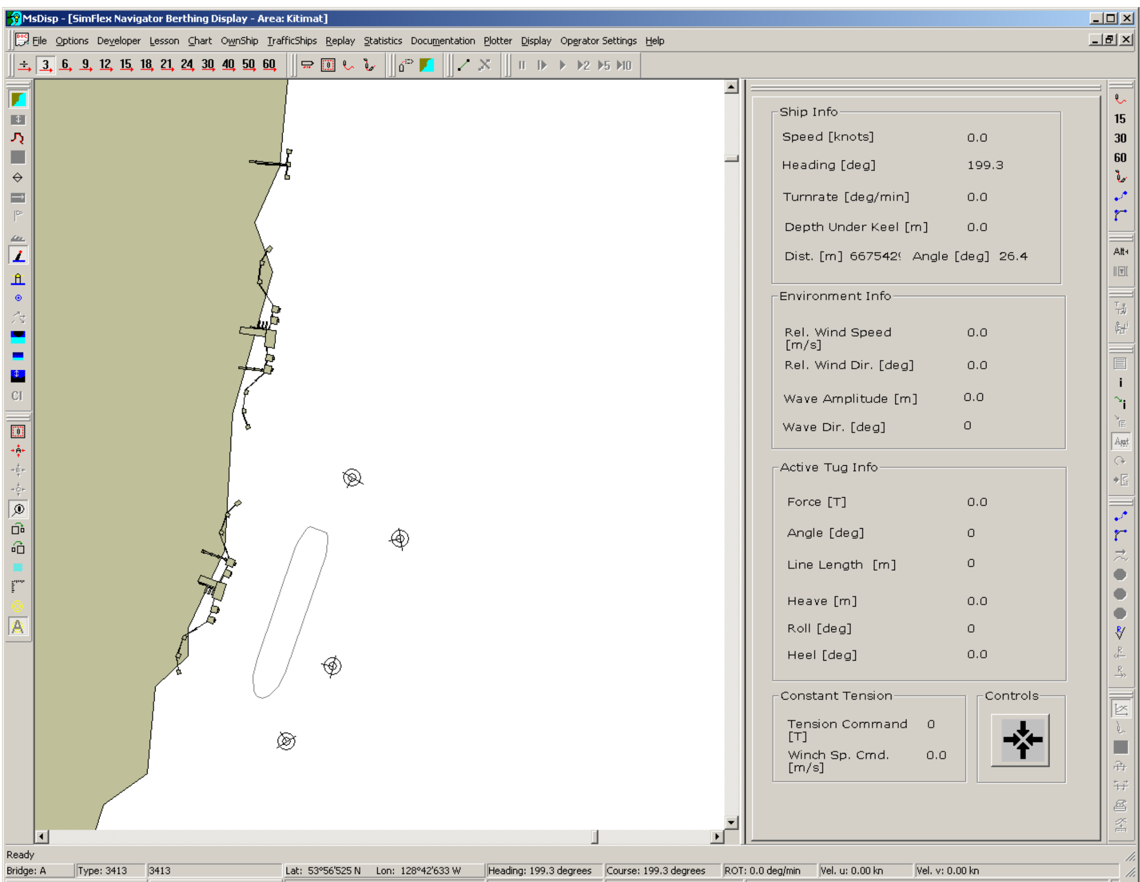


Figure 5.3 Berthing display

5.2 Full-Bridge Tanker Mock-up

The bridge set-up for the tanker using configuration B and C was installed on the simulator bridge (Bridge D), which unlike Bridge A provided a 120º visual range. By means of a view-selection panel the line of sight could be changed (panned) to any direction and the eye-point could be changed from bridge centre to starboard or port bridge wing.

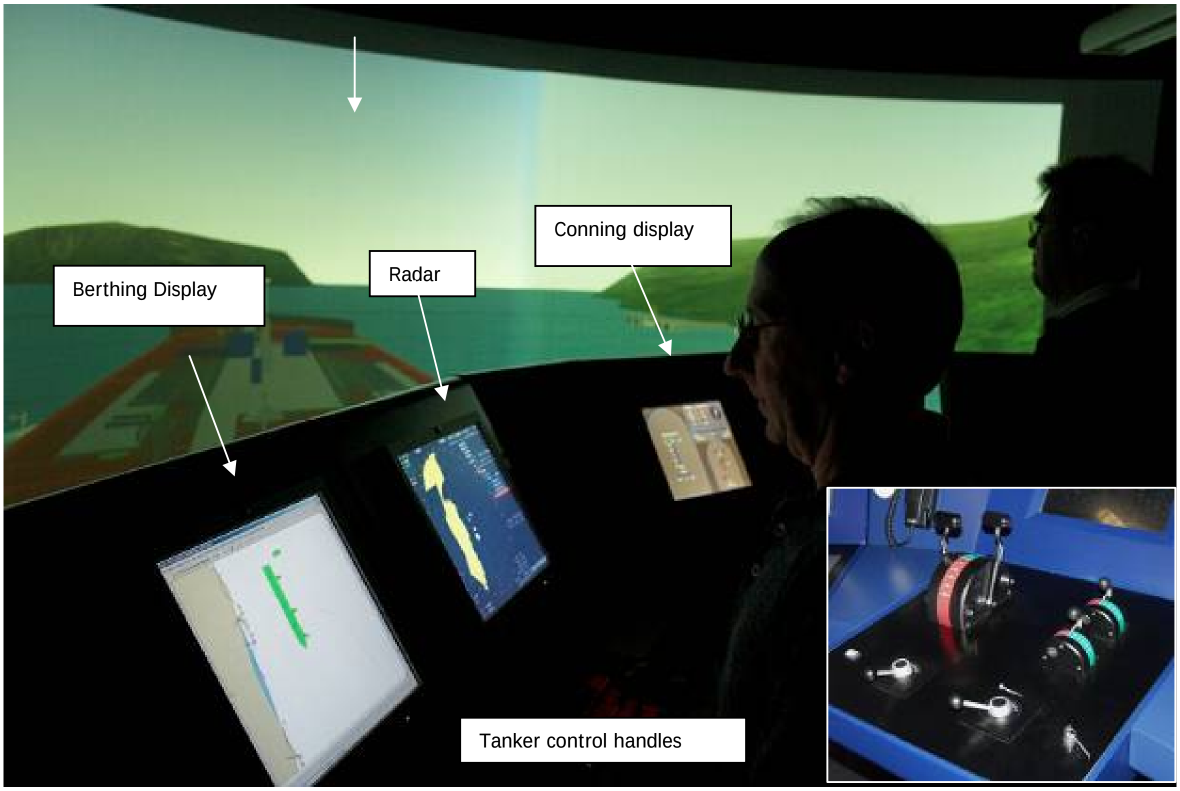


Figure 5.4 the Tanker bridge (Bridge D) i.e. assisted ship. Lower right corner shows close up of the tanker control handles.

The equipment on the tanker bridge (seen from left on figure 5.4):

- Berthing display
- Radar
- Conning Display
- View selection panel
- Handles controls for speed and rudder

A vector tug control panel was installed on a separate PC at the tanker bridge positioned behind the pilot outside his view.

5.3 Tug Cubicles

The bridge set-up for the tug cubicles was characterized by a limited field of view as seen in figure 5.5. By means of a view-selection panel on the top of the screen, the line of sight could be changed to any direction and the eye-point could also be changed. It should be noticed that the limited field of view together with the winch handles, which were only controllable by hand, were the only difference compared to the full-tug bridge. The mathematical models of the tugs were fully interactive and were identical to the ones on the full-tug bridge.

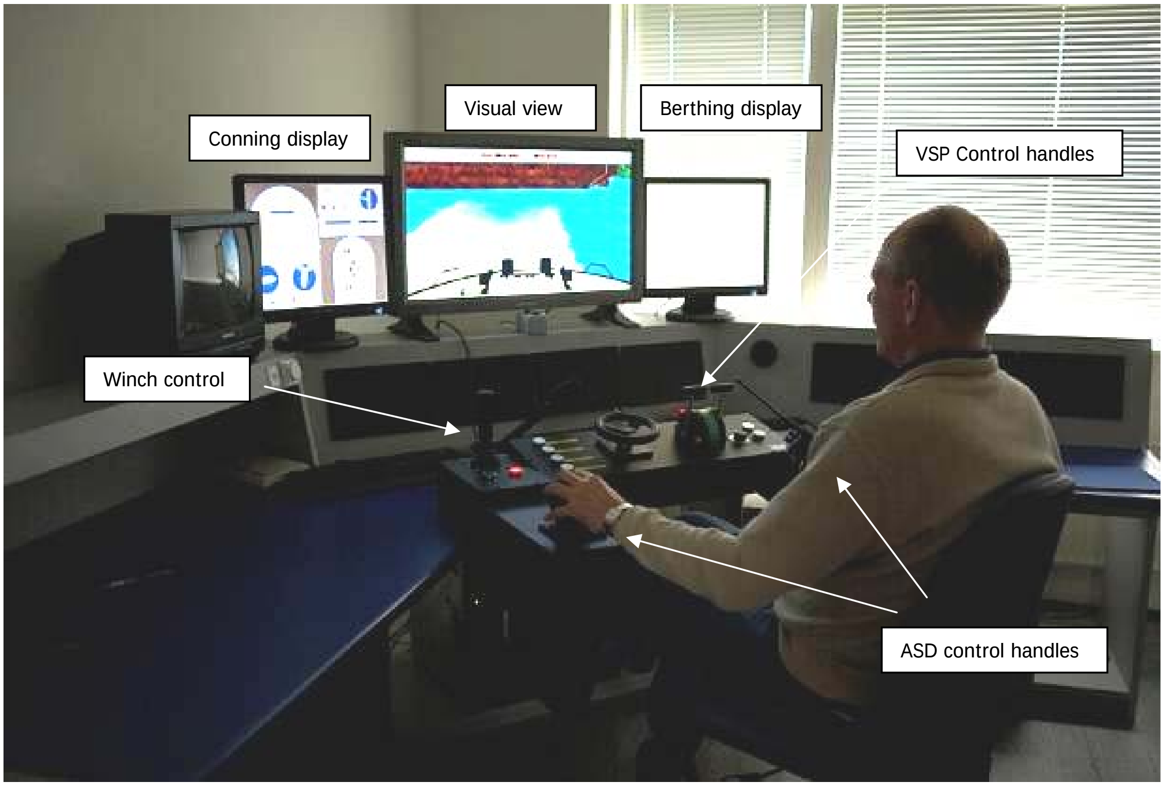


Figure 5.5 Auxiliary tug control cubicles

The tug cubicle set-up consisted of:

- ASD control handles (one handle control on each side of tug captain)
- VSP control handles (in front of tug captain)
- Conning display
- Berthing display see fig. 5.3
- Winch control handles
- Visual display

5.4 Operator's Control Centre

The Simflex Operator's Control Centre, OCC, is the Instructor's interface to the simulator and the place where he supervises and interacts with the simulation.

From the OCC the Instructor is able to control all aspects of a simulation such as start-up, system initialization, configuration of simulator set-up, data recoding, supervision, and interaction with the exercises. The OCC is based on modern man-machine interface design for menus and graphical pages operated by standard mouse and keyboard.

The OCC is furnished with a color display, figure 5.6, and shows a bird's-eye-view representation of all three tugs, the LNG Carrier and the GBS. In addition it contains:

- Position and track of LNG Carrier with identification
- Position and track of all tugs with identification
- Position of vector tugs with identification
- Hawser lines
- Hawser forces
- Fender forces
- Display of water depths

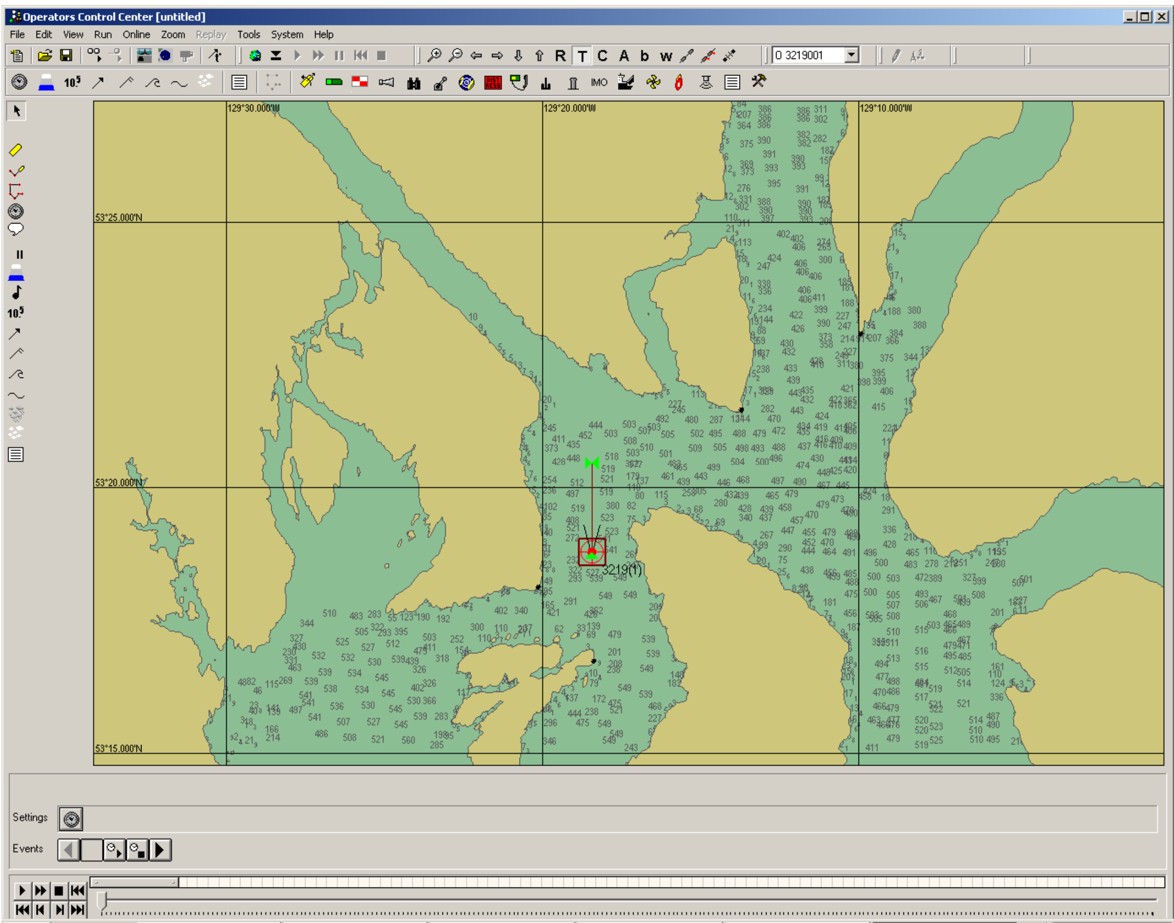


Figure 5.6 OCC display window

5.5 Replay and evaluation

A debriefing facility was established in a debriefing room making it possible to replay and evaluate the simulations by use of the FT replay program.

