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Ferry Operations at Lymington, Phase 1: The Present Situation and Future Predictions

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FERRY OPERATIONS AT LYMINGTON, PHASE 1: THE PRESENT SITUATION AND FUTURE PREDICTIONS

Prepared by ... **Checked by ......**

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EXECUTIVE SUMMARY

It is proposed to introduce new ferries on the Lymington/Yarmouth route. As part of this process it is important that any change in the marine risk on the route is as low as reasonably practicable. This consideration is especially important in the Lymington River as it is a waterway with a large number of leisure users, especially at the height of the sailing season. With this in mind, BMT SeaTech Ltd (BMT) was commissioned by the Lymington Harbour Commissioners (LHC) to carry out a risk assessment for the introduction of the new ferries.

The study falls naturally into two parts:

- Phase 1: An assessment of the present situation with informed predictions of the situation with the new ferries
- Phase 2: A re-assessment of the situation after initial trials with the new ferries.

This report deals with Phase 1 of the overall study. It discusses the present situation on the river and lists the concerns of local users regarding the introduction of the new ferries. With these in mind, the design of the new ferries is then discussed in some detail and their possible impact on operations is predicted. The effect of the present international intact and damaged stability requirements as a primary driver in the design of the new ferries is discussed, and the way that this has led to the hulls of the new vessels being the size and shape they are is described.

The present level of marine risk on the river then assessed and, in terms of the incidents per vessel movement, the historical value is found to be very low, implying that the present safety levels are high. A Risk Register is proposed which combines risks and their magnitudes with suitable control measures. Arising from this, it is concluded that, at times when the river is congested with leisure and other craft, an increased presence of LHC patrols in the lower reaches would be beneficial to all concerned.

In order to provide a further basis for comparison in Phase 2, measurements of water disturbance caused by the ferries and other craft were made at two locations on the river – one in the vicinity of the passing place in Short Reach and one in Horn Reach. The ferries and a self-propelled dredge barge created their own characteristic disturbance patterns, as did smaller vessels such as work boats, fishing vessels and RIBs. Natural waves were also measured during a period of reasonably high winds from a direction somewhat to the north of that which prevails in the area, resulting in some shelter from the wind and a reduced fetch. Nevertheless such waves were in general higher than those produced by the ferries and other boats, although one fishing vessel produced large free waves.

Although it is made clear that the final assessment of the actual impact of the new vessels must await the completion of the trials in Phase 2, an attempt is made to predict the orders of magnitude of some of the effects the new ships could have on leisure users. From this, and with the information presently to hand, we are of the opinion, at this stage, that there is no need for leisure craft risk control measures which are any more demanding than those presently in place. This is especially so in Horn Reach where most of the Junior Sailing takes place; indeed we see no need for the new ferries to reduce their speed from the advisory 4 knots in this part of the river, thereby causing no additional disruption to Junior Sailing activities there. However, some aspects of operation and

behaviour with the new ferries have been identified as requiring special attention in the Phase 2 trials.

It is, however, concluded that the present practice of ferries waiting in the river should be abandoned where practicable, with the norm being unhindered passing.

In conclusion, therefore, the following recommendations are made:

- Make ferry waiting in the river the exception and unhindered passing the rule
- In peak season, increase the Harbour Master's patrols in Short Reach, especially near the passing place
- Ensure that ferries continue to make sound signals on leaving the terminal when junior sailing is in progress, and make it common practice to give similar signals when inbound at the Cocked Hat navigation post.
- Ensure that the navigation posts in the river mark the limits of the navigable channel and provide a visual indication of the channel in all conditions, including fog.
- Install visual tide boards on navigation posts
- Ensure that a structured programme of trials is undertaken with the new ferries. (A preliminary template for such trials is suggested in the report)

FERRY OPERATIONS AT LYMINGTON. PHASE 1: THE PRESENT SITUATION AND FUTURE PREDICTIONS

1. Introduction

It is proposed to introduce new ferries on the Lymington/Yarmouth route. As part of this process it is important that any change in the marine risk on the route is as low as reasonably practicable. This consideration is especially important in the Lymington River portion of the route as it is a waterway with a large number of leisure users, especially at the height of the sailing season. With this in mind, BMT SeaTech Ltd (BMT) was commissioned by the Lymington Harbour Commissioners (LHC) to carry out a risk assessment for the introduction of the new ferries.

