INFORMATION FOR APPROPRIATE ASSESSMENT

Proposed replacement Ferries by Wightlink Ltd for the Lymington to Yarmouth route

Summary and Technical Report

From
The Lymington River Association

Draft for discussion with Natural England
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SUMMARY

Technical sections 13 to 18 have been added to the Summary Report that was issued to Regulators on 12/8/08.

This Revision 2 of the report is being issued in draft to Natural England prior to a meeting with them to discuss and define the conservation objectives for the Solent and Southampton Water SPA, the Solent and Southampton Water Ramsar Site and the Solent Maritime SAC.

Section 13 of the report is in draft form pending the outcome of the discussions on conservation objectives.

This report has been prepared by the Lymington River Association (LRA) for consideration by the Regulators when deciding on the Appropriate Assessment for the proposed new Wightlink Ltd Ferry service to operate between Lymington and Yarmouth.

At present the test that Wightlink Ltd, their consultants ABPmer and Natural England have agreed is that “no adverse effect” on the integrity of the project on the European sites means that the ferries should cause no loss of extent of the SAC in the inter-tidal areas adjacent to the navigational channel from an established baseline subject to natural change.

In this report LRA have found evidence from three sources that have measured the loss of extent of the inter-tidal. The first is from a report by HR Wallingford in 1991 (ref. 3). The second is from aerial photographs taken between 1948 and 1999 and presented by LRA (ref. 4). The third is from an analysis of river cross-sections between 1988 and 2006 provided by ABPmer (ref.1). The report describes how the net effects from ferry only were separated from other forcing functions such as tidal currents and wind-generated waves.

The conclusion shows that the average loss of inter-tidal mudflat due to the C-Class ferry is approximately 2 metres per annum. Evidence shows that the W-Class would exceed this figure.

The report also discusses secondary erosion damage that the ferry causes by deepening the river; possible mitigating measures; in-combination effects with other plans or projects, and possible alternative solutions.

We have also carried out a detailed appraisal of ABPmer’s report. We found that their ‘energy’ method, which predicted that W-Class ferries would only contribute 1.7% of the total wave energy from ferries and wind-waves, contained serious errors such that their conclusions were misleading and should be set aside. Other evidence seemed to be based mostly on conjecture not backed up by evidence.

Our detailed conclusions are set out in section 10. We recommend that the Regulators should not grant permission for the W-Class ferries to operate on the Lymington to Yarmouth route.

TABLE OF CONTENTS

SUMMARY I

1. INTRODUCTION 4

2. CONSERVATION OBJECTIVES 4

3. AN EXAMINATION OF THE WIGHTLINK/ABPMER METHOD FOR ESTABLISHING RELATIVE FERRY EFFECT 4

4. METHOD FOR ESTIMATING FERRY EFFECTS PROPOSED BY LRA 5

- 4.1.1 Horn Reach 1981 to 1991 6
- 4.1.2 Aerial photo survey 1948 to 1999, downstream from Yacht Haven marina 6
- 4.1.3 Sub-tidal survey from Cage Boom to Posts 5 to 6, 1988 to 2006 7
- 4.1.4 Relative ferry effect Cage Boom to Posts 5 to 6 7

5. 'ADVERSE EFFECT ON INTEGRITY' FOR C-CLASS AND W-CLASS FERRIES ACTING ALONE 8

6. TWO FURTHER CONSIDERATIONS 8

- 6.1 Long term adverse effect caused by deepening of the river by ferries 8
- 6.2 Additional damage likely to be caused by much larger thruster force required in W-Class 8

7. POSSIBLE MITIGATING MEASURES 9

8. IN-COMBINATION EFFECTS WITH OTHER PLANS OR PROJECTS 9

9. POSSIBLE ALTERNATIVE SOLUTIONS 10

10. CONCLUSIONS AND RECOMMENDATIONS 10

- 10.1 Conclusions from LRA concerning introduction of Wightlink's W-Class ferries on the Lymington to Yarmouth route 10
- 10.2 Appraisal and response to conclusions by Wightlink / ABPmer 11
- 10.3 Recommendations 14

11. REFERENCES 14

12. CONTENTS OF TECHNICAL REPORT 14

13. CONSERVATION OBJECTIVES 15

14. APPRAISAL OF THE WIGHTLINK / ABPMER ENERGY METHOD FOR COMPARING NATURAL WIND-WAVES AND FERRY-GENERATED WAVES 20

- 14.1 Introduction 20
- 14.2 Wind-generated wave energy 20
  - 14.2.1 Assumptions in ABPmer's wind-wave energy derivation 21
- 14.3 Ship-generated wave energy 24
- 14.4 Conclusions concerning ABPmer's energy method 24

15. APPRAISAL OF HR WALLINGFORD'S 1991 REPORT 26

- 15.1 Introduction to HR Wallingford's study 26
- 15.2 Bathymetric surveys 27
- 15.3 Mud properties 27
- 15.4 Assessing the forcing functions on erosion 27
  - 15.4.1 Tidal currents 27
  - 15.4.2 Wind-waves 28
  - 15.4.3 Ship return currents 28
  - 15.4.4 Ship waves 28
  - 15.4.5 Ship-induced rapid water drawdown 29
  - 15.4.6 Vessel slipstream (thruster) effects 29
  - 15.4.7 Discussion 29
- 15.5 Conclusions by HR Wallingford in 1991 30

16. ANALYSIS OF SUB-TIDAL SURVEY FROM CAGE BOOM TO POSTS 5 AND 6 31

17. CALCULATION FOR RELATIVE FERRY EFFECTS BETWEEN CAGE BOOM AND POSTS 5 AND 6 33

- 17.1 Introduction 33
- 17.2 Bed shear stress and bed shear strength 33
- 17.3 Erosion factor from wind-generated waves 34
  - 17.3.1 Wave erosion factor at Point 2 35
  - 17.3.2 Wave erosion factor at Point 13 (mid-channel in Long Reach) 36
  - 17.3.3 Erosion factors from C-Class ferries 36
  - 17.3.4 Erosion factors from W-Class ferries 37
- 17.4 Sensitivity of assumptions 38
- 17.5 Conclusions on the relative effects of ferries and wind-generated waves on causing erosion near Cage Boom 39

18. LONG-TERM ADVERSE EFFECTS CAUSED BY DEEPENING OF THE RIVER BY FERRIES. 40

WIGHTLINK REPLACEMENT LYMINGTON TO YARMOUTH FERRIES: INFORMATION FOR APPROPRIATE ASSESSMENT

1. Introduction

This report has been prepared by the Lymington River Association (LRA) for consideration by the Regulators when making an Appropriate Assessment for the proposed Wightlink Ferry service to operate between Lymington and Yarmouth. The Wightlink Ltd proposal consists of shoreside works at Lymington and Yarmouth and the introduction of larger W-Class ferries to replace the existing C-Class ferries. This LRA report addresses the ferry operation only.

The Marine and Fisheries Agency (MFA) has already received a document entitled "Information for Appropriate Assessment" from the developer Wightlink Ltd, prepared by their consultant ABPmer. The aim of this LRA report is to present additional information to MFA, as the Competent Authority, together with Natural England (NE), the Environment Agency (EA) and New Forest District Council (NFDC), to aid in the decision as to whether the introduction of new W-Class ferries would have an adverse effect on the integrity of the Solent Maritime Special Area of Conservation (SAC) and the Solent and Southampton Water Ramsar Site and Special Protection Area (SPA).

This document summarises the technical findings, which are set out in full in the Technical Report (sections 13 to 18).

2. Conservation objectives

(A more detailed discussion of conservation objectives is in section 13.)
The conservation objectives for the Wightlink proposal have been set out by ABPmer, in conjunction with NE, in Section 3 and Table 2 of their document. They have defined the target for the SAC as "no decrease in extent from an established baseline, subject to natural change". In our report we use the same criteria to judge whether or not W-Class ferries would have an "adverse effect". In line with NE's advice to Wightlink/ABPmer, we focus on changes to the extent of the inter-tidal mudflats and saltmarsh. Based on calculations supported by bathymetric data, we reveal the loss of extent in the SAC, attributable to C-Class ferries, at different times since they entered service in 1973. Based on other published data, we then compare the effects of C-Class and W-Class ferries. We predict how the extent of the SAC would be further diminished if the larger W-Class were permitted to enter service.

3. An examination of the Wightlink/ABPmer method for establishing relative ferry effect

(A more detailed discussion of ABPmer's report is in section 14.)
Our initial task was to examine the methods used by ABPmer. One of their main techniques was to compare the relative energy of waves acting on the saltmarsh edge and inter-tidal mudflats, from ferries and from the 'natural' background wind-wave climate. Based on this, they predicted that the larger W-Class ferry would contribute on average 1.7% of the total energy, compared with 3.6% from the existing C-Class ferry, both travelling at 6 knots. However, the energy comparison took no account of the soil shear strength, nor the size of waves that could trigger erosion. We show that,

for this and other reasons, the wind-wave effects were greatly exaggerated. Likewise, the ferry energy was greatly under-estimated, since it ignored energy contributions from thruster wash, backflow and drawdown. We conclude that errors in the relative energy method as applied were so large that the results and conclusions drawn should be set aside.

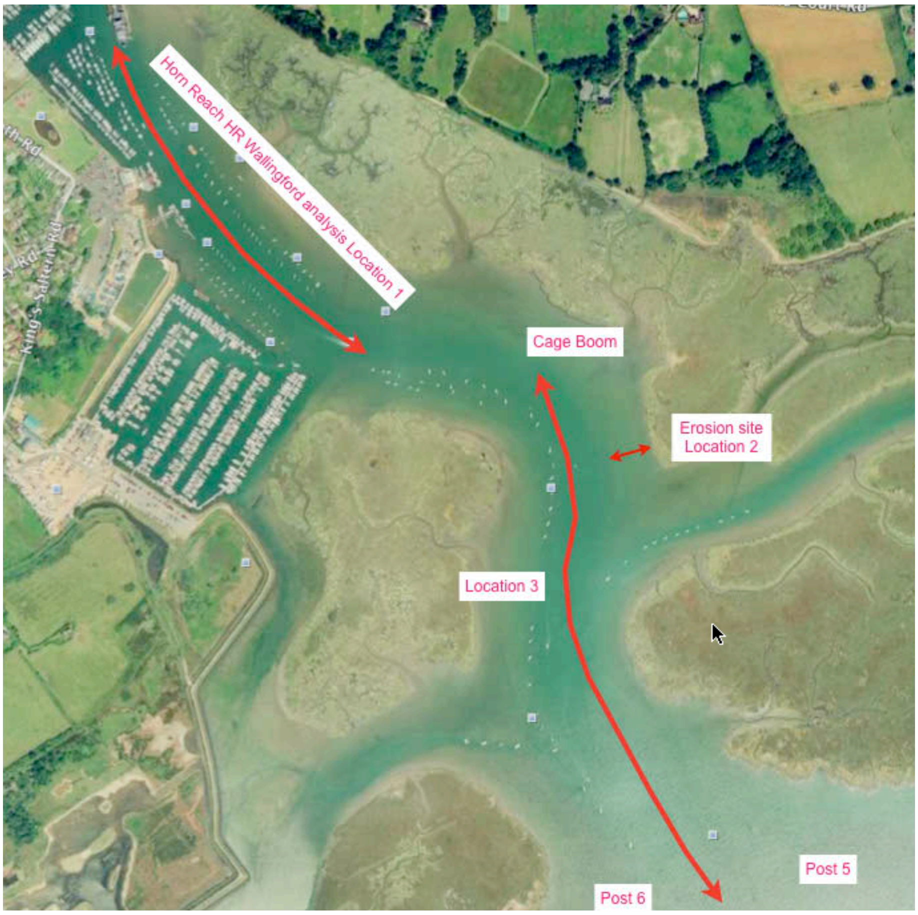
The summary of ferry effects in Section 8.2 of ABPmer’s report claims that mean low water level (MLW) throughout the estuary ‘has not changed significantly since 1984’. This implies that the extent of inter-tidal area has also not changed and therefore the existing C-Class ferries are not having an “adverse effect”. We have examined the bathymetric survey data supplied in ABPmer’s report and show that in fact the loss of inter-tidal mudflats between 1984 and 2006 was considerable.

Many of ABP’s statements are unsubstantiated (see section 10.2). In our opinion some of the conclusions in their report are not ‘robust’.

4. Method for estimating ferry effects proposed by LRA

We have therefore analysed the available data and reviewed other reports to determine whether conclusions based on firm evidence can be reached about the possible impact of the ferries on the habitats.