The debriefing program offered possibilities for simultaneous or individual projection of track plots of the tanker and the tugs together with time histories of a variety of logged variables, and also visual and audio recordings of the pilot and the tug captain’s behavior on the bridges.

Figure 5.7 shows an example of display of track plot and time history.

An executable version of the Replay program has been made available for post-processing of results in the Client’s office.

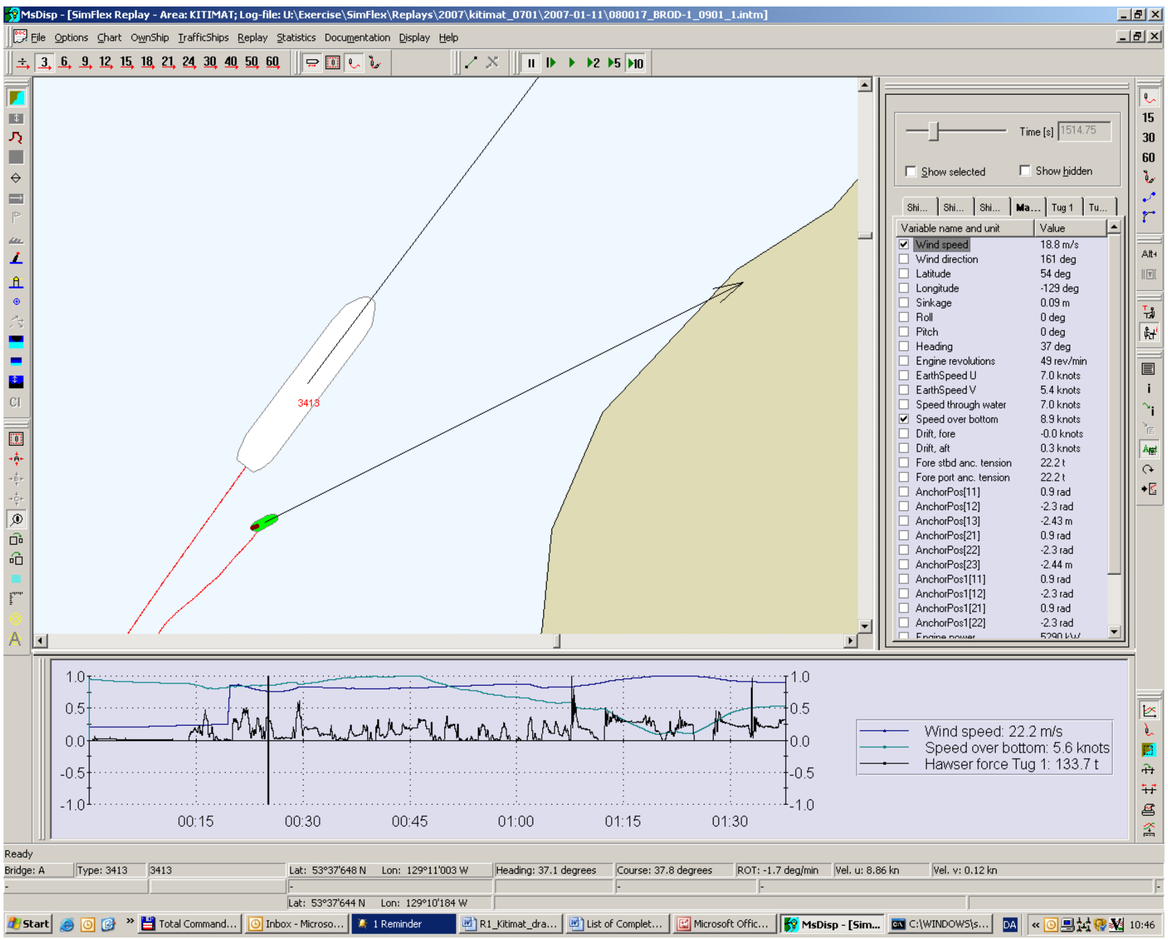


Figure 5.7 Display of track plot and time history

6 Results

The results described below are divided to match the objectives described in Section 2.

6.1 Basis and results of Fast-time simulations

The list of simulated scenarios covers a combination of different ship types in different loading conditions together with varying wind and current conditions. Generally the scenarios have been chosen among those considered to be the most critical scenarios. For example following (F), or Beam (B) wind and current are considered to be more problematic in contrast to opposing (O) current and wind.

Also the fact that, for example, the Aframax ships arrive and depart in both ballast and loaded condition has been considered in the simulation program. This resulted in a total of 12 scenarios each repeated 3 times that represent both prevailing environmental conditions in the Kitimat area and conditions that might be critical for maneuvering. The simulated scenarios are presented in table 6.1 thus covering the following two routes:

Route 1: Arrival from Caamaño Sound to Kitimat Terminal and vice versa for departure
Route 2: Arrival from outside entrance to Principe Channel to Kitimat Terminal and vice versa for departure

Sim no.	Route	Ship	Ship no.	Loading condition	Operation	Current	Wind from
1	1	Aframax	3303	Ballast	Arrival	Flood	SE
2	1	Aframax	3267	Loaded	Arrival	Flood	SE
3	1	Aframax	3267	Loaded	Departure	Ebb	NW
4	1	VLCC	3219	Loaded	Departure	Ebb	NW
5	1	VLCC	3413	Ballast	Arrival	Flood	SE
6	2	Aframax	3303	Ballast	Arrival	Flood	NW
7	2	Aframax	3267	Loaded	Arrival	Flood	NW
8	2	Aframax	3267	Loaded	Departure	Ebb	NW
9	2	VLCC	3219	Loaded	Departure	Ebb	NW
10	2	VLCC	3413	Ballast	Arrival	Flood	NW
11	2	VLCC	3219	Loaded	Departure	Ebb	SE
12	2	VLCC	3413	Ballast	Arrival	Flood	SE

Table 6.1 Simulated Scenarios

The environment in the Kitimat area is rather complex which together with two different and very long routes make it difficult to maintain an overview of the simulated scenarios. In order to provide this overview table 6.2 is given below. The table shows the direction of wind and current in relation to the sailing direction of the ship. It should be noticed that beam wind or current are used for directions that are everything other than but almost either opposing or following.

Sim No.	Caamaño Sound		Squally Channel		Lewis Pass		Wright Sound		Douglas Channel		Principe Channel		Otter Channel	
	Wind	Current	Wind	Current	Wind	Current	Wind	Current	Wind	Current	Wind	Current	Wind	Current
1	B	B	F	F	F	F	O/B	O/B	F	F	-	-	-	-
2	B	B	F	F	F	F	O/B	O/B	F	F	-	-	-	-
3	B	B	F	F	F	F	O/B	F/B	F	F	-	-	-	-
4	B	B	F	F	F	F	O/B	F/B	F	F	-	-	-	-
5	B	B	F	F	F	F	O/B	O/B	F	F	-	-	-	-
6	-	-	-	-	O	F	F/B	O/B	O	F	F	O	B	O
7	-	-	-	-	O	F	F/B	O/B	O	F	F	O	B	O
8	-	-	-	-	F	F	O/B	F/B	F	F	O	O	B	O
9	-	-	-	-	F	F	O/B	F/B	F	F	O	O	B	O
10	-	-	-	-	O	F	F/B	O/B	O	F	F	O	B	O
11	-	-	-	-	O	F	F/B	F/B	O	F	F	O	B	O
12	-	-	-	-	F	F	O/B	O/B	F	F	O	O	B	O

Table 6.2 Overview of wind and current directions relative to the ships sailing direction at different locations along the routes.

* O = Opposing
F = Following
B = Beam

Results of F-T simulations

The fast-time simulation results comprise a huge amount of data for each of the 12 tested scenarios. Three runs have been performed for each scenario giving a total of 36 simulations.

The results of the simulations can be presented and analyzed in different ways to provide an overview and also a more detailed comprehension of the results.

Time series of parameters gives an overview of each simulation for e.g. how much rudder and engine revolutions have been used in each turn and straight passages, drift angles due to current and wind, etc.

In Figure 6.1 a track plot including all 36 simulated tracks is shown together with some close ups of turn D, E, F, 2, 3, 5, 6, 7, 8. Hence, the plots show the tracks of the ships under all tested environmental conditions.

The plots show that the numerical navigator always has been able to maneuver the ships according to the planned route.

However, just as in real life the navigator turned a little late or a little early in some of the simulations, thus over- or undershooting of the turns, resulting in a deviation from the planned track as shown in figure 6.1.

It is concluded that there are sufficient space for maneuvering under the tested environmental conditions and ship speeds.

Finally, it is possible for each of the three runs, to determine statistical values based on the time series of parameters such as ROT, speed, rudder angle, and engine revolutions.

For each of the scenarios statistical values such as mean value, minimum, maximum, and standard deviation have been calculated for speed, use of rudder and engine revolutions. Figure 6.1 shows the results.

Run no.	Ship no.	Current	Wind/ coming from	Rudder mean deg.	Rudder rms *deg.	Max. rudder used in turn	Rev. mean RPM	Rev. rms RPM	SOG mean kn	SOG rms kn	STW mean kn	STW rms kn
1	3303	Flood	SE	-0.12	3.83	5	69	19	8.62	1.18	8.63	2.00
2	3267	Flood	SE	0.01	5.26	2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14	66	17	8.52	1.07	8.54	1.87
3	3267	Ebb	NW	0.50	6.38	2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14	60	14	8.62	0.92	7.84	1.48
4	3219	Ebb	NW	-1.33	9.48	2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14	51	13	8.70	0.67	7.89	1.53
5	3413	Flood	SE	-0.14	6.91	2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14	51	12	8.77	1.23	8.81	1.90
6	3303	Flood	NW	-0.62	2.38	6, 10	78	13	8.73	1.19	9.36	2.42
7	3267	Flood	NW	-0.88	3.80	D, E, 6, 7, 8, 10, 11,12, 13, 14	73	13	8.69	1.24	9.30	2.46
8	3267	Ebb	NW	-0.77	4.72	E, F, 6, 7, 8, 10, 11, 12, 13, 14	68	16	8.41	0.70	8.96	1.81
9	3219	Ebb	NW	-1.79	8.03	D, E, F, 6, 7, 8, 10, 11, 12, 13, 14	56	14	8.29	0.50	8.80	1.85
10	3413	Flood	NW	-0.98	5.62	D, F, 6, 7, 8, 10, 11, 12, 13, 14	54	7	8.56	1.26	9.16	2.51
11	3219	Ebb	SE	-2.40	7.57	A, D, E, F, 6, 7, 8, 10, 11, 12, 13, 14	52	9	8.67	1.11	8.06	0.75
12	3413	Flood	SE	-0.57	5.87	D, F, 6, 7, 8, 10, 11, 12, 13, 14	55	14	8.40	1.02	9.07	2.15

Table 6.3 Statistical results from fast-time simulations

* rms = root mean square

For the speed, generally the ships have no problems with keeping the desired speed of around 8 to 10 knots. With opposing wind and current along the routes the mean speed is generally higher than for the simulations with following wind and current. Run 1 with following wind and current along the whole route and run 6 with opposing wind in the Douglas Channel and Lewis Pass and opposing current in Principe channel can be used as an example, where it can be found that the mean speed for run 1 is higher than the mean speed for run 6. This is due to the fact that the numerical navigator priorities keeping the ship as close to the desired route as possible over the speed. With a following current or wind, the amount of water flowing to the propeller is less and thereby the maneuverability of the ship is lower.

When studying the time series of the rudder activity the general picture is that the numerical navigator, when reaching the turning way point, the turn is initiated by putting the rudder more or less hard over and quickly after reduced again. When the turning has been completed a counter rudder is given to reduce the turn rate. Thereafter, being on the straight passage before the next turning point the navigator adjusts slightly on the rudder in order to cope with the change of relative directions of wind and current. Even so, that full rudder has been used in many of the turns for some of the simulations it is only for a short period of time in order to initiate the turn and there is generally a reserve in the engine to i.e. give kick ahead in the case the turn rate drops too fast during the turns.

