

Gulf of Mexico MODU Mooring Practices for the 2007 Hurricane Season— Interim Recommendations

API RECOMMENDED PRACTICE 95F
SECOND EDITION, APRIL 2007



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Gulf of Mexico MODU Practices for the 2007 Hurricane Season— Interim Recommendations

1 Scope

This document provides guidance for design and operation of MODU mooring systems in the Gulf of Mexico for the 2007 hurricane season. The guidance was developed through a cooperative arrangement with the American Petroleum Institute's Subcommittee on Offshore Structures RP 2SK Work Group and the Joint Industry Project entitled "US Gulf of Mexico (GOM) Mooring Strength Reliability" (MODU JIP). The information presented herein is premised on the existence of a MODU evacuation plan, the intent of which is to assure timely and safe evacuation of all MODU personnel in anticipation of hurricane conditions.

This guidance is supplemental to the latest editions of the following documents:

- API RP 2SK, "Design and Analysis of Stationkeeping Systems for Floating Structures."
- API RP 2I, "In-Service Inspection of Mooring Hardware for Floating Structures."
- API RP 2SM, "Recommended Practice for Design, Manufacture, Installation, and Maintenance of Synthetic Fiber Ropes for Offshore Mooring."

Note: The 3rd Edition of API RP 2I has been approved by API, but it was not yet published at the time of publication of this edition of RP 95F. Inspection guidance from the approved 3rd edition is included in Appendix III.

This Recommended Practice replaces API RP 95F "Interim Guidance for Gulf of Mexico MODU Mooring Practice—2006 Hurricane Season," 1st Edition, May 2006.

2 Basic Considerations

2.1 BACKGROUND

In 2004 and 2005, Hurricanes Ivan, Katrina, and Rita moved through the Gulf of Mexico with extreme wind and waves, causing a number of MODU mooring failures in their path. Mooring failures have occurred in previous hurricanes, including Hurricanes Andrew and Lili, but the number of failures was much lower.

Assessment of MODU mooring systems for worldwide operations has frequently been based on API RPs. The first MODU mooring RP, released in 1987, specified a design environment lower than the five to ten year return period in the present version of API RP 2SK, principally driven by the MODU mooring capacities available at that time. Building on the results of a Joint Industry Project focused on MODU mooring code calibration (Noble Denton, 1995), API RP 2SK incorporated more severe MODU metocean design criteria. These criteria, which are still in the current version of API RP 2SK, are as follows:

- 5-year return period (away from other structures)
- 10-year return period (in the vicinity of other structures)

There have been significant modifications in the underlying calibration parameters and Gulf of Mexico operations since the 1995 mooring code calibration study conducted twelve years ago which may influence the applicability to future activities. Differences include:

1. There are more floating and subsea installations and pipelines. This may result in higher risk of property damage or environmental impact, should a MODU break loose or drag its anchors under hurricane conditions.
2. The number of deepwater permanent installations has increased significantly. These are high production rate installations that often share a pipeline to shore. Therefore the cost for an incident can be much higher.
3. There are more deepwater MODU operations that typically use taut leg moorings with pile anchors. These systems may respond to hurricanes differently than catenary moorings with drag anchors. These types of mooring systems in deeper water were not part of the 1995 calibration study.

2.2 MOORING ISSUES

This document supplements API RP 2SK for Gulf of Mexico MODU mooring design and operating practice during the 2007 hurricane season. Topics addressed herein that will be part of the overall mooring design and MODU operations include:

- Site- and well-specific data
- Design criteria for the mooring

- Indicative Gulf of Mexico hurricane extreme metocean conditions
- Mooring analysis
- Site-specific risk assessment and mitigation
- Mooring hardware issues such as anchor system and mooring system upgrade
- Mooring operation issues such as deployment, hurricane preparedness, and inspection

2.3 SITE-AND WELL-SPECIFIC DATA

When planning a MODU mooring operation, the following site-and well-specific data should be collected:

1. Location Description
 - Block area
 - Water depth and seafloor bathymetry
 - Seabed conditions (soils) and hazards
 - Site characteristics (e.g., chemosynthetics, archeological, etc.)
2. Site-Specific Metocean Data and Source
3. Well Description
 - Well type such as exploratory, development, workover
 - Time of planned operations
 - Expected duration
 - Confidence in duration and potential overrun
 - Possible causes of delay
4. Installation Hazards
5. Close Surface and Subsea Infrastructure
6. Distant Surface and Subsea Infrastructure

2.4 STACKED MODUS

These guidelines also apply to MODUs that are “stacked” and not working. MODUs that are not actively working should be moored in accordance with the provisions of this document to minimize the likelihood of breaking free and inflicting damage. Alternate methods of stacking MODUs, e.g., setting on bottom for MODUs that can accommodate bottom founding, may be acceptable provided appropriate engineering is performed to assure performance comparable to or better than that of moored MODUs.

2.5 EXCEPTIONAL MODU MOORING OPERATIONS

It is recognized that a MODU may be required to perform exceptional operations, for example to prevent major losses or pollution. Alternately, it may be necessary to relocate a MODU (e.g., to a low consequence location) with a damaged mooring while it awaits repair. In these exceptional cases a risk assessment should be performed to assess the consequences of not performing the MODU mooring operation and the risks associated with mooring system failure. In these special circumstances an environmental return period of less than 10-years may be acceptable for the particular operation under consideration.

2.6 MOORING INSPECTION

Mooring inspection is more critical for operations in the areas of tropical cyclone activity to ensure the integrity of the mooring system and minimize the probability of mooring failure resulting from premature failure of substandard components. Guidance for inspection, and reuse of MODU mooring components is contained in Appendix III. Further guidance on inspection can be found in API RP 2I.

3 Mooring Analysis

3.1 MOORING ANALYSIS METHOD

Following API RP 2SK, quasi-static or dynamic analyses may be utilized for MODU moorings. Either the 1-hour wind speed with wind spectrum or the 1-minute steady wind speed may be used for the wind force calculation. It should be noted that the wind spectrum approach requires good estimates of low-frequency damping.

Wind, wave, and current forces and vessel motions shall be evaluated using the best available, updated MODU information. Many MODUs have gone through significant modifications involving additional hull structures and deck equipment that can

change the environmental loads on the vessel. Wind, wave, and current force coefficients and models for hydrodynamic analysis should be adjusted to reflect the changes. The adjustment can be based on new model tests, analysis, or combination thereof.

It is not possible to predict precise wind, wave, and current directions under hurricane conditions; therefore, sufficient environmental directions shall be investigated to capture critical cases for line tensions and anchor load and uplift angle. As a minimum, bow, beam, quarter, down-line, and between-line environmental directions should be analyzed. Analysis for the damaged condition should investigate as many conditions as necessary to capture the critical cases, including, as a minimum, damage of the most highly loaded line and adjacent lines. For mooring systems with lines of unequal strength, damage of the most utilized lines and adjacent lines should also be considered.

3.2 IDEALIZED MOORING SYSTEM BEHAVIOR: ROBUSTNESS CHECK OR WEAK POINT ANALYSIS

In addition to the API RP 2SK safety factor check, a mooring sensitivity or weak point analysis should be performed. The objective of this analysis is to determine the probable failure mode of the mooring system. It is a useful tool for comparing different mooring systems for a given design criteria. Such an analysis can provide useful information for risk assessment and mitigation strategies. As such, there are no defined acceptance criteria for mooring analysis results discussed in this Section 3.2.

The mooring sensitivity or weak point analysis should be conducted for both the intact and the damaged conditions. Performing this analysis does not guarantee MODU mooring survival because of other potential failure modes, such as bending over the fairlead, wire fretting, elasto-plastic fatigue damage, etc.

For line components such as chain, wire rope, and fiber rope, the capacity of the component is normally the break strength (minimum break load (MBL), catalog break strength (CBS), minimum break strength (MBS) as appropriate) adjusted for the condition of the component. For example, API RP 2I allows a mooring component to remain in use until its break strength is reduced to 90% of its original break strength. In addition, wire rope bending around the fairlead experiences further strength reduction; for example, a D/d (fairlead diameter / wire rope diameter) ratio of 16 reduces the strength to 90% of CBS. Strength reduction can also be expected for chain.

