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References

1. Roseman, D.P., "The Marad Systematic Series of Full-form Ship Models," The Society of Naval Architects and Marine Engineers, New Jersey, 1987.
2. ABS Guide for Vessel Maneuverability, March 2006, Updated February 2017.
3. Crane, "Maneuevering Trials of a 278,000-DWT Tanker in Shallow and Deep Waters," *SNAME Transactions*, Vol. 87, 1979.
4. Bogdanov, P. et al. '"Esso Osaka" Tanker Manoeuvrability Investigations in Deep and Shallow Water, Using PMM,' *International Shipbuilding Progress* , Vol. 34, No. 390, 1987.
5. Capt. Harris email to Glosten, re: "High level modeling of VLCC mooring/unmooring operations," dated 2 June 2021.
6. Capt. Harris email to Glosten, re: "Modeling – first look at two scenarios," dated 7 June 2021.
7. Glosten letter to Capt. Harris, re: "Texas GulfLink Deepwater Port – Ship Simulations," dated 30 July 2021.

Purpose

This report documents the modeling approach, calibration efforts, and simulation results for a 320,000 DWT VLCC class tanker in shallow water. The calibrated VLCC model was used to simulate engine failure in shallow water at the Texas GulfLink Deepwater Port.

Modeling Approach

The calculations of the stopping and turning trajectories of the tanker chosen for this project were made using the Glosten program, SHIPMAN. SHIPMAN is programmed to solve in the time domain a set of three coupled differential equations for the horizontal plane motions of a ship. The equations of motion correspond to the maneuvering model detailed in a study carried out for the United States Maritime Administration (MARAD) by Hydronautics Inc. [Reference 1]. The Glosten simulation models start with data from a MARAD standard series. This study [Reference 1] provides a systematic and comprehensive database on resistance, propulsion and maneuvering for large tanker-type hull forms with a high block coefficient, low length-to-beam ratios and high beam-to-draft ratios. Reference 2 also provides thorough documentation of the mathematical maneuvering model implemented in SHIPMAN.

The approach we take to modeling a new ship is to first obtain a set of maneuvering derivatives for a "standard vessel" corresponding to the same type and shape of ship. The derivatives are non-dimensionalized by a suitable length scale of the "standard vessel." When re-dimensionalized, the derivatives correspond to maneuvering properties of the new vessel. The accuracy and validity of the derivatives for the new vessel depends on the extent of departure of the new vessel from the standard vessel. SHIPMAN simulations are then carried out with the new vessel for a series of standard maneuvers, including; spirals, zigzag maneuvers, turning maneuvers and stopping maneuvers. Results of the simulated maneuvers are then compared with available full-scale maneuvering data for the newly modeled vessel (usually from delivery trials from the particular ship or a sister ship). If appropriate, the maneuvering derivatives are modified to match the trials data.

Model Calibration

The computer model of the tanker used in this study was developed by Glosten, Inc. specifically for shallow water tanker maneuvers. The model is based on MARAD Hull B maneuvering coefficients, tuned to full-scale trials data for the Esso Osaka, a 278,000 DWT vessel (References 3 and 4), and then scaled to a typical 320,000 DWT VLCC class tanker.

The 320,000 DWT VLCC identified in this report is a dimensionally scaled version of the 278,000 DWT Esso Osaka. Since the mathematical maneuvering model used in the Glosten simulator is based on non-dimensional maneuvering coefficients, it is acceptable and standard procedure to approximate the maneuvering performance of an unknown ship using dimension proportioning. It is deemed appropriate to use this approach for port development studies.

Figure 1 shows the turning circle produced by SHIPMAN for the Esso Osaka in deep water at 7.7 knots. Figure 2 shows the turning circle produced by SHIPMAN for both the Esso Osaka and the 320,000 DWT VLCC in shallow water at 7.2 knots. The figures show good correlation between the trials data and simulation results.

Table 2 compares the SHIPMAN results with the full-scale trials data. The tactical diameter, advance, and transfer are similar for both the simulation and trials, indicating the ship model is calibrated. The first overshoot for a 20-20 zig zag maneuver also compares well between simulations and trials.

Table 1 278k DWT tanker calibration results

Parameter	Water Depth	SHIPMAN	Trials
Tactical diameter [m]	Deep	970	895
Advance [m]	Deep	990	1005
Transfer [m]	Deep	445	310
First Overshoot [deg]	Deep	9.6	9.8
Tactical diameter [m]	Shallow	1595	1590
Advance [m]	Shallow	1175	1180
Transfer [m]	Shallow	610	705
First Overshoot [deg]	Shallow	7.1	7.8

Shallow water is defined as a depth to draft ratio (H/T) of 1.2.