The study falls naturally into two parts:

- Phase 1: An assessment of the present situation with informed predictions of the situation with the new ferries
- Phase 2: A re-assessment of the situation after initial trials with the new ferries.

Based on the combined results of both parts of the assessment, recommendations will be made regarding safe operation of the new ferries bearing in mind the safety of all river users.

This report deals with the first phase of this study – an assessment of the present situation together with estimates of the effects the new ferries may have in the river. This will be used as a baseline against which to judge the effects of the new ferries on completion of their sea trials on the route, before operations commence.

2. Aims and Scope

2.1 Aims

The main aims of the whole study are given in the Terms of Reference (see Appendix 1) and may be summarised as follows:

- Review of Previous Study Work
- Provision of a methodology for measuring impacts on risk using field measurements and sea/river trials
- Risk Assessment for the existing situation (Phase 1) as well as that associated with the new vessels (Phase 2)
- Provision of reports on both phases of the study. The Phase 1 report is to include recommendations as to likely control or mitigation measures necessary for the operation of the new vessels, based on estimates and detailed investigations of available material. This is to be provided prior to the trials so that concerned users can better understand the implications of the introduction of the new ferries on operations in the river.

2.2 Scope

The scope of the study is fairly wide and encompasses:

- The ferry operation between Lymington and Yarmouth
- Measurements of water level changes and flow due to the ferries, other vessels, weather conditions and tidal action.
- Operations with both existing and new ferries.
- Liaison with all parties with an interest in the ferry operation.

3. Definitions

In this report a number of terms are used which are best defined at the outset to avoid confusion. These are:

Wash – wash is defined as the disturbance to the water surface from vessel waves. All vessels create two forms of waves - a free wave system and a local, or Bernoulli, system. The former comprises waves commonly seen with all vessels as the characteristic wave pattern, while the latter is usually most often apparent in shallow water where it is encountered as a local lowering of the water surface around a vessel, the lowest point amidships.

Backflow – when a ship moves in water it induces flow velocities over its hull, some of which are greater than its speed through the water. This effect is enhanced in shallow water and may be seen as an additional current in the water close to the ship. This is called *backflow*.

Slipstream – a slipstream is a jet of water produced by an active propeller or thruster. Its effect is seen in the wake of a vessel.

Voith Thrusters – these are a special form of propulsor used when excellent manoeuvrability and control is required, often in shallow and confined waters. They consist of a rotating circular base set in the hull, from which protrude a number of vertical hydrofoils, or blades. The incidence angle of these blades can be changed during a revolution (rather like the blades on the paddle wheels of the early steam ferries on the Lymington/Yarmouth route which ensured they entered the water vertically with least disturbance). By changing the incidence of the blades as the thruster rotates, sideways “lift” forces are produced, in an action similar to that of a helicopter rotor. Adjustment to the control of this incidence allows the thrust from these lift forces to be adjusted in azimuth thereby providing fine control of both manoeuvring and propulsion.

Batter – an outward inclination to the sides of the body sections in the parallel middle body of a hull. Effectively, batter is the opposite of tumblehome.

Parallel Middle Body – that area of the flat hull side where the beam is constant.

Ro-ro – “roll on-roll off”. A vessel on which vehicular traffic can drive on and drive off, and trailers can be rolled on and rolled off.

Drawdown – The lowering of the water level amidships from the local wave system is seen, for example, on the banks of a waterway as a “drawdown”. In severe cases it can erode the bank, by producing breaking free waves as the water level recovers. It is of interest to note that drawdown is closely related to squat and the magnitude of drawdown gives a good indication of the magnitude of squat.

Skeg – a short fixed fin or keel, usually in the after part of a hull, used to improve directional stability.

Directional stability – the tendency of a vessel when moved off course to settle on a new steady course. Generally used to describe the tendency of a ship to stay on course without the need for excessive control action.

ALARP – As Low As Reasonably Practicable. This principle relates to the mitigation of risk and aims to make the residual risk so low that the cost involved in reducing it further would be grossly disproportionate to the benefit gained.

Squat – when a floating body moves ahead in calm water, the hydrodynamic pressure changes over its hull combine to cause the vessel to sink and trim from its at-rest attitude. This combination of sinkage and trim is referred to as *squat*.

