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PORTS of GENOA
THE SOUTHERN GATEWAY TO EUROPE.

PROGETTO DI FATTIBILITA' TECNICA ED ECONOMICA

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RIF. PERIZIA	**P.3062**

TITOLO PROGETTO

NUOVA DIGA FORANEA DEL PORTO DI GENOVA
AMBITO BACINO SAMPIERDARENA

TITOLO ELABORATO:

I TEST DI MANOVRA DI NAVIGAZIONE CON SIMULATORE PER LE SOLUZIONI D'INTERVENTO

ELABORATO N°: MI046R-PF-D-I-R-026B-01

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REALIZZAZIONE DELLA NUOVA DIGA FORANEA DEL PORTO DI GENOVA AMBITO BACINO DI SAMPIERDARENA

PROGETTO DI FATTIBILITA' TECNICA ED ECONOMICA

I test di manovra di navigazione con simulatore per le soluzioni d'intervento

RTP - Mandataria: Technital
Mandanti: Modimar - HR Wallingford - Socotec - Sener - Studio Ballerini - EPF - Ing. Albert

HR Wallingford
Working with water

Genoa breakwater

Navigation simulation study

CAR6211-RT001-R04-00

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Contents

Figures

Tables

1. Introduction

The Port of Genoa is one of the main ports in Italy. Situated in the north-west of the country, the port is part of the Western Ligurian Sea Port Authority (AdSPdMLO). The port deals with both passengers and cargo: 4.5 million passengers, 2.7 million TEUs and 15.3 tons of general cargo in the 2019.

According to Italian law (n.130/2018), which was issued to relaunch Genoa's infrastructure after the collapse of the Morandi's Bridge, interventions need to take place to assure the economic recovery of the region. To this extent, the port is preparing to accept Ultra Large Container Ships (ULCSs) with the construction of a new breakwater and development of the port infrastructure.

As part of the development plan for the port, different layouts have been selected as possible solutions to increase the port capacity. The AdSPdMLO commissioned the RTP (*Raggruppamento temporaneo dei progettisti* - Temporary grouping of the designers) to undertake the economic and technical feasibility study. HR Wallingford, as part of the RTP, was commissioned to undertake a ship navigation study to identify the advantages and disadvantages of the alternative solutions under consideration from a navigation perspective.

As part of the navigation simulation study, a 5 day duration simulation session was held at HR Wallingford's UK Ship Simulator Centre (UKSSC) from 21st to 25th September 2020, which examined manoeuvres at the Port of Genoa for three alternative layouts.

Figure 1.1: Existing layout – view from Levante Entrance

Source: HR Wallingford UK Ship Simulator Centre

2. Background to the study

2.1. Proposed solutions

Different solutions were identified to allow ULCSs to call at the Port of Genoa. After an economical and technical review and various consultations with the Harbour Masters, Coast Guard and the Chief Pilot, these solutions were reduced to three and were approved by the AdSPdMLO on the 21st April 2020.

Following analysis of the berth downtime, a minor variation on the layouts was made to reduce the wave agitation inside the port and at the entrance. These revised solutions (Figure 2.1 to Figure 2.3) were then included in HR Wallingford's ship simulation system in July 2020 and used for the simulation study described in this document.

In Solutions 2 and 3, the main access to the port is from the east (*levante*), while in Solution 4 the main access is from the west (*ponente*). There were two phases defined for each of the solutions, providing a total of six layouts to be considered in the navigation simulation study.

The three solutions were mainly characterised by a new turning circle (Phase A) and the widening of the Sampierdarena Basin (Phase B). Several elements differ from Phase A to Phase B. In Phase B, the Sampierdarena Basin is widened to 400m, the existing berths in the Sampierdarena Basin are reclaimed to create a continuous quay for the ULCSs with an orientation of 165-345°N and restrictions from the nearby airport are removed.

The length of the approach channel of Solution 2 and 3 is greater (about 800m) than the approach channel of Solution 4 due to the need to reduce the wave agitation inside the port for Solution 2 and 3. This made the layout comparable in terms of downtime of the operations while the ship was alongside.

Further details of the three solutions are:

- Solution 2:
  - Approach channel: 2,880m long to the end of the turning circle, 310m wide, orientation 295°N
  - Turning circle: 800m diameter
  - Porto Vecchio Entrance: 185m wide
  - Ponente Entrance Phase B: 150m wide
  - Bacino Sampierdarena Phase B: 400m wide.
- Solution 3:
  - Approach channel: 2,725m long to the end of the turning circle, 310m wide, orientation 295°N
  - Turning circle: 800m diameter
  - Porto Vecchio Entrance: 400m wide
  - Ponente Entrance Phase B: 150m wide
  - Bacino Sampierdarena Phase B: 400m wide.
- Solution 4:
  - Approach channel: 2,000m long to the end of the turning circle, 310m wide, orientation 090°N
  - Turning circle: 800m diameter
  - Porto Vecchio Entrance: 400m wide
  - Ponente Entrance Phase B: 150m wide
  - Bacino Sampierdarena Phase B: 400m wide.

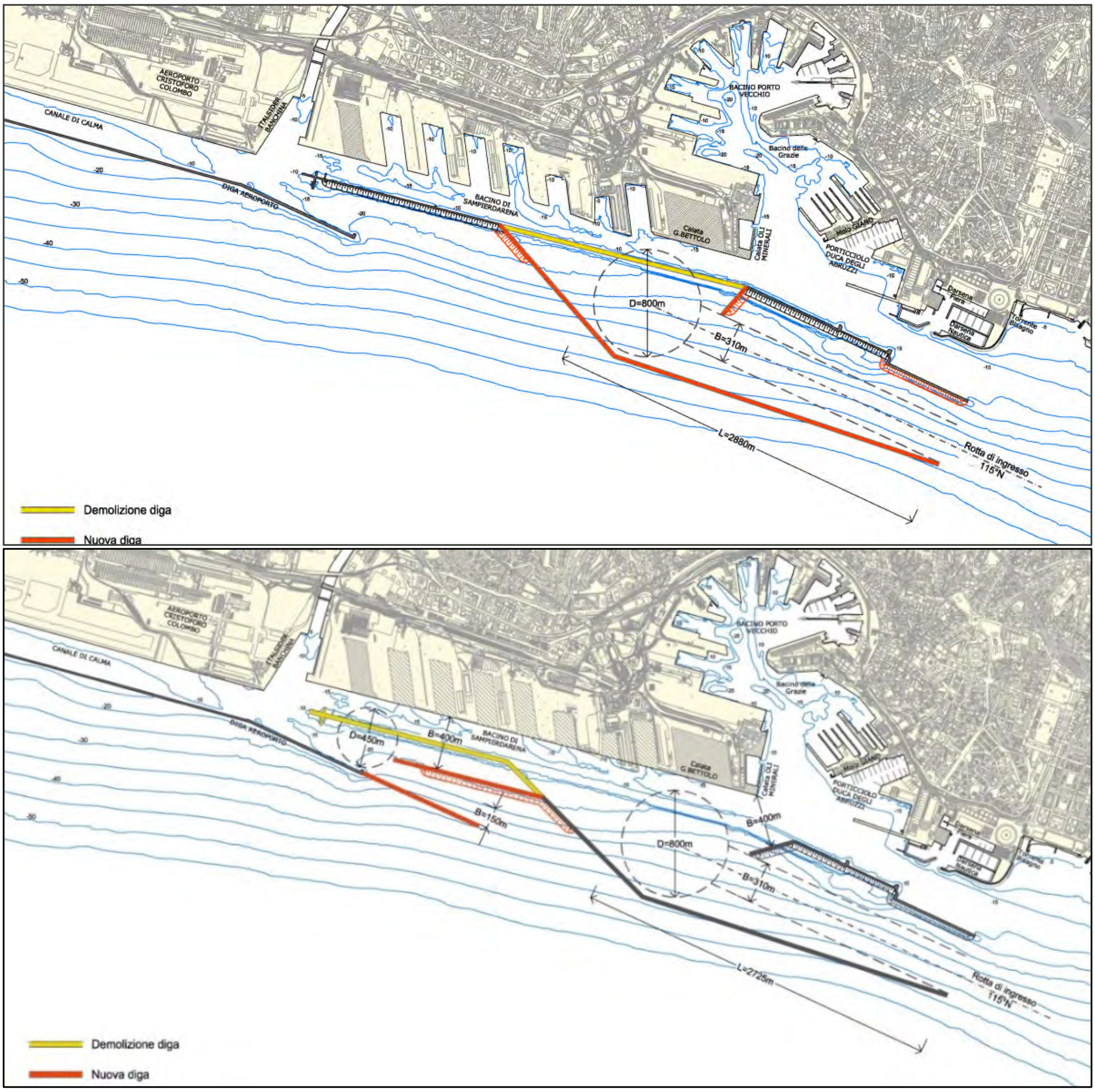

Figure 2.1: Solution 2: Phase A (top) and Phase B (bottom)

Note: Yellow – demolished structures; Red – new structures

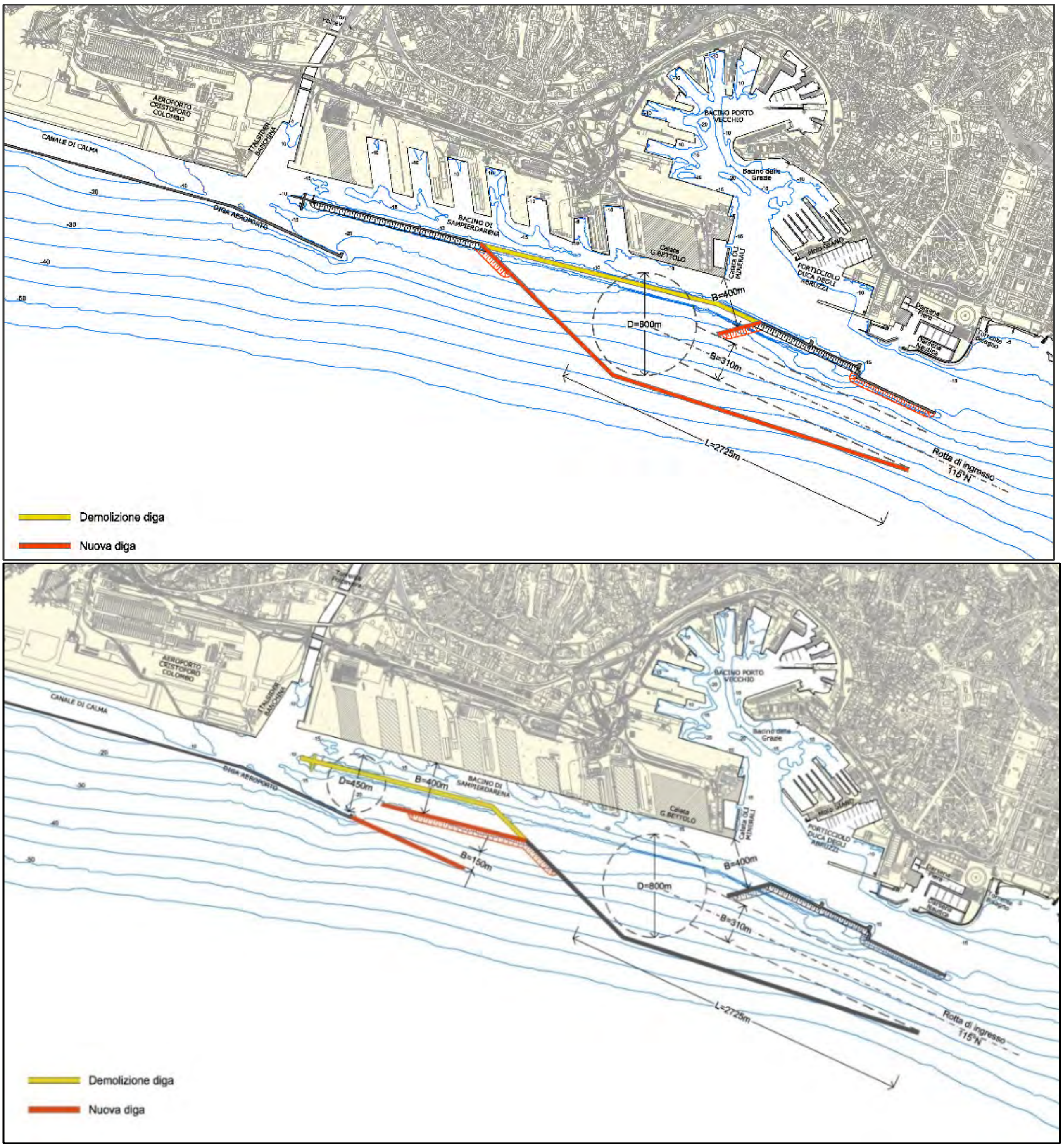

Figure 2.2: Solution 3: Phase A (top) and Phase B (bottom)

