

Interim Guidance on Hurricane Conditions in the Gulf of Mexico

API BULLETIN 2INT-MET
MAY 2007

ERRATA, OCTOBER 2007



Interim Guidance on Hurricane Conditions in the Gulf of Mexico

Upstream Segment

API BULLETIN 2INT-MET
MAY 2007

ERRATA, OCTOBER 2007



SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, N.W., Washington, D.C. 20005.

Copyright © 2007 American Petroleum Institute

FOREWORD

This bulletin is under the jurisdiction of the API Subcommittee on Offshore Structures.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API Standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API Standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

Suggested revisions are invited and should be submitted to the Standards and Publications Department, API, 1220 L Street, NW, Washington, D.C. 20005, standards@api.org.

CONTENTS

	Page
1 INTRODUCTION	1
1.1 Background	1
1.2 Organization	1
1.3 Limitations and Ongoing Work	2
2 DEFINITIONS	2
3 REGIONS AND AREAS OF APPLICABILITY	2
4 INDEPENDENT EXTREME WIND, WAVE, CURRENT AND SURGE	3
4.1 Wind	4
4.2 Waves	6
4.3 Currents	7
4.4 Surge and Tide	10
4.5 Independent Extremes by Region	10
5 ASSOCIATED WIND, WAVE, CURRENT AND SURGE FOR LOAD CASES	35
6 EXAMPLE APPLICATIONS: DETERMINING CONDITIONS AT A SITE	36
6.1 Example: Shallow Water Site	36
6.2 Example: Intermediate Depth Site Between Regions	37
7 SUDDEN HURRICANE CONDITIONS	42
8 SEASONAL HURRICANE CONDITIONS	49
9 GUIDELINES FOR SITE-SPECIFIC METOCEAN STUDIES	49
10 COMMENTARY	50
10.1 Basis of New Metocean Conditions	50
10.2 Regional Considerations	51
10.3 Length of Hindcast Database	52
10.4 Site-specific Studies	53
10.5 References	53

Figures

3.1 Gulf Regions and Areas of Applicability	3
4.2.2-1 Direction Factor for Wave Heights North of 26°N, West of 84°W, WD > = 30m (98 ft), Return Periods > 10 Year	8
4.3.1-1 Current Heading North of 26°N, WD < = 70m (230 ft)	9
4.5.1-1A N-Year H_s , West Region	12
4.5.1-2A N-Year H_{max} , West Region	12
4.5.1-3A N-Year Max Crest Elevation, West Region	13
4.5.1-4A N-Year Surge with Tide, West Region	13
4.5.1-1B N-Year H_s , West Region	15
4.5.1-2B N-Year H_{max} , West Region	15
4.5.1-3B N-Year Max Crest Elevation, West Region	16
4.5.1-4B N-Year Surge with Tide, West Region	16
4.5.2-1A N-Year H_s , West Central Region	18

4.5.2-2A	N-Year $H_{\max}$, West Central Region	18
4.5.2-3A	N-Year Max Crest Elevation, West Central Region	19
4.5.2-4A	N-Year Surge with Tide, West Central Region	19
4.5.2-1B	N-Year H_s , West Central Region	21
4.5.2-2B	N-Year $H_{\max}$, West Central Region	21
4.5.2-3B	N-Year Max Crest Elevation, West Central Region	22
4.5.2-4B	N-Year Surge with Tide, West Central Region	22
4.5.3-1A	N-Year H_s , Central Region	24
4.5.3-2A	N-Year $H_{\max}$, Central Region	24
4.5.3-3A	N-Year Max Crest Elevation, Central Region	25
4.5.3-4A	N-Year Surge with Tide, Central Region	25
4.5.3-1B	N-Year H_s , Central Region	27
4.5.3-2B	N-Year $H_{\max}$, Central Region	27
4.5.3-3B	N-Year Max Crest Elevation, Central Region	28
4.5.3-4B	N-Year Surge with Tide, Central Region	28
4.5.4-1A	N-Year H_s , Eastern Region	30
4.5.4-2A	N-Year $H_{\max}$, Eastern Region	30
4.5.4-3A	N-Year Max Crest Elevation, Eastern Region	31
4.5.4-4A	N-Year Surge with Tide, Eastern Region	31
4.5.4-1B	N-Year H_s , Eastern Region	33
4.5.4-2B	N-Year $H_{\max}$, Eastern Region	33
4.5.4-3B	N-Year Max Crest Elevation, Eastern Region	34
4.5.4-4B	N-Year Surge with Tide, Eastern Region	34
7-1A	N-Year H_s , All Regions	44
7-2A	N-Year $H_{\max}$, All Regions	44
7-3A	N-Year Max Crest Elevation, All Regions	45
7-4A	N-Year Surge with Tide, All Regions	45
7-1B	N-Year H_s , All Regions	47
7-2B	N-Year $H_{\max}$, All Regions	47
7-3B	N-Year Max Crest Elevation, All Regions	48
7-4B	N-Year Surge with Tide, All Regions	48

