



TETRA TECH

June 12, 2026

Eng. Angel Soto Rodriguez
Sr. Engineering Project Mgr.
Molinos de Puerto Rico
PO Box 364948
San Juan, PR 00936

Subject: MV Beatrice – Recommendation for Berthing at Molinos de Puerto Rico

Dear Eng. Soto Rodriguez,

On May 1, 2026, Tetra Tech PR, LLC (Tetra Tech) issued the Final Certification for Dolphins M1, M2, M3, and M4 constructed at the Molinos de Puerto Rico facilities, certifying the completed construction activities and endorsing use of the berthing structures.

On June 12, 2026, Tetra Tech received a request to verify and certify whether the MV Beatrice can safely berth at the Molinos terminal.

Based on the vessel specifications provided for MV Beatrice (Appendix A), Tetra Tech hereby certifies that the MV Beatrice can be safely berthed at the Molinos Dolphins (M1, M2, M3, and M4) under normal operating conditions. The MV Beatrice is within the design parameters and criteria established for the berthing structures at Molinos de Puerto Rico. Appendix B contains the Dynamic Mooring Analysis conducted, which establishes the design parameters and criteria applicable to the Molinos Dolphin structures.

Should you require any further information or clarification, please do not hesitate to contact us.

Sincerely,

Fernando L. Pagés Rangel, PE, D. CE
Director, Principal Coastal Engineer
Tetra Tech PR, LLC

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APPENDIX A: MV Beatrice Specifications

MV BEATRICE specifications:

VESSEL DESCRIPTION

MV NAME: MV BEATRICE

IMO: 9865245

YEAR: 2019

FLAG: LIBERIA

CLASS: NKK - NIPPON KAJI KYOKAI

P&I: NOORD NEDERLANDSCHE P&I CLUB

LOA/BEAM: 182.87M / 31M

CRANES: 4X30.7T

HATCHES: 5HO/HA

GRT/NT: 24,332T / 12,403T

DWT/DRAFT/TPC: 39,278T / 10.15M / 51.54

GRAIN: 48,333.15 CBM

BEATRICE (9865245)

Vessel Specifications (from IHS)			
Vessel Name	BEATRICE	Vessel Type	Bulk Carrier
IMO#	9865245	Flag	LR/Liberia
Call Sign	D5SH7	Capacity	48,333 / 5 holds / 5 hatches
Year Built	2019	Draft	10.18 M
DWT	39,278 MT	Breadth (Moulded)	31.00 M
GRT	24,332 MT	Breadth (Extreme)	0.00 M
NRT	12,403 MT	LOA	182.87 M
TPC	52.20 MT/CM	Depth Moulded	14.50 M
TPI	20.55 MT/IN	Status	In Service/Commission

APPENDIX B: Dynamic Mooring Analysis for Molinos Terminal



DYNAMIC MOORING ANALYSIS FOR MOLINOS DOLPHIN REPLACEMENT, SAN JUAN

Proposal produced for
Tetra Tech, Inc. and Molinos de Puerto Rico



Revision – 0a

Produced by:
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No part of this document should be read in isolation or quoted in part in a manner inconsistent with the intent of the complete document. This document must be read as a whole.



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REVISION HISTORY

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1. EXECUTIVE SUMMARY

This dynamic mooring analysis has the main aim of providing design loads for the new breasting dolphins at the Molinos Terminal, San Juan Bay.

The largest vessel (63,000 DWT) known to have used the terminal is used in the dynamic simulations. Smaller vessels will result in lower loads on the dolphins (as was found in a previous study for the ADM dolphins). This vessel is analyzed in three positions:

- to the south, loading all four new Molinos dolphins
- to the north, loading two ADM and two Molinos dolphins, and
- central, loading two Molinos and one ADM dolphin.

The load cases presented in this report show a maximum dynamic fender load of 176 kips. However, the cases presented are well balanced, in that the ship and its mooring lines are positioned intelligently to minimize likely fender loads. Other cases have been investigated for the same size vessel where the ship puts higher loads on individual dolphins. The highest fender load with a poorly moored 63,000 DWT bulker was found to be 200 kips. Thus **200 kips has been given as the maximum design load for the dolphins. This is an unfactored load.**

The maximum fender loads for each condition analyzed are reported in Sections 15, 16, and 17.

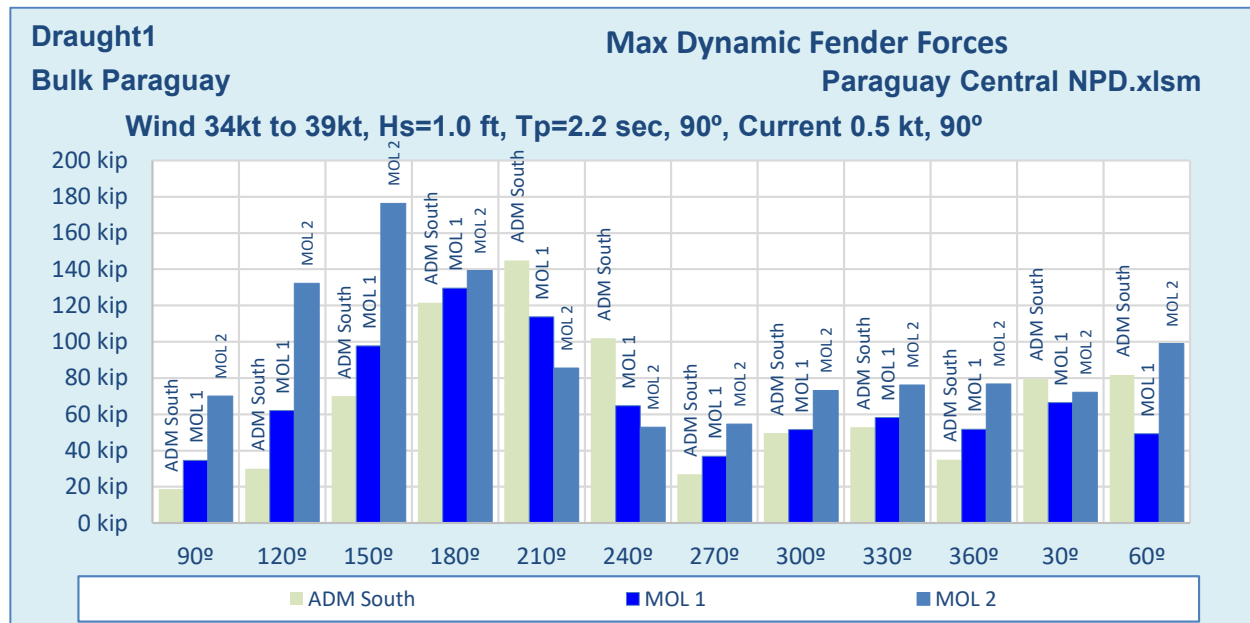


Figure 1 – Max Fender Forces, 63,000 DWT Bulker, Central

The load cases with the 176 kips maximum fender load are summarize in Figure 1, above.

The maximum bollard loads are reported in Figure 31, Figure 36, and Figure 40.

The maximum mooring line tensions are reported in Figure 30, Figure 35, and Figure 39.

2. INTRODUCTION

This document presents a dynamic mooring analysis for the Molinos Breasting Dolphin Replacement Project. Tetra Tech recommend replacing the existing five pile cluster dolphins with four new steel pile dolphins with concrete pile caps, almost identical to those recently designed for the adjacent ADM terminal. The arrangement is shown in Figure 2 below.

From recent experience with dynamic mooring analysis at the ADM terminal, the largest vessel at the Molinos terminal will cause the largest design loads on the fenders and dolphins. In some cases, the mooring loads (including fender loads) will be shared by the new ADM dolphins.

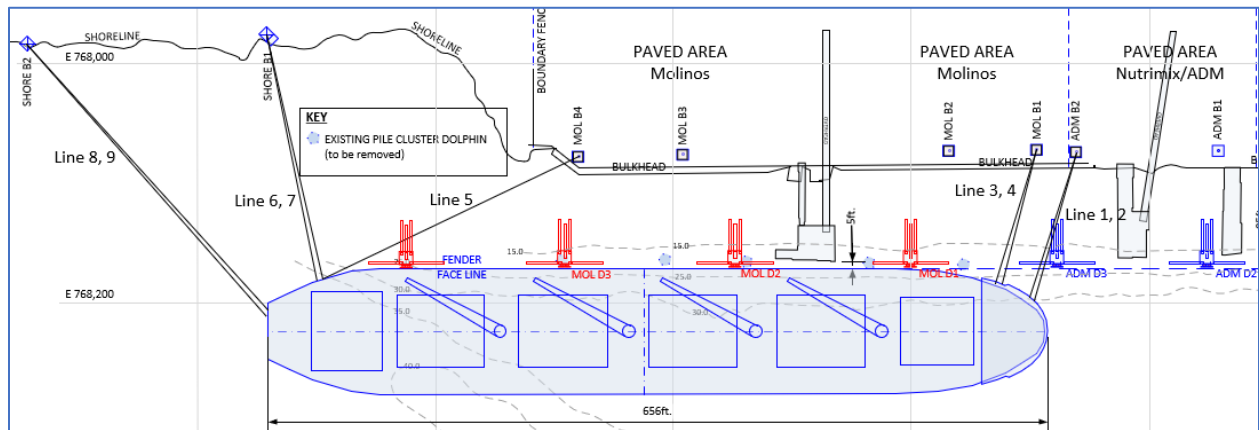


Figure 2 – Mooring Condition with 65,000 DWT Bulker to the South

All four new Molinos dolphin fenders have contact with the ship side in Figure 2.

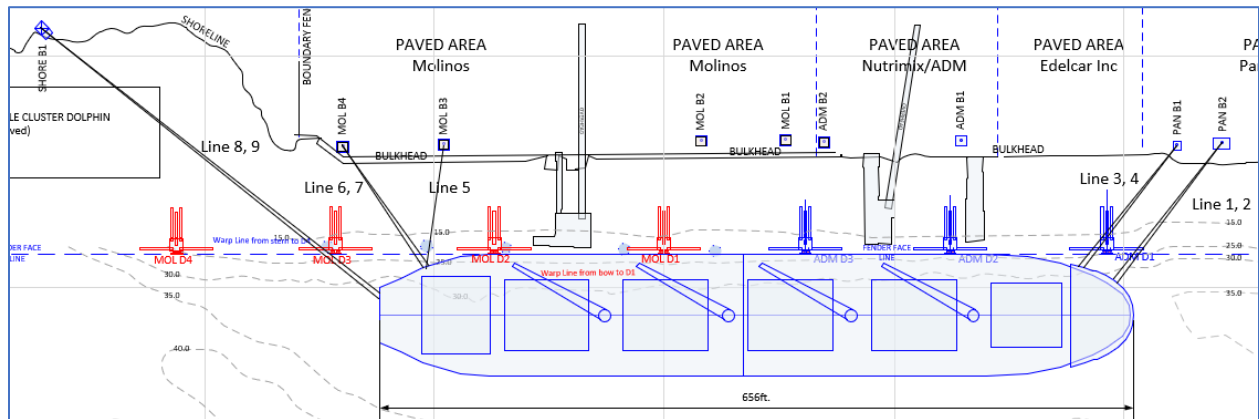


Figure 3 – Mooring Condition with 65,000 DWT Bulker to the North

In Figure 3 the vessel is too far north for fenders on the new Molinos dolphin MOL D2 to make contact with the ship side. Only the fenders on the three dolphins MOL D1, AMD D3, and AMD D2 have contact with the ship's side. This results in the highest load case for the new Molinos dolphin MOL D1. The vessel can be moved aft to get load sharing on four dolphins (see Section 18.2).

Various vessel sizes, all limited to 23 ft draft, are analyzed in various north- south positions along the terminal.



In each case the fender and bollard forces are reported in a 50-year return period wind spectrum with associated waves and currents, are reported.

This mooring analysis conforms to the requirements of the most recent relevant OCIMF and PIANC guidelines, codes and standards.

3. LOCATION PLAN

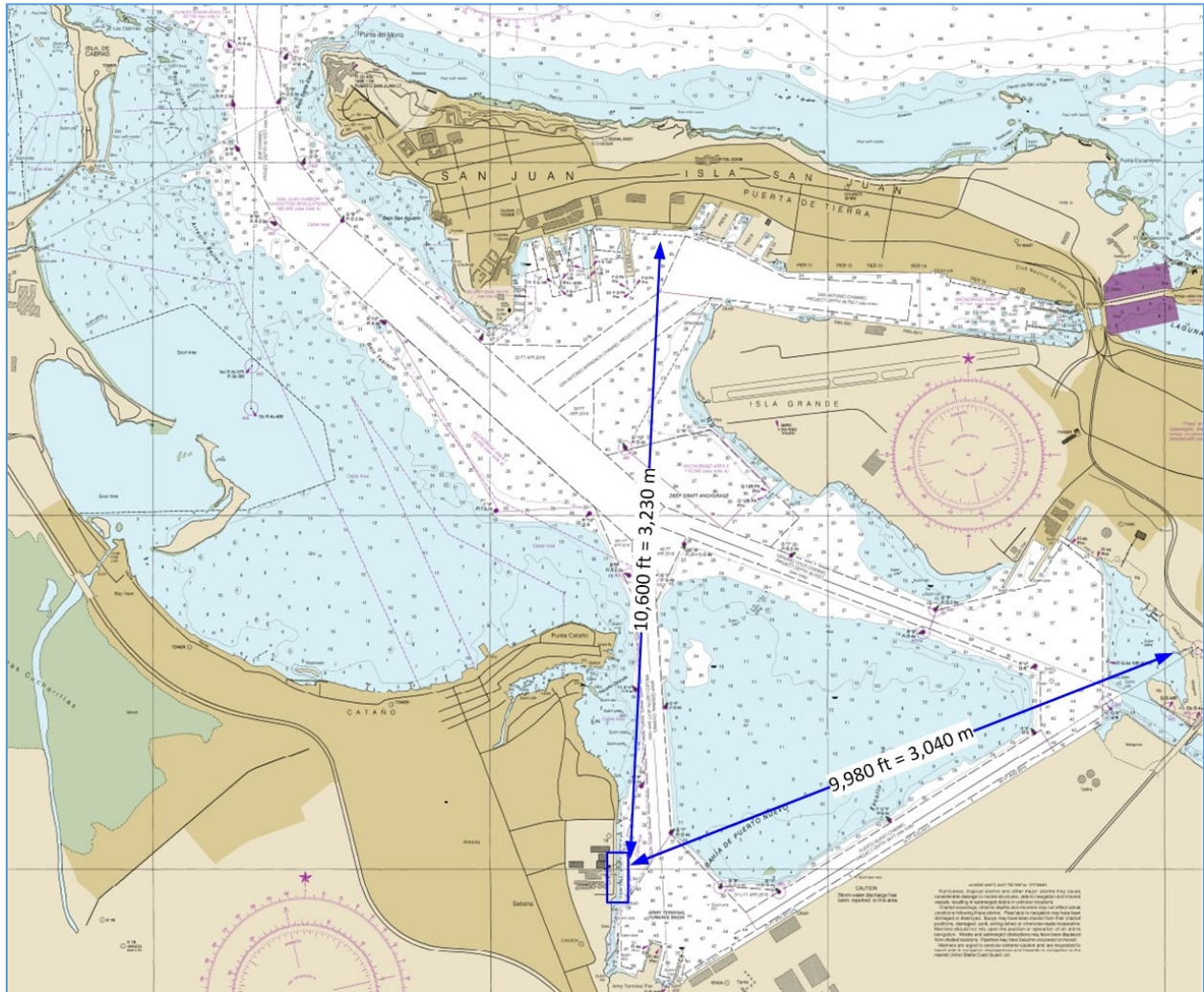


Figure 4 – Project Location Showing Fetch Distances to North and ENE

4. VESSEL SIZES AT TERMINAL

A draft limitation of 23 feet is imposed on vessels berthing at the ADM terminal. Eight of the vessels that have visited the terminal are shown below. The larger vessels cannot be fully laden owing to the draft limitation. The last column in Table 1 shows the approximate maximum deadweight that can be on board with the limiting draft at the terminal. The load line drafts, and fully loaded deadweights are also shown for information.

Name	LOA	B	Depth	Summer Draft	Limiting Draft at Molinos	Disp. at Molinos Draft	DWT at Summer Draft	Approx. DWT at Molinos Draft
UBC Tampico	599 ft	93.8 ft	49.2 ft	35.7 ft	23.0 ft	44,251 MT	37,821 MT	29,360 MT
CS Calvina	620 ft	93.5 ft	49.5 ft	34.1 ft	23.0 ft	43,824 MT	37,456 MT	29,362 MT
UBC Hamburg	585 ft	91.2 ft	51.2 ft	35.8 ft	23.0 ft	42,028 MT	35,921 MT	28,421 MT
Papua	580 ft	96.5 ft	44.3 ft	31.3 ft	23.0 ft	37,226 MT	31,817 MT	29,054 MT
MV Latika Naree	594 ft	98.4 ft	45.0 ft	32.2 ft	23.0 ft	39,627 MT	33,869 MT	29,371 MT
MV Federal Yukina	656 ft	78.0 ft	48.7 ft	35.6 ft	23.0 ft	41,945 MT	35,850 MT	25,459 MT
MV Cygnus	600 ft	105.8 ft	56.3 ft	39.9 ft	23.0 ft	59,459 MT	50,820 MT	35,223 MT
MV Bulk Paraguay	656 ft	106.1 ft	62.8 ft	44.0 ft	23.0 ft	74,249 MT	63,461 MT	36,430 MT

Table 1 - Vessel Characteristics and Maximum Drafts & Deadweights at Molinos

Bulker normal ballast displacement conditions are generally in the range of 40% to 50% of full displacement conditions. The resulting drafts in ballast conditions result in the largest freeboards and hence largest wind areas for the vessels.

5. WATER DEPTHS, MAXIMUM DRAFTS, & TIDES

The water depth is set to be 24' at the dolphins, which is modelled as the OrcaFlex seabed origin. The seabed slopes up to the shoreline at the bulkhead slopes down on the east side of the dolphins. The 30-ft (at MLLW) depth contour is around 40 feet away from the dolphin's east faces. Beyond the 30-ft contour the local seabed levels out at about 33-ft depth. All vessels at the ADM terminal enter and leave Puerto Nuevo Bay via the Army Terminal Channel, which has a 40-ft depth.

Bathymetry data was supplied in file 3956-3881-Molinos-HYDRO-VF-2 4.pdf on August 8, 2023. The water depth contours for 15', 25', 30', 35' and 40' were copied by hand onto the STA VISIO drawings of the site and are shown on the plan view drawings in this proposal. It is assumed that the depths are relative to MLLW.

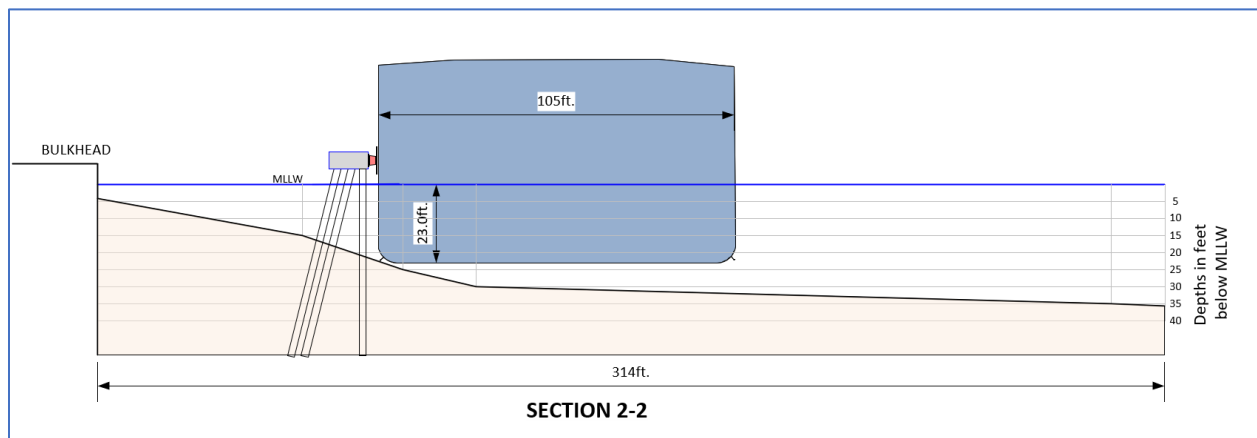


Figure 5 – Cross Section 2-2 Showing Water Depths at Proposed New Molinos North Dolphin

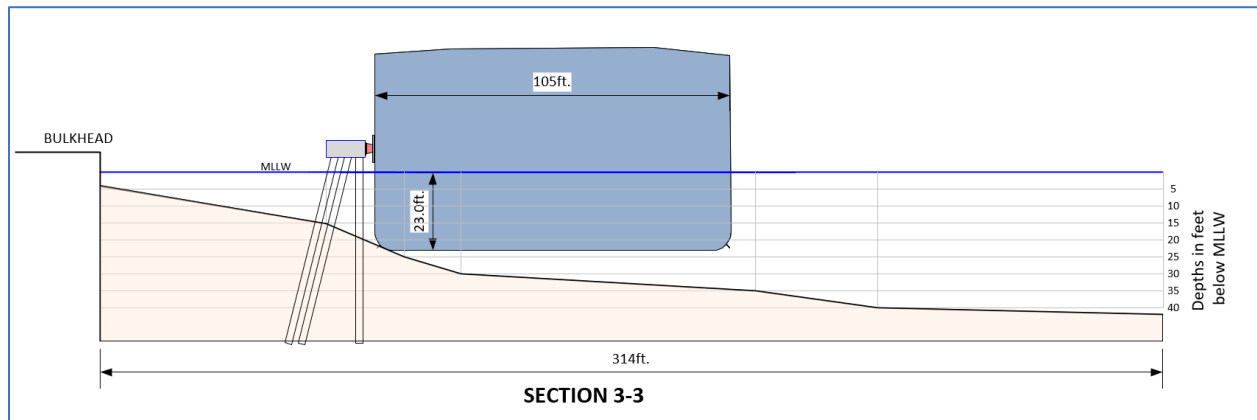


Figure 6 – Cross Section 3-3 Showing Water Depths at Proposed New Molinos South Dolphin

Cross sections were made by hand assuming linear depth slopes between contours.

