APPENDIX G
HYDRODYNAMIC ASSESSMENTS

PORT KEMBLA PORT CORPORATION
PROPOSED OUTER HARBOUR RECLAMATION

SUPPLEMENTARY REVIEW OF HYDRODYNAMIC AND SEDIMENT MOBILITY ISSUES

1. Introduction
Port Kembla Port Corporation (PKPC) propose to undertake the Outer Harbour Development Project which includes the construction of an armoured perimeter bund, dredging and reclamation to provide two berths and approximately 23ha of land adjacent to the berths. The proposed reclamation and dredging layout, known as Option 4, Stage 1, is shown on Figure 1.

PKPC are also engaged in the redevelopment of berth facilities in the Eastern Basin of the Inner Harbour, which includes dredging of approximately 235,000m^3 of bed sediment. It is intended that the dredged material will be deposited in the proposed Outer Harbour reclamation area prior to construction of the armoured perimeter bund.

Sydney Ports Corporation, in conjunction with Lawson and Treloar Pty Ltd, developed and calibrated numerical hydrodynamic models of the Inner and Outer harbours at Port Kembla and have subsequently carried out a number of hydrodynamic and sediment mobility model studies for a range of reclamation configurations for PKPC in the Outer Harbour.

PKPC have now commissioned Sydney Ports to review the results of these model studies and provide an assessment of the effects of the proposed Option 4 Stage 1 reclamation on the current patterns and the long and short wave climates in the Outer Harbour, together with an assessment of the fate and mobility of proposed dredge spoil deposition in the reclamation area. The scope of work is limited to the review of results from previous modelling and does not include further model studies.

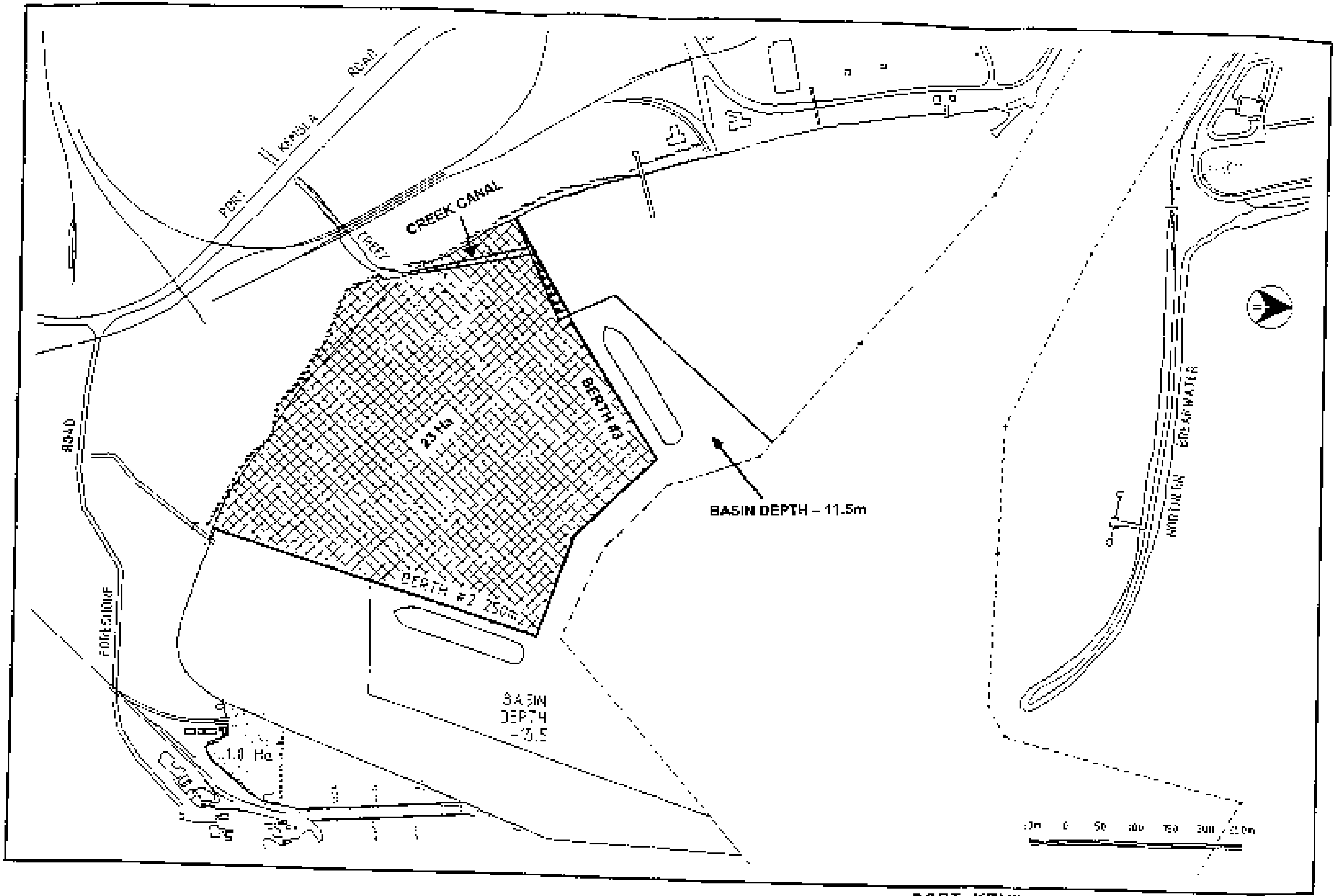
All levels in this report are given to Port Kembla harbour datum which is 0.87m below AHD.