Tables

4.1.3.1	Coefficients and Distances for the 3-D ($i = 1,2,3$) Coherence Spectrum	6
4.5.1-1A	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Western Gulf of Mexico (97.5°W to 95.0°W)	11
4.5.1-1B	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Western Gulf of Mexico (97.5°W to 95.0°W)	14
4.5.2-1A	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, West Gulf of Mexico (94.0°W to 90.5°W)	17
4.5.2-1B	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Western Central Gulf of Mexico (94.0°W to 90.5°W)	20
4.5.3-1A	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Central Gulf of Mexico (89.5°W to 86.5°W)	23
4.5.3-1B	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Central Gulf of Mexico (89.5°W to 86.5°W)	26
4.5.4-1A	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Eastern Gulf of Mexico (85.5°W to 82.5°W)	29
4.5.4-1B	Independent Extreme Values for Hurricane Winds, Waves, Currents and Surge, Eastern Gulf of Mexico (85.5°W to 82.5°W)	32
5-1	Factors for Combining Independent Extremes into Load Cases in Deep Water ($WD \geq 150$ m or 492 ft)	35



	Page
5-2	Factors for Cominbing Independent Extremes into Load Cases in Shallow Water (10 m or 33 ft $\leq$ WD $\leq$ 70 m or 230 ft)
7-1A	Independent Extreme Values for Sudden Hurricane Winds, Waves, Currents and Surge (All Regions)
7-1B	Independent Extreme Values for Sudden Hurricane Winds, Waves, Currents and Surge (All Regions)
	36
	43
	46

Interim Guidance on Hurricane Conditions in the Gulf of Mexico

1 Introduction

This interim document presents hurricane-driven metocean conditions (wind, wave, current and surge) for use with and reference by other API standards. These conditions are intended to replace the conditions documented in Sections 2.3.4.c and 17.6.2.a of API RP 2A-WSD, 21st Edition and Appendix C.4 of ISO 19901-1.

The metocean conditions documented herein are for guidance and will not generally provide as accurate a result as a dedicated site-specific study. Performance of a site-specific metocean study is the preferred way of ensuring that regional variations in storm climate and local topographic and bathymetric effects are properly accounted for, and that sufficient data is available to properly identify the phasing between wind, wave, current and surge. When performing response-based analyses, a site-specific study must be performed to develop the necessary time histories of metocean parameters. Site-specific studies should be performed within the guidelines included in this document.

1.1 BACKGROUND

The hurricane metocean conditions presently contained in the 21st Edition of API RP 2A-WSD have not been updated since 1993. Since that time, several major severe storms, most notably Opal (1995), Ivan (2004) and Katrina (2005), have affected the Gulf, resulting in increases to local extremes in the areas affected by these storms. Most importantly, however, industry's understanding of hurricane risk has continued to evolve. Strong evidence now exists for there being a regional dependence for large, intense wave-making storms. Also, investigations into the underlying hurricane record, HURDAT, used as the foundation for the industry's storm hindcast database, have revealed that storms from the early period of the database are probably biased low in terms of intensity.

A new set of hurricane conditions has been derived for reference by other API standards using the latest hindcast storm record and incorporating the industry's best understanding to date of the regional dependence of storm intensity. Conditions are presented for four regions, the boundaries of which are:

- West, between 97.5°W and 95°W
- West Central, between 94°W and 90.5°W
- Central, between 89.5°W and 86.5°W
- East, between 85.5°W and 82.5°W

The database used to establish conditions has been restricted to the years from approximately 1950 through 2005, the period for which better characterization of storms offshore exists by virtue of aerial reconnaissance and later satellite observations.

Of the four regions, changes relative to previous API RP 2A-WSD values are most pronounced in the Central region. Conditions in other regions are similar to those contained in API RP 2A-WSD.

The conditions presented herein are based on an “as-is” acceptance of the hindcast record from approximately 1950 through 2005. They do not include artificial increases to values derived from statistical analysis of the hindcast record beyond those associated with several of the extrapolations involved and make no claim to be conservative. Nor do they consider the possibility of storms with a wave-making potential like Opal, Ivan and Katrina affecting the non-Central regions with a frequency similar to that which has been observed in the Central region.

1.2 ORGANIZATION

The document is organized as follows:

- Section 1: Introduction.
- Section 2: Definitions of terms used.
- Section 3: A description of the four regions, and notes of areas and water depths where the conditions do not apply.
- Section 4: Hurricane-driven independent extremes of wind, wave, current and surge.
- Section 5: Factors for combining the independent extremes in Section 4 into load cases centered on a particular extreme (peak wind, peak wave or peak current).
- Section 6: Example applications of deriving conditions at sites.
- Section 7: A description of “sudden” hurricane conditions for the Northern Gulf of Mexico.

- Section 8: Recommendations for deriving “seasonal” hurricane conditions.
- Section 9: Guidelines for the performance of site-specific studies of hurricane conditions.
- Section 10: Commentary on the conditions presented, summarizing how they were derived and listing select references.

Users of this interim document should thoroughly review the commentary on hurricane conditions included in Section 10 prior to referencing any of the conditions or methods presented herein. The commentary summarizes the technical basis and assumptions used in deriving the conditions. A review of Section 6 is also recommended, as it presents several examples on how wind, wave, current and surge conditions can be established for a given site from the charts and tables in this document.