The closest seabed interference at MLLW is seen at Section 3-3 and is shown in the enlarged view in Figure 7. The bilge keel is shown entering what is expected to be soft mud. It is expected that the soft mud will be disturbed, and the vessel motions will be virtually unchanged.

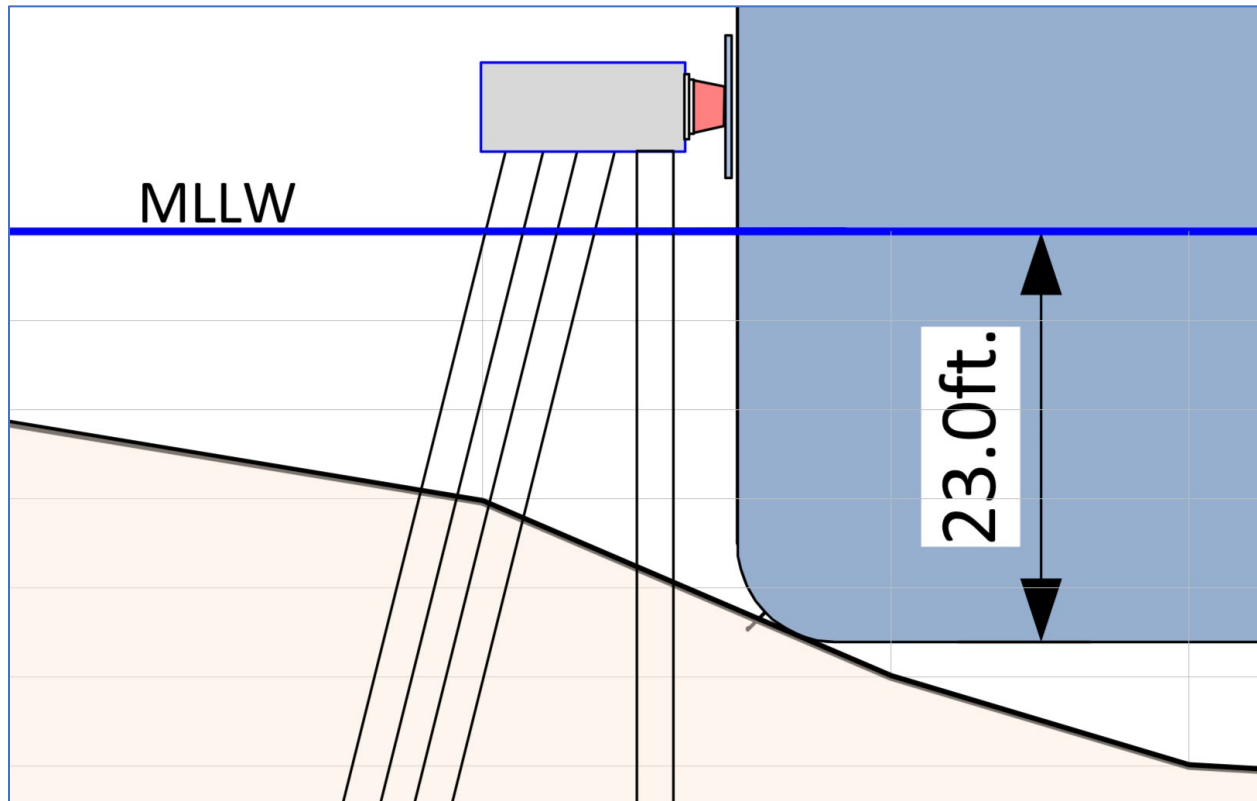


Figure 7 – Typical Bilge Keel of Typical 63,000 DWT Bulker Enters Interpreted Sea Bed, Section 3-3

The 24' water depth is used for all the wave theory calculations. For nonlinear waves in particular, in shallow water, the form of the wave is heavily dependent on the water depth.

The maximum vessel draft is 23 feet and is specified by Molinos.

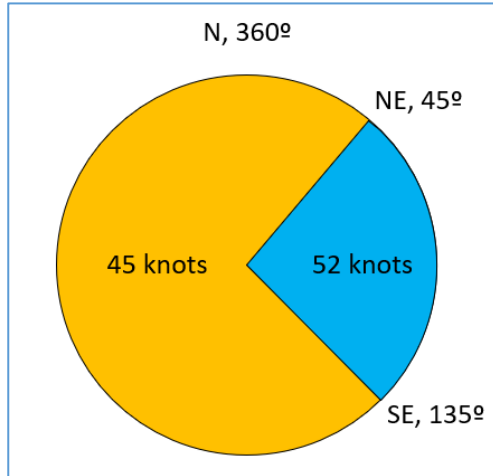
The tidal range between MLLW and MHHW is less than 2 feet. All mooring analysis is performed at MLLW.

See Section 18 for larger drawings and location of the cross sections in Figure 5 and Figure 6

From the cross section drawings, it is seen that the 23-ft draft appears to be workable using the supplied bathymetry.

6. WIND SPEEDS

The 50-year wind speed selected for the mooring analysis is 52 knots (or 60 mph) from the east and 45 knots for other directions as shown in the figure below. A detailed derivation of these wind speeds is provided (from a previous analysis for the site by STA) in Appendix 1.



The 52 knot wind speed corresponds to a 30-second gust (or 30-second averaging time) at a standard height of 10 m (or 33 feet) and with a 50-year MRI (Mean Recurrence Interval) based on 20 years of hourly wind speed measurements at the site.

Figure 8 – Mooring Design Wind Speed and Directions

6.1. Wind Spectra

For all critical conditions, a time domain simulation with fluctuating wind modeled by a steady component, based on the 1-hour average velocity, plus a time-varying component calculated from a suitable empirical wind gust spectrum (API, NPD or ESDU) is performed.

The 1-hour wind speed is equal to the 30-second wind speed divided by 1.32. The wind speeds input to OrcaFlex are shown in the table below.

OrcaFlex	30-sec wind	30-sec wind	1-hr wind
Set Wind Speed1	52.00 kt	87.8 ft/s	66.5 ft/s
Set Wind Speed2	45.00 kt	76.0 ft/s	57.5 ft/s

Table 2 - Input to OrcaFlex Wind Spectrum is the 1-hr Wind Speed

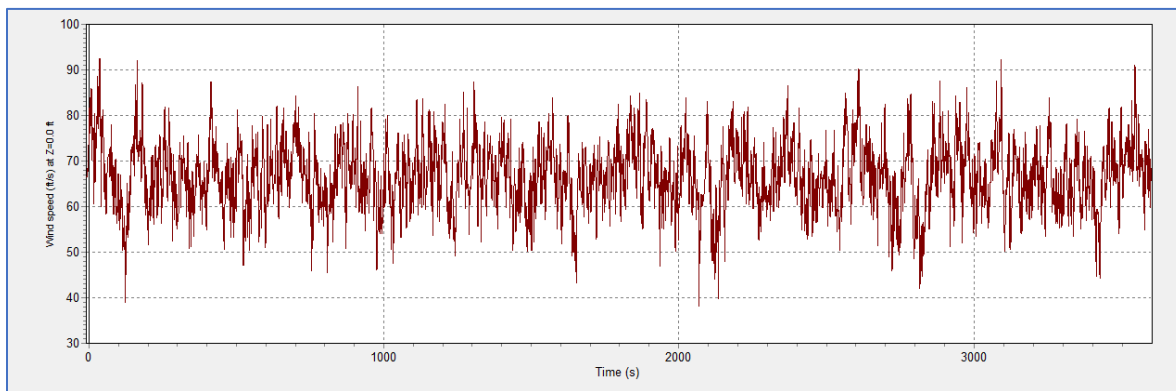
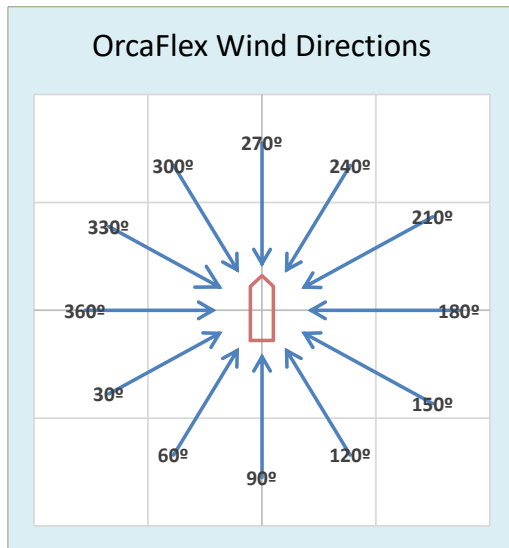


Figure 9 Time History of Wind Speed with 66.5 ft/sec Mean Value

The 30-second gust speed is reached or exceeded on around 13 occasions in 3600 seconds.

6.2. Wind Directions



In this mooring analysis the vessel is typically headed towards the north and along the OrcaFlex y-axis, which is at a heading of 90° in the OrcaFlex coordinate system.

The load cases specify wind directions towards which the wind is blowing in the OrcaFlex coordinate system. A wind blowing towards 90° in OrcaFlex is blowing towards the stern of the vessel, and is blowing towards the north, or towards 360°N.

A wind blowing towards 180° OrcaFlex is blowing towards 270°N, or towards the west, and is coming from the east.

Figure 10 – OrcaFlex Wind Directions with Vessel Headed towards OrcaFlex 90°

7. CURRENTS

Currents are very small and will be modelled as 0.5 knots aligned within ±15° of the berth flowing from south to north.

8. WAVES

Waves at the terminal are generated by local winds. The maximum fetch is 2.9 km from 56° N. The characteristics of these locally generated waves are calculated by methods and equations described in the Coastal Engineering Manual (Reference 15). The Excel application STA WAVEGEN, illustrated in Figure 11, below, is used to make the calculations.

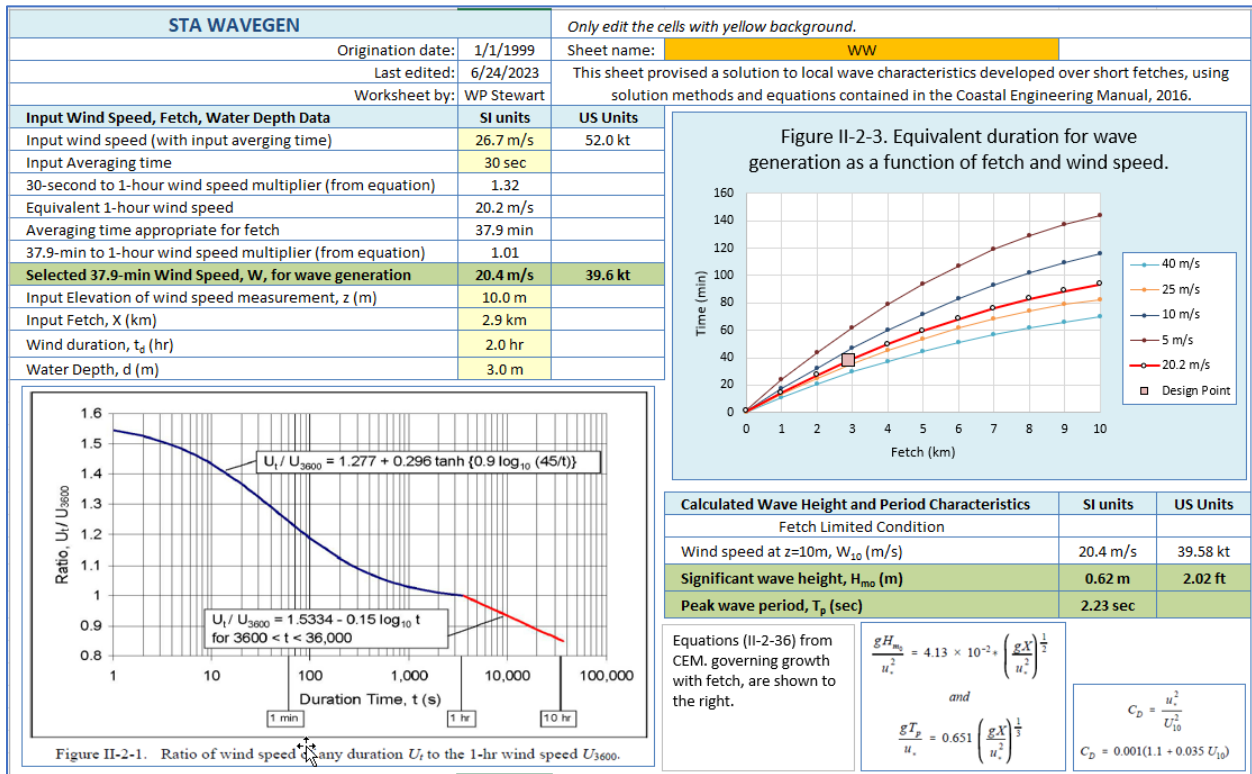


Figure 11 - STA WAVEGEN Showing Wind-Driven Wave Calculations

The wind speed of 52 knots for the mooring analysis (see Appendix 1) is input. The averaging time for the wind speed is 30 seconds. The program calculates a multiplier on the 52-kt 30-second wind to find a 1-hour wind speed. The 1-hour wind speed (of 20.4 m/s) is drawn on the active chart on Figure 11, which is taken from Figure 11-2-3 in Reference 15.

STA WAVEGEN then finds the appropriate averaging time to use for the wind speed used in the wave height and period calculations. In this case the appropriate averaging time, based on a 2.9-km fetch, is 39 minutes and the resulting wind speed is 20.4 m/s (39.6 kt).

The resulting significant wave height, H_s, and peak energy period, T_p, are 2.02 ft and 2.23 seconds.

The waves will not be simulated when the wind is from the western sector. When the wind is from the northeastern sector the wave direction will be from 56°N. When the wind is from the southeastern sector the waves will be from 30°N.



9. LOAD CASES ANALYZED

For the final agreed dolphin layout, time domain dynamic mooring analyses is performed with wind, waves and currents (defined in Sections 6, 7, and 8). The runs simulate up to 3 hours of environmental conditions.

For each environmental condition (maximum allowable draft and corresponding displacement) dynamic wind forces (using spectra) are applied in directions from zero degrees to 330° in steps of 30°. The waves and current are as defined in Sections 7 and 8.

Case ->	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8
Wind, Waves, Current - Group	Wind 34kt to 39kt, Hs=1.0 ft, Tp=2.2 sec, 90°, Current 0.5 kt, 90°							
Wind Direction towards °N	359°N	330°N	300°N	270°N	240°N	210°N	180°N	149°N
Wind Speed	34 kt	34 kt	39 kt	39 kt	39 kt	34 kt	34 kt	34 kt
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°	270°	300°
Wind Spectrum	NPD spect	NPD spect	NPD spect	NPD spect	NPD spect	NPD spect	NPD spect	NPD spect
Current Speed	0.5 kt	0.5 kt	0.5 kt	0.5 kt	0.5 kt	0.5 kt	0.5 kt	0.5 kt
Current Direction	90°	90°	90°	90°	90°	90°	90°	90°
Wave Type	JONSWAP	JONSWAP	JONSWAP	JONSWAP	JONSWAP	JONSWAP	JONSWAP	JONSWAP
Hs, Sig Wave Height	1.0 ft	1.0 ft	2.0 ft	2.0 ft	2.0 ft	1.0 ft	1.0 ft	0.0 ft
Tp, Wave Peak Period	2.2 sec	2.2 sec	2.2 sec	2.2 sec	2.2 sec	2.2 sec	2.2 sec	2.2 sec
Tz, zero crossing Period	1.58 sec	1.58 sec	1.58 sec	1.58 sec	1.58 sec	1.58 sec	1.58 sec	1.58 sec
Wave Direction	90°	120°	150°	180°	210°	240°	270°	300°
Loaded Condition	Draught1	Draught1	Draught1	Draught1	Draught1	Draught1	Draught1	Draught1

Table 3 – First 8 out of 12 Load Cases

10. FENDER CONSIDERATIONS

The same fenders as designed for the adjacent ADM breasting dolphins are used in the dynamic mooring analysis.

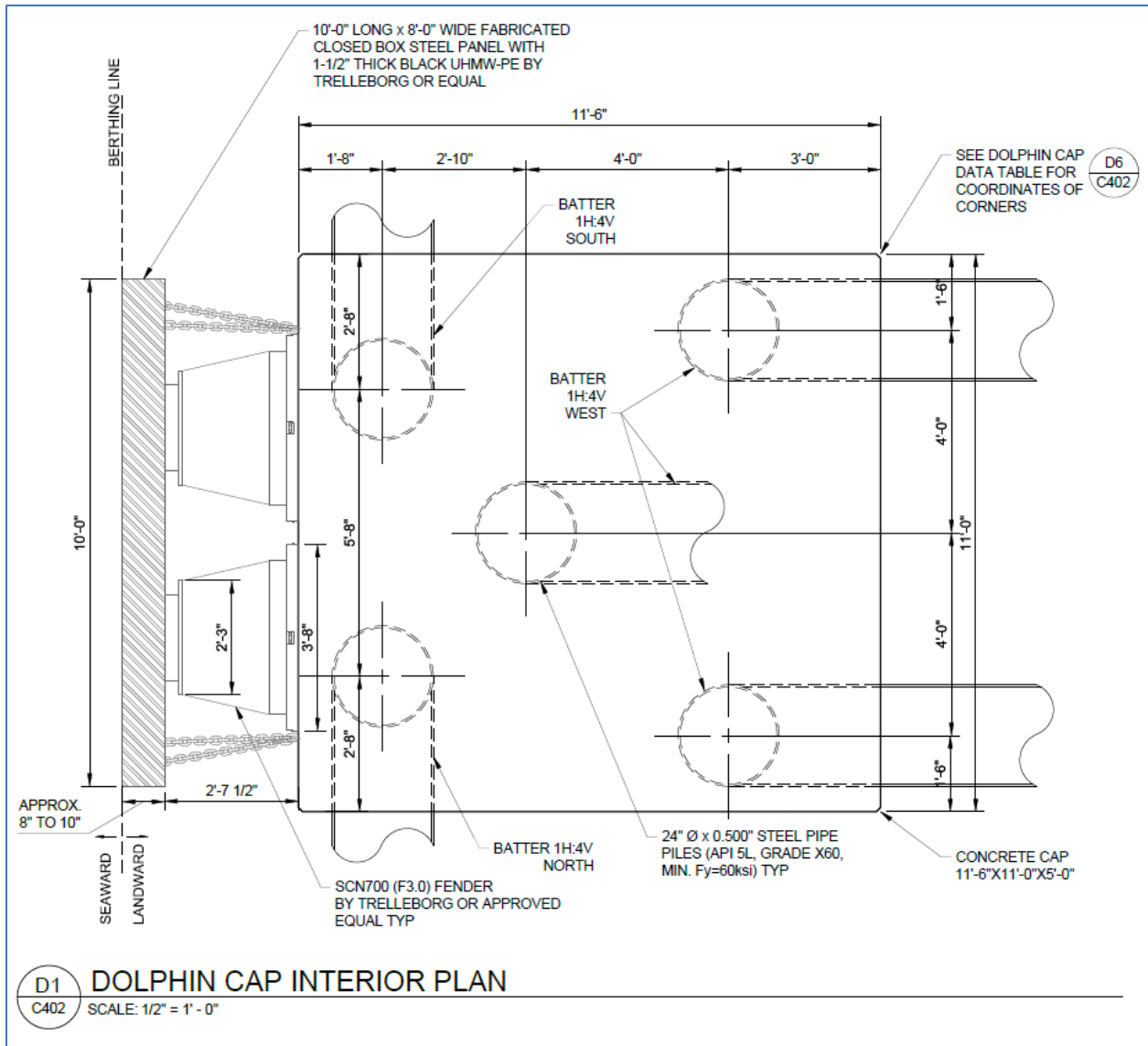


Figure 12 – Arrangement of Fenders on East Faces of Dolphins from Tetra Tech Drawing C401, 2024

10.1. Dolphin Fenders and Stiffnesses

The non-linear load-deflection curves of the new fenders (Trelleborg SCN 750 F3.1 x 2) are shown in Figure 13. Also shown in Figure 13 is a load deflection curve for the fender with the likely maximum elastic deflection of the dolphin structure in the seabed soil. This is estimated to be 1364 kips/ft, or 114 kips/in, which is around 3 times the combined initial stiffness of the dual SCN 200 F3.1 cone fenders. The effect of using the combined softer *dolphin + fender* stiffness on either increasing or reducing fender reactions is checked for all load cases.

