DAMPIER PORT AUTHORITY

Vessel Cyclone Moorings
Critical Aspects for Consideration
by Vessel Owners and Operators

PROJECT: 032/07210
DATE: 16 July 1998
DOCUMENT NO.: 032/07210/1

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Appendix A - DPA Cyclone Mooring Procedures
1 INTRODUCTION

The Dampier Port Authority (DPA) have commissioned Port and Harbour Consultants (PHC) to prepare this report on critical aspects of vessel cyclone moorings, within the Port of Dampier. The purpose of the report has been to help highlight and to quantify (approximately, if possible) the concerns and risks associated with the mooring of vessels during cyclone events, for consideration by vessel owners and operators.

The port area contains numerous wharf facilities and associated moorings for working vessels. The area also contains a large number of pleasure boats.

For many vessels, the approach of a Tropical Cyclone indicates a need for the relocation of the vessels from the day to day moorings to areas offering higher expected levels of protection from cyclonic forces. In particular, many commercial vessels seek shelter in the mooring area immediately south of West Lewis Island.

Many of these vessels rely on the holding power of the ships anchor in this case, which is often inadequate for the magnitude of the cyclone loadings which can occur.

Accordingly the DPA is concerned that all vessel owners and operators are aware of the critical aspects of vessel moorings in these areas and the possible magnitudes of forces that the cyclone moorings need to withstand. Thus it is necessary to ensure that each particular vessel is suitably moored, so that the safety of all vessels sharing the mooring area is not affected by those vessels with inadequate moorings dragging or breaking loose, leading to possible collisions.

It is anticipated that the issues discussed in this report will lead all concerned owners and operators to review their cyclone moorings and procedures for adequacy.
2 PORT OF DAMPIER

The Port of Dampier contains numerous wharf facilities and vessel mooring areas. These are summarised below, together with brief details of vessel types, numbers and current cyclone mooring arrangements and practices.

### TABLE 2.1 - PORT OF DAMPIER FACILITIES

<table>
<thead>
<tr>
<th>FACILITY DESCRIPTION</th>
<th>VESSEL DETAILS</th>
<th>CYCLONE MOORINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodside LPG and LNG Berths (2 of)</td>
<td>LPG, LNG and condensate Vessels</td>
<td>Not Applicable - All vessels clear the Port</td>
</tr>
<tr>
<td>Dampier Public Wharf Berths (7 of)</td>
<td>Various Cargo and Supply Vessels</td>
<td>Not Applicable - Larger vessels clear the Port, smaller vessels relocate to WLI*</td>
</tr>
<tr>
<td>Woodside King Bay Supply Base</td>
<td>Supply Vessels (2 of) Tugs (4 of) Pilot Boat (1 of)</td>
<td>Supply Vessels (2 of) Tugs (4 of) Pilot Boat 1 of</td>
</tr>
<tr>
<td>Mermaid Marine Supply Base</td>
<td>Various Workboats and Barges</td>
<td>Relocate to WLI * or HH**</td>
</tr>
<tr>
<td>Hamersley Iron - Service Wharf - Parker Point Wharf - East Intercourse Island Wharf - Tug Pens</td>
<td>Petroleum Tankers Iron Ore Carriers Iron Ore Carriers Tugs (4 of) Pilot Boat (1 of) Line Boats (3 of) Pontoon (1 of)</td>
<td>Not Applicable - All vessels clear the Port Not Applicable - All vessels clear the Port Not Applicable - All vessels clear the Port Relocate to WLI * Relocate to HH ** Relocate to HH ** Relocate to HH **</td>
</tr>
<tr>
<td>Dampier Salt Wharf</td>
<td>Dry Bulk Cargo Freighters</td>
<td>Not Applicable - All vessels clear the Port</td>
</tr>
<tr>
<td>Yacht Club Floating Jetty (Dampier)</td>
<td>Day berthing of various Work Boats, Tugs, Charter Vessels and Pleasure Craft from Hampton Harbour</td>
<td>Not Applicable (and Floating Pontoon removed from water)</td>
</tr>
</tbody>
</table>
### TABLE 2.1 - PORT OF DAMPIER FACILITIES

<table>
<thead>
<tr>
<th>FACILITY DESCRIPTION</th>
<th>VESSEL DETAILS</th>
<th>CYCLONE MOORINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hampton Harbour</td>
<td>Various Work Boats, Tugs, Charter Vessels and Pleasure Craft (up to approx 40 of)</td>
<td>Some vessels relocate to WLI* or adjacent tidal inlets, others go to onshore hard standing, others stay at moorings.</td>
</tr>
<tr>
<td>Yacht Club’s Kaiser Marina</td>
<td>Pleasure Craft (up to approx 35 of)</td>
<td>Some vessels go to onshore hard standing, others to moorings within HH**.</td>
</tr>
<tr>
<td>West Lewis Island (South of)</td>
<td>-</td>
<td>Various operator supplied moorings. Other vessels also moor using their own anchors.</td>
</tr>
</tbody>
</table>

**Note:**  
* Indicates that vessels are relocated to the mooring area south of West Lewis Island (WLI)  
** Indicates that vessels are relocated to the mooring area within Hampton Harbour (HH)
3 CYCLONE MOORING ISSUES

Vessel owners and operators in the region are expected to be well aware of the risks associated with the adequate securing and mooring of vessels during cyclonic events. These risks relate to both the vessel itself, its crews and responsibilities towards other vessels moored in the vicinity.