2. Proposed Reclamation and Dredge Spoil Disposal
The proposed Option 4 Stage 1 dredging and reclamation configurations in the Outer Harbour are shown on Figure 1 and comprise:

- Construction of a rock armoured perimeter bund (1:1.5 armour slope) enclosing the 23ha reclamation area.
- Dredging of a southern berthing basin to a depth of -13.5m and a northern berthing basin to a depth of -11.5m, with the dredged material to be placed within the bunded reclamation area.
- Construction of 250m long suspended concrete berth faces over the armoured perimeter bund at each berth.

In 1994 approximately 100,000m^3 of clay size sediment derived from dredging in the Inner Harbour adjacent to the casting basin and multi-purpose berth was deposited in the area of the proposed Outer Harbour reclamation in water depths of 6m to 7m. Prior to construction of the perimeter bund, it is intended to deposit a further 235,000m^3 of sediment in the proposed reclamation area in

Figure 1



PORT KEMBLA OUTER HARBOUR
MASTER PLAN DEVELOPMENT
OPTION 4 STAGE 1

water depths of 7.5m to 10m. This material has been characterised as ranging from alluvial clays to sandy clays and clayey gravels with sand lenses [1], and will be derived from dredging in the Inner Harbour for the redevelopment of berth facilities

Other sources of reclamation fill material are currently being considered by PKPC.

3. Previous Studies

During the three month period from October to December 1992, three recording current meters were deployed on the seabed in the Port Kembla Outer Harbour at the heads of Nos 3 and 6 jetties and at the head of the eastern breakwater to record tidal currents and currents generated by long and short waves. The instrument at No 3 jetty also recorded water levels. Together with data from a waverider buoy located offshore, the results from these instruments were used to assess the long wave characteristics of the harbour and for the calibration and validation of numerical models to simulate long wave, short wave and tidal current flows in the harbour. Details of the instrumentation and results are given in [2].

Short waves are readily visible and periods ranging from 2 to 20 seconds, while long waves have periods from 30 seconds to 3 minutes approximately. Long waves are associated with significant horizontal water motions which can cause severe ship ranging, resulting in a reduction in berth utilisation and possible damage to both the moored vessel and the berth. In the design of mooring systems it is important to ensure that the natural frequency of oscillation of the combined vessel and mooring system lies outside the range of normally occurring long and short wave frequencies.

Analysis of the long wave data derived from the instrumentation indicated that observed ship ranging in the Outer Harbour is primarily generated by progressive long waves during periods of storm activity, rather than by any major resonant oscillations of the harbour. A correlation between offshore short waves and long waves in the harbour with periods ranging from 45 seconds to 100 seconds indicated that long waves rarely exceed 0.4m in height and are most likely caused by short wave grouping.

As reported in [2], the calibrated and verified long and short wave numerical simulation models were used to assess the effect of proposed reclamation in the Outer Harbour. The reclamation configuration, designated Option 2A, had some similarity to that shown on Figure 1, but covered a significantly greater area. Conclusions from the modelling were:

- Short wave heights at the new berths would be approximately 50 per cent of the existing wave heights at the No 6 jetty and would be similar to the existing wave heights at the No 3 jetty
- On the basis of a comparison of current speeds and particle excursions at the new berths with those at the existing No 6 and No3 jetties, it was concluded that the proposed reclamation would have no adverse effects on the long wave climate in the harbour, and could result in a marginal reduction in long wave activity at the new berth relative to conditions at the existing berths