Navigable Channel – a navigable channel is one that is safe to navigate. This must take into account:

- Vessel size, speed and inherent manoeuvrability
- Available water depths which combines soundings and height of tide. At Lymington a maintained sounding depth of 2 metres is kept in the channel.
- Squat and any other vertical movements due to wave action
- An allowance for the effects of winds and currents along and across the channel.
- The presence of banks and bank type, because of so-called “bank effect”
- The need for vessels to pass and the provision of sufficient width to avoid the effects of “ship-ship interaction”

Bank Effect – when a vessel passes close to a bank, the pressure changes over its hull caused by the bank can draw it toward the bank while at the same time turning it away. In severe cases the vessel can sheer away from the bank.

Ship-ship interaction – when two vessels pass each other, the underwater pressure field around one will interact with the pressure field around the other. The changes in behaviour this induces can cause the vessels to move away from their intended course; in severe cases, control can be lost. This is less likely in reciprocal (“head-on”) passing than in overtaking because the pressure forces and moments on the vessel have less time to act on each vessel and cause a change in behaviour.

Leisure craft – by this is meant all vessels used for recreational purposes and not engaged in commercial or LHC work on the river. They may be sail or motor powered, and some sailing vessels may have auxiliary power. It is recognised that some yachts and dinghies sailing in the river do so with no auxiliary power.

Amplitude – when referring to waves, is half the wave height.

4. The ELP Report

The report from Eagle Lyon Pope (ELP) in December 2006 regarding the introduction of the new ferries (Reference 1) has been reviewed by one of the BMT study team who is a Master Mariner.

The overall impression is that the report is satisfactory. Its overall conclusions and recommendations are confirmed in general, although it is appreciated that things have moved on since it was written. For example, ferry speeds over the ground are now monitored and there is now good adherence to the statutory and advisory speed limits. However, having had the opportunity to travel on the ferries and interview a number of their masters, the following points have arisen with regards to detailed navigational points raised in the ELP report:

- In paragraph 7B, the cessation of mooring small craft on the west side of Short Reach and Long Reach is recommended. At first sight this seems a sensible recommendation, given the low water restrictions, but, the view of the Masters is that the boats moored on these buoys only pose a problem at low water in periods of strong westerly winds. Furthermore, the line of buoys provides a useful visual cue when navigating the channel in thick fog. In addition, when it is really windy, small sailing craft generally do not use the river.
- In page 4, speed limits are mentioned. For the new vessels, this will be an issue to be resolved after their trials, but the Masters' view is that any speed reduction from the present values will be unnecessary. At present, when the tide is low, ferries may move at lower speeds in any event, partly through navigational prudence and partly due to hydrodynamic effects on their resistance. We see no need to change present practice with the new ferries.
- On page 10, the question of passing is addressed and it is stated that the passing place "…cannot be considered as a generous width". The Masters do not see passing at the designated place as a serious issue. They believe that the similarity in dimensions of the new ferries to those of the old means that the standard of care required with the new vessels will be about the same as at present. (see Section 7.3.5 below)
- In page 11 (para 2.5.2) current magnitudes in the river are mentioned. One Master agreed that 1.5 knots might be experienced just after a spring high water and thought that the 0.5 knot value often mentioned, while generally correct, did not represent the maximum. In passing, the navigational challenges from current are much greater at Yarmouth than anywhere in the Lymington River.
- In paragraph 2.5.3 on the same page, wind speeds are mentioned and it is noted that small boats are unlikely to be sailing in strong winds. In this study, strong winds are assumed to be those of BF6 and above.
- Regarding potential incidents with small boat proximity to the ferries (para 2.6.5 on page 12), the Masters are conscious of the potential hazards when this occurs. Given the option of bridge wing manoeuvring position on the new ferries, there may be an issue with visibility of small craft hidden on the other side of the vessel. A remedy, put forward by one Master, was to post an extra lookout when passing through congested areas.
- In paragraph 2.6.6, the question of wash is raised and the low incidence of wash-related events is mentioned. Observations suggest that natural wind-driven waves are more likely to be a cause of bank erosion than ferry wash, especially in periods of strong westerly winds.
- In pages 15 to 20 a description of a ferry trip is given. There is some discussion on the mooring buoys in the passing region and the encroachment on to the navigable area by moored craft swinging on these moorings is demonstrated. There was general concern among the Masters interviewed by the present study team regarding this encroachment in high westerly winds and at low water. This is regarded as the main navigational issue in the passing area, especially at low water springs, and is one which needs some attention in this study.
- Section 4.4 of Reference 1 relates to ferry speeds. Since this report was written, there is now good adherence to the speed limits of 4 and 6 knots; these will be reviewed once trials with the new ferries have been carried out.

