

Wind, Wave and Water Level Analysis

Jaycee Park, Fort Pierce, FL

Prepared for:

Bolchoz Marine Advisors
Jupiter, FL

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Executive Summary

Water Environment Consultants, LLC (WEC) was contracted by Bolchoz Marine Advisors (BMA) to complete a study to define the seasonal and extreme wind, wave, and water level conditions at Jaycee Park in Fort Pierce, Florida.

WEC reviewed readily available water level information from the National Oceanic and Atmospheric Administration (NOAA) and Federal Emergency Management Agency (FEMA). WEC analyzed wind records from the Witham Field Airport and the America Society of Civil Engineers (ASCE) database for seasonal and extreme wind conditions. WEC determined wave conditions using the straight-line fetch methodologies described by the US Army Corps of Engineers' (USACE) Coastal Engineering Manual (CEM). The results of the analysis are summarized in the following tables.

Table ES-1. Tidal water level datums

Datum	Description	Elevation (ft NAVD88)
NAVD88	North American Vertical Datum of 1988	0.0
MHHW	Mean Higher-High Water	-0.1
MHW	Mean High Water	-0.3
MSL	Mean Sea Level	-1.0
MLW	Mean Low Water	-1.7
MLLW	Mean Lower-Low Water	-1.9

Table ES-2. Extreme water elevations at Jaycee Park

Return Period (yrs)	Stillwater Elevation (ft NAVD88)
25	2.65
50	3.35
100	4.20

Table ES-3. Seasonal and extreme wind speeds

Return Period (yrs)	Gust (3-sec) wind speed (mph)	Duration for Fetch-Limited Conditions (min)	Adjusted wind speed (mph)
Western Fetch			
1	-	56	25
25	109	41	65
50	122	39	73
100	133	38	80
Southwestern Fetch			
1	-	61	25
25	109	44	65
50	122	42	73
100	133	41	80

Table ES-4. Maximum calculated wave conditions at the Jaycee Park dock

Return Period (yrs)	Approach Direction (From)	Significant Wave Height H_s (ft)	Peak Wave Period T_p (sec)
1		1.0	1.8
25	Western Fetch	3.2	2.6
50		3.7	2.8
100		4.2	2.9
1		1.1	1.9
25	Southwestern Fetch	3.4	2.7
50		3.9	2.9
100		4.4	3.0

1 Introduction

Water Environment Consultants (WEC) prepared this wind wave analysis to define the seasonal and extreme wind, wave, and water level conditions for Bolchoz Marine Advisors. The objective of this analysis is to support the design of new concrete floating docks that are proposed to replace the existing, fixed courtesy docks at Jaycee Park. The Jaycee Park in Fort Pierce is located along the eastern shores of the Indian River/Intracoastal Waterway, just south of the Fort Pierce Inlet and Fort Pierce South Bridge (Figure 1-1). For this study, the extreme conditions included an analysis of winds, waves, and water levels associated with 25-, 50- and 100-year return period events. The seasonal analysis was associated with the annual or 1-year return period.

WEC reviewed and analyzed readily available water level information from the National Oceanic and Atmospheric Administration (NOAA) and Federal Emergency Management Agency (FEMA). WEC analyzed wind records from the Witham Field Airport and the American Society of Civil Engineers (ASCE) database for seasonal and extreme wind conditions. WEC determined wave conditions using the straight-line fetch methodologies described by the US Army Corps of Engineers' (USACE) Coastal Engineering Manual (CEM).

This report summarizes the results in the following sections:

- Section 2, Water Levels – summarizes tidal and extreme water levels at the site.
- Section 3, Wind Speeds – provides estimates of extreme wind speeds that may occur during hurricane events as well as analysis of airport data to determine typical seasonal wind conditions.
- Section 4, Annual and Extreme Waves – estimates the annual and extreme wind generated waves at the project site.



Figure 1-1. Project location map

2 Water Levels

2.1 Astronomical Tides

The project site is located just south of the Fort Pierce South Bridge, where NOAA tide station 8722219 (South Beach Causeway, FL) is located. The tidal datums at this station reflect those at the project site as well and are listed in Table 2-1.

