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SHIP - BANK INTERACTION EFFECTS: A CASE STUDY - PORT OF TOWNSVILLE

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Navigation in restricted waterways has many challenges for even the most experienced ship handlers. Bank effect is a well known phenomenon that poses ship handling difficulties through the creation of a force and moment which can cause a ship to suddenly deviate from its course. Ship response to bank effect can be very difficult to predict.

Following construction of a new berth pocket and swing basin emanating from the main approach channel at the Port of Townsville, ships began to experience bank effect when passing the new berth. The lack of symmetry in the channel caused ships to slew into the dredged area, at times making ship handling very difficult and dangerous.

A comprehensive study involving full-scale Differential GPS(DGPS) measurements, model-scale testing and theoretical modelling was undertaken to determine the optimum dredging program to reduce the existing bank effect by 50%.

The paper concludes with the justification of the option chosen by Townsville Port Authority.

1. INTRODUCTION

Townsville is north Queensland's third largest industrial port serving the north Queensland region and North West Mineral Province. Cargo through the Port has grown dramatically over the past ten (10) years with cargo trebling from 2.4 million tonnes in 1987/88 to more than 7.8 million tonnes in 1997/98. This has resulted in approximately 625 cargo vessel visits to the port per year.

As part of the infrastructure development to accommodate such growth and, in particular, the BHP Cannington project, port planning determined that it was necessary to construct a new outer harbour berth adjacent to the main shipping channel at the entry to the existing harbour. The berth is a 6 dolphin configuration with an independent wharf deck and ship loader conveying system perched over the dolphins. The wharf alignment is some 3.0 meters inboard of the fender line to reduce the potential for impact and is approximately 5.5m above HAT in order to provide clearance above cyclone wave attack. Establishment of the berth involved dredging of a new swing basin and berth pocket approach emanating from the eastern side of the main shipping channel, the configuration of which was determined by. ship simulation at the Australian Maritime College (AMC), and safe navigation assessment by the Regional Harbour Master, see Figure 1.

As a consequence of the Berth 11 construction, it became apparent that a bank effect was being experienced by deep draught ships entering the existing harbour which required up to 30° of helm to remain in the channel over this section of the passage.

Recognising the problem the Townsville Port Authority (TPA) commissioned O'Brien Maritime Consultants (OMC) to undertake a study to determine the optimal solution for overcoming this bank effect problem.

A comprehensive study involving full-scale DGPS measurements, model-scale testing and theoretical modeling was undertaken to determine the reduction in bank effect as a result of proposed dredging options, involving removal of varying amounts of the western bank and deepening of the approach channel. The aim of the study was to determine the optimum (least cost) dredging program required to reduce the existing bank effect by the target figure of 50%.

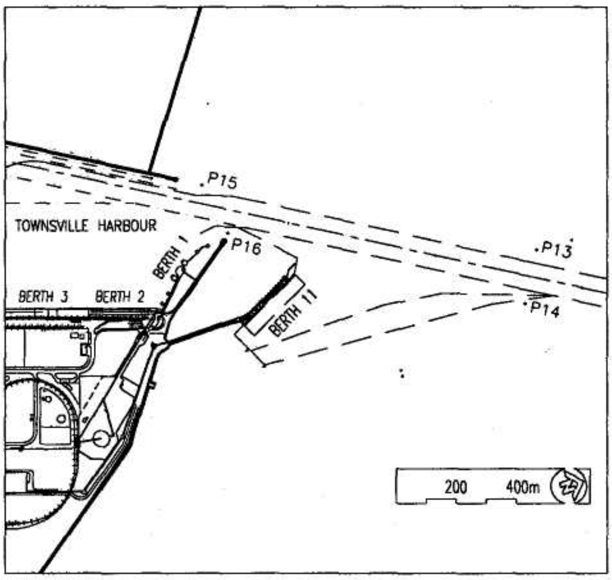

Figure 1: Location Diagram

2. BACKGROUND

Bank effect is caused when there is an uneven pressure distribution around the hull of the vessel due to a bank in close proximity on only one side. This creates a sway force, which is repulsive for small underkeel clearances (depth/draft < 1.20 approximately) and attractive for large underkeel clearances. In addition and generally of greater concern, the bank produces a bow-away moment, which can cause the vessel to sheer across the channel, unless corrective rudder action is applied.