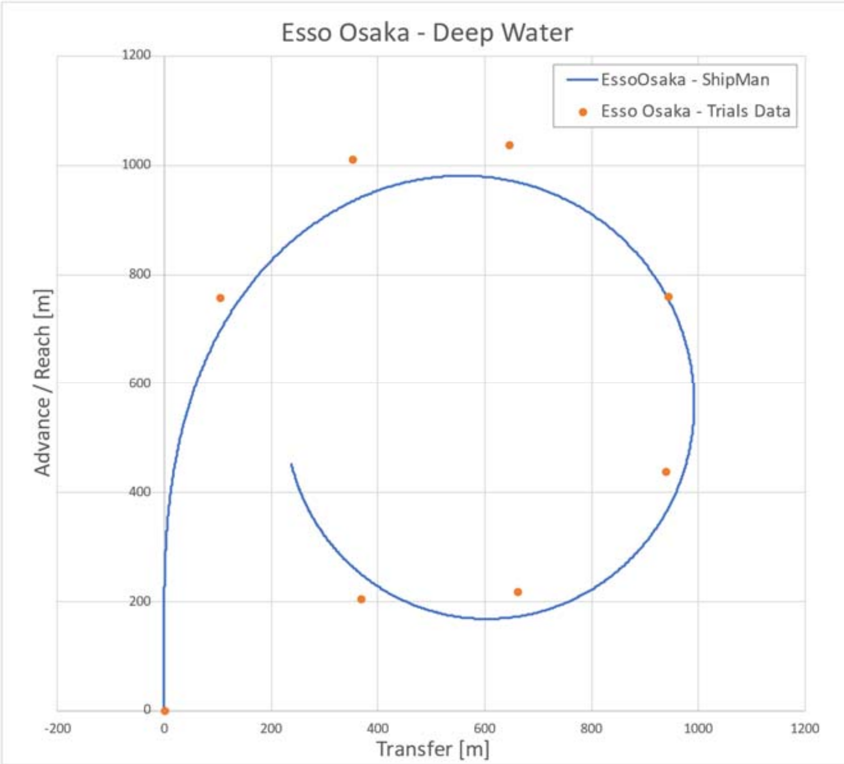


Figure 1 Turning circle for 278k DWT tanker, 7.7 knots, deep water

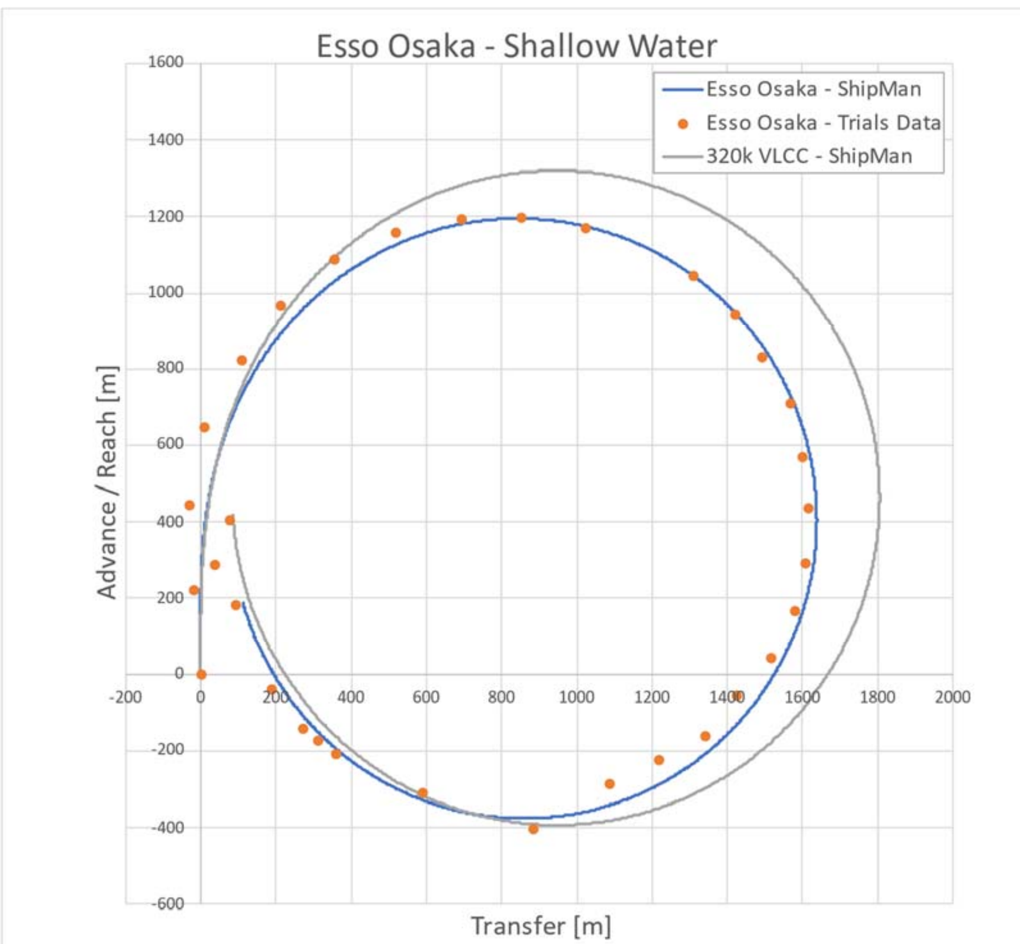


Figure 2 Turning circle for 278k DWT tanker and 320k DWT VLCC, 7.2 knots, shallow water

Simulation Assumptions

Ship maneuvering simulations were completed for the 320k DWT VLCC assisted by a 90 mt ASD tug for the subject project configured at distances of a 0.65 nautical mile and 1.25 nautical miles distance between the single point mooring (SPM) and the platform. The simulations were performed for shallow water using the calibrated 320k DWT VLCC SHIPMAN model described above.

The port layout and engine failure simulation scenario are setup as described in References 5 and 6. The wind, wave, and current are directed toward the platform and the ship has weather-vaned about the SPM so that the stern is aligned with the platform. Wind speed is 30 knots, wave height is 9.7 feet, and current speed is 1.5 knots.