5. The Present Situation

5.1 The Route

The ferry route from Lymington to Yarmouth is some 3.4 nautical miles long, of which about 1.4 nautical miles (or 41%) is in the Lymington River (see Figure 1). In terms of time, about 50% of the journey is spent in the river, unless the ferry has to wait. It is a shuttle service and the ferries, being double-ended, have no need to swing at the berth in normal service.

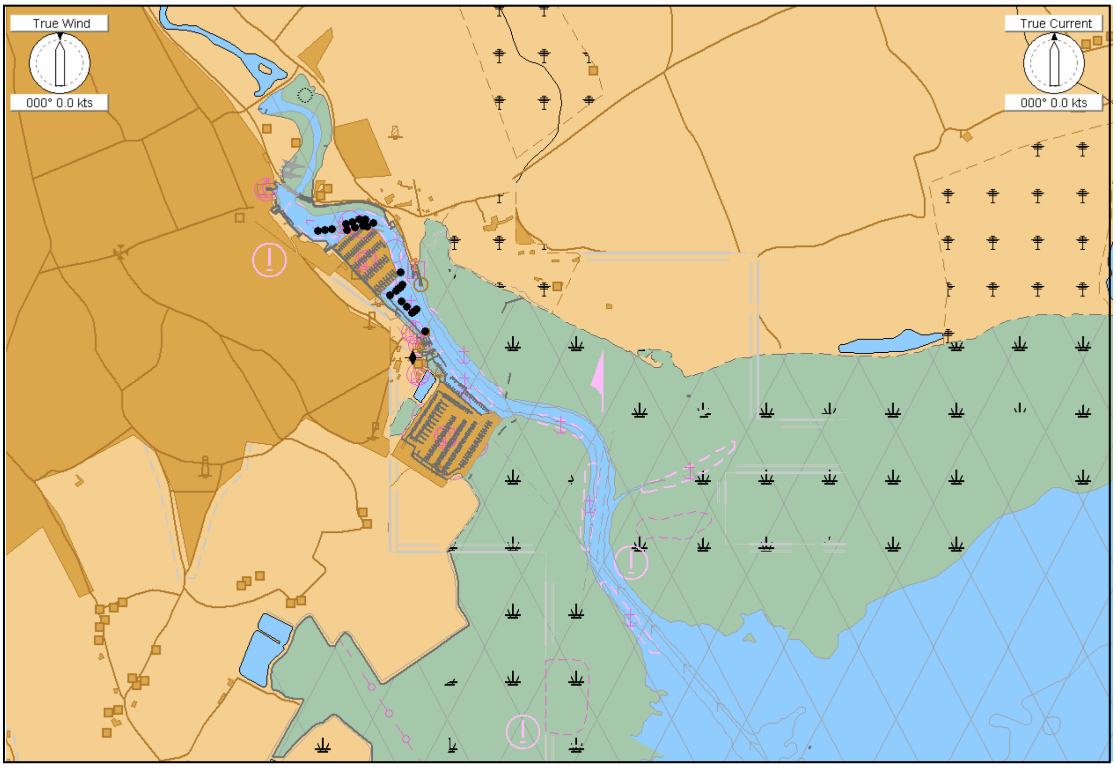


Figure 1: The Lymington River

The river is shallow and marked by a number of piled beacons or navigation posts. Its banks and bed are mud and it has three bends at the Tar Barrel and Cocked Hat navigation posts and at the wave screen near Harper's post.

The river is popular with, and much used by, leisure users whose boats are located in various mooring areas near the town and in the river. The users form a very active population and there is considerable leisure traffic along, and sometimes across, the river in the sailing season which extends, in terms of activity, from roughly March to November.

Large vessels such as the ferries and some large motor yachts, together with many of the marina-based yachts, use the deep water channel which runs roughly down the middle of the river as defined by the navigation marks. However, at very low water, the river banks can dry out, thereby confining users to a waterspace which is notably more restricted than at high water. There is an area in the section of the river known as the 'layby' in Short Reach where ferries can pass and, in some circumstances, wait. In bad weather, waiting may also occur in the Solent, off the river mouth.

Salt marshes border the river and provide protection from wave activity from the prevailing south westerly direction as well as from the north and east. These marshes are eroding.