1.3 LIMITATIONS AND ONGOING WORK

This document only addresses hurricane conditions for the Gulf of Mexico. It does not address other phenomena such as winter storms, the Loop Current, and other deepwater currents, or the joint occurrence of hurricane and Loop/deepwater current phenomena. Furthermore, it does not specify conditions for hurricane-generated bottom currents for water depths beyond 70 m (230 ft). Conditions for these phenomena should be derived through site-specific studies using appropriate hindcast models and quality measurements.

Users of this interim document should be aware that work on hurricane conditions by the API RP 2MET work group is ongoing; additional work is in progress to further examine the following:

- Extremal estimates for all parameters, for return periods in excess of 200 years.
- Wave-current interaction.
- Hurricane currents in shallow and deep water.
- Sudden hurricane conditions.
- Conditions in extremely shallow water (0 m – 10 m or 0 ft – 33 ft).

The provisions in this document are intended to remain in force until a new API recommended practice covering metocean conditions (not limited to hurricanes), API RP 2MET, is published.

2 Definitions

WD	Water depth, referenced to MLLW
MLLW	Mean lower low water
WS	Wind speed
H_s	Significant wave height, defined by $4(m_0)^{0.5}$
$H_{\max}$	Expected maximum individual wave height
$\eta_{\max}$	Expected maximum individual crest height
m_0	The energy contained in the wave spectrum
Surge	The change in sea level caused by the passage of a storm
Tide	Astronomically-driven changes in sea level
Heading	Heading convention is “towards” i.e., the direction T_0 which wind, wave or current are acting
COV	Coefficient of Variation
Shallow	Water depths between 10 m and 70 m (33 ft and 230 ft)
Deep	Water depths greater than or equal to 150 m (492 ft)
Transition	Water depths greater than 70 m (230 ft) and less than 150 m (492 ft)

3 Regions and Areas of Applicability

Hurricane-driven metocean conditions are provided for most areas of the Gulf of Mexico north of 26°N, in water depths (WD) greater than or equal to 10 m (33 ft) mean lower low water level (MLLW). Conditions are presented for four approximate regions of differing hurricane climatology, as shown in Figure 3-1. The regions have been selected based on consideration of trends in (1).

storm size and intensity, (2) regional wind and wave extremes, (3) frequency of Loop Current and eddies, and (4) paths storms may take entering the Gulf. The regions are:

- West, between 97.5°W and 95°W
- West Central, between 94°W and 90.5°W
- Central, between 89.5°W and 86.5°W
- East, between 85.5°W and 82.5°W

Between each region are areas of transition (unshaded), 1° longitude wide. Conditions for these transition areas should be derived by linearly interpolating between the values of the two adjacent regions across the width of the transition. For example, if a site lies at 90.25°W, then conditions for that site would be derived by using those from the West Central region weighted 0.75 and those from the Central region weighted 0.25.

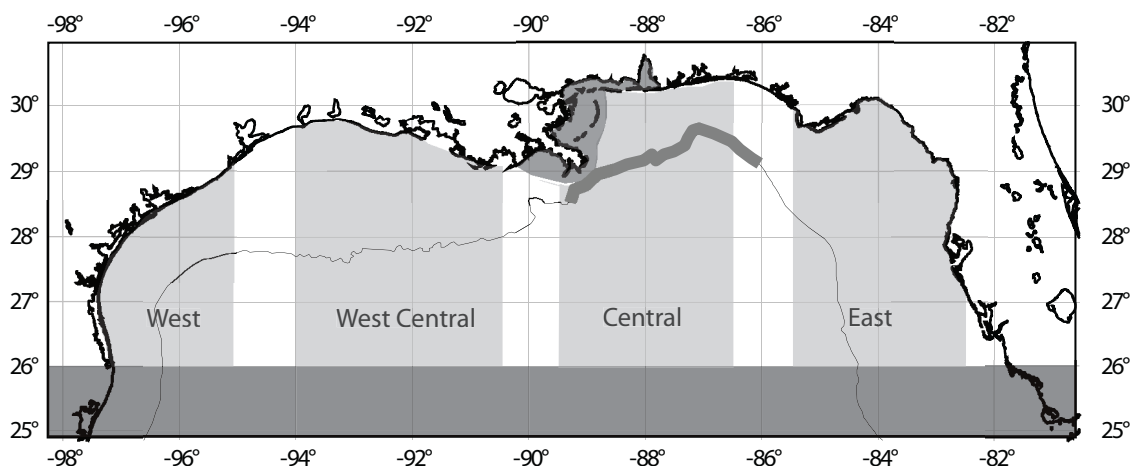


Figure 3.1—Gulf Regions and Areas of Applicability

The conditions in this document do not apply to the following:

- Water depths less than 10 m (33 ft). Shallow areas near the coast will be subject to high surge levels which will depend on the steepness of the local terrain (both bathymetry and overland elevation) as well as the coastal profile. The storm surge very near the coast may allow for the existence of large waves which otherwise would not be possible for calm water conditions.
- Areas inside barrier islands and those around the Mississippi Delta. The shaded areas around the Delta and inside barrier islands will be subject to sheltering, limited fetch and possible attenuation of waves by interaction with mud, and may have complicated surge and current patterns, while areas east of the barrier islands will be subject to complicated currents.
- The steep bathymetry transition (70 m – 500 m or 230 ft – 1640 ft) of the Central region. This shaded area is subject to complicated currents following the passage of hurricanes, which result from the superposition of local wind-generated currents and offshore flow from surge trapped in the area of Eastern Louisiana.