Illustrative Example

Following is an example demonstrating how this analysis may be used for risk assessment and mitigation. The mooring is a chain/wire rope combination system with high efficiency drag anchors. Based on mooring analysis results, plots of utilization versus return period are generated for anchor load and line tension under intact (Figure 3.1) and damaged (Figure 3.2) conditions. For line tension, utilization is the ratio of the maximum line tension to break strength. For anchor load, utilization is the ratio of the maximum anchor load to anchor holding capacity. These two figures provide the following information.

1. API RP 2SK's utilization limits are 0.6 (intact line tension), 0.8 (damaged line tension), and 1.25 (MODU intact anchor load for drag anchor) based on dynamic analysis. These utilization limits are satisfied for environmental return periods of 12 years for the intact mooring system and 10 years for the damaged system. Therefore, this mooring system meets the API RP 2SK line tension utilization requirements for a 10-year return period hurricane.
2. As an example, consider a wire rope with a reduced break strength of about 80% CBS (e.g., 10% strength reduction due to wire condition and 10% strength reduction due to bending over the fairlead). If there is no faulty component in the windward lines, the intact mooring system may survive a 20 to 25 year return period hurricane (see Figure 3.1). However, the anchors of the most loaded lines are expected to move and bury deeper, resulting in redistribution of the load between the highly loaded lines and a reduction in the maximum line tension and anchor load. For hurricane conditions that exceed the 25-year return period, a complete stationkeeping failure—breaking of a number of lines and dragging the anchors of the remaining lines a large distance—is possible if further reduction in mooring line and anchor load cannot be achieved by anchor movement.
3. If a faulty component results in a premature failure of a highly loaded mooring line, then a complete stationkeeping failure can be expected to occur in about a 10-year return period hurricane, based on Figure 3.2. This highlights the importance of keeping the mooring system in good condition through mooring inspection and maintenance.

4 Mooring Design Criteria

4.1 EXISTING DESIGN CRITERIA

API RP 2SK provides the basis for mooring design in the Gulf of Mexico for both MODUs and permanent installations.