5.2 Navigation Marks

The channel in the river is defined by its aids to navigation. They consist of posts to delineate the channel and two pairs of fixed leading marks to define the tracks of inbound and outbound vessels in the passing region near the Enticott and Pylewell Boom posts.

The following posts dry out at very low water, close to chart datum:

- Enticott
- Bag of Halfpence
- Seymours
- The “outbound” leads

It also appears, from the same source, that the Seymours and Bag of Halfpence posts are some way to the west of the navigable channel.

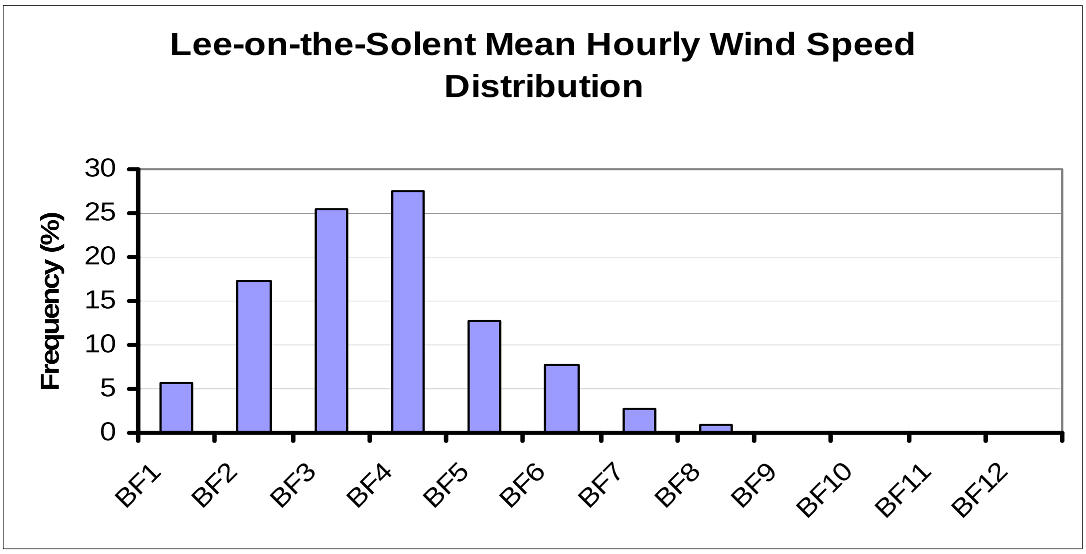
5.3 Metocean Considerations

Wind

The prevailing wind is predominantly from a south-westerly direction as shown in Figure 2 which is derived from wind data for Lee-on-the-Solent. These winds will vary their direction along the coast but will generally be felt as beam winds by users of the lower reaches of the river.

Waves

The river is protected from the larger waves in the Solent by the salt marshes mentioned above. There are, however, wind-generated waves experienced in the lower reaches and, in severe weather, these may affect smaller craft. The wave screen in the vicinity of Harper’s post protects Horn Reach from significant wave effects.



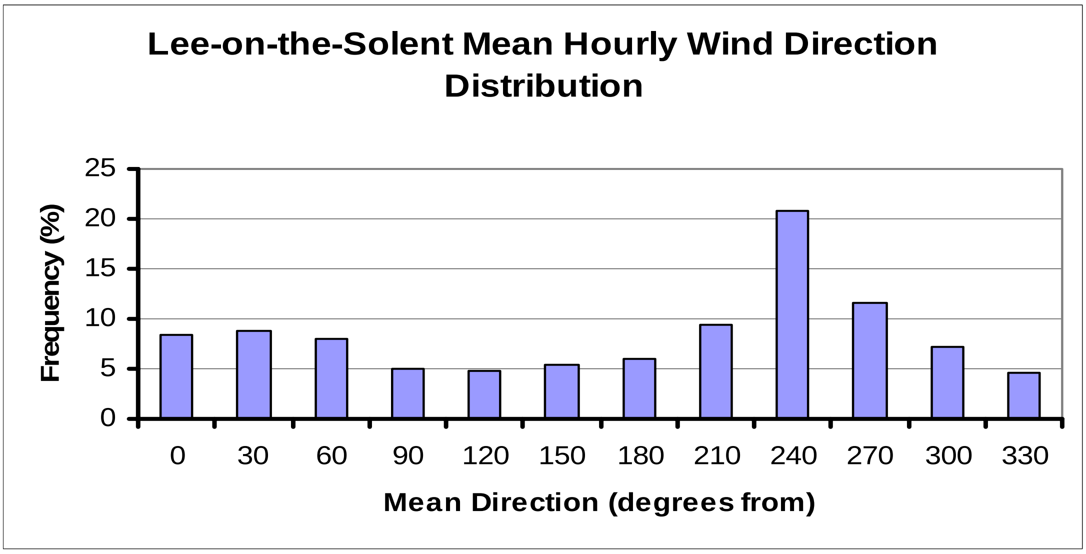


Figure 2: Mean Hourly Winds (based on 12 months of data)