The major factors affecting bank effect are:

- depth/draft (h/T) ratio
- depth of water over the bank of greatest influence
- distance between the ship and the bank of greatest influence
- distance between the ship and the bank of least influence
- vessel speed

Research conducted by Ch'ng (1) shows that depth/draft ratio significantly affects the bank effect, not only in magnitude but also ship response.

Classic bank effect is a bodily suction of the vessel to the bank of greatest influence, producing a yaw moment that results in a bow away orientation of the vessel. However, Ch'ng showed that at low depth/draft ratios of approx. 1.1 - 1.2 the suction force acting on the vessel was reversed to become a bodily repulsion. The yaw moment associated with this repulsive force is much larger than that associated with the suction force and hence, the bank effect becomes much larger.

Thus, maximum repulsive forces and bow-away moments will occur at minimum depth/draft ratio (approximately 1.10 for vessels loaded to maximum draft for the tide or sailing at the beginning or end of a tidal window). Port records show that in excess of 100 vessels sailed at this minimum depth/draft ratio during the past year.

The findings that the force changes from attraction to repulsion at very low depth/draft ratios are supported by work conducted by Vantorre (2).

Dredged bank options, similar to those proposed by Townsville have been considered by Norrbin (3) who found that the amount of water cover over the side bank was a considerable factor in determining bank effect. This work suggests that if the depth of water over the bank is £ approx. 70% of the total water depth, then bank effects are negligibly small.

The distances between the ship and the bank of greatest influence and the bank of least influence also affect the magnitude of the bank effect. As the bank of least influence gets further away from the ship the forces and moments become unbalanced and the bank effect increases.

Ship speed also affects bank forces and moments. Increasing speed causes increased bow away moments and, for small underkeel clearances, can change bank repulsion forces into suction forces as shown by Dand (4).

3. FULL SCALE TESTING

Full-scale measurements were performed by OMC to accurately quantify how much movement the ships were experiencing due to bank effect. The testing program involved six deep draft vessels; one departing, five arriving.

DGPS equipment, capable of centimeter accuracy horizontally was used to provide very accurate vessel movement measurements. Two DGPS instruments were set-up on each ship, one on the bow the other on the bridge, to log the horizontal locations of these two points within the channel.

The results showed significant vessel movement off the centreline of the channel as vessels entered the cut away section. Each vessel applied between 20° and 30° of helm through most of the section to maintain course, indicating a significant bank effect.

The testing provided a range of actual vessel speeds through the critical section of the channel. A typical speed of 6.5 knots was chosen by OMC for use in calculating bank effect throughout the remainder of the study.

4. MODEL SCALE TESTING

4.1 Dredging of the Western Bank

The dredging option under consideration involved dredging the remaining (western) bank to RL7.0m out a distance of 40m from the toe of the existing channel. This option resulted in a stepped channel bank that had not previously been tested in model scale trials and for which no known empirical model existed.

It was therefore necessary to undertake physical testing of the dredged bank.

Model-scale testing of the existing situation and the dredged option was conducted in the Ship Hydrodynamics Centre at the Australian Maritime College using a model of a Panamax vessel.

Diagrams of the bank arrangements tested in the towing tank are shown below in Figures 2 and 3.