We set out to record the known changes in the morphology of the river over time and then to determine the extent of any erosion and how much of this could be attributed to the ferries. Three locations are known to have been surveyed at different dates:

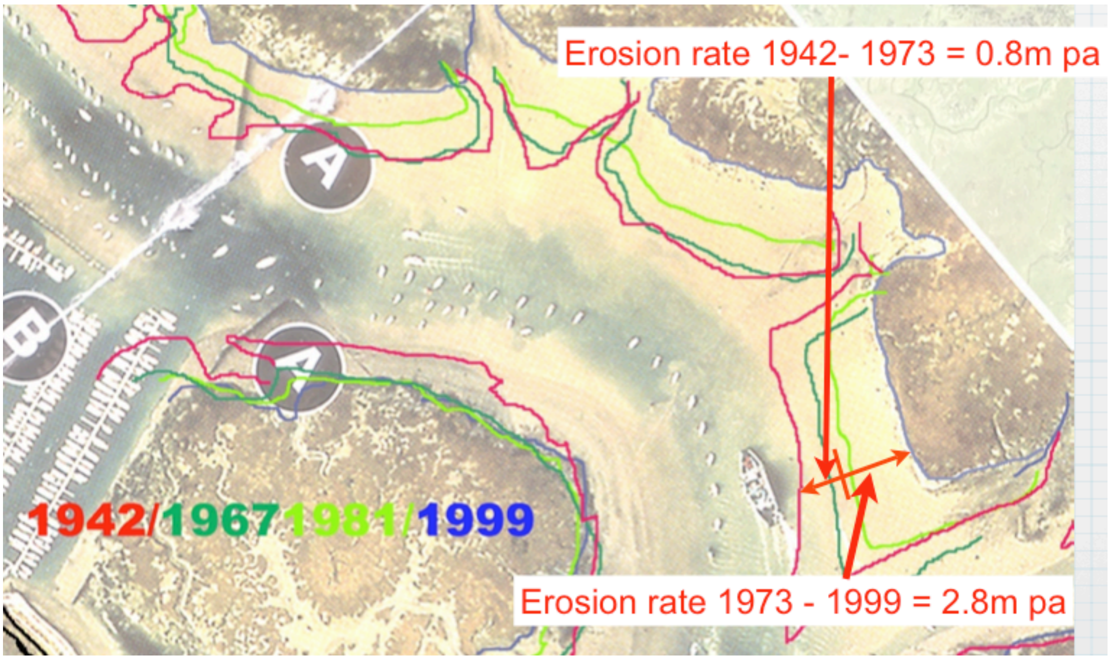


4.1.1 Horn Reach 1981 to 1991

(A more detailed discussion of HR Wallingford's report is in section 15.)
The first location is Horn Reach. It was surveyed in 1981 and 1991. The surveys were analysed by HR Wallingford (ref. 3) in 1991. They showed that 4867 m³ had been eroded in the period and that the channel was deeper by an average of 0.4 m in the southern and 0.2 m in the northern part. At the same time Wallingford measured in-situ shear strength of soil in the inter-tidal mudflats. They tested soil samples in the laboratory to identify the water velocity required to trigger erosion. They also measured tidal velocity in the river and analysed forcing functions to identify the causes of the erosion that had been measured. Their calculations showed that tidal and wind-wave effects were too small to erode the banks in Horn Reach, while the C-Class ferry effects were predicted to deepen the channel by 0.3 m in the period. This agreed closely with the actual observations. They further concluded that the increased depth of the river would lead to bank erosion so that the same natural slope (approximately 1:75) was maintained.

This showed that bank erosion, leading to loss of inter-tidal and saltmarsh area, would take place at an average rate of 2.25 m/y.

4.1.2 Aerial photo survey 1948 to 1999, downstream from Yacht Haven marina



The second location is the upper reaches of the river. This evidence was presented by LRA in our previous report (ref. 4) and based on aerial photographs taken at intervals between 1948 and 1999. The successive photographs plot the recession of saltmarsh during that time. The rate of loss increased from 0.8 m/y prior to 1973 (when C-Class entered service) to 2.8 m/y post 1973. Wallingford's work discounted possible erosion contribution from increased tidal prism effects from the marina construction that had taken place in 1971/72. Likewise, they showed that wind-wave effects in that part of the river were negligible.

Therefore we can conclude that inter-tidal erosion due to the existing C-Class ferries had caused the saltmarsh to recede at 2 m/y. At the high-tide boundary, saltmarsh was exchanged for mudflat. This constitutes a qualitative change to the SAC. Because the inter-tidal mudflats tend to maintain their natural slope, mudflat extent at the mean low water mark would recede at the same rate. So the extent of the SAC was being reduced by 2 m/y.

4.1.3 Sub-tidal survey from Cage Boom to Posts 5 to 6, 1988 to 2006

(A more detailed discussion of the sub-tidal survey is in section 16.)
The third location was between Cage Boom and Posts 5 and 6. Our analysis is based on six bathymetric cross-sections in the navigation channel of the river, below Chart Datum (CD), provided by Wightlink Ltd (ABPmer) in their Information for Appropriate Assessment document. Sections were given for four years: 1988, 1993, 1999 and 2006. They are spread over a stretch of river of approximately 1088 metres, representing about one-quarter of its total length. We analysed the cross-sections to calculate the sub-tidal volume and area of the navigation channel at CD.

Our analysis showed that in 18 years the sub-tidal volume had increased by 27% and the area of the navigation channel had increased by 38% in this stretch of river. The average depth of the river had also increased by 1.5 metres. The increased width of the navigation channel causes a corresponding loss in extent in the inter-tidal mudflats.

Thus we found that the inter-tidal area receded by an average of 2400 m^2 per year between Cage Boom and Posts 5 and 6. This is an average of 2.2 m/y, caused by all forcing functions.

4.1.4 Relative ferry effect Cage Boom to Posts 5 to 6

(A more detailed discussion of relative ferry effects is in section 17.)
The next step in our study was to determine the relative contribution of the C-Class ferries to the total erosion identified by the survey data in paragraph 4.1.3 above. In locations 1 and 2, HR Wallingford's analysis had shown that ferry effects were the only forcing functions able to erode the inter-tidal mudflats (although tides, wind-waves and ferries could all re-erode material that had recently been accreted on the river bed). HR Wallingford had advised that we could assume that ferry erosion per unit length of river in Horn Reach would occur throughout its length to the estuary, irrespective of additional erosion from wind-generated waves nearer the estuary. But the effects are more complex. The ferry only travels at 4 knots in Horn Reach and at 6 knots nearer the estuary. On the other hand, as the channel is narrower in Horn Reach, so 'blockage' will be greater, causing larger backflow and drawdown velocities. The effects may tend to cancel each other out.

Neverthess, we calculated the ratio of ferry erosion compared with the other forcing functions at Point 2 (Cage Boom) and at Point 13 (mid-channel in Long Reach, adjacent to Cage Boom) nearby. Data for these locations was available in ABPmer's report. We used the significant wave height data from Tables A4 and A6 and wind frequency data from Table A2. This was combined with soil shear strength information and the water velocity found to trigger soil shear, from HR Wallingford's 1991 report. The calculation and its assumptions are summarised in section 17 of this report.

The calculation indicates that C-Class ferries contribute around 77% of the total erosion at Points 2 and 13. The W-Class would increase this to 86%. Applying these percentages to the total measured erosion of 2.2 m/y shown above (para 4.1.3) indicates that loss of inter-tidal mudflats would be 1.7 m/y from C-Class and 1.9 m/y from W-Class.

5. ‘Adverse Effect on Integrity’ for C-Class and W-Class ferries acting alone

HR Wallingford’s 1991 analysis, the photographic evidence pre- and post-1973, and the morphological changes between 1988 and 2006 near Cage Boom, with calculations to allow for ‘natural’ effects, all indicate that the existing C-Class ferries have been causing loss of inter-tidal mudflats and hence reducing the extent of the SAC by around 2 metres per annum. The W-Class ferries would increase this rate of inter-tidal loss.

6. Two further considerations

We draw the attention of the Regulators to two other significant effects of the ferries.

6.1 Long term adverse effect caused by deepening of the river by ferries

(A more detailed discussion of long-term adverse effects from ferries is in section 18.)
The first effect is caused by deepening of the river. We know that maintenance dredging of the navigation channel has not been required since 1973 after C-Class entered service. It is often claimed by Wightlink Ltd to be a benefit that the ferries ‘keep the channel clear’. It is known that the water jets from their Voith-Schneider thruster units are the principal reason for this effect. We know from echo-sounder tracks (see LRA’s previous report , ref 4) that the ferries have dredged out two channels through the estuarial mudflats. We have shown (para 4.1.3 above) that the sub-tidal volume increased by 27% between Cage Boom and Posts 6 and 7 in 18 years. The consequence of this has been to allow larger wind-driven waves from the Solent to penetrate the outer defences of Lymington Harbour. Our report shows that the direction of waves entering the harbour is aligned with the straightened river, rather than the prevailing wind direction of 240 degrees. Thus some of the so-called ‘natural’ effects from wind-generated waves are in fact indirect consequences of ferry action since 1973.

6.2 Additional damage likely to be caused by much larger thruster force required in W-Class

The second effect concerns the extent of water jet velocities from the Voith-Schneider thrusters. This is of particular concern on the W-Class vessel. Not only does this ferry require about 50% more power than the C-Class to drive the hull at any speed but, because the windage area of the W-Class is twice that of the C-Class, the jet forces required to resist wind forces will be 100% greater. We know from BMT Seatech’s Tables 3 and 4 (ref. 2) that jet velocity is 10% greater and mean mass flow 68% greater in W-Class compared with C-Class at all wind speeds. But no detailed information has been supplied, so far, on mapping Voith-Schneider jet velocity contours on the river bed in the area surrounding the ferry. The annual erosion damage from this feature of the W-Class, taking into account the annual wind frequency data, cannot yet be assessed accurately. This feature represents a significant difference between C-Class and W-Class. The assessment so far is considered to be an under-estimate. Concern has also been expressed that the thruster jets are causing significant erosion at Yarmouth.

7. Possible mitigating measures

The Regulators may need to know whether the adverse effects identified in section 5 above could be avoided by possible mitigating measures. The obvious suggestion would be for the vessel to slow down such that its backflow velocity, ship-induced rapid water level drawdown velocity and thruster jet velocity were all less than the velocity required to shear mud from the inter-tidal and sub-tidal areas. Although there is some scatter on their test results, HR Wallingford's 1991 tests indicate that the critical velocity to induce shearing of the river banks is approximately 0.4 m/s. BMT Seatech's backflow estimates, in Figure 14 of their Phase 1 report, indicate that the W-Class would need to reduce speed to 2.4 knots to achieve this in 4 metres depth of water.

However, the jet velocity near the thrusters considerably exceeds backflow velocity. At low speed in cross winds, steerage way is considerably reduced. Thrusters will be required to help keep the vessel on station by increasing the jets' force and vectoring them towards the bank. As stated in section 6.2 above, insufficient data is available to predict whether slowing down the ferry could, in principle, prevent an adverse effect on the habitats.

Other consequences would arise if the ferry were to slow down substantially. Increased dwell time in the river would have an adverse effect on safety and on river usage by others. There would also be operational and scheduling consequences to be addressed by Wightlink Ltd.

8. In-combination effects with other plans or projects

Under the Habitats Regulations it is necessary to consider effects that the project may have in combination with other plans or projects. The proposed Lymington breakwater scheme is being considered as a possible protection against increased wave loads entering the harbour. As we have shown, this is largely due to the ferries deepening and widening the channel through the marshes in the estuary. We do not know whether the scheme has considered the effect the breakwaters would have on the Solent Maritime SAC, the Solent and Southampton Water Ramsar Site and SPA.

A consequence if both projects were approved would be to permit the W-Class ferries to travel at 12 knots to near the entrance of the new breakwaters. The greatly increased water velocities from backflow, drawdown and thruster jets would accelerate mudflat and saltmarsh erosion. We conjecture that the likely consequence of this would be the removal of the existing mudflats to the south of Oxey and Pylewell creeks within a few years, with implications both for the habitats and for coastal defence. Adverse consequences for coastal defence may lie outside the scope of this Appropriate Assessment but should be of concern to the Environment Agency.

The Wightlink ABPmer report has not considered this impact pathway in detail, nor provided evidence to show that adverse effect on the habitats would not occur. We believe that the burden of proof for this lies with the developer.

9. Possible alternative solutions

Before considering whether there are imperative reasons of overriding public interest sufficient to override the harm to the site, the Regulators need to consider whether there are alternative solutions that would have a lesser effect, or avoid the adverse effect, on the integrity of the site.

Such alternatives are possible.

One solution that has been suggested to Wightlink Ltd is to move the ferry operation from the Lymington River to Port Pennington nearby. This in turn might adversely affect the habitats near Pennington, but with sensitive design it might be possible to reduce the effects to an acceptable level.

A second alternative solution is to commission smaller ferries that would operate in a manner that sustains the habitats. This should be a mandatory design requirement of any future ferry.

We consider that one or both of these alternative solutions merit further study before granting permission for W-Class ferries to operate out of Lymington.

10. Conclusions and recommendations

Our conclusions are in two parts: section 10.1 summarises our own conclusions based on our analysis of the available data; section 10.2 contains our appraisal and response to the conclusions made by Wightlink / ABPmer in their Appropriate Assessment Information Document. Section 10.3 contains our recommendations.

10.1 Conclusions from LRA concerning introduction of Wightlink's W-Class ferries on the Lymington to Yarmouth route

1. The test for "adverse effect" proposed by Wightlink Ltd and ABPmer and on the advice of NE is that there should be no loss of extent from an established baseline, subject to natural change, in the Solent Maritime SAC.
2. Based on this definition, we have shown that at three locations in the Lymington River, from three different baselines with natural changes screened out, the C-Class ferries have caused the extent of the Solent Maritime SAC to be reduced by approximately 2 metres per annum. Therefore, since 1973 they have been having an adverse effect on the integrity of the European Site.
3. The erosion that would be caused by the W-Class ferry has been shown to be exceed that due to the C-Class. Therefore if the W-Class were permitted to enter service it would have a greater adverse impact on the integrity of the Solent Maritime Site.
4. ABPmer have suggested that mitigation measures might be possible to allow the W-Class to operate in such a way that their effects are similar to the C-Class. We have shown that the C-Class also have "adverse effect". To be

effective, mitigation measures would require the ferry to proceed at a slow speed so that its wash velocities on the river bed, from all sources, were less than the eroding velocities. With the increased windage and displacement of the W-Class ships, no evidence has been presented to show that this is feasible. On present evidence, the precautionary principle should be invoked to reject the effectiveness of mitigation.

5. The Regulators should be mindful of the secondary effect of river deepening and widening by the existing C-Class ferries that has allowed so-called ‘natural wind-generated waves’ to penetrate the estuary and increase adverse effects on the habitats.
6. The ferries acting in combination with the proposed breakwater project would greatly diminish the extent of existing inter-tidal mudflats and saltmarsh lying to the south of Oxey and Pylewell creeks. This would further adversely affect the integrity of the Solent Maritime SAC.
7. Alternative solutions exist that would avoid the adverse effect on the integrity of the Site.

