Framework for Decision Making while Operating Dynamically Positioned Mobile Offshore Drilling Units in the Gulf of Mexico during Hurricane Season

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Introduction

Tropical cyclones ranging from depression to hurricane are a seasonal weather occurrence in the Gulf of Mexico (GoM). Whereas fixed facilities in the GoM are designed to weather these storms, mobile offshore drilling units have the capability to move out of the path of the storm. Timely decision on suspension of operations and thereafter move away from the well location is important to safeguard personnel, environment and assets. Operators and rig contractors have extensive experience in making these decisions and the methods to ensure safe operations. This framework proposes a consistent approach to decision-making around evasion of an approaching storm.

Framework for Decision Making Operating Dynamically Positioned Mobile Offshore Drilling Units in the Gulf of Mexico During Hurricane Season

1 Scope

This document is applicable to all dynamically positioned Mobile Offshore Drilling Units working in the US Gulf of Mexico (GoM) that have the ability to self-vacate from the well location to evade storms. This guide provides a consideration but does not replace respective company's procedures for hurricane or severe storm mitigation. In the event of an inconsistency between this guide and the drilling contract, including any assignments, extensions, amendments, or agreements related thereto, the drilling contract terms and conditions shall prevail. This document recognizes that the master of the vessel is in command of the vessel at all times and is not intended to mandate any particular decision regarding any specific vessel or storm situation.

2 Terms and Definitions

For the purposes of this document, the following definitions apply.

2.1 T-Storm

Timeline in hours to tropical storm force winds (>39 mph) expected at the rig or well location. e.g. Rig A will see winds >39 mph in 50 hours based on a weather forecast, thus Rig A's T-Storm is 50 hrs. This may sometimes be short formed as to T minus 50 or "T-50".

2.2 Hurricane

A tropical cyclone in which the maximum sustained wind speed is 74mph or more. The max sustained wind definition by the National Weather Service is used for reference in this document.

2.3 Hurricane Watch

An announcement that hurricane conditions are possible for development within a specified area. (per NOAA)

2.4 Hurricane Warning

An announcement that hurricane conditions are expected within a specified area. (per NOAA)

2.5 Invest

A designated area of disturbed weather that is being monitored for potential tropical cyclone development

2.6 Loss of Favorable Flight Conditions

Crew movements by aircraft will be suspended when wind conditions are above 45 knots (51 MPH). This results in loss of search and rescue (SAR) aircraft capability due to wind and/or sea state.

2.7 NHC

National Hurricane Center (division of NOAA)

2.8 NOAA

National Oceanic and Atmospheric Administration

2.9 Storm Nomenclature

Throughout this document the description of a tropical cyclone's attributes such as cone of uncertainty, speed, wind speed, and category of storm are based on the definitions and normal interpretation used by the National Hurricane Center.

2.10 T-Time
Calculated amount of time per activity that the dynamically positioned Mobile Offshore Drilling Unit requires to suspend work and secure the well, secure equipment, stabilize the asset and to execute evasion plan of vessel from well location to avoid tropical storm conditions.

2.12 Storm Action Circle (SAC)
A circle with a radius of the Storm Action Radius around a rig or well site. When a storm contacts this circle, it is a trigger point for decisions to be taken. The SAC can be viewed as the lead time needed for the rig to Secure Well, Recover LMRP and sail to Evade the forecasted storm.

Storm Action Radius is defined in section 4.