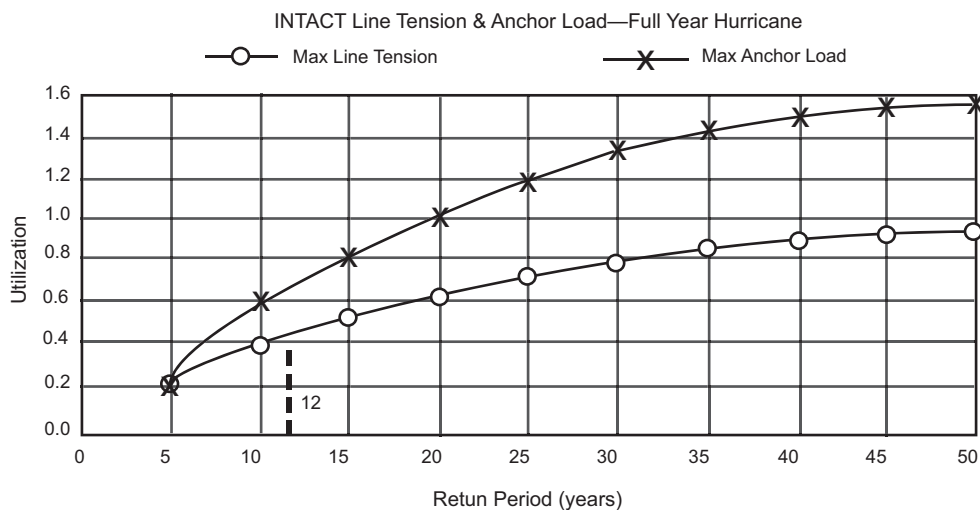


Figure 3.1—Utilization versus Return Period for Intact Condition

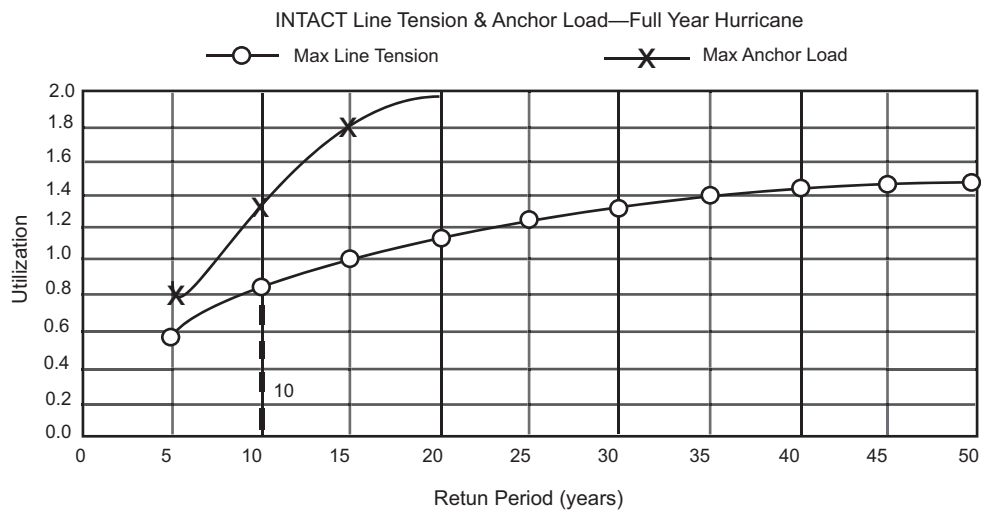


Figure 3.2—Utilization versus Return Period for Damaged Condition

4.2 RECOMMENDED MODIFICATIONS FOR GULF OF MEXICO MODU MOORINGS

4.2.1 Design Environment Return Period

4.2.1.1 Basic Considerations

A very simple consequence based approach is specified in API RP 2SK, (see Section 3.1.1.2 of 3rd Edition), for selecting the minimum design return periods for MODU moorings for worldwide operations:

- 5-year return period (away from other structures)
- 10-year return period (in the vicinity of other structures)

Mooring system failures during recent hurricanes in the Gulf of Mexico point to a need for modifying the criteria for MODU operations. The modifications include:

1. For typical MODU operations, a risk assessment is required to determine the mooring system design return period.
2. For atypical MODU operations (defined in Section 5.4), an appropriate risk assessment is required to establish the design return period. The risk assessment for atypical MODU mooring operations is expected to be more rigorous and detailed than that performed for typical MODU mooring operations.
3. Mitigation strategies for reducing consequences of mooring failure should be considered during the design of the mooring system.
4. Guidelines are provided to establish the metocean parameters for a specific site.

Items 1 and 2 are addressed in Section 5, and Item 4 is addressed in Section 10.

4.2.1.2 Minimum Design Environment

For typical MODU operations during the hurricane season, the design environment should be established from the following principles:

- The return period should not be less than 10 years for the design of any mooring system based on site-specific metocean criteria.
- A minimum 1-minute wind speed of 64 knots at 10m above mean water level shall be used even if site-specific studies indicate a lower value.
- In the absence of site-specific data, the environmental criteria presented in Section 10 shall be used.
- Data used in preparing site-specific hurricane metocean criteria shall be inclusive of weather information for the period 1950 through 2005.
- A site specific assessment as described in Section 5 shall be conducted for the specific drilling operation and location.

4.2.2 Anchor Considerations

Anchor holding capacity (for all types of anchors) shall be considered in the design of the mooring system. Anchor selection should be based upon capacity, availability, and potential to minimize damage to subsea infrastructure should an anchor failure occur in conditions such as:

- A marine installation such as a pipeline lies in the dragging path between the anchor and the MODU or in a location in which mooring system failure could result in an anchor dragging across the installation
- A mooring line that can cross another mooring line
- Density or importance of seafloor or water column infrastructure merits a higher safety margin

Unless site-specific soil data are available, appropriate upper and lower bound soil conditions for the general area of operation shall be considered.