Conditions for areas where the conditions do not apply must be derived by site-specific studies, the performance of which is discussed in Section 9.

4 Independent Extreme Wind, Wave, Current and Surge

Independent extreme values of wind, wave, current and surge have been calculated for return periods of 10, 25, 50, 100, 200, 1000, 2000, and 10000 years for each region and are presented in the tables and figures in 4.5.

Each table shows the following parameters for a given region:

- N-year wind velocities for all water depths.
- N-year waves for water depths greater than or equal to 1000 m (3281 ft).

- Associated periods for n-year waves in all water depths.
- N-year current profiles for water depths greater than or equal to 150 m (492 ft).
- N-year depth-averaged currents for water depths between 10 m and 70 m (33 ft and 230 ft).
- N-year surge for water depths greater than or equal to 500 m (1640 ft).
- Astronomical tide amplitude (0.42 m or 1.4 ft) from MLLW for all water depths (constant for all return periods).

The figures show the following parameters for each region over the water depth range from 10 m – 1000 m (33 ft – 3281 ft):

- N-year H_s .
- N-year $H_{\max}$.
- N-year $\eta_{\max}$ (including associated storm surge and astronomical tide).
- N-year storm surge including astronomical tide.

Each of the parameters is further described below.

4.1 WIND

The 10 m (32.8 ft) elevation wind velocities presented in Tables 4.5.1 to 4.5.4 are applicable to all water depths. The extreme winds should be treated as omni-directional. When adjusting these wind speeds to different averaging intervals and/or elevations, or when developing wind spectra, the following formulas should be used. These formulas are dimensional; one set is provided in SI Units and the other in U.S. Customary Units. It should be noted the spatial coherence formulas (2.3.2-6 and 2.3.2-7) contained in API RP 2A-WSD, 21st Edition (with Supplement 2) are not dimensionally correct for U.S. Customary Units, and the value of α_3 is incorrect. This error has been fixed in API RP 2A-WSD, 21st Edition Supplement 3.

4.1.1 Wind Profiles and Gusts, SI Units

For strong wind conditions (near-neutral stratification) the design wind speed $u(z, t)$ (m/s) at height z (m) above sea level and corresponding to an averaging time period $t \leq t_0 = 3600$ s is given by:

$$u(z, t) = U(z)[1 - 0.41 I_u(z) \ln(t/t_0)]$$

where the 1-hour mean wind speed $U(z)$ (m/s) at level z is given by:

$$U(z) = U_0 \left[1 + C \ln\left(\frac{z}{10}\right) \right], \quad C = 0.0573 \sqrt{1 + 0.15 U_0}$$

and where the turbulence intensity $I_u(z)$ at level z is given by:

$$I_u(z) = 0.06 [1 + 0.043 U_0] \left(\frac{z}{10} \right)^{-0.22}$$

where U_0 (m/s) is the 1-hour average wind speed at 10 m elevation.

4.1.2 Wind Profiles and Gusts, U.S. Customary Units

For strong wind conditions (near-neutral stratification) the design wind speed $u(z, t)$ (ft/s) at height z (ft) above sea level and corresponding to an averaging time period $t \leq t_0 = 3600$ s is given by:

$$u(z, t) = U(z)[1 - 0.41 I_u(z) \ln(t/t_0)]$$

where the 1-hour mean wind speed $U(z)$ (ft/s) at level z is given by:

$$U(z) = U_0 \left[1 + C \ln\left(\frac{z}{32.8}\right) \right], \quad C = 0.0573 \sqrt{1 + 0.0457 U_0}$$

and where the turbulence intensity $I_u(z)$ at level z is given by:

$$I_u(z) = 0.06[1 + 0.013 U_0] \left(\frac{z}{32.8} \right)^{-0.22}$$

where U_0 (ft/s) is the 1-hour average wind speed at 32.8 ft elevation.