Note: Yellow – demolished structures; Red – new structures

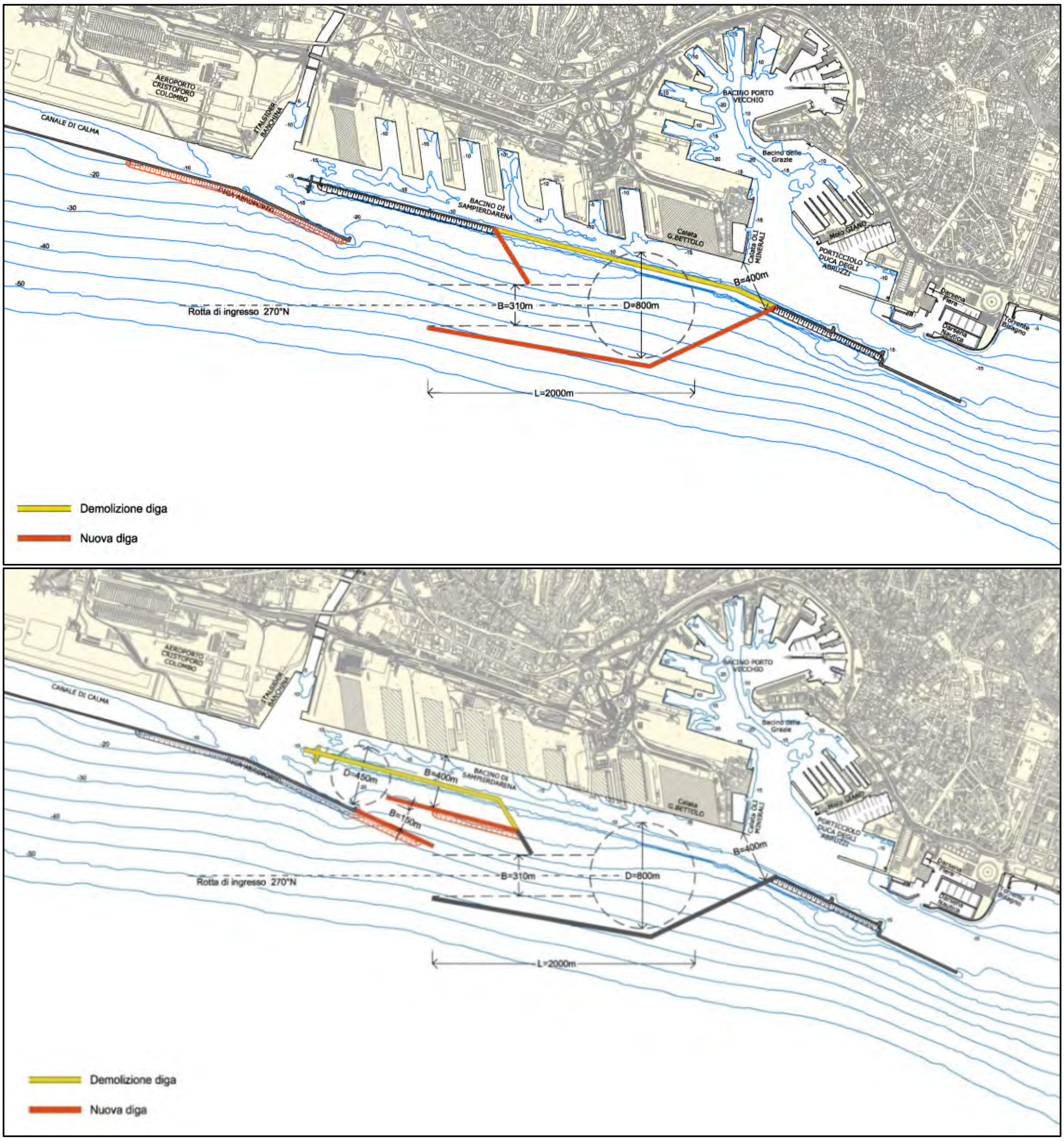

Figure 2.3: Solution 4: Phase A (top) and Phase B (bottom)

Note: Yellow – demolished structures; Red – new structures

Source: Technital

2.2. Layout downtime

Preliminary results of the downtime assessment (Reference 2) showed that the proposed layouts will not increase the wave agitation inside Porto Vecchio. For both Phases A and B, all the solutions tested during the simulation study were similar in terms of wave agitation inside the port.

2.3. Design ships

The design ships for Genoa Port are the widest range of existing ships which can access the port while maintaining the airport restrictions. The ships examined were selected and agreed prior the simulation session. In particular, the characteristics of the design ships were as follows:

- 400m x 62m Ultra Large Container Ship:
  - Length overall: 399.3m
  - Beam: 61.5m
  - Draught: 16.5m / 14.5m
  - Laden displacement: 293,000t.
- 330m x 48.2m Container Ship:
  - Length overall: 330m
  - Beam: 48.2m
  - Draught: 11.0m
  - Laden displacement: 113,000t
  - Single fixed pitch propeller
  - MAN BW 8G95ME C9.5 engine and bow thruster 3000kW (4020hp).

3. Navigation simulation

3.1. Simulator configuration

3.1.1. Simulated layouts

The layouts used in the simulation are taken from the proposed solutions. These include the variation of the breakwater to reduce the wave agitation inside the port as mentioned in Section 2.1. The layouts used in the simulation session are shown from Figure 3.1 to Figure 3.3.

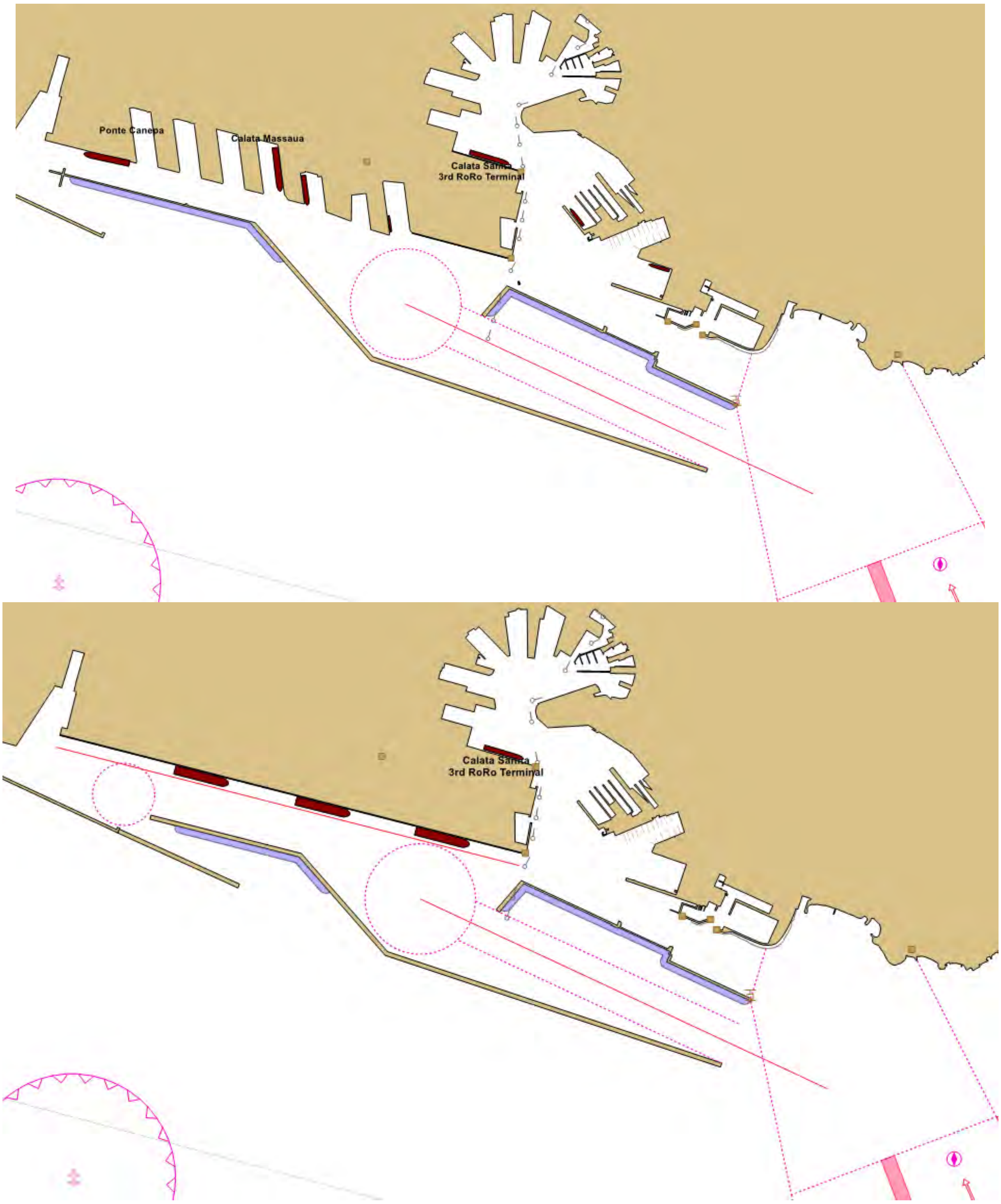

Figure 3.1: Solution 2: Phase A (top), Phase B (bottom)

Source: HR Wallingford Ship Simulation System

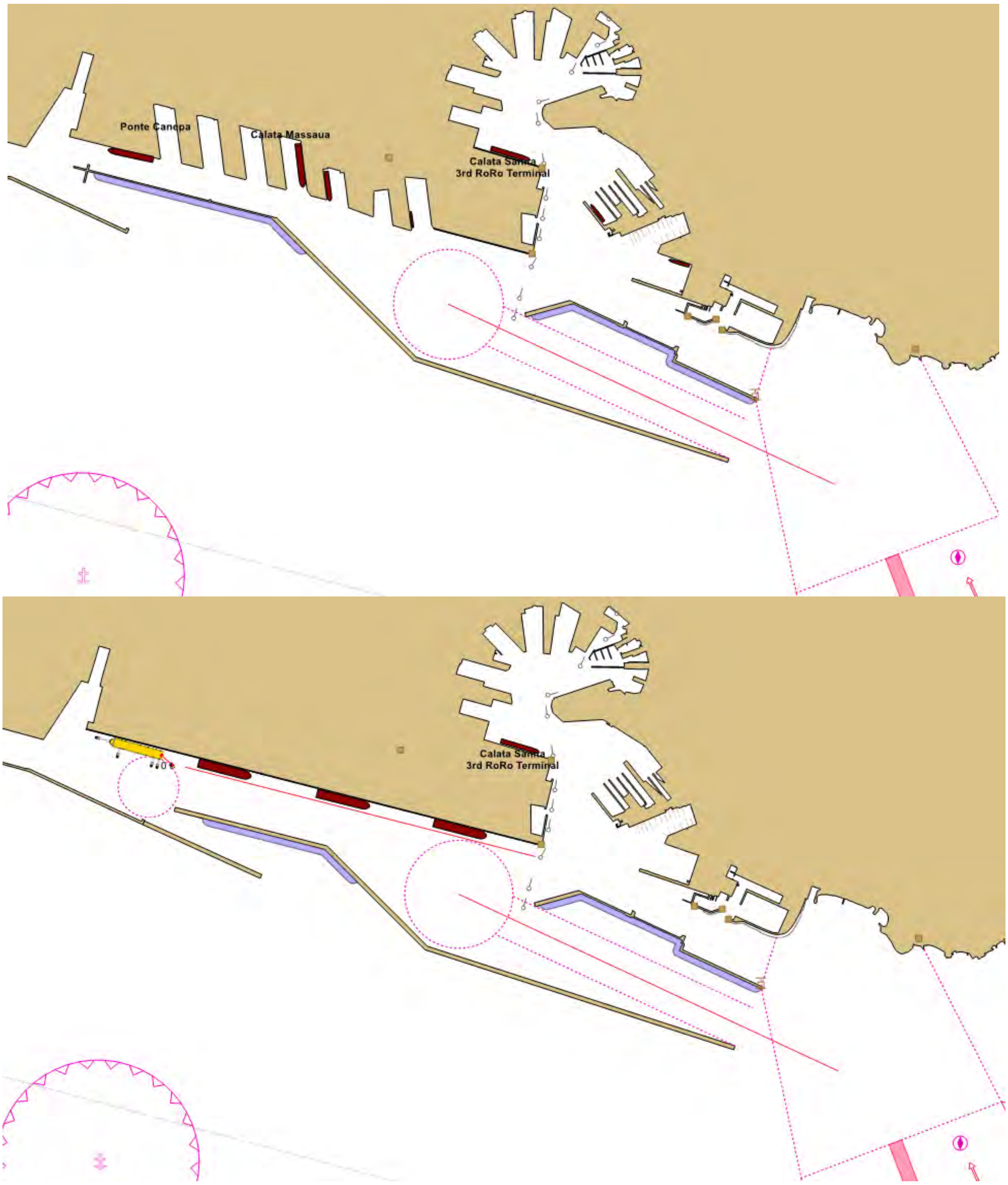

Figure 3.2: Solution 3: Phase A (top), Phase B (bottom)