Guidance on anchor behavior and selection is provided in Section 7 of this document.

5 Consequences of MODU Mooring Failure and Return Period (Risk Assessment)

The probability and consequences of a MODU losing station when operating at any location within the US Gulf of Mexico should be assessed. The intent of the assessment process is to determine the characteristics of the area near the drilling operation and identify options related to mooring component selection, mooring system design, and mitigation opportunities prior to finalizing the mooring design and installing the mooring system. For the planned MODU operation, the mooring system should be associated with an acceptable risk, either by minimizing potential consequences of mooring component or system failure or by reducing the probability of mooring component or system failure.

In performing a site specific risk assessment, one source of infrastructure information is the Gulf of Mexico infrastructure map maintained by the Minerals Management Service (MMS).

5.1 RISK

Risk is defined as:

Risk = [Probability of an adverse event occurring] × [The consequences associated with that event]

The risk can be reduced either by reducing the probability of experiencing an incident or by reducing the consequences of that incident should it occur. A fundamental part of reducing the risk associated with MODU operations is to ensure that all parties, including owners, operators, regulators, etc., have a clear understanding of their “Risk Exposure.”

The consequences of a MODU mooring failure may be divided into two categories: (1) the consequences of damage to the surrounding subsea and surface infrastructure and (2) the consequences of damage to the MODU and its mooring system. This risk assessment addresses the consequences of damage to surrounding infrastructure. For MODU operations in the hurricane season, where the MODU is evacuated, it is the responsibility of the drilling contractor and operator to manage the risk associated with damage to the MODU and its mooring system.

The consequences (to infrastructure) of a MODU mooring failure depend on the density and type of subsea and surface infrastructure that surrounds the location of interest and, to some extent, on the type of MODU mooring system. The probability of MODU mooring system failure decreases as the design return period increases, i.e., the return period for which the mooring system satisfies all of the requirements of API RP 2SK (intact and damaged line tension, anchor load, and clearance requirements). Consequently, the management of risk to surrounding infrastructure requires that the design return period increases as the consequence of failure increases. It should be noted that the required return period is independent of the duration of the operation and the season of operation. However for a given return period, the intensity of the environmental conditions (wind, wave, and current) are dependent on the particular site and the season(s) of operations.

Note: The following example serves to illustrate that the return period is independent of duration. An operator has two wells that need to be drilled near an existing facility. Each well will take one month to complete, and they will be drilled consecutively. If two independent Applications for Permit to Drill (APDs) are submitted, each for a drilling program of one month operation, then the design return period for each well should be the same as for a single APD for a MODU operating on the same location for a duration of two months. Clearly, different return periods for two one-month APDs compared to a single two month APD is not a logical solution: the exposure risk for the facility is the same in both cases, so the design return periods should be the same. In effect, the daily risk to the infrastructure should be consistent, so the duration of an operation should not influence the design return period for MODU (temporary) operations.

Seasonal variations, both within and out of hurricane season, of wind, wave, and current parameters, for the same return period are site specific, e.g., the ratio of the 20-year June to 20-year September wind speed is not constant over the entire Gulf of Mexico. Seasonal variations in extreme metocean conditions, if required, should be developed as part of the site specific metocean criteria. There is no simple method of providing seasonal corrections to all-year metocean criteria that are valid for the whole Gulf of Mexico.

For all MODU operations in the Gulf of Mexico, a risk assessment is required to determine the design return period for the mooring system. The risk assessment is used to assess the consequences of mooring systems failure to the Gulf of Mexico hydrocarbon production and transportation infrastructure. Consequence mitigation options should also be addressed.

Note: The checklist used by the MMS to evaluate APDs is an example of a tool that can be used to help determine the consequence category of a given MODU operation as part of a risk assessment.

A sample of a simple checklist tool is contained in Appendix I.

The flow chart shown in Figure 5.1 describes the recommended method for determining the design return period for a MODU mooring operation. An appropriate risk assessment methodology needs to be selected based on the type of MODU mooring operation.