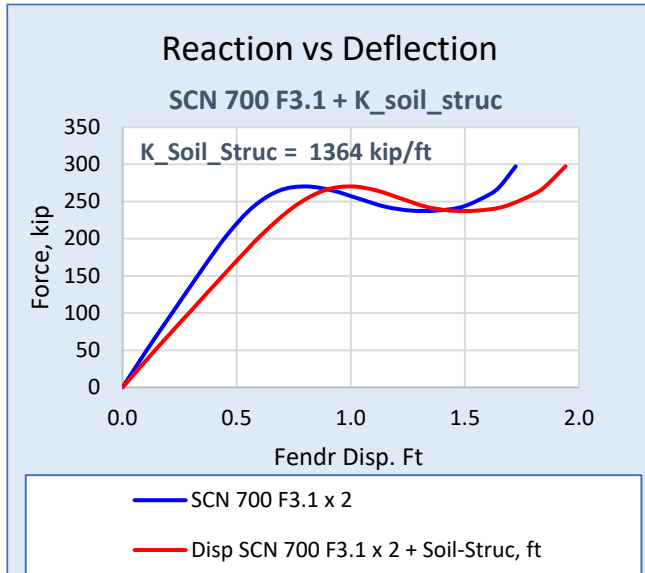


Figure 13 – OrcaFlex Fender Force-Deflection Curves

Both curves need to be modelled beyond the maximum force and deflection values shown in Figure 13 to enable OrcaFlex to find initial static equilibrium values. Maximum final dynamic values fall within the ranges shown in Figure 13.

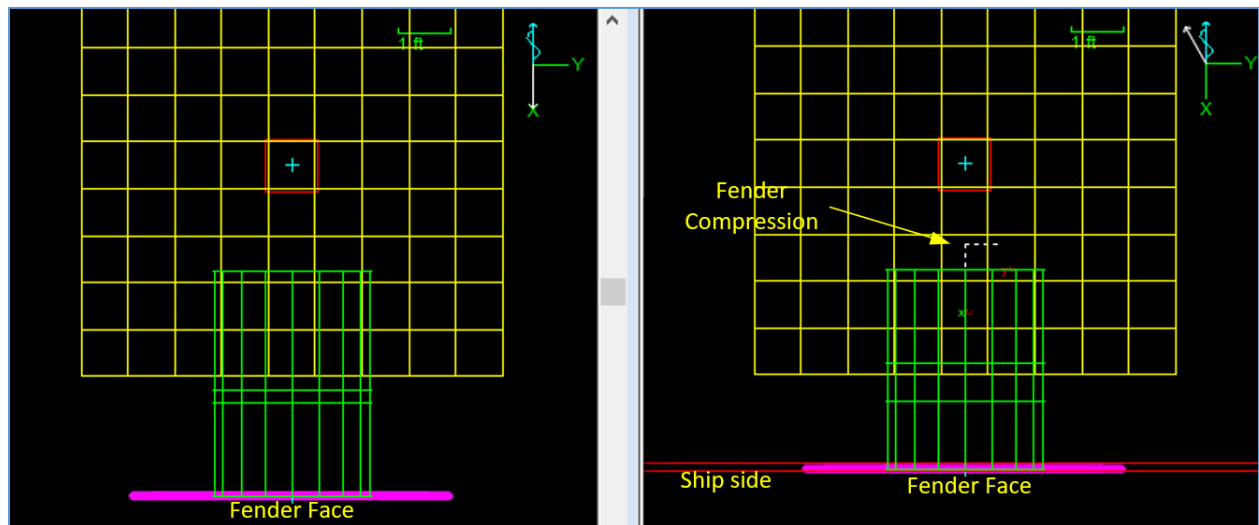


Figure 14 – Two Close Plan Views of Fender, Left is Unloaded, Right is Loaded by Ship Side

Figure 14 shows details of the OrcaFlex fender models, using OrcaFlex line drawings (as opposed to shaded graphic perspective drawings). The amount of fender compression is indicated graphically by the broken white line, indicating movement of the fender constraint element. A single OrcaFlex fender model represents the load-stiffness properties of the two SCN 700 F3.1 cone fenders.

11. BREASTING DOLPHINS

The same breasting dolphins as designed for the adjacent ADM terminal are used in the dynamic mooring analysis. The structural design is presented elsewhere.

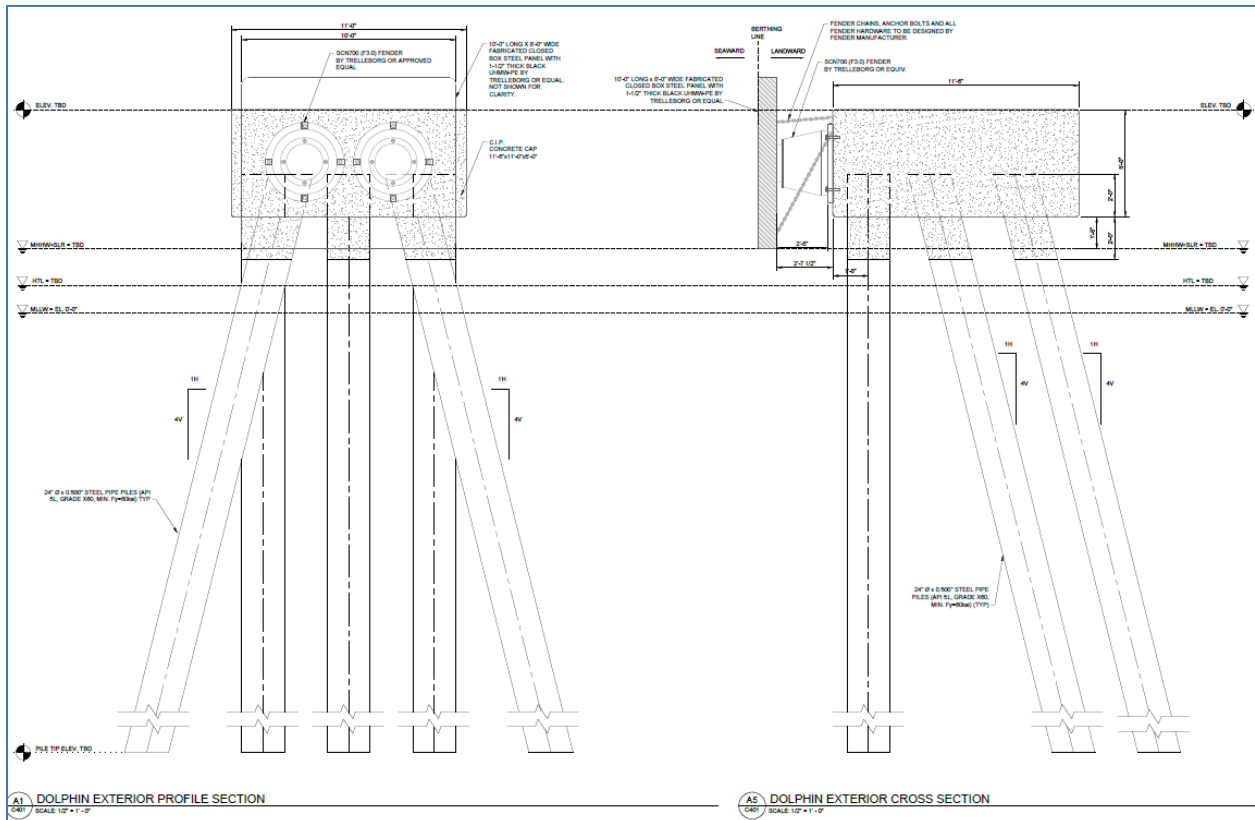


Figure 15 – Concrete Dolphin Exterior Sections from Tetra Tech Drawing C401 Sheet 8 of 9, 2024

The uniform design of all seven Molinos and ADM dolphins and fenders, with the same fender face line, or berthing line, is important for optimum equalization of mooring loads when berthed vessels share dolphins from both companies. This condition is illustrated in Figure 3.

12. MOORING LINE MATERIAL AND ELASTIC PROPERTIES

Typical polyester mooring lines are simulated, generally with an elastic stiffness (AE value) of 1300 kips, representative of a used 2.5" line with around 75 MT MBL (Minimum Break Load). For each set of simulations, the lines lengths are adjusted to achieve around 5 kips of pretension with no environmental load. This mooring preload pulls the vessel onto the fenders.

13. WIND & CURRENT FORCE AND MOMENT COEFFICIENTS

The tabular input and results tables that follow provide the wind and current force and moment calculations for each vessel using the methods of UFC-4-159-03 MOORINGS (Reference 3). Similar forces and moments are produced by the methods of OCIMF MEG4 (Reference 5) although the OCIMF method is intended for oil tankers, not bulk carriers.

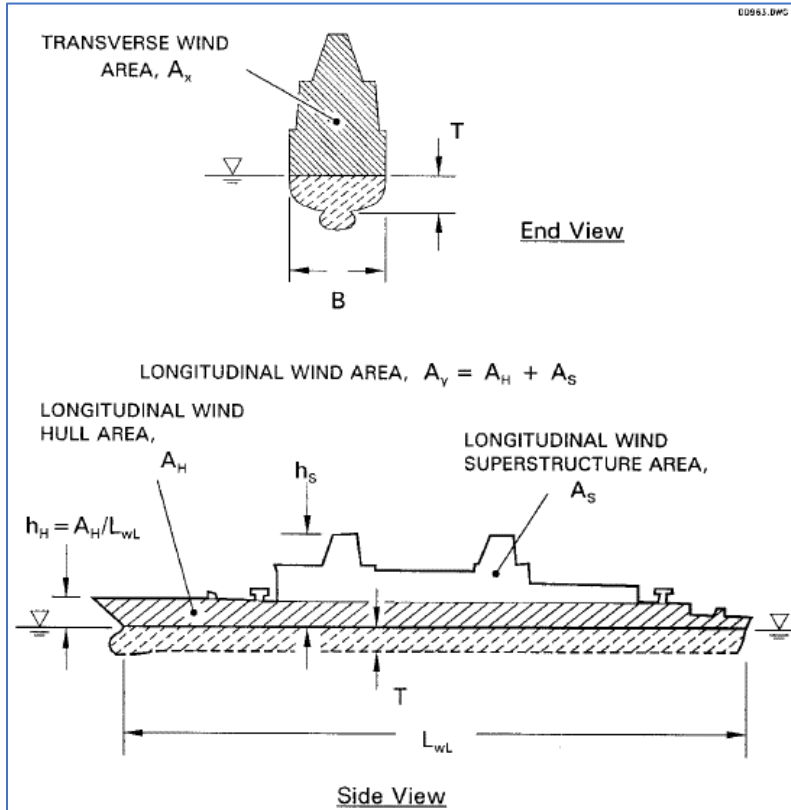


Figure 16 – Wind Area Definitions from Reference 3

Terms defined in Figure 16 are used in the tables that follow for wind force calculations.

Note that the UFC wind force calculation method uses the lateral wind force coefficient C_{yw} , shown below.

$$C_{yw} = C * \left[\left(\frac{0.5(h_s + h_H)}{h_R} \right)^{2/7} A_S + \left(\frac{0.5 * h_H}{h_R} \right)^{2/7} A_H \right] / A_Y$$

Where h_R is the reference height of the wind speed, as described in Appendix 1, and other terms are shown in Figure 16. Other mooring codes use height coefficients to account for the vertical wind speed profile.

13.1. Bulk Paraguay, Wind & Current, 23.0' Draft

Drawings for the vessel with some of the principal dimensions are shown below.

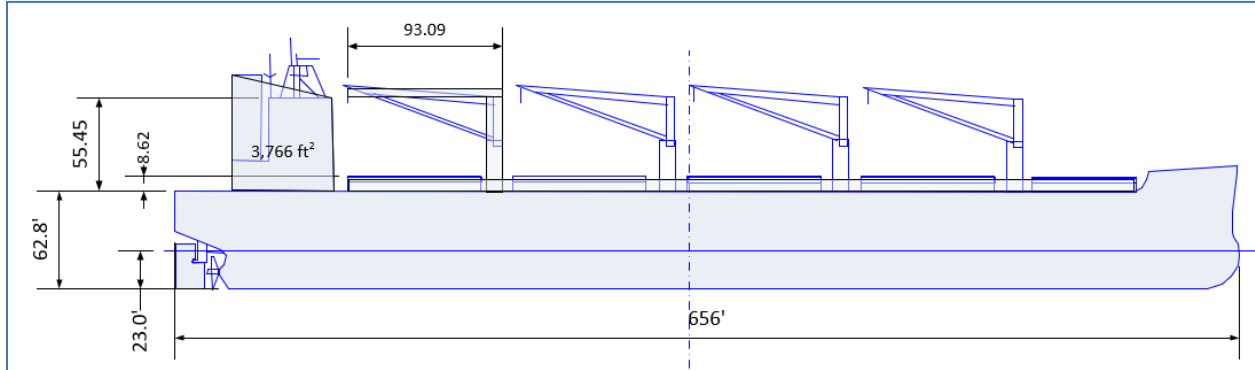


Figure 17 – Bulk Paraguay Side View, 23' Draft

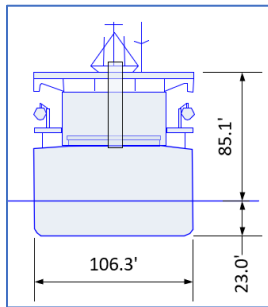


Figure 18 – Bulk Paraguay End View

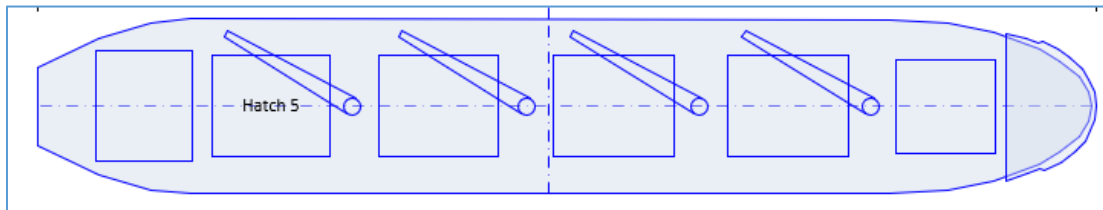


Figure 19 – Bulk Paraguay Plan View

Side Area Component	Length	height	area, A	LCA from Midships	VCA above Orca Center	Cs	Ch	F
A _H , Hull above water	656.00 ft	39.83 ft	26127 ft ²	0.0 ft	11.5 ft	0.90	1.00	214.91 kpf
Hatch and focsle area	533.00 ft	7.20 ft	3838 ft ²	61.5 ft	35.0 ft	0.90	1.00	31.57 kpf
Deck house, Stack			3766 ft ²	-245.0 ft	66.4 ft	1.20	1.00	41.30 kpf
Gantry Crane booms	372.00 ft	5.10 ft	1897 ft ²	-4.0 ft	89.4 ft	1.20	1.00	20.81 kpf
Gantry Crane Columns	38.00 ft	56.00 ft	2128 ft ²	48.0 ft	59.4 ft	1.00	1.00	19.45 kpf
			37756 ft²	-22.34 ft	28.46 ft	(force based)		328.04 kpf
			3508 m²	-15.68 ft	25.98 ft	(area based)		149 MTF
A _S , Area Superstructure			11629 ft²	-64.77 ft	60.68 ft			113.13 kpf

Table 4 – Bulk Paraguay Lateral Wind Area Calculations, 23' Draft



Bulk Paraguay		Wind Areas and Forces (UFC 4-159-03 March 2020)				Last Edit:		4/16/2022	
Bulk Paraguay		<Vessel Name	ADM Dolphins		<Project	Excel app developed by W.P. Stewart, C.Eng., D.OE, Stewart Technology Associates			
V _w	26.7 m/s	< Wind speed for charts	Sheet name->	Bulk Paraguay UFC	ρ _a =	1.280 kg/m ³	γ _a =	11.978 N/m ³	
F _{yw}	$F_{yw} = 0.5 \rho_a V_w^2 A_y C_{yw} f_{yw}(\theta_w)$		UFC Eqn. 4-0	V _w specified =	52.00 kt	$F_{xw} F_{xw} = 0.5 \rho_a V_w^2 A_x C_{xw} f_{xw}(\theta_w)$			
C _{yw}	$C_{yw} = C^* \left[\frac{((0.5(h_s + h_H)) / h_R)^{2/7} A_s + (0.5 * h_H / h_R)^{2/7} A_H}{A_Y} \right]$		UFC Eqn. 4-2		C _{xw}	Calculated below with UFC eqn.			
Lateral Wind Forces			Longitudinal Wind Forces			Longitudinal Single test angle area below			
L _{OA}	199.9 m		A _x	837 m ²	Trans. Area	θ _w ^o Selected	160 ^o	Fx Negative	
Variable	No Blockage	w/Pier Blockage	Select Ship Type for C, C _{xwB} & C _{xwS}			CASE I: Sing. Distinct Supstruct. & Hull Dominated			
A _H	2427 m ²	2054 m ²	Hull Dominated			φ ⁻ for θ _w < θ _x	17561.0		
A _S	1080 m ²	1080 m ²	C selected	C _{xwB} Selected	C _{xwS} Selected	φ ⁺ for θ _w > θ _x	170.0		
A _Y	3508 m ²	3134 m ²	0.82	0.40	0.40	f _{xw} (θ _w)	-0.98		
L _{WL}	199.9 m	199.9 m	Select Superstructure Case (Case I or Case II)			C _{xw} f _{xw} (θ _w)	-0.39		
h _H	12.14 m	10.27 m	Case II: Distributed Superstructure			CASE II: Distributed Superstructure			
h _S	28.9 m	26.9 m	Select Location of SuperStruc.	θ _x ^o		γ ⁻ for θ _w < θ _x	17651.0	0.12	
h _{ref}	10.0 m	10.0 m	Aft of midships (tankers)		80 ^o	γ ⁺ for θ _w > θ _x	260.0	-1.02	
C	0.92	0.92	Click on bright yellow cells and select variables from drop-down lists.			f _{xw} (θ _w)	-1.02		
C _{yw}	0.900	0.877				C _{xw} f _{xw} (θ _w)	-0.41		
Longitudinal Wind Force Coefficients									
Ship Superstructure Type		Notes and Examples				C	C _{xwB}	C _{xwS}	
Hull Dominated		aircraft carriers, submarines, passenger liners, drydocks, LHA/LHD				0.82	0.40	0.40	
Typical, or "normal" military. See Note a, to right		ships with moderate superstructure. Note a: an adjustment of up to +0.10 to C _{xwB} and C _{xwS} should be made to account for significant cargo or cluttered decks				0.92	0.70	0.60	
Center-Island Tankers. See Note a, to right		Note a: an adjustment of up to +0.10 to C _{xwB} and C _{xwS} should be made to account for significant cargo or cluttered decks				0.9	0.80	0.60	
Extensive Superstructure		destroyers, cruisers				1.02	0.70	0.80	
Max Wind Force and Moment Values for cases without and with pier blockage, from 0 ^o to 180 ^o									
26.7 m/s	Wind Speed	Max F _{xw}	Min F _{xw}	Max F _{yw}	Min F _{yw}	Max M _{xyw}	Min M _{xyw}		
	Without Pier Blockage	33.24 MT	-29.08 MT	147.8 MT	0.0 MT	4537 MT.m	-2431 MT.m		
	With Pier Blockage	33.24 MT	-29.08 MT	128.7 MT	0.0 MT	4054 MT.m	-2172 MT.m		

Table 5 – Bulk Paraguay Wind Load Calculations, 23’ Draft, Part 1

Maximum wind forces and moments are shown for the selected 26.7 m/s (52 kt) wind speed in the last three rows of the above table. Note that 1 MT = 2,205 lbf.

Note that there are reduced coefficients and reduced areas when accounting for pier blockage. However, the full areas and forces were conservatively used in the analysis.



