DREDGING TO MINIMIZE WAVE PENETRATION INTO A HARBOUR

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ABSTRACT

Wave protection within a new harbour development has been achieved by shaped dredging in place of long breakwaters. The dredging shape was initially established through wave refraction calculations and then confirmed and optimized in a physical three dimensional model. The cost of additional dredging for the specified shape was A$100,000 compared to estimated breakwater costs of A$1,000,000.

1. INTRODUCTION

For the development of offshore gas reserves near Dampier, northern Western Australia, the developers, Woodside Offshore Petroleum, required a supply base harbour to be established. A harbour site was selected at the southern end of Mermaid Sound. See Figure 1. The site is protected from Indian Ocean swell and subjected to a relatively mild short period wave climate because of limited fetches. However, the area is subjected to cyclones with their associated winds, waves and storm surge.

The harbour site has natural protection from three sides and is only directly exposed to waves on the western side. Preliminary design had allowed for a breakwater to provide protection from the west. During detailed design, shaped dredging was investigated as an alternative to breakwater type protection.

As an aid to design of the facility, a three-dimensional physical model had been constructed to optimise the layout with respect to wave protection and to assist in the determination of design waves for seawall, revetment and breakwater design. In the modelling process it was found that a conventional channel approach as shown in Figure 2 tended to concentrate wave energy in the northeast corner of the basin. A breakwater length of approximately 200 metres was required to reduce waves to an acceptable height in the basin during cyclones.

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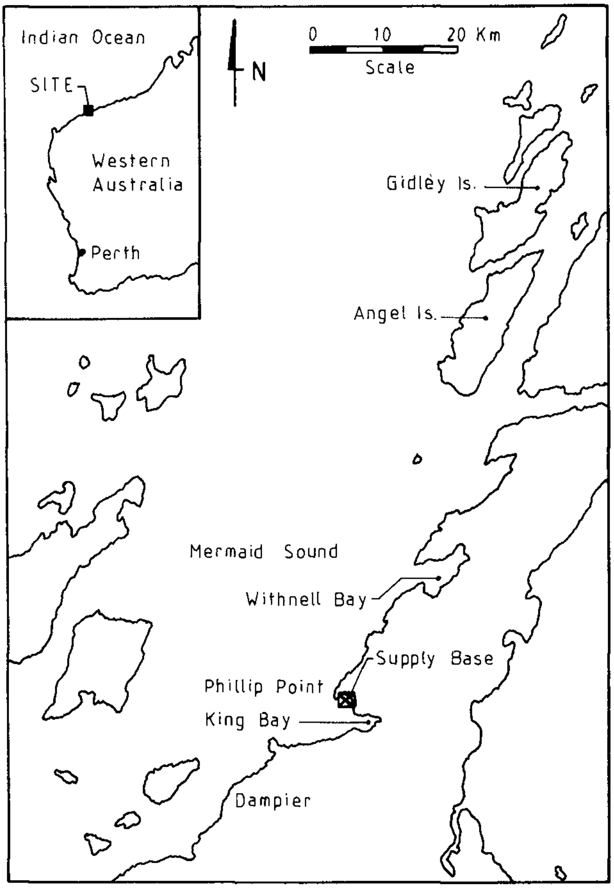

Figure 1. Location Diagram

It was therefore decided to investigate the possiblity of reducing wave heights by shaping the entrance channel so that it would act as a diverging lens. Initially, variations in channel shape and alignment were investigated by mathematical wave refraction calculations. These calculations indicated that shaped entrance channel dredging would reduce wave heights in the basin.

The calculations were confirmed in the physical model where both refraction and diffraction could be simulated.

2. CONCEPTUAL SUPPLY BASE LAYOUT

The layout shown in Figure 2 was chosen to utilise the natural wave protection in the lee of Phillip Point. The alignment and position of the basin was primarily controlled by geotechnical constraints so that rock dredging was minimised. The channel alignment and width were chosen to minimise the extent of dredging keeping in mind safe navigation for the vessels using the supply base.

Whilst the supply base design required that damage be negligible for a cyclone of 50 year return period intensity, it was not intended to provide a haven for vessels during a cyclone. There were therefore two sets of design criteria for wave activity in the harbour:

(i) that wave heights along the supply base wharf be less than 0.5 metre aligned with berthed vessels or less than 0.3 metres beam on for operational (non-cyclonic) conditions.

(ii) that wave heights be minimised to give the most economic, safe design of revetments and breakwaters for cyclonic conditions.

The design wave for operational conditions is generated from the western sector with H_{sig} = 0.9 m and a wave period of 3.5 seconds.

Cyclone generated waves can arrive at Phillip Point from any direction between west and north. The largest and longest period waves arrive from the north and are generated outside Mermaid Sound and propagated to the site. The supply base is well protected from these waves. Shorter period waves are generated within Mermaid Sound. For cyclone conditions these have a significant wave height of 2.5 metres and period of 5 to 6 seconds.