10.2 Appraisal and response to conclusions by Wightlink / ABPmer

	ABP mer Conclusions for Wightlink from report R.1427 project ref R/3772/1 **Bold and underline by LRA**	**LRA comment**
1	The contribution to intertidal erosion in the estuary from ship waves from either C-Class or W-Class ferries is unlikely to be significant	Agreed; ship waves are too small to cause erosion. This was established by HR Wallingford in 1991. It is backflow, drawdown and thruster effects that are causing the loss of extent - not referred to here by ABPmer.
2	The new W-Class ferries are predicted to create ship wash waves of a similar magnitude to the existing C-Class at equivalent vessel speeds	There is as yet no evidence of this; an increase in displacement of 71.5% is unlikely to result in similar waves, but this is not the issue. (See 1 above.)
3	The contribution of ferry waves is much smaller than the maximum height of wind waves within the estuary.	For those without technical knowledge this may look convincing. ABPmer attribute 82% of total energy causing erosion to natural wave action and only 12% to the C-Class ferry. However LRA analysis of ABPmer’s calculations shows 77% of erosion energy being due to the C-Class ferry and 23% being due to natural wave action in storm conditions.
4	The energy associated with average height ship waves is not large enough to cause erosion of intertidal areas in the estuary	Agreed, but ship waves are not the issue; the energy from backflow, drawdown and thruster effects does cause erosion, as ABPmer state in their conclusion no. 5.
5	The predicted drawdown from W-Class ferries is greater than for the existing C-Class ferries and there is some potential for such drawdown to cause erosion on the lower intertidal. However such erosion is likely to be	No evidence is provided that erosion to be caused by W-class will be limited. The LRA analysis calculates this effect and draws the conclusion that the erosion by C-Class vessels at low water is causing erosion and loss of habitat and that the W-Class will

	limited.	increase erosion.
6	Current evidence suggests that the position of MLW throughout the estuary has not changed significantly since at least 1994, suggesting that drawdown associated with the current C-Class ferries is not having a major impact on intertidal areas.	NE advise that their interest is in the inter-tidal area between MLW and MHW. This has changed significantly. LRA analysis shows a threefold increase in loss since the introduction of the C-Class in 1973.
7	At most locations in the estuary the cross-sectional area of the channel and the waterline width at low water are significantly larger than at Horn Reach (where the original assessment of drawdown was made by HR Wallingford).	This conclusion seems to be seeking to devalue the conclusion of the HR Wallingford report of 1991. That report used original scientific measurements concluding that the operation of the C-Class was eroding the river bed and destabilising and eroding the banks, causing loss of extent of habitat. The HRW report predicted continuing accelerating loss throughout the river estuary, and this has indeed occurred. ABPmer's report is a re-analysis of old information and does not appear to consult HR Wallingford.
8	It will be possible to manage the speed of W-Class ferries during extreme low water periods to ensure that drawdown impacts are no worse than the existing C-Class ferries	This conclusion overlooks the fact that the existing C-Class ferries are already having an adverse effect on the SAC. The target for the W-Class ferries should be zero adverse effect. Furthermore, from this conclusion it follows that if the W-Class is operated at 6 knots in the lower river and 4 knots in the upper river at low water it will cause erosion, further instability of the banks and habitat loss. The new much larger W-Class vessel must therefore accept a speed restriction at low tide as a condition of its approval. This is the conclusion of Wightlink's own consultants. Independent conclusion from this is that the W-Class are too big for the Lymington River. These large vessels proceeding at less than 4 knots at low tide will have an excessive "dwell" time causing vigorous bank erosion and impossible operating conditions for other river users.
9	The predicted backflow for W-Class ferries is greater than for the existing C-Class ferries at the same speed. It is noted that backflow from C-Class ferries in the past when they operated at 8 knots is likely to have been greater than for W-Class at 6 knots.	We have calculated that the backflow will be much bigger. So the conclusion is that C-Class operating at 8 knots or more, as they have in the past, have been causing habitat loss! See 8 above. If C-Class have exceeded the speed limit in the past, there is no guarantee that the W-Class will not do so in the future.

10	The increased backflow from the W-Class has the potential to cause erosion to the bed of the navigation channel particularly at the shallowest locations in the channel. Any deepening is **expected to be of a minor** nature up to 0.5 metres	No evidence is given for this. ABPmer state that the backflow will be bigger and the river cross-sections presented in their report show major changes due to the existing C-Class. ABP have ignored the increased bank erosion caused by deepening of the river, as pointed out by HR Wallingford.
11	The deepening to be caused by the W-Class may create instability in the existing channel side slopes resulting in an eventual widening of the channel. Such changes are unlikely to propagate into intertidal areas because MLW is some tens of metres away from the channel banks	The deepening by the C-Class has already shown widening of the channel. HRW demonstrated that as the banks recede the bank material is lost into the channel where the passage of the ferries re-suspends it for export up or down river on the tide. ABPmer are right in saying that this material is lost to the system.
12	Slipstream effects on the channel banks are likely to be less than for the equivalent C-Class as the W-Class thrusters are more centrally aligned on the vessel than on the C-Class ferries	This is incorrect. The slipstream effects of the power needed to hold these much larger vessels on station in a cross wind will be much larger with resulting loss of river banks. Central placing of the thrusters will increase backflow under the much bigger flat-bottomed hull, further increasing channel deepening. The W-Class thrusters are also set deeper in the water, bringing their jets closer to the river bed.
13	The operational regime for W-Class ferries will reduce the number of occasions ferries are waiting in the estuary.	The conclusion here is that ferries waiting in the river are eroding the river bed and banks. If the W-Class are too big to pass in the river, as they must do operationally, then they are too big for the river. An operational 'regime' can be changed in times of necessity such as gale conditions. Vessels need to be designed for normal circumstances and should not be the biggest that can be floated in the waterway.
14	Slipstream impacts of W-Class ferries on the channel bed are likely to be greater than for C-Class ferries. The increased flow velocities associated with W-Class slipstream could cause additional erosion in the shallowest stretches of the channel during periods of extreme low water. A maximum deepening of 0.2 m **might be expected**	Why is only 0.2 metres expected? This is not within the tolerance of the measurement system and no evidence is presented to support this conjecture.
15	The passage of ferries along the navigation channel at low water contributes to maintenance of navigable depths by re-eroding deposit settlement within the channel. The introduction of W-Class ferries will	We agree: the LRA analysis shows this effect, as the lost river bank material is continually re-eroded by 22,500 sailings per year; therefore the river never has the chance to settle down. All this material comes from the saltmarshes and mud banks

	increase the proportion of deposited sediment that is re-eroded by ferries compared with that eroded by natural flow.	and is not being re-supplied, hence the evident habitat loss (see point 16) caused by the C-Class ferries. Other studies have demonstrated that tidal currents in the river are not sufficient to cause erosion.
16	The significance of changes for estuary sediment supply is **considered to be minimal** because there are no natural mechanisms for redistributing such material to inter-tidal areas and the sediment is effectively lost to the estuary system.	The report does not say what changes. There are no natural mechanisms for redistributing the lost sediment back to the saltmarsh that can be fast enough to keep up with the re-erosion process caused by the ferries. Hence the need to dredge the upper river and the build up of lost sediment at the river mouth. (see LRA Erosion paper)

10.3 Recommendations

For all the reasons given in sections 10.1 and 10.2, we recommend that the Regulators do not grant permission for the W-Class ferries to operate on the Lymington to Yarmouth route.

11. References

1. Report no R.1427 by Wightlink Ltd (ABPmer) as Information for Appropriate Assessment, dated May 2008.
2. BMT SeaTech: Ferry Operations at Lymington, Phase 1: The Present Situations and Future Predictions. Ref C13537.R01.V2. March 2008
3. H.R. Wallingford: Proposed New Tonnage Lymington/Yarmouth Ferry Mud Erosion in the Lymington River. Report EX 2390. July 1991
4. LRA Appraisal: Contribution to erosion of Lymington River by present C-Class and proposed larger W-Class ferries. May 2008.
5. Black and Veatch: Lymington Harbour Protection Environmental Statement. April 2008.
6. LRA: Information for Appropriate Assessment. Replacement Ferries Lymington to Yarmouth. Technical Report with Appendices in support of summary report by Lymington River Association. August 2008.

12. CONTENTS OF TECHNICAL REPORT

13: Conservation objectives

14: Appraisal of Wightlink / ABPmer energy method for comparing natural wind-waves and ferry-generated waves.

15: Appraisal of HR Wallingford 1991 report

16: Analysis of sub-tidal survey from Cage Boom to Posts 5 and 6

17: Calculation for relative ferry effects between Cage Boom and Posts 5 and 6

18: Long-term adverse effects caused by deepening of the river by ferries

13. Conservation Objectives

The conservation objectives for the Appropriate Assessment of the proposed shore works and linked introduction of much larger ferries have been stated in the information document supplied by Wightlink consultants ABPmer, in consultation with NE, in Section 3 Table 2 of their Document.

The objectives are defined for the Solent and Southampton Water SPA features as "no decrease in extent (of the habitat) from an established baseline, subject to natural change" and further set out as follows:

Feature/Criteria	Attribute	Target
SAC Feature Atlantic salt meadows	Distribution and extent of low mid upper and transitional high marsh communities	Distribution and extent of marsh communities should not deviate significantly from an established baseline, subject to natural change
	Species composition of characteristic low, upper and transitional high marsh communities	Presence and abundance of constant species of characteristic marsh communities should not deviate significantly from established baseline, subject to natural change
SAC Feature Salicornia and other annuals colonising mud and sand	Common cordgrass (spartina anglica) community	No increase in extent from an established baseline, subject to natural change
	Distribution and extent	No change in distribution and extent of annual Salicornia saltmarsh communities from an established baseline, subject to natural change
SAC Feature Intertidal mudflats and sandflats	Extent	No decrease in extent from an established baseline, subject to natural change
	Topography	Shore profile should not deviate significantly from an established baseline, subject to natural change
SAC Feature Int.imp populations of regularly occurring Annex 1 species and Int Imp. Waterfowl assemblage including the internationally important regularly occurring migratory species	Disturbance	No significant reduction in numbers or displacement of birds from an established baseline, subject to natural change
	Intertidal mudflats and sand flats	As above for SAC feature Intertidal mudflats and sandflats

Note: It is assumed that "increase" in col. 3, box 3 is an ABP typing error and should read "decrease"

The text states the focus is on the change to the extent of inter-tidal mudflats and saltmarsh and the disturbance of birds. Further "**other conservation objectives have been scoped out in consultation with NE and are not relevant**"!

Therefore the Appropriate Assessment has been brought down to a decision on whether or not the new W-Class ferries will reduce the extent of the habitat on either side of the Lymington River. Wightlink has to show that the evident loss of extent is from an established baseline (not defined) and is due to natural processes. The specification of "will the introduction of larger ferries affect the integrity of the features of the Lymington River" for which it is protected under law, has been reduced to a measurement of loss of extent from an unknown baseline.

In this context, and in response to an LRA request for clarification, NE state: "extent is a key measure of the nature of an impact. So is functionality (or character) although this can be more difficult to assess. In assessing whether an effect is adverse or not, we would need to understand the significance of these changes to the site or aspects of the site."

NE further state: "If a change from one type of habitat to another resulted from a plan or project then this would be a relevant impact to consider in the assessment. The question would be around its distinction from background or other causes and its significance. Subject to natural changes means changes resulting from natural effects (eg. climate, atmospheric, oceanographic etc). These are not directly attributable to an operation or development."

So how much loss is acceptable? MFA state in response to LRA questions: "bearing in mind the precautionary principle, no loss caused by the ferries would be acceptable."

NE state: "very difficult to say absolutely no loss we don't put a magic figure on this as a threshold. The legislation is quite precautionary and puts the onus on Wightlink to demonstrate that the development will not have an adverse effect rather than regulators provide a threshold to pass. The decision makers need to be assured that the project will not have an adverse effect. This therefore needs to show that the overall coherence of the site in terms of structure and function is not compromised."

In this LRA information for appropriate assessment document we use the same criteria to judge whether or not W-Class ferries will have "an adverse effect". In line with NE's advice to Wightlink/ABPmer, LRA focus on changes to the extent of the inter-tidal and saltmarsh.

In the report, based on calculations supported by bathymetric data, we reveal the loss of extent in the SAC, attributable to C-Class ferries, at different times since they entered service in 1973. Based on published data, we compare the effects of C-Class and W-Class ferries. We predict how the extent of the SAC will alter if the larger W-Class are permitted to enter service.

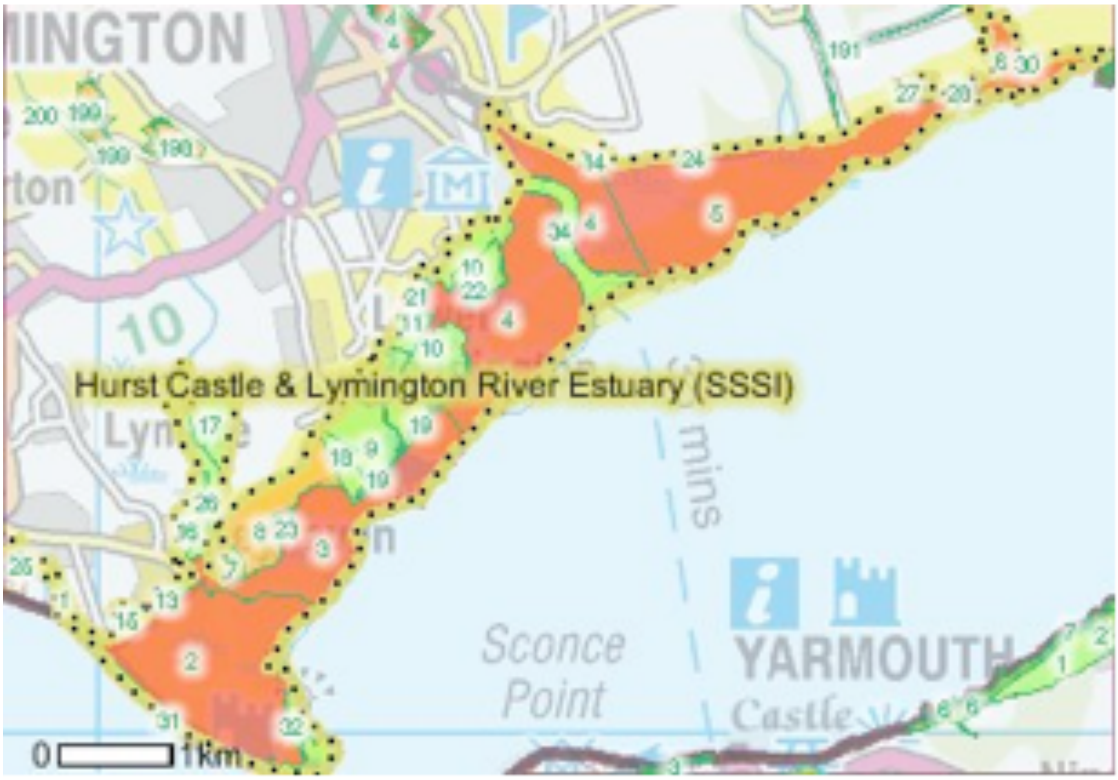
There is clearly change taking place in the inter-tidal environments of all rivers and estuaries in the SPA and SAC of the western Solent as observed and measured over the past century. All these features are to be conserved under regulations at national and European level and the precautionary principle is to be applied. Therefore central to this analysis are the questions:

1. To what extent is the deteriorating environment of the Lymington River due to changes beyond the control of regulators, i.e. natural?
2. What is the contribution of the existing C-Class ferries to the deteriorating environment?