Wind Areas and Forces (UFC 4-159-03 March 2020)			
<i>Only edit yellow cells. Refer to UFC 4-159-03, March 2020, for details.</i>	File name->	Force_Coefficients_Rev13.xls	
$\rho_w =$	1025 kg/m ³	$v =$	0.000015 m ² /s
M_{xyw}	$M_{xyw} = 0.5 \rho_a V_w^2 A_y L C_{xyw} (\theta_w)$		
Yaw Wind Moments			
$\lambda = 180/(180 - \theta_z)$	3.600	No Blockage	Pier Blockage
$C_{xyw} (\theta_w) \quad 0 < \theta_w < \theta_z$	0.086	$A_y L_{OA}$	$A_y L_{OA}$
$C_{xyw} (\theta_w) \quad \theta_z < \theta_w < 180$	0.024	701350 m ³	626683 m ³
Select Ship Type	θ_z selected	a1 selected	a2 selected
Others: stern superstructure	130 ^a	0.130	0.025
Ship Type	Zero Moment Angle, θ_z	Negative Peak, a1	Positive Peak, a2
Liner	80	0.075	0.140
Carrier	90	0.068	0.072
Tanker, center island, cluttered deck	95	0.077	0.070
Tanker, center island, trim deck	100	0.085	0.040
Cruiser ^a , outdated	90	0.064	0.050
Destroyer	68	0.020	0.120
Others: stern superstructure	130	0.130	0.025
aft midships superstructure	102	0.096	0.029
midships superstructure	90	0.100	0.100
forward midships superstructure	75	0.030	0.050
bow superstructure	105	0.180	0.120
Note a: Modern Cruisers (CG) should be analyzed using the normalized wind yaw moment variables for the Destroyer (DDG) ship type.			

Table 6 – Bulk Paraguay Wind Load Calculations, 23’ Draft, Part 2

As the normal ballast draft for the Bulk Paraguay is 22.9’, no separate wind and current load area and load calculations are performed. The results for the 23.0’ draft are used.

Bulk Paraguay		<Vessel Name	ADM Dolphins	<Project	Excel app developed by W.P. Stewart, C.Eng., D.OE, Stewart Technology Associates			
Current Areas and Forces (UFC 4-159-03 March 2020)								
Static Transverse Current Force				Static Longitudinal Current Force & Yaw Moment				
V_c	0.154 m/s	< Current speed for charts	$v =$	1.19E-06 m ² /s	Kinematic viscosity	$\gamma_w =$	10.06 kN/m ³	Weight density seawater
F_{yc}	$F_{yc} = 0.5 \rho_w V_c^2 L_{WL} T C_{yc} \sin \theta_c$	<- UFC Eqn. 4-8	V_c specified =	0.30 kt	$F_{xc} = F_{xForm} + F_{xFriction} + F_{xProp}$			UFC Eqn. 4-15
C_{yc}	$C_{yc} = C_o + (C_i - C_o)(T/d)^K$	<- UFC Eqn. 4-10	$C_{yc} =$	2.04	$F_{xForm} = 0.5 \rho_w V_c^2 B T C_{xcb} \cos \theta_c$			UFC Eqn. 4-16
T	7.0 m	Average Draft	Vc < 3kt, UFC C1 OK		$C_{xcb} =$	0.1		UFC recom.
WD, or d	9.4 m	Water Depth	T/d =	0.74	$F_{xFriction} = 0.5 \rho_w V_c^2 S C_{xca} \cos \theta_c$			UFC Eqn. 4-17
B	32.4 m	Max ship width at waterline	$C_m = A_m/(TB)$	UFC Eqn. 4-14	$S = 1.7 T L_{WL} + D/(T \gamma_w)$			UFC Eqn. 4-18
A_m	227 m ²	Immersed midship section	$C_m =$	1.000	$S =$	7391 m ²		
Δ	36000 MT	Displacement	$\chi =$	7.98	$R_N = V_c L_{WL} \cos(\theta_c)/v$			UFC Eqn. 4-20
V	35122 m ³	Submerged Volume	$C_o = 0.22 + \chi^{-7}$	UFC Eqn. 4.11	Max $R_N =$	2.59E+07		
χ	$\chi = L_{WL}^2 A_m/(B.V)$	UFC Equation 4-15	$C_o =$	0.621	Max $\log_{10} R_N =$	7.41		
C_i	3.2	Shallow water drag coef. Where T/d = 1.0 & velocity < 1.5 m/s					$C_{xca} = 0.075/(\log_{10} R_N - 2)^2$	UFC Eqn. 4-19
K	2	Suggested by UFC for use in Equation 4-10					Min $C_{xca} =$	0.00256
$L_{WL} T$	1402 m ²	Underwater Broadside Area, calculated elsewhere					$F_{xProp} = 0.5 \rho_w V_c^2 A_p C_{Prop} \cos \theta_c$	UFC Eqn. 4-21
C_{dYaw}	5	Drag coef. for OrcaFlex Yaw Moment Factor: $K_{yaw} = C_d D L^4 / 32$					$A_p = A_{Tpp} / 0.838$	32.24 m ²
F_{block}	100%	Reduced % of sway area, $L_{WL} T$, remaining after pier blockage					$C_{Prop} =$	1.00
Max Current Force and Moment Values for cases without and with pier blockage, from 0° to 180°								
0.15 m/s	Current Speed	Max Fxc	Min Fxc	Max Fyc	Min Fyc	Max Mxyc	Min Mxyc	
Without Pier Blockage		0.092 MT	-0.092 MT	3.505 MT	0.0 MT	0.000 MT.m	-68.524 MT.m	
With Pier Blockage		0.092 MT	-0.092 MT	3.505 MT	0.0 MT	0.000 MT.m	-68.524 MT.m	

Table 7 - Bulk Paraguay Current Load Calculations, 23' Draft, Part 1

Maximum current forces and moments are shown for the selected 0.154 m/s (0.3 kt) current speed in the last three rows of the above table. Note that 1 MT = 2,205 lbf.

Only edit yellow cells. Refer to UFC 4-159-03, March 2020, for details.	
Force_Coefficients_Rev13.xlsm	
Static Longitudinal Current Force & Yaw Moment	
θ_c Selected (from stern)	0°
$A_{Tpp} = L_{WL} B/A_R =$	27.02
Select Ship for A_R , prop area ratio	A_R Selected
Cargo	240
Max $F_{xForm} =$	0.03 MT
Max $F_{xFriction} =$	0.02 MT
Max $F_{xProp} =$	0.04 MT
Max $F_{xcTotal} =$	0.09 MT
Static Current Yaw Moment	
$M_{xyc} = F_{yc} (e_c/L_{WL}) L_{WL}$	UFC Eqn. 4-24
Select Ship Type for e_c	
Series 60, full hull form typical of cargo ships	
a, Y-intercept	b, Slope/°
-0.291	0.00353

Table 8 – Bulk Paraguay Current Load Calculations, 23' Draft, Part 2

Note that the UFC method for longitudinal current force calculation includes skin friction and propeller drag.

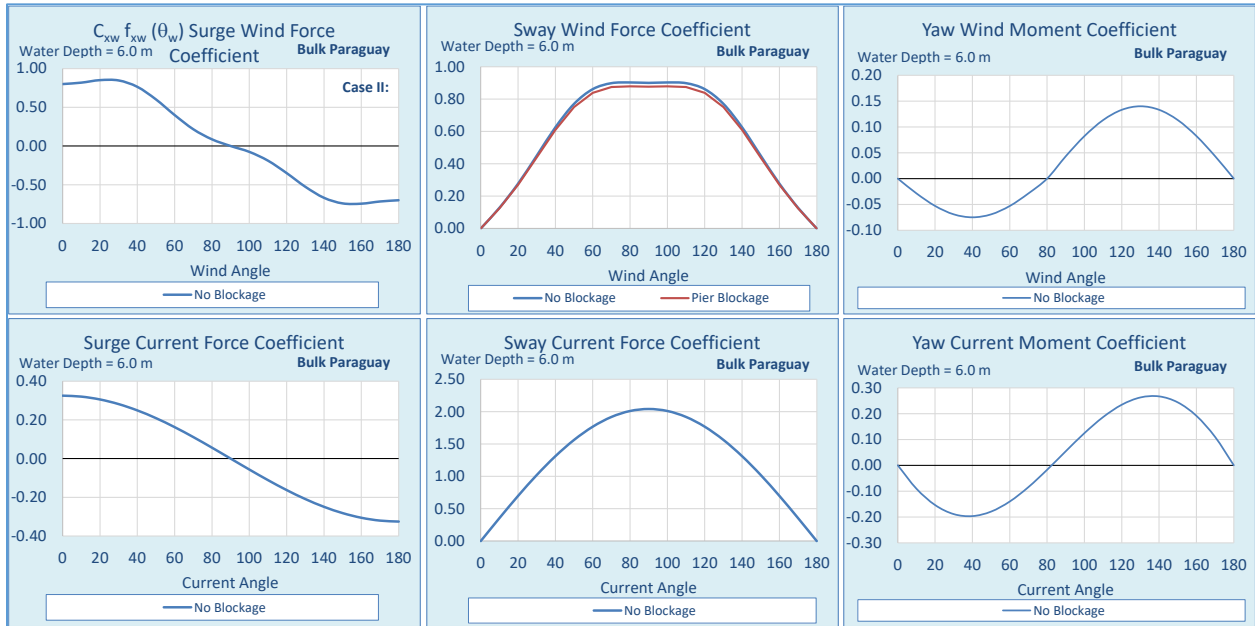


Figure 20 – Bulk Paraguay Wind and Current Force & Moment Coefficients, 23' Draft

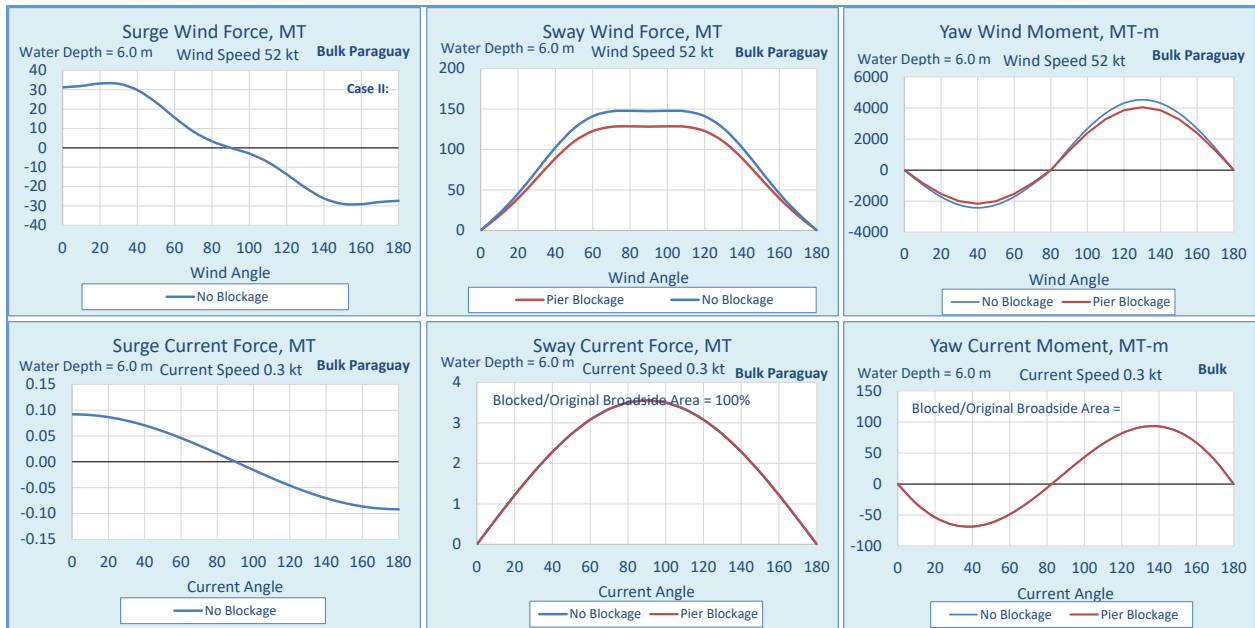


Figure 21 – Bulk Paraguay Wind and Current Forces and Moments for Selected Speeds, 23' Draft

Note that 1 MT = 2,205 lbf.

14. ORCAFLEX DYNAMIC WAVE FORCES & VESSEL LOAD RAOs

The vessel hulls are analyzed with diffraction analysis, using the industry standard program OrcaWave (Reference 16). A combined panel model of the 63,000 dwt bulk carrier in this report, with superstructure added, is shown below.

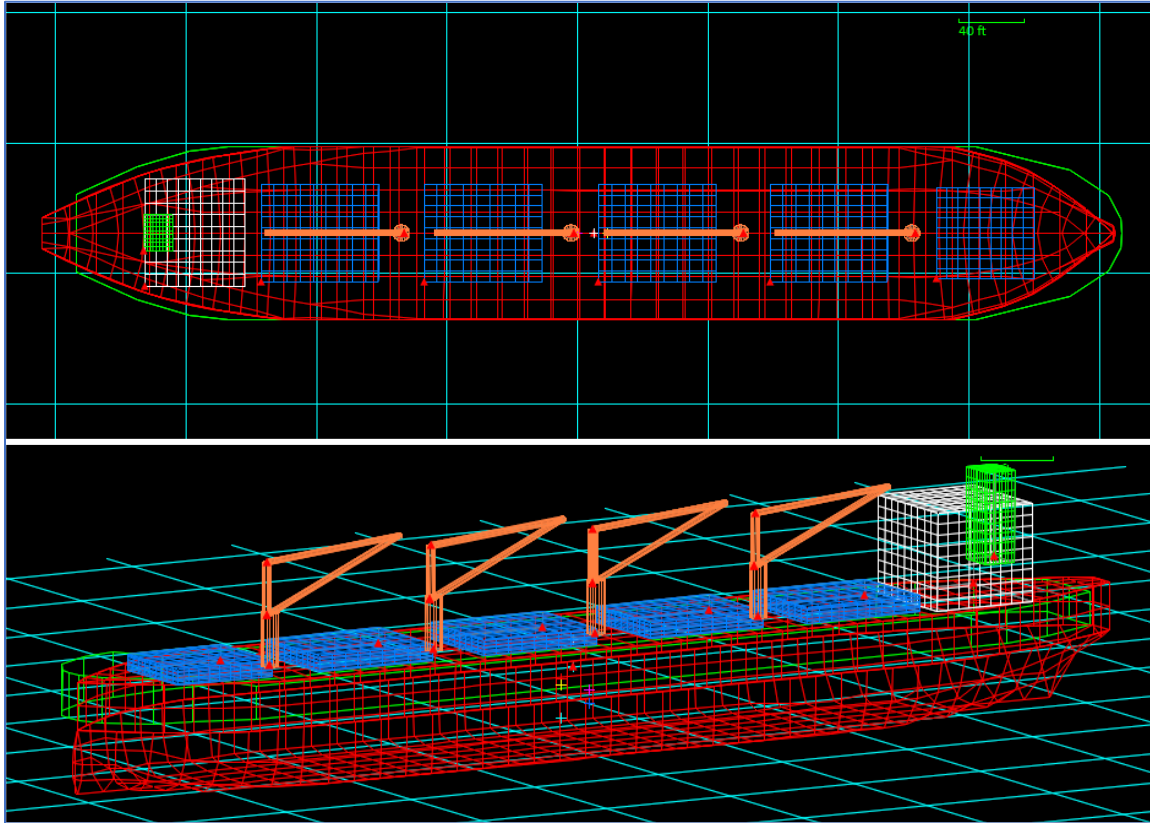


Figure 22 – Combined Diffraction Panel and Superstructure Model of 63,000 DWT Bulk Carrier

The diffraction analysis produces displacement RAOs (response amplitude operators), load RAOs and second-order wave drift forces, or QTFs (quadratic transfer functions). These terms are calculated in the frequency domain and passed to industry standard dynamic mooring analysis program, OrcaFlex, to perform time domain analysis.

On the following three pages examples are provided of:

- Vessel Displacement RAOs Figure 23
- Vessel Load RAOs Figure 24
- Mean Drift Loads Figure 25.

These terms are produced at typically 25 wave periods, or frequencies and 12 wave headings, for each ship, for each draft, or loaded condition.



It should be noted that the waves contribute a relatively small amount to the fender forces. Nevertheless, they are included in the time domain analyses. By far the greatest static and dynamic fender force contributions come from the gusting wind effects.

In this report the vessel load RAOs calculated by OrcaWave, together with the frequency dependent added mass and radiation damping terms are used in OrcaFlex to calculate the vessel responses to first order wave forces. The second order wave drift forces are also used in the time domain by OrcaFlex.

In this report the wind loads on the vessel superstructure are calculated in the time domain by OrcaFlex using a wind speed time history developed from a wind spectrum (generally the NPD wind spectrum).

The environmental forces (including current) cause vessel motions in six degrees of freedom, reaction forces from the non-linear fenders and from the mooring line tensions all contribute to the OrcaFlex time domain simulation.