Table 2-1. Tidal water level datums

South Beach Causeway (8722219)		
Datum	Description	Elevation (ft NAVD88)
NAVD88	North American Vertical Datum of 1988	0.0
MHHW	Mean Higher-High Water	-0.1
MHW	Mean High Water	-0.3
MSL	Mean Sea Level	-1.0
MLW	Mean Low Water	-1.7
MLLW	Mean Lower-Low Water	-1.9

2.2 Extreme Water Levels

The extreme water level or stillwater elevation (SWEL) is the projected elevation of floodwaters, in the absence of waves, due to astronomical tides, storm surge, and wave setup. FEMA evaluated the stillwater elevations for different return period events (i.e. 10-, 25-, 50-, 100-, and 500-yr), which are published in the effective Flood Insurance Study (FIS) for St. Lucie County (FEMA 2020). WEC recommends using these water level estimates as they are the result of the most recently completed, detailed storm surge analysis near the project site.

FEMA modeled hurricane storm surge along Florida’s east coast using a coupled hydrodynamic and wave model (the ADCIRC+SWAN model). The model includes extreme water levels generated by hurricane wind stresses, atmospheric pressure deficit effects, and wave setup effects. The site is protected from open ocean SWEL based on the modeled water level results. Table 2-2 lists the extreme stillwater elevations at the project site which are the SWEL values within the Indian River adjacent to the site.

Table 2-2. Recommended extreme stillwater elevations at the project site

Return Period (yrs)	Stillwater Elevation (ft NAVD88)
25	2.65
50	3.35
100	4.20

3 Wind Speeds

3.1 Seasonal Wind Speeds

WEC evaluated seasonal wind patterns based on meteorological data recorded at the Witham Field Airport from January 2006 through September 2022. Table 3-1 lists the monthly maximum wind speeds for the length of record in miles per hour. The maximum observed, 2-min sustained wind speed was 47 mph. Note the below table does not include wind gusts, which are measured as 3-sec sustained durations, and can measure higher than 2-min sustained speeds. Figures 3-1 through 3-4 show seasonal wind rose plots based on the hourly wind records for 2006 through 2022. Between April and September, winds blow predominantly from the southeast quadrant. Between October and March, winds also blow predominantly from the east and east-southeast, however records show a high percent of northwest winds as well.

WEC used the annual, or 1-yr return period wind speed, as the maximum wind speed during operational conditions at the park. To estimate the 1-yr return period wind speed, WEC analyzed the monthly maximum airport wind records (Table 3-1). WEC found that a Weibull distribution ($k=1.0$) provided the best fit to the data (Figure 3-5). The resulting 1-yr return period 2-min duration wind speed is 32.2 mph.

Table 3-1. Monthly maximum wind speeds, 2-min duration (mph)

Year	Monthly Maximum											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	30	24	28	24	20	21	26	24	21	20	22	23
2007	21	24	23	23	24	23	20	15	22	26	18	21
2008	24	21	24	22	25	16	29	34	22	22	20	20
2009	22	24	23	43	21	25	32	23	18	20	25	20
2010	21	29	26	23	23	18	21	26	21	22	18	31
2011	21	21	26	23	20	21	18	28	20	30	21	21
2012	23	24	29	25	20	29	24	29	29	33	22	24
2013	22	24	28	23	47	18	36	27	22	29	34	20
2014	22	24	26	43	23	34	23	33	23	18	24	22
2015	24	23	23	22	22	21	28	22	23	23	28	23
2016	32	26	25	23	45	28	29	18	23	41	25	34
2017	36	25	23	23	25	23	18	22	25	29	24	28
2018	28	18	25	28	29	20	25	23	23	24	25	28
2019	34	23	29	25	23	23	21	25	28	21	25	25
2020	25	23	21	24	25	23	31	29	24	24	33	22
2021	20	25	24	24	23	23	24	25	21	21	22	24
2022	26	23	38	34	25	24	16	17	32	-	-	-
Max	36	29	38	43	47	34	36	34	32	41	34	34