Source: HR Wallingford Ship Simulation System

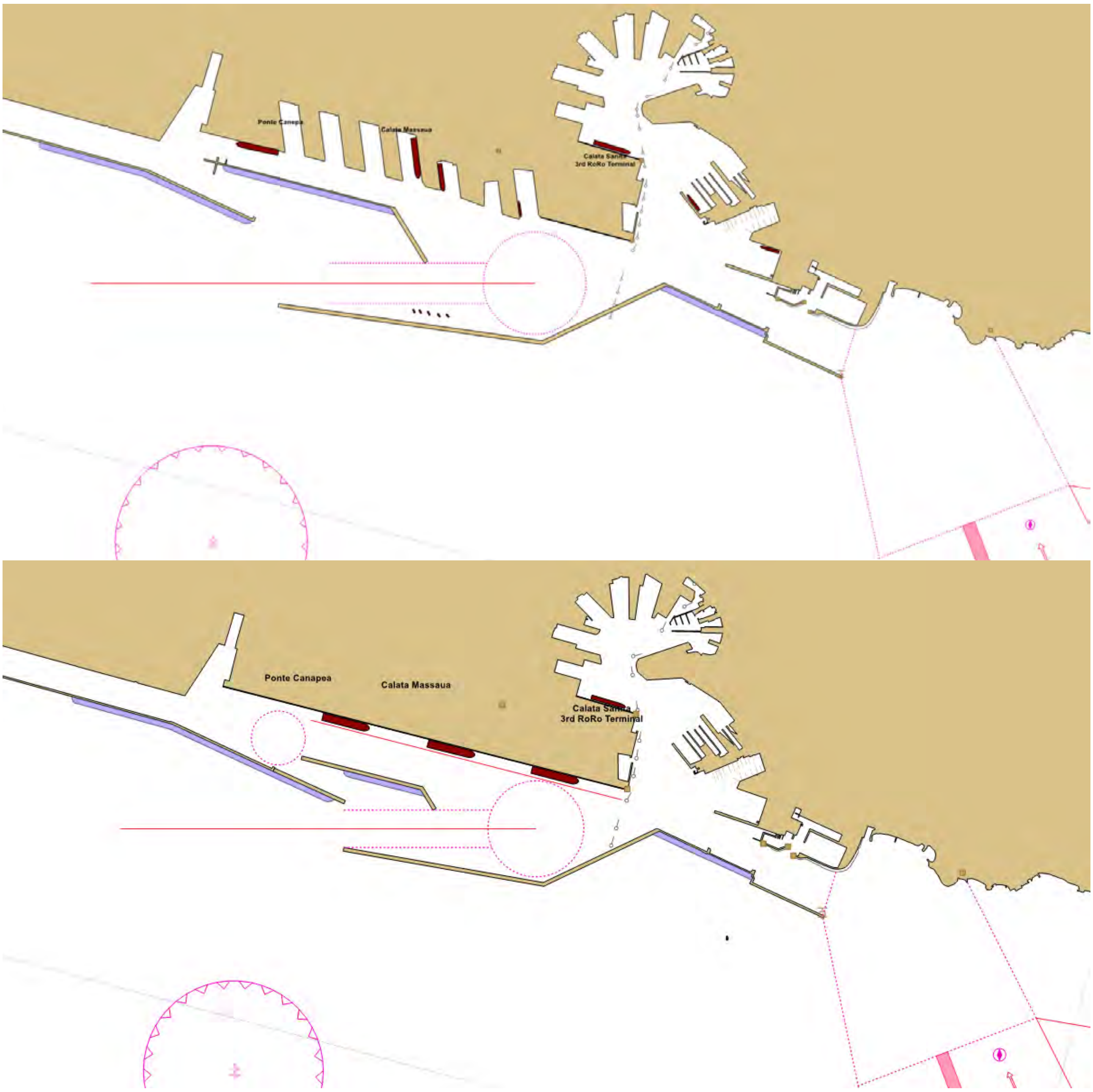

Figure 3.3: Solution 4: Phase A (top), Phase B (bottom)

Source: HR Wallingford Ship Simulation System

3.1.2. Visual scene

A visual model was created based on drawings, satellite imagery and photographs to represent the Port of Genoa and the proposed layouts. Examples of typical visual scenes are shown in Figure 3.4 to Figure 3.6. All the simulations were conducted in daylight.

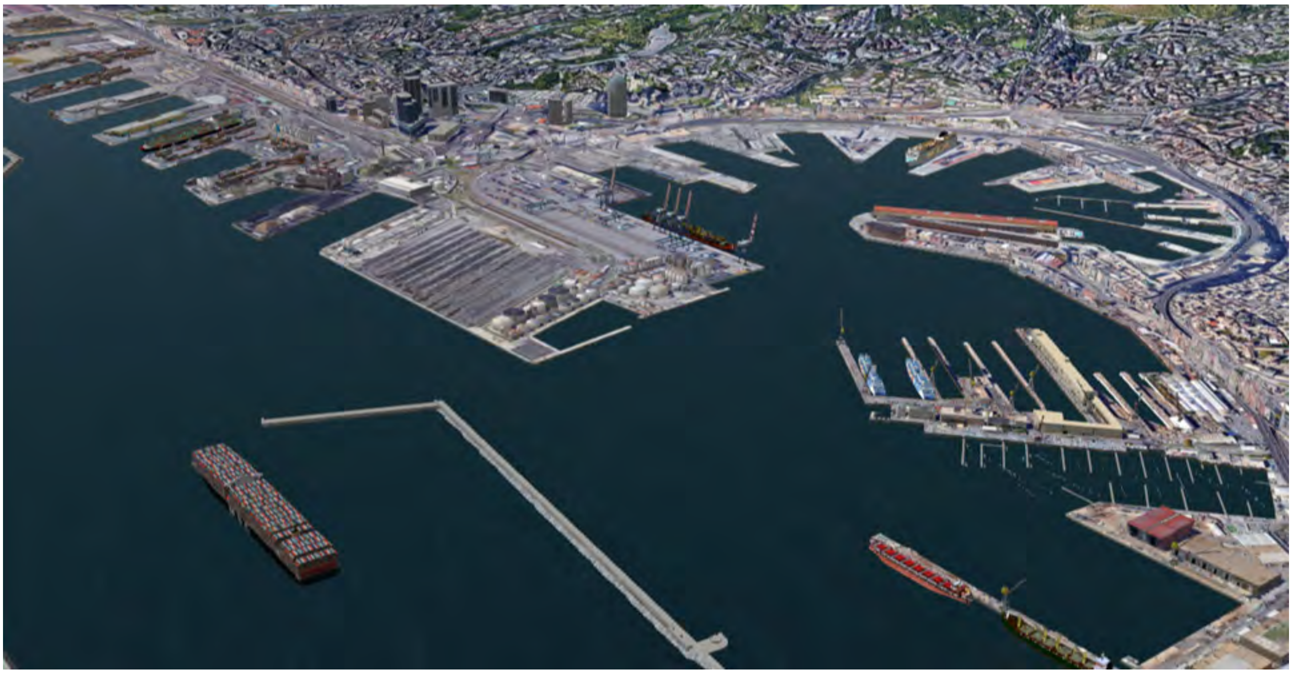

Figure 3.4: Aerial view of Solution 2

Source: HR Wallingford Ship Simulation System

Figure 3.5: Aerial view of Solution 3

Source: HR Wallingford Ship Simulation System

Figure 3.6: Aerial view of Solution 4

Source: HR Wallingford Ship Simulation System

3.1.3. Bathymetry and water depth

The bathymetric data was provided as per Reference 1 along with grids of current and wave conditions. The existing bathymetry was updated with a dredged depth of -18.5m in the turning circle, -17.0m from the turning circle to Calata Massaua and -15.5m in the Sampierdarena Basin beyond Ponte Eritrea. In Phase B, the same areas will all be dredged to -18.5m.

3.1.4. Wind

The wind in the area is mainly from the northeast ("Grecale") and southeast ("Scirocco") as shown in Figure 3.7. Figure 3.8 shows that wind speeds up to 14m/s at the port are only exceeded 0.2% of the time. The Port of Genoa Pilots also say they experience a strong component from the south-southwest (Mezzogiorno) that generates high waves due to the long fetch. This wind was tested as waves are considered to affect the navigability in the port. The Genoa's Port Authority and the Chief Pilot declared the Tramontana wind (000°N) to be the less favourable for the manoeuvres involving the larger ships. Therefore they agreed that this should be used in the simulation runs as the most onerous direction and representative of the Grecale wind (000°N), as approved by them prior the simulation session (Run 03-04-05-07-10-21-22-24-26). The runs entering the Calata, Genoa's Port Authority and the Chief Pilot agreed upon using the Grecale wind (045°N) as it was considered the most onerous in the situation (Run 13-19-31).

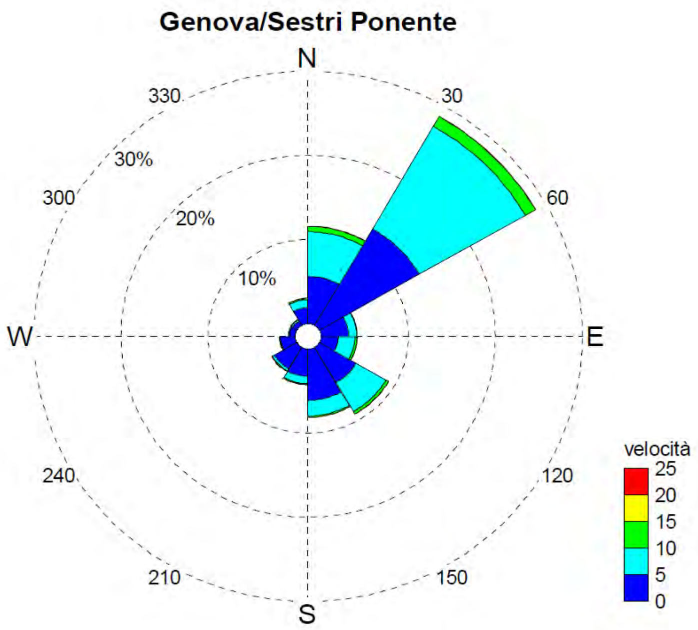

Figure 3.7: Genoa Airport wind rose 1963-2007

Source: "Vento e porti - Analisi statistica dei dati storici di vento registrati dalle stazioni anemometriche"

		Classi di Direzione °N													
		10	40	70	100	130	160	190	220	250	280	310	340		
U_w (m/s)		30	60	90	120	150	180	210	240	270	300	330	360	**Tot**	**Cum**
0	1	0.34	0.23	0.09	0.06	0.10	0.13	0.14	0.13	0.07	0.06	0.07	0.23	**1.6**	**1.6**
1	2	2.10	3.38	0.98	0.49	0.81	1.81	1.51	1.74	0.85	0.35	0.30	0.99	**15.3**	**16.9**
2	3	1.75	3.77	1.06	0.55	1.39	2.50	1.37	1.24	0.71	0.24	0.18	0.57	**15.3**	**32.3**
3	4	1.37	4.44	1.00	0.69	1.88	1.85	0.60	0.44	0.33	0.14	0.10	0.30	**13.1**	**45.4**
4	5	1.41	4.67	0.77	0.65	1.90	1.33	0.44	0.19	0.15	0.06	0.09	0.29	**12.0**	**57.4**
5	6	1.65	4.57	0.49	0.64	1.67	0.84	0.32	0.12	0.06	0.03	0.09	0.37	**10.9**	**68.2**
6	7	1.73	4.72	0.34	0.67	1.51	0.73	0.29	0.09	0.04	0.03	0.07	0.31	**10.5**	**78.8**
7	8	1.54	3.85	0.19	0.50	0.86	0.40	0.21	0.05	0.02	0.01	0.05	0.26	**7.9**	**86.7**
8	9	1.02	2.63	0.12	0.37	0.57	0.22	0.14	0.04	0.01	0.01	0.03	0.16	**5.3**	**92.0**
9	10	0.69	1.74	0.06	0.21	0.32	0.13	0.11	0.04	0.01	0.01	0.02	0.10	**3.4**	**95.5**
10	11	0.37	0.94	0.03	0.14	0.17	0.08	0.06	0.02	0.00	0.00	0.01	0.08	**1.9**	**97.4**
11	12	0.20	0.44	0.01	0.09	0.11	0.05	0.03	0.02	0.00		0.01	0.04	**1.0**	**98.4**
12	13	0.12	0.16	0.00	0.04	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.03	**0.5**	**98.9**
13	14	0.04	0.07	0.00	0.02	0.03	0.01	0.01	0.00		0.00	0.00	0.02	**0.2**	**99.1**
14	15	0.03	0.02		0.02	0.02	0.01	0.01	0.00			0.00	0.01	**0.1**	**99.2**
15	16	0.02	0.00		0.01	0.01	0.00	0.00	0.00			0.00	0.01	**0.1**	**99.3**
16	17	0.00			0.01	0.00	0.00	0.00	0.00				0.00	**0.0**	**99.3**
17	18	0.01	0.00		0.00	0.00							0.00	**0.0**	**99.3**
18	19	0.00	0.00		0.00							0.00	0.00	**0.0**	**99.3**
19	20	0.00				0.00						0.00	0.00	**0.0**	**99.3**
20	21								0.00					**0.0**	**99.3**
		14.42	**35.64**	**5.13**	**5.16**	**11.42**	**10.11**	**5.28**	**4.13**	**2.25**	**0.95**	**1.03**	**3.78**	**99.3**	
													Indefiniti	**0.7**	
													Totale	**100.00**	

Figure 3.8: Genoa Airport: Wind climate

Note: Data in parts per hundred thousand

3.1.5. Currents

The currents in the Port of Genoa are mainly wind driven. Due to the topography of the port, the currents were considered negligible when the wind comes from the north-northeast. Currents were taken from the data models provided in July 2020 based on the wind speed and direction, with a return period as in Section 3.1.4. These were converted into a fixed grid of 20m x 20m cells. The grid was scalable in the simulator accordingly to the data agreed prior to the run.