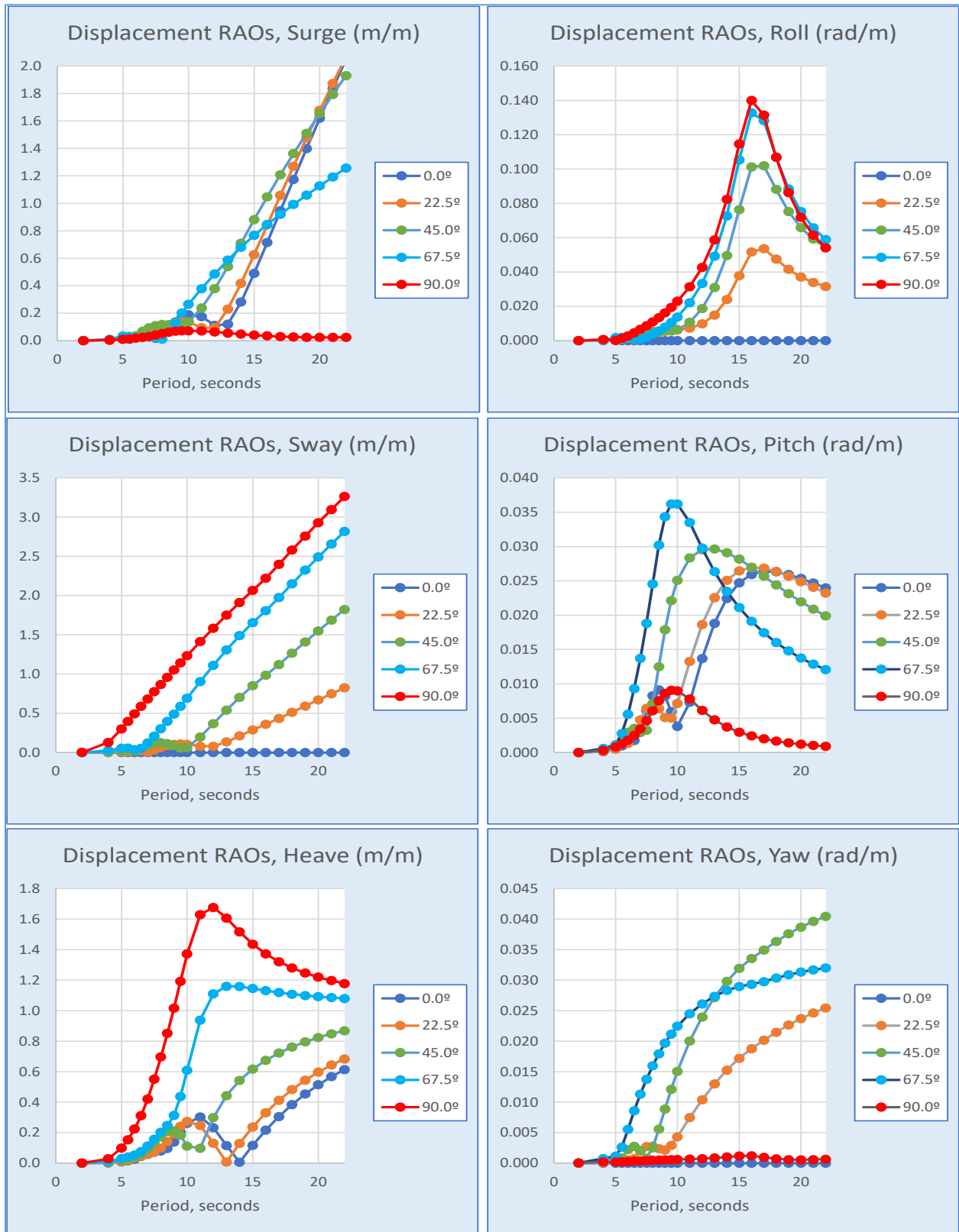


Figure 23 – OrcaWave, Displacement RAOs, 10.5m Water Depth, 8.32m Draft

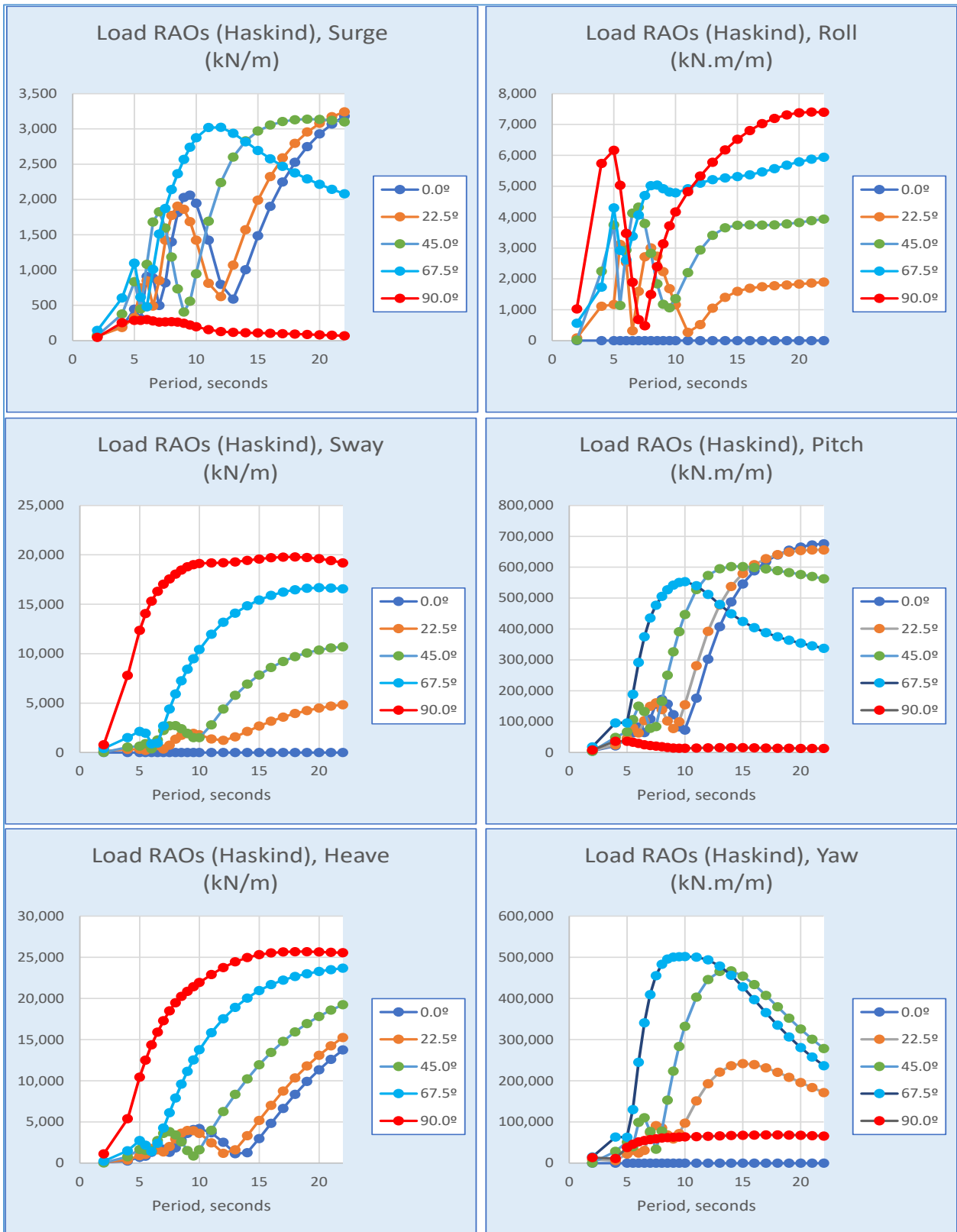


Figure 24 – OrcaWave, Diffraction (Haskind) Load RAOs, 10.5m Water Depth, 8.32m Draft

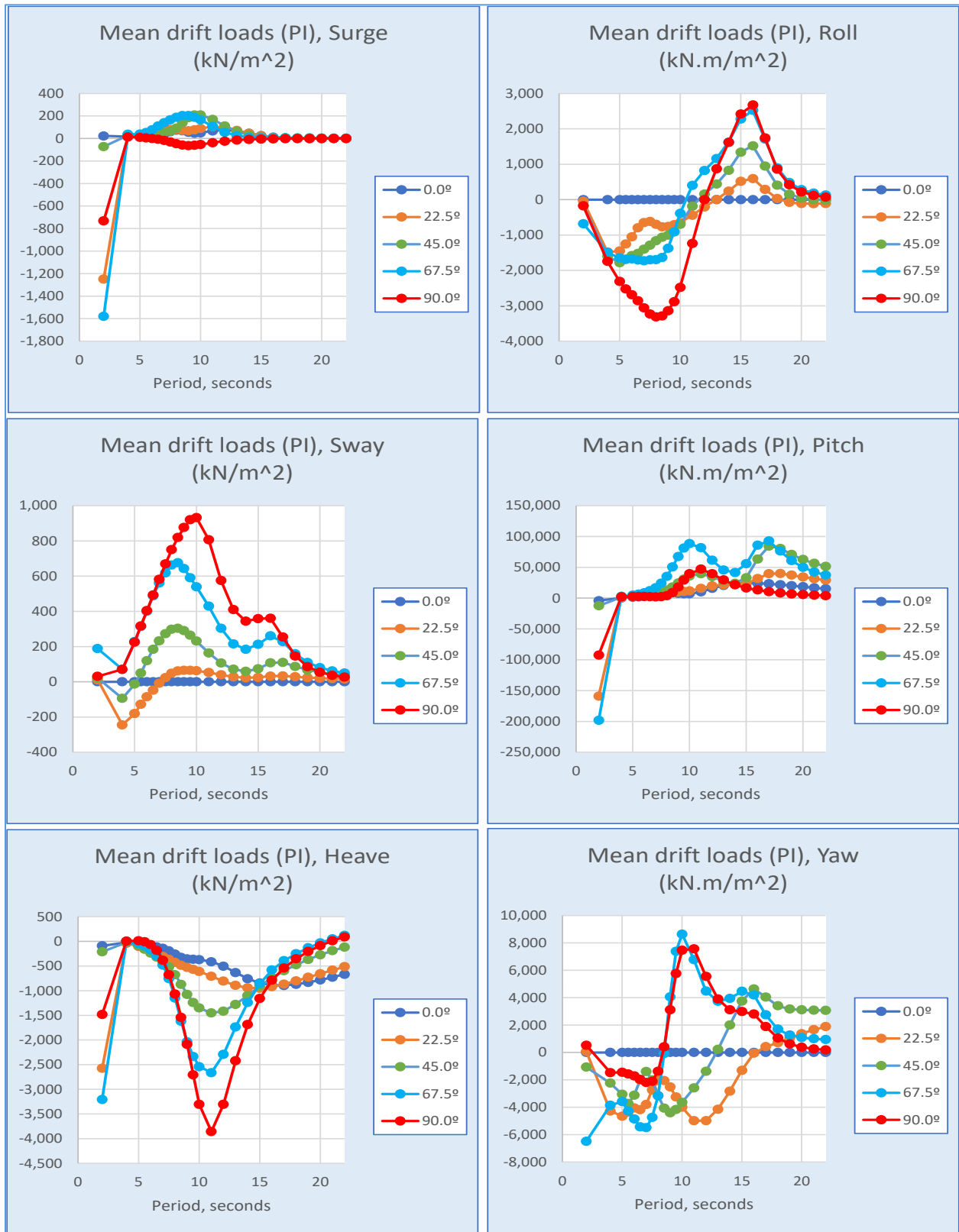


Figure 25 – OrcaWave, Mean Wave Drift Loads, 10.5m Water Depth, 8.32m Draft

15. RESULTS 63,000 DWT BULK CARRIER: SOUTH

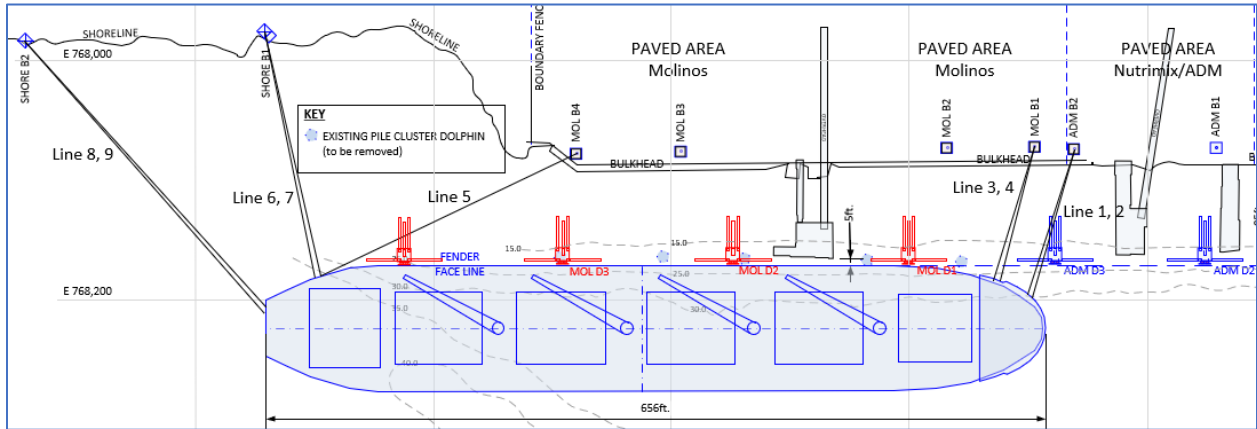


Figure 26 – 63,000 DWT Bulker South

The vessel has contact with all four Molinos dolphins.

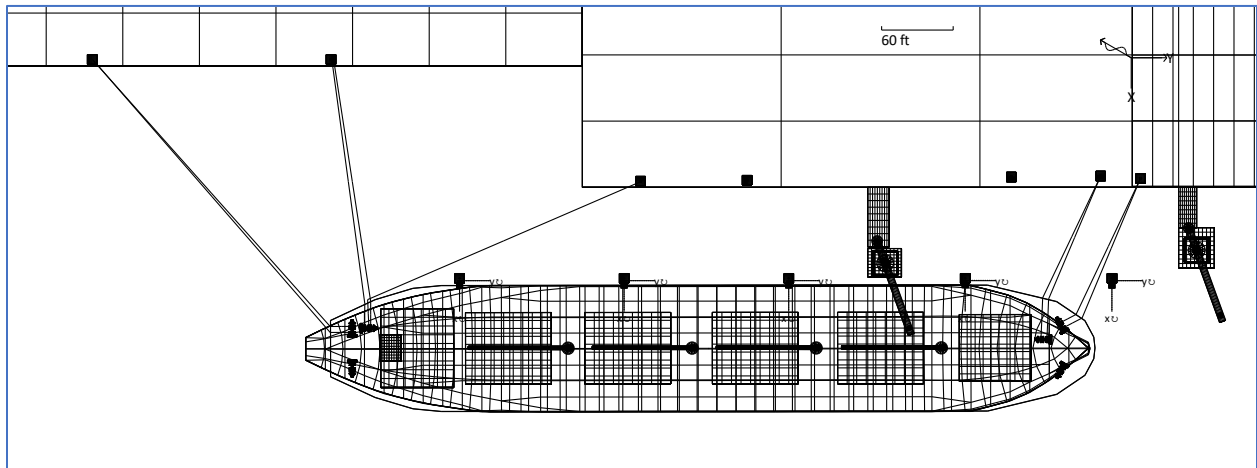


Figure 27 – OrcaFlex Plan View of 63,000 DWT Bulk Carrier in South Position

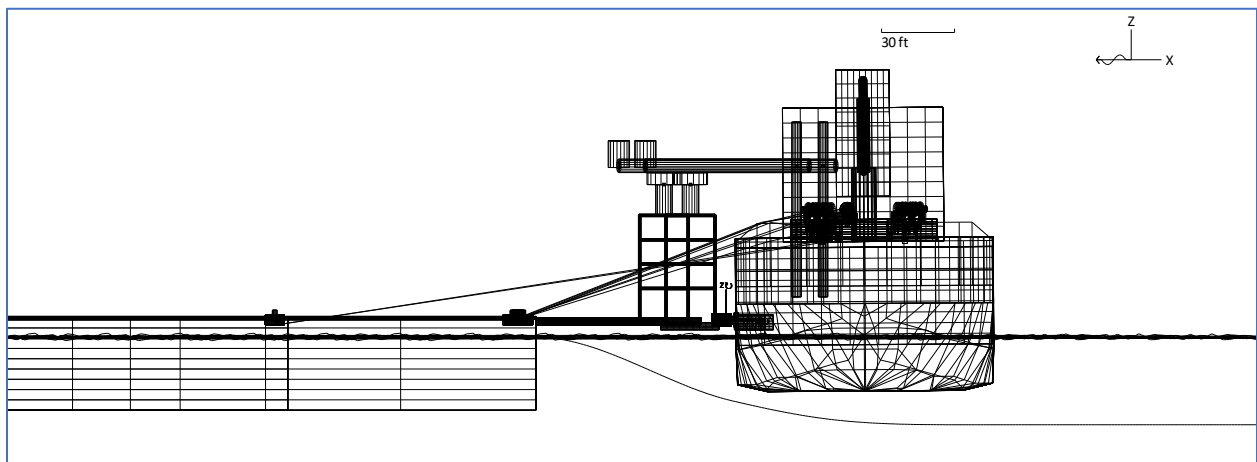


Figure 28 – OrcaFlex End Elevation of 63,000 DWT Bulk Carrier wit 23 ft Draft



Paraguay South NPD.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction to Vessel	360°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 1	32.1 kip	49.3 kip	35.2 kip	82.1 kip	117.1 kip	99.2 kip
MOL 2	27.6 kip	46.9 kip	58.7 kip	89.5 kip	87.0 kip	54.9 kip
MOL 3	24.4 kip	59.3 kip	91.9 kip	96.4 kip	62.8 kip	25.8 kip
MOL 4	104.3 kip	147.5 kip	130.0 kip	103.4 kip	46.2 kip	15.7 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction to Vessel	180°N	150°N	120°N	90°N	60°N	30°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 1	76.1 kip	107.6 kip	69.4 kip	0.0 kip	0.0 kip	59.4 kip
MOL 2	25.8 kip	20.5 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 3	11.3 kip	38.7 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	13.9 kip	96.4 kip	126.2 kip	91.4 kip	88.0 kip	128.8 kip

Table 9 – 63,000 DWT Bulker South, Max Fender Load 147.5 kips, with soil stiffness

Paraguay South NPD no soil stiff.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction to Vessel	360°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 1	36.9 kip	62.8 kip	36.6 kip	83.6 kip	120.0 kip	102.9 kip
MOL 2	30.9 kip	55.5 kip	59.0 kip	88.1 kip	88.5 kip	55.9 kip
MOL 3	26.3 kip	58.7 kip	92.4 kip	95.5 kip	62.8 kip	26.3 kip
MOL 4	99.9 kip	151.8 kip	130.5 kip	103.0 kip	45.9 kip	14.8 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction to Vessel	180°N	150°N	120°N	90°N	60°N	30°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 1	77.8 kip	125.5 kip	75.0 kip	0.0 kip	0.0 kip	59.6 kip
MOL 2	24.2 kip	19.9 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 3	10.5 kip	43.9 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	13.1 kip	101.9 kip	147.9 kip	104.3 kip	99.6 kip	129.8 kip

Table 10 – 63,000 DWT Bulker South, Max Fender Load 151.8 kips, without soil stiffness