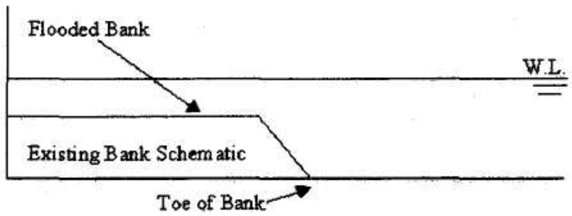

Figure 2: Existing Bank Schematic Tested

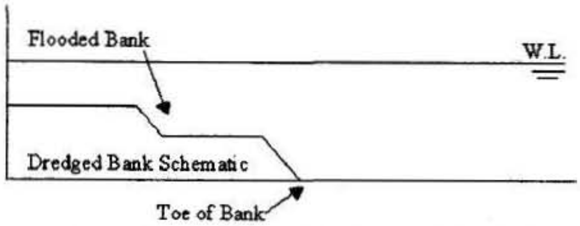

Figure 3: Dredged Bank Schematic Tested

This set of model scale testing was conducted at h/T = 1.12, which is within the critical range for bank effect, discussed earlier in this paper. The results clearly showed that the resultant force acting at this condition is a repulsive force.

This confirms the findings of Ch'ng (1), Vantorre (2) and Dand (4), that at very low depth/draft ratios the force is repulsion rather than attraction causing a much larger bow away moment.

The results of these tests showed a reduction in yaw moment of 28% by dredging the bank as proposed. Thus this option, *per se*, was not a satisfactory solution to the bank effect problem.

4.2 Deepening Existing Channel

Further model scale testing was conducted at the Ship Hydrodynamics Centre to assess the effect of deepening the channel by one and two metres, thereby increasing depth/draft ratio to 1.20 and 1.29, respectively.

Previous modelling work had shown that there is a significant decrease in bank effect as the depth/draft ratio increases above 1.10. The previous research was not comprehensive enough to allow full confidence in applying the results to the situation at Townsville, therefore additional testing was undertaken.

The existing bank was used in the towing tank tests, being raised slightly to reflect the increases in depth.

Figure 4 shows the change in direction of resultant force from attraction at h/T=1.29 to repulsion at h/T=1.12. At h/T = 1.20 the resultant force is almost zero. The tests were conducted at a speed equal to 6.5 knots full-scale.

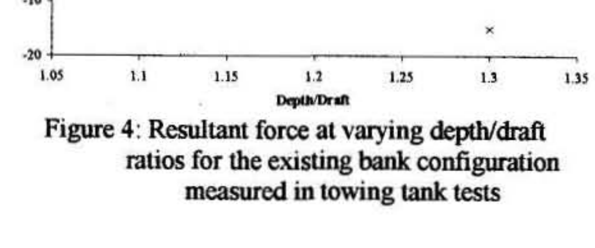

Figure 4: Resultant force at varying depth/draft ratios for the existing bank configuration measured in towing tank tests

Figure 5 shows the reduction in yaw moment resulting from increased water depth at 6.5 knots.

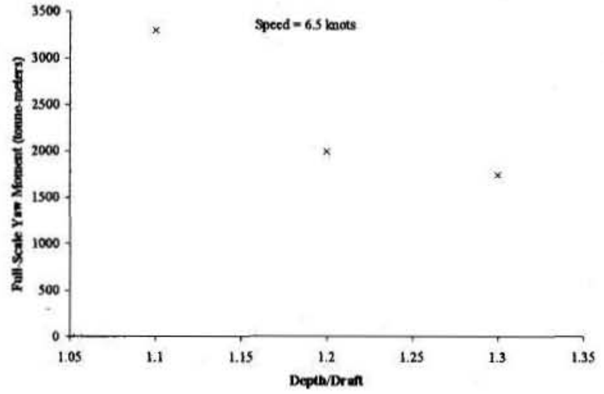

Figure 5: Yaw moment at varying depth/draft ratios for the existing bank configuration measured in towing tank tests

As h/T increases from 1.12 to 1.20 there is a 40% reduction in yaw moment. A further increase in water depth to h/T=1.29 reduces the yaw moment by only an extra 7%.

The results clearly show that neither dredging the remaining bank nor deepening the existing channel alone will reduce the bank effect by 50%.

Although deepening by 2m closely approaches the objective of 50% reduction in yaw moments, the gain achieved from the **second** metre of deepening is very small relative to the considerable cost involved, and is less effective than an equivalent amount of dredging of the western bank.