The engine failure scenario is described by the following sequence of events:

1) Ship backs away from SPM at 1 knot with 15 mt tug pull to stern
2) Engine failure occurs at ahead bell when the ship clears the hoses (704 ft from start)
3) Engine failure recognition delay: 60 s
4) Tug notification delay: 60 s
5) Tug applies full bollard to turn the ship

The bow of the VLCC is located 281 feet from the SPM when moored. The cargo hoses are 985 feet long, so the ship must back 704 feet to clear the hoses. Appendix A illustrates the port layouts [References 5 and 6].

Simulation Results

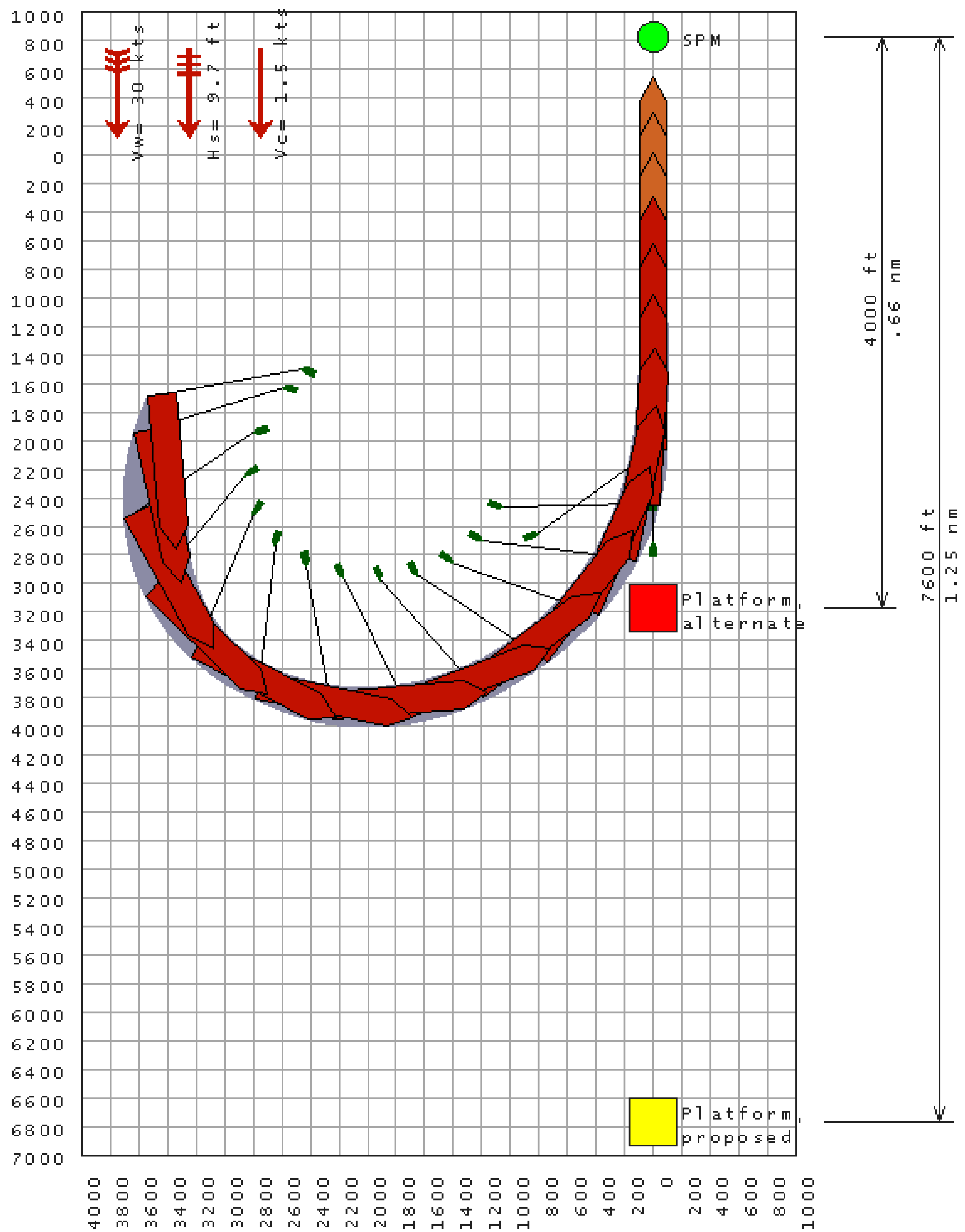
Figure 3 illustrates the resulting track line for the engine failure scenario in shallow water. We note that the 0.65 nautical mile minimum distance between the ship and platform in this scenario does not provide an adequate safety margin given the extreme sea conditions. On the other hand the simulations show that a distance of 1.25 nautical miles provides enough sea room to avoid the platform.