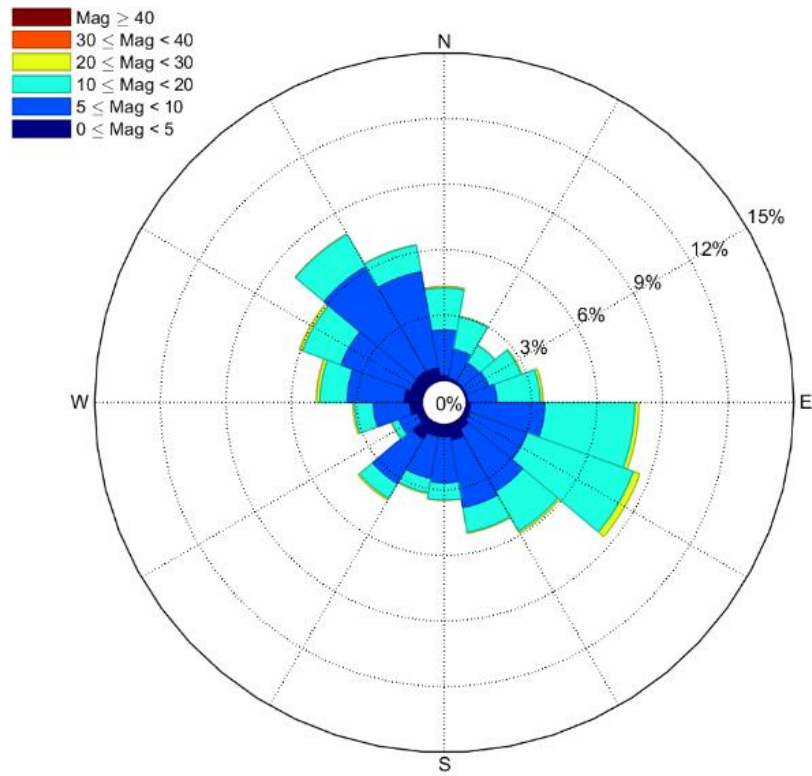


Figure 3-1. Wind rose of hourly wind speeds at Witham Field Airport, 2006-2022; January - March.

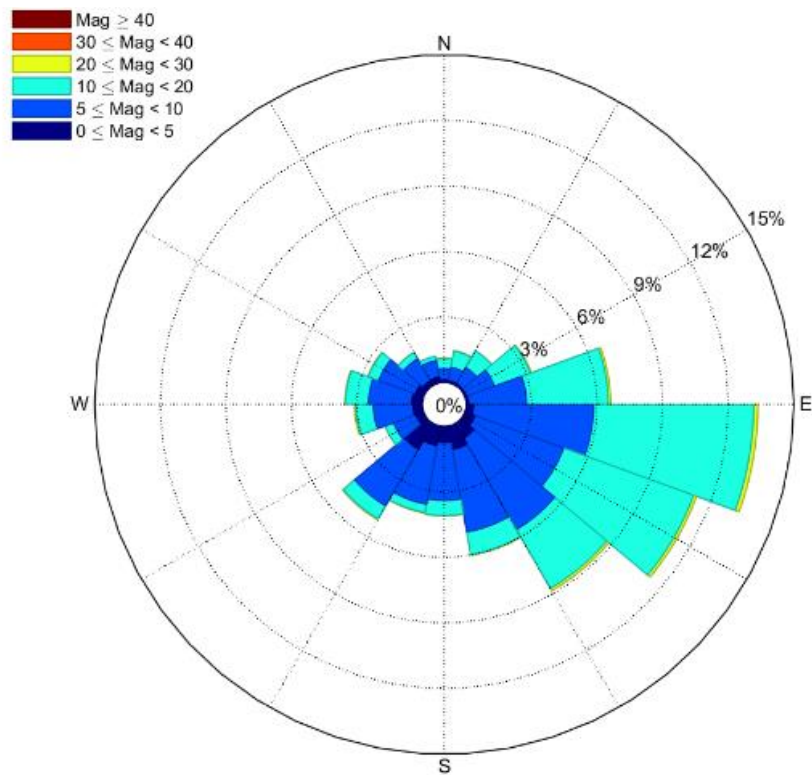


Figure 3-2. Wind rose of hourly wind speeds at Witham Field Airport, 2006-2022; April - June.