The aim of this report is to highlight the nature and types of mooring loadings and where possible, the magnitude of these loadings, (where available) for different vessel sizes. Throughout this report, the issues raised and loadings discussed are based upon the use of swing moorings. Vessels moored to fixed wharves or substantial floating pontoons are subject to additional mooring issues not discussed herein.

Cyclonic events influencing the region can vary greatly in intensity. This can be expressed more accurately as an average return period for the cyclone based upon its central pressure, peak wind velocity, wave heights, and storm surge levels. Depending upon the criteria used, events such as T C Orson (April 1989) are around 100 - 125 years return period, while T C Ilona (December 1988) was around 10 - 20 years return period.

The design of a mooring to a particular level of cyclonic return period will depend upon the owner or operators acceptance of risk (of that level of cyclonic event being exceeded followed by possible mooring failure and vessel loss), the consequences for the vessel from mooring failure during a cyclone (including those consequences for adjacent moored vessels) and any regulations set out by the Dampier Port Authority.

In previous mooring analysis and design work undertaken by PHC on behalf of vessel operators such as Woodside Offshore Petroleum, Robe River Iron Associates and Hamersley Iron; return periods of between 10 and 100 years have been considered to obtain design loadings and information on mooring excursions and vessel behaviour.

The basic elements of these loadings are discussed in the following sections.

3.1 Cyclonic Winds

Depending upon the moored vessel location and characteristics, the steady loading applied to a vessel's superstructure and hull, above the waterline, can form a large proportion of the total load on the mooring system.

Windspeeds of typically between 30 to 60 metres/second (equivalent to 110 to 220 km/h) should be used in the assessment of mooring loads. Actual design values can be derived from the Wind Code (AS 1170.2) with suitable adjustments for the following factors:

- Return Period
DAMPIER PORT AUTHORITY

VESSEL CYCLONE MOORINGS - DAMPIER PORT CRITICAL ASPECTS FOR CONSIDERATION BY VESSEL OPERATORS

- Basic Regional Windspeed
- Surface Roughness
- Gust Duration
- Elevation

The Port of Dampier is in the Wind Codes Region D (Severe Tropical Cyclones). Surface roughness’s of Terrain Category 2 (consistent with rough open water conditions) may be used at many exposed locations within the Port.

Gust durations of 10 minutes can be used for the later derivation of the locally generated wave climate, while higher velocities appropriate to shorter gust durations should be used to derive wind loadings on vessels, depending upon size and response characteristics (i.e. ranging between 15 to 30 seconds).

Over the period 1961 to 1996 inclusive, the Dampier region (within ± 100km) has experienced an average 0.6 cyclones per year while the North West shelf region (within ± 1000km) experiences around 2.2 cyclones per year.

Moorings should be designed to resist steady wind forces from all directions, as there are no directional reductions put forward in the Wind Code and further investigations by PHC (Reference 3) have indicated that a wide range of historical cyclone tracks do not support any reductions in wind speed based upon directionality.

3.2 Wave Conditions

Cyclones can generate a widely varying wave regime throughout the Port of Dampier. Wave loadings on a vessel can vary depending upon its response to waves of varying periods and heights.

Wave Period

Wave periods within the Port can be as large as long period (10 - 14s) swell propagating into Mermaid Sound or Mermaid Strait from deepwater offshore. Within southern portions of Mermaid Sound, and other less exposed areas, natural processes of wave transformation will reduce these periods to between typically 6 - 10s and are often accompanied by shorter period wind regenerated sea.

In the most sheltered areas of the Port, for example Hampton Harbour or in the lee of Islands, wave periods may be only 3 to 4 seconds. However the presence of other longer period wave energy from other directions (diffracted around islands or from changed wind directions before, during or after the passage of a cyclone) should also be considered.