The statistical values for the rudder activity show as expected that the VLCC generally has to use more rudder (higher rms value for comparable runs such as run 4 and run 9) than the Aframax ships. This is due to the VLCC's being more affected by wind and current due to their larger wind area and wetted surface, and relatively smaller rudder.

Regarding use of engine Table 6.3 shows that the engine revolutions are higher in simulations with opposing wind or current on long passages of i.e. Principe Channel or Douglas Channel (i.e. run 6 and 7). This is only natural as the ships have to work against the opposing wind or current. Generally, the mean value of the revolutions is 60 – 67% of the maximum revolutions for the VLCC and 53 – 69 % for the Aframax. So a careful conclusion is that based on these values for the entire routes there is a reserve in the engine for i.e. kick ahead's to correct for minor errors or unforeseen situations.

However the values give in Table 6.3 gives an indication of the different scenarios for route bends.

It is evident that more engine revolutions and rudder angle are required in the turns and significantly less on the straight passages.

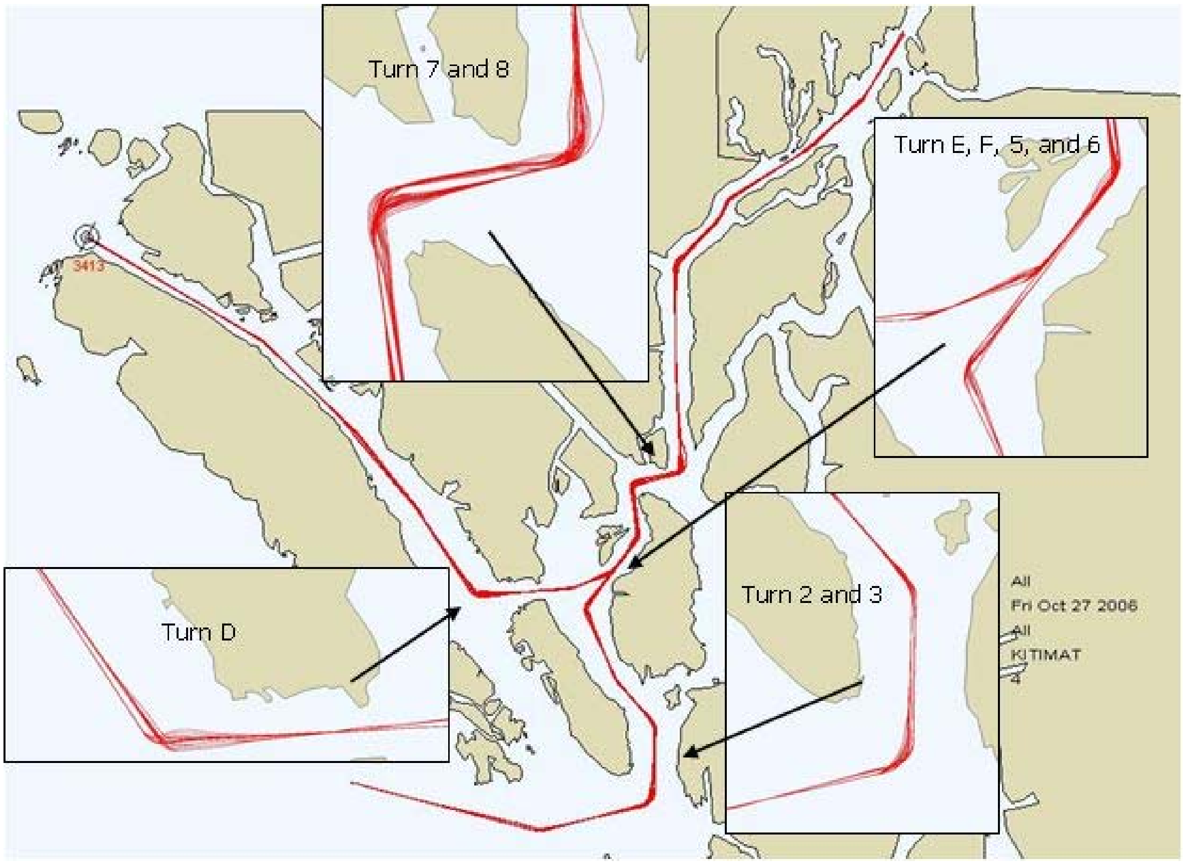


Figure 6.1 Track plots of all runs and for selected turns

6.2 Results from Real time simulations in 2007, 2008 and 2009

The results are based on the completed simulations and discussions with the pilot, tug captains, Enbridge representative and FORCE instructor and hence, apply only for different vessel ranging from 110.000 Dwt to 340.000 Dwt tested environmental conditions.

The simulated wind, current and wave environment consisted of conditions considered as the upper limit for maneuvering in inland waters and at the terminal area.

For open water simulations e.g. out side Caamaño sound wave heights of 4 to 5 m were used for emergency situations as this was considered maximum for the escort tug to handle when towing a tanker with engine stop clear of the coast line. This was combined with 2.5 knots of current and 40 to 50 knots of wind.

6.2.1 Entering the Kitimat area from open waters

6.2.1.1 General comment

- The majority of the route is in wide relatively straight channels.
- All routes including bends can be safely navigated without use of tugs.
- Tugs are recommended for low probability emergency scenarios.
- Meeting and crossing traffic at important sections e.g. higher density areas have been tested and can be safely navigated.

Douglas Channel and the Kitimat area can be accessed from open sea via three alternative routes:

- A northern approach via Principe Channel
- A southern approach via Caamaño Sound
- A southern approach via Browning Entrance

The southern approach via Browning Entrance was not modeled at this time since the outer section is in open water.

Northern Approach via Principe Channel and Otter Channel

The Principe Channel approach can be accessed either via Dixon Entrance north of Haida Gwaii or from the south via Hecate Strait. The Principe Channel approach can be sailed under the design ship's own power and steering in all weather conditions tested (up to 50 knots of wind) and by all three ship types tested, including the largest VLCC up to 340,000 DWT.

The Principe Channel approach is considered the "all-weather-safe-approach". The channel provides excellent protection from westerly winds and the swell from the Pacific Ocean. The smallest width in the Channel is 0.78 nm (1.43 km) which provides adequate room for maneuvering a VLCC tanker in relatively deep natural water depths. The channel width in this and other channels along the route is well over a nautical mile and in some locations 3 to 4 nm wide.

Navigation of the full length of the channel routes (from Browning Entrance or Caamaño Sound to Kitimat terminal) was completed in the fast-time simulation model, and areas of more challenging navigation were selected for simulation on the FMBS.

6.2.1.2 Entering via Caamaño Sound

The advantage of this approach is that it is the shortest and therefore the fastest way into Kitimat. The disadvantage is that the approach is poorly protected from winds and swells from the West. Therefore this approach will only be used during fair to moderate weather conditions. No fixed weather limit was established in this study. In a previous simulation study in 2006/2007 winds up to 40 knots were handled with no problems.

However, the concern with the Caamaño approach in heavy weather (wind above 40 knots) is that if an emergency occurs, it might be difficult for the escort tug to hold the vessel or even tow it out to sea because of the heavy swell that can occur.

6.2.1.3 Entering via Laredo Channel

The Southern approach through the Laredo Sound and Channel were tested for the first time in this study. According to the pilots this alternative approach is only suitable for smaller tankers.

During the busy summer season where many large cruise ships uses this route it is not considered as a usable approach.

6.2.2 Passing of two tankers

One objective of the simulations was to determine the viability of two large ships, e.g. tankers, LNG carriers or other ships, passing one another at the following 5 locations:

1. From berth to passage of Clio Pt. This area should be considered as terminal manoeuvring area rather than a one-way route area. See figure 6.2
2. From abeam Kersey Pt (Maitland Il) to abeam Paisly Pt. See figure 6.3
3. From abeam Turtle Pt (Gil Is) to passage of Keld Pt (Fin Il). See figure 6.4
4. From abeam Fanny Pt through Otter Channel until abeam Fleishman Pt. See figure 6.5
5. From abeam Wheeler Is. to abeam Bush Il (SW of Dixon Is.) See figure 6.6

Referring to TERMPOL guidelines and other ship channel design guidelines such as the PIANC (Permanent International Association of Navigation Congresses), providing guidance for sustainable waterborne transport infrastructure for ports and waterways. The minimum available channel width throughout the five above mentioned locations exceeds these guidelines' recommendations for a two way ship channel.

TERMPOL and PIANC recommend a minimum two way channel width of 7 times the design ship beam. In the entire area from open sea to the terminal area there is well over 20 x ship beam. See section 11 for link and reference.

While it is considered feasible to have ships pass in these locations, the Pilot evaluations noted that this would subject navigation to increased risk, and in normal practice, ships will pass in sections of the channel where the channel alignment is straight and has a wider cross section than those noted above.

Two ships meeting near location 1) close to the Kitimat Marine Terminal is not problematic as there is a large channel width that can accommodate ships arriving or departing from other terminals in the Port of Kitimat at the same time as a tanker is berthing/un-berthing at the Kitimat Marine Terminal.

One of the scopes of the simulations was to determine the safety level when two large ships e.g. tankers meet another at the following 5 locations:

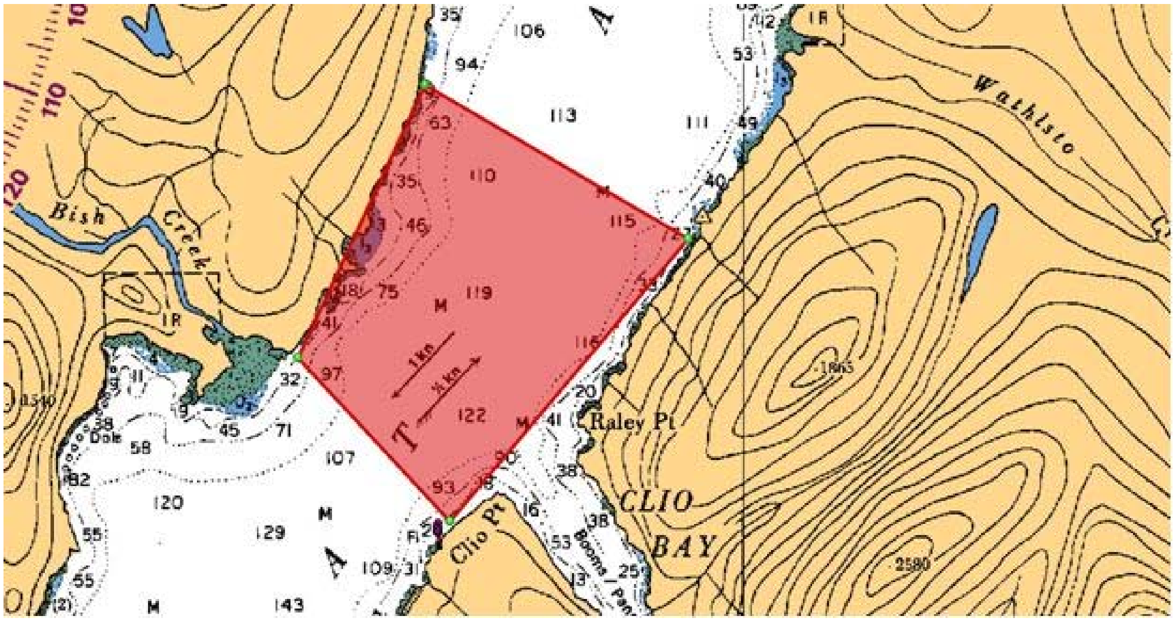


Figure 6.2 Maneuvering area at the Terminal Site

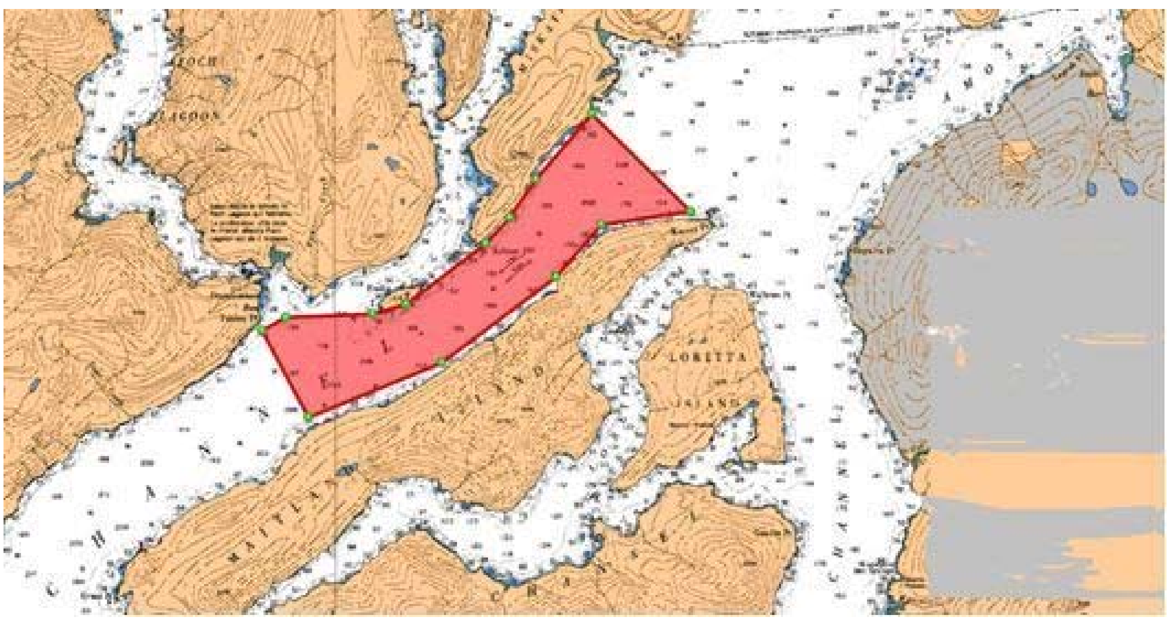


Figure 6.3 Traffic area in Douglas Channel

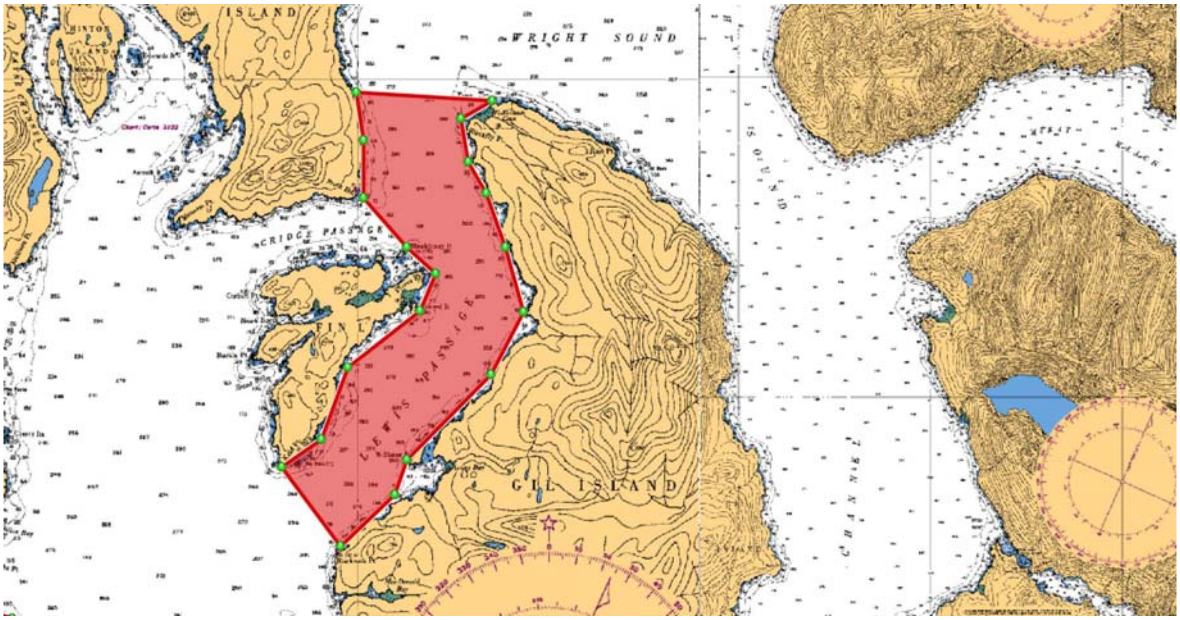


Figure 6.4 Traffic area at Lewis Passage

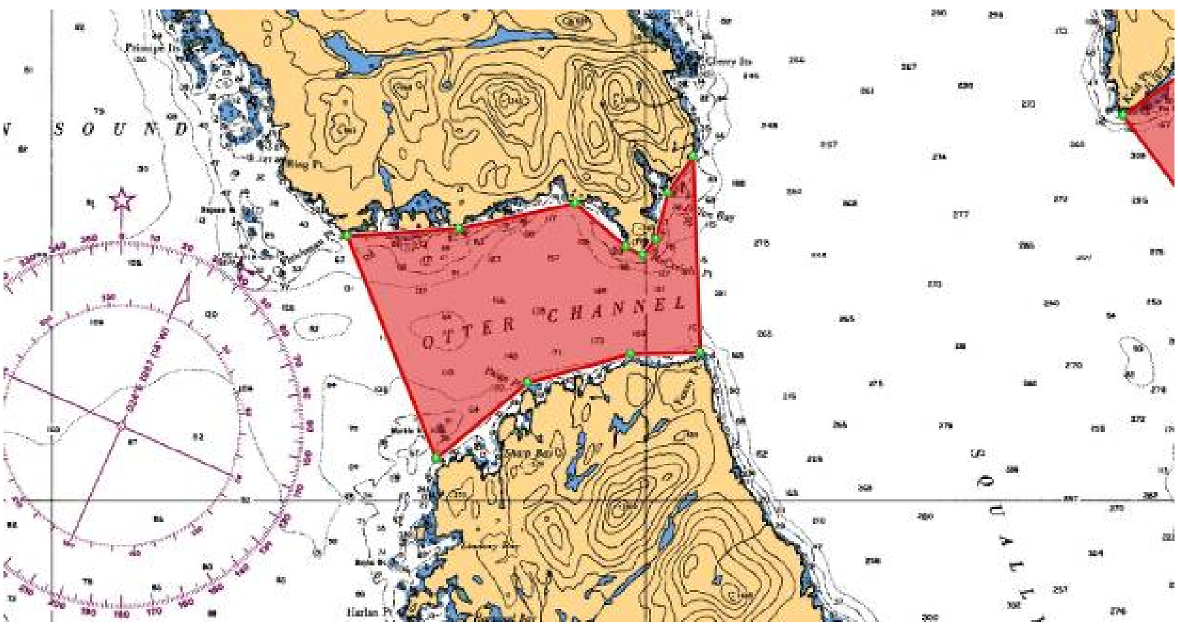


Figure 6.5 Traffic area at Otter Channel

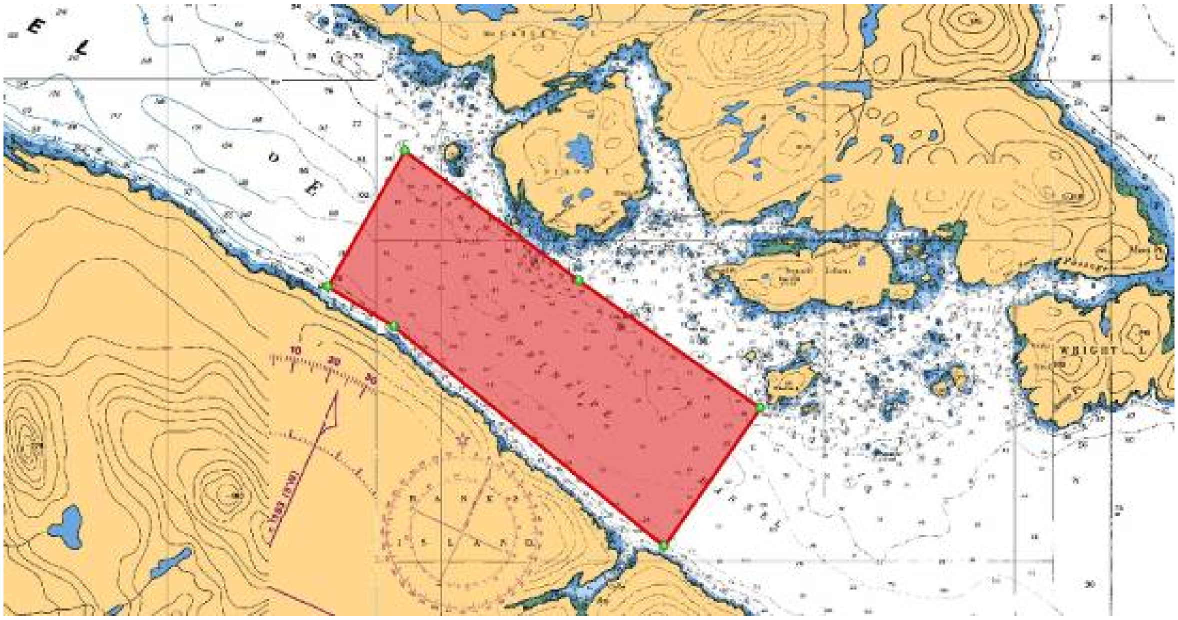


Figure 6.6 Traffic area in Principe Channel

6.2.3 Meeting ships

One of the scopes of the simulations was to determine the safety level when two large ships e.g. tankers meet each other at the same locations.

During the discussions with the pilots a general point was made: It should be avoided to meet with two large ships at location 2), 3), 4), and 5) in general and in particular during severe (wind 30 knots or above) weather conditions.

The reason for this is that the margins for safe navigation are limited in case of an emergency situation where the engine is lost or the rudder is locked at an angle different from "mid ship". However, according to the pilots these meeting situations can easily be avoided through:

1) Proper planning
2) Use of a VTS service in the area
3) Use of AIS data of other ships movement

Therefore it is safe to navigate the design ships through these areas.

One should keep in mind that at present it has been discovered that coverage of VHF communication and AIS data are limited in some areas from open sea to Kitimat due to "blind spots". Repeater stations should be installed at strategic locations to solve this problem.

6.3 Results from arrest simulations

The outcome from the arrest simulations was to check the stopping distance with and without use of escort tug.

The results presented in table 6.4 and 6.5 show stopping distances for 3 sizes of tankers (approx. 110,000 dwt, 200,000 dwt and 300,000 dwt) in ballast and full loaded condition and with two different sizes of escort tugs (100t BP and 125 t BP).

For each ship the stopping distance has been recorded for 1) stop with ship engine only 2) tug only and 3) ship engine and tug together.

6.3.1 Arrest with a 100 t BP VSP escort tug

The stop distance (in meters) is set at 100% for arresting with ship engine only.

Speed 8 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	858	822	548
Suezmax ballast	724	580	398
Aframax ballast	580	386	305
VLCC loaded	2509	1786	948
Suezmax loaded	1262	1338	747
Aframax loaded	1106	690	445
In percentage	Approx 100%	Approx 75%	Approx 50%

Speed 12 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	3648	1556	1178
Suezmax ballast	1462	1184	893
Aframax ballast	1597	586	446
VLCC loaded	3988	3674	2099
Suezmax loaded	3478	2442	1626
Aframax loaded	2727	1247	1027
In percentage	Approx 100%	Approx 80%	Approx 60%

Table 6.4 Stop distances in meters of 3 tanker types in ballast and loaded condition with an initial speed of 8 knots or 12 knots using ship engine only, tug only and both ship engine and tug. The tug had a bollard pull of 100 t.

6.3.2 Arrest with a 125 t BP VSP escort tug

The stop distance (in meters) is set at 100% for arresting with ship engine only.

Speed 8 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	858	689	455
Suezmax ballast	724	568	349
Aframax ballast	580	295	291
VLCC loaded	2509	1235	924
Suezmax loaded	1262	1273	719
Aframax loaded	1106	520	443
In percentage	Approx 100%	Approx 75%	Approx 50%

Speed 12 knots	Ship engine only	Tug only	Ship and tug together
VLCC ballast	3648	1441	1178
Suezmax ballast	1462	1034	893
Aframax ballast	1597	524	446
VLCC loaded	3988	3199	2099
Suezmax loaded	3478	2311	1626
Aframax loaded	2727	1163	1027
In percentage	Approx 100%	Approx 80%	Approx 60%

Table 6.5 Stop distances in meters of 3 tanker types in ballast and loaded condition with an initial speed of 8 knots or 12 knots using ship engine only, tug only and both ship engine and tug. The tug had a bollard pull of 125 t.

Two Voith Schneider tug (VSP) models were used for escorting the tanker and assisting the stop maneuvers:

- Enhanced VSP tug of 125 t BP (Bollard Pull) and about 230 t steering pull
- VSP tug of 100 t BP (Bollard Pull) and about 180 t steering pull

Note that 230 t steering pull exceeds current tow (strong) point capability and Cycloidal (VSP) tug capacity.

A total of 144 runs were performed. All 72 combinations were repeated twice. The results in meters are presented in tables 6.8 and 6.9 are averages of the two runs for each combination.

6.3.3 Comparison of arrest with ship engine and tug

Stopping with tug only shows that the time and stopping distance for the tanker and escort tug is reduced from about 100% to 75% compared to stopping with the vessel's own engine only.

Stopping with the tug is more effective because the reversing power starts immediately independent of the tanker's speed.

When a tanker shops using only it's own engine the stopping distance is dependent on the speed where the engine can be reversed.

Tug design and crew education and training are also factors that have to be taken into consideration.

The test results shown in tables 6.4 and 6.5 were achieved in an ideal situation with experienced tug captains.

6.4 Environment limits for safe navigation

All three tanker classes were successfully tested under their own power and steering, inbound and outbound, in straight sections and in channel bends and in wind speeds of 50 knots from the prevailing direction NW, W, SW and SE. In some cases wind speeds of 60 knots were tested. These conditions were modeled together with the current and wave conditions described below.

In general, the Pilots could handle the ships in 50 knots of wind. However, they felt a safe upper limit of operation would be when the wind speed did not exceed 40 knots. Pilots will base their decisions for arrival or departure at the Kitimat Marine Terminal on long-term weather forecasts and real-time weather monitoring and will wait until the wind speeds are at safe level both for transit and berthing maneuvers.

Tankers travelling in currents of up to 2.5 knots together with the wind conditions described above were found to be maneuverable. Currents in the areas studied are normally less than 2.5 knots with the majority of currents running parallel to the path of the tanker and therefore of minor concern.

Tugs were found to be able to handle the design tankers in waves of up to 4 meters significant height (Hs) outside Caamaño Sound together with the wind and current described above. Pilots would avoid transit of Caamaño Sound with wave and swell conditions of more than 4 meter.

Waves in the confined channel areas were simulated to a maximum of 2 meters (Hs). Waves of this magnitude were not found to be challenging to the navigation of the tankers or tugs.

At the terminal, 1 to 1.5 meter waves are considered maximum. These waves are generated by the wind, have a short wavelength and therefore do not pose a challenge to the navigation of tankers or tugs.