4.1.3 Wind Spectra, SI Units

For structures and structural elements for which the dynamic wind behavior is of importance, the following 1-point wind spectrum may be used for the energy density of the longitudinal wind speed fluctuations:

$$S(f) = \frac{320 \left(\frac{U_0}{10} \right)^2 \left(\frac{z}{10} \right)^{0.45}}{(1 + \tilde{f}^n)^{(5/3n)}}$$

$$\tilde{f} = 172f \left(\frac{z}{10} \right)^{2/3} \left(\frac{U_0}{10} \right)^{-0.75}$$

where $n = 0.468$ and where:

- $S(f)$ ($\text{m}^2\text{s}^{-2}/\text{Hz}$) is the spectral energy density at frequency f (Hz)
- z (m) is the height above sea level
- U_0 (m/s) is the 1-hour mean wind speed at 10 m above sea level

4.1.4 Wind Spectra, U.S. Customary Units

For structures and structural elements for which the dynamic wind behavior is of importance, the following 1-point wind spectrum may be used for the energy density of the longitudinal wind speed fluctuations:

$$S(f) = \frac{3444.8 \left(\frac{U_0}{32.8} \right)^2 \left(\frac{z}{32.8} \right)^{0.45}}{(1 + \tilde{f}^n)^{(5/3n)}}$$

$$\tilde{f} = 172f \left(\frac{z}{32.8} \right)^{2/3} \left(\frac{U_0}{32.8} \right)^{-0.75}$$

where $n = 0.468$ and where:

- $S(f)$ ($\text{ft}^2\text{s}^{-2}/\text{Hz}$) is the spectral energy density at frequency f (Hz)
- z (ft) is the height above sea level
- U_0 (ft/s) is the 1-hour mean wind speed at 32.8 ft above sea level

4.1.5 Spatial Coherence, SI Units

The squared correlation between the spectral energy densities $S(f)$ of the longitudinal wind speed fluctuations of frequency f between two points in space is described by the 2-point coherence spectrum.

The recommended coherence spectrum between two points (x_i, y_i, z_i in m)

- at levels z_1 and z_2 above the sea surface
- with across-wind positions y_1 and y_2
- with along-wind positions x_1 and x_2

is given by:

$$\text{Coh}(f) = \exp \left\{ -\frac{1}{U_0} \left[\sum_{i=1}^3 A_i^2 \right]^{\frac{1}{2}} \right\}$$

where

$$A_i = \alpha_i f^{r_i} \Delta_i^{q_i} z_g^{-p_i}, \quad z_g = \sqrt{\frac{z_1 z_2}{10}}$$

and where the coefficients α , p , q , r and the distances Δ are given in Table 4.1.3.1.

4.1.6 Spatial Coherence, U.S. Customary Units

The squared correlation between the spectral energy densities $S(f)$ of the longitudinal wind speed fluctuations of frequency f between two points in space is described by the 2-point coherence spectrum.

The recommended coherence spectrum between two points (x_i , y_i , z_i in ft)

- at levels z_1 and z_2 above the sea surface
- with across-wind positions y_1 and y_2
- with along-wind positions x_1 and x_2

is given by:

$$\text{Coh}(f) = \exp \left\{ -\frac{1}{U_0/3.28} \left[\sum_{i=1}^3 A_i^2 \right]^{\frac{1}{2}} \right\}$$

where

$$A_i = \alpha_i f^{r_i} \left(\frac{\Delta_i}{3.28} \right)^{q_i} z_g^{-p_i}, \quad z_g = \sqrt{\frac{z_1 z_2}{32.8}}$$

and where the coefficients α , p , q , r and the distances Δ are given in Table 4.1.3.1.

Table 4.1.3.1—Coefficients and Distances for the 3-D ($i = 1, 2, 3$) Coherence Spectrum

i	Δ_i	q_i	p_i	r_i	α_i
1	$ x_2 - x_1 $	1.00	0.4	0.92	2.9
2	$ y_2 - y_1 $	1.00	0.4	0.92	45.0
3	$ z_2 - z_1 $	1.25	0.5	0.85	13.0

4.2 WAVES

Wave conditions are presented in the form of H_s , $H_{\max}$, and $\eta_{\max}$ as well as associated T_p and $T_{H\max}$. The wave heights in the tables are applicable for water depths greater than or equal to 1000 m (3281 ft), while the associated periods in the tables are applicable to all water depths. For wave heights in depths between 10 m and 1000 m (33 ft and 3281 ft), the appropriate regional wave height depth decay curve figure should be consulted.

4.2.1 Wave Crests

The crest elevations $\eta_{\max}$ shown in the tables and figures include associated surge and tide. The crest elevations provided in this document do not include any artificial air gap allowance like the 1.5 m (5 ft) previously recommended in API RP 2A-WSD. It should be noted that the maximum n-year $\eta_{\max}$ does not necessarily occur together with the n-year $H_{\max}$.

It must be understood that these crests are based on the risk of exceedance at a single point; as a platform deck is in affect represented by many points, the probability of exceeding this value at some location within the deck area is higher than the single point exceedance probability. For the same risk of non-exceedance, the highest local maximum crest which could occur within a typical deck area may be as much as 15% higher than the point estimate. In shallow water, the local crest height will not, however, exceed the breaking-constrained crest height.

4.2.2 Extreme Wave Direction

The extreme waves presented in the tables and figures in 4.5 are omni-directional. Directional extreme waves for return periods greater than 10 years and for water depths greater than 30 m (98 ft) may be approximated by factoring the omni-directional value using Figure 4.2.2-1. The principal wave heading varies with longitude. The factors listed apply within $\pm 22.5^\circ$ of the headings shown. When estimating directional extreme waves, the directional extreme should not be reduced below the level of the omni-directional 10-year return period wave. Figure 4.2.2-1 does not apply to depths less than 30 m (98 ft), as inside this depth refraction will begin to turn the wave crests parallel to the local bathymetry. It also does not apply east of 84°W , where principal wave direction becomes quite variable depending on proximity to the Florida coast.