The currents were generated from the wind only, as a study conducted and presented in Reference 1 demonstrated that the Polcerva and Bisagno Rivers do not affect the currents in the relevant area of the port. The currents used during the simulation were those provided in the current model, from the sea surface to the depth of the maximum draught of the ship. This values were averaged over the ship's hull.

3.1.6. Waves

The waves configured in the simulator were taken from the data models provided in July 2020 (Reference 1). These were converted into a fixed grid of 10m x 10m cells and named by direction and wave height in the outer boundary of the grid.

In all the solutions, there is a large reflection of the offshore waves that increase the disturbance of the area in front of the breakwater. Wave conditions outside the port were limited to 2.5m as this is limit for pilot boarding as discussed with Port of Genoa Pilots.

3.1.7. Water levels

Water depth information is an important input to the ship manoeuvring models during the simulation exercises, as a ship's dynamic behaviour is influenced by the depth of water and the associated under keel clearance. The depth was taken from the data models and based on the specific current and wind condition (Reference 1).

3.2. Ship and tug manoeuvring models

3.2.1. Ships

During the navigation simulation, the behaviour and performance of the ships, in terms of the response to helm and engine settings, as well as the effects of the local wind, wave and current conditions, were governed by mathematical ship manoeuvring models. The mathematical models of the ships must behave in such a way that the position, velocity, swept path and heading of the simulated ship are always representative of real ship behaviour.

In the simulations two container ships were used as follows:

- 400m x 62m Ultra Large Container Ship ("MSC MegaMax" type) – to establish the safety of the port in terms of available plan area (approach channel width, manoeuvring area) in Phase A, the plan area of Sampierdarena Basin and the passing speed and distance in the basin in Phase B. This ship had the following main characteristics:
  - Length overall: 399.3m
  - Beam: 61.5m

  - Draught: 16.5m / 14.5m
  - Laden displacement: 293,000t
  - Single fixed pitch propeller
  - MAN BW 11G95ME C9.5 engine and bow thruster 6,000kW (8,040hp).
- 330m x 48.2m Container Ship – to establish the possibility to increase the ship size calling at Calata Massaua using the space available from the new breakwater in Phase A. This ship had the following main characteristics:
  - Length overall: 330m
  - Beam: 48.2m
  - Draught: 13.5/11.0m
  - Laden displacement: 143,000t
  - Single fixed pitch propeller
  - MAN BW 8G95ME C9.5 engine and bow thruster 3,000kW (4,020hp).

3.2.2. Tugs

HR Wallingford understands that there is a wide range of existing tugs available at the Port of Genoa, with a maximum bollard pull of 82t.

HR Wallingford's simulation system supports two methods for representing tug assistance, as follows:

Centrally-controlled tugs: The tug(s) assisting the ship are controlled by the Simulator Operator following the Pilot's commands, and in a manner similar to that which would be expected in practice, with realistic delays applied. The response of each centrally-controlled tug is governed by a tug performance model that ensures the response times and maximum force deliverable by each tug varies with tug type, winch type, ship water speed and assist mode (push, direct pull, powered indirect, indirect pull and transverse arrest) as well as the local wave conditions and any hull sheltering effects. For most of the runs, the Simulator Operator was supervised by the Port of Genoa Tug Master to ensure the tugs behaviour was as close as possible to the tugs at the Port of Genoa.

Simulator operated tugs: The independently controlled tugs are operated by a Tug Master from separate, but linked, simulator bridge(s) configured as a tug. The behaviour and performance of each independent tug model, in terms of the response to any helm, engine and towline/fender forces, along with the effects of the local wind, wave and current conditions, is governed by a full mathematical tug manoeuvring model. The tug model represents motions in all six degrees of freedom (6DOF), i.e. surge, sway, heave, roll, pitch and yaw motions, and includes tug interactions with waves, the tow line, winches and fenders. Independent tugs can be used in conjunction with centrally-controlled tugs to complete the full tug complement required for a manoeuvre.

Both types of tug model were used in this simulation session.

With the simulator operated tugs, the operating delays and performance degradation were automatically taken into account. The centrally-controlled tugs were subject to operating delays as shown in Table 3.1, and tug performance curves as shown in Figure 3.9 and Figure 3.10.

Table 3.1: Simulated tug response delay times

Tug response delay			Delay
Time to attach and secure			5 minutes (+ 3 minutes line pay-out)
Time to react to new thrust level command			1 minute
Time to react to change in thrust level			20 seconds
Time to change thrust direction	Direct	up to 90°	Up to 1 minute
		90 to 180°	Up to 2 minutes
	Indirect	Roll into assist	Up to 30 seconds
		quarter to quarter	Up to 1 minute
Time to detach	Push/pull mode		1 minute
	Working on line		3 minutes

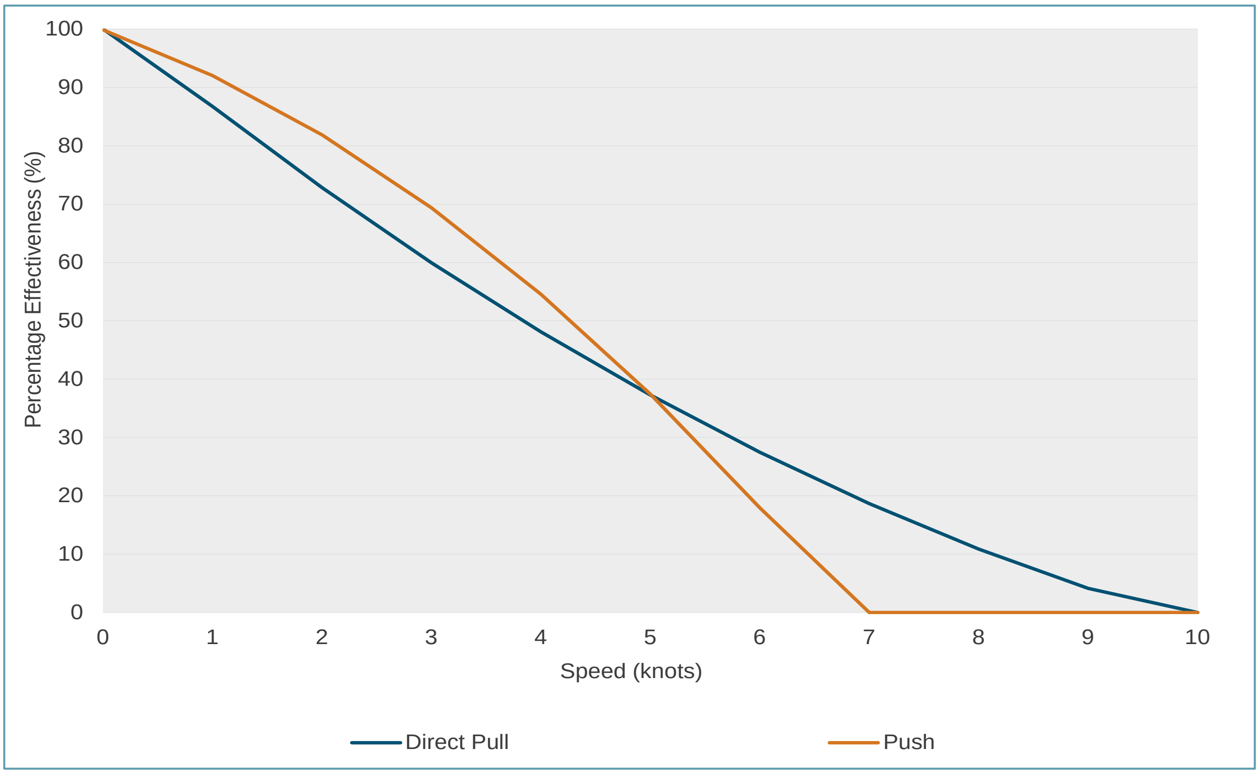

Figure 3.9:Degradation of tug power with speed

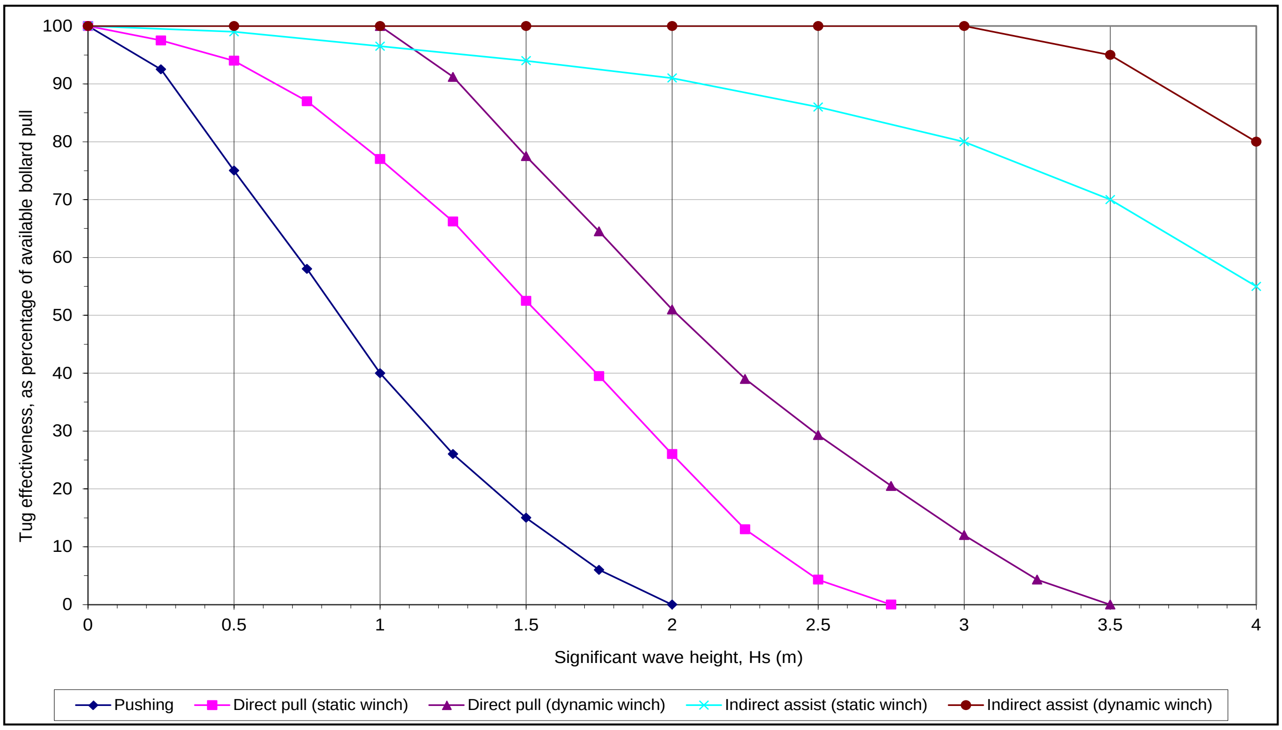

Figure 3.10:Tug effectiveness in waves

3.3. Verification of simulation configuration

HR Wallingford routinely performs a series of internal simulator configuration checks and tests, in order to ensure that the simulation worked in line with expectations.

The ship manoeuvring models were tested using standard trials such as turning circle and emergency stop tests to ensure the model behaviour was consistent with the known and assumed behaviour of similar ships. An HR Wallingford Pilot also verified the performance of each of the modelled ships using a series of test manoeuvres in a range of environmental conditions.

A series of standard simulator set-up verification tests were undertaken to confirm that all components of the simulation were configured correctly and were interacting as expected. These included:

- Engine and helm control tests;
- Effect of wind, waves and/or current on stationary ships;
- Wind force on ship;
- Spatial and orientation checks on the relative positions of the infrastructure, channel boundaries and aids to navigation etc.;
- Spatial checks on water depths;
- Confirmation of the ship footprint and location with the simulation visual scene and situation display.

3.4. Navigation simulation session

3.4.1. Overview

The Genoa real time navigation simulation session was held in HR Wallingford's UK Ship Simulator Centre in Wallingford over five days from 21st September and 25th September 2020. A total of 31 simulation runs were performed. The simulations runs, design ships and layouts were agreed in advance by the Port of Genoa representatives and only minor changes to the runs conditions were made based on the results of the simulations.

The objective of the simulation session were to assess the safety and the feasibility of navigation at the three proposed layouts with a particular attention on requirement and improvement of:

- Approach channel
- Manoeuvring area
- Berthing to Calata Bettolo, Calata Massaua and Ponte Canepa.

3.4.2. Participants

The simulation session participants were:

Western Ligurian Sea Port Authority – Port of Genoa

- Marco Vaccari — AdSPdMLO
- Alberto Battaglini — Harbour Master Coast Guard
- Valerio Berardi — Harbour Master Coast Guard
- Danilo Fabricatore — Chief Pilot and Pilot Manager
- Albert Sturlese — Tug Master
- Paolo Oneto — Linesman.

Technital

- Antonio Lizzadro — Project Manager.

Modimar (remotely)

- Paolo De Girolamo — Modimar – Project Manager
- Marco Tartaglini — Modimar – Project Engineer.

HR Wallingford

- Captain Ian Love — HR Wallingford Pilot
- Roberta Riva — Project Engineer
- Jonathan Woodhams — Principal Engineer
- Jessica Carter — Simulator Operator
- Giulia Sforzi — Principal Engineer
- Dr Mark McBride — Task Manager.