6.5 Berthing and un-berthing at the terminal

During all 3 real-time simulation sessions, several berthing and un-berthing maneuvers were performed in different weather conditions with starboard and port side alongside.

Un-berthing

Departure from the oil terminal can be achieved safely in wind speeds of up to 40 knots from different directions, however, the Pilots would in such cases consider waiting until the wind has dropped to 30 knots.

The proposed procedure for un-berthing is to let the tugs pull the tanker parallel off the berth if the ship was berthed head to the sea. As soon as the tanker is 2-3 ship beams off the berth, the Pilot will order ahead on the engine. After the tanker has picked up speed and is heading away from the shore, the forward tug (tug no. 1) and second tug (tug no. 2) on the ship side will be disconnected.

If the ship was berthed port side to the shore the tugs will turn the ship once it is clear of the berth structures.

The escort tug aft (tug no. 3) is connected at all times and will escort the loaded tanker all the way to open sea.

Berthing

The arrival maneuver will normally be done with the ship stemming the wind and current as it gives the Pilot the best control of the tanker.

In inflow winds, the strategy is to sail the tanker just north of the terminal, make a turn well off shore and slowly maneuver the tanker back towards the berth.

The tanker will be assisted by at least one escort tug and two tugs of approx. 50 t BP. This has shown to be sufficient and provides good safety margins with about 50% spare power capacity on the tugs.

In outflow winds, the berthing maneuver will be to navigate the tanker directly to the berth and at about 1 to 2 ship beams off the berth and parallel to it. Tugs will then push the tanker towards the berth.

Berthing was done safely in wind speeds of up to 40 knots, but it is anticipated that wind speed limits for berthing will be set below this value

6.6 Emergency maneuvers

Different emergency maneuvers were performed to test the capabilities of the escort tugs. The emergency situations included “black-outs” where the tankers lost all electrical and propulsion power and were therefore unable to steer.

Another type of emergency simulated included a situation where the rudder was locked at an angle due to a steering engine failure that could be caused by a hydraulic or an electrical malfunction.

In both the above emergency situations, the Pilot on the tanker ordered the escort tug to take over control of steering and speed. The time span from the start of the malfunction to the time where the tug was in position to assist was 1 to 2 minutes.
The emergency maneuvers were all completed successfully. There was no instance of ship grounding, and the closest point of approach (to shore) was in the order of 250 meters.

6.7 Size of escort tugs

The tug size is dependent on the size of the tanker as can be seen in figure 3.1 of the IMO guidelines as follows:

- Tanker of 100,000 dwt, required steering pull of 50 t to 75 t
- Tanker of 200,000 dwt, required steering pull of 80 t to 120 t
- Tanker of 300,000 dwt, required steering pull of 110 t to 140 t

These steering pull ranges (at 10 knots) are guideline recommendations only. Each case has to be evaluated separately. For the Kitimat operation preliminary assessments shows that the needed steering pull may be 25% to 50% higher than the IMO guidelines. These criteria will be confirmed in final design of the tugs.

It should be noted that VLCC fitted with strong points today would normally have a max SWL (Safe Weight Load) of 200 t and a breaking load of 400 t. These strong points might just be a bit under sized if applied with a constant pull of 230 t. During the simulations it was recorded that peak loads of about 300 t could occur.

Primarily two types of tug boats appropriate for escort towing are known in the art, one of them being called a tractor tug boat in which the towing winch is positioned on the aft deck and in which the propeller means have been disposed on the front side to the towing winch, closer to the bow of the vessel.

The other type is the stern drive tug boat in which the towing winch is placed on the fore deck and in which the propeller means have been arranged in the stern of the vessel.

Looking into what already have been done by some class societies and IMO it has been be found that the escort tug size in different terminals and ports in 2009 were as follows.

Existing escort tugs for escort towing with maximum bollard pull and maximum steering pull are as follows May 2010:

AREA / TERMINAL	TBP	EST. STEERING PULL	TUG NAME	Estimated size of tanker, DWT
Valdez, Alaska	100	160	Alert, ASD	300.000
Valdez, Alaska	100	170	Nanuq, VSP	300.000
San Francisco Bay, USA	55	75	Protector, VSP	230.000
Placentia Bay, Newfoundland	57	91	Placentia Hope	120,000
Southampton, UK	90	144	Thorax	245.000
Milford Haven, UK	110	176	Svitzer Lindsway	350.000
Mongstad, Norway	95	157	Baut	320.000
Hammerfest, Norway	67	148	Boxer	320.000
Sture, Norway	67	107	Apex	300.000
Sullom Voe, Shetland	55	88	Tystie	320.000
Stenungsund, Sweden	82	131	Svitzer Ran	65.000
Gothenburg, Sweden	57	91	Boss	65.000
Brofjorden, Sweden	82	131	Svitzer Oden	500.000

Table 6.6 shows estimated indirect steering pull for escort tugs at 10 knots in some existing terminals

Tug steering pull certificates obtained by the class society are dependent on fin (skeg) layout and how much indirect power obtained during sea trials, connected to a tanker or other type of vessel.

Due to little information from tug owners about the steering pull, the steering pull in table 6.6 is estimated by multiplying the bollard pull by 1.8 to 2.4 in case of a VSP tug and 1.6 to 1.8 in case of an ASD tug.

Today many oil and LNG terminals are building escort tugs and planning to implement escort towing for large tankers.

The speed of a vessel required to have escort tug shall not exceed the escort operating speed of the escort tug. (Abt.10 knots). Service speed is 13 to 15 knots free running.

The speed of the assisted vessel shall be such that the escort can reasonably be expected to bring the vessel under control within the navigational limits of the waterway.

This speed shall take into consideration ambient sea and weather conditions, maneuvering and other characteristics of the vessel, surrounding vessel traffic, hazards, and other factors reducing maneuvering room.

6.8 Conclusions reached following completion of Real time simulations

The following represent conclusions that all of the participants supported at the completion of the Real time simulations.

- Vessels up to VLCC size as tested in the present study can safely transit the inland waters to and from the terminal and under the tested environmental conditions.

- An escort tug of the tested size and type (125 t BP VSP tug) is recommended by the pilots for the transits in inland waters. Optimization of tug design and power were not included in this project and would have to be investigated in a future tug simulation study using fully modeled tug models as in this project.

- The pilots were able to safely recover from all the tested emergency scenarios by use of the 125 t BP VSP tug.

- The limiting wind speed for all three ship sizes (Aframax, Suezmax, and VLCC) is 50 knots from the prevailing wind directions NW and SE.

- The limiting current speed for ebb and flood conditions is 3 knots.

- To confirm the safest approach to the berth in different wind directions and current direction additional terminal simulation is required.

- The selected position for Point Of No Return (P.O.N.R. – a position before which a decision to proceed is made) for Caamaño Sound was determined as a distance of 8 nm from Jacinto light at the S side of Dewdney Island, with a clearance of 3 nm to Cran shoals. The P.O.N.R. is reached after approximate 9 nm sailing with pilot onboard giving the bridge team and the pilot enough time to make the decision to abort or continue through Caamaño Sound. An important factor to consider is that it is recommended that the escort tug must be connected before passing P.O.N.R. which implies maximum wave height of 3.0 meter. See Figure 6.2. If it is decided to abort the entrance via Caamaño Sound, the alternative route is to turn north and do the approach through Browning entrance down into Principe Channel.

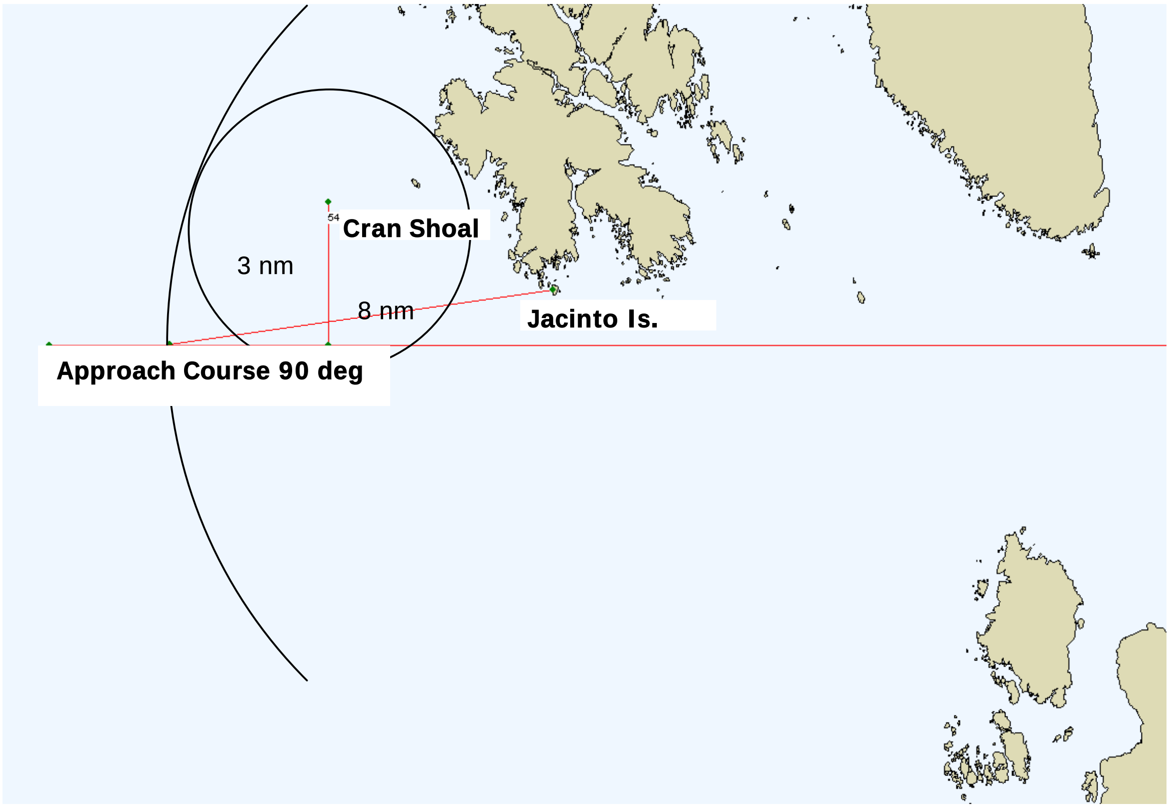


Figure 6.7 Definition of Point Of No Return (P.O.N.R.)

- A number of additional lights and Racon are recommended to be implemented or changed in the inland waters. See also section 8 for additional marking. It is important that the pilots are involved in the final decision process of selection and positioning of these additional navigation aids.

- It is recommended that the entire area is investigated in order to discover DGPS shadow areas and act accordingly to establish full DGPS cover

- In the situation of rudder failure, an escort tug will act as the escorted vessels rudder. During such operations the escort tug use the principle of opposing rudders by i.e. positioning the escort tug approximately 85 degrees on the escorted vessels port quarter and thereby turning the escorted vessels forward bow to starboard. When the pilot orders "steady" the escort tug will maintain power on the towline and with the same speed as a normal rudder reposition himself at the escorted tanker's starboard quarter and thereby slow down the escorted vessel's ROT to starboard until the escorted vessel is on a steady course. Then, the pilot will order the escort tug to stop and proceed to a position right astern and be standby for new rudder manoeuvres. Should the escorted vessel experience engine failure the pilot will order the escort tug to reduce the headway speed until it can be taken in tow. During the escort tug operations it is only possible for one tug to assist, simply because there is no room for more than one tug. When the escorted vessel's speed is reduced to less than approximately 5 knots the escort tug will only work as a normal harbour tug and can effectively be assisted by more tugs.

- One-way traffic areas are recommended for the following areas:
    - From berth to passage of Clio Pt. This area should be considered a terminal maneuvering area more than a one way route area. See Figure 6.2.
    - From abeam Kersey Pt (Maitland Il) to abeam Paisly Pt. See Figure 6.3.
    - From abeam Turtle Pt (Gil Is) to passage of Keld Pt (Fin Il). See Figure 6.4.
    - From abeam Fanny Pt through Otter Channel until abeam Fleishman Pt. See Figure 6.5.
    - From abeam Wheeler Is. to abeam Bush Il (SW of Dixon Is.) See Figure 6.6.
- Vessel holding areas are recommended for the following positions:
    - South of Alexander Is (S Campania Il) and Dunkers Pt (SW Princess Royal Il) and Wall Is (N of Rennison Il)
    - Between Nepean Sound and Estevan Sound
    - NW of Anger Is, at Anger anchorage.
    - N/NW of Banks Is before entering Principe Channel

7 Tankers' maneuvering performance

One basis for the simulations was to test the maneuvering capabilities of the tankers and tug boats.

A ship's maneuverability is evaluated from trial test results. There are 4 main characteristics that are of particular interest for this study. These are:

- Steering ability – shown by a zigzag test
- Turning ability
- Sensitivity to wind
- Stopping ability (by own power)

7.1 Steering ability

A ship's steering ability depends on the loading condition, hull shape, engine power, the propeller and the rudder. During the ship's sea trial, the steering ability is measured by performing a zigzag test. The test is typically performed at the ship's service speed abt. 15 knots which are a little lower than its maximum speed, but higher than the 8 to 12 knots transit of the channels.

Figure 6.1 shows a 10-10 zigzag test for the three tankers involved in this study. The plots include the test for both loaded and ballasted condition.

The test is performed by commanding the rudder 10 deg. to port. When the ship has changed its course 10 deg. from its initial course, the rudder is commanded 10 deg. to starboard. When the ship has changed its course 10 deg. to starboard from its original course, the rudder is again commanded 10 deg. to port. The test typically continues until the ship had done two zigzags.