4.2.3 Wave Spectra and Spreading

Hurricane-driven seas can be reasonably represented by the JONSWAP spectrum with a γ of 2.0 – 2.5. Wave spreading can be represented using the form $\cos^n(\theta)$, with n in the range of 2.0 – 2.5.

4.3 CURRENTS

Currents are shown in the tables for water depths between 10 m and 70 m (33 ft and 230 ft), and water depths greater than 150 m (492 ft). It should be noted no deepwater bottom currents from hurricanes are provided; these should be derived by site-specific studies.

4.3.1 Shallow Water Currents

Currents in water depths less than or equal to 70 m (230 ft) are nearly uniform with depth due to their driving mechanism (horizontal pressure gradients). The table for each region lists uniform currents for 10 m and 70 m (33 ft and 230 ft); between these depths, the current should be derived by interpolation. Extreme currents in water depths less than or equal to 70 m (230 ft) generally follow the shelf contours, and flow in a westerly direction. Figure 4.3.1-1 provides guidance for current headings in water depths less than 70 m (230 ft).

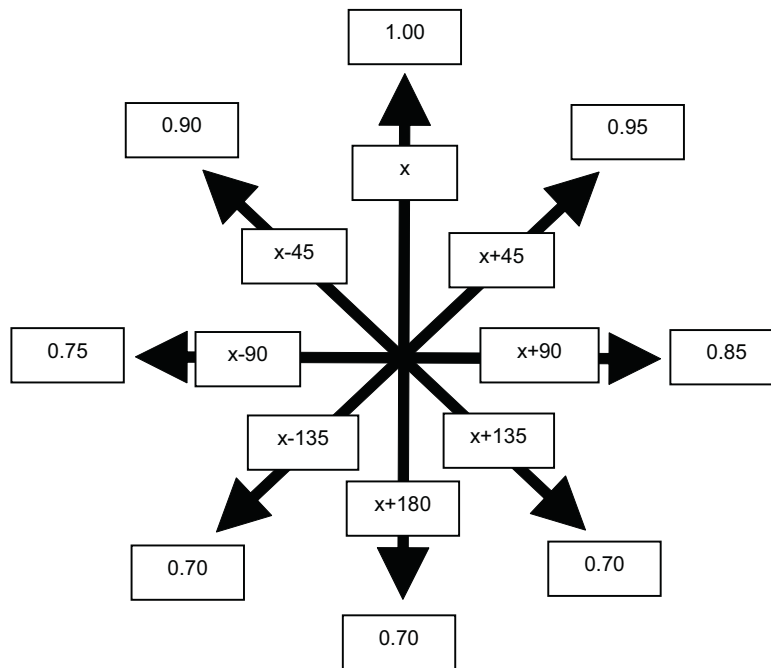
4.3.2 Deepwater Currents

Currents in water depths greater than or equal to 150 m (492 ft) have a sheared velocity profile which penetrates to the bottom of the mixed layer of the upper ocean. They are represented in the regional tables as a 3-point profile:

- Surface speed: current speed at the surface ($WD = 0$) of the ocean, including any surge and tide.
- Speed at mid-profile: current speed at a depth halfway between the surface ($WD = 0$) and the depth of the bottom of the profile (0-speed depth).
- 0-speed depth: the depth, measured from the surface, at which the current speed goes to zero, which is the bottom of the profile.

Current speeds between the surface, mid-profile and 0-speed depths should be derived by linear interpolation.

The deepwater currents provided in the tables represent those which are generated at or within 12 hours of the closest approach of a hurricane to a given site. As such the currents are confined to the upper layer of the ocean. No current is specified below the 0-speed depth in the tables, however this should not be taken as an indication that hurricane-driven currents do not penetrate deeper into the water column. Over a time period of several days, some of the momentum in the upper layer of the ocean will be trans-