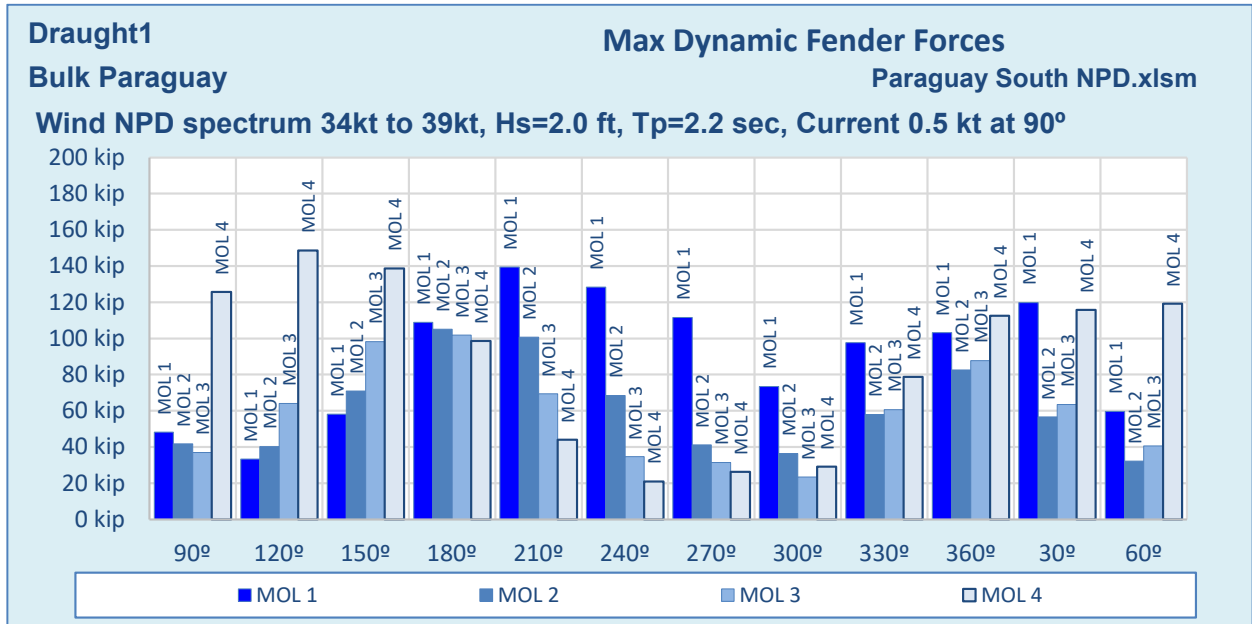


Figure 29 – Max Fender Forces, 63,000 DWT Bulker, South

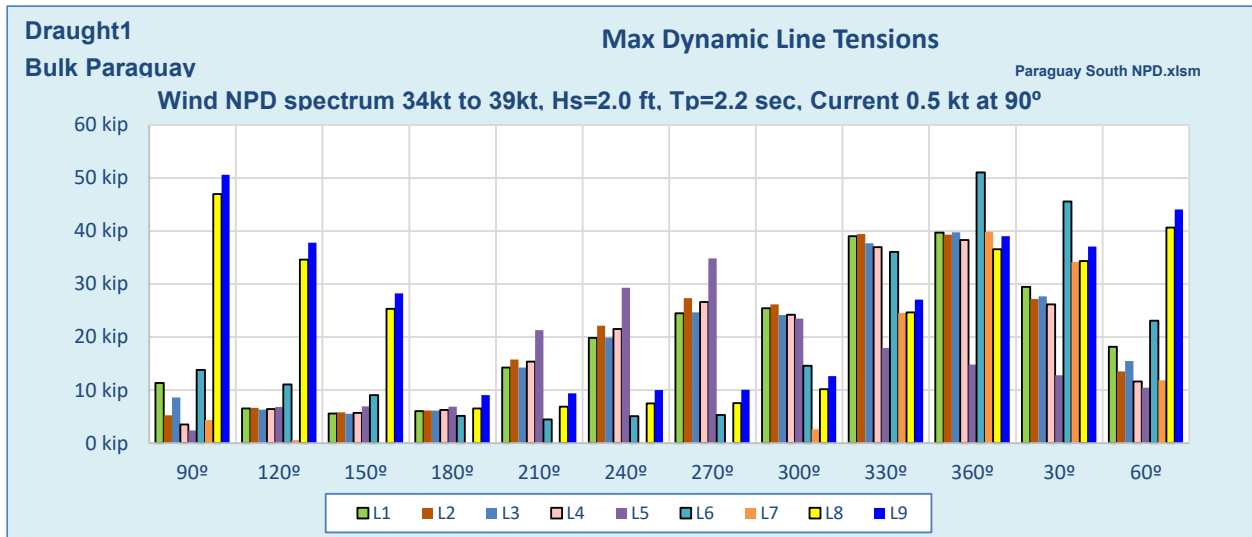


Figure 30 – Max Line Tensions, 63,000 DWT Bulker, South

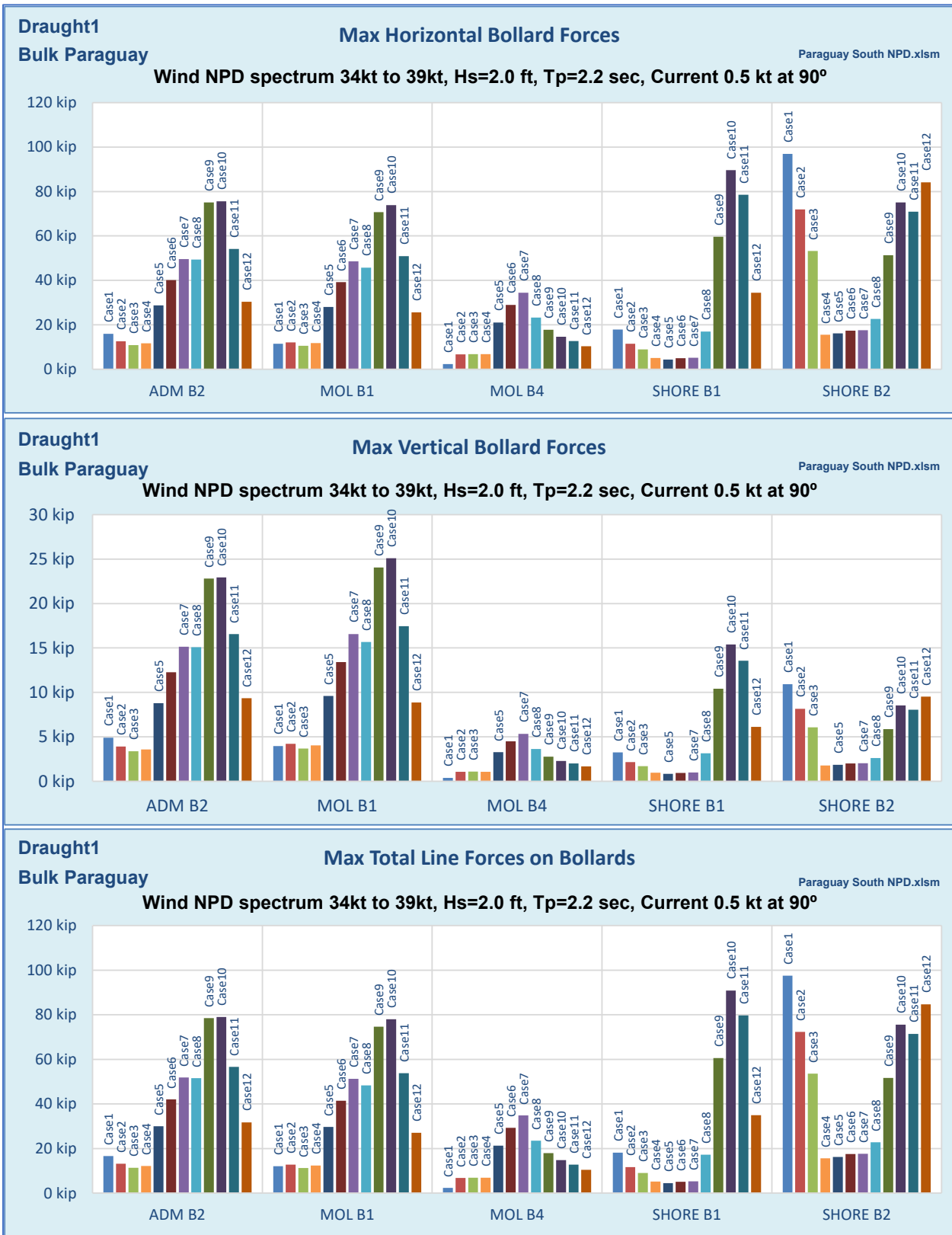


Figure 31 – Bollard Forces, 63,000 DWT Bulker, South

16. RESULTS 63,000 DWT BULK CARRIER: NORTH

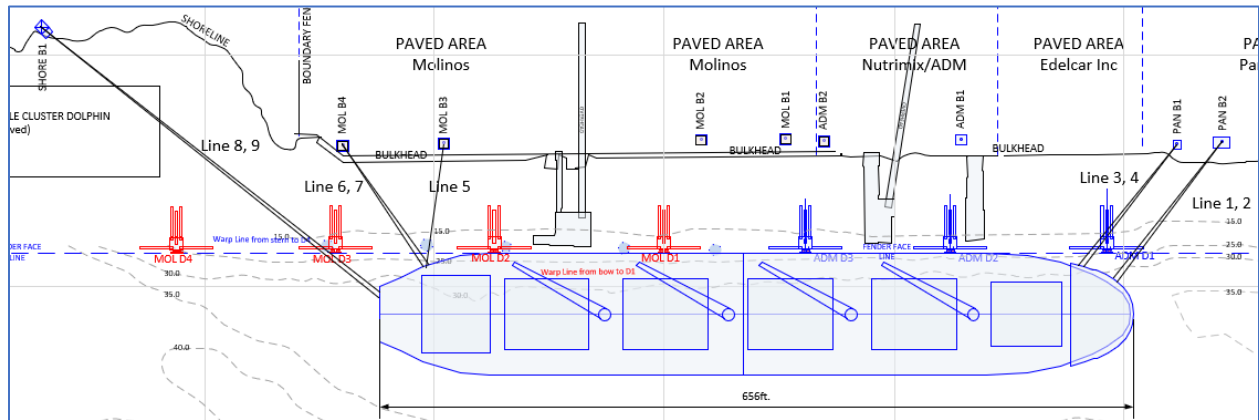


Figure 32 - 63,000 DWT Bulker North

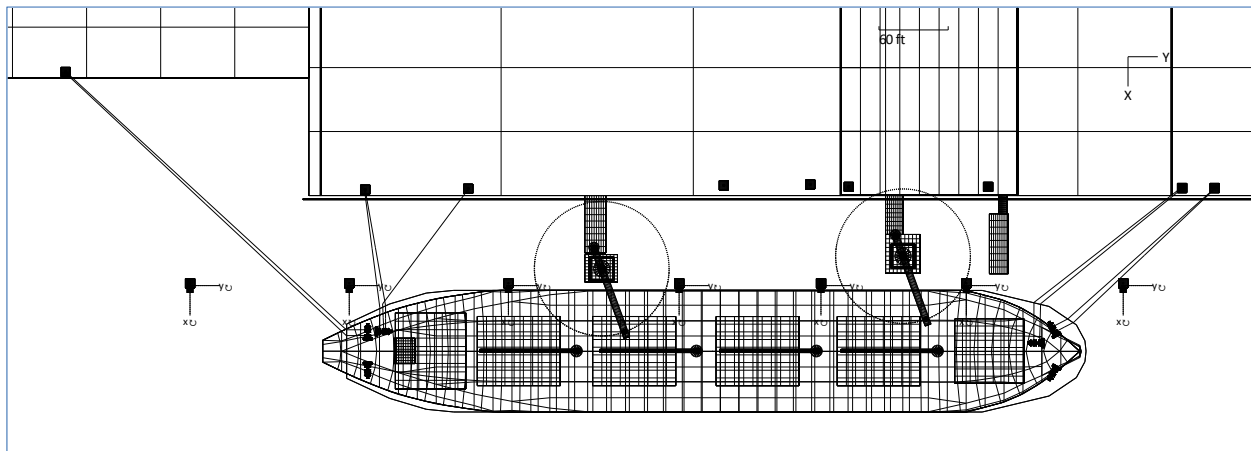


Figure 33 - OrcaFlex Plan View of 63,000 DWT Bulk Carrier in North Position

The vessel has contact with two Molinos and two ADM dolphins.



Paraguay North NPD.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction towards °N	359°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	37.6 kip	25.9 kip	71.1 kip	104.2 kip	84.6 kip
ADM South	0.0 kip	47.0 kip	51.8 kip	87.7 kip	86.9 kip	59.0 kip
MOL 1	0.0 kip	56.9 kip	94.7 kip	104.8 kip	71.8 kip	35.7 kip
MOL 2	90.4 kip	165.0 kip	153.4 kip	127.5 kip	61.6 kip	30.7 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction towards °N	180°N	149°N	119°N	88°N	59°N	29°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	49.9 kip	12.5 kip	0.0 kip	0.0 kip	0.0 kip	41.7 kip
ADM South	31.9 kip	16.6 kip	0.0 kip	0.0 kip	0.0 kip	28.4 kip
MOL 1	17.1 kip	20.9 kip	0.0 kip	0.0 kip	0.0 kip	15.6 kip
MOL 2	35.3 kip	102.8 kip	134.1 kip	139.2 kip	138.1 kip	78.7 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip

Table 11 – 63,000 DWT Bulker North, Max Fender Load 165.0 kips, with soil stiffness

Paraguay North NPD no soil stiff.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction towards °N	359°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	60.4 kip	25.2 kip	73.5 kip	108.2 kip	84.8 kip
ADM South	0.0 kip	62.7 kip	55.4 kip	87.3 kip	89.7 kip	58.9 kip
MOL 1	0.0 kip	68.9 kip	94.1 kip	104.3 kip	72.1 kip	36.7 kip
MOL 2	91.5 kip	161.9 kip	153.7 kip	126.9 kip	61.1 kip	31.2 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction towards °N	180°N	149°N	119°N	88°N	59°N	29°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	50.9 kip	16.9 kip	0.0 kip	0.0 kip	0.0 kip	50.8 kip
ADM South	32.0 kip	19.7 kip	0.0 kip	0.0 kip	0.0 kip	28.8 kip
MOL 1	17.9 kip	22.8 kip	0.0 kip	0.0 kip	0.0 kip	7.9 kip
MOL 2	37.1 kip	114.1 kip	148.0 kip	160.9 kip	151.5 kip	88.1 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip

Table 12 – 63,000 DWT Bulker North, Max Fender Load 161.9 kips, without soil stiffness

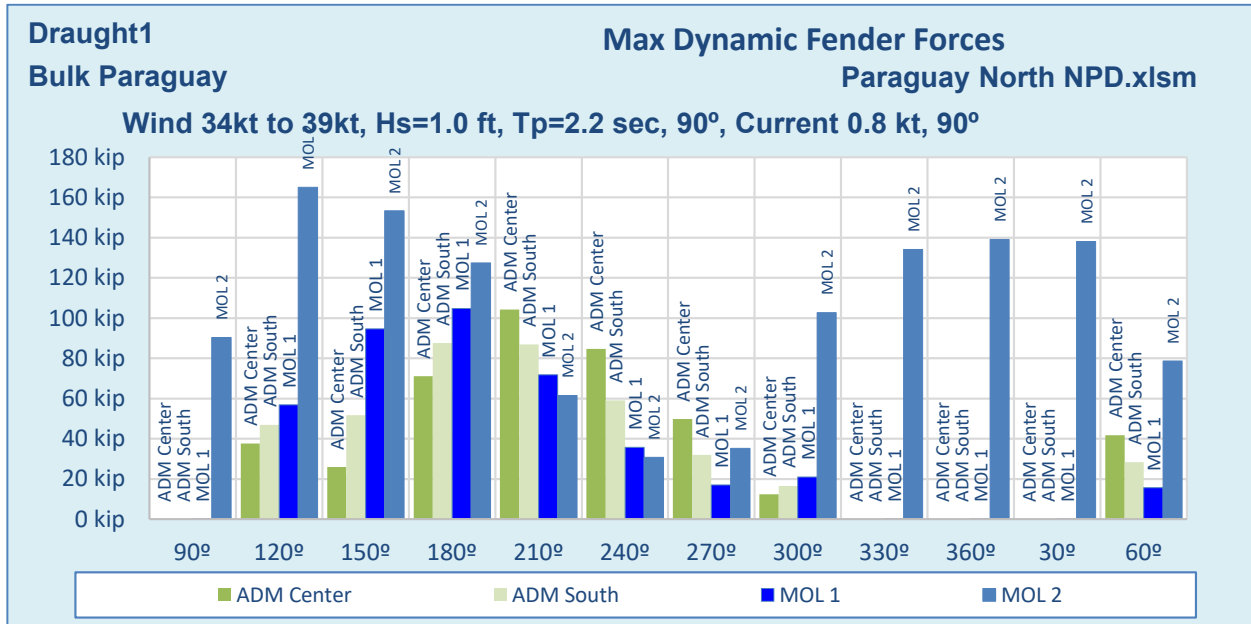


Figure 34 - Max Fender Forces, 63,000 DWT Bulker, North

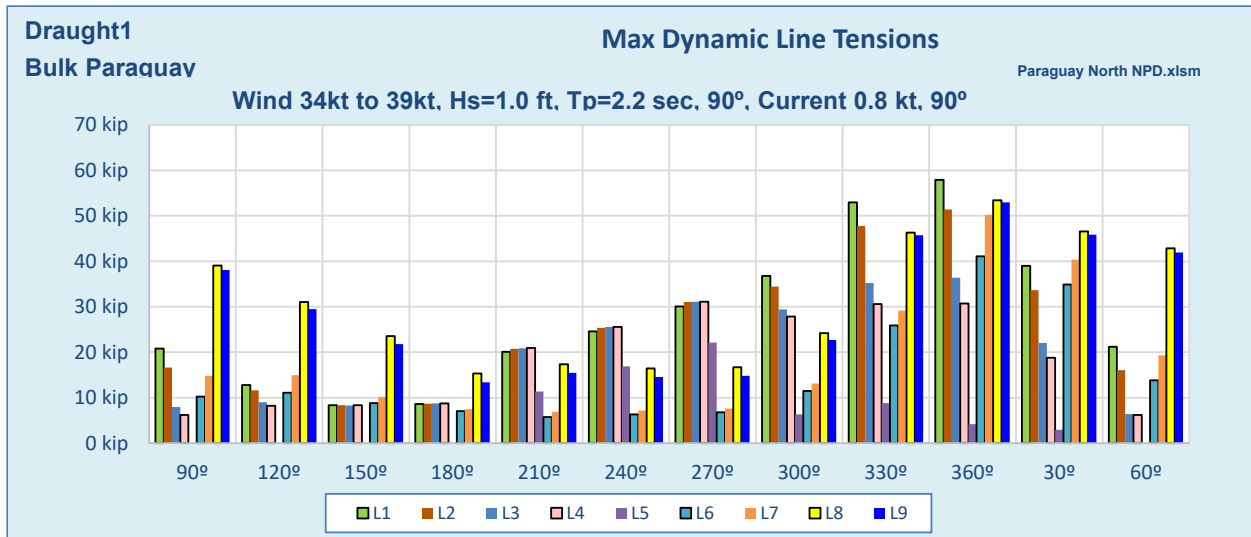


Figure 35 – Max Line Tensions, 63,000 DWT Bulker, North

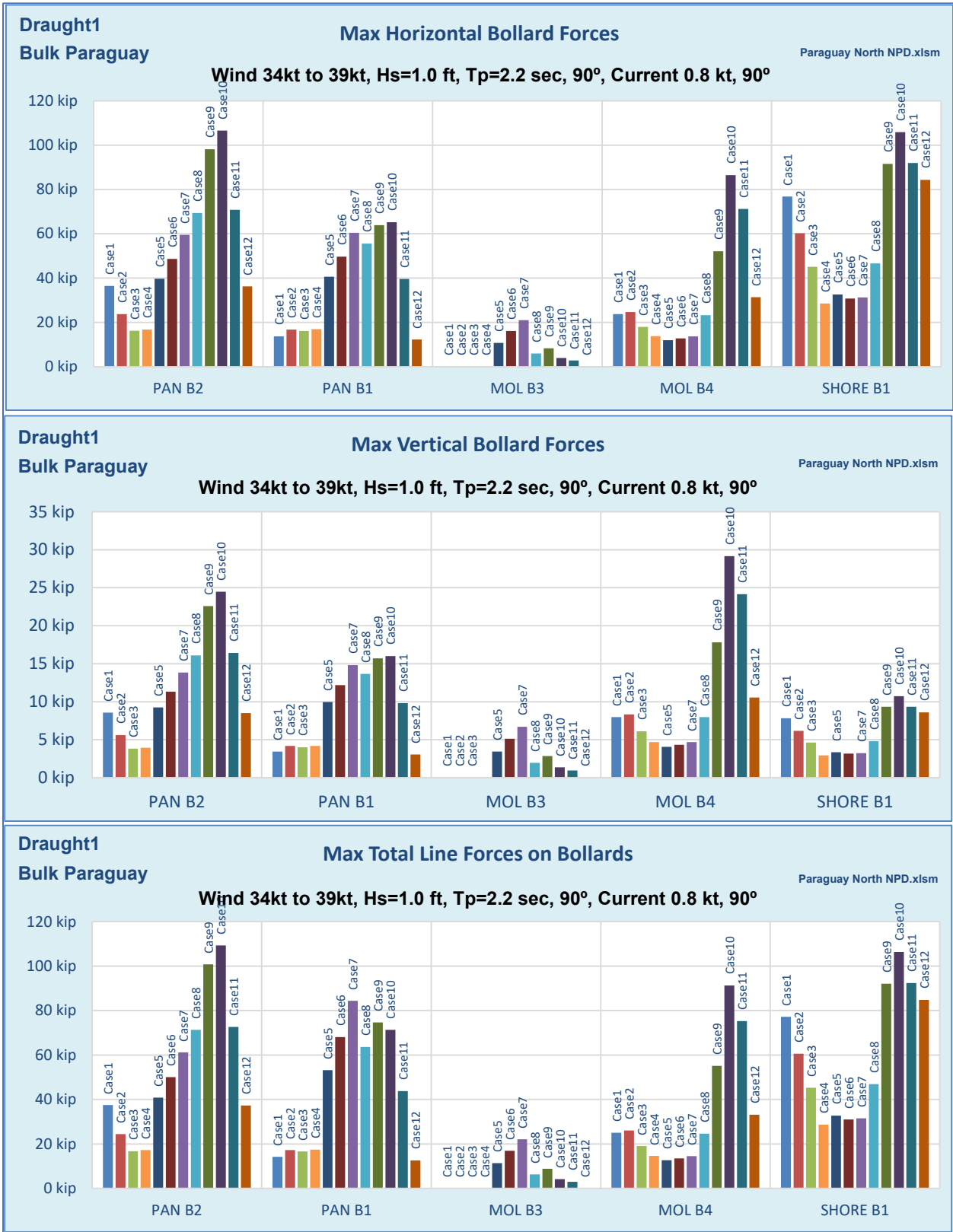


Figure 36 – Bollard Forces, 63,000 DWT Bulker, North

17. RESULTS 63,000 DWT BULK CARRIER: CENTRAL

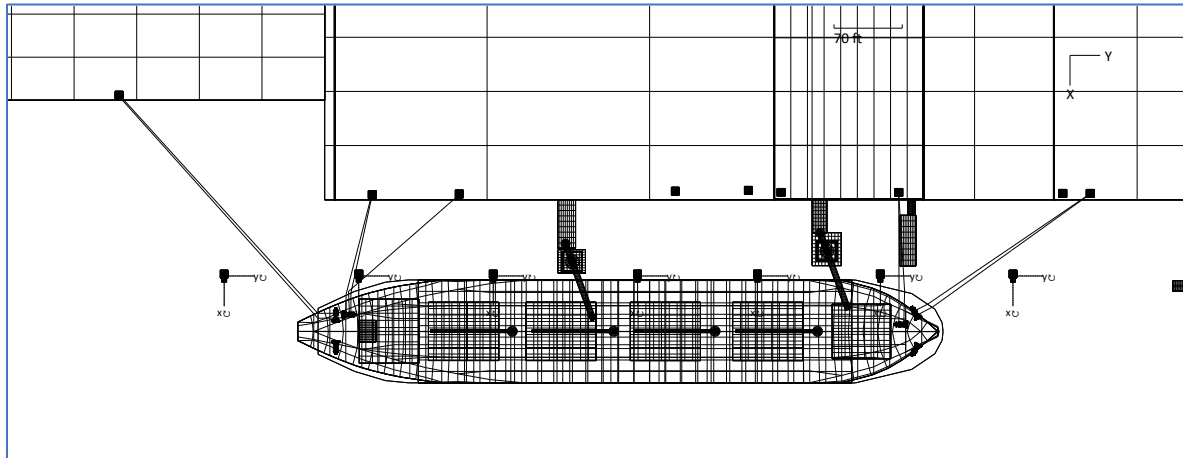


Figure 37 - OrcaFlex Plan View of 63,000 DWT Bulk Carrier in Central Position

The vessel has contact with two Molinos and one ADM dolphin.