Wave Height

Similarly wave heights can vary widely throughout the Port due to exposure to transformed offshore swell and regenerated local sea. Cyclonic wave conditions are very chaotic, however for numerical
analysis they can be described on the basis of significant wave height (average of the highest one-third of the waves) and maximum wave height (during a specified storm duration). Maximum wave heights can be up to 1.6 - 2.0 times larger than the significant wave height. Depending upon design methods used to determine peak mooring loads, the maximum wave height may be appropriate for analysis. At some sites and in shallower water depths, the maximum wave height may be limited by wave breaking however this can act to further increase wave loads due to the associated wave non-linearities and difficulty of analysis.

Previous studies by PHC have indicated the following general ranges of significant wave height across return periods of 10 to 50 years.

### TABLE 3.1 - WAVE HEIGHTS

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>$H_{\text{sig}}$ (m) Range *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern Mermaid Sound</td>
<td>3.0 to 4.5m</td>
</tr>
<tr>
<td>(at facilities shown in Table 2.1)</td>
<td></td>
</tr>
<tr>
<td>Hampton Harbour</td>
<td>1.5 to 3.0m</td>
</tr>
<tr>
<td>(Zones B &amp; C, refer to Appendix A)</td>
<td></td>
</tr>
<tr>
<td>Mermaid Strait</td>
<td>2.0 to 4.0m</td>
</tr>
<tr>
<td>(South of West Lewis Island)</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** * Design may require $H_{\text{max}} = 1.6$ to 2.0 times $H_{\text{sig}}$.

The wave regime at the proposed or existing mooring locations should be determined based upon a full consideration of cyclonic wind conditions and wave height generation mechanisms. In sheltered locations this will require manual calculations based upon accepted coastal engineering analysis techniques, for example as set out in the Shore Protection Manual. More exposed locations will require more advanced numerical analysis by tropical cyclone modelling and wave transformation assessment.

### 3.3 Tides and Storm Surges

The Port of Dampier is subject to a large normal tidal range as shown in Table 3.2.

### TABLE 3.2 - DAMPIER TIDAL RANGE

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>LEVEL TO CHART DATUM * CD (M)</th>
<th>LEVEL TO AUSTRALIA N * HEIGHT DATUM AHD (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAT</td>
<td>5.22</td>
<td>2.51</td>
</tr>
<tr>
<td>MHWS</td>
<td>4.55</td>
<td>1.84</td>
</tr>
<tr>
<td>MHWN</td>
<td>3.22</td>
<td>0.51</td>
</tr>
</tbody>
</table>
Tropical cyclones act to further modify site water levels by the presence of storm surge and wind setup, due to their low atmospheric pressure and high wind speeds applying a wind stress to the water surface that causes it to “pile up” against land masses and confined water bodies, such as Hampton Harbour.

Previous analysis by PHC has found that within Mermaid Sound the storm surge can raise the water levels, above normal tidal levels, by between approximately 1.5 to 3.0m (for the 10 to 50 year return period range) while wind setup can add a further 0.2 to 0.5m, depending upon location.

Similarly, basic statistical analysis by PHC of the joint probabilities of occurrence of high tidal water levels and high storm surges have indicated design values for total storm surge water levels in the range of approximately 2.5 to 4.0m AHD for the 10 to 50 year return periods, excluding wind setup.

The above data are supplied only to indicate possible ranges of tidal and storm surge water levels. Data for design shall be independently derived by the vessel owner or operator.

### 3.4 Water Depth at Mooring

Subsequent to the possible ranges of tidal and storm surge water levels discussed in Section 3.3, vessel owners and operators must also consider the water depth at the mooring. The influence of cyclone loadings on their vessels moorings should be determined under the full range (low and high) of tidal and storm surge conditions.

Of special concern are moorings in relatively shallow water depths, under low tide and high wave conditions. Such a combination of conditions can exist for example, in the West Lewis Island mooring area and in some portions of Hampton Harbour. These conditions can lead to violent vessel behaviour at the moorings (breaking waves, excessive motions, snatch loads etc) and in extreme cases, loss of underkeel clearance in wave troughs for larger, deeper draft vessels.

We note that Woodside MSPMS cyclone procedures do not allow vessels (except the Burrup Tide) to be moored within the West Lewis Island cyclone mooring area. All other vessels are instructed to proceed to sea, with the vessel Masters exercising their judgement to avoid a close encounter with a cyclone.
3.5 Steady Currents

Similarly to total storm surge water levels, discussed in Sections 3.3 and 3.4 of this report, the steady currents that impinge upon a mooring location can be considered as a combination of normal tidal streams and storm surge induced circulation.

Some published data on tidal streams is contained in published Charts, Tide Tables or Pilots for the region. However little detailed information is available on storm surge induced currents. These can be crudely represented by an assumed near-surface water particle velocity of between 2 to 5% of the windspeed. A basic combination of these two parameters results in velocities from 1.0 to 1.5 metres/second.