The HR Wallingford Pilot selected for the study had considerable experience of a wide range of container ship operations, including extensive experience of both of the container ships represented, as well as extensive experience of navigation simulation based work.

In this study, the simulation runs were performed using mostly one ship bridge, but occasionally with two linked simulator bridges (one ship bridge and one tug bridge). Furthermore, all the runs were conducted by the Port of Genoa's Chief Pilot. In these runs the Pilot controlled the ship manoeuvres from the one of the Ship Simulation Centre's ship bridge simulators. The Pilot's view position was typically from any position on the bridge of the ship, and the Pilot gave orders to the tug(s) using a radio, in the usual manner. One of the tugs (the stern/brake tug) was controlled from one of the centre's tug simulator bridges for some of the runs. Other tug(s) assisting the ship were modelled as centrally-controlled tugs (see Section 3.2.2).

Observers were able to monitor the manoeuvres from any of the simulator bridges, or from an independent and interactively controllable displays in the Ship Simulation Centre's Observation Room.

The general simulation session procedures were as follows:

- Before each run, the Pilot(s) and Tug Master were briefed and the run conditions were discussed with the Simulation Team;
- At the start of each run, the ship's position, heading, forward and transverse speeds were set by the Simulation Team, based on the manoeuvring scenario and on the environmental conditions selected;
- During departures the ship was positioned with zero ground speed and no mooring lines attached;
- Typically a run was terminated once the manoeuvring objective had been achieved and/or the Simulation Team considered no further insight would be gained by continuing the run;
- Immediately after each run, the Pilot and Tug Master were debriefed and the run was discussed with the Simulation Team.

The run scenarios were selected in a flexible manner during the simulation session, to maximise the time available, with each run taking account of the outcomes of previous runs.

3.4.3. Presentation of the results

The data and results from each real time simulation run are presented in a range of formats.

Run summary

Following each run, a summary table entry was completed. This is presented in Appendix B.

The table details the set-up of the run including the reference to the previously agreed run, the ship used, the manoeuvre conducted, the environmental conditions used, and also describes key aspects of the manoeuvre and captures the remarks and comments made by the Pilot and the rest of the Simulation Team.

Pilot debrief

Immediately after each simulation run, there was a debrief at which comments and insights on various aspects of the run were discussed and recorded. Relevant comments captured in these debriefs are included within the "Comments and pilot/tug master remarks" column of the run summary presented in Appendix B.

Grading of the runs

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

Successful — Arrival/departure manoeuvres:

- The ship remains under control at all times retaining a margin of unused controllability.
- The ship and any assisting tugs maintain an acceptable clearance from all port structures, and other ships berthed at the port, where an acceptable clearance is considered to be

when sufficient horizontal separation between the manoeuvring ship and adjacent structures exists to the satisfaction of the Pilot.

- The ship's water and ground speed is appropriate for the nature of the fairway/channel e.g. to avoid adverse interactions with other moored ships, to allow for safe tug assistance.
- For berthing manoeuvres, the ship ends the run alongside, or in such a position that lines would be ashore without appreciable difficulty, at controlled lateral, with an acceptable sway velocity and no appreciable yaw rate.
- For departure manoeuvres the ship exits smoothly, without risk of being blown or set onto port structures or other ships.

Marginal Arrival/departure manoeuvres:

- The Pilot considers the ship is at the limit of control during the manoeuvres.
- The ship stays within the fairway, but with unacceptable clearances, or inappropriate ship speed.
- The ship clears all port structures, and other ships berthed at the port, but with unacceptable clearances.
- For approach manoeuvres, the ship ends up alongside, but may have a high approach velocity. The manoeuvre can be concluded, but with the potential for minor damage.
- On departure, the ship may get off the berth only with some difficulty. The manoeuvre is completed with the potential for minor damage only.

Failure Arrival/departure manoeuvres:

- The Pilot loses control of the ship.
- The ship strays outside the fairway and/or grounds.
- The ship either contacts, or has a near-miss, with port structures, and/or other ships berthed at the port.
- On departure, the ship either cannot lift off the berth at all, or encounters significant difficulty in manoeuvring, such that severe damage may have occurred.

Simulation track and data plots

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

The ship data and track plots show:

- The position of the ships at 2 minute intervals is indicated by a succession of different hue blue ship outlines. Red ship outlines indicate the ship's position every 10 minutes from the start of the run. The grey shading indicates the total swept path of the ship and tugs throughout the manoeuvre.
- The positions of port structures and aids to navigation.
- The direction and severity of the metocean conditions during the run, presented in the form of metocean symbols for wind, waves, and current.
- A north arrow.
- A scale bar.

The data graphs plot the variation of various key parameters against elapsed simulation time and graphs have been included for the design ship in all of the runs. The ship ID is identified in the text block on the bottom right of each page.

The ship data graphs comprise:

- Current speed in knots acting on the ship along the ship's track.
- Speed (knots) and direction (°N) of the wind acting on the ship.
- Significant wave height (meters) and direction (°N).
- Ship's rate of turn in °/minute and heading in °N.
- Ship's course over ground (CoG) in °N and drift angle in degrees.
- Ship's speed (over the ground and through the water) in knots, expressed in terms of longitudinal and lateral components relative to the ship's head.
- Ship's under keel clearance(s) (UKC) in metres. The data plotted in these UKC graphs does not take account of wave-induced ship motions.
- Ship's propeller RPM (RPM).
- Ship's rudder angle in degrees.
- Ship's bow thruster (%).

Track animations

"Track animations" were generated for each run based on the data recorded. The track animations have been supplied separately as .mp4 format files.

Images captured during the simulation runs

During the simulations runs, observers were able to capture images from the visual scene at key points of the manoeuvres. A selection of these images have been included in this report.

4. Discussion of results

4.1. Overview

As previously mentioned, a total of 31 simulation runs were completed during the real time navigation simulation session. Of these:

- 9 considered Solution 2, of which 7 were with a ULCS and 2 emergency scenarios with a ULCS in Phase A;
- 9 considered Solution 3, of which 1 was with a ULCS using the existing entrance, 3 with a ULCS in Phase B and 5 with the small container ship in Phase A;
- 13 considered Solution 4, of which 5 were with a ULCS in Phase B and 4 with the small container ship.

The layouts all have similar areas and therefore some runs were used to determine conclusions for more than one layout. In particular these common areas were:

- Channel approach for Solution 2 and Solution 3 for ULCS: Runs 1 to 7, 20 to 23 and 31 (Figure 4.1);
- Calata Massaua in Phase A for all solutions for 330m Container Ship: Runs 13 to 20 (Figure 4.2);
- Sampierdarena Basin in Phase B for all the solutions: runs 21 to 26 (Figure 4.3).

The pilot used the same general manoeuvring methods throughout the simulation runs, as follows:

- The tugs were always made fast (connected to the ship's bitts by a tow-line) when the ship was entering the channel adjacent to the south breakwater, prioritising the aft tug with the aim of controlling the ship's speed. It was noted that the pilot generally did not make use of the tug to slow down the ship in the approach channel, using only the ship's engine astern once the aft tug was fast, and mainly while approaching the manoeuvring area.
- The turns were generally carried out using "dynamic manoeuvres" (so turning whilst still carrying headway) using the space available and reducing the duration of the manoeuvre by turning close to the berth.
- Whilst a channel and a turning circle were marked on the electronic chart, a larger area with natural depths greater than the design depths was also available and so was used to perform the manoeuvres, especially when in proximity to the manoeuvring area.

Each run is described individually in the summary table presented in Appendix B and simulation track plots are available in Appendix C. Some additional explanation of the runs grouped by berth and solutions are shown from Sections 4.2 to 4.4. Consideration of future ship sizes is contained in Section 1.