3. Will the proposed W-Class ferries cause further loss of extent?

The features of the Solent and Southampton water SPA and the Solent Maritime SAC were registered in 1998 and the designation approved in 2005.

Features of the Hurst Castle and Lymington River Estuary SSSI were first notified in 1961, revised in 1986 and again in 1995.



Map of Hurst Castle and Lymington River SSSI incorporated into the Western Solent SAC.

Therefore the baseline should be established either from 1961 or 1986.

Target agreed NE/ABP mer	**Conclusions offered by ABPmer**	**LRA Findings**
Distribution and extent of marsh communities should not deviate significantly from an established baseline, subject to natural change	No analysis of marsh communities, no conclusion	Loss of extent to east and west of the river navigation channel
Presence and abundance of constant species of characteristic marsh communities should not deviate significantly from established baseline, subject to natural change	No analysis or conclusion offered	Loss of extent

No decrease in extent from an established baseline, subject to natural change	The contribution to intertidal erosion in the estuary from ship waves from either C- Class or W-Class ferries is unlikely to be significant. The predicted drawdown from W-class ferries is greater than for the existing C-Class ferries and there is some potential for such drawdown to cause erosion on the lower intertidal . However such erosion is likely to be limited.	Agreed, ship waves are too small to cause erosion, this was established by HR Wallingford in 1991. It is backflow, drawdown and thruster effects that are causing the loss of extent,as shown in section 17.3.3 and not referred to by ABP. Where is the evidence that erosion to be caused by W-Class will be limited? Our analysis calculates this effect and draws the conclusion that the erosion by C-Class vessels at low water is causing erosion and loss of habitat, and that the W-Class will increase erosion
No change in distribution and extent of annual Salicornia saltmarsh communities from an established baseline, subject to natural change	No analysis or conclusion offered	Measured loss of extent has reduced
No significant reduction in numbers or displacement of birds from an established baseline, subject to natural change	No analysis or conclusion offered	
As above for SAC feature Intertidal mudflats and sandflats		

Natural change and anthropogenic change in the Lymington River

The effects of change in the nutrition of the outer south facing edges of the salt marshes and mud banks are described in Bradbury, 2001.

Since the 1930s a portion of the large sediment store of fine-grained sediment currently “locked up” in the Lymington, Keyhaven and Beaulieu saltmarshes and mudflats has been relatively rapidly eroded and transferred to suspended load. Some sediments are re-deposited onto marsh and mudflat surfaces, but the majority become distributed throughout the Solent system, or lost to the English Channel.

In conclusion, it will be essential to adopt a combination of approaches to the problem that have minimum impacts and will maintain existing ecological diversity. This may not necessarily involve the maintenance of all existing plant and animal communities, but instead accept a degree of dynamic change. The existing extents of “hard” defence solutions are clearly unsustainable and inappropriate over the longer term (A. Bradbury, *Western Solent Saltmarsh Study*, 1995, quoted in Bradbury, 2001).

The LRA analysis shows that as the banks of the Lymington River are eroded through drawdown and backflow of passing ferries the resulting sediments falling into the bed of the river are re-suspended by the ferries’ Voith-Schneider thrusters. In Horn Reach this process was documented by HR Wallingford and predicted the further bank loss and deepening that has now taken place. In the Short Reach the eastern side of the river has been widened and the bathymetric cross-sections for Cocked Hat and Bag of Halfpence show the deepening of the river from 1993 to 2006. In the Long Reach the river banks have receded much more and the wave action from the south increased as natural protection from the now eroded marshes reduces.

References

Bradbury, A.P., *Strategic monitoring of the coastal zone: towards a regional approach*. Report to SCOPAC, South Downs Coastal Group, South East Coastal Group and the Environment Agency. 2001.

14. Appraisal of the Wightlink / ABPmer energy method for comparing natural wind-waves and ferry-generated waves

14.1 Introduction

One of the main conclusions put forward by ABPmer in defence of Wightlink's ferries is that erosion of the inter-tidal mudflats and the saltmarsh caused by ship-generated waves from the ferries is "very small" compared with so-called "natural" erosion caused by wind-generated waves. This conclusion was based mainly on an energy calculation, which is stated as being "to set the ship waves from the ferries in context". The method is described in Appendix A of their report.

ABPmer's Table 6 shows the relative energies of ferry-waves and wind-waves according to their "energy method". Relative energies were calculated at 16 points in the river (shown on their figure 14). According to Table 6, the average contribution at the 16 points from existing C-Class ferries travelling at 8 knots is 17.1% of the total ship and wind energy. If the C-Class travelled at 6 knots the average energy contribution would fall to 3.6% of the total. The W-Class ferry also travelling at 6 knots would only contribute 1.7% of the total energy, in spite of being a much larger vessel (with 71.5% larger displacement, 28.7% greater beam, a block coefficient 20.5 % greater and a power requirement 50% more than for the C-Class).

This claim that the W-Class would contribute less energy than the C-Class was improbable and seemed misleading. We suspected either an error or a flaw in the method. We decided to examine the method and the assumptions on which it is based in more detail.

14.2 Wind-generated wave energy

The energy from the wind-generated waves is derived from an hourly normalised wind speed frequency distribution at Lee-on-Solent. (We have since obtained Lymington's wind frequency distribution and found that it agrees closely with both Lee-on-Solent and with Hurst.) This is reproduced in ABP's Table A2 shown below. The table shows the number of occurrences for each wind speed "package" in each compass direction at 30 degree intervals. For example, we see there are 135 occurrences per year for an hourly mean wind speed of 6.94 m/s in the 180 degree direction.

Table A2 Wind frequency data for Lee on Solent

Wind speed (m/s)	Frequency of I hour occurrences												Total
	Direction												
	0	30	60	90	120	150	180	210	240	270	300	330	
1.03	67	62	43	41	29	24	32	22	32	42	50	49	493
2.57	197	187	155	121	108	90	81	61	98	119	159	141	1517
4.37	236	251	259	158	164	168	110	114	234	230	183	131	2238
6.94	174	202	191	103	108	121	135	228	578	344	153	69	2406
9.77	44	53	44	18	12	40	85	172	416	174	55	11	1124
12.60	12	11	6	2	2	18	63	134	314	80	26	3	671
15.68	1	1				4	18	62	117	20	6	1	230
19.02						1	6	25	39	7	1		79
22.62								3	3	1			7
26.47								1	1				2
30.58													0
32.90													0
Total	731	767	698	443	423	466	530	822	1832	1017	633	405	8767

The next step was to derive the wave heights at the 16 points (shown in ABP's figure 14). Table A3 in ABP's report shows the fetch lengths around the compass for each of the 16 points. The significant wave height Hs, at each of the 16 points, for each compass direction and at each wind speed, was calculated using an empirical formula by Sverdrup-Munk-Bretschneider. The significant wave height Hs is the average height (crest to trough) of the highest third of the waves.

Table A4 **Significant wave heights at Point 2 (Cage Boom)**

Wind speed (m/s)	Wave height (m)											
	Direction											
	0	30	60	90	120	150	180	210	240	270	300	330
1.03	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.02
2.57	0.03	0.03	0.03	0.03	0.03	0.05	0.11	0.06	0.05	0.05	0.07	0.05
4.37	0.06	0.06	0.06	0.06	0.06	0.09	0.21	0.11	0.09	0.10	0.13	0.09
6.94	0.10	0.10	0.10	0.10	0.10	0.16	0.37	0.19	0.16	0.18	0.23	0.15
9.77	0.15	0.15	0.15	0.15	0.15	0.24	0.57	0.28	0.24	0.27	0.34	0.22
12.60	0.19	0.19	0.19	0.19	0.19	0.32	0.77	0.38	0.32	0.36	0.46	0.29
15.68	0.25	0.25	0.25	0.25	0.25	0.40	1.01	0.48	0.40	0.46	0.59	0.37
19.02		0.31				0.50	1.27	0.60	0.50	0.57	0.73	
22.62						0.61	1.54	0.73	0.61	0.69		
26.47							1.84	0.87	0.73	0.82		
30.58												
32.90												

ABP’s Table A4 (above) shows the computed significant wave heights for Point 2 at Cage Boom. The wave energy at each point, each compass bearing and each wind speed is proportional to the square of the wave height times the number of occurrences. The total wave energy at Point 2 over one year is found by summing all the individual energies for each wind speed and compass direction. We have tabulated this below as Table AA1.

Table AA1 **Wind-Wave Energy for Point 2 (Cage Boom)** E= Hs^2 (from table A4) x frequency (table A2) as per ABP-MER

Wind speed (m/s)	Frequency of I hour occurrences												Total
	Direction												
	0	30	60	90	120	150	180	210	240	270	300	330	
1.03	0.01	0.01	0.00	0.00	0.00	0.01	0.05	0.01	0.01	0.02	0.02	0.02	0
2.57	0.18	0.17	0.14	0.11	0.10	0.23	0.98	0.22	0.25	0.30	0.78	0.35	4
4.37	0.85	0.90	0.93	0.57	0.59	1.36	4.85	1.38	1.90	2.30	3.09	1.06	20
6.94	1.74	2.02	1.91	1.03	1.08	3.10	18.48	8.23	14.80	11.15	8.09	1.55	73
9.77	0.99	1.19	0.99	0.41	0.27	2.30	27.62	13.48	23.96	12.68	6.36	0.53	91
12.60	0.43	0.40	0.22	0.07	0.07	1.84	37.35	19.35	32.15	10.37	5.50	0.25	108
15.68	0.06	0.06	0.00	0.00	0.00	0.64	18.36	14.28	18.72	4.23	2.09	0.14	59
19.02	0.00	0.00	0.00	0.00	0.00	0.25	9.68	9.00	9.75	2.27	0.53	0.00	31
22.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	1.12	0.48	0.00	0.00	3
26.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.53	0.00	0.00	0.00	1
30.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
32.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total	4	5	4	2	2	10	117	68	103	44	26	4	390
% direction	0.01	0.01	0.01	0.01	0.01	0.02	0.30	0.18	0.26	0.11	0.07	0.01	1.00

The annual total is seen to be 390 ‘energy units’. (NB The constants in the energy equations have been taken as unity by ABP, so that energy units can be compared as relative terms.)

14.2.1 Assumptions in ABPmer’s wind-wave energy derivation

(a) ABPmer state that their energy assessment does not take into account the changing water level in terms of water depth and varying fetch lengths and “therefore only gives an order of magnitude of the relative effect of the natural forces and the ferry-generated forces for the existing conditions”. We are looking for small differences between ferry and wave effects. If the assumptions produce results that are in error by an order of magnitude (i.e. a factor of about 10), they become meaningless.

(b) The wave heights – Hs or Hrms?
The wave heights generated from the wind speeds and fetch lengths have been expressed as Hs, the significant wave height. This is the average height of the highest third of the waves. In lieu of analysing a full wave spectrum, a more appropriate wave

height for calculating total energy would be to use the average or root-mean-square wave height (Hrms). This is generally expressed as approximately = Hs/1.4. As energy is proportional to height squared, the energy would reduce by approximately $(1/1.4)^2 = 0.51$. So the wave energy should be reduced by approximately 50%.

(c) The wave height required to trigger erosion
ABPmer's energy method is intended to compare ferry-generated wave energy with wind-generated wave energy in order to assess their relative contribution to erosion of the saltmarsh and intertidal areas and thereby provide evidence as to whether or not the ferries affect the integrity of the European sites.

Their method ignores the soil shear strength and water shearing velocities required to trigger erosion. In section 15 below, we describe HR Wallingford's test results (ref. 3) for soil shear strength and shearing water velocity. There was some scatter with the results but a reasonable conclusion was that a water velocity of 0.25 m/s would re-suspend soft mud on the river bottom, 0.5 m/s was sufficient to erode undisturbed soil from the river banks and mudflats, and 0.75 m/s would erode sand and gravels that lie deep in the river bottom.

The minimum wave heights that generate water particle velocities exceeding 0.25 m/s, 0.5 m/s and 0.75 m/s were found using an algorithm from the Centre for Applied Coastal Research, University of Delaware. As water velocities are also depth-dependent we selected a range of depths at three of ABPmer's locations.

The table below shows the water depths at HW, mid-tide and LW for points 2, 13 and 9 in ABP's report. These were the points for which Hs values were supplied.