2.13 Tropical Depression
A tropical cyclone in which the maximum sustained surface wind speed is 38 mph or less

2.14 Tropical Storm
A tropical cyclone in which the maximum sustained surface wind speed is 39 mph to 73 mph.

Saffir-Simpson Scale for Hurricane Classification				
Strength	Wind Speed (Kts)	Wind Speed (MPH)	Pressure (Millibars)	Pressure
Category 1	64- 82 kts	74- 95 mph	>980 mb	28.94 "Hg
Category 2	83- 95 kts	96-110 mph	965-979 mb	28.50-28.91 "Hg
Category 3	96-113 kts	111-130 mph	945-964 mb	27.91-28.47 "Hg
Category 4	114-135 kts	131-155 mph	920-944 mb	27.17-27.88 "Hg
Category 5	>135 kts	>155 mph	919 mb	27.16 "Hg
Tropical Cyclone Classification				
Tropical Depression	20-34kts			
Tropical Storm	35-63kts			
Hurricane	64+kts or 74+mph			

2.15 Extreme Weather Committee
A group of individuals with applicable knowledge and positioning within each company to serve as a management team for extreme weather events. The structure and responsibilities are to be defined annually prior to 1 June.

3 Background

3.1 Intention

This framework is intended to provide a consistent approach to decision making as adverse weather forecast arise during well operations in the Gulf of Mexico. Recommendations are also made for important preparation steps that should be considered in relation to MODU operations in the Gulf of Mexico throughout the year. The framework is intended to facilitate decision-making that can:

- Avoid any harm to personnel from adverse weather conditions,
- Avoid environmental impact and/or asset damage, and
- Minimize disruption to well operations

Referencing National Hurricane Center's tabulation of hurricane forward speed below, a hurricane's average forward speed is some 10 to 12 mph in the Gulf of Mexico, Caribbean Sea, and tropical Atlantic Ocean from 10 to 30 degrees north latitude. Taking an average of 3 days to suspend and depart from a well location, using a 12.5 mph storm system approach speed, results in potentially needing to suspend operations when a tropical system is 781 nautical miles away. For comparison, the span of the GoM east west from Corpus Christi, Texas to St Petersburg, Florida is approximately 783 nautical miles.

Latitude	Hurricane forward speed average		Number of cases
	knots	mph	
0°- 5°N	14	16.1	186
5°-10°N	11.9	13.7	4678
10°-15°N	10.4	11.9	7620
15°-20°N	9.4	10.8	7501
20°-25°N	9.4	10.8	8602
25°-30°N	10.8	12.5	6469
30°-35°N	14.6	16.9	3397
35°-40°N	21	24.2	1120
40°-45°N	26.6	30.6	264
45°-50°N	27.8	32	34

Tropical cyclones that originate of the tip of West Africa and transit across the Atlantic Ocean typically have sufficient lead time and predictability to effectively forecast arrival in the GOM. However, tropical cyclones that form in the GoM, including the Bay of Campeche, northern Caribbean Sea or in the waters west of the Turks and Caicos Islands, are less predictable and will typically not provide sufficient time for normal suspension and evasion operations. These storm scenarios are discussed in this guide.