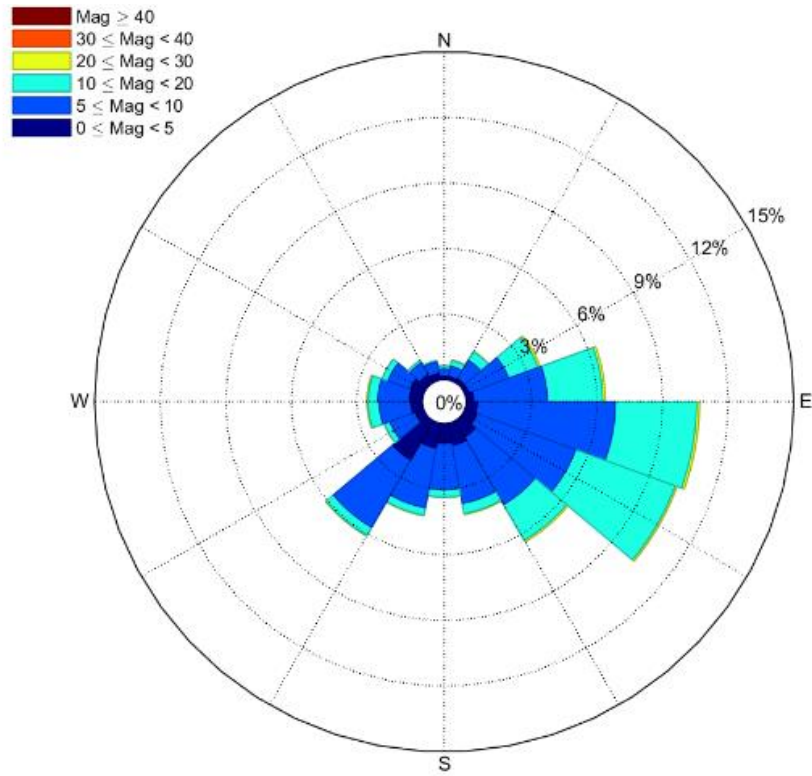


Figure 3-3. Wind rose of hourly wind speeds at Witham Field Airport, 2006-2022; July - September.

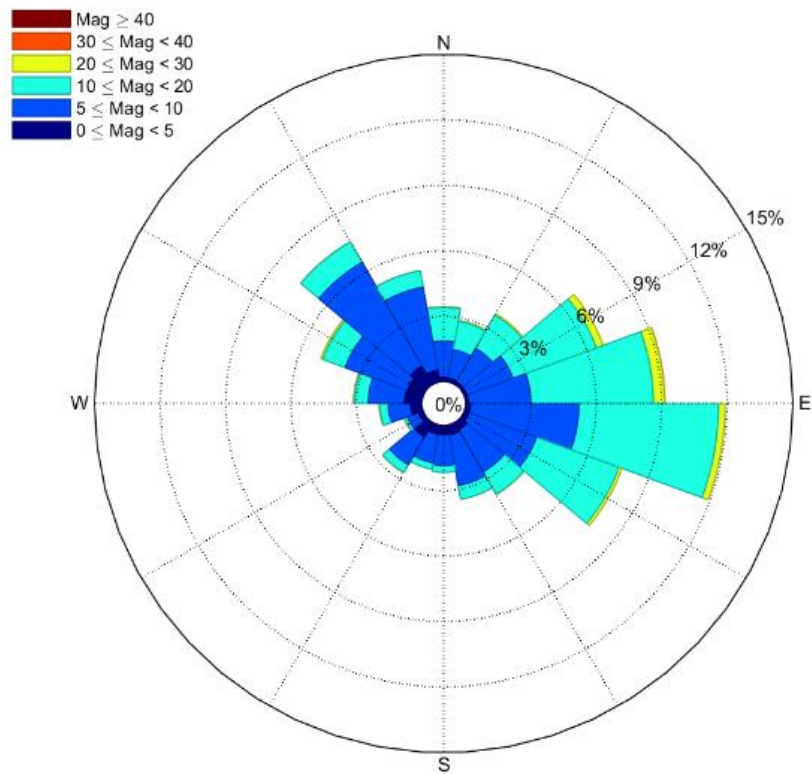


Figure 3-4. Wind rose of hourly wind speeds at Witham Field Airport, 2006-2022; October - December.