Depths of water (metres) at ABPmer's selected points

Point No	Location	depths relative to chart datum			Net water depth		
		sea bed	HW	LW	HW	mid tide	LW
2	Cage Boom	-1.5	3.0	0.5	4.5	3.3	2.0
13	Mid channel Long Reach	-4	3.0	0.5	7.0	5.8	4.5
9	Western side Long Reach	-1.5	3.0	0.5	4.5	3.3	2.0

The next table shows maximum water particle velocities under the waves at depths ranging from 2.0 metres to 7.0 metres and at wave heights (Hs) from a maximum of 1.84 metres (at Point 2, Cage Boom) down to 0.25 metres.

The algorithm was run for each combination of water depth and wave height at various periods from 3 seconds to 7 seconds. The longer periods produce increased wave lengths and larger velocities. Without a full spectral analysis, a judgement was made to adopt the period T = 4 seconds.

The right-hand column shows the value of Hs that corresponds to water velocity Umax = 0.5 m/s. Thus we see that Hs required to trigger erosion varies from 0.42 m at a water depth of 2 m to 0.61 m at 7 m depth. For the purpose of this exercise we adopted a value of H=0.5m as the minimum wave height required to trigger erosion, corresponding to the mid-tide water depth of 3.3 metres at Point 2.

Maximum water particle velocity (m/s) at different water depths
and significant wave heights Hs (m) for wave period T= 4.0 seconds

Water	Hs 1.84	Hs 1.5	Hs 1.25	Hs 1	Hs 0.75	Hs 0.5	Hs 0.25	Hs min for U>0.5
2.00	1.93	1.81	1.51	1.20	0.9	0.60	0.30	0.42
3.30	1.84	1.5	1.25	1.00	0.75	0.50	0.25	0.50
4.50	1.67	1.36	1.13	0.90	0.68	0.45	0.22	0.56
5.80	1.57	1.28	1.06	0.85	0.64	0.42	0.21	0.59
7.00	1.51	1.23	1.03	0.82	0.61	0.41	0.20	0.61

Next, a filter table was derived for the wave height Hs at Point 2 shown in Table A4 above. The filter sets a counter to 0 for H<0.5m and to 1 for H>0.5m. The filter table is shown in Table AA2 below:

Table AA2 **filter for locations where maximum water particle velocities for Point 2 (Cage Boom) exceed 0.5m/s**
Hs minimum = 0.5 m/s for mid tide water depth = 3.3 metres

Wind speed (m/s)	Frequency of I hour occurrences Direction 0	30	60	90	120	150	180	210	240	270	300	330	Total
1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
9.77	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1
12.60	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1
15.68	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	2
19.02	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	6
22.62	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	5
26.47	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00	0.00	4
30.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
32.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total	0	0	0	0	0	2	6	3	3	3	2	0	19

The filter is applied to the "energy units" in Table AA1 above by multiplying each "energy cell" by the filtered value of 0 or 1. This discounts wind-wave energy from waves too small to trigger erosion at Cage Boom Point 2. The net energy is shown in Table AA3:

Table AA3 **Wind-Wave Energy for Point 2 (Cage Boom) where water particles exceed 0.5 m/s**
E = ABP value (fromTable AA1) x filter value for Hs from Tabel AA2

Wind speed (m/s)	Frequency of I hour occurrences Direction 0	30	60	90	120	150	180	210	240	270	300	330	Total
1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
9.77	0.00	0.00	0.00	0.00	0.00	0.00	27.62	0.00	0.00	0.00	0.00	0.00	28
12.60	0.00	0.00	0.00	0.00	0.00	0.00	37.35	0.00	0.00	0.00	0.00	0.00	37
15.68	0.00	0.00	0.00	0.00	0.00	0.00	18.36	0.00	0.00	0.00	2.09	0.00	20
19.02	0.00	0.00	0.00	0.00	0.00	0.25	9.68	9.00	9.75	2.27	0.53	0.00	31
22.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	1.12	0.48	0.00	0.00	3
26.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.53	0.00	0.00	0.00	1
30.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
32.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total	0	0	0	0	0	0	93	11	11	3	3	0	121
% direction	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.09	0.09	0.02	0.02	0.00	1.00

We now see that the total wave energy that could cause erosion at Point 2 has fallen to 121 "energy units" from the unfiltered value of 390 units. This is only 31% of the energy derived by ABP. As this energy value is still based on significant wave height Hs values, we would expect it to be an over-estimate compared with using the full wave spectrum at all frequencies or the mean wave height Hrms as discussed above.

We therefore consider that the ABPmer report has over-estimated the magnitude of wave energy that could trigger erosion by a factor between 3 and 6.

14.3 Ship-generated wave energy

Sections A4 and A5 of the ABPmer report calculate the energy generated by the ship's bow and stern waves. The energy is proportional to peak wave height squared times frequency of vessel movement and duration of wave activity. The peak wave height is derived from a semi-empirical equation for a vessel in deep water. The empirical constant α for the ferries was unknown, so estimated values have been adopted. We are not told the maximum wave heights that were assumed, but maximum heights of 0.25 m were indicated elsewhere in the text. We are also told that "there is not much difference" between the wave heights of C-Class and W-Class travelling at the same speed. (In spite of this the figures given in Table 6 for the two ferries were in fact considerably different, in favour of the W-Class.)

Vessel wave heights seem to have been verified by sea trial observation and tank test results. ABPmer also expressed concern in justifying a value for the duration of ship wave activity (t) (see Section A5 in their report). A duration of 30 seconds was assumed and considered "to be conservative".

We have two major concerns with this calculation for ship wave energy:

1. Setting aside the assumptions made in deriving the bow and stern wave heights for deep water and applying them to shallow water, if the resulting wave heights are indeed approximately 0.25 metres or less, their relevance to erosion of river bank, mudflat or saltmarsh is minimal. According to HR Wallingford's test data, wave heights of 0.25 m are only sufficiently large to re-suspend silt particles that have already been accreted on the river bed in earlier erosion cycles. The velocity is less than required to erode material from the river banks.
2. The proportion of the ship's energy expended by the engines in generating bow and stern waves is a small fraction of the total energy. The bulk of the energy transfer will be dissipated from thruster jets and turbulence, the high backflow velocities in shallow water and the drawdown wash.

Just as the wind-wave energy has been exaggerated by a factor of around 4, we find the ship energy under-estimated by a similar amount. So the ratio of the two is seriously skewed.

14.4 Conclusions concerning ABPmer's energy method

We were alerted to errors or to possible mathematical ill-conditioning in the process by inconsistent and unconvincing results in the stated energy ratios of the ferries in Table 6 of ABPmer's report.

Closer examination revealed serious flaws in the method:

1. The assumption that the energy of wind-generated and ship-generated waves could be compared in order to draw conclusions about relative erosion damage is not sound because only the energy of waves higher than about 0.5 m can generate water velocities sufficient to shear the soil. When the energy of waves too small to cause erosion was filtered out of ABPmer's method, the wave energy total reduced by 69% at Point 2 (Cage Boom).

2. Wave energies based on Hs values also over-estimated the total energy in the wave spectrum by a factor of 2.
3. The widening and deepening of the channel caused by ferries, allowing larger waves into the river, has not been taken into account in the wind-wave energy build-up. There is no acknowledgment that wind-generated waves in the river are now greater than in the past because of river deepening by the C-Class ferry since 1973. This part of the wind-wave spectrum must be regarded as “man-made”, not “natural”.
4. The ship-wave energy considered by ABPmer only includes the energy in bow and stern waves, which is shown to be insufficient to shear the soil on the inter-tidal banks. The energy component in the thrusters, backflow and drawdown were ignored. The energy from the ships that contributes to channel erosion may be under-estimated by a factor of 3 or 4.
5. Thus the energy ratio of ship-waves to wind-waves was skewed by a factor so large as to make the results in ABP’s Table 6 meaningless. **The values in Table 6 of their report should be set aside.**
6. **We consider that the energy method as used was not only unsound but is misleading, particularly to readers who are less familiar with hydrodynamics.**

15. Appraisal of HR Wallingford's 1991 report

15.1 Introduction to HR Wallingford's study

In 1991 HR Wallingford carried out a study at the request of Lymington Harbour Commissioners in order to assess the mud erosion in the Lymington River from the C-Class ferry and another larger ferry that had been proposed by Wightlink Ltd at that time. The following table compares the sizes of the proposed 1991 ferry and the C-Class and today's proposed W-Class vessels:

	C-Class In service since 1973	W-Class Proposed for late 2008	Proposed 1991 ferry (withdrawn)
Length (m)	55.5	62.4	75
Breadth WL (m)	12.24	16.00	13.6
Max submerged cross-sectional area (m^2)	25.7	35.6	27.0
Draught (m)	2.3	2.3	2.3
Displacement loaded (tonnes)	900	1489	1450
Horsepower	2 x 400 hp	2 x 1700 hp	2 x 675 hp

It is interesting to note that the proposed 1991 ferry was withdrawn because it was recognised as being too large for the Lymington River. Seventeen years later Wightlink Ltd is trying to introduce an even larger ferry into the river. Although the W-Class is shorter in length, its displacement, beam and submerged cross-sectional area are greater than those of the 1991 vessel. The extra cross-sectional area causes increased blockage in the river, leading to additional backflow and drawdown water velocities, both of which increase river erosion. The most striking difference compared with the W-Class is the greatly increased horsepower of the latter's engines. This is not merely a matter of increased redundancy, as argued by Wightlink Ltd. The power is necessary to resist additional lateral wind loads on the W-Class, whose windage area is 100% greater than that of the C-Class.

The HR Wallingford report describes field, laboratory and desk studies that they carried out to quantify the magnitude and frequency of the natural and ship-induced factors which could cause erosion of the mud banks and channel. Each of the factors was considered in turn to see how it might change with the proposed increase in the ferry size.

The factors which could cause erosion in the mud bank and channel were identified as: tidal currents and ship return currents in the main channel, and ship-waves, wind-waves and ship-induced rapid water level drawdown on the inter-tidal mudflats.

Field measurements of tidal velocity, and its variation with depth, were taken. Continuous measurements of sediment in the channel were recorded. This varied from 20 ppm to 275 ppm. A video camera was used to record ship-induced rapid water level drawdown on the mudflats and to observe ship wash. Return currents were calculated theoretically from ship and channel dimensions, and wind-wave induced currents were calculated from existing wind data with the help of numerical wave models.

15.2 Bathymetric surveys

The 1991 report was ordered because Lymington Harbour Commissioners staff had noticed that the mudflats in the river had been eroding rapidly and the river banks had been receding over the previous 15 years since C-Class started service in the river. These observations were causing considerable concern.

HR Wallingford compared bathymetric charts over a time span of 10 years (dated 1981 and 1991).

A summary of the morphological changes in Horn Reach revealed by the two bathymetric surveys has been given in section 4.1.1 of this report.

15.3 Mud properties

In-situ shear strength measurements were taken at six locations in the inter-tidal mudflats. Undisturbed samples were also taken back to the lab, where they were tested in a 27 metre reversing flume. The samples were placed in the bed of the flume. The flume was flooded and water pumped over the samples at increasing speeds to determine the flow velocity required to cause the soil to shear.

The samples were found to be “soft” with a bulk density of 1400 kg/m^3. The surfaces were bound by biological material, with many tube worm burrows evident. On eroding, slimy surfaces were observed, which the scientists attributed to worm secretions that bound the mud particles together, increasing their surface cohesion. Erosion seemed to create small sheets of material that were matted with algal material. The material remaining underneath was uneven and pitted with ripped algal threads and worm holes.

Mid-shore samples eroded at shear stresses in the range 1.1 to 2.0 N/m^2, and low shore samples between 0.4 and 0.6 N/m^2.

15.4 Assessing the forcing functions on erosion

15.4.1 Tidal currents

Field measurements showed that the maximum tidal velocity was around 0.3 m/s, giving a maximum shear stress of 0.12 N/m^2. This was associated with ebb spring tides. The percentage of the year when shear stresses due to tidal currents exceed 0.1 N/m^2 was around 1%. These are low stress values. However, it was concluded that ebb flow currents would be sufficient to re-suspend soft mud that had recently been deposited but would not be sufficient to erode undisturbed sediments on the bank.

ABPmer suggested that the additional tidal prism of 15% caused by capital dredging for Lymington’s two marinas could cause additional scour in the river. They also suggested that the changes to the river morphology that had been noted and attributed to the C-Class ferries could have been caused in part by the marinas that had been constructed one to two years before 1973, when C-Class entered service. However, we should note that HR Wallingford measured the tidal velocities in 1991, some 19 years after construction of the Lymington marinas. Therefore the effects of the 15% additional tidal prism were included in their tidal velocity measurements.

15.4.2 Wind-waves

HR Wallingford calculated the seasonally averaged distribution of wave heights and periods for Horn Reach. They calculated the shear stresses exerted on the bed by the waves, which were largest in shallow water and decreased very rapidly for deeper water. This showed that waves would have more effect on the inter-tidal mudflats than in the channel.

The bed shear stresses were seasonally averaged to take account of the water depth variation due to rise and fall of the tide. The mudflats at +1.0 m CD are subject to higher shears most often because the water is quite shallow there for a large part of the tide. The seasonally averaged distribution of wave height, wave period and shear stresses is shown in Table 4 of HR Wallingford's report.

HR Wallingford concluded that the maximum shear stress exerted on the bed in Horn Reach only exceeds 0.5 N/m^2 for about 1% of the time (~ 3 days per year), although this would be sufficient to erode the softer mud at the edge of the channel.

15.4.3 Ship return currents

HR Wallingford calculated return currents and drawdown for the C-Class ferry by Pianc's method and using Schijf's method. Based on a blockage ratio of 0.17 and 5 knots speed, the average return current was 1.0 m/s, resulting in a bed shear of 1.0 N/m^2, sufficient to erode mud on the low shore and probably sufficient to erode the more consolidated middle part of the mudflats. They estimated that peak return currents were 1.3 to 1.5 times the average value for the hull shape of C-Class. It was pointed out that the blockage ratio increased by 30% when the ferry turned corners, although this was partially offset by the extra drag slowing the vessel in the bend. The result was a net increase in scouring round bends, an effect that has been observed by the larger increases in channel depth around Post 11 and Harper's Post.