Reference 7 presents results for the engine failure scenario in deep water. By comparison the shallow water track line has similar reach, but greater transfer away from the original track line. The minimum ship separation to the alternate platform is similar in both the deep and shallow water simulations; however, the ship clips the platform in shallow water. The primary effect of shallow water is greater transfer (3800 ft vs 3200 ft) away from the original track line before the tug reverses the ship’s course.

VLCC 320 DWT (Full load): Length= 1092.3 ft Beam= 196.8 ft Draft= 69.3 ft Disp= 348418 LT

SentinelMidstream - Engine Failure in Shallow Water, Initial Speed: -1 kts - w/ Wind, Waves or Currents

Time Delays: Failure Recognition = 60 sec. Tug Notification = 60 sec.



Ship, Tug and Towline to Scale
Positions highlighted every 60 seconds.
Last position plotted.
Engine or Steering Failure Occurs 704 ft. from 0,0

Ship is Green when Propulsion is On
Ship is Orange when Propulsion is Backing
Ship is Red when Propulsion is Off

Figure 3 - Shallow water engine failure

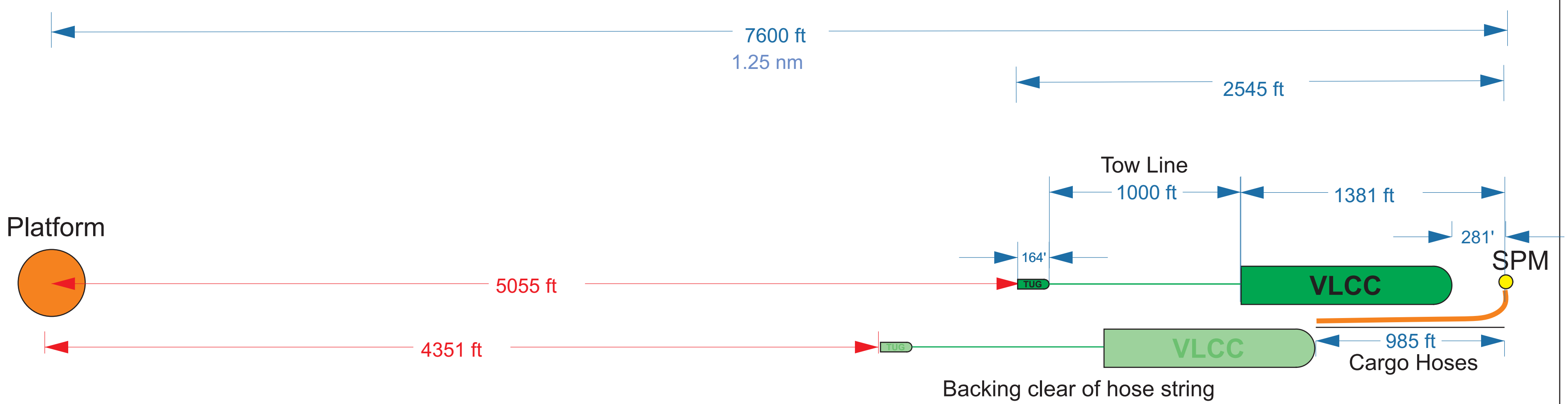
Appendix A – Port Layouts