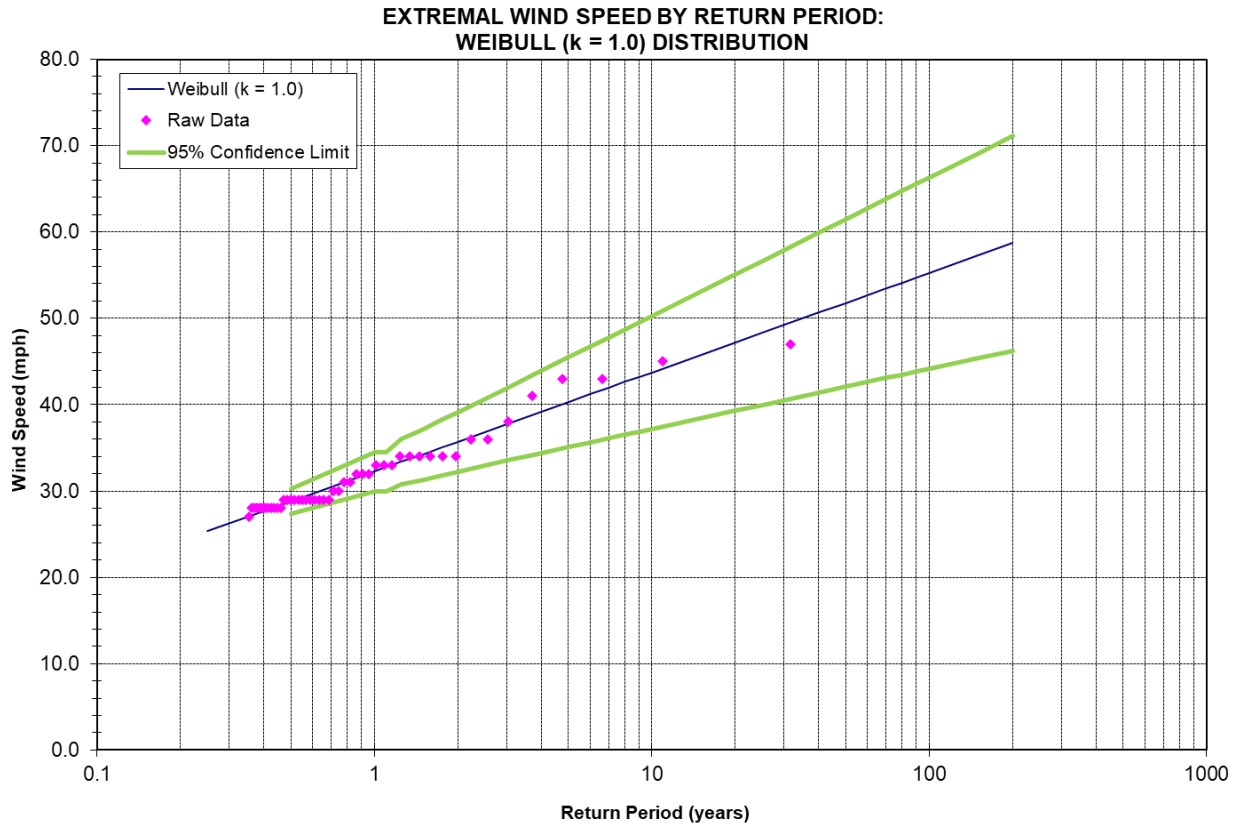


Figure 3-5. Wind speed by return period determined using Weibull (k=1.0) distribution analysis

3.2 Extreme Wind Speeds

Extreme wind speeds are dominated by different meteorological events (i.e., extratropical cyclones, thunderstorms, hurricanes and tornadoes) in different regions of the country. Along the Atlantic and Gulf coastal regions, extreme wind speeds are dominated by hurricane and tropical storm events.