Paraguay Central NPD.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction towards °N	360°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	18.8 kip	30.1 kip	70.0 kip	121.6 kip	144.9 kip	102.0 kip
MOL 1	34.6 kip	62.0 kip	97.7 kip	129.6 kip	113.8 kip	64.6 kip
MOL 2	70.0 kip	132.2 kip	176.3 kip	139.2 kip	85.6 kip	52.9 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction towards °N	180°N	150°N	120°N	90°N	60°N	30°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	27.0 kip	49.6 kip	52.8 kip	34.9 kip	79.6 kip	81.7 kip
MOL 1	36.8 kip	51.5 kip	58.1 kip	51.8 kip	66.4 kip	49.2 kip
MOL 2	54.6 kip	73.2 kip	76.2 kip	76.8 kip	72.2 kip	99.0 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip

Table 13 – 63,000 DWT Bulker Central, Max Fender Load 176.3 kips, with soil stiffness

Paraguay Central NPD no soil stiff.xlsm						
Run Identifier	Case1	Case2	Case3	Case4	Case5	Case6
Wind Direction towards °N	360°N	330°N	300°N	270°N	240°N	210°N
OrcaFlex Wind Direction	90°	120°	150°	180°	210°	240°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	17.4 kip	25.0 kip	67.3 kip	122.7 kip	144.9 kip	106.7 kip
MOL 1	35.1 kip	59.0 kip	98.1 kip	130.5 kip	113.9 kip	64.6 kip
MOL 2	70.5 kip	134.9 kip	170.0 kip	139.9 kip	86.2 kip	50.5 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
Run Identifier	Case7	Case8	Case9	Case10	Case11	Case12
Wind Direction towards °N	180°N	150°N	120°N	90°N	60°N	30°N
OrcaFlex Wind Direction	270°	300°	330°	360°	30°	60°
ADM North	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM Center	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
ADM South	26.0 kip	61.2 kip	58.7 kip	39.0 kip	92.1 kip	88.7 kip
MOL 1	36.9 kip	57.7 kip	65.5 kip	58.8 kip	75.8 kip	48.2 kip
MOL 2	54.9 kip	84.0 kip	93.2 kip	90.8 kip	79.4 kip	107.0 kip
MOL 3	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip
MOL 4	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip	0.0 kip

Table 14 – 63,000 DWT Bulker South, Max Fender Load 170.0 kips, without soil stiffness

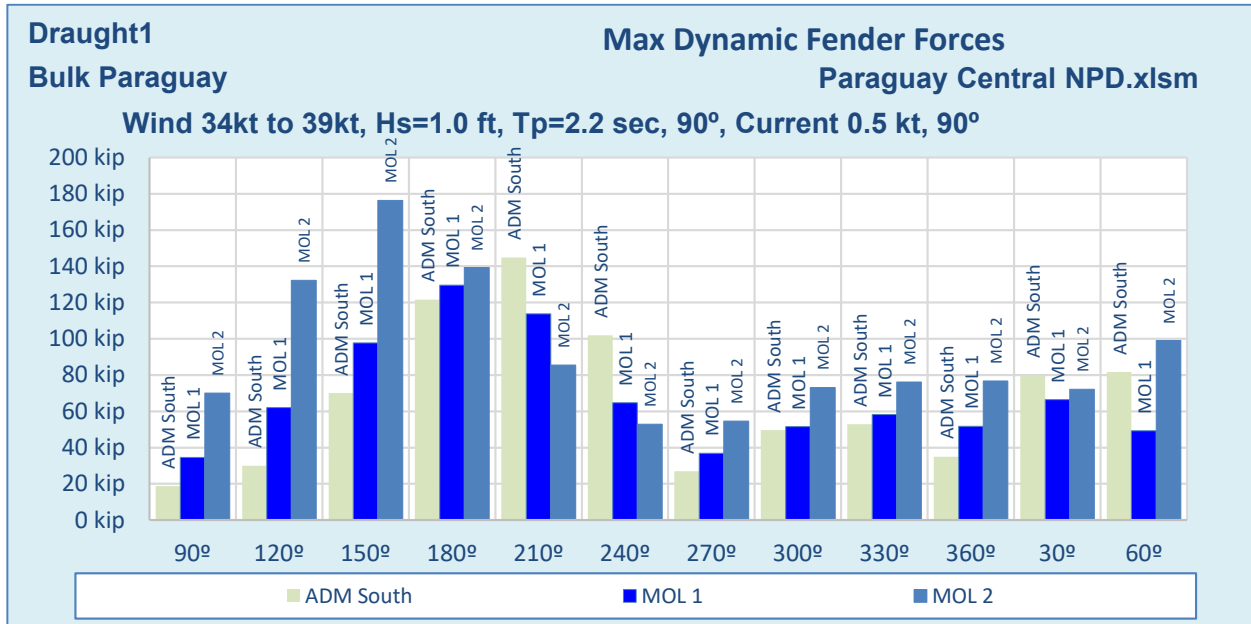


Figure 38 – Max Fender Forces, 63,000 DWT Bulker, Central

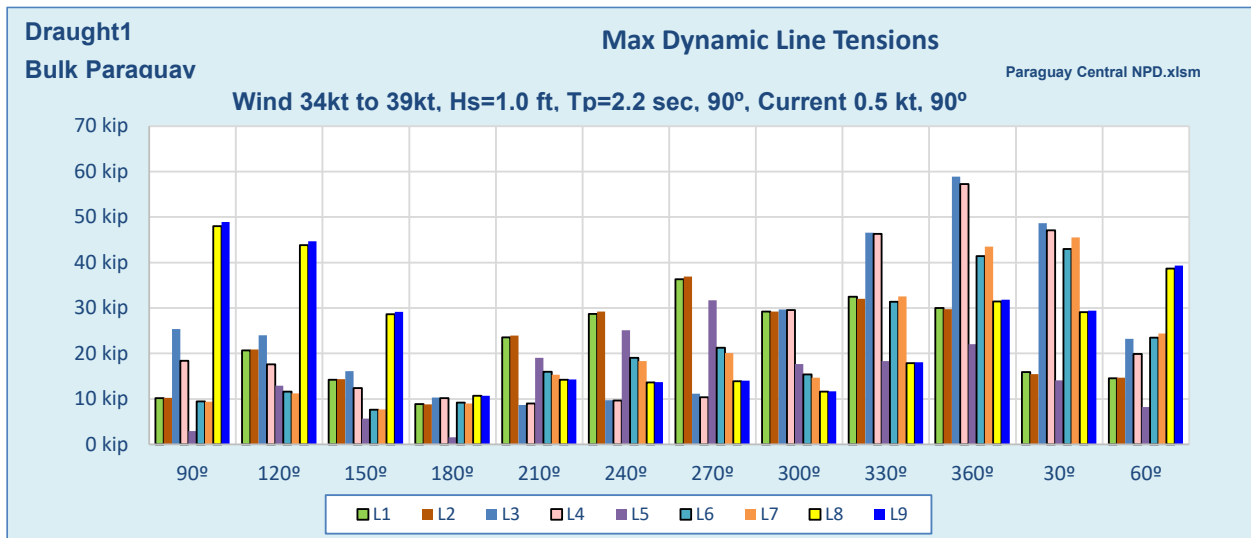


Figure 39 – Max Line Tensions, 63,000 DWT Bulker, Central

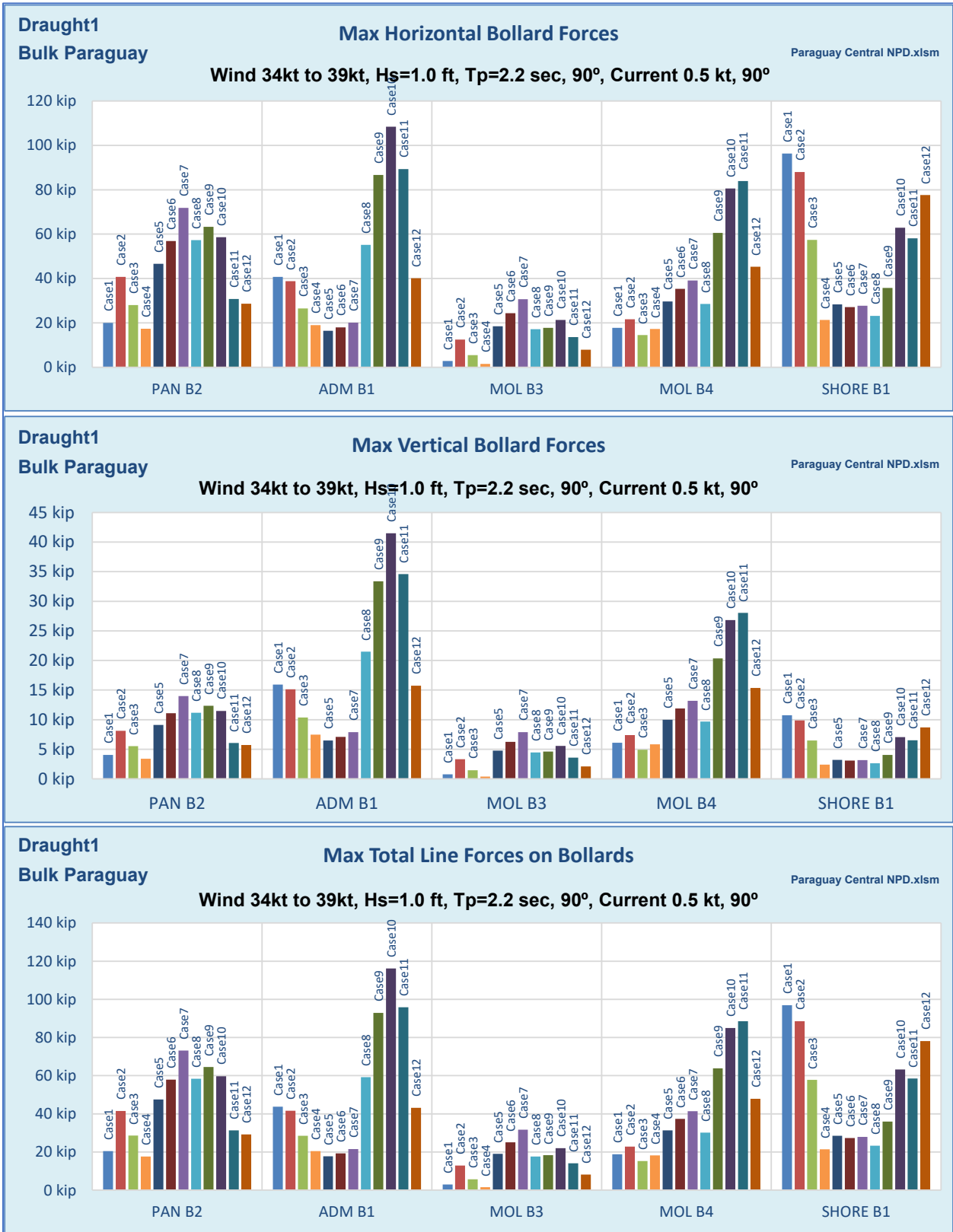


Figure 40 – Bollard Forces, 63,000 DWT Bulker, Central

18. SCREEN CAPTURES OF KEY DYNAMIC RESPONSES

18.1. 63,000 DWT Bulker, South, Wind Direction 150°

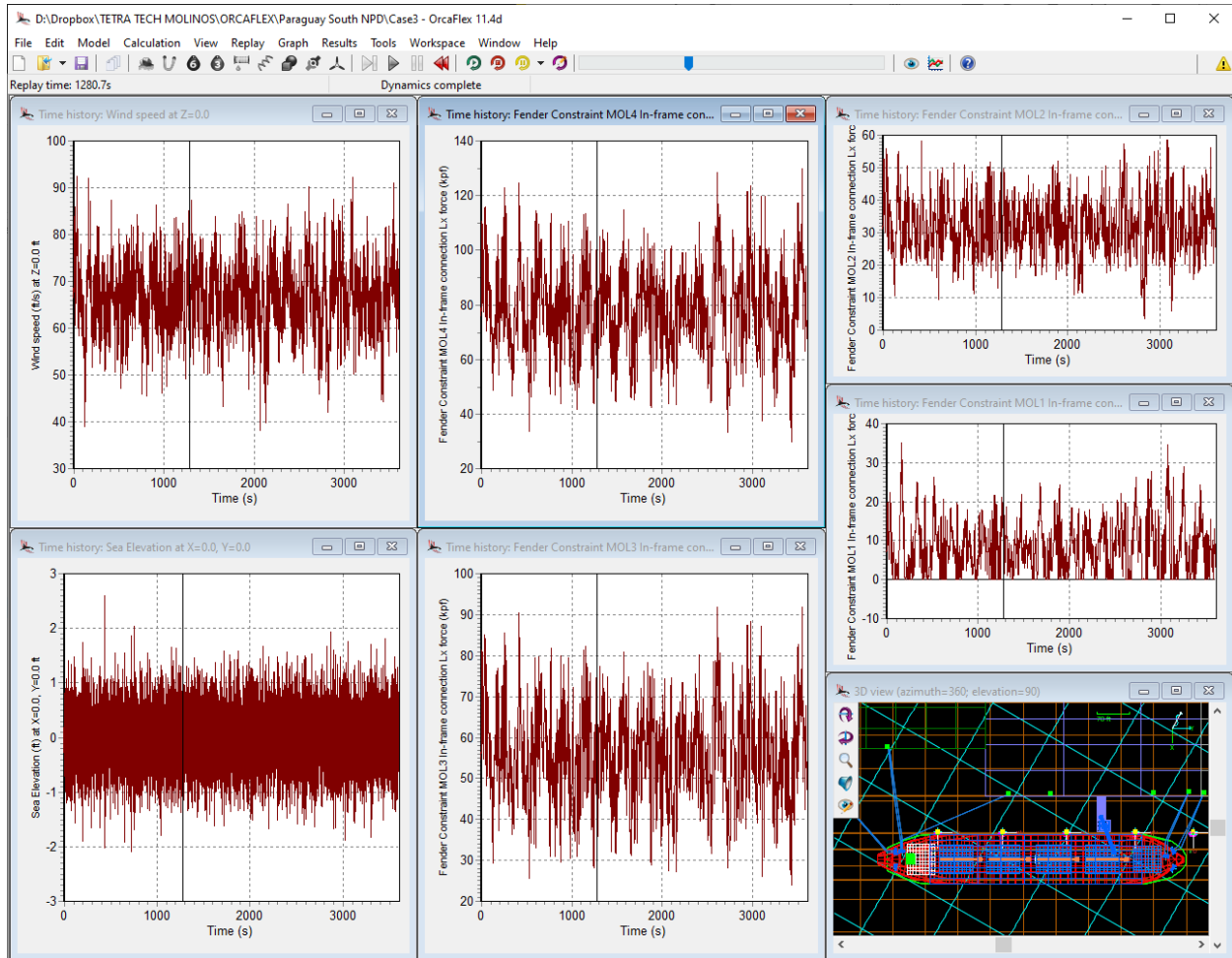


Figure 41 – Fender Force Time Histories, Bulker South, Wind 150°

18.2. 63,000 DWT Bulker, North, Wind Direction 120°

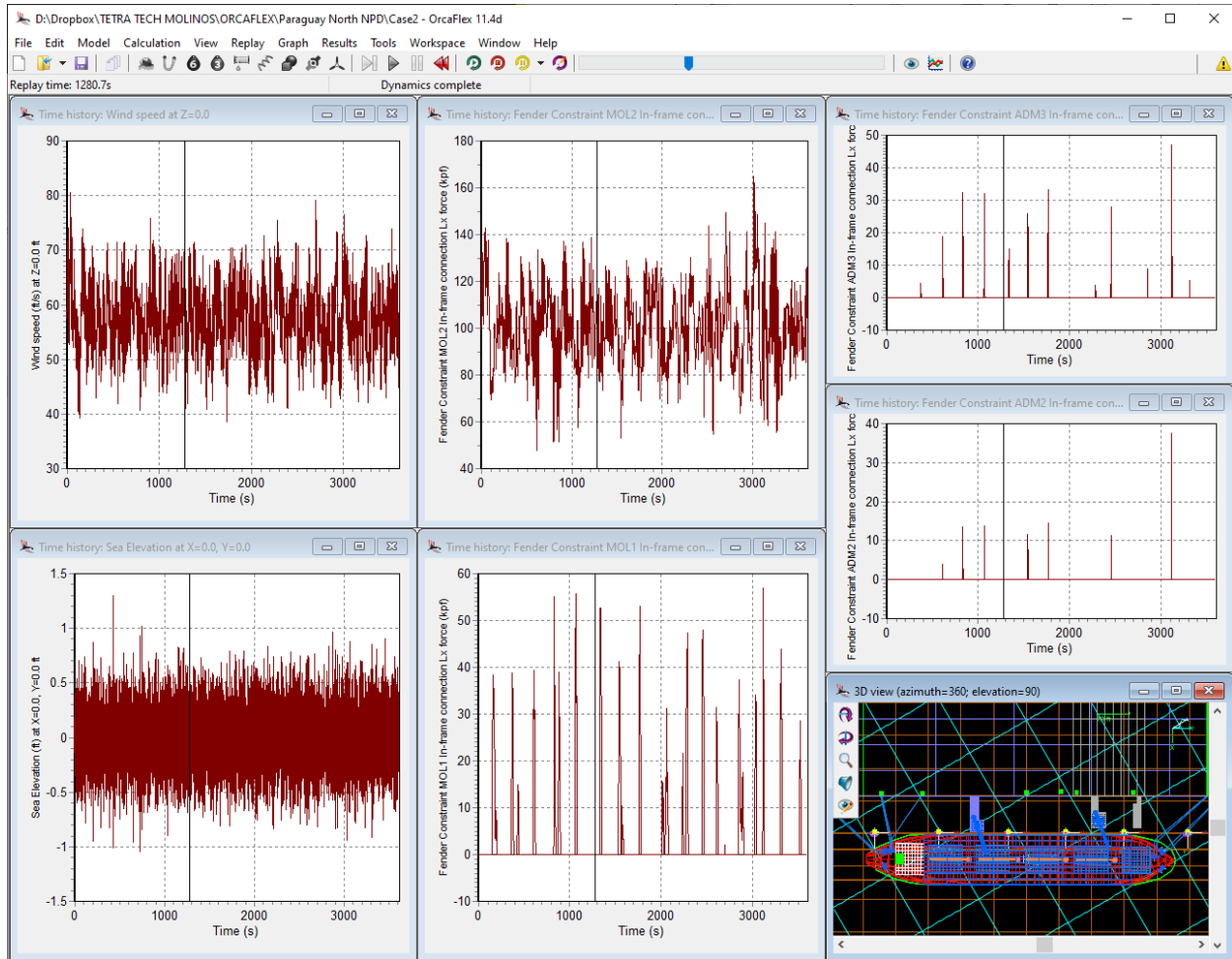


Figure 42 - Fender Force Time Histories, Bulker North, Wind 120°

Note that the contact between fenders ADM2, ADM3 and MOL1 is intermittent as the ship sways and yaws in response mainly to the wind gusts.

The maximum loads in fender MOL2 could probably be reduced by increasing the pretensions in the forward mooring lines.

18.3. 63,000 DWT Bulker, Central, Wind Direction 180°

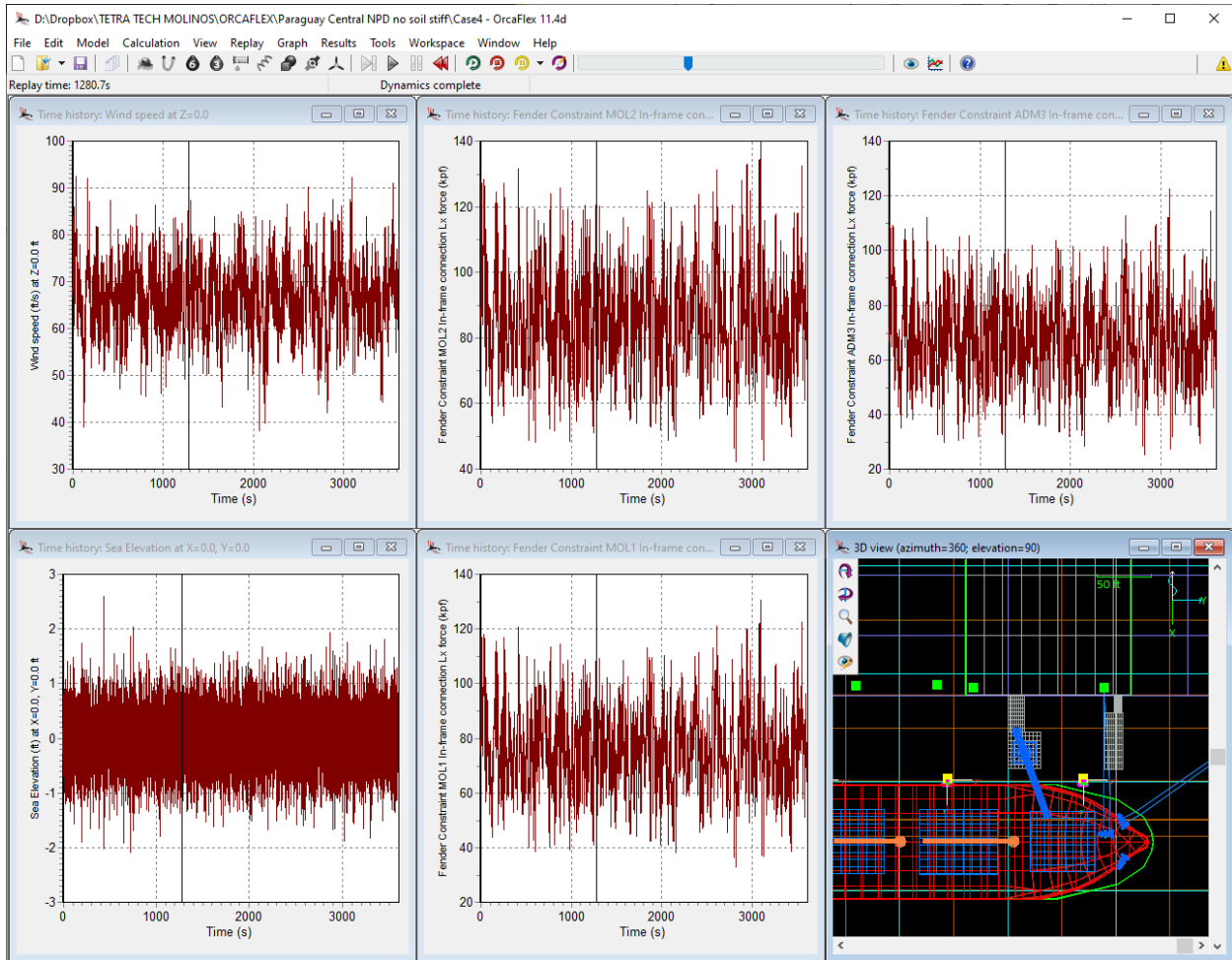


Figure 43 - Fender Force Time Histories, Bulker North, Wind 180°

Good load sharing is seen between the three sets of fenders resisting the ship. The tendency for the bulker is to swing stern away from the wind and to rotate about the fender furthest aft. The lines 3 and 4 provide efficient resistance to this as they are perpendicular to the ship longitudinal axis.