The test reveals if the ship is course stable or unstable. For tankers, it is normal that the ship is somewhat course unstable.

For the 3 tankers used in this study, the steering ability can be summarized as follows:

340, 000 dwt VLCC:

Ship 3219, loaded condition: The steering ability is slightly below average. It is somewhat course unstable, but normally not difficult to control.

Ship 3413, ballast condition: The steering ability is course stable.

200,000 dwt tanker:

Ship 3017, loaded condition: The steering ability is about average. It is rather course unstable, but normally not difficult to control.

Ship 3414, ballast condition: The steering ability is course stable. It is marginally course stable and not difficult to control.

110,000 dwt tanker:

Ship 3267, loaded condition: The steering ability is about average. It is somewhat course unstable, but normally not difficult to control.

Ship 3303, ballast condition: The steering ability is course stable. It's is marginally course stable and not difficult to control.

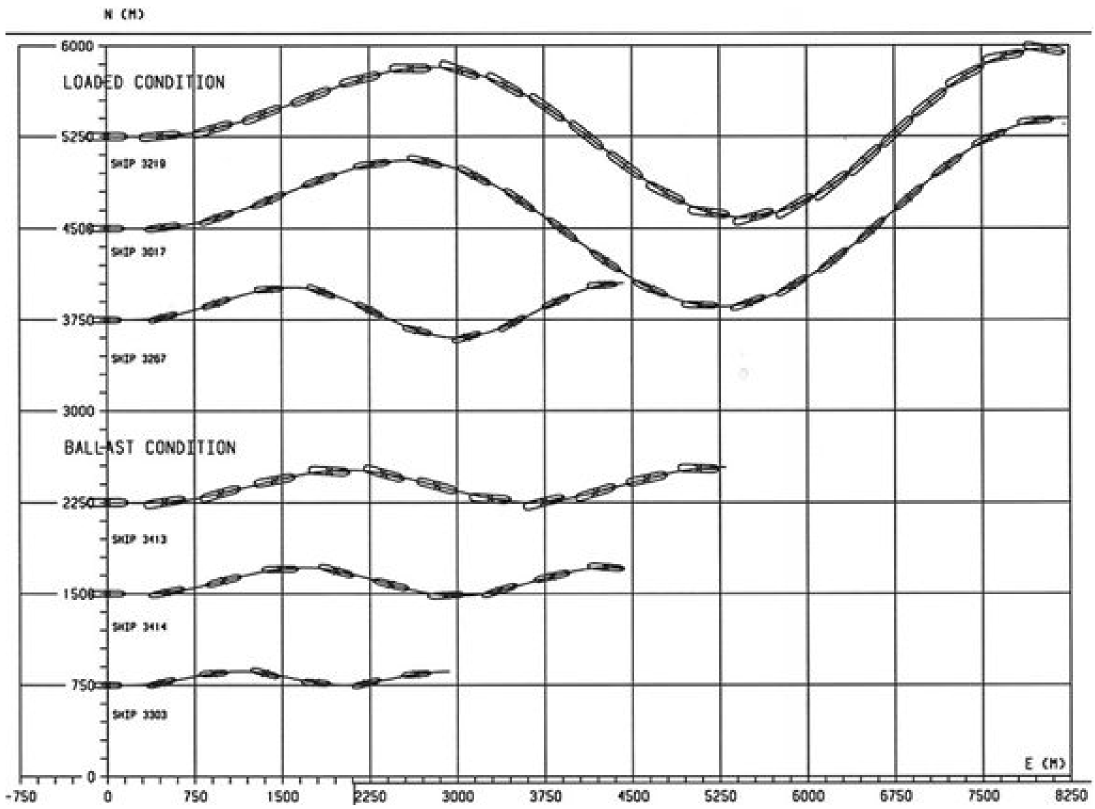


Figure 7.1 Comparison of tankers' steering ability in loaded and ballasted condition. The plot shows the so called 10-10 zigzag test.

7.2 Turning ability

A ship's turning ability also depends on the loading condition, hull shape, engine power, the propeller and the rudder. During the ship's sea trials, the turning ability is measured by performing a sharp turn at maximum rudder angle.

Figure 7.2 shows a hard to starboard turn test for the three tankers involved in this study. The plots include the test for both loaded and ballasted condition.

The test is performed by commanding the rudder 35 deg. to starboard while the engine is running at the maximum load. As the ship starts to turn, a great part of the ship's longitudinal speed is transferred into a transverse (drift) speed that due to the great resistance reduces the longitudinal speed significantly.

The primary parameters for this maneuver are:

- advance (of longitudinal movement)
- transfer (total width of the turning circle)
- speed reduction

For the 3 tankers used in this study, the turning ability can be summarized as follows:

340, 000 dwt VLCC:

Ship 3219, loaded condition: The turning ability is very good with a large speed loss
Ship 3413, ballast condition: The turning ability is about average with a large speed loss

200,000 dwt tanker:

Ship 3017, loaded condition: The turning ability is very good with a large speed loss.

Ship 3414, ballast condition: The turning ability is about average.

110,000 dwt tanker:

Ship 3267, loaded condition: The turning ability is good.

Ship 3303, ballast condition: The turning ability is normal.

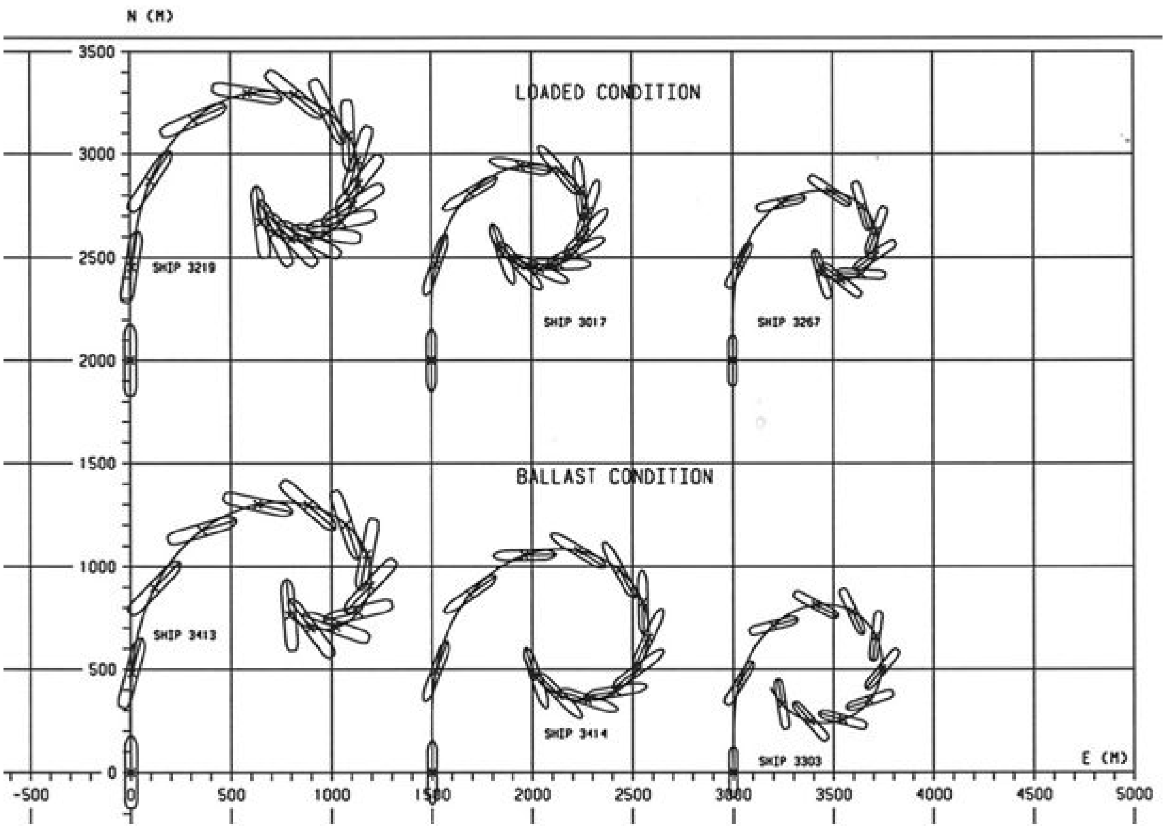


Figure 7.2 Comparison of tankers' turning ability in loaded and ballasted condition. The plot shows a hard a starboard turn test at full sea speed and engine going full ahead.

The figure below shows a hard to starboard turn at 10 knots. The shape of the turns is almost identical to that of full sea speed (see figure 7.2).

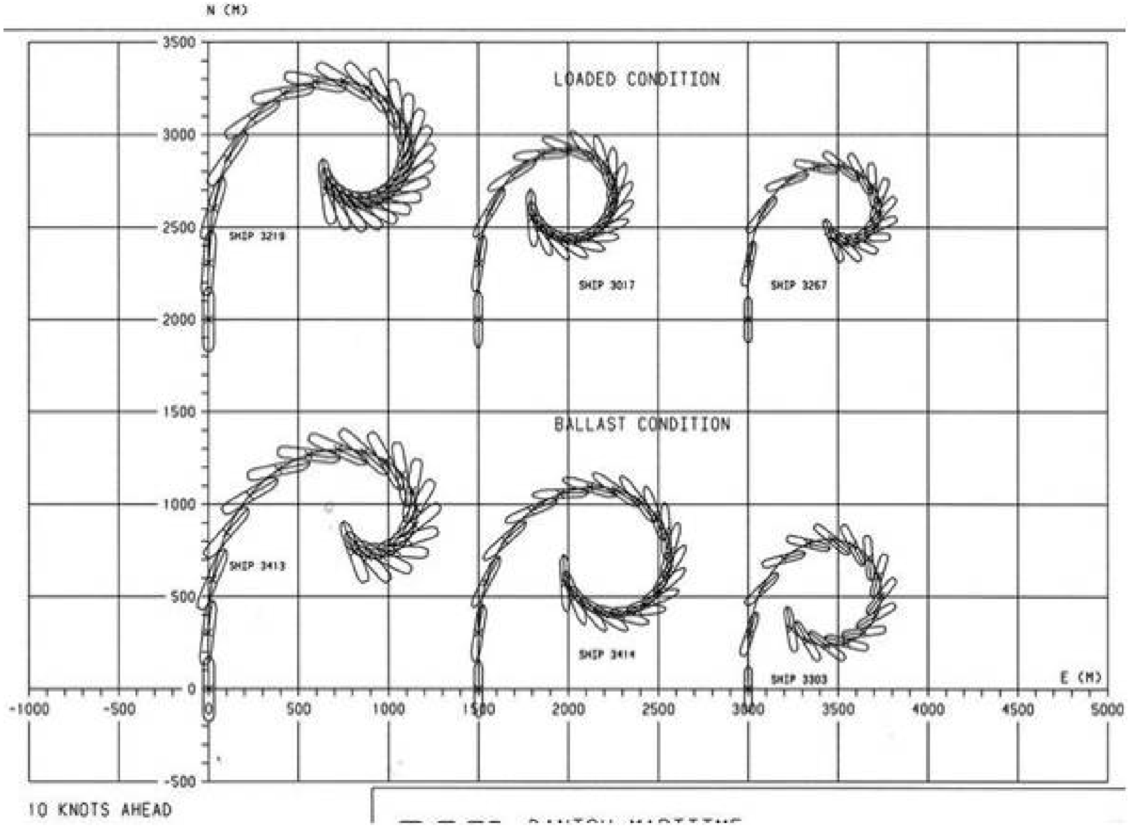


Figure 7.3 Comparison of tankers' turning ability in loaded and ballasted condition. The plot shows a hard a starboard turn test at 10 knots with engine going at RPM corresponding to 10 knots.

7.3 Stopping ability

A ship's ability to stop is tested during the sea trials by letting the vessel steam at full speed (15 knots) and then ordering the engine full astern. This is done by first cutting off the fuel oil to the engine and then waiting for the engine to slow down to the RPM where it is safe (and possible) to start the engine in the reverse direction.

Because most tankers today are diesel driven with the propeller shaft directly coupled to the engine (with no clutch connection), the propeller will turn the engine for a while until the speed is reduced to the level where the engine can be reversed. That part of the stop maneuver is called a coasting stop. From that point on, when the engine is running in the reverse direction, it is actively stopping the ship until it has come to a full stop. The total distance the tanker has moved is considered the ship's stop distance.

In sea trials, the ship undergoes a so-called crash stop which means that the engine is ordered full astern. This maneuver can be destructive with damage to the engine, shaft bearings, foundation etc. That is why most mariners avoid this maneuver. A gentler stop where the engine is ordered half astern is considered a normal stop.

In figure 7.4 the crash stop at 10 knots for the ships used in this study is shown, and figure 7.5 shows a normal stop.