The conceptual layout provided satisfactory wave conditions for operational conditions. However, for cyclone generated waves approaching from the west, wave heights at the northeast corner of the basin were large and for some test conditions even amplified. Without a breakwater at Phillip Point, waves as high as 3 metres were recorded.

In order to reduce waves to a nominal 1 metre height, a 200 metres long breakwater would have been required. The 1980 cost estimate was A$1 million.

3. ALTERNATIVE CHANNEL DESIGNS

Since in the physical model it was apparent that the navigation channel was focusing wave energy into the basin, methods of altering the channel were investigated in the hope of reducing the breakwater length. Wave refraction calculations were carried out for several channel alignments and finally for a channel with a large hole dredged in its northern side. Figure 3 shows the range of channels used for wave refraction calculations. The refraction calculations indicated a significant improvement for both a straightened channel and a channel with the adjacent dredged hole. Figure 4, a typical forward ray refraction diagram, shows the diverging lens effect of the dredged hole.

The refraction calculations excluded the effects of diffraction and wave reflection which would be expected to have some influence.

These calculations were sufficient to show that wave heights could be reduced significantly in the harbour basin by redesigning the approach channel. Confirmation of these calculations was necessary in the physical model where the effects of diffraction and reflection were included.

4. MODEL TESTING

The dredged hole was modified to a shape shown in Figure 5 which could realistically be dredged. Extensive model tests were then conducted in the three dimensional physical model at an undistorted scale of 1:100. Both the straightened channel and the channel with the adjacent dredged hole were modelled. A total of 75 tests were completed to investigate the two channels and the improvements in wave conditions inside the harbour with a range of breakwater lengths. Earlier modelling had been conducted on the channel shown in Figure 2.

Figure 6 shows the 2 metre wave height contours in the harbour basin for the original channel and the two improved channel shapes identified by the refraction calculations for a typical test condition. The approach channel with the adjacent dredged hole gave consistently calmer wave conditions than a straightened channel to the harbour basin. This channel was chosen for detailed model testing and design and resulted in the design wave for the revetments being halved in height without the need of a costly breakwater.

Earlier model testing had shown that a 200 metre long breakwater was required to reduce the design wave heights to these levels with the original approach channel.