5.2 SIMPLIFIED CONSEQUENCE ASSESSMENT

A simple assessment may be based on a checklist to determine a modified consequence score, which allows the stakeholders to assess on a relative basis the consequences of MODU mooring failure associated with the proposed operations. The MMS's approval is based on the return period for which API RP 2SK's intact and damaged safety factors are satisfied. The intent of this approach is to be more conservative by comparison to a more detailed risk assessment. However, the consequence checklist can be completed with the routinely available information and data that should be available to the operator and drilling contractor.

The consequence checklist should be based on:

1. Consequence factors based on location (infrastructure that could be damaged in the event of a mooring failure)
2. Consequence factors based on mooring components and system details.)

5.3 RISK ASSESSMENT

A more detailed risk assessment may always be used to assess the risks associated with the proposed operations, the consequences of mooring line, anchor and system failure and the probability of mooring line, anchor, and system failure. The risk assessment process contains a series of steps to formally assess the risk at any given location. Due consideration should be given to the time required to complete this process.

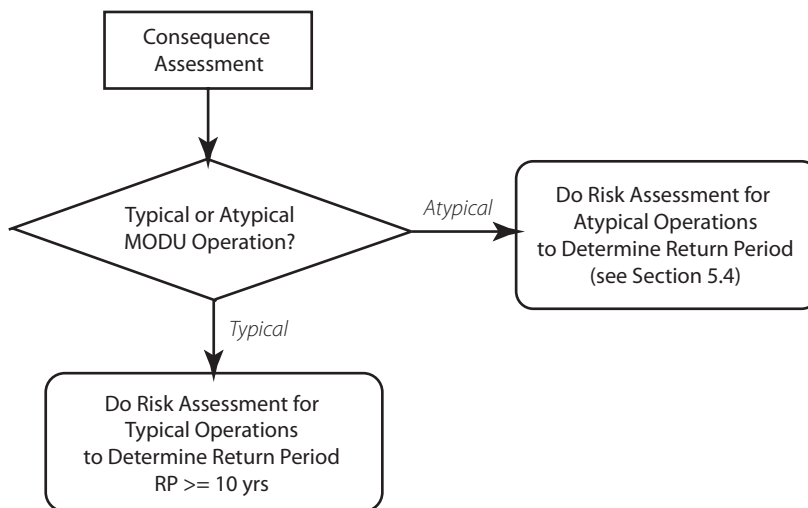


Figure 5.1—MODU mooring consequence assessment flowchart

The steps can be summarized as:

- Definition of location and well parameters
- Identification of local and distant infrastructure
- Undertaking a hazard identification (HAZID) study
- Probability of mooring failure (mooring system reliability analysis)
- Quantification of the consequences of failure (e.g., through event tree analysis)
- Risk mitigation
- Documentation

Note: The risk assessment entails a documented and structured identification of options available, impact of these options, and selection of the lowest consequence mooring system available, and is a valuable tool in designing the mooring system.

5.4 ATYPICAL MODU OPERATIONS

There may be atypical MODU operations associated with extremely high risks that may require that the mooring be designed to meet very high environmental return periods. MODU operations that may be associated with extremely high risks include but are not limited to:

- MODU offset drilling
- Tender assisted drilling adjacent to a permanent facility
- MODU operations where the MODU is within a mooring diameter of a permanent surface facility
- MODU operations where the MODU is within a mooring diameter of an active oil pipeline with an outer diameter greater than or equal to 12 in. or an active gas pipeline with an outer diameter greater than or equal to 16 in.

Note 1: The term “mooring diameter” is the MODU mooring diameter. The MODU mooring diameter is two times the distance from the nominal center of the mooring spread to the most distant anchor.

Note 2: An “Active Pipeline” is defined as any pipeline located within the OCS that currently has throughput. Pipelines that are abandoned, cancelled, out of service, proposed, or relinquished are not active. However an active pipeline could be temporarily shut-in.