The American Society of Civil Engineers (ASCE) produced the consensus national standard for the engineering field for wind load design provisions as defined in *ASCE 7 - Minimum Design Loads on Buildings and Other Structures*. The 2022 edition (ASCE 2022) predicted extreme wind speeds for the project site are shown in Table 2-3 for the 25, 50 and 100-year return period events. These values are 3-second average gust wind speeds.

Table 3-2. Extreme wind speeds

Return Period (yr)	Wind Speed Gust (mph)
25	109
50	122
100	133

4 Waves

The Jaycee Park dock is subjected to both wind wave and vessel wakes, as discussed in the sections below.

4.1 Wind Waves

WEC calculated extreme wave conditions at Jaycee Park using the straight-line fetch methodologies and equations described in the US Army Corps of Engineers' (USACE) Coastal Engineering Manual (CEM) (USACE 2002). This method evaluates wind wave growth along the critical fetches, resulting in the largest locally generated wind waves that affect the site. The site is protected from open ocean waves by elevated topography between the park and coastline. Thus, wave exposure at the site is limited to local, wind-generated waves blowing across the river towards the site.

WEC calculated the effective fetch distance as the average of nine fetch radials spread in 3° increments, as recommended by the Shore Protection Manual (USACE 1984). The longest fetch exposure at the site is to southwest, as shown in Figure 4-1. The average fetch length in this direction is 2.2 miles.

WEC also calculated the effective fetch and associated wind-waves from the western direction. The resulting wave characteristics are less than those from the longest fetch distance. However, the floating dock design must consider waves approaching from multiple angles in order to properly evaluate its performance.

The CEM (USACE 2002) gives the following equations governing wave growth as a function of fetch length and wind speed:

$$\frac{gH_{m0}}{u_*^2} = 4.13 \times 10^{-2} \left(\frac{gX}{u_*^2} \right)^{1/2}$$

$$\frac{gT_p}{u_*} = 0.751 \left(\frac{gX}{u_*^2} \right)^{1/3}$$

$$C_D = \frac{u_*^2}{U_{10}^2}$$

$$C_D = 0.001(1.1 + 0.035 U_{10})$$

where H_{m0} is the energy-based significant wave height,
 u_* is the friction velocity, T_p is the peak wave period,
 C_D is the drag coefficient, and
 U_{10} is the wind speed at 10 m elevation.

Table 4-1 and 4-2 summarizes the results of the wind wave analysis for each return period and approach direction. WEC determined the wind time-averaging durations that resulted in the maximum fetch-limited wind wave growth. The energy-based significant wave height, H_{m0} , listed in these tables is equivalent to the significant wave height, H_s , in deep water. A realistic wave field includes a range of wave heights, and the significant wave height, H_s , represents the average of the highest one-third of the