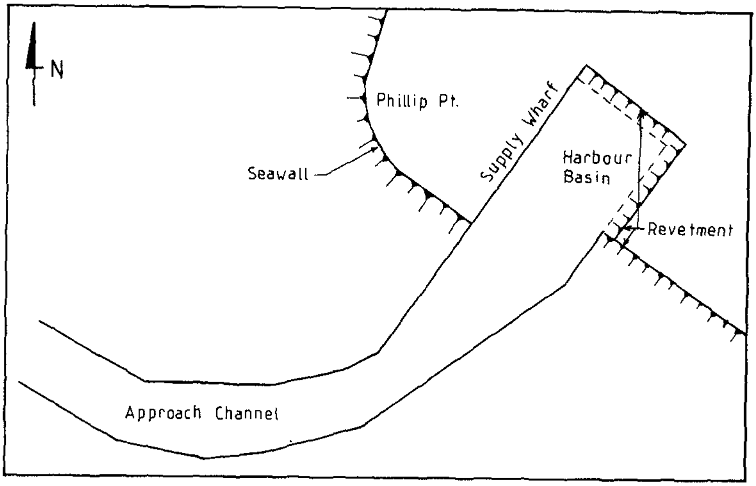

Figure 2. Initial Approach Channel

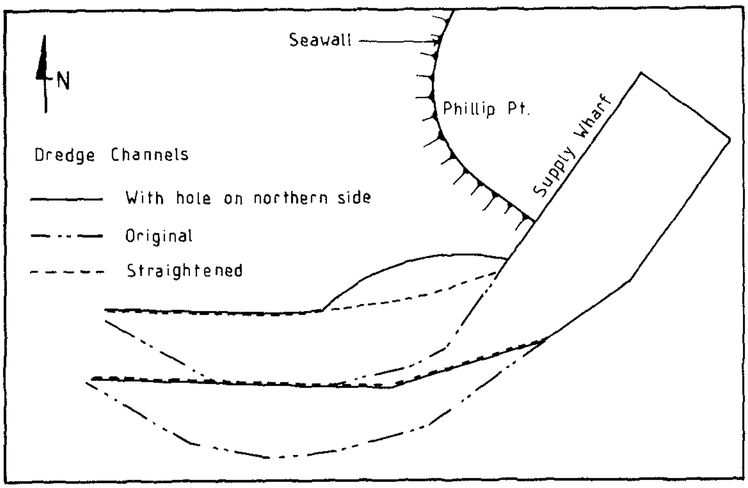

Figure 3. Channels Used in Wave Refraction Calculations

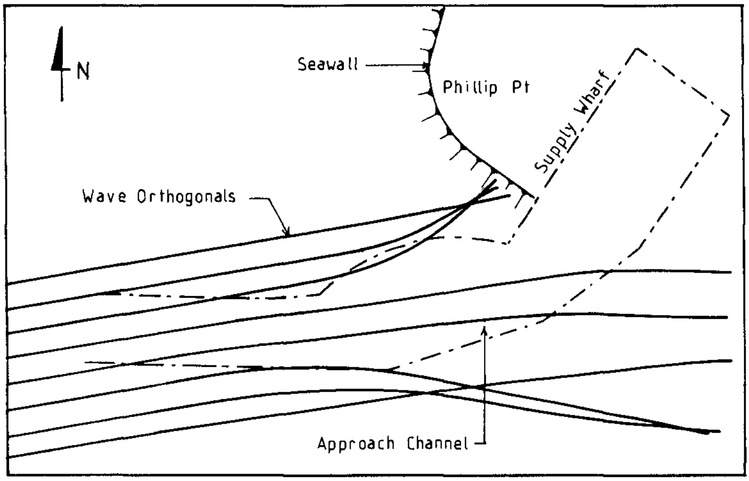

Figure 4. Typical Wave Refraction Diagram for Preferred Solution

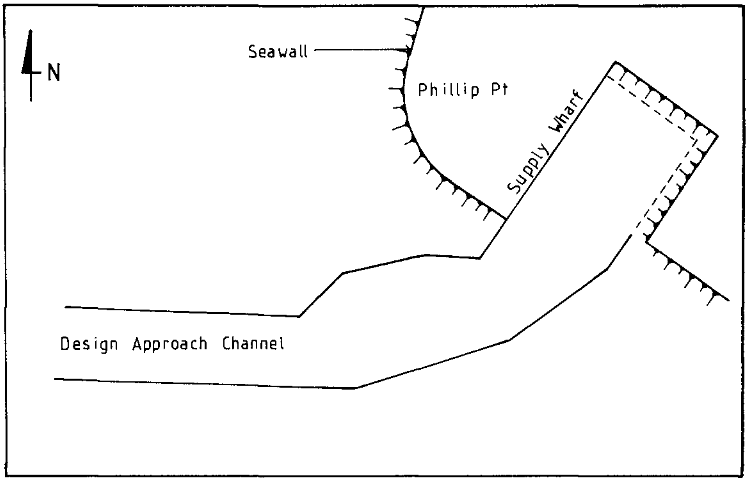

Figure 5. Design Approach Channel

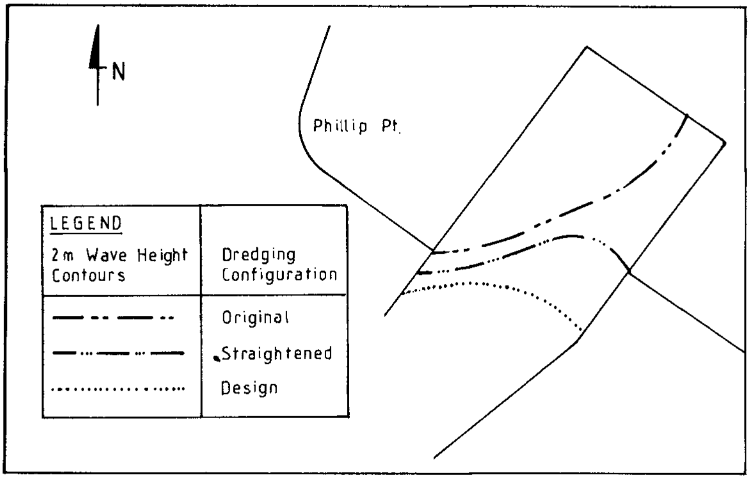

Figure 6. Comparison of Wave Height Contours for Typical Cyclone condition.

5. ECONOMIC CONSIDERATIONS

For the operation of the supply base there was no need for a breakwater under non cyclonic conditions with the original channel. However, during a cyclone if the breakwater were not present the revetments lining the harbour basin would have had to be constructed of much larger rock and to a higher crest elevation if damage during a cyclone were to be negligible. This would have required higher levels of reclamation so that the additional cost would have been in excess of A$0.5 million. Also any future extension of facilities to the eastern side of the basin would need to be designed for these high waves.

A 200 metre long breakwater would have cost about A$1 million in 1980.

By comparison, a dredge hole positioned so that all material to be removed was relatively soft and easily dredged with available plant, cost about A$100,000. The dredging of the hole was an extension of dredging that had to be carried out for the approach channel regardless of the final design.

6. CONCLUSIONS

Shaped dredging can be an effective method of changing wave conditions in the lee of the dredged area. For the North West Shelf project it was possible to effect substantial cost savings by the use of shaped dredging rather than a breakwater to provide wave protection for the Supply Base.

Caution must be applied to ensure that shaped dredging does not cause an unacceptable worsening of wave conditions adjacent to the site under investigation.

Dredged entrance channels and harbour basins may have a profound effect on waves propagated over them. The effects of wave concentration should always be checked in the design stage.

7. ACKNOWLEDGEMENTS

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