It is often assumed that the forces resulting from steady currents form only a small portion of the overall loadings on a mooring. However previous analysis by PHC has indicated that in combination with other loadings, especially at low water levels with breaking wave conditions, the restoring nature of these steady forces can become critical.

Moorings should be designed to handle mooring forces due to all environmental loadings, or part thereof. Where insufficient data exists, reasonable conservative judgements are required or further investigations and modelling should be undertaken.

3.6 Cyclonic Event Variability

Cyclone warnings are issued by the Bureau of Meteorology, with estimates of cyclone location, track and forward speed together with classification of cyclone category (from 1 to 5). These can provide advance notice of the cyclone influencing a mooring area.

However, studies by the Bureau have indicated that cyclones have the potential to increase in severity by up to 2 categories in the final 24 hours prior to landfall. Estimates of cyclone track and forward speed can also vary as a cyclone approaches a coastline.

Accordingly we note, for the attention of all vessel owners and operators, that these factors require careful consideration for the provision of cyclone moorings to withstand loadings for all cyclone conditions. It is not sufficient to have cyclone moorings suitable for weak or low return period events only, and plan to put to sea for severe events. Indicative loadings are discussed in the following section.
4 INDICATIVE LOADINGS

PHC were commissioned by the Dampier Port Authority to prepare this report on the basis of previous tropical cyclone analysis and mooring assessment work undertaken for several operators in the region. Table 4.1 provides a range of indicative loadings, for various vessel sizes and mooring locations, extracted from these previous analyses. In order to maintain some confidentiality of these results, the data has been generalised however the value of the data in illustrating indicative loadings under various return periods remains.

**TABLE 4.1 - INDICATIVE VESSEL MOORING LOADINGS**

<table>
<thead>
<tr>
<th>VESSEL SIZE</th>
<th>CYCLONE MOORING LOCATION</th>
<th>APPROXIMATE RETURN PERIOD</th>
<th>TOTAL MOORING FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Vessel 10m LOA, 10t displ</td>
<td>Hampton Harbour</td>
<td>50 Years</td>
<td>3-8t</td>
</tr>
<tr>
<td>Medium Vessel 18m LOA, 25t displ</td>
<td>Hampton Harbour</td>
<td>50 Years</td>
<td>10-15t</td>
</tr>
<tr>
<td>Large Vessels 30-35m LOA, 500-800t displ</td>
<td>West Lewis Island</td>
<td>10-50 Years</td>
<td>50-300t</td>
</tr>
<tr>
<td>Small Ship 60-75m LOA, 2000t displ</td>
<td>West Lewis Island</td>
<td>25-100 Years</td>
<td>40-70t (Wind Only) Total loadings not available (but would be expected to exceed 250-500t)</td>
</tr>
</tbody>
</table>

The variations in mooring loads shown in Table 4.1 are due to the full range of environmental parameters discussed in this report. The 300t mooring force for the large vessels illustrate the high loadings that can occur due to, a foreseeable combination, of low tide, shallow water depths, high winds and near breaking wave conditions.

Additionally it is noted that other factors can significantly influence actual mooring behaviour and loadings including:

- Type of seabed anchorage (embedment anchor, drag anchor, spread mooring etc)
- Mooring line configuration (chain and mass, clump weights, soft lines and type, buoys etc)
- Vessel behaviour (windage, length, displacement response amplitude operators etc).
- Method of analysis (static, frequency or time-domain numerical modelling etc).
5 SUMMARY

This report has presented an overall treatment of the key critical aspects relating to vessel cyclone moorings, that should be considered by all vessel owners and operators.

The large number of wharf and mooring facilities within the Port of Dampier presents a special range of responsibilities to all vessel owners and operators to ensure that their vessels are adequately moored to withstand the very high mooring forces that can arise during severe Tropical Cyclone events.

A summary of the range and magnitudes of these forces has been provided in this report, together with indicative mooring loads for several different mooring locations and vessel sizes as available from previous studies by Port and Harbour Consultants.

We recommend that all vessel owners and operators review their present cyclone mooring arrangements, in light of this report. This recommendation especially applies to vessels that use the current cyclone mooring areas of Hampton Harbour and (south of) West Lewis Island. We stress that the data contained herein are provided for general information and guidance only. Owners and operators shall make their own inquiries and calculations of mooring conditions and loadings to suit their specific vessel characteristics, mooring location and risk assessment.

In some regions, for example Hampton Harbour, the Dampier Port Authority, provide environmental criteria that can be used in such assessments. A copy of the Authorities current procedures for Hampton Harbour is contained in Appendix A of this report. For other regions, for example West Lewis Island, the Dampier Port Authority, while it does not want to ban use of the area, wants to ensure that vessels using the area have moorings in place that are adequate for the size and type of vessel moored.
6 REFERENCES


APPENDIX A

DPA Cyclone Mooring Procedures