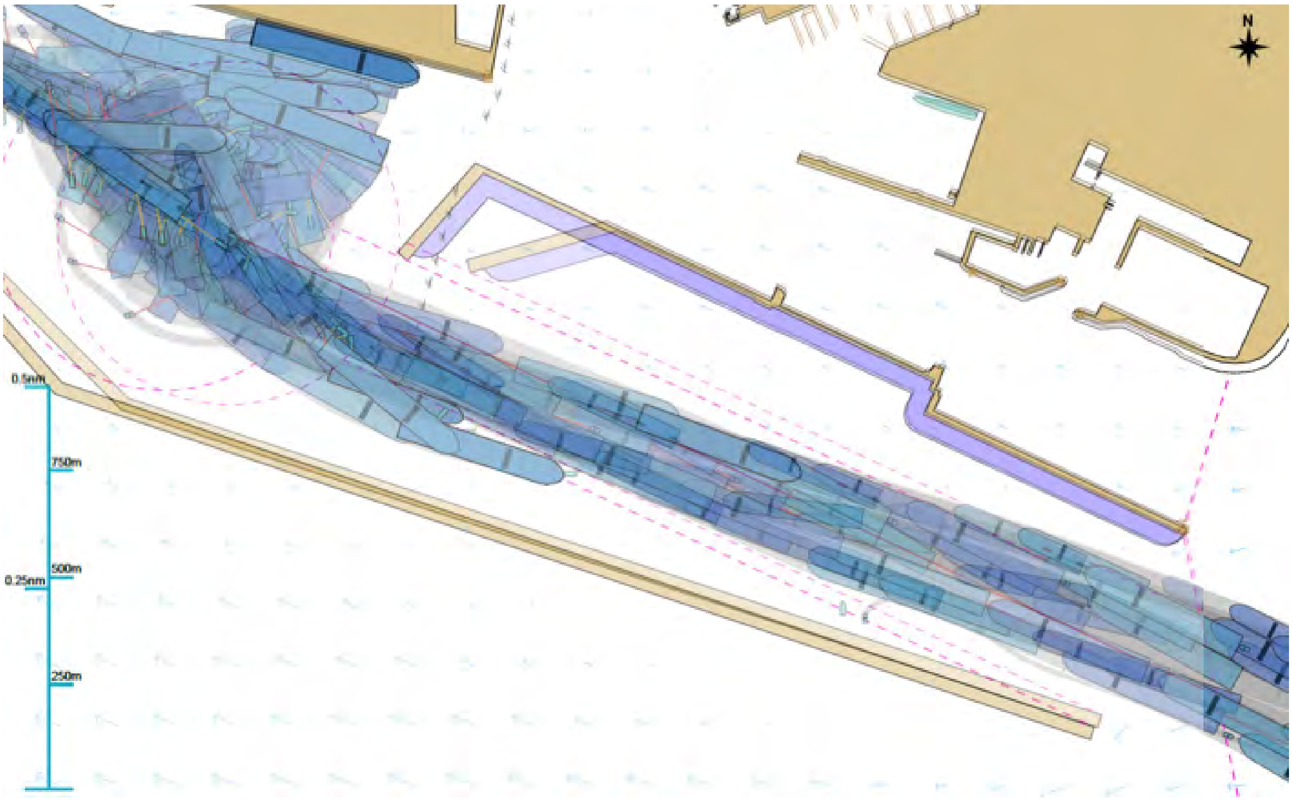

Figure 4.1: Multi-track plot: Channel and manoeuvring area for Solution 2 and 3

Note: Solution 2 layout is overlapped to Solution 3 layout in the picture

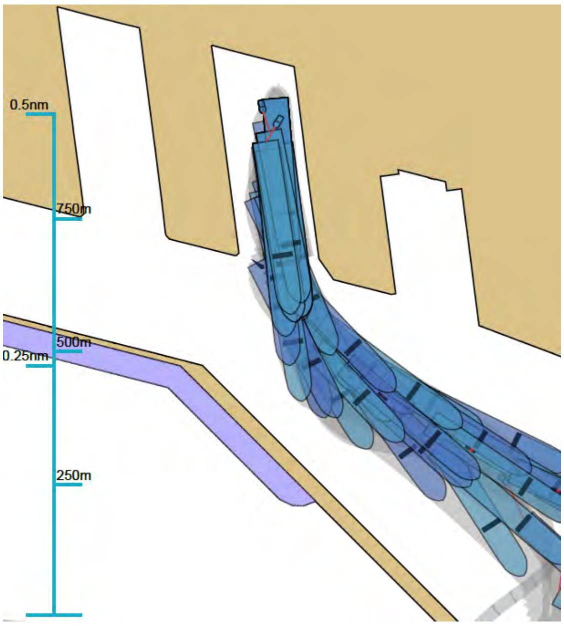

Figure 4.2: Multi-track plot: Calata Massaua in Phase A for all solutions

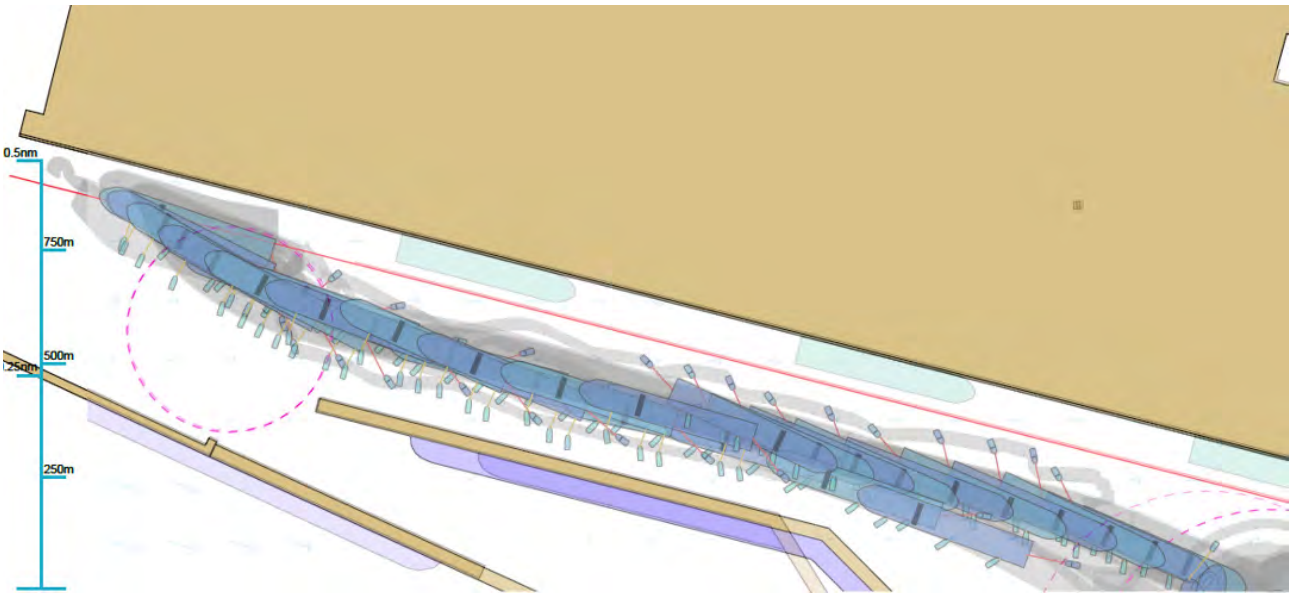

Figure 4.3: Multi-track plot: Sampierdarena Basin in Phase B for all solutions

Note: Solution 3 layout is overlapped to Solution 4 layout in the picture

4.2. Solution 2

Runs 1 to 6 and Run 27 simulated manoeuvres of the Ultra Large Container Ship at Calata Bettolo in its ballast condition to test the higher windage exposure. Runs 28 and 29 simulated emergency manoeuvres in the laden condition.

Solution 2 provides a defined traffic separation between Porto Vecchio and the Sampierdarena Basin, as no access to Porto Vecchio is possible for larger ships from the new entrance.

Runs 1 to 6 and Run 27

Runs 1 to 6 and Run 27 investigated all the main wind conditions for a ULCS in Solution 2.

The ship generally entered the channel with a speed of up to 7.5 knots and was kept at a transit speed higher than 4 knots with a maximum drift angle of 11°. The ship was kept on the up-wind side of the channel entrance through the breakwaters to ensure a good position, which is a normal procedure anticipating that the ship will drift based on the wind direction while the ship's speed is reducing. The pilot was aiming to have the lowest drift angle possible and was therefore keeping as much forward speed as possible, leaving sufficient space from any nearby infrastructure (135m minimum distance, Figure 4.4).

For Solution 2, the channel length was optimised to bring the wave agitation inside the port to a reasonable value. This resulted in a sufficient area in which to make the tugs fast ready for use in the manoeuvring area for both ballast and laden conditions. It was also noted that the large available space allowed the ship to manoeuvre using the minimum tug power up to the manoeuvring area, with the exception being the aft tug which was used to control the ship's speed.

The tugs were used at up to full power in conjunction with the ship's bow thruster to perform the manoeuvres in the manoeuvring area. Given the available space, the pilot manoeuvred such that the space used on the final approach to the berth was minimised (Figure 4.5).

The minimum clearance for this solution was recorded departing from the northern breakwater, Run 5 (77m, see Figure 4.6). It has to be noted that the relatively low clearance was due to the pilot anticipating the ship drifting to the south of the channel in case the ship's speed decreased during the channel transit, due to the strong beam-on wind. The relative position of the ship exiting the manoeuvring area in Run 6 showed the same strategy as in Run 5, but with a south-southwesterly wind.

In some conditions, the tugs were considered on the limit with no spare capacity to overcome possible failures. In northerly winds, 5 tugs of more than 70t BP were considered on the limit for arrival and departure manoeuvres. In particular, the ship used an initial tug fleet of 4 tugs of 70t BP (Run 3). The available power was just about sufficient to perform the manoeuvre. A repeat of Run 3 with 5 x 70t BP tugs resulted in a lateral speed of 0.3 knots, while the ship was brought alongside the berth parallel to the berthing line and no power was left to stop the ship. As a result, the strong beam-on wind requires more than 5 tugs of 70t BP.

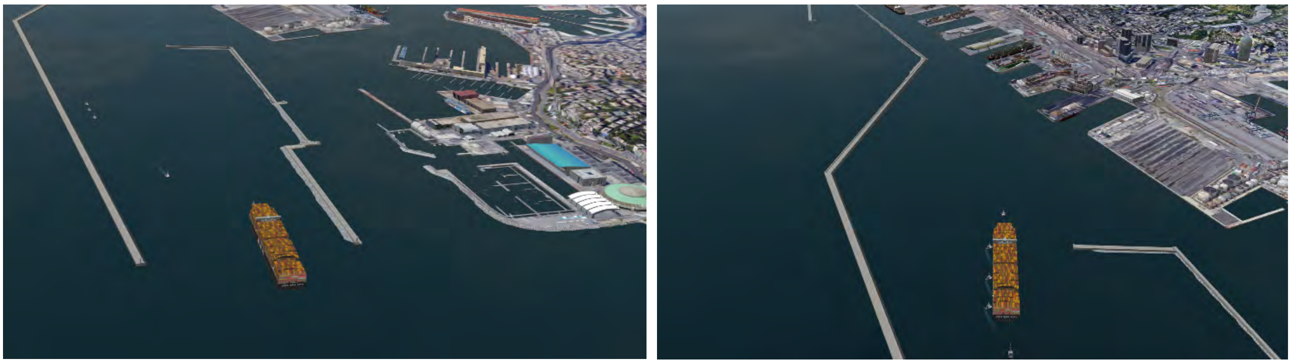

Figure 4.4: ULCS entering the channel (left hand side) and entering the manoeuvring area (right hand side) – Run 4

Source: HR Wallingford Ship Simulation System

Figure 4.5: ULCS performing a dynamic turn (left hand side) and berthing to Calata Bettolo (right hand side) – Run 4

Source: HR Wallingford Ship Simulation System

Figure 4.6: ULCS departing from Calata Bettolo (left hand side) and leaving the port (right hand side) – Run 5

Source: HR Wallingford Ship Simulation System

Runs 28 and 29

An emergency scenario was performed using the ship in its laden condition. The emergency was a complete blackout of the ship while the ship was entering the manoeuvring area. The tugs provided were 5 x 70t BP tugs. The pilot unsuccessfully used the aft tug to control the ship speed and the other tug to induce the ship to turn. The manoeuvre ended with the ship making contact Ponte Etiopia and Ponte Idroscalo. The run was repeated with a more powerful tug fleet of 5 x 80t BP tugs and a different methodology. In addition to the aft tug pulling on full power, the tugs on the side were used at 45° off the ship to slow the ship in the manoeuvring area. The ship was under control inside the manoeuvring area.

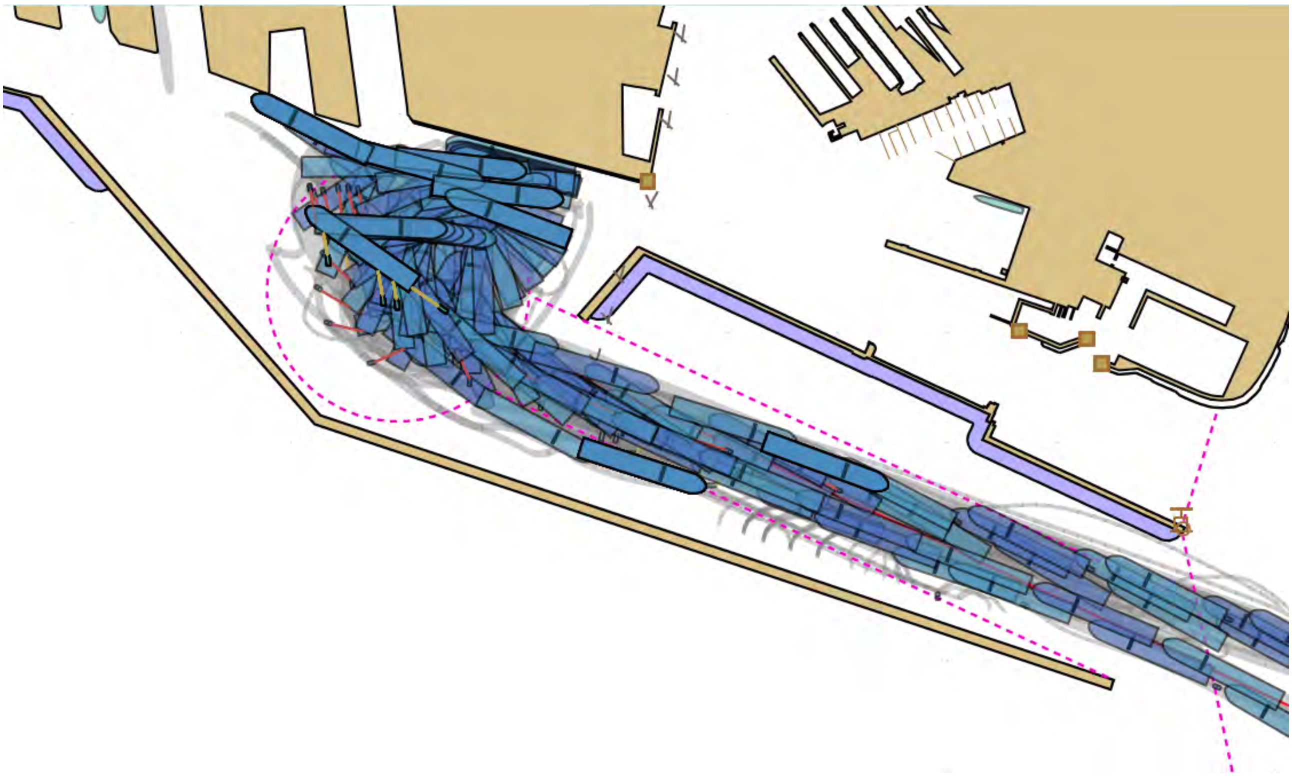

Figure 4.7: Multi track plot of ULCS manoeuvring in Solution 2

Source: HR Wallingford Ship Simulation System

4.3. Solution 3

Solution 3 has common elements to Solution 2 in the approach channel and manoeuvring area, and therefore, the conclusions in this regard for Solution 2 also apply to Solution 3, as mentioned in Section 4.1.

Run 7 simulated an arrival and a departure of a ULCS using the old entrance. Runs 21 to 23 simulated manoeuvres of the Ultra Large Container Ship at Ponte Canepa in ballast and an arrival in the laden condition to test the channel entrance with a laden ship.

Runs 13 to 16 and Run 31 simulated a 330m long container ship with a 48m beam both arriving and departing Calata Massaua in Phase A.

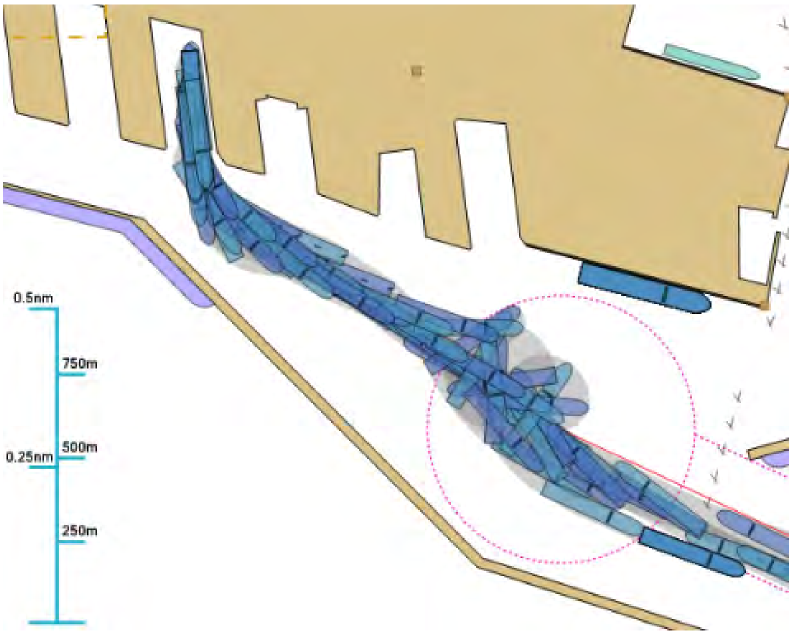

Figure 4.8: Multi track plot of 330m Container Ship manoeuvring in Solution 3 to and from Calata Massaua

Run 7

Solution 3 is differing to Solution 2 for the opening to Porto Vecchio, increasing flexibility in the traffic management between the new and the old port entrance. This run was performed to test an arrival and departure of a ULCS using the old entrance. This was considered as emergency situation where the ship is not able to enter the port from the new entrance.