The percentage of time over which the return currents were expected to have an effect was based on ferry movements. For C-Class in Horn Reach at that time it was based on 15,000 ferry movements per year. One-sixth of these would be within 1 hour of low water and the duration approximately 30 seconds for the ferry travelling at 4 knots. This effect was included in the calculation for total erosion from the ferry in a set period of time. (It should be noted that ferry movements are now reported to be around 22,500 per year.)

The discussion also considered the estimate for the increased ship return current erosion that the larger proposed 1991 ferry would have made had it entered service.

15.4.4 Ship waves

The study found that bow waves from the ferry – even at speeds up to 7 knots – were not expected to be significant, because of the hull shape. As the waves, approximately 0.15 m high, travelled into shallow water (<0.5 m) they could result in shear stresses of around 0.2 N/m^2, lower than required to erode mudflat samples tested in the laboratory.

15.4.5 Ship-induced rapid water drawdown

The rapid water level drawdown off the banks in Horn Reach was recorded by video camera during the survey on 16-17 May 1991. Markers were placed 1m apart in a line down the mudflat to near the channel edge. Horizontal distance and duration of the drawdown was then quantified by video tape analysis. The results showed a slight rise in water level followed by a rapid reduction. The water rushes back up the mudflats very quickly, usually above its initial level. A second drawdown may then be seen before the water level returns to its original level.

The maximum distance the water was drawn down was 10m, corresponding to 0.2m vertically. This represented water velocities in the range 0.5m/s to 1.0m/s over the mudflats. The observations agreed with calculations from Schijf's diagram. The water velocities would be sufficient to erode deposits at the edge of the channel. The stirred-up mud was noticed in the turbulent water as it was sucked off the mudflats.

It was concluded that the time over which the drawdown effect would be felt was around 0.2% of the year, a little less than that of the return currents.

15.4.6 Vessel slipstream (thruster) effects

This was not addressed in HR Wallingford's report.

15.4.7 Discussion

The relative magnitudes of the factors contributing to erosion of the banks were summarised in Table 5 of Wallingford's paper, reproduced below:

	Max velocity (m/s)	Max height (m)	Bed shear stress (N/m²)	% time	Erode bed?
Tide	0.3		0.1	1	No
Wind-waves		0.28	0.5	1	Yes
Ship-waves		0.1	0.2	0-0.5	No
Ship return currents	1.0		1.0	0.3	Yes
Horizontal drawdown	0.5 – 1.0		0.5 1.5	0.2	Yes

It was concluded that only wind-waves, ship return currents and drawdown would be sufficient to erode the consolidated mud on the banks, although all the factors are sufficient to re-suspend soft materials that had only just been deposited. Ship effects act evenly over the whole year, whereas wind-generated wave effects are probably due to a few large storms. The largest shear stresses are due to the return currents and drawdown but these only act for a short period of time.

HR Wallingford then calculated the depth of erosion due to the ferries over a 10-year period to be 0.3 m. This calculated depth corresponded well with the observed depth of erosion in Horn Reach from the bathymetric survey during the same period (see section 4.1.1). The observed erosion depths between 1981 and 1991 were 0.4 m in the southern part and 0.2 m in the northern part.

15.5 Conclusions by HR Wallingford in 1991

In their conclusions HR Wallingford reiterated the tests, observations and conclusions about the bed shears and percentage times of their actions, for the erosion forcing functions. In addition they drew attention to bank erosion. They said that increase in depth of the channel was likely to cause the banks to recede, in order to maintain the same slope on the mud banks. This would be visually more obvious than increase in depth in the channel.

The natural angle of repose of the banks is approximately 1:75, so their predicted bank erosion corresponding to the 0.3m depth increase in the 10-year period mentioned above would be around 22.5m, or 2.25 metres per year.

We will utilise HR Wallingford’s data to help predict the erosion effect of C-Class and W-Class ferries in section 17.

16. Analysis of sub-tidal survey from Cage Boom to Posts 5 and 6

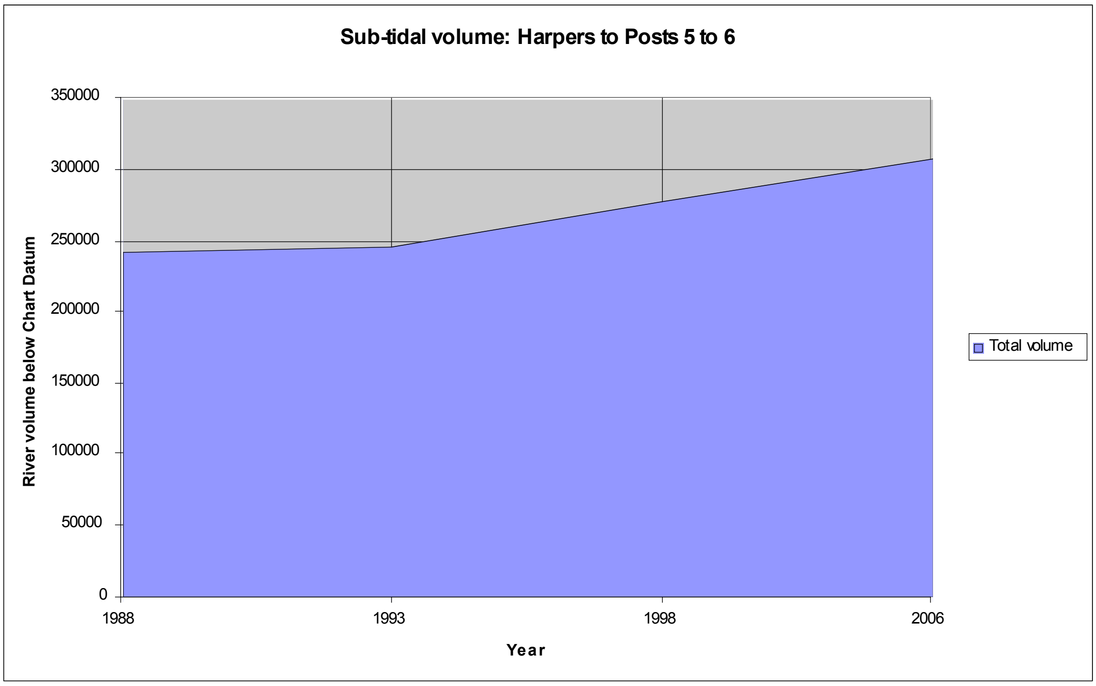
ABPmer present six cross-section of the Lymington River, from Harper's Post to Posts 5 to 6, on their Figures 7, 8 and 9. The plan location is shown on ABP's Figure 6. At each location a cross-section was drawn from measurements taken in 1988, 1993, 1999 and 2006.

The six cross-sections have been presented for the navigation channel only, between the level of Chart Datum (CD) and below. To judge "adverse effect" we are required to show whether changes to the extent of the SAC have occurred due to the ferries. We are surprised that bathymetric data was not available for the inter-tidal area from below the high tide level.

Therefore it has only been possible to measure volume and width change over time for the navigation channel. From this we can deduce the morphological changes to the inter-tidal mudflats and saltmarsh area at CD level.

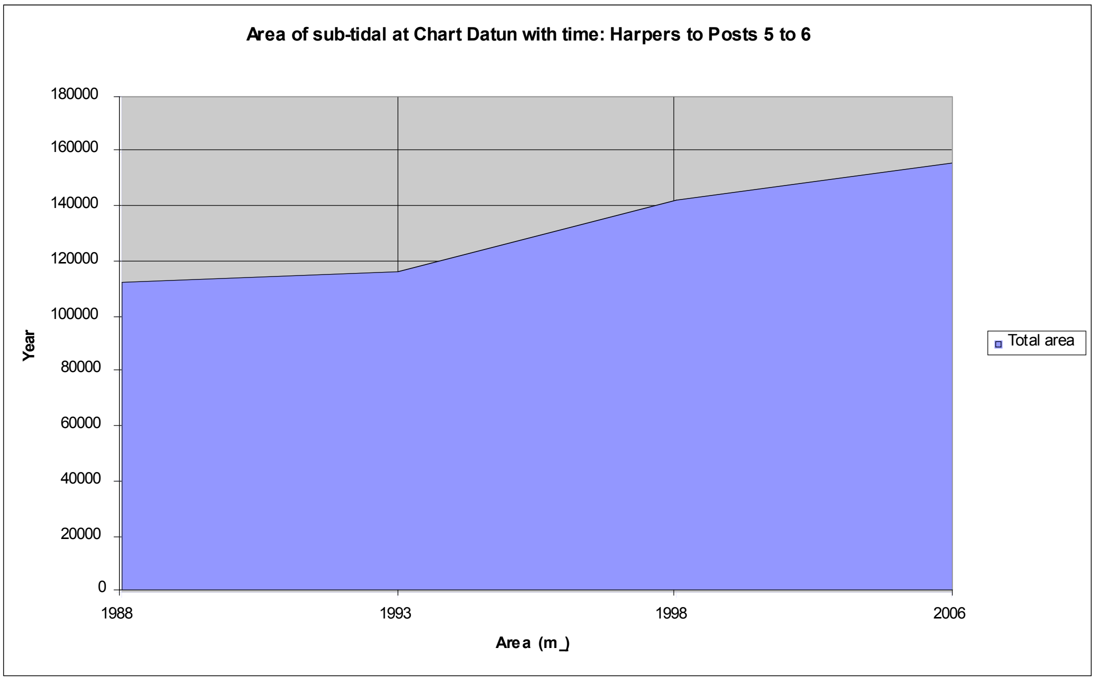
Therefore we measured the area of each cross-section, at each date, and the mean linear distance between the sections. We calculated the volume of the river below CD and the width of the river at CD at each date. These have been plotted to show how volume and area vary with time. The results are as follows:

The figure below shows how the sub-tidal volume of the river between Harpers Post and Posts 5 and 6 (a length of 1,088 metres) has varied between 1988 and 2006. The distance represents approximately one-quarter of the length of the river.



The sub-tidal volume increased from 243,340 m³ in 1988 to 308,260 m³ in 2006. The erosion (or increase in volume) was 64,920 m³ in the 18-year period. The average annual rate of erosion was 3,600 m³/y. The increase in tidal prism in this sector of the river (below CD) is 27% in 18 years

The next figure shows how the plan area of the river at Chart Datum, from Harpers Post to Posts 5 to 6, has varied between 1988 and 2006.



The area of the river at Chart Datum channel, along the 1088 metre length, increased from 113,150 m² in 1988 to 156,425 m² in 2006. Over the period the area increased by 43,275 m².

Thus the area of sub-tidal at CD in 1988 has increased by 38% to the area it became in 2006. Therefore, the loss of inter-tidal mudflat area was also 43,275 m² in the period.

The average rate loss of the inter-tidal mudflats, over 18 years, was 2,400 m² per annum in this sector.

This equates to an average loss of inter-tidal mudflat of 2.2 metres per annum per metre of river, in the sector, between 1988 and 2006.

The above figures also show that the average depth of the sub-tidal, in the sector, increased by approximately 1.5 metres in the 18-year period. As maximum depth increased by approximately 0.5 m, it demonstrates that the depth increase occurred over a wide extent of the channel.

17. Calculation for relative ferry effects between Cage Boom and Posts 5 and 6

17.1 Introduction

The rate of erosion of the bed is proportional to the difference between the shear stress (τuv) applied to the river bed by friction from water flowing tangentially to the mud-line and the critical shear strength of the sea-bed soil ($\tau crit$).

The water flow can be caused by the tidal stream or wash from vessels (including their bow and stern waves, backflow, drawdown and wash from propellers or Voith-Schneider thrusters). Wind-driven waves cause water particles under the wave to rotate in circular orbits in deep water. In shallow water the orbits become elliptical. At the mud-line the water oscillates tangentially to the mud-line in phase with the wave frequency. Calculating the water velocities is complex and is affected by wave height, frequency (or period) and water depth. We have used an approximate method that calculates maximum water velocity under the wave and assumes this also acts tangentially on the mud-line. This will over-estimate bed friction and hence the erosion caused by wind-generated waves. As we are estimating the relative rate of erosion caused by ferries and waves, the assumption will tend to under-estimate the contribution from ferries.

Thus erosion rate per unit time, dm/dt = E x ($\tau uv - \tau crit$), where E is the erosion constant.

The total erosion depth D, after time T, will be as follows:

D = (dm/dt) x T / gammas, where gammas is the bed density of the soil.

Because we wish to find the relative erosion rate of different forcing factors, we can take the constants E and gammas as unity. Time T will be taken as the time of the occurrence of the forcing function in hours, over the course of one year.

17.2 Bed shear stress and bed shear strength

HR Wallingford’s 1991 investigation (section 2.3.3; ref. 3) found that the mid-shore in-situ samples eroded at shear stresses between 1.1 and 2.0 N/m² and the corresponding water velocities that caused the samples to shear in the flume varied between 0.33 and 0.45 m/s.

We have adopted the average of these values for this calculation.