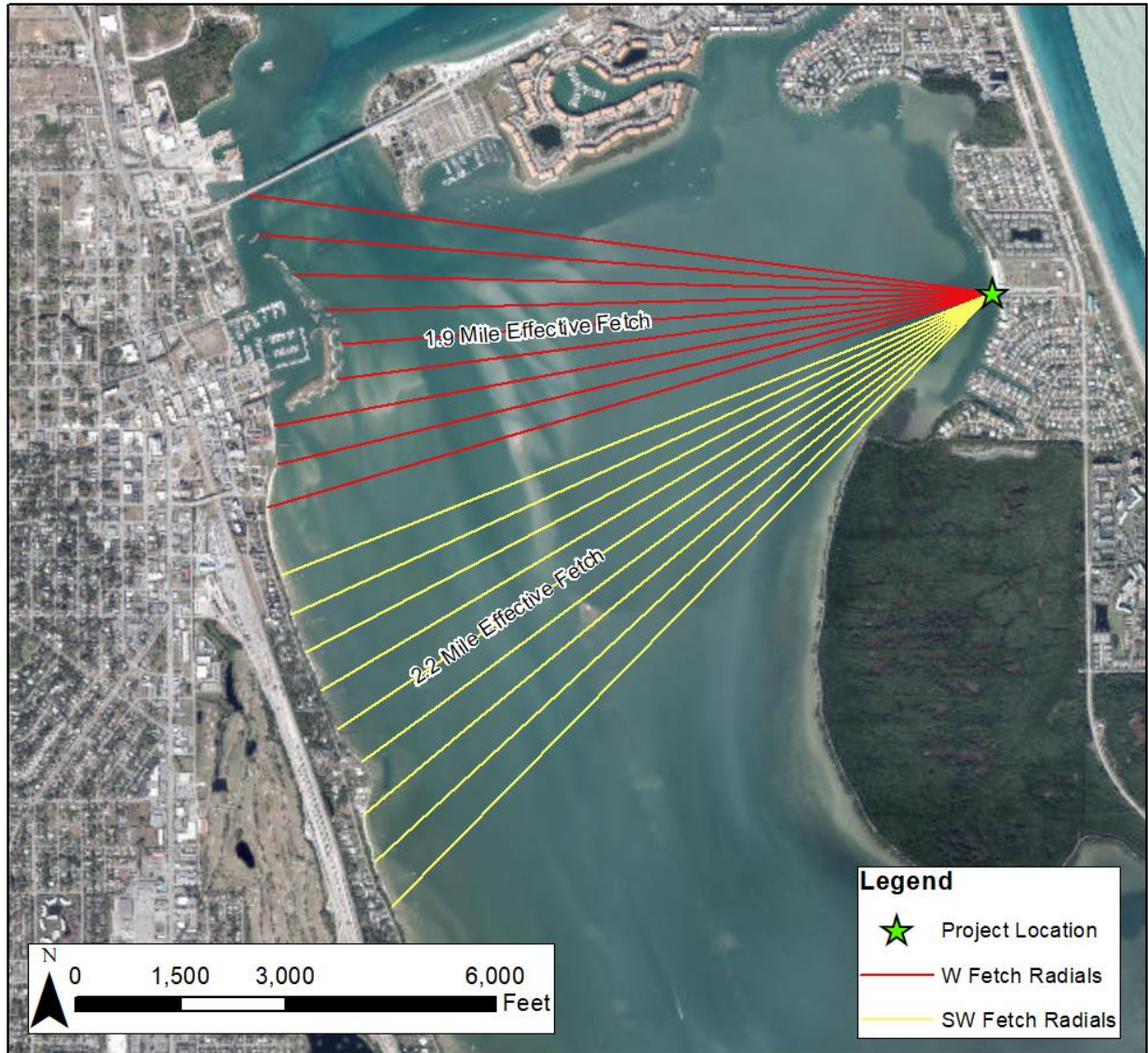


Figure 4-1. Straight-line fetch rays relative to the project site

wave height spectrum. Extreme individual waves can have heights on the order of $2H_s$ (USACE 2002). FEMA defines the controlling wave height as $1.6H_s$, which is a value approaching the average height of the highest one percent of waves during storms (FEMA 2007).

4.2 Vessel Wakes

Boat wakes are another source of locally-generated waves. Wakes are short period waves that range in height depending on the size, draft, and speed of the vessel. A review of published vessel wake heights for various vessels indicates a range of wake heights from 0.7 to 2.3 feet for 23- to 40-foot small craft, at a range of 100 ft from their sailing line (USACE 2002). Wake heights attenuate with distance from the vessel sailing line, and typical wakes decrease to one foot or less at 500 feet from their origin.

Table 4-1. Seasonal and extreme wind speeds

Return Period (yrs)	Gust (3-sec) wind speed (mph)	Duration for Fetch-Limited Conditions (min)	Adjusted wind speed (mph)
Western Fetch			
1	-	56	25
25	109	41	65
50	122	39	73
100	133	38	80
Southwestern Fetch			
1	-	61	25
25	109	44	65
50	122	42	73
100	133	41	80

Table 4-2. Maximum calculated wind-wave conditions at the Jaycee Park dock

Return Period (yrs)	Approach Direction (From)	Significant Wave Height H_s (ft)	Peak Wave Period T_p (sec)
1		1.0	1.8
25	Western Fetch	3.2	2.6
50		3.7	2.8
100		4.2	2.9
1		1.1	1.9
25	Southwestern Fetch	3.4	2.7
50		3.9	2.9
100		4.4	3.0