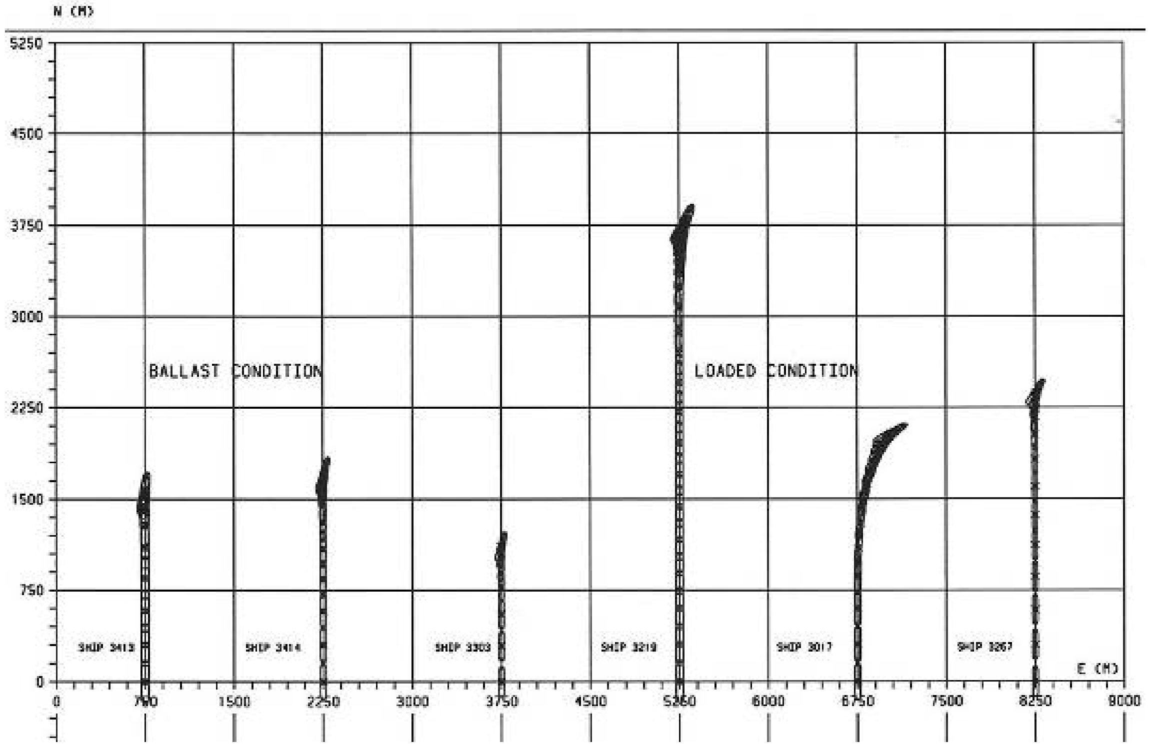


Figure 7.4 Comparison of tankers' emergency stop distances at 10 knots where the engine are running astern at full power.

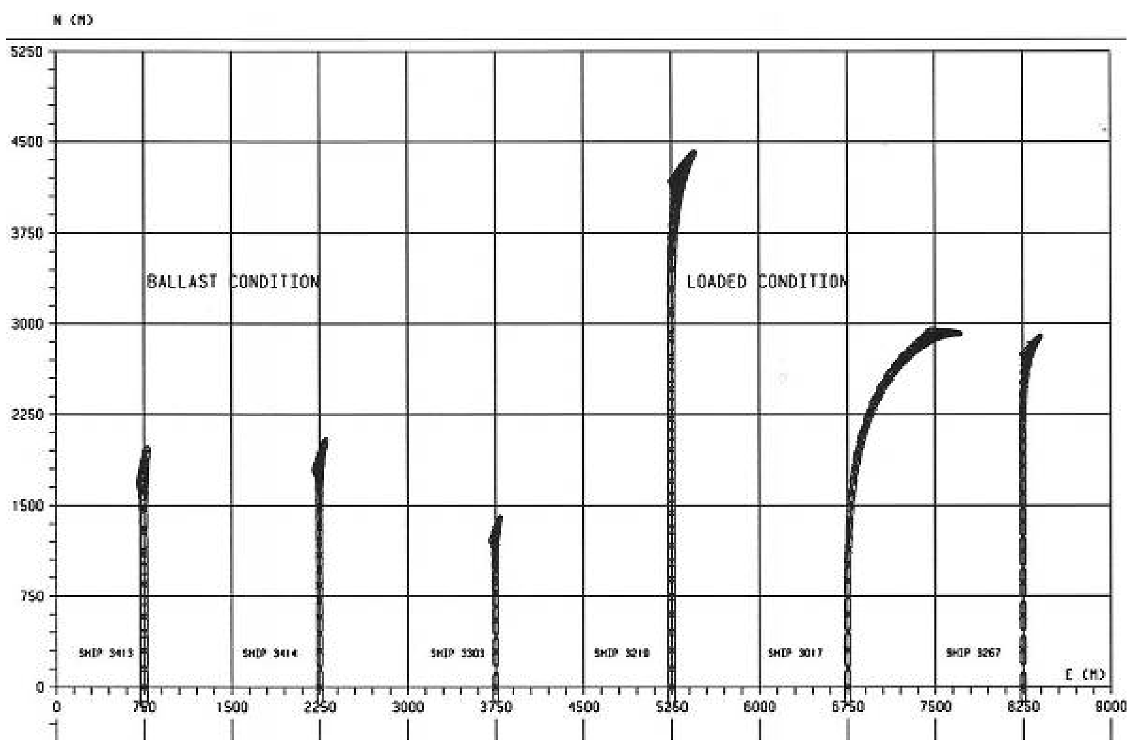


Figure 7.5 Comparison of tankers' normal stop distances at ship speed of 10 knot where the engine are running astern at 50 % power.

7.4 Transverse wind sensitivity

A ship's sensitivity to side wind can by measured by letting the ship steam at full speed with the rudder amid ship and the wind abeam. The ship's course change in e.g. 5 minutes will indicate the sensitivity, and a comparison can be made with other similar ships.

This maneuver is normally not performed during sea trials. Figure 7.6 shows the actual tankers' sensitivity.

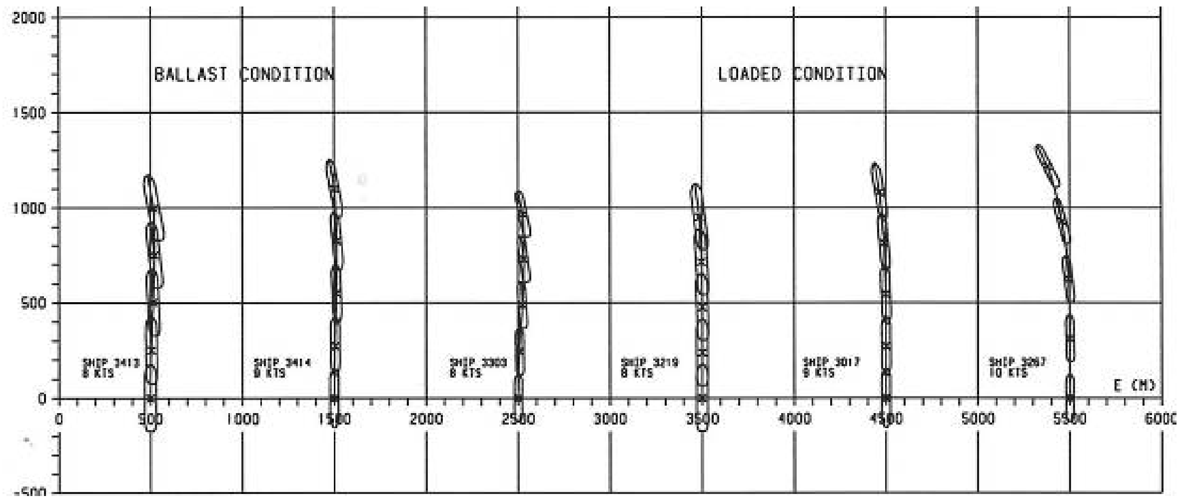


Figure 7.6 Comparison of tankers' sensitivity to 30 knots of wind on port side at ship speed of 8 to 10 knot. Note how the ships turn port into the wind!

The large tankers are less maneuverable compared to the smaller tankers, but still capable of safely navigating the routes to and from Kitimat.

The turn rates used by the pilots during the simulations were about 10 degree per minute which gave a controlled turn that could easily be stopped if needed.

The vessel descriptions in appendix F, shows that all vessels used are able to obtain a turn rate of more than 20 degree per minute which leaves a good safety margin in case a higher turn rate than the 10 degrees per minute is needed which also is required by IMO standards.

8 Additional navigational marking

During the simulations program the pilots have made recommendations for consideration of additional navigation aids or changes to the existing navigation aids.

A listing of these recommendations is as follows:

Additional Buoys, leading and marking lights Chart 3724 Caamaño and area. (Approaches to Caamaño Sound to Surveyed)

1. In Squally Channel. Dougan Pt at the east side of Campania Il. The light should be established as a channel marker for both inbound and outbound vessels.
2. Light and RACON at Rennison Island north point. The light to be used as leading light for inbound vessels from Caamaño, the (RACON ?) light can be used both during good visibility and during fog periods and as a position marker during reduce visibility for vessel that holding in the holding area between Alexander Is – Duckers Is – Ulric Pt – Wall Il.
3. At the light Jacinto it should be inserted a red sector that clears Borthwick Rk and red sector extending N and W over Cran Sh.
4. The light at Duckers Is at the SW side of Princess Royal Is needs to be intensified as the light today being too weak for safe use as a leading and marking light.
5. Logan Rk intensified
6. Spencer Bk Wx buoy on 18 fm patch (R or Y).
7. Ness Rk buoy G
8. Yates Sh buoy R
9. Buoy G on 4¼ fm Sh 2.5' NW of Yates Sh
10. Buoy R on 10 fm Sh N end Aramzazu Bks 52º 53.5'N 129º 39.2'W
11. Buoy G Cran Sh

Additional leading and marking lights chart 3742.

1. Light at the NE side of Gil Is to be used as leading light for outbound vessels coming from Douglas Channel and from McKay Reach.
2. Light at the Farrant Is east side to be used as leading light for outbound vessels in Wright Sound and as a channel marking light for both in and outbound vessels.
3. Light at the NW side of Gil Is (possibly on Gil Rk) to be used as leading light for outbound vessels in to Lewis Passage and as channel marking light.
4. Light with white and red sectors at the NE side of Campania Is used as channel marking light for outbound and inbound vessels and the red/white sectors for Nepean Rock shallow area can be used for w/o point for incoming vessels from Principe Channel.
5. Light and recon at the SE side of Bank Is used as a leading light/Recon for outbound vessel showing the centre of Otter Channel the light/(Racon ?) can also be used by inbound vessel keeping the light right astern.
6. The light at Blackrock Pt on the NW side of Gil Is needs to be intensified as the light today being too weak for safe use as a leading and marking light.
7. Light at the NW side of Gil Is (approximate position 53º 17.2'N 129º 16.0'W) to be used as a leading light for inbound vessels to Lewis Channel and w/o point for vessels coming from Otter Ch into Lewis Ch.
8. Light at Blackfly Point on the NW side of Gil Is to be used as a channel marking light and w/o point marking light
9. Light in Cridge Pass on small islet north end of Fin Island

Additional leading and marking lights chart 3743

1. Light west of Grant Point (approximate position 53º 41.5'N 129º 08.0'W) to be used for outbound vessels as a steering light and for in and outbound vessel as a channel marker. The light should visible minimum 12 nm.

2. Light at the west point of Coste Is (approximate position 53º 50.5'N 128º 46.5'W) to used for outbound and inbound vessels from/to the terminal to steer on.

Dixon Entrance and Hecate Strait chart 3902

1. ODAS Buoys in Dixon Entrance and Hecate Strait – Access to Wx and swell info for pilot boarding conditions.
2. Buoy (Racon?) 7.5 W of Triple Is. to mark the NE corner of Dogfish Bk 54º 16.0′N 131º 05.5′W.
3. Buoy 9 miles of Stevens Is to mark 10 fm edge 54º 09.0′N 131º 05.0′W.
4. Buoy 13' W of Porcher Is to mark 10 fm edge 53º 58.0′N 131º 05.0′W.
5. Buoy Grenville Rk.
6. North Danger Rks Buoy

North end Principe Ch Chart 3927 and 3746

1. Deadman Is light with red sector showing WNW over White Rks to Ludlam Rk
2. Buoy or Beacon Ethel Rk
3. Buoy on 5 fm Rk .3' SSW of Freberg Rk (Foul Pt)

9 Prospective vessel holding area

There is only one anchorage area (at Anger Island) considered viable for the design tankers proposed for this project.

The pilots have suggested areas where ships may be positioned in a “holding” pattern. These are areas where the ships may slow steam accompanied by an escort tug until it is considered safe to continue the transit.

Suggested holding areas for vessels passing through the inner portion of Caamaño Sound en-route to Kitimat would be a position bounded by and slightly south of Alexander Is, Dunkers Pt and Wall Is, the total diameter of the holding area being approximately 5 nm and holding vessels can stem into the wind and/or current in either direction.

A short-term holding area for vessels southbound in Principe Channel en-route to Kitimat via Otter Sound is located between Nepean Sound and Estefan Sound just before entering Otter Channel. In this area, the prevailing winds are NW or SE, and the current NW flooding or SE ebbing which is the same direction as the channel alignment. The holding and steaming distance against the wind and the current drift is approximately 5 nm, and the turning circle is approximately 1.5 nm.

A holding area for vessels coming from the north through Principe channel is the area NW of Anger Island at Anger anchorage. The anchorage area is narrow and with a maximum distance to the shore side of 2.0 nm. The anchorage area currently has no marking or range lights and is considered a viable anchorage in fair to moderate weather conditions. This holding area would also require a tug in attendance at all times.

An alternative holding area is the area N/NW of Banks Is before entering Principe Channel. In this area, it is also possible to anchor, if the weather permits, in 2 – 3 shackle deep water. However, anchoring would be a poor alternative as a tug would have to be in constant attendance. This area is well-known for variable currents and abrupt weather changes.