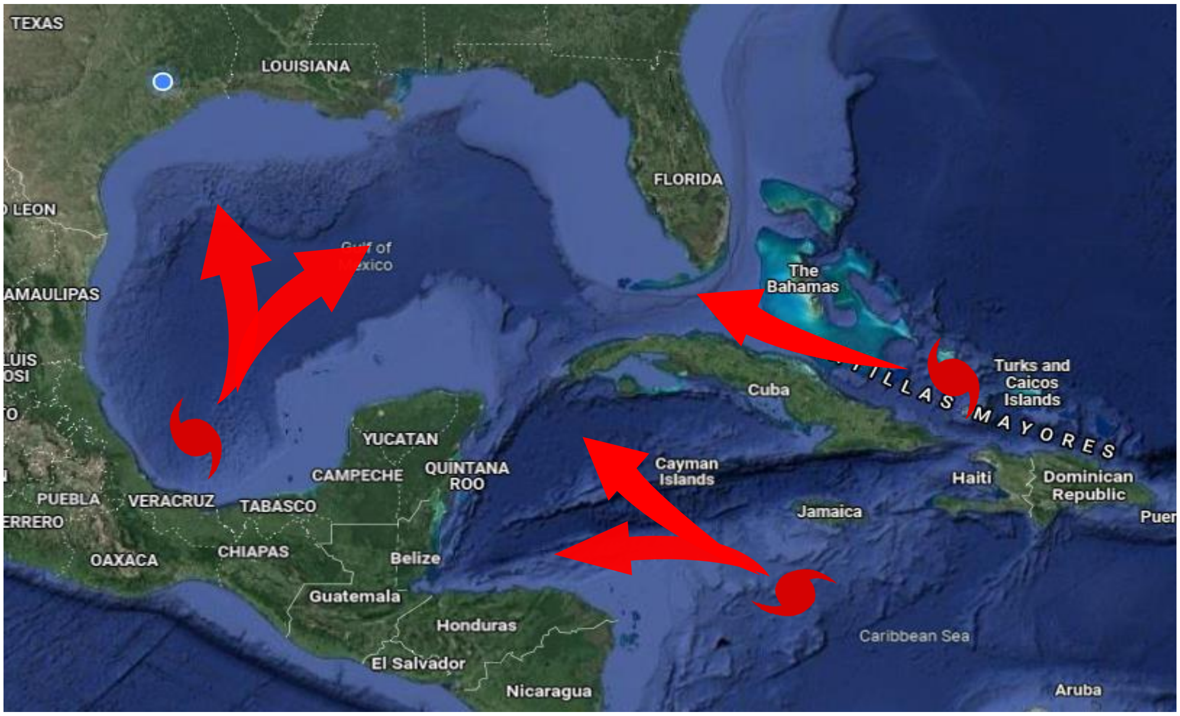


Figure 1: Storm Origins of Bay of Campeche, Caribbean Sea Area or in the waters west of the Turks and Caicos Islands

3.2 Adverse Weather in the GOM

Throughout the typical hurricane season, June 1st to November 30th, Emergency Management teams of companies conducting activities in the Gulf of Mexico, along with local government agencies, monitor the weather conditions in the Atlantic, Pacific and Caribbean, and will start various activities based on projected storm threat and timing.

3.3 Weather Forecast and Decisions

Over the past 10-15 years, as jack-ups and moored assets gave way to DP and self-propelled rigs, the traditional “Direct Path” model was set aside in favor of a dynamic forecasting model. This model relies on interpretations of meteorological data resulting in a forecast and a forecast’s uncertainty. The combination of the forecast uncertainty and the estimated T-time for the rig is the basis of many decisions when adverse weather approaches. The forecast is expected to change as the weather system approaches well location and further decisions must be taken to respond this change. This is the essence of using dynamic storm action circles (SAC) to trigger consistent decision making to achieve the intention of this document.

Weather forecasting is inherently uncertain due to the uncertainty of the models themselves and the uncertainty or incompleteness of the data that goes into the models. Various weather services available employ different forecasting models and assumptions that can create significantly different prediction outcomes. Forecast services need to provide the weight of constituent models used in their forecast.

Below is a list of Weather Providers (this list is not all-inclusive and not an endorsement of the services):

National Hurricane Center www.nhc.noaa.gov

National Weather Service	www.weather.gov/marine/offnt4mz
StormGeo	www.stormgeo.com
DTN	www.dtn.com
BuoyWeather	www.buoyweather.com
Mike's Weather Page	www.spaghettimodels.com
Cyclocane	www.cyclocane.com/spaghetti-models/

Prior to hurricane season, companies conducting activities in the Gulf of Mexico should choose the weather services that they subscribe to and rely on throughout the hurricane season.

The well operator and the rig owner should have access to a minimum of two (2) weather forecast service to understand a range of possible outcomes. The subscription weather services often provide access to meteorologists who can explain the reasons for weather model prediction, divergence from other models and explain its cone of uncertainty. These can be important for informed decisions to be made.

Storm Action Circle (explained in the next section) can be derived from a forecast. Multiple forecasts could result in different Storm Action Circles (SAC). If there is a significant difference between the SACs, this is a trigger point for discussion between the well operator and the rig owner and their teams on the SAC to be used for decision making. If the operations or weather committees are unable to converge on the SAC to be used, escalation within each company should be considered or adoption of multiple SAC can be considered. The vessel master has the final decision.