Average assumed shear strength, $\tau crit$ = 1.55 N/m²
Average shearing velocity, Uc = 0.39 m/s
So bed shear friction constant, Cbf = $\tau crit$/Uc = 4.0

We can substitute these values into the equation for rate of erosion to obtain:

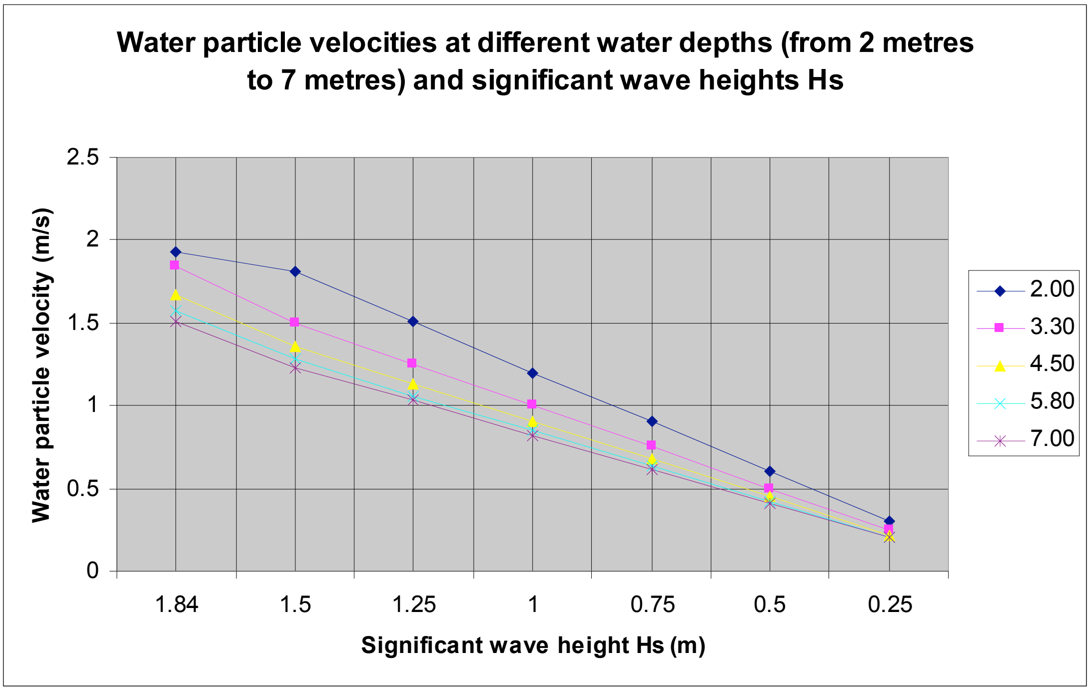
Erosion rate, dm/dt = constant x (1.55 – Uw x 4.0) > 0 per hour

Note: the erosion rate constant, being taken as unity, means that the rate is ‘dimensionless’. To find the ratio of the forcing functions, we do not need to establish a value for this constant.

17.3 Erosion factor from wind-generated waves

We calculated the wave erosion at Points 1 and 13, based on their significant wave height (Hs) data from Tables A4 and A5 in ABPmer's report. The wind frequency data for Lee-on-Solent (from Table A2) was used to establish the time duration for each wind speed and wind direction.

The correlation between water velocity and wave height was obtained from the graph below:



The mid-height depth of water at Point 3 is 3.3 m and for Point 13 is 5.8 m. The graph shows little change in particle velocities at these depths, so velocity of 1.3m/s at Hs = 1.5m was used to establish a linear relationship between Uw and Hs, as follows:

Uhsratio = 1.3/1.5 = 0.87 per second

Therefore the bed shear stress was calculated, at each point in the table as follows:

τuv = uhsratio x Cbf x Hs / 1.4 = 2.49 x Hs N/m²

The division of 1.4 was used to convert Hs to Hrms.

From this value for bed shear we subtracted the bed shear strength $\tau crit$.
Negative values indicate that bed shear is not sufficient to shear the soil.
Positive values only were then multiplied by the duration (in hours) from the wind frequency data in Table A2. The positive values were summed to obtain the wind-generated wave erosion factors at Points 2 and 13, over the course of one year. The results are below.

17.3.1 Wave erosion factor at Point 2

Table A2 **Wind frequency data for Lee on Solent**

Wind speed (m/s)	Frequency of 1hour occurrences												Total
	Direction												
	0	30	60	90	120	150	180	210	240	270	300	330	
1.03	67	62	43	41	29	24	32	22	32	42	50	49	493
2.57	197	187	155	121	108	90	81	61	98	119	159	141	1517
4.37	236	251	259	158	164	168	110	114	234	230	183	131	2238
6.94	174	202	191	103	108	121	135	228	578	344	153	69	2406
9.77	44	53	44	18	12	40	85	172	416	174	55	11	1124
12.60	12	11	6	2	2	18	63	134	314	80	26	3	671
15.68	1	1				4	18	62	117	20	6	1	230
19.02						1	6	25	39	7	1		79
22.62								3	3	1			7
26.47								1	1				2
30.58													0
32.90													0
Total	731	767	698	443	423	466	530	822	1832	1017	633	405	8767

Table A4 **Significant wave heights at Point 2 (Cage Boom)** ref ABP page A4

Wind speed (m/s)	Wave height Hs(m) distribution											
	Direction											
	0	30	60	90	120	150	180	210	240	270	300	330
1.03	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.02
2.57	0.03	0.03	0.03	0.03	0.03	0.05	0.11	0.06	0.05	0.05	0.07	0.05
4.37	0.06	0.06	0.06	0.06	0.06	0.09	0.21	0.11	0.09	0.10	0.13	0.09
6.94	0.10	0.10	0.10	0.10	0.10	0.16	0.37	0.19	0.16	0.18	0.23	0.15
9.77	0.15	0.15	0.15	0.15	0.15	0.24	0.57	0.28	0.24	0.27	0.34	0.22
12.60	0.19	0.19	0.19	0.19	0.19	0.32	0.77	0.38	0.32	0.36	0.46	0.29
15.68	0.25	0.25	0.25	0.25	0.25	0.40	1.01	0.48	0.40	0.46	0.59	0.37
19.02		0.31				0.50	1.27	0.60	0.50	0.57	0.73	
22.62						0.61	1.54	0.73	0.61	0.69		
26.47							1.84	0.87	0.73	0.82		
30.58												
32.90												

Table A4.1 **Wind-Wave erosion rates at Point 2 (Cage Boom)**
based on significant waves Hs

bed shear = H x uhsratio x Cbf
erosion rate = bed shear - tawc
negative numbers indicate bed shear less than soil strength

Wind speed (m/s)												
	Direction											
	0	30	60	90	120	150	180	210	240	270	300	330
1.03	-1.53	-1.53	-1.53	-1.53	-1.53	-1.50	-1.45	-1.50	-1.50	-1.50	-1.50	-1.50
2.57	-1.48	-1.48	-1.48	-1.48	-1.48	-1.43	-1.28	-1.40	-1.43	-1.43	-1.38	-1.43
4.37	-1.40	-1.40	-1.40	-1.40	-1.40	-1.33	-1.03	-1.28	-1.33	-1.30	-1.23	-1.33
6.94	-1.30	-1.30	-1.30	-1.30	-1.30	-1.16	-0.64	-1.08	-1.16	-1.11	-0.98	-1.18
9.77	-1.18	-1.18	-1.18	-1.18	-1.18	-0.96	-0.15	-0.86	-0.96	-0.89	-0.71	-1.01
12.60	-1.08	-1.08	-1.08	-1.08	-1.08	-0.76	0.34	-0.62	-0.76	-0.66	-0.42	-0.84
15.68	-0.93	-0.93	-0.93	-0.93	-0.93	-0.57	0.93	-0.37	-0.57	-0.42	-0.10	-0.64
19.02	-1.55	-0.79	-1.55	-1.55	-1.55	-0.32	1.57	-0.07	-0.32	-0.15	0.25	-1.55
22.62	-1.55	-1.55	-1.55	-1.55	-1.55	-0.05	2.24	0.25	-0.05	0.15	-1.55	-1.55
26.47	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	2.98	0.59	0.25	0.47	-1.55	-1.55
30.58	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55
32.90	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55

Table A4.2 **Total erosion based on 1 hour occurances in one year and positive values of erosion rates**
based on significant waves Hs **Point 2 Cage Boom**

Wind speed (m/s)													Total
	Direction												
	0	30	60	90	120	150	180	210	240	270	300	330	
1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12.60	0.00	0.00	0.00	0.00	0.00	0.00	21.70	0.00	0.00	0.00	0.00	0.00	21.7
15.68	0.00	0.00	0.00	0.00	0.00	0.00	16.83	0.00	0.00	0.00	0.00	0.00	16.8
19.02	0.00	0.00	0.00	0.00	0.00	0.00	9.45	0.00	0.00	0.00	0.25	0.00	9.7
22.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.15	0.00	0.00	0.9
26.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.25	0.00	0.00	0.00	0.8
30.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
32.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	48.0	1.3	0.2	0.1	0.2	0.0	49.9
							Annual erosion from wind-waves at Point 2 Cage Boom						Eww2

We see that the total wind-wave erosion at point 2, Eww2 = 49.9 units

17.3.2 Wave erosion factor at Point 13 (mid-channel in Long Reach)

Table A5 **Significant wave heights at Point 13 (Mid-channel in Long Reach)** ref ABP page A4

Wind speed (m/s)	Wave height (m)											
	Direction											
	0	30	60	90	120	150	180	210	240	270	300	330
1.03	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.02	0.01	0.02	0.02	0.02
2.57	0.04	0.04	0.04	0.04	0.05	0.05	0.11	0.06	0.04	0.05	0.06	0.05
4.37	0.07	0.07	0.07	0.07	0.09	0.09	0.21	0.10	0.07	0.10	0.11	0.10
6.94	0.12	0.12	0.12	0.12	0.16	0.15	0.37	0.17	0.12	0.18	0.20	0.18
9.77	0.18	0.18	0.18	0.18	0.24	0.22	0.57	0.25	0.18	0.27	0.30	0.27
12.60	0.23	0.23	0.23	0.23	0.32	0.29	0.77	0.34	0.23	0.36	0.40	0.36
15.68	0.30	0.30	0.30	0.30	0.40	0.37	1.01	0.43	0.30	0.46	0.50	0.46
19.02		0.37				0.46	1.27	0.54	0.37	0.57	0.63	
22.62						0.56	1.54	0.65	0.45	0.69		
26.47							1.84	0.78	0.54	0.82		
30.58												
32.90												

Table A5.1 **Wind-Wave erosion rates at Point 13 (mid channel) based on significant waves Hs**

bed shear = H x uhsratio x Cbf
erosion rate = bed shear - tawc
negative numbers indicate bed shear less than soil strength

Wind speed (m/s)	Frequency of I hour occurrences											
	Direction											
	0	30	60	90	120	150	180	210	240	270	300	330
1.03	-1.53	-1.53	-1.53	-1.53	-1.50	-1.50	-1.45	-1.50	-1.53	-1.50	-1.50	-1.50
2.57	-1.45	-1.45	-1.45	-1.45	-1.43	-1.43	-1.28	-1.40	-1.45	-1.43	-1.40	-1.43
4.37	-1.38	-1.38	-1.38	-1.38	-1.33	-1.33	-1.03	-1.30	-1.38	-1.30	-1.28	-1.30
6.94	-1.25	-1.25	-1.25	-1.25	-1.16	-1.18	-0.64	-1.13	-1.25	-1.11	-1.06	-1.11
9.77	-1.11	-1.11	-1.11	-1.11	-0.96	-1.01	-0.15	-0.93	-1.11	-0.89	-0.81	-0.89
12.60	-0.98	-0.98	-0.98	-0.98	-0.76	-0.84	0.34	-0.71	-0.98	-0.66	-0.57	-0.66
15.68	-0.81	-0.81	-0.81	-0.81	-0.57	-0.64	0.93	-0.49	-0.81	-0.42	-0.32	-0.42
19.02	-1.55	-0.64	-1.55	-1.55	-1.55	-0.42	1.57	-0.22	-0.64	-0.15	0.00	-1.55
22.62	-1.55	-1.55	-1.55	-1.55	-1.55	-0.17	2.24	0.05	-0.44	0.15	-1.55	-1.55
26.47	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	2.98	0.37	-0.22	0.47	-1.55	-1.55
30.58	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55
32.90	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55

Table A5.2 **Total erosion based on 1 hour occurances in one year and positive values of erosion rates based on significant waves Hs** **Point 13 mid channel**

Wind speed (m/s)	Frequency of I hour occurrences												Total
	Direction												
	0	30	60	90	120	150	180	210	240	270	300	330	
1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12.60	0.00	0.00	0.00	0.00	0.00	0.00	21.70	0.00	0.00	0.00	0.00	0.00	21.7
15.68	0.00	0.00	0.00	0.00	0.00	0.00	16.83	0.00	0.00	0.00	0.00	0.00	16.8
19.02	0.00	0.00	0.00	0.00	0.00	0.00	9.45	0.00	0.00	0.00	0.00	0.00	9.4
22.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.15	0.00	0.00	0.3
26.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.4
30.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
32.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	48.0	0.5	0.0	0.1	0.0	0.0	48.6
							Annual erosion from wind-waves at Point 13 mid channel						Eww13

We see that the total wind-wave erosion at point 13, Eww13 = 48.6 units

17.3.3 Erosion factors from C-Class ferries

Basic calculation

Assumed speed of ferry = 3.0 m/s
Length of ferry = 55.5 m
Time above a point in river = 55.5/3 = 18.5 seconds
Number of journeys per year = 22500
Only allow for journeys + or – 1 hour each side of low water
So effective journeys p.a. = 22,500/6 = 3750
Therefore, annual erosion time = 3750 x 18.5 seconds
= 19.3 hours

Backflow effect

Backflow velocity (BMT Seatech, Fig 14: ref . 2) = 0.72 m/s

Bed shear from backflow = 0.72 x Cbf = 2.9 N/m^2
Net shearing force = 2.9 – τcrit = 1.33 N/m^2
So erosion factor = 1.33 x 19.3 = 25.7 units

Drawdown effect
Drawdown velocity (HR Wallingford: ref. 3) = 1.08 m/s
Bed shear from drawdown = 1.08 x Cbf = 4.3 N/m^2
Net shearing force = 4.3 – τcrit = 2.77 N/m^2
So erosion factor = 2.77 x 19.3 = 53.5 units

Thruster jet effect
Ave jet vel.on sea bed (BMT Seatech, Table 3: Ref 2) = 1.6 m/s
Bed shear from thruster jets = 1.6x Cbf = 6.4 N/m^2
Net shearing force = 6.4 – τcrit = 4.85 N/m^2
So erosion factor = 4.85 x 19.3 = 93.6 units