Principal Wave Heading by Longitude

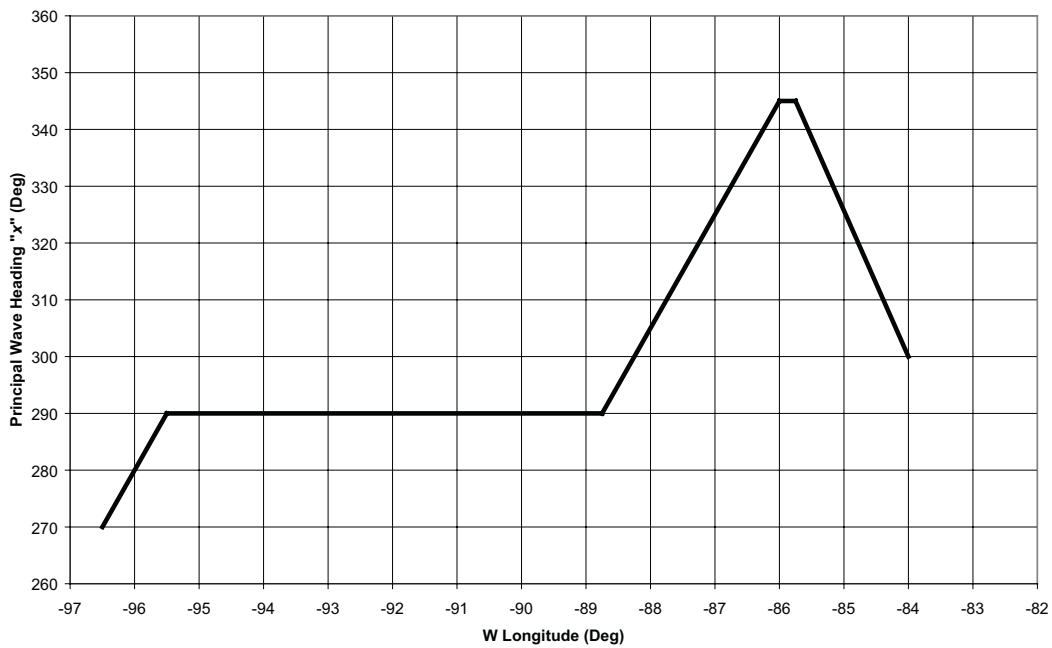


Figure 4.2.2-1—Direction Factor for Wave Heights North of 26°N, West of 84°W, WD ≥ 30m (98 ft), Return Periods > 10 Year

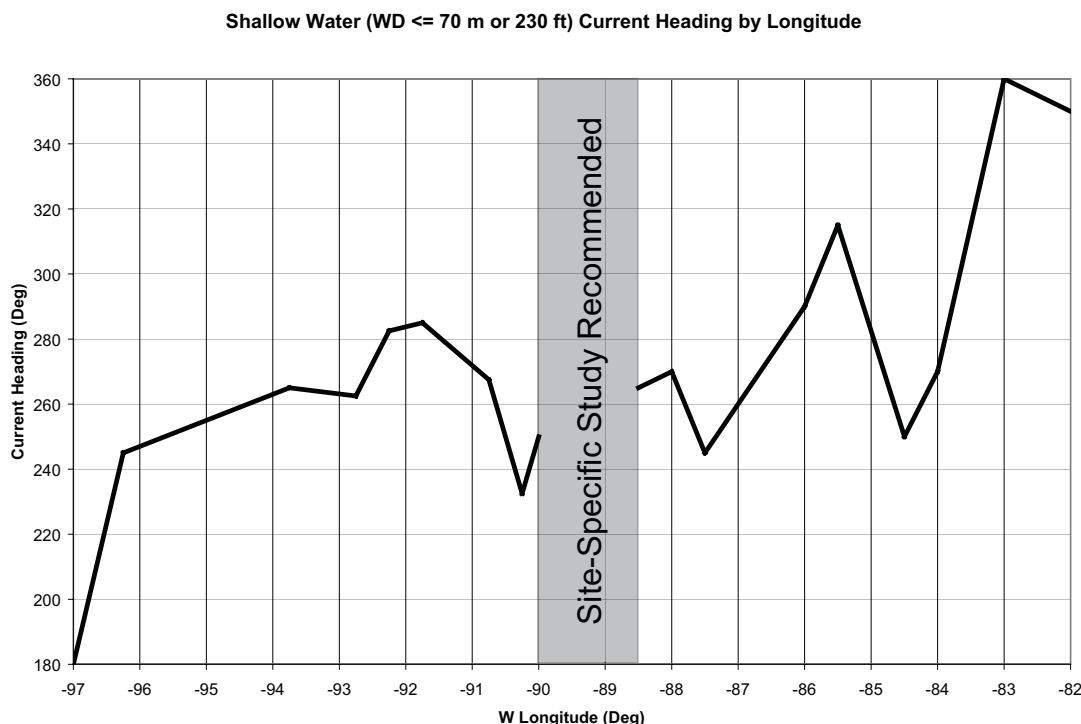


Figure 4.3.1-1—Current Heading North of 26°N, WD ≤ 70m (230 ft)

ferred downward, resulting in currents below the 0-speed depth given in the table. Resolution of these deeper hurricane current components should be resolved by site-specific studies.

Extreme currents in water depths greater than or equal to 150 m (492 ft) should be treated as omni-directional; they should not be factored in proportion to wave height. The headings of these currents will generally rotate clockwise in time under the action of coriolis force as they slowly decay following the passage of a storm. For the latitude range of the Gulf of Mexico, the current heading will rotate a full 360° clockwise approximately every 22 hours.

4.3.3 Currents in Transition Zone

Currents in water depths between 70 m and 150 m (230 ft and 492 ft) will be in a state of transition as controlled by the relative magnitudes of the two current forcing mechanisms (horizontal pressure gradients and local wind stress). Currents in these water depths can be approximated by interpolating between the nearly uniform current profile specified for 70 m (230 ft) (assuming it has a 3-point shape), and the deepwater storm current 3-point profile specified for water depths greater than or equal to 150 m (492 ft). The interpolation involves several steps; the example in Section 6 should be reviewed carefully.