Tidal current modelling indicated that the fastest currents, which do not exceed approximately 0.05m/s, occur at the entrance and in the Cut between the Inner and Outer harbours. Under existing conditions, tidal current speeds over the proposed reclamation areas in the Outer Harbour are less than 0.02m/s. Elsewhere, tidal currents were not significantly effected by the proposed reclamation

However, the current structure is very dependent on the prevailing wind and even low wind speeds (< 8 knots) have a major influence, although speeds still rarely exceed 0.02m/s

The numerical circulation model was used to drive a numerical advection-dispersion model to assess the spread and fate of turbid plumes generated during dumping of dredge spoil in the proposed reclamation area. Salient parameters, detailed in [3], were:

Tidal range	1.0m	
Sediment concentration at the end of the convective descent phase	50mg/l over 900m²	based on published data and settling measurements of the actual material
Effective fall velocity of the sediment	0.0003m/s	From actual dump plume measurements of similar fine material

The modelling results for both ebb and flood tides showed minimal advection and dispersion of the dump plume, due to the very low current velocities in the dump area.

In 1994 the long and short wave models were again used to assess, to a limited extent, the effects of two further reclamation options, known as Option 2A Stage 1 and Option 3 Stage 1, and the results of this work were reported in [4]. The reclamation area of both options was significantly less than that of Option 2A and that shown on Figure 1. It was assumed that the reclamation perimeter comprised a 1:1.5 slope rubble revetment.

In comparison to existing short and long wave conditions at No 3 and No 6 jetties, salient conclusions were:

- short wave conditions were judged to be acceptable and not significantly different from existing conditions
- long wave activity was greater at the new berths, although the increase translated into only a marginal reduction in berth utilisation.

In 1997 a further three reclamation options, designated Option 2B Scenarios 1 to 3, were modelled to assess the relative long and short wave climates at the new berths. In these studies, described in [5], berth faces were assumed to be vertical, fully reflective faces and all other reclamation perimeters were assumed to be 1:1.5 slope rock revetments.

Option 2B Scenario 2 is essentially the same as Option 4 Stage 1 shown on Figure 1, with the following exceptions:

- Minor variations in the reclamation configuration
- Option 2B Scenario 2 includes a 14.5m deep eastern basin surrounded by an 11.5m deep basin.

Results for Option 2B Scenario 2 were as follows:

Average Short Wave Heights (H, m) at Berths

	West Berth		East Berth	
Entrance Wave Condition	Existing (No 6 jetty)	Proposed	Existing (No 3 jetty)	Proposed
2.0m, 7.6s, 90°	0.36	0.30	0.13	0.16
2.0m, 5.6s, 80°	0.36	0.28	0.12	0.12
2.5m, 8.5s, 85°	0.54	0.46	0.22	0.20

That is, the short climate at the western (11.5m deep) berth is predicted to be milder than the existing wave climate at the No 6 jetty, while the predicted short wave climate at the proposed eastern berth will be marginally more energetic than that at the existing No3 jetty, although still significantly calmer than at the western berth.

RMS Long Wave Velocities (m/s) at Berths

	West Berth		East Berth	
Long Wave Condition	Existing (No 6 jetty)	Proposed	Existing (No 3 jetty)	Proposed
0.1m, 81.3s, 20°	0.017	0.024	0.018	0.025
0.3m, 81.3s, 20°	0.052	0.073	0.052	0.078
0.5m, 81.3s, 20°	0.066	0.131	0.073	0.144
0.1m, 66.6s, 20°	0.013	0.023	0.014	0.021
0.1m, 66.6s, 20°	0.039	0.069	0.043	0.063
0.1m, 66.6s, 20°	0.088	0.124	0.087	0.109

These long wave results indicate an increase in long wave induced RMS current speeds of up to 50 per cent, particularly at the western berth. However, long waves with heights of 0.5m occur very rarely and long waves exceeding 0.3m occur for only 0.4 days per annum on average. Consequently, it was concluded that the maximum reduction in berth utilisation would be no more than 0.2 days per annum relative to the existing No 6 jetty, and the utilisation could be significantly improved with the use of more appropriately designed mooring systems.

4. Assessment of Effects of Proposed Reclamation on Waves and Currents

Short Waves

In all three previous model studies it was concluded that the proposed reclamation options would result in acceptable short wave climates at the new berths.

The modelled reclamation option which most closely resembles the proposed option shown on Figure 1 is Option 2B Scenario 2 for which it was shown that short wave conditions at the proposed western berth would be milder than the conditions prevailing at the existing No 6 jetty, while conditions at the eastern berth would not be significantly different to the relatively mild conditions which prevail at the existing No 3 jetty.