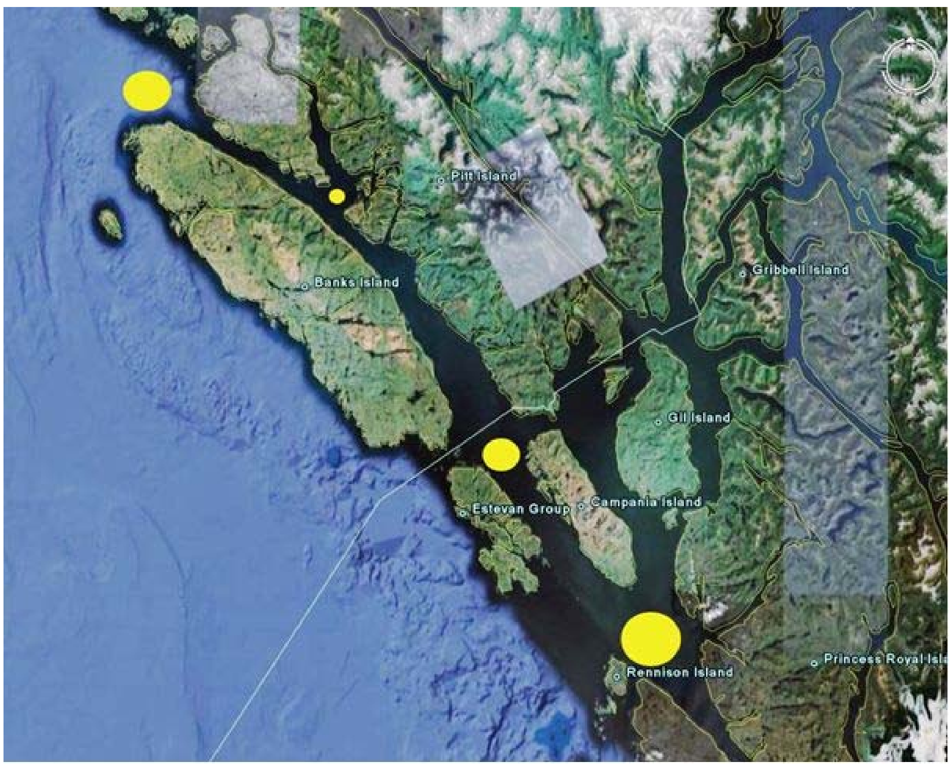


Figure 10.1 Map of prospective four holding areas for tankers. Source: Google Earth. Holding area north of Banks Island (top), Anger Island (top centre), Neapean Sound (bottom centre) and Caamaño Sound north of Alexander Island (bottom)

10 Conclusions and recommendations

The conclusions and recommendations presented in this report are based on the simulations completed to date and discussions with the Pilots, Tug Captains, Northern Gateway representatives and FORCE Instructors for the 110,000 DWT Aframax Tanker, the 200,000 DWT Suezmax Tanker and the 300.000 DWT and 340,000 DWT VLCC´s simulated under the tested environmental conditions.

The simulated wind, current and wave environment consisted of conditions considered at or near the upper limit for maneuvering at open sea, confined channels and the terminal area.

10.1 Entering the Kitimat area from open waters

Entering the confined channels of the Kitimat area from the open sea can be done by the 2 main approaches, as follows:

- The north route approach via Principe Channel
- The south route approach via Caamaño Sound

Each of the approach areas are described below:

10.2 Approach via Principe Channel

The Principe Channel approach can be accessed either via Dixon Entrance north of Haida Gwaii or from the south via Hecate Strait. The Principe Channel approach can be safely navigated under the ship's own power and steering in all weather conditions tested (up to 50 knots of wind) and by all the ship types tested including the largest VLCC´s of up to 340,000 DWT.

This is considered an "all-weather-safe-approach". The channel gives excellent protection from westerly winds and the swell from the Pacific Ocean.

The results from section 5 show that it can be concluded that under the conditions simulated, (combined wind of 40 to 60 knots and current of 1.5 to 2.0 knots) the design vessels can safely and effectively navigate the Lewis Passage, Wright Sound, Douglas Channel as well as the terminal area.

10.3 Approach via Caamaño Sound

The direct approach via Caamaño Sound is the shortest route into Kitimat. The outer (seaward) approach section is unprotected from winds and swells from the open ocean to the southwest.

A concern expressed with the Caamaño Sound approach is that in heavy weather, if an emergency occurs, it may be difficult for an escort tug to hold the tanker or tow it out to sea because of the sea conditions that are experienced in winter months. Consequently, this approach will only be used during moderate weather conditions.

10.4 The viability of the two main routes

Both routes can be safely navigated by the design ships without use of the tugs. All bends can be made with safe control at rates of turn in the order of 10 degree per minute.

10.5 Passing and crossing ship traffic

One objective of the simulations was to determine the safety level when two large ships, e.g. tankers, LNG, or Bulk carriers meet one another at any of the narrower channel sections or in areas such as Wright Sound where crossing traffic is anticipated to be more frequent.

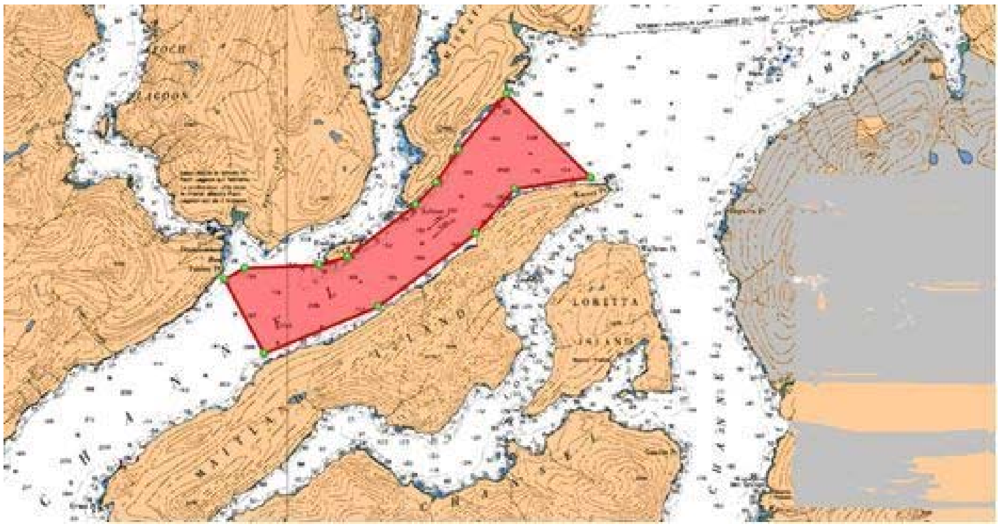


Figure 10.2 Example of area with limited width in Douglas Channel

The outcome of the simulation runs was that it is theoretically feasible for two large ships to pass each other; at the following locations passing of two large ships should, however, be avoided in general and particularly in severe weather conditions:

1. In a section of Principe Channel, a length of 2 nautical miles, from abeam Wheeler Island to abeam Bush Island (southwest of Dixon Island)

2. In Otter Channel, a length of 4 nautical miles, from abeam Fanny Point through the Channel until abeam Fleishman Point

3. In Lewis Passage, a length of 8 nautical miles, from abeam Turtle Point (Gill Island) to passage of Keld Point (Fin Island)

4. In a section of Douglas Channel, a length of 6 nautical miles, from abeam Kersey Point (Maitland Island) to abeam Paisley Point

In addition to the narrow areas listed above, additional care is required in the navigation of Wright Sound on the northeast side of Gill Island where traffic density is higher and crossing traffic situations will be experienced.

It was noted that current coverage of VHF communication and AIS data are limited in some areas from the open sea to Kitimat due to “blind spots”. Repeater stations should be installed at strategic locations to solve this problem.

Consensus from discussions with the Pilots is that the meeting of two large ships at locations 1), 2), 3), and 4) should, in general, be avoided, particularly during severe (wind 30 knots or above) weather conditions. The reason for this restriction is that the margins for safe navigation are limited in case of an emergency situation where the engine is lost or the rudder is locked at an angle different from "mid ship". According to the pilots, the meeting of ships at these locations can easily be avoided through:

- Proper planning and pilot to pilot communication

- Use of a VTS service in the area
- Use of AIS data of other ships' movements

With the use of the above three tools, it is not considered to be problematic for tankers to maneuver through areas 1), 2), 3) and 4).

10.6 Safe speed profile for tankers

The tankers' maximum recommended speed with an escort tug is estimated at 10 to 12 knots. The speed will depend on the design of the escort tug and what is the design speed at which the tug can operate safely.

Maximum safe speed throughout the confined channel areas from open sea to the Kitimat Marine Terminal is considered to be 10 to 12 knots. This provides a speed and time for tankers to complete safe and controlled maneuvers.

When the tankers need to make a turn, the turn can be completed at rates of turn up to and exceeding 20 degrees per minute. However, it is considered preferable to keep the tankers' turning speed closer to a rate of 10 degrees per minute. With a ship speed of 10 knots, that will result in a turning radius of 1 nm. This is considered a smooth, safe and easy to control turn. There is a "reserve" rudder angle capacity, and there is adequate maneuvering room on all channel bends to safely make this radius of turn.

10.7 Suggested speed for assistance tugs

The tanker will always be operated within the performance capabilities of the escort tug taking into account speed, sea and weather conditions, navigational considerations and other factors that may change or arise during the escort transit.

As mentioned, the escort tugs assumed for this study were designed to safely operate in emergency maneuvering mode at an optimal speed of 10 knots. At this speed, the tugs can perform the maximum steering pull they were designed for and keep a safe heeling angle. The heeling angle should typically not exceed 12 degrees.

The tugs free running speed will be in the order of 15 knots therefore the maximum speed for emergency operations should be less than 12 knots.

10.8 Berthing and un-berthing maneuvers

Arrival to the Kitimat Marine Terminal can be achieved safely in wind speeds of up to 40 knots parallel to the terminal as this is the prevailing wind direction (southwest or northeast) with the assistance of at least one escort tug and 2 or 3 Cycloidal or ASD tugs of 50 t BP.

Arrivals and departure from the oil terminal has been simulated in wind speeds of up to 40 knots, however, it is anticipated that in practice limiting wind speeds for berthing and un-berthing operations will be set below this value.

10.9 Emergency maneuvers

Safe handling of emergency situations was an important part of the simulations. All emergency situations tested were handled within reasonable safety margins.

It is important to keep in mind that the emergency situations described rarely occur, but that it is necessary for the Pilots and Tug Masters to rehearse these situations on a regular basis in order to be prepared in case an incident actually occurs.

Proper training of Pilots and especially Tug Masters is essential for a generally safe operation.

The results from all the simulated emergency maneuvers were that the escort tugs of 100 t BP (and 180 t steering pull) and 125 t BP (and 230 t steering pull) was able to take control of the tanker within an acceptable time frame. The Pilots have indicated a preference for tugs of the maximum bollard pull to respond to emergency maneuvers on the largest loaded design ship, but this decision will have to be made in light of final design of the tugs and in consideration of the regulations governing the tanker towing (strong) point capacity.

10.10 Pilots' Evaluation and Comments

During the simulations no real concerns were found during the approach from open sea as long as the maximum wave height is about 3.0 meter and maximum wind speed abt. 40 knots. The escort tug must be connected before point of no return, which means 8 nautical miles from Jacinto light at the south side of Dewdney Island, with a clearance of 3 nautical miles to Cran shoal.

Turning the different types of tankers in Wright Sound, Lewis Passage and Squally Channel in transit can be handled with average rudder angle of 10 to 15 degree rate of turn as long as the wind speed is below 40 to 50 knots. The tugs have been used now and then to assist in steering with maximum 75% of power to demonstrate the tugs capability.

Meeting ships at locations with limited width should be avoided if the wind speed is more than 30 knots or current speed is more than 1 knot. Communication is an important key in meeting situations. New leading lights will help, when passing other ships in the narrows.

Berthing and un-berthing at Kitimat could be done in the simulator in wind forces up to 40 to 50 knots and current speeds up to 1.5 knots along the jetty. In case of high wind speeds the tugs were using between 50% to 75% power, leaving a safety margin of approx. 25% to 50%.

It is recommended to establish general and specific Standard Operational Procedures (SOP) for the operations at the terminal, including number of tugs to be used when arriving and departing with different size tankers and also limit for wind and current speeds.

It is recommended to acquire a portable pilot support system when navigating in the routes. The system is considered essential in reduction the risks when navigating the different routes from open sea to the terminal.

A large number of emergency and arrest manoeuvres' were done in the simulator and in general the escort tug was used in all emergency runs to control the heading and the speed of the tankers.

More detailed information can be found for each run in appendix D1 and D2.

10.11 Recommendations for training

It is essential that the pilots in cooperation with the local tug masters receive simulator training with the purpose of using the escorting tug in the most optimal way.

It is furthermore recommended that the pilots attend training with the purpose of gaining experience with handling of the large VLCC's.

Should it be decided to invest in a supporting portable piloting system it is strongly recommended that the pilots receive training in using the system to a level that makes them fully familiarized and confident with the system.

10.12 Recommendations for defining SOP’s

The simulation results show that within the limits adopted for both Fast-time (FT) and Real-time (RT) simulations, all the modelled navigation manoeuvres could be safely undertaken.

The limits (e.g. weather) stated in the report are therefore the maximum values for which the simulations are valid, and should consequently be one of the foundations on which Standard Operational Procedures (SOP’s) are based.

SOP’s should be developed with all involved parties (Pilots, tug masters and terminal operators) covering the maximum limits for operation during transit from and to open sea to the terminal, and arrival and departure operations at the terminal.

Some of the limits adopted for the simulations may prove to be conservative, and it is therefore recommended that after the first year of operation the SOP should be re-evaluated and revised according to the practical experience gained.

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