Note 3: Details of active oil and gas pipelines in the Gulf of Mexico are available at:
<http://www.gomr.mms.gov/homepg/pubinfo/freeasci/pipeline/freepipe.html> and
<http://www.gomr.mms.gov/homepg/pubinfo/PI%20Catalog.pdf>

5.5 SITE SPECIFIC AND MOORING SYSTEM INFORMATION

The general and local site specific information available to the operator and drilling contractor should include the following:

1. Gulf of Mexico Block designation for drilling location.
2. Water depth for drilling location.
3. Complexity of bathymetry, geo-hazards, or other restrictions to anchor placement.
4. Other mooring lines, tendons, etc., within mooring pattern.
5. Distances and directions of surface facilities.
6. Mooring lines crossing subsea infrastructure (pipelines, umbilicals, wells, etc.).
7. Distances and directions of subsea infrastructure (pipelines, umbilicals, wells, etc.).

The information related to the mooring system that affects the consequences, or mitigates the consequences, of mooring failure includes:

1. Type and size of anchors, drag embedment, plate, pile, etc.
2. Types of mooring components that could damage subsea infrastructure if dragged or dropped.
3. Other components used to mitigate the consequences of mooring failure (buoyancy, fiber rope, etc.).

5.6 METOCEAN CRITERIA

The consequences to surrounding infrastructure of mooring system failure determine the required minimum design return period. The flow chart shown in Figure 5.2 describes a method for selection of metocean criteria. Table 10.1 of Section 10 provides default metocean criteria that are intended to be conservative for the Gulf of Mexico, and may be used instead of site specific criteria. Section 10 outlines the minimum requirements for the development of site specific metocean criteria. Additional guidance on development of metocean extremes are contained in API Bulletin 2INT-MET, “Interim Guidance on Hurricane Conditions in the Gulf of Mexico,” (publication planned for May 2007).

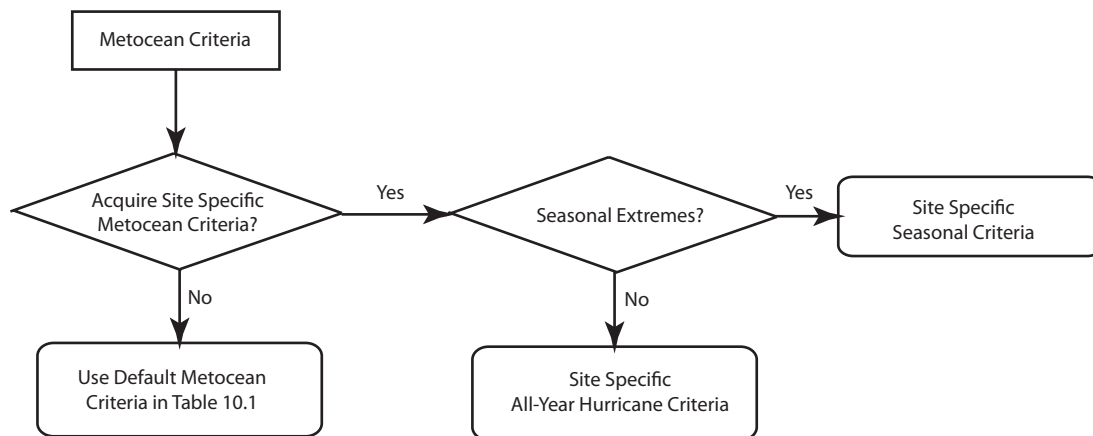


Figure 5.2—Metocean Criteria Flowchart

6 Mooring System Improvement

There are various options to improve the survivability of the mooring system and reduce the consequences of a mooring failure under hurricane conditions, such as the use of higher strength components, additional mooring lines, and steel or fiber rope inserts. These options have design and hardware issues that require special attention, as discussed below.

6.1 HIGHER STRENGTH COMPONENTS AND ADDITIONAL LINES

Replacement of existing chain and wire ropes with higher strength components may be considered.

Additional lines may also be placed on a MODU to increase mooring system strength. The additional lines may be terminated in a number of ways, such as:

- Standard fairlead and tensioning equipment with full tensioning capability