Safe-Port-Design

minimum maneuvering distance

1.25 nm Distance SPM -> Platform

VLCC stern aligned with platform
unmooring with hoses unattended due seas



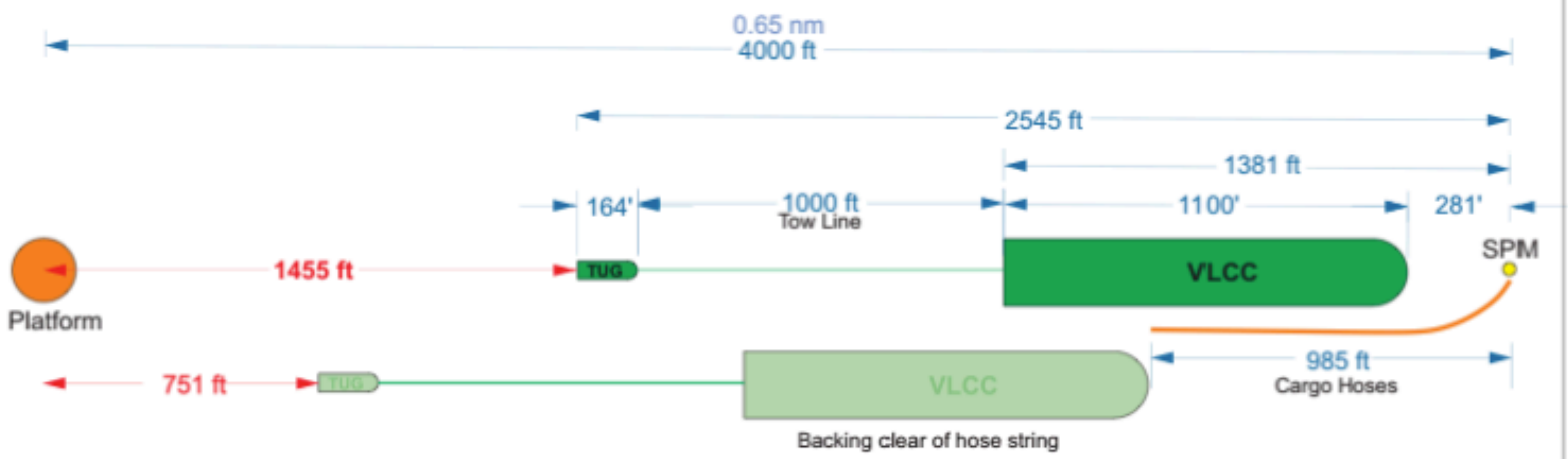
VLCC must back clear of the hoses floating in the water before turning to clear the SPM
when support boats cannot pull hoses clear in rough seas

VLCC	1100 ft
SPM R	19 ft
Buoy Offset	33 ft
Hawser Elongation	33 ft
Hawser	180 ft
76mm Chain	8 ft
Buoy Chain	8 ft
Tow Line	1000 ft
Tug	164 ft
	2545 ft

LEGEND		
Cargo Hoses	DRAWN BY: Captain Dan Harris	**TEXAS GULFLINK PROJECT**
	DATE: 9 May 2020	1.25 nm Port Layout Profile
	DWG NAME: Port layout 125	
0 400 800 1200 ft	SHEET of	REV: 01 REV DATE:
		SENTINEL MIDSTREAM

Port Layout - ABS minimum maneuvering distance

0.65 nm Distance SPM -> Platform
VLCC stern aligned with platform
unmooring with hoses unattended due seas



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	2545 ft

LEGEND

Cargo Hoses

0 200 400 600 ft

DRAWN BY: Captain Dan Harris	**TEXAS GULFLINK PROJECT**
DATE: 9 May 2020	0.65 nm Port Layout Profile
DWG NAME: Port layout 065	
SHEET of	REV: 01 REV DATE:
	SENTINEL MIDSTREAM