When determining currents in the transition zone, current profiles for the shallow and deep areas should first be determined. The shallow water current should be assumed to also follow a 3-point profile for the purpose of interpolation by the following conversion:

- Surface speed: 70 m (230 ft) current speed
- Speed at “mid-profile”: 70 m (230 ft) current speed, mid-point set to 70 m (230 ft)
- 0-speed depth: 70 m (230 ft)

The resulting profile at the depth between 70 m and 150 m (230 ft and 492 ft) should then be derived by linearly interpolating between the 70 m and 150 m (230 ft and 492 ft) profiles to the desired depth for each of the three points (surface speed, mid-profile level and speed, and 0-speed depth) to define a new 3-point profile. For example, if a site is in 100 m (328 ft), the new profile would be derived by weighting the points from the profile at 70 m by $(150\text{ m} - 100\text{ m}) / (150\text{ m} - 70\text{ m})$, or 230 ft by $(492\text{ ft} - 328\text{ ft}) / (492\text{ ft} - 230\text{ ft})$, and the points from the profile at 150 m by $(100\text{ m} - 70\text{ m}) / (150\text{ m} - 70\text{ m})$, or 492 ft by $(328\text{ ft} - 230\text{ ft}) / (492\text{ ft} - 230\text{ ft})$.

The peak current in the transition region may be considered omni-directional, however, in reality the current would tend to align parallel to the local bathymetry in depths closer to 70 m (230 ft). In situations where the 70 m and 150 m (230 ft and 492 ft) currents have prescribed headings, the direction of the new profile can be approximated as the heading of the resultant derived from the 70 m (230 ft) current and the average current over the upper 70 m (230 ft) of the 150 m (492 ft) current profile. The magnitudes of each should be weighted to the desired depth as is done for the profile calculation, prior to resolving the resultant direction.

4.4 SURGE AND TIDE

The tables show storm surge for water depths greater than or equal to 500 m (1640 ft), and astronomical tidal amplitude applicable to all water depths. For storm surge in water depths between 10 m and 500 m (33 ft and 1640 ft), the appropriate regional figure should be consulted; note that the curves in the figures include the tidal amplitude.

4.5 INDEPENDENT EXTREMES BY REGION

The following subsections present the independent extremes for each of the four geographical regions (West, West Central, Central and East). Tables and figures marked “A” are in SI Units, while those marked “B” are in U.S. Customary Units.

4.5.1 West

Table 4.5.1-1A—Independent Extreme Values for Hurricane Wids, Waves, Currents and Surge, Western Gulf of Mexico (97.5°W to 95.0°W)

Return Period (Years)	10	25	50	100	200	1000	2000	10000
Wind (10 m Elevation)								
1-hour Mean Wind Speed (m/s)	22.5	31.2	36.0	39.9	43.0	49.9	51.9	57.9
10-min Mean Wind Speed (m/s)	24.5	34.4	40.0	44.7	48.4	56.8	59.3	66.8
1-min Mean Wind Speed (m/s)	27.0	38.6	45.2	50.8	55.3	65.7	68.8	78.3
3-sec Gust (m/s)	30.2	43.9	52.0	58.8	64.4	77.3	81.2	93.1
Waves, WD ≥ 1000 m								
Significant Wave Height (m)	6.8	9.8	11.3	13.1	13.7	16.4	17.0	19.0
Maximum Wave Height (m)	12.0	17.3	20.0	23.1	24.2	28.9	30.1	33.6
Maximum Crest Elevation (m)	8.0	11.4	13.1	15.2	16.0	18.9	19.6	21.7
Peak Spectral Period (s)	12.2	13.8	14.4	15.1	15.3	16.7	17.1	18.0
Period of Maximum Wave (s)	11.0	12.4	13.0	13.6	13.8	15.1	15.4	16.2
Currents, WD ≥ 150 m								
Surface Speed (m/s)	1.13	1.56	1.80	2.00	2.15	2.49	2.59	2.89
Speed at Mid-profile (m/s)	0.84	1.17	1.35	1.50	1.61	1.87	1.95	2.17
0-Speed Depth (m)	47.3	65.5	75.6	83.8	90.3	104.7	108.9	121.5
Currents, WD 10 m – 70 m								
Uniform Speed at 10 m Depth (m/s)	0.61	1.17	1.56	1.91	2.22	2.69	2.91	3.61
Uniform Speed at 70 m Depth (m/s)	0.46	0.88	1.17	1.43	1.66	2.01	2.18	2.71
Water Level, WD ≥ 500 m								
Storm Surge (m)	0.17	0.32	0.46	0.60	0.76	0.84	0.91	1.14
Tidal Amplitude (m)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42

Notes:

Wind speeds for a given return period are applicable to all water depths throughout the region.

Crest elevation includes associated surge and tide.

See Figures 4.5.1-1A, 4.5.1-2A and 4.5.1-3A for wave and crest elevation values for water depths between 10 m and 1000 m.

The peak spectral period and period of maximum wave apply to waves in all water depths.

Currents in water depths between 70 m and 150 m should be estimated as described in 4.3.3.

See Figure 4.5.1-4A for surge and tide in water depths less than 500 m.