For example, in 2020, WEC measured attenuation of wakes generated by a wake surfing boat, and Figure 4-2 shows observed wake height attenuation versus distance from the sailing line. The federal navigation channel is roughly 1.5 miles from the Jaycee Park, and therefore any boat wakes generated from vessel in the channel would be insignificant when they reach the project site. However, boat wakes may be generated from recreational vessels in the vicinity of Jaycee Park. Enforcement of a no-wake zone along the park’s frontage would help reduce the potential for damaging wake activity. If the City of Fort Pierce has observed unacceptable levels of vessel wake activity affecting the existing dock structure, WEC recommends a field study to measure the problematic wake heights and periods affecting the site so that the performance of the wave attenuation system can be evaluated for these frequently occurring waves.

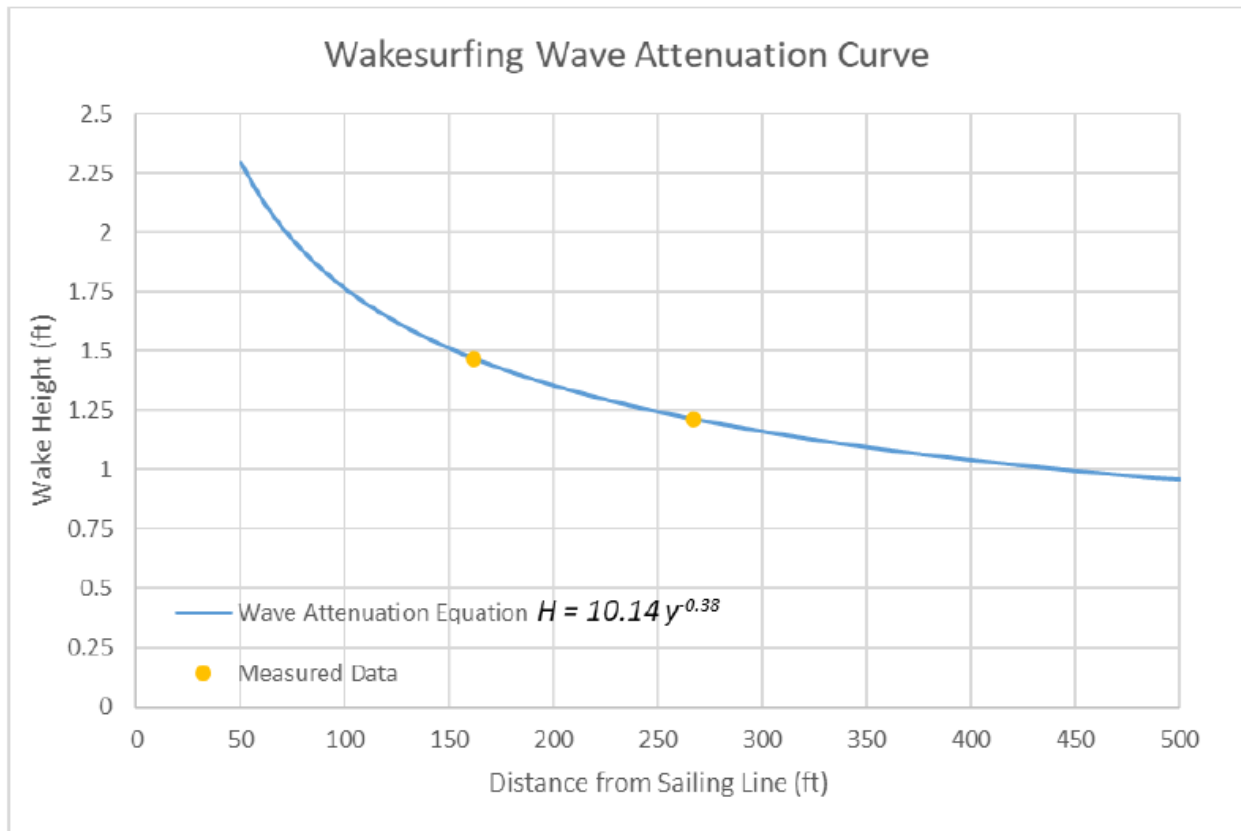


Figure 4-2. WEC measured wake height data and best-fit wake attenuation by distance from sailing line (wakesurfing conditions)

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