The ship was not under control in the transit, although the tug power was considered sufficient to bring the ship alongside (Figure 4.9). The impact of passing ship interaction on adjacent moored ships, given the speed and ship's displacement, may also be significant. Nonetheless, a slow speed transit is also a high risk manoeuvre due to the likely vessel drift. The existing approach channel was therefore deemed unsuitable for manoeuvring the design ship.

Run 7 conclusions were considered valid for both Solution 3 and 4.

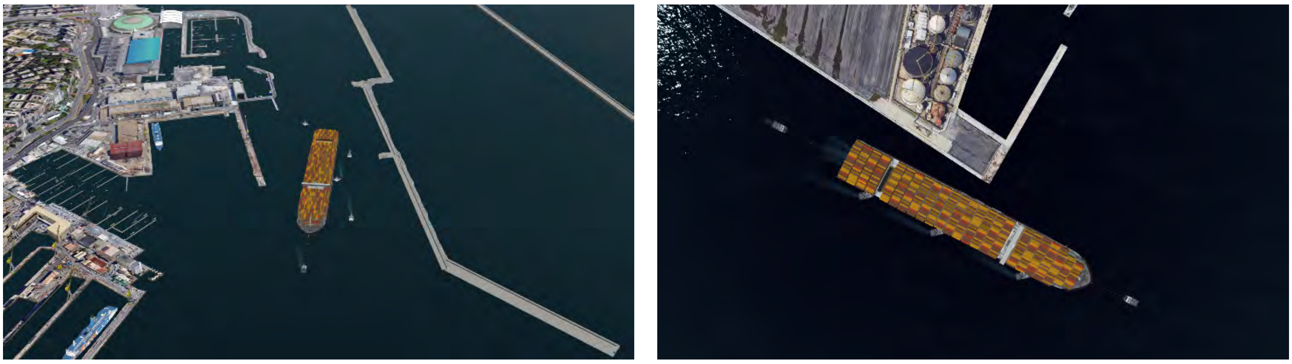

Figure 4.9: ULCS arriving from existing entrance (left hand side) and leaving to the existing entrance (right hand side) – Run 7

Source: HR Wallingford Ship Simulation System

Run 21

Run 21 was performed to test the feasibility of entering the port in a laden condition. This was proved to be feasible and sufficient distance was kept from the infrastructures with a minimum clearance of 88m from the north breakwater. The ship was kept under control and able to stop in the manoeuvring area.

Figure 4.10: Arrival of ULCS in laden conditions – Run 21

Source: HR Wallingford Ship Simulation System

Runs 22 and 23

A ULCS was simulated both arriving and departing port and starboard sides alongside Ponte Canepa in Phase B, with the widening of the Sampierdarena Basin. This was shown to be feasible for all the solutions. With Runs 17 to 20 carried out with the Solution 4, this showed that a suitable passing speed and distance from the other moored ships was kept by the ULCS.

The tug fleet used was up to 5 x 80t BP tugs. The conditions with these tugs were considered to be on the limit, due to the natural decrease in tug efficiency while the ship was keeping speed during the transit in the basin (Figure 3.9). The impact on the moored ships should be considered to determine if the passing effects of a ULCS, with a displacement up to 280,000t, would impact the operations of the moored ship. The similarity in the available manoeuvring area for Sampierdarena Basin, made these runs acceptable also for Solution 2 and 4.

Figure 4.11: ULCS arriving from existing entrance - Run 22

Source: HR Wallingford Ship Simulation System

Runs 13 to 16 and Run 31

Runs 13 to 16 and Run 31 simulated a 330m long container ship with a 48m beam both arriving and departing Calata Massaua in Phase A, in all the predominant wind conditions. These runs were considered representative also for both Solution 2 and Solution 4 due to the similarities in the layouts.

A run with northerly wind was also conducted with a 222m long and 20m beam general cargo ship at Ponte Eritrea (Figure 4.12 - Run 14). This would have been a run where the tugs on the side were use in the push position, so occupying less space around the ship. Nonetheless, the available space was not considered to be sufficient for the design ship to enter the basin. A wind speed of 25 knots from SSW, using 4 x 70t BP tugs, was considered to be at the limit.

In conclusion, the runs showed that manoeuvring to and from Calata Massaua is feasible for all the Solutions, provided there is no other ship berthed on Ponte Eritrea, opposite Calata Massaua.

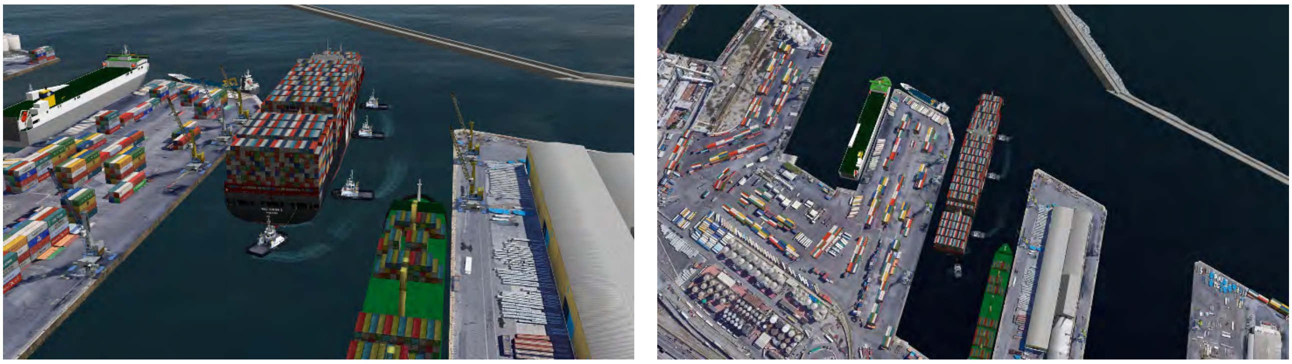

Figure 4.12: 330m container ship entering Calata Massaua with 222m ship at Ponte Eritrea – Run 14

4.4. Solution 4

Runs 8 to 12 simulated manoeuvres of the Ultra Large Container Ship at Calata Bettolo in its ballast condition to test the higher windage exposure. Runs 24 to 26 simulated the same design ship manoeuvring to Ponte Canepa in Phase B and Run 30 simulated an emergency scenario in a laden condition.

Runs 17 to 20 simulated a 330m long container ship with a 48m beam both arriving and departing Calata Massaua in Phase A.

The Pilot Boarding Stations (PBS) and anchorage areas outside the new channel entrance must be re-examined. A run was carried out to provide an indication of the duration of the transit from the existing PBS to the new entrance. This took 32 minutes from the existing PBS to being aligned for the approach to the new entrance, which was approximately 1.5nm from the entrance.

A multi-track plot of all the runs in Solutions 4 are shown in Figure 4.17.

Runs 8 to 12

Runs 8 to 12 investigated all the main wind conditions for a ULCS in Solution 4. The ship generally entered the channel with a speed up to 8 knots and kept a transit speed higher than 4 knots, with a maximum drift angle of 15°. A ULCS was able to enter the channel maintaining more than a beam width from any infrastructure (minimum clearance of 68m – Run 10). The ship was drifting slightly before approaching the channel entrance. In particular in a southerly wind, the ship's northerly position was using the available area in the north of the channel before entering the narrowest area of the channel (Figure 4.13). The pilot was aiming to have the smallest drift angle possible and found a speed between 7.5 and 5.5 knots to be the best to perform the manoeuvre.

As the wave agitation inside the port was not a restraint for Solution 4, the channel length was optimised to control the ship's speed and therefore resulted in a lower available time to make fast the tugs than Solutions 2 and 3. Nonetheless, the channel length, from the outer extent of the south breakwater was sufficient to make the tugs fast ready for use in the manoeuvring area, for both ballast and laden conditions. Furthermore, the large space available permitted the ship to manoeuvre up to the berth with a minimum usage of the tugs. These were needed only to assist during the turning and to berth alongside (Figure 4.15).

In SE winds the Pilot was able to use the wind in his favour to perform the manoeuvre and berthing on the port side (Run 08). In SSW and N winds, the tugs were considered on the limit with no spare capacity to overcome possible failures. In the worst condition, 5 x 70t BP tugs were considered on the limit to bring the ship alongside the berth. In particular, the ship used an initial tug fleet of 4 x 70t BP tugs (Run 9), which were just about sufficient to control the lateral speed of the ship while berthing alongside with a 25 knot beam-on wind. With a northerly wind, 5 tugs and the bow thrusters used on full power were just sufficient to hold the ship in position (Run 10).

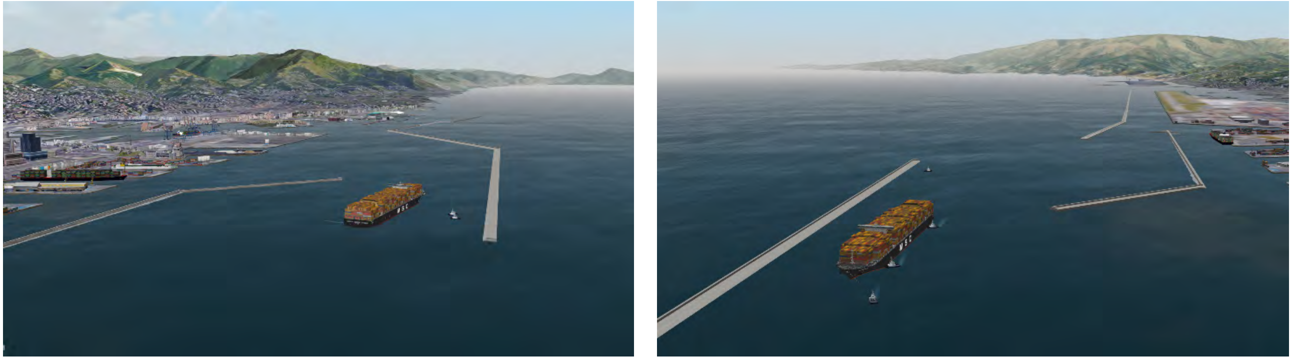

Figure 4.13: ULCS entering the channel (left hand side) and entering the manoeuvring area (right hand side) – Run 12

Source: HR Wallingford Ship Simulation System

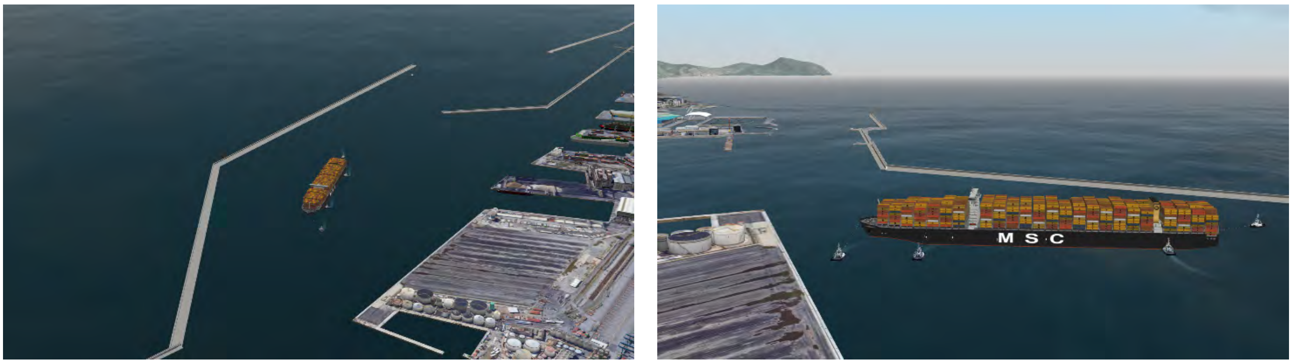

Figure 4.14: ULCS performing a dynamic turn – Run 12

Source: HR Wallingford Ship Simulation System

Figure 4.15: ULCS departing from Calata Bettolo (left hand side) and leaving port (right hand side) – Run 11

Source: HR Wallingford Ship Simulation System

Runs 17 to 20

Runs 17 to 20 simulated a 330m long container ship with a 48m beam both arriving and departing Calata Massaua in Phase A in all the predominant wind conditions.

Compared to Solution 3, Solution 4 showed a higher usage of tug power in the final approach and less in the manoeuvring area (see Run 17 and Run 16).

In conclusion, the runs showed that manoeuvring to and from Calata Massaua is feasible for all the solutions, provided there is no other ship berthed on Ponte Eritrea, opposite Calata Massaua.