Total erosion factor for C-Class = 25.7 + 53.5 + 93.6 = 171.8 units

Erosion ratio for C-Class compared to wind-waves
Average wind-wave factor for points 2 and 13 = (49.9+48.6)/2
= 49.25
C-Class erosion ratio = 171.8/(171.8+49.25) = 0.77

This tells us the C-Class ferries contribute 77% of the erosion measured near Point 2 and Point 13 (Cage Boom and Western side of Long Reach)

17.3.4 Erosion factors from W-Class ferries

Basic calculation
Assumed speed of ferry = 3.0 m/s
Length of ferry = 62.4 m
Time above a point in river = 62.4/3 = 20.8 seconds
Number of journeys per year = 22500
Only allow for journeys + or – 1 hour each side of low water
So effective journeys p.a. = 22,500/6 = 3750
Therefore, annual erosion time = 3750 x 20.8 seconds
= 21.7 hours

Backflow effect
Backflow velocity (BMT Seatech, Fig 14: Ref 2) = 0.1.03 m/s
Bed shear from backflow = 1.03 x Cbf = 4.12 N/m^2
Net shearing force = 4.12 – τcrit = 2.57 N/m^2
So erosion factor = 2.57 x 21.7 = 55.8

Drawdown effect
Drawdown velocity (+80% BMT) = 1.94 m/s
Bed shear from drawdown = 1.94 x Cbf = 7.78 N/m^2
Net shearing force = 7.78 – τcrit = 6.22 N/m^2
So erosion factor = 6.22 x 21.7 = 133.8 units

Thruster jet effect
Ave jet vel.on sea bed (+10%BMT) = 1.76m/s

Bed shear from thruster jets = 1.76 x Cbf = 7.04 N/m²
Net shearing force = 7.04 – τcrit = 5.49 N/m²
So erosion factor = 5.49 x 21.7 = 119 units

Total erosion factor for W-Class = 55.8 + 133.8 + 119 = 308 units

Erosion ratio for W-Class compared to wind-waves
Average wind-wave factor for points 2 and 13 = (49.9+48.6)/2
= 49.25 units
W-Class erosion ratio = 308/(308+49.25) = 0.86

This tells us the C-Class ferries contribute 86% of the erosion measured near Point 2 and Point 13 (Cage Boom and Western side of Long Reach).

17.4 Sensitivity of assumptions

There was some scatter in the values obtained by HR Wallington in 1991, for the soil shearing strength and for the water velocity that was measured to trigger erosion of their samples.

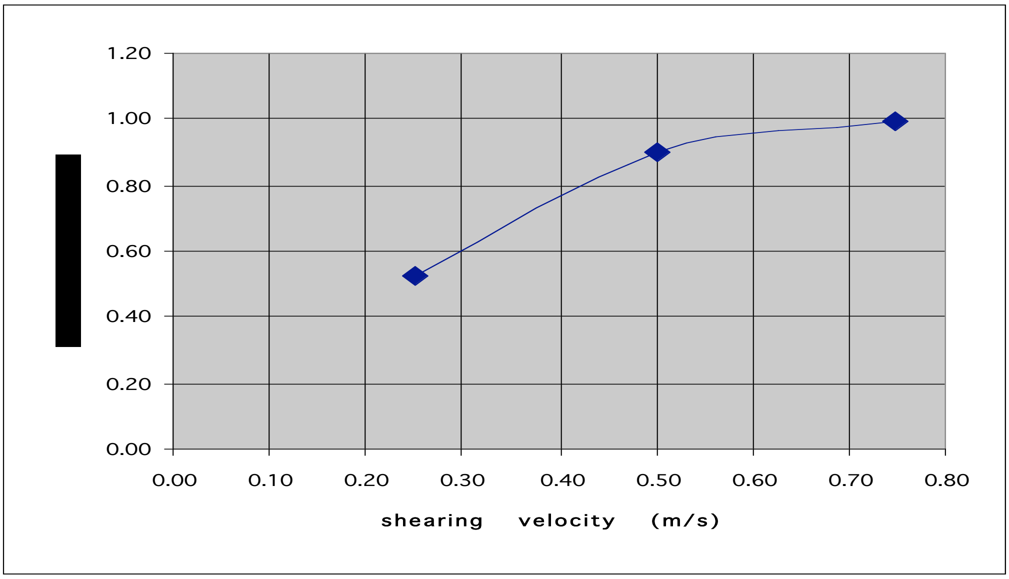
So we carried out a simple sensitivity study to investigate how the value of the erosion ratio would change if we altered the assumed value of soil shear strength and the value of minimum water velocity necessary to trigger shear failure.

Soil shear strength variation
With minimum shearing velocity held constant at the adopted design value of 0.39 m/s, we varied the soil shear strength between its minimum and maximum measured values (1.1 to 2.0 N/m²). Although the individual erosion factors altered, we found that the percentage of the total damage caused by the ferries remained unaltered at 77% for C-Class ferries.

Water shearing velocity variation
Keeping the average shear strength value of 1.55 N/m² constant, we next altered the assumed minimum shearing velocities between 0.25 m/s and 0.75 m/s. At the lowest value, we found that the percentage of erosion caused by the ferry decreased to 53% of the total but increased to 90% at 0.5 m/s. If the value increased to 0.75 m/s, we found that the ferry would contribute 99% of the erosion (see graph below).

The explanation for this is instructive and leads to an understanding of the mechanism of erosion. Ferry peak velocities, particularly for thruster jets, exceed the velocity of water particles caused by the waves. In the navigation channel most Solent waves are too small to cause erosion of the mudflats, whilst the ferry causes damage on each journey, particularly near low tide.

At the mean value of shearing velocity of 0.39 m/s the percentage of erosion caused by the C-Class at Cage Boom is 77%.



17.5 Conclusions on the relative effects of ferries and wind-generated waves on causing erosion near Cage Boom

This calculation is in marked contrast to the energy ratio calculation carried out by ABPmer.

ABPmer did not establish a relationship between wave energy and the velocity of water caused by waves at sea bed level causing bed shear, nor on the shear strength of the inter-tidal mudflats. As a result the contribution of waves causing erosion was greatly exaggerated in their calculation. Likewise, for ferry-generated energy they only considered the effects of bow and stern waves, which were in any case too small to cause bed erosion. The effects on erosion of backflow, drawdown and thruster jets were not included in the erosion calculation. Our conclusion is that the results shown in ABPmer's Table 6 are both incorrect and misleading, so should be set aside.

We consider that the calculation performed above provides a more reliable guide to the relative erosion caused by the ferries compared with the wind-generated waves. But this calculation also contains approximations and assumptions.

The sensitivity of answers to assumed values of soil strength and water shearing velocity were discussed above and shown not to affect the damage ratio to a great extent.

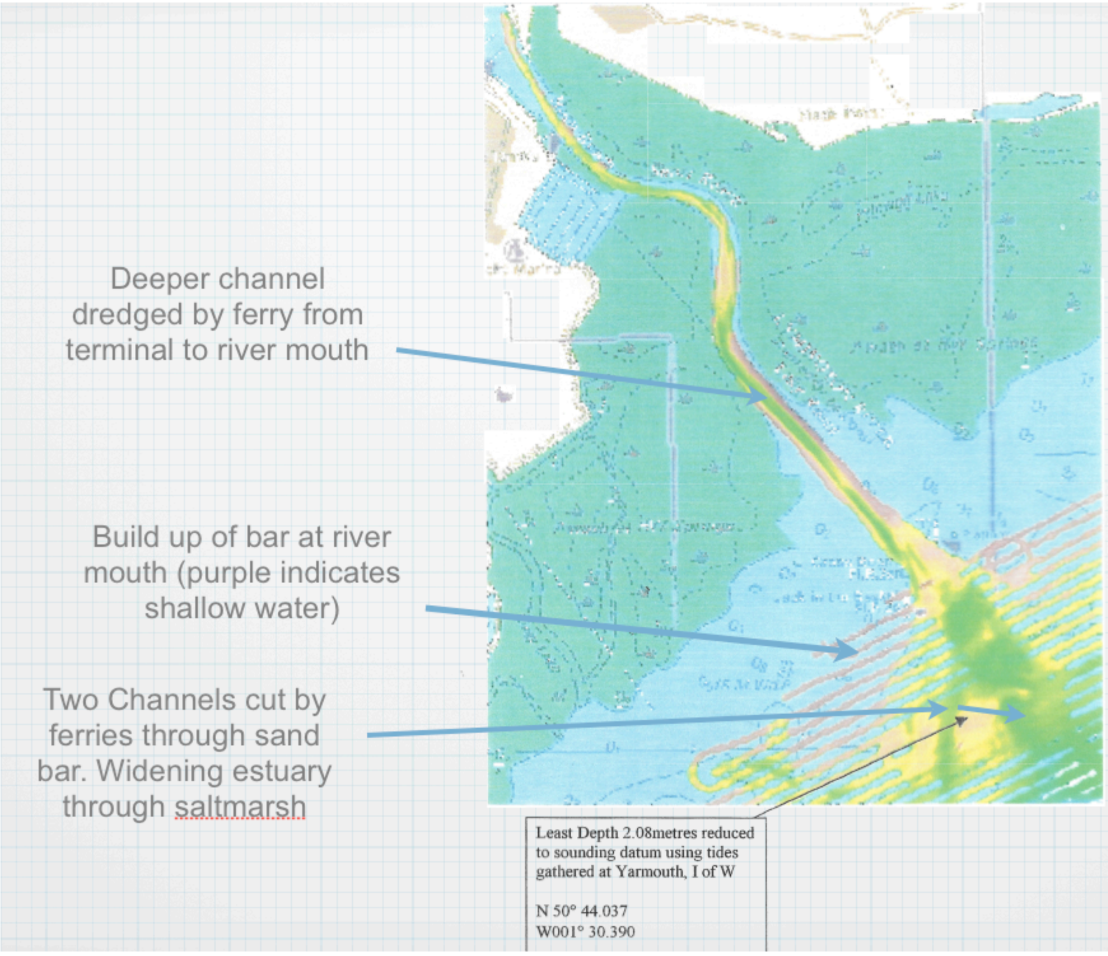
An important issue that the calculation reveals is the importance of the thruster jet velocity profile on the river bed and banks. Figure 20 in ABPmer's report appears to show water velocities from 4m/s to 8m/s near the thrusters. The maximum velocities on W-Class thruster jets are said to be 10% greater than on C-Class but the mass flow is 65% greater and the units are lower in the water. Therefore we might expect the rate of erosion caused by thrusters to be 80% to 90% greater than in C-Class.

This difference has not been included in the above calculation because of insufficient data available from Wightlink and Voith-Schneider.

18. Long-term adverse effects caused by deepening of the river by ferries.

We have seen evidence from the sub-tidal bathymetric profiles in section 16 that the ferry has caused the sub-tidal volume to increase by 27%, the area of the navigation channel at CD to widen by 36% and the average depth to increase by 1.5 metres in the period between 1988 and 2006, in the stretch of river between Cage Boom and Posts 5 and 6.

The sonar trace reproduced below shows the Lymington River sand bar in the estuary and where east and west tracks have been cleared by the ferries. The two tracks are caused by ferries laying off their course to and from Yarmouth to allow for east- or west-flowing Solent tides.



Deeper channel dredged by ferry from terminal to river mouth

Build up of bar at river mouth (purple indicates shallow water)

Two Channels cut by ferries through sand bar. Widening estuary through saltmarsh

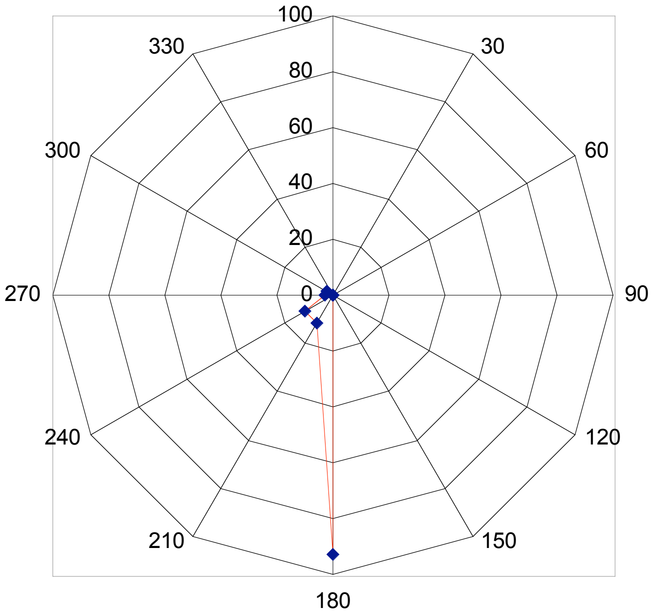
Least Depth 2.08metres reduced to sounding datum using tides gathered at Yarmouth, I of W

N 50° 44.037
W001° 30.390

These pieces of evidence show that the C-Class ferries have partially breached the Lymington estuary mudflats, which protect the river and harbour from larger Solent waves.

To illustrate the effect of the breach we show below the frequency distribution of significant wave heights Hs that arrive at Point 2 Cage Boom, after values of Hs<0.5m have been filtered out. This is the plot from Table AA3 in section 14.2.1 (c). The distribution only shows waves that are large enough to cause bed erosion. 77% of the wave energy is aligned with the widened river bearing 180 degrees. A further 9%

comes from direction 210 degrees and another 9% from the prevailing wind direction of 240 degrees. This can be compared with the Lee-on Solent wind frequency distribution that showed its peak energy from 240 degrees (Refer to Figure A1 in ABPmer's document). It vividly demonstrates the effectiveness of the mudflats in protecting Lymington harbour, except where they have been partially breached by the deepened and widened channel eroded by C-Class ferries.



Spectrum of 'filtered' wave energy at Point 2, Cage Boom
For Hs>0.5m (from section 5.5.4, Table AA3)

It is important that the Regulators should recognise that most of the recent so-called 'natural' wind-generated wave erosion has in fact been caused by the ferries, which have deepened and widened the river since 1973.