A key variable for determining the Storm Action Circle is the movement speed of the storm. Storms can pick up speed as they develop, and this could lead to undesirable results. Recognizing this uncertainty, a minimum storm speed of 12 mph or the actual forecasted storm movement speed, whichever is higher, is recommended for calculation of the SAC.

4 Operational Response to Weather Predictions

4.1 Phases of Preparedness

Below are various phases of preparedness for an organization to manage adverse weather's impact to operations.

Phase	Description
0 – Off season	Phase 0 reflects the off-hurricane season (typically Dec 1 - June 1). During this time hurricane team members, offshore personnel & onshore support personnel should review plans, update rosters, compile data for T-Times calculation in particular riser pulling times and identify any critical work activities that will occur during hurricane season. Offshore personnel should follow their company's procedures for maintaining equipment, supplies, fuel & communications. As an example, a month prior to the hurricane season, companies are recommended to discuss with their weather provider on the season's outlook, test communications and establish minimal fuel stock. Organizations should refresh inventory plans for critical equipment spares such as Cranes, Sea Chest, Isolation Packers, Hydraulic Torque Wrenches, etc. Critical maintenance that should not occur during hurricane season should be scheduled during this period. Hurricane response exercise should be done during this phase. Note: In the event of a pre-season, early season or late season storm, the hurricane emergency teams need to determine when to move to Phase I or II.
I – Readiness	Phase I typically begins June 1st, at the beginning of Hurricane Season. Preparedness efforts initiated in Phase 0 will be maintained. T time reporting will commence at the start of the season in addition to status of project work and any other change to storm preparedness efforts. It is recommended to have site situational awareness (seabed bathymetry map, latest seabed infrastructure layout, and nearby installations) for any well location, and it is especially important during this phase. During this phase drilling (through) or completing (perforating, or open hole) in hydrocarbon bearing zones will be managed through a formal risk assessment that, as a minimum, includes the proposed temporary abandonment modes for securing the well and a checklist of minimum

	equipment or materials to be available at rig site in accordance with good oilfield practice.
II – Alert	Phase II begins when a weather system is identified in the GOM, Caribbean or in the Atlantic between West Africa and GOM that has the potential to develop into a named storm. This could be in the form of a weather formation with the potential for Tropical Weather/Hurricane. It could also be a named storm without an immediate threat to GOM that might develop to impact the GOM. Crew safety meeting should include information on the hurricane evasion plan to brief crew, raise awareness and communicate plan. Respective company's Emergency Management & hurricane teams should monitor & communicate status. An agreed frequency of review of the Storm Scenarios versus Forecast will be conducted to guide decision making on operational activities to be undertaken, especially activities that increases T-time. Any maintenance that is planned to be carried out on equipment needed for executing T-time operations that renders the equipment to be out of service for longer than 24 hours, should be formally risk assessed and documented in a management of change (MOC) signed off by the Master of the vessel prior to maintenance being carried out. Any non-critical maintenance item will be suspended and any system status change that impacts T-time must be accounted for in the T-time calculation.
III – Response	Phase III begins when a Tropical Weather/Hurricane event is confirmed as a known threat to a GOM Asset. Generally, this is when the well location is within the cone of uncertainty of the storm's forecasted path. Respective Incident Commanders will activate the Emergency Response and/or hurricane team. Evasion plans will be communicated based on storm track. Those team members will assemble to support efforts to coordinate fleet response for suspension and evasion operations, monitor progress and communicate with support functions.
IV - Post-Storm/ Recovery	Phase IV begins after the Tropical Weather/Hurricane event has passed. Phase IV brings damage assessments and re-start of operations.

Note: These recommendations are non-exhaustive and each organization should consult with their respective emergency procedure for adverse weather.