Consequently, it is considered that short wave conditions at the proposed new berths will also be acceptable and, with a proposed 1:1.5 rock revetment perimeter, similar to or lower than those predicted for Option 2B Scenario 2.

Long Waves

Long waves generate oscillatory horizontal currents which cause ship ranging at a berth. The rms (root mean square) velocity of the horizontal currents is a measure of the ranging potential and severity.

On the basis of the modelling results described above, it is expected that the proposed reclamation will cause an increase of approximately 50 per cent in the severity of long wave generated horizontal currents at the proposed berths, relative to prevailing conditions at No 3 and No 6 jetties. These results were derived assuming fully reflective berth faces. Since the proposed reclamation is intended to incorporate significantly less reflective 1:1.5 rock revetments, it can be expected that the speed and excursion distance of long wave generated horizontal currents at the berths will be less than those derived from the modelling. In addition, further reductions can be achieved by incorporating a number of long wave absorbing filter layers in the revetment design.

It should also be noted that, since relatively large long waves occur infrequently, the reduction in berth utilisation should be no more than 0.2 days per annum. relative to the existing utilisation rates of No3 and No 6 jetties. An increase in utilisation can also be achieved by employing appropriately designed mooring systems which generate friction between the vessel and the berth fenders, and which have a natural resonant frequency outside the wave frequency range.

Currents
Current speeds in the Outer Harbour are low and the proposed reclamation is not expected to have any significant effect on current speeds and patterns outside the proposed reclamation area.

5. Assessment of Dredge Spoil Mobility

Numerical advection-dispersion modelling of turbidity plumes generated by the dumping of dredge spoil in the Outer Harbour showed minimal advection and dispersion because the tidal velocities are low. Consequently, there is no reason to believe that the proposed dumping of a further 235,000m^3 of fine sediment in the proposed reclamation area in water depths of 7.5m to 10m will result in any significant widespread turbidity generation. Nevertheless, it is expected that the dumping area will be enclosed by a confining silt curtain extending to within a few metres of the seabed.

In considering the potential for resuspension and dispersal of the sediment after completion of work and removal of the confining silt curtain, the following factors are relevant:

- The writer is unaware of any reports of observed surface plumes in the area where approximately 100,000m^3 of fine sediment was disposed in 1994. This suggests that bottom tidal and wave generated currents are insufficient to resuspend the sediment. It is recommended that this be confirmed by turbidity measurements in the water column during periods of significant short wave activity in the harbour.

- The significant wave height exceeded for one per cent of the time in the proposed dump area is approximately 0.5m as reported in [5]. In 8m water depth the corresponding wave orbital velocity at the bed is approximately 0.25m/s and this is insufficient to significantly suspend flocculated fine sediment particles.

6. References

[1] Maunsell McIntyre (1998) *Report on Geotechnical Investigation, Proposed Tug Fleet Base Development* Prepared for Port Kembla Ports Corporation by Maunsell McIntyre Pty Ltd, Nov 1998

[2] MSB Sydney Ports Authority (1993) *Hydrodynamic Model Studies of Port Kembla Harbour, Vol 1: Text and Figures; Vol 2 Hydrodynamic Data* Report No 93/02 prepared in conjunction with Lawson and Treloar Pty Ltd for MSB Illawarra Ports Authority

[3] Willoughby, MA (1993) *Letter dated 12 October 1993 to Mr P McGavin from MSB Sydney Ports Authority re Advection-Dispersion Modelling of Dump Plume*

[4] MSB Sydney Ports Authority (1994) *Hydrodynamic Model Studies of Port Kembla Harbour, Supplementary Report No 1* Report No 94/02 prepared in conjunction with Lawson and Treloar Pty Ltd for MSB Illawarra Ports Authority

[5] Sydney Ports Corporation and Lawson and Treloar Pty Ltd (1997) *Hydrodynamic Model Studies of Port Kembla Harbour, Supplementary Report No 2* Draft Report prepared Port Kembla Port Corporation

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Dear Sirs,

RE: PORT KEMBLA OUTER HARBOUR STABILITY OF DREDGED SPOIL & BLAST FURNACE SLAG

Preamble

The following background, prepared by Maunsell, describes proposed long term reclamation works in the Outer Harbour at Port Kembla

> PKPC, ASMS and Blue Scope Steel have commissioned a consolidated concept report for a slag reclamation within the Port Kembla Outer Harbour, which will eventually provide about 23Ha of reclaimed land and two berths for Panamax size vessels. This reclamation is to feature a basin of 250,000m³ capacity, to accommodate dredge spoil from future harbour maintenance operations. This development is generally as described in Maunsell's Additional Concept Advice Report to PKPC, dated August 2004.
>
> Prior to construction of this reclamation, PKPC expects to let contracts for construction of the Eastern Basin Berth 4 (EB4) and Multipurpose Berth 3 (MPB3) developments. These contracts are likely to include dredging and disposal of up to 400,000m³ of material that is deemed unsuitable for offshore disposal. PKPC is investigating alternative options for disposal of these materials and has commissioned Maunsell to assess the capacity of the proposed Outer Harbour Reclamation and surrounding water areas to accommodate them.