In addition, a major concern with deepening by 2m would be the possible occurrence of dynamic squat effects caused by large and abrupt variations in bed depth as shown by Renilson and Hatch (5), which would need to be minimised by extensive tapering lengths, especially at the seaward end.

A combination of deepening the existing channel and dredging the western bank was required to reduce the bank effect by the target 50%. To find the optimum combination required further work, however due to budget and time constraints it was not possible to test each available combination and so an empirical model was developed and applied.

5. EMPIRICAL MODELLING

An extensive literature search on bank effect studies was undertaken by OMC, and some differences were noted in the published results, especially for small underkeel clearances.

From this OMC developed a model to simulate results obtained in model scale testing based primarily on the work conducted by Ch'ng (1), with modifications based on research by Norrbin (3), as mentioned earlier.

The empirical model was then calibrated against the measured model-scale results obtained from this study for the existing channel, proposed dredging of the western bank and deepening options. This model was then used to evaluate combinations of dredging the western bank and deepening the existing channel.

The yaw moment results from the empirical modelling together with the measured tank testing results of the existing situation and deepening options are shown in Figure 6.

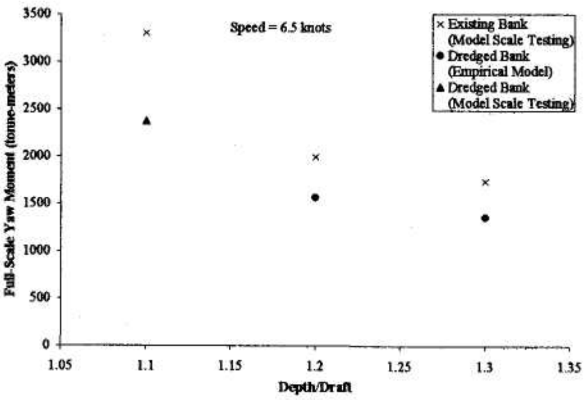

Figure 6: Yaw moment at varying depth/draft ratios for the existing bank configuration and dredged bank option

The results show that the dredged option combined with 1.0m deepening of the channel through the critical section would reduce the maximum yaw moments by 53% and would therefore provide a satisfactory solution to the bank effect problem.

6. RECOMMENDATION

The following recommendation was made to Townsville Port Authority based on the results detailed above:

- The western bank should be dredged to create a bench at RL7.0m over a width of 40m from the existing toe of the channel.
- The existing channel should be deepened by lm between beacons P14 and P16. Tapering of the deepened section should occur over 400m seaward of P14 to minimise any dynamic squat effects produced from sudden changes in depth.

7. STUDY OUTCOME

The final recommended solution is considered appropriate by the Authority for the following reasons:

- It offers a confidence level to safe navigation in an area not previously addressed.
- Of the options addressed, the recommended solution is clean and simple.
- Implementation can be phased by initially only dredging the RL7.0m bench with a trailer suction dredge, thereby introducing a nominal 28% reduction in bank effect forces, followed ultimately by deepening the existing channel by a further 1.0m using a cutter suction dredge for the harder, deeper material thereby offering the targeted reduction in bank effect.
- It offers an easily accessible configuration for future maintenance dredging requirements.
- It minimises the requirement for beacon and navigation relocations etc.

Implementation of the recommended option is currently being assessed by the Authority in conjunction with strategic planning considerations being developed for the construction of a new adjacent outer harbour Berth 12 facility.

Synergies exist with respect to the dredging plant requirements for the two projects and it is likely that the strategy to be adopted will be determined primarily through a tender process and, in particular, the mobilisation costs associated with various dredging plant.

It is likely that this process will be concluded in February/March 1999 with dredging planned to be undertaken during the non-cyclone period.

This study has developed a better understanding of bank effect/UKC relationships and has promoted additional research work with respect to improved inclusion of bank effects on the AMC ship handling simulator.

8. REFERENCES

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