4.2 T-Times, Action Radiuses and Storm Action Circle

T-Time for a well generally will consist of the following 3 elements:

T-Secure Well	The time it takes from stopping rig operations (to progress the well work scope) until the time the well has 2 independent barriers installed including the time it takes to conduct a negative pressure test. The barriers must meet the requirements of 30 CFR §250.720 and the negative test meet 30 CFR §250.721. When a rig's absolute H-Hour (hours before tropical storm winds is expected at well location) is less than the T-Time, this is called negative T-Time. Negative T-time often starts the discussion to expedite well suspension by using just a single barrier. Any single barrier option will require risk assessment and regulatory approval. Typically, T-Secure Well is calculated for a logical section of the well operations considering the longest span of operations to secure the well from any point within that logical section. T-Secure Well is the average time it takes to perform all the well securing activities described above and can vary from rig to rig.
T-Recover LMRP	The average time it takes from completing the negative test to until the time the LMRP/BOP/Well Connected Equipment is secured such that the rig can proceed at normal rig transit speeds. It is normal practice to move the rig to a safe work location once the LMRP/BOP/ Well Connected Equipment is disconnected from the well.
T-Evade	This is normally taken as 24 hrs to allow the rig to make passage away from the storm path. The passage will be determined by the vessel master. Typical drill ships have transit speed of 10 knots or more and is more than capable of evading a storm's cone of uncertainty in a 24 hrs period. The 24 hrs assumed, provides some operational relief should T-Recover LMRP or T-Secure Well takes longer than expected.

Once the elements of the T-times are established, the T-time is simply the summation of these elements. These T-time elements can be further translated to a series of radiuses consisting:

Evade Radius	T-Evade multiplied by the storm speed (assume minimum of 12 mph or forecasted speed, whichever is higher)
Recover LMRP Radius (RLR)	T-Recover LMRP multiplied by the storm speed forecasted (assume minimum of 12 mph or forecasted speed, whichever is higher)
Secure Well Radius (SWR)	T-Secure Well (hrs) multiplied by the storm speed forecasted (assume minimum of 12 mph or forecasted speed, whichever is higher)

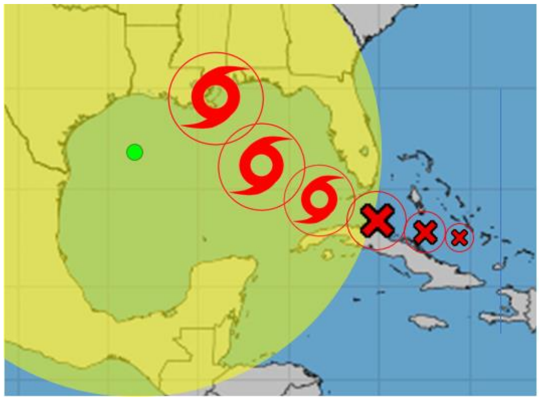
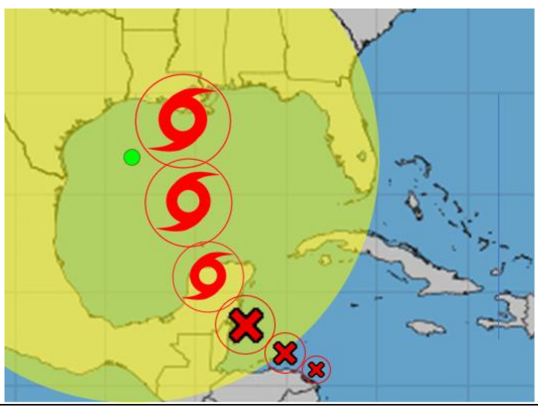
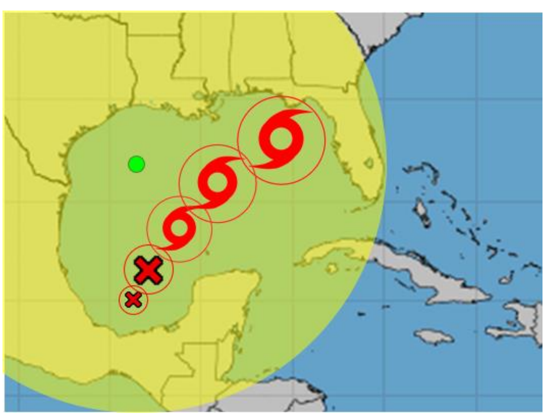
Storm Action Radius (SAR)	Storm Action Radius = Evade Radius + Recover LMRP Radius + Secure Well Radius
Storm Action Circle (SAC)	A circle with a radius of the Storm Action Radius.