Acting upon your instructions, we have undertaken a two-staged study to determine the likelihood that storm wave activity might re-suspend those sediments. These stages addressed the preparation of wave climate parameters at three locations nominated by Maunsell, see Figure 1, and then the assessment of likely sediment re-suspension conditions.

Wave Parameters

The existing MIKE-21 Boussinesq Wave model of the Port Kembla Outer Harbour, together with the regional SWAN wave model were used to determine wave parameters at selected average recurrence intervals (ARI) of 1, 5, 10 and 25 years.

Offshore wave conditions were based upon the long-term offshore Port Kembla Waverider buoy system and six hours of storm duration at each ARI. The SWAN model was used to transfer those offshore wave conditions to the

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harbour entrance using an assumed offshore wave direction of ESE. Generally, at the entrance, refraction causes these waves to have a direction close to east. Other offshore wave directions are likely to have slightly lower wave heights at the entrance.

The outcome of the combined system of offshore data, see Table 1, together with the SWAN and MIKE-21 models is presented in Table 2.

ARI (Years)	H_s (m)	T_p (s)	Adopted Direction
1	5.6	7.4	ESE
5	7.0	8.2	ESE
10	7.5	8.5	ESE
25	8.7	9.2	ESE

Table 1: Offshore Wave Conditions

		Inshore Wave Parameters	
Location	**ARI (Years)**	**H_s (m)**	**T_z (s)**
1	1	0.84	7.4
	5	0.96	8.2
	10	1.02	8.6
	25	1.04	9.2
2	1	0.84	7.4
	5	0.96	8.2
	10	1.02	8.6
	25	1.04	9.2
3	1	0.46	7.4
	5	0.52	8.2
	10	0.56	8.6
	25	0.60	9.2

Table 2: Wave Conditions at Selected Locations and ARI

These wave heights are generally consistent, but somewhat lower, than those reported previously in L8925, see Location 2. There is not a large difference between offshore wave heights at the 1 and 25 years ARI. This difference is reduced by the effects of the seabed around the Five Islands. Hence, in absolute terms, wave heights at all ARI are similar. The present heights are lower because of the different basis adopted in this case – probability of exceedance versus a peak storm wave height as adopted previously.

Initiation of Sediment Movement

This condition can only be determined from the wave parameters, sediment characteristics and accumulated laboratory testing experience. For this study, methods and threshold conditions set down in van Rijn (1993) and by Ahrens and Hands (1998) were applied. Generally the sediments assessed were:-

Sediment	Particle Size Range (mm)	Adopted Mean Diameter (mm)	SG
1 – Slag Fill	2 to 63	10	2.00
2 – Sandy Fill	0.075 to 0.6	0.2	2.65
3 – Soft to Firm Clay	-	-	2.65
4 – Stiff Clay	-	-	2.65
5 – Slag on Bund Face	25 to 300	100	2.00

For the slag and sandy sediments, the initiation of sediment movement condition was based on a critical velocity and specific gravity, whereas for the clays, only a critical velocity was needed (van Rijn, 1993). These velocities were 0.6m/s and 12m/s for moderately compacted and stiff clays, respectively. In a physical sense, these critical velocities relate to critical shear stress conditions. These critical velocities are related to wave parameters - H_s and Tz in a water depth of 4m, though, because all wave periods were long and similar, most sensitivity for swell is related to H_s.

Results

The outcomes of these analyses were:-

Sediment	H_s (m)
1	0.8
2	0.3
3	0.7
4	0.9
5	2.0

Thus, these results show that, apart from the sandy sediment and the soft clay, the sediments are stable in 1-year ARI wave conditions. The coarse slag would be stable up to at least ARI 25 years.

Yours faithfully,

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References

Van Rijn, L (1993) Principles of Transport in Rivers, Estuaries and Costal Seas AQUA Publications

Ahrens and Hands (1998) ASCE, Journal of Waterway, Port, Coastal and Ocean Engineering Vol 124, No 1