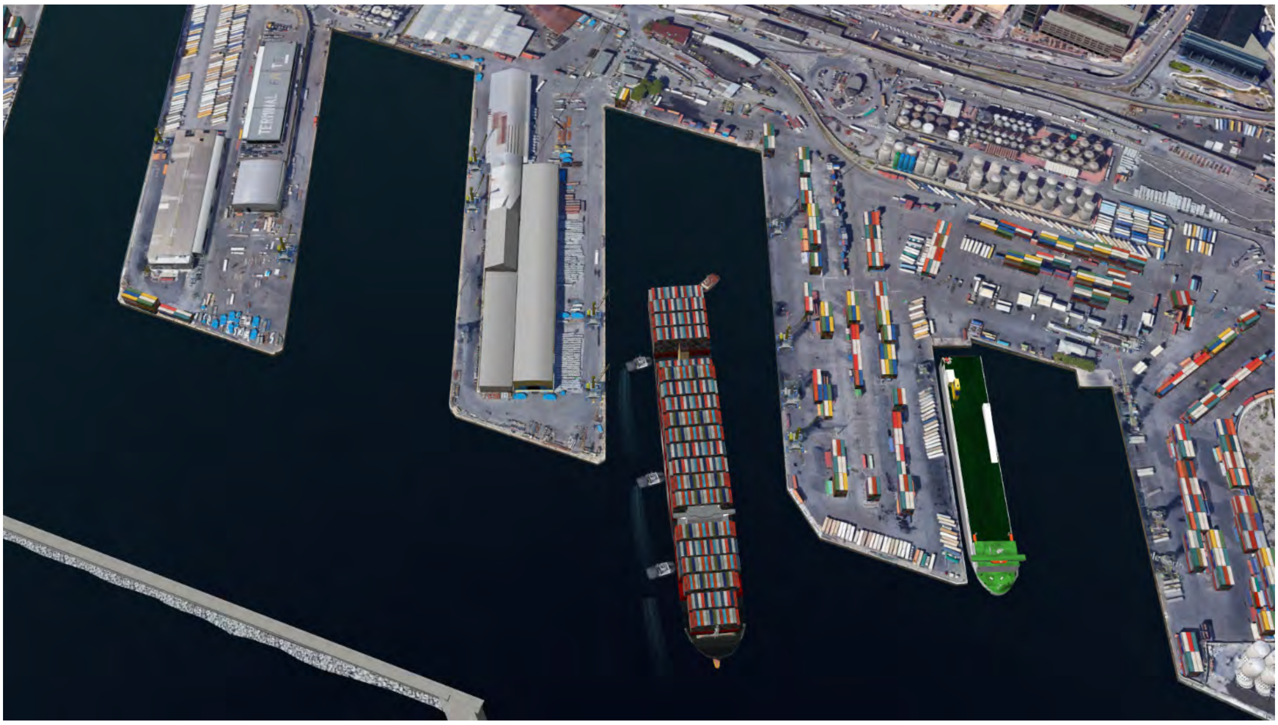

Figure 4.16: 330m x 48m container ships entering to Calata Massaua stern first – Run 19

Run 30

Similarly to Solution 2 and 3 (Run 29), an emergency scenario was examined also for Solution 4. The emergency was again a complete blackout of the ship while the ship was entering the manoeuvring area with 5 x 80t BP tugs. The methodology used was the same as Run 29. So in addition to the aft tug pulling on full power, the tugs on the side were used at 45° off the ship to control the ship in the manoeuvring area. The ship was kept under control in the eastern side of the manoeuvring area, so remaining away from any infrastructure.

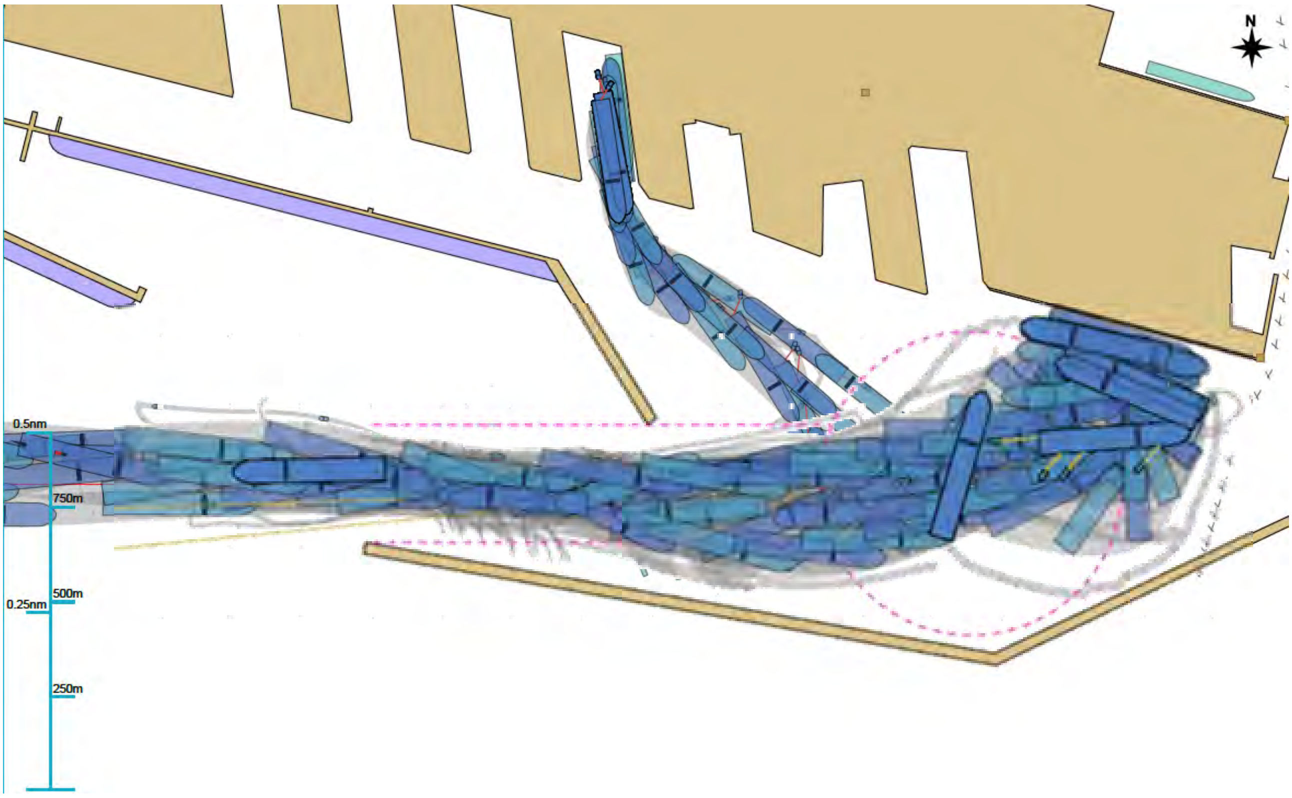

Figure 4.17: Multi track plot: Channel and manoeuvring area for Solution 4

5. Conclusions and recommendations

General

A total of 31 runs was performed by the Port of Genoa Chief Pilot, Captain Danilo Fabricatore and the tugs were operated under the supervision of the Genoa Tug Master, Albert Sturlese. The session covered three proposed layouts using the corresponding wave and current numerical models (as approved by the AdSPdMLO on the 21st April 2020), each with a Phase A and B, as defined in Section 3.1:

- Solution 2, with eastern approach
- Solution 3, with eastern approach
- Solution 4, with western approach.

The PIANC channel design guidelines, for use in conceptual design, were previously used to design the layouts, which provided a manoeuvring area with minimum dimensions of 2 times the length of the design ship, an approach channel with a minimum width of 310m (5 times the design ship's beam) and a minimum stopping distance of 2,000m (5 times the design ship's length).

The runs performed during the session followed the scheduled runs discussed with AdSPdMLO during the different meetings and approved on 21st April 2020. Only minor changes to the run conditions were made based on the results of the simulations and approved by the participants prior the execution of each run.

The following general conclusions were drawn from the navigation study:

- All of the solutions examined were shown to be safe from a navigation standpoint.
- Whilst a channel and a turning circle were marked on the electronic chart, a larger area with natural depths greater than the design depths was also available and so this area was used to perform the manoeuvres, especially when in proximity to the manoeuvring area.
- The tugs were always made fast (connected to ship's bitts by a tow-line) when the ship was entering the channel adjacent to the south breakwater, prioritising the aft tug with the aim of controlling the ship's speed. It was noted that the Pilot generally did not make use of the tug to slow down the ship in the approach channel, using only the engine astern once the aft tug was fast, mainly while approaching the manoeuvring area.
- The manoeuvres were generally carried out using "dynamic manoeuvres" using the space available and reducing the duration of the manoeuvre by turning close to the berth.
- An Ultra Large Container Ship (ULCS) was simulated both arriving and departing port and starboard sides alongside Calata Bettolo. This was shown to be feasible for all the solutions in Phases A and B.
- A 330m long container ship with a 48m beam was simulated both arriving and departing Calata Massaua in Phase A. This was shown to be feasible for all the solutions, provided there was no other ship berthed on Ponte Eritrea, opposite Calata Massaua.
- A ULCS was simulated both arriving and departing port and starboard sides alongside Ponte Canepa in Phase B, with the widening of the Sampierdarena Basin. This was shown to be feasible for all the solutions.
- ULCSs manoeuvring in the widened Sampierdarena Basin in wind conditions of up to 25 knots passed moored ships with more than a 1.5 beam separation at a speed of between 2.3 and 3.0 knots. The impact on the moored ships should be considered to determine if the passing effects of a ULCS, with a displacement up to 280,000t, would impact the operations of the moored ship.
- For manoeuvring with the ULCS, a tug fleet of 4 or 5 x 70tBP ASD tugs (or tugs with similar manoeuvring characteristics) were required for draughts up to 14.5m and 5 x 80tBP ASD tugs for draughts greater than 14.5m. For the 330m x 48m container ship 4 x 70tBP ASD tugs were required.
- A distance of 1.5nm from the outer breakwaters was considered sufficient for the pilot to board the ship on the approach to the port. The position of the Pilot Boarding Station should be determined based on a consultation carried out by the Port Authority.
- The Aids to Navigation considered during the simulation were considered appropriate, although additional marks on the breakwater are required.
- All solutions are expected to improve the traffic management in the port, as each solution offers two possible entrances to the port. It is expected that the traffic will be separated depending on the ship size and the berth to which they are calling.
- It is recommended that real time navigation simulation training and familiarisation is carried out to allow the Pilots to familiarise themselves with the new port layout and design ships, and refine their manoeuvring strategies as required before the new development is constructed.

Solution 2

The conclusions drawn from the study for Solution 2 were as follows:

- A ULCS was able to enter and exit the channel maintaining more than one beam width from any infrastructure (minimum clearance of 77m).

- The ship generally entered the channel with a speed of up to 7.5 knots and keeping a transit speed higher than 4 knots with a maximum drift angle of 11°.
- The channel length, from the outer extent of the south breakwater, was sufficient to make the tugs fast ready for use in the manoeuvring area for both ballast and laden conditions.
- The ship used most of the manoeuvring area available, maintaining a good distance from all the infrastructure. The tugs were used at up to full power in conjunction with the ship's bow thruster to perform the manoeuvres. Given the available space, the Pilot manoeuvred such that the space used on the final approach to the berth was minimised.
- In certain conditions, the tugs were considered on the limit with no spare capacity to overcome possible failures.
- Emergency scenarios showed that sufficient space was available to control the ship. A tug fleet consisting of up to 5 x 80tBP ASD tugs were required to adequately deal with credible emergency scenarios.
- Solution 2 provides a defined traffic separation between Porto Vecchio and the Sampierdarena Basin, as no access to Porto Vecchio is possible for larger ships from the new entrance.

Solution 3

The conclusions drawn from the study for Solution 3 are as follows:

- Solution 3 has common elements to Solution 2 in the approach channel and manoeuvring area, and therefore the conclusions in this regard for Solution 2 also apply to Solution 3.
- Solution 3 differs from Solution 2 as the opening to the Porto Vecchio is increased which allows more flexibility between the new and the old port entrance. An emergency scenario using the existing entrance for an arrival and departure of a ULCS was examined in a 25 knot northerly wind. The displacement of the ULCS, the control of the ship and the speeds required when passing the Ponente Superbacino Jetty and marina meant that the manoeuvre was at high risk of making contact with other moored ships and port infrastructure in the vicinity. It may be possible to use the existing entrance at lower wind speeds or with smaller ships, however, this entrance is not recommended to be used by the ships using the Sampierdarena Basin berths in normal conditions.

Solution 4

The conclusions drawn from the study for Solution 4 are as follows:

- A ULCS was able to enter the channel maintaining more than a beam width from any infrastructure (minimum clearance of 68m).
- The ship generally entered the channel with a speed up to 8 knots and kept a transit speed higher than 4 knots with a maximum drift angle of 15°.
- The channel length, from the outer extent of the south breakwater was sufficient to make the tugs fast ready for use in the manoeuvring area for both ballast and laden conditions, although it was noted that the channel length is reduced when compared with Solutions 2 and 3.
- The ship used most of the manoeuvring area available, maintaining a good distance from all port infrastructure. The tugs were used at up to full power in conjunction with the ship's bow thruster to perform the manoeuvres Given the available space, the Pilot manoeuvred such that the space used on the final approach to the berth was minimised.
- In certain conditions, the tugs were considered on the limit with no spare capacity to overcome possible failures.

- Emergency scenarios showed that sufficient space was available to control the ship. A tug fleet consisting of up to 5 x 80tBP ASD tugs were required to adequately deal with credible emergency scenarios.
- The Pilot Boarding Stations and anchorage areas outside the new channel entrance must be re-examined. A run was carried out to provide an indication of the duration of the transit from the existing Pilot Boarding Station to the new entrance. This took 32 minutes from the existing Pilot Boarding Station to being aligned for the approach to the new entrance, which occurred approximately 1.5nm from the entrance.

6. References

1. RTP, “Le condizioni meteomarine per le manovre di navigazione per le soluzioni di intervento”, MI046R-PF-D-Z-R-016-00.
2. RTP, “Verifiche dell’agitazione ondosa nell’area portuale per le soluzioni d’intervento”, MI046R-PF-D-Z-R-015-00.

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