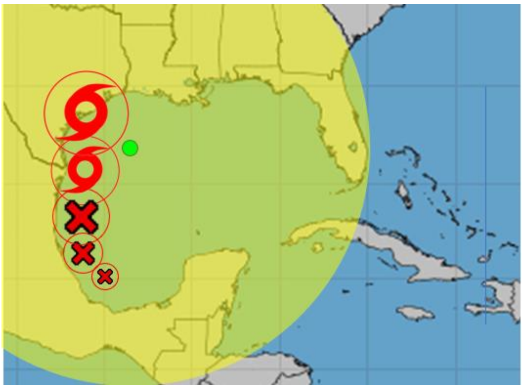
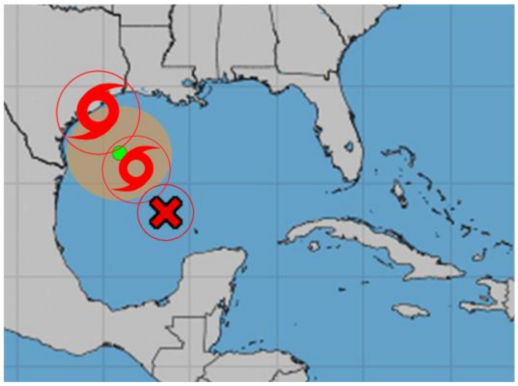
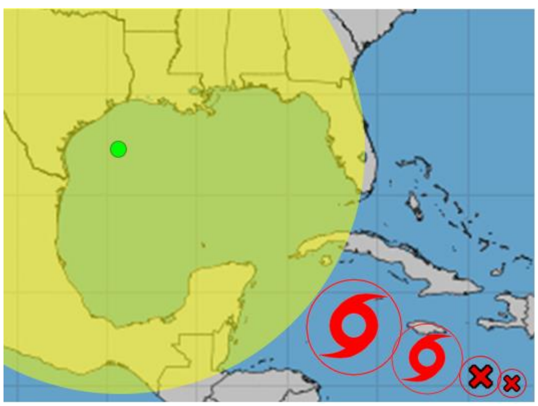
Examples of the calculations are shown in Appendix 1.

The following non-exhaustive list of factors can impact T-Time and should be considered when calculating the T-time elements. Other factors specific to a specific well or vessel may need to be considered.

	Operations scenarios	Considerations
1.	Non shearables across the BOP stack	Additional operations and equipment that will be needed to remove non-shearables from across the stack if stuck. Shallow below mud line operations with large casings have this consideration.
2.	Higher than expected formation pressures	Single barrier suspension may not be an option in certain pressure scenarios.
3.	Well control or severe losses	Complications and recovery from complex well situations may require extra T-time margin or mitigation equipment.
4.	Loop Current	Longer riser trip times due to positioning adjustment needed to center the riser. ROV launch complications.
5.	Displacement of Riser	Liquid storage capacity on the rig to be able to take on the displaced mud. If needed, availability of supply vessel to take part of the displacement will need to be factored into T-time.
6.	Hydrates on connector	Added operations needed to clear hydrates from connector before trying to unlatch