19. REFERENCES & RELEVANT DOCUMENTS

1. PIANC WG 121 Harbour Approach Channels - Design Guidelines 2014.
2. EM_1110-2-1613 Hydraulic Design of Deep-Draft Navigation Projects, May 2006.
3. PIANC InCom WG 141 DESIGN GUIDELINES FOR Inland Waterway Dimensions 2019.
4. PIANC WG 153 REC. FOR DESIGN & ASSESSMENT OF MARINE OIL & PETROCHEMICAL TERMINALS 2016.
5. PIANC MarCom-WG-235 SHIP DIMENSIONS AND DATA, 2022.
6. PIANC WG 33 Guidelines for the Design of Fender Systems 2002-2004.
7. OCIMF MEG4-Mooring Equipment Guidelines, 4th Edition, 2018.
8. UFC-4-159-03 MOORINGS, US Department of Defense, 2020
9. API RP2SK- Design and Analysis of Stationkeeping Systems for Floating Structures, 2005
10. ABS Rules for Building Floating Production Installations, 2022.
11. ASCE 7-16 (and 22) Minimum Design Loads and Associated Criteria for Buildings and Other Structures, 2016, 2022.
12. USACE, Coastal Engineering Manual, EM 110-2-1100, Part II, Change 4, September 2015, Meteorology and Wave Climate.
13. OrcaFlex, software for the dynamic analysis of offshore marine systems, Orcina Ltd., <https://www.orcina.com/orcaflex/>.

APPENDIX 1 WIND SPEEDS FOR MOORING ANALYSIS

No vessels will be permitted at the Molinos Terminal if a hurricane is forecast.

A single maximum allowable wind speed for all vessels using the terminal may be specified. Alternatively, several wind speeds may be specified with larger allowable speeds for smaller vessels. PIANC (Reference 2) advises that in no case should the design mean wind speed be less than 20 m/sec (39 knots or 45 mph).

It is common to relate the design wind speed for terminals to a return period wind speed. OCIMF (Reference 3) mentions a one-year (non-hurricane) or longer return period.

Consideration of wind directions and exposure factors (higher wind speeds blowing over water compared to over land) must be made.

Consider ASCE 7 & Local Building Code Return Period Wind Speeds

MRI, Return Period, years	ASCE 7-22 Wind speed	Puerto Rico Building Code, 2018
10	74 mph	71 mph
25	104 mph	101 mph
50	117 mph	119 mph
100	132 mph	134 mph

Table 15 – ASCE 7 and Local Building Code Extreme Value Wind Speed Comparisons

The data are available online at <https://asce7hazardtool.online/> and <https://hazards.atcouncil.org/>. ASCE 7 refers to these as Service Level wind speeds. Note that a 50-year MRI (Mean Recurrence Interval) wind speed has an annual exceedance probability of $1/50 = 2\%$. These MRI or return period wind speeds are referred to in most mooring codes.

Note that these wind speed data sets include the effect of hurricanes. As the ADM terminal will not be occupied during hurricanes, additional statistics are needed to define maximum wind speeds expected outside hurricanes.

These wind speeds are given at a height of 10 m and represent the speed of a 3-second gust and do not have directional information.

Relate Wind Speeds to 10-m Reference Height, if Necessary

Wind speed increases with height. The design wind speed is defined at the standard reference height of 10 meters. The wind speed profile is typically modelled as a power law:

$$V_z/V_{10} = (z/10)^{1/10}$$

Where:

- z = height above water level
- V_z = wind velocity at height z
- V_{10} = wind velocity at 10 m height

The power 1/10 is used in some codes. The power 1/7 is used in other codes.

If wind speed data is given at an elevation other than 10 m, the above equation is used to convert the wind speed to that at the 10 m standard elevation. In most mooring codes a height coefficient is used, instead of a speed conversion, to calculate the force resulting from increasing wind speed with height. In mooring analysis, the calculation of forces on ship hulls from the waterline to 10 m is treated differently from wind forces on buildings on land.

Relate Wind Speeds to 30-second Averaging Period

Because wind gusts shorter than 30 seconds normally have no significant effect on ship mooring response, the 30-second gust speed is normally used for static mooring analysis. This 30-second period is used in PIANC, OCIMF, and US Navy UFC (Unified Facilities Criteria) see References 2, 3 and 4. A longer averaging period of 60 seconds is used in API and ABS offshore mooring codes (References 5 and 6).

The widely used ASCE Standard 7-16 (this year released as ASCE 7-22, see Reference 7) contains wind hazard maps giving Basic Wind Speed contours used for LRFD building design. The contours are for 3-second gust speeds at 10 m height above the ground for Exposure Category C. ASCE 7 contains four sets of Basic Wind Speed contour maps, one for each ASCE 7 Building Risk Category. Each set shows building design speed contours for a different MRI (Mean Recurrence Interval) from 300 to 3000 years. The data for wind speeds corresponding to 10-yr, 25-yr, 50-yr and 100-yr return periods is summarized in Table 15, above.

The wind speed with a 30-second averaging period is found from the 3-second averaging period using the figure below from Reference 7.

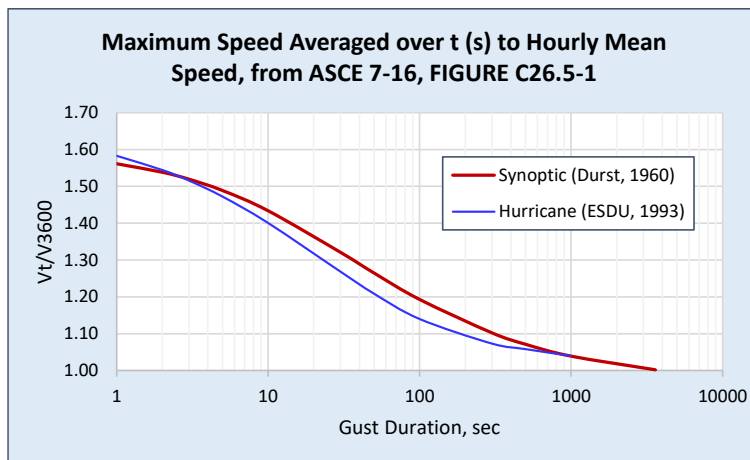


Figure 44 – Gust Speed Averaging Period Relationships

To convert a 3-second (non-hurricane) gust speed to a 30-second gust speed, divide by 1.155. To convert a 5-second (non-hurricane) wind to a 30-second wind speed, divide by 1.127.

Use Locally Measured Wind Speeds and Filter out Hurricane Data

Locally recorded wind speed records are available through a variety of sources. Standard historical data sets are available through NOAA. Data from the San Juan L.M. Marin Airport, NOAA Station 11641 has been used on this project.

The wind direction and speed data has been stripped out of the full data sets and input to an excel

MRI, Return Period	Max 5-sec gust speeds from Measured data, Exposure D, Excluding Hurricanes	Max Equivalent 3-sec gust speeds from Measured data, Exposure D, Including Hurricanes	ASCE 7-22, 3-sec gust speeds
25-year	64 mph	87 mph	100 mph
50-year	67 mph	104 mph	114 mph
100-year	71 mph	124 mph	128 mph

workbook 108,000 rows of data, representing a wind speed data set every hour for years 2012 through 2021. The data is divided into epochs of one month. Months with hurricanes can be excluded or included. The generalized extreme value distribution is used to predict extreme values using the Gumbel reduced variate (Reference 8).

Table 16 – ASCE 7 and Measured Wind Speed Extreme Value Comparisons

Table 16, above, shows comparisons of measured wind speed data with ASCE 7-22 return period data. The extreme maximum values predicted from the measured data are multiplied by 1.086 to account for the equivalent exposure factors at the airport (Exposure C) to the ADM terminal (Exposure D for winds from the east). The charts below indicate the methodology.

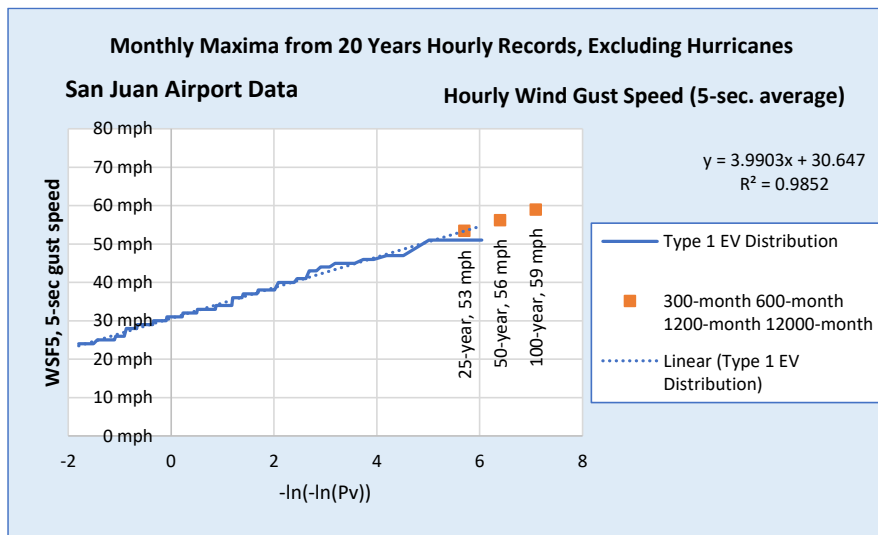


Figure 45 – Gumbel Plot, Extreme Value Wind Speeds, Excluding Hurricane Data (linear extrapolation)

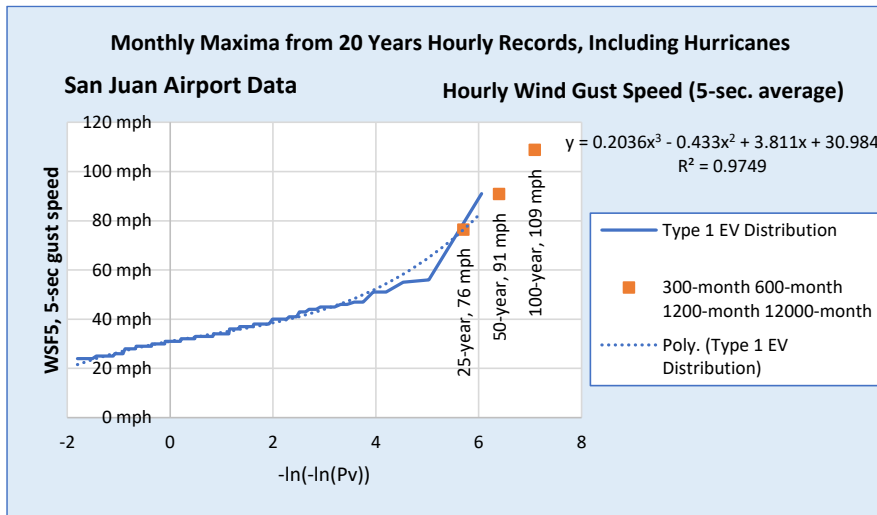


Figure 46 – Extreme Value Plot of Wind Speeds, Including Hurricane Data (non-linear extrapolation)

The non-linear extrapolation of the 20 years of measured data, including hurricanes, results in similar wind speed extreme values to those from ASCE 7-22.

The much lower wind speed extreme values, excluding hurricanes, are appropriate for consideration in mooring design. The data in Table 16 is shown plotted in Figure 47, below. The 5-second gust data speeds must be but must still be corrected for 30-second gust duration used in mooring analysis.

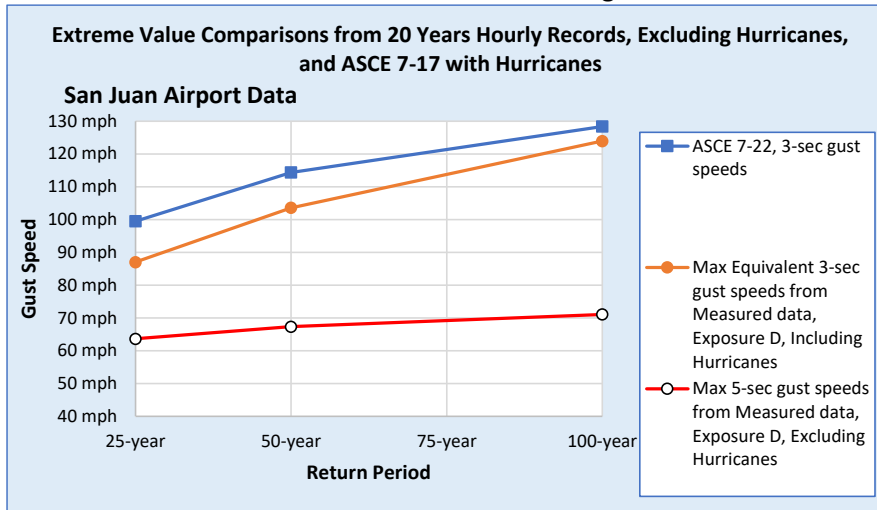


Figure 47 – ASCE 7 and Measured Wind Speed Extreme Value Comparisons

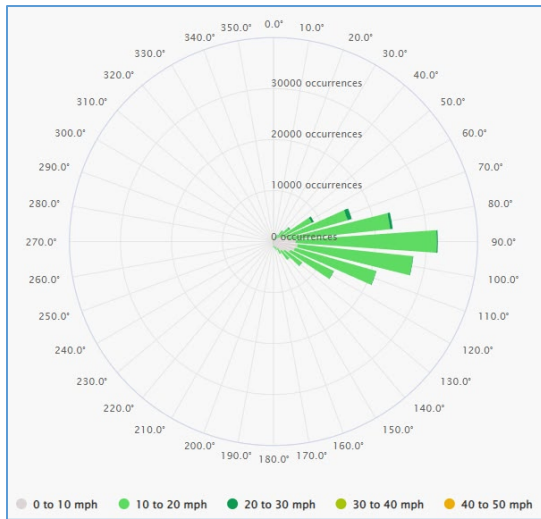
Summary of 30-Second Wind Speeds and Return Periods at ADM Site

Table 17, below, summarized the maximum 30-second wind speeds with 26-year, 50-year and 100-year return periods at the ADM site, based on statistical analysis of 20 years of good quality hourly measurements.

MRI, Return Period	Max 30-sec gust speeds from Measured data, Exposure D, Excluding Hurricanes	
25-year	56.5 mph	49.1 kt
50-year	59.8 mph	52.0 kt
100-year	63.1 mph	54.8 kt

Table 17 – Maximum 30-second Gust Speeds at ADM Site, Based on Measured Data

Directions for Extreme Wind Speeds for Mooring Analysis



The wind rose in Figure 48 is taken from 20 years of hindcast data at San Juan from a Meteoblue study (Reference 9). The wind is almost entirely from within the quadrant from 45° to 135° from NE to SE. However, a dozen or so occurrences of 35-38 mph 5-second gusts have been observed from the west in non-hurricane conditions in the last 20 years.

The maximum 30-second wind speeds with a 50-year return period coming from all other directions (from 135° through 360° to 45°) are conservatively estimated to be less than 45 knots.

Figure 48 – Wind Rose of 20 years of Hindcast Data at San Juan

Selected Design Wind Speed and Direction for Mooring Analysis

The selected design wind speeds and directions for the mooring analysis (and hence loads on the breasting dolphins) is summarized in Figure 49. A 30-second wind speed of 52 knots (at standard height of 10 m) will be used coming from directions 45° to 135°. This is indicated by the blue sector in Figure 49. A 30-second wind speed of 45 knots (at standard height of 10 m) will be used for all other directions. This is indicated by the orange sector in Figure 49.

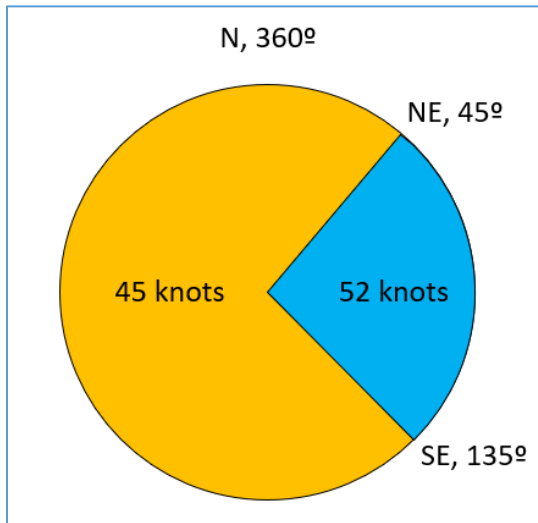


Figure 49 – Mooring Design Wind Speeds & Directions

These wind speeds are in line with local observations of environmental conditions at the terminal. They are 50-yr return period, non-hurricane (30-second average) wind speeds.

A wind speed time history is used in OrcaFlex, created from one of three available wind spectra:

- API (American Petroleum Institute)
- NPD (Norwegian Petroleum Directorate)
- ESDU (Engineering Sciences Data Unit)

The mean wind speed for the chose spectrum is the 1-hr mean wind speed, which is equal to the 30-second speed divided by 1.32. The relationships are shown in the table below.

OrcaFlex	30-sec wind	30-sec wind	1-hr wind
Set Wind Speed1	52.00 kt	87.8 ft/s	66.5 ft/s
Set Wind Speed2	45.00 kt	76.0 ft/s	57.5 ft/s

Table 18 – Input to OrcaFlex Wind Spectrum is the 1-hr Wind Speed

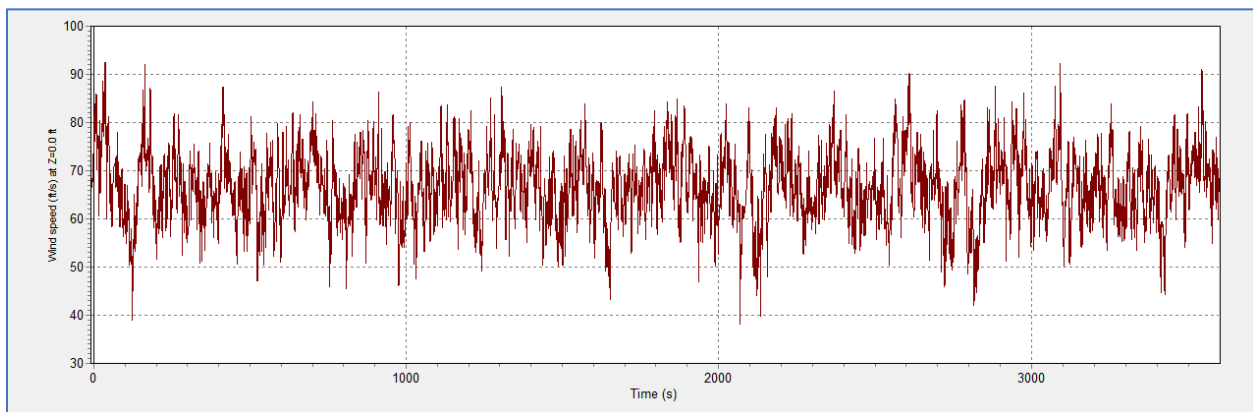


Figure 50 Time History of Wind Speed with 66.5 ft/sec Mean Value

The 30-second gust speed is reached or exceeded on around 13 occasions in 3600 seconds.



Linked statistics: Environment		
OrcaFlex 11.4d: Case3.sim (modified 10:13 PM on 9/21/2024 by OrcaFlex 11.4d)		
Period: Whole simulation		
	Time (s)	Wind speed (ft/s) at Z=0.0 ft
Mean		66.6208
Std. Dev.		7.37579
RMS		67.0278
Mean up-crossing period Tz (s)		8.92178
Mean crest period Tc (s)		3.44761
m0		54.4023
m2		0.68346
m4		0.0575
Bandwidth (ε)		0.92232
max	37.6	92.5491
min	2068.2	38.149

Table 19 – Statistics of the OrcaFlex Generated Wind Speed Time History.