4.3 Example Storm Scenarios and Recommended Actions

	Storm – Operations Scenario	Description and Recommended Action
A.		• Disturbance forms outside of the Storm Action Circle • Forecast cone of uncertainty misses well location <u>Recommendation</u> • If range of forecast's cone of uncertainties misses well location, continue operations that do not increase T-time. • If range of forecast's cone of uncertainties contacts secure well radius, begin securing well activities once the disturbance or storm contacts the SAC.
B.		• Disturbance forms outside of the SAC • Forecast cone of uncertainty intersects well location <u>Recommendation</u> • Begin securing well activities once the disturbance contacts the SAC.
C.		• Disturbance forms inside of the SAC • Forecast cone of uncertainty misses well location <u>Recommendation</u> • If range of forecast's cone of uncertainties misses well location, continue operations that do not increase T-time. • If range of forecast's cone of uncertainties contacts secure well radius, begin securing well activities immediately.

D.		• Disturbance forms inside of the SAC • Forecast cone of uncertainty intersects well location Recommendation • Begin securing well activities immediately. • As operations is now in negative T-time, discuss options to reduce T-time such as controlled EDS, hard hang off and disconnect, making passage while pulling LMRP
E.		• Brown shading in the visual is a circle with a radius of the Secure Well Radius. • Disturbance forms intersecting the Secure Well Radius. • Forecast cone of uncertainty intersects well location. Recommendation • Employ fastest option to secure well with a minimum of one barrier, regulatory approval allowing. • Decide to weather the storm connected or disconnected considering nearby subsea infrastructure, vessel capability, storm forecast and well barrier situation.
F.		• Storm approaches a good distance away from the Storm Action Circle • Cone of uncertainty intersects Storm Action Circle. Recommendation • Risk-assess any new activities that increases T time • As storm approaches, Scenario A or B applies.

Nomenclature

Depression: Maximum sustained wind <39 mph
Storm: Maximum sustained winds: 39 -73 mph
Hurricane: Maximum sustained winds >74 mph

: Represents current or future forecast of Depression or Disturbance with boundary indicating wind extent of the depression or disturbance (<39 mph)

: Represents current or future forecast of Storm or Hurricane with boundary indicating wind extent exceeding tropical storm strength

: Storm Action Circle

5 Response Model and Extreme Weather Committee

The proper response to a storm should be coordinated by a team or committee. The organization of team can follow a structure similar to the Emergency Management command system. Typically, the team will consist of Region/Area General Manager, Operations Supervisor/Superintendent, Marine Operations Manager/Advisor and at times may require the company operator representative to be present. The team should be stood up pre-storm arrival, and an operations cadence is started.

During pre-storm management, it is recommended that operational cadence calls occur a minimum every 24 hours and as the storm system gets closer, the frequency of calls should be every 12 hours.

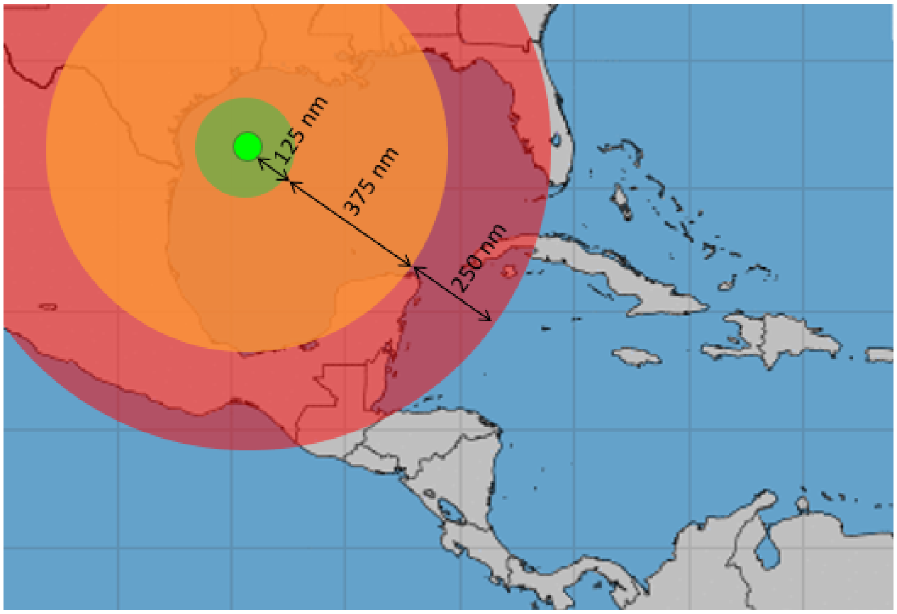
The objective of the extreme weather committee is to assist and advise the rig in securing the well and evade a storm. If rig is in negative T-time, the response team can assist in determining options such as single well barrier, mode of disconnect, logistics etc.

6 Post Storm Management / Return to Work

The proper management of post storm impacts is key to ensure safe start-up of operations. The following are considerations before starting up:

- Rig Integrity Check – DROPS and full equipment check. This applies to rigs that had to shut down systems or rigs that have experienced storm conditions while evading the storm.
- Logistics operations (road, marine and air) could be impacted, and alternative arrangements may be needed before resuming operations.
- Assess the shore base impact on being able to resume operations. Operations require both equipment, materials and personnel for planned operations, and also may require well emergency response such as well control response and oil spill response.
- Personnel emergency response capabilities such as Medevac must be available before resuming operations.
- The post storm operations teams will need to assess the rig personnel that have been impacted by the storm's landfall.
- Due to the very unique circumstance of each restart post storm, it is recommended that all post storm actions to restart deliberately follow a management of change process with risk assessment done by teams and sign off by authorized persons.

Appendix 1: Example Calculation of Storm Action Circle



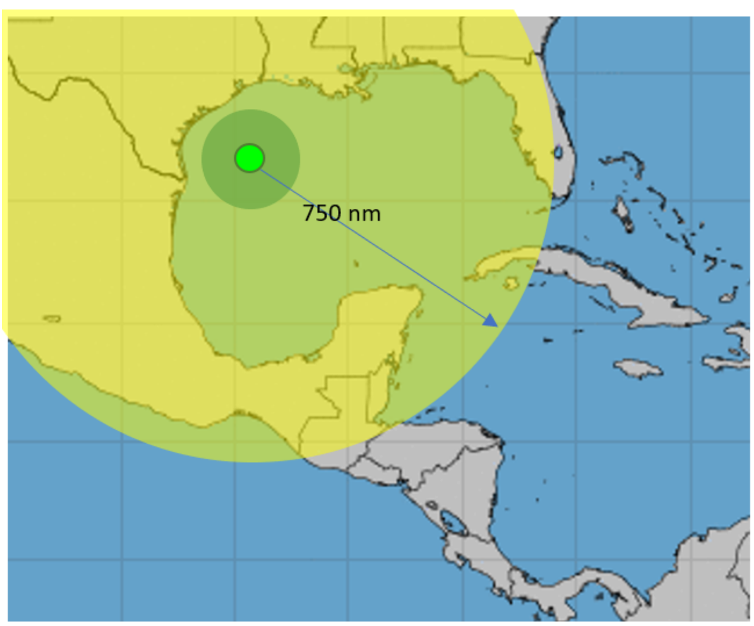
T-Evade= 24 hrs / T-Recover LMRP = 36 hrs / T Secure Well = 12 hrs
Storm Speed = 12 mph (10.43 knts)

Secure Well Radius
T-Secure Well hrs x Storm Speed = 125 nm

Recover LMRP Radius
T-Recover LMRP hrsx Storm Speed = 375 nm

Evade Radius
T-Evade hrs x Storm Speed = 250 nm

Storm Action Circle
Circle with a 750 nm radius
(Secure Well Radius + Recover LMRP Radius + Evade Radius)



Storm Action Circle

- Light green dot is the well location
- Green inner circle is the secure well radius
- Using a minimum storm speed of 12 mph, most Storm Action Circle will cover the entire GOM
- As weather forecast of the storm speed changes, the Storm Action Circle will also change
- Storm Action Circle together with the Storm's Cone of Uncertainty will determine the recommended action to be taken.