Current

Few measurements of current exist for the river and a number of estimates had been made in the past as to its strength. Some measurements of tidal flow and direction were therefore carried out as part of the Phase 1 study. Details are given in Appendix 2 and the results indicate that, during the January measurement period (when a spring tide of 2.63 metres range was experienced), the maximum flow in the channel near the Pylewell Boom navigation post was 1.1 knots, while that measured in Horn Reach on a similar tide was 0.33 knots. The latter result suggests that overground speed in Horn Reach is very similar to speed through the water. It should also be noted that the measurements indicated that flow velocities at other states of the tide at both locations were also very low for much of the time, indicating that speed overground, as measured by the LHC AIS equipment, will be a reasonable measure of ferry through-water speed in the whole river most of the time. However, in order to determine the effect of, say, a 0.6 knot increase in speed through the water, as opposed to measured speed over the ground, it is proposed that trials in Phase 2 be run at speeds in excess of 6 knots through the water.

5.4 Bathymetry in the Lymington River

A bathymetric survey of October 2006 (Reference 2) extends from the Lymington Terminal to an area in the Solent about 600 metres to seaward of the Yacht Club Starting Platform. Plots are given in Appendix 3.

Soundings are shown, together with various depth contours, one of which is set to the draught of the ferries. This contour shows a navigable channel at LAT about 44m wide east of the wave screen, 64m wide where the ships pass and about 54m in Long Reach. It is not clear whether the soundings have been interpreted to indicate the nautical bottom (due to the uncertainties in determining the actual navigable bottom in certain types of mud), but these depths appear to be adequate for ferry operations at all states of the tide.

It is noted that in the passing region, the ferries have cleared deeper areas in line with the leads, there being a noticeably shallower patch between these, roughly in the middle of the overall channel, of about 2.3 to 2.8 metres BCD. Elsewhere the soundings vary between 3 and 4 metres until depths increase to about 6.5 metres some 1200 metres to seaward of the Yacht Club Starting Platform.

Finally, it may be seen that the local depth in the terminal area, close to the Linkspan, shows soundings increased to 4.2 metres compared to neighbouring values of around 3 metres. It is assumed this is due to scouring from the ferry thrusters remaining active while the vessel is berthed. Deeper scour pits are apparent at the layby berths where the ferries lay up overnight, the pits presumably indicating the effect on the river bed of the ferry thrusters when manoeuvring in and out of the berth and running up the engines (and thrusters) each morning before the first service. Similar scouring effects have been noted at Yarmouth where the associated accretion at the sides of the pits is causing some concern.

5.5 Tides

Tides at Lymington are characterised by:

- A double high water (as at nearby Southampton) in which the double high waters are often subsumed into a stand of about two hours duration.
- A short ebb of about 3.5 to 4 hours duration at springs and neaps
- A longer flood of about 6 hours at springs and neaps. Sometimes a short stand occurs at about half flood.

Figure 3 shows a typical tide curve measured on 23 January 2008.

Tidal levels for Lymington are available on www.channelcoast.org, the measurements being obtained from the yacht clubs' starting platform at the mouth of the river.

Comparisons with predictions from the Proudman Oceanographic Laboratory show that the high and low water levels are sensitive to barometric pressure, set-up from strong and persistent south west winds and, no doubt, local surges in the Solent and adjacent waters. Of these the effect of barometric pressure seems to be the most significant because the corrections for pressure given in the Southampton tide tables, work well at Lymington as Figure 4 shows.

The relevance of this is that it is not uncommon to experience low water values at or below the chart datum of Lowest Astronomical Tide (LAT) due to atmospheric pressure effects; for example, lower than predicted levels at low water are encountered in periods of high pressure. When shallow water effects are considered below and in the trials in Phase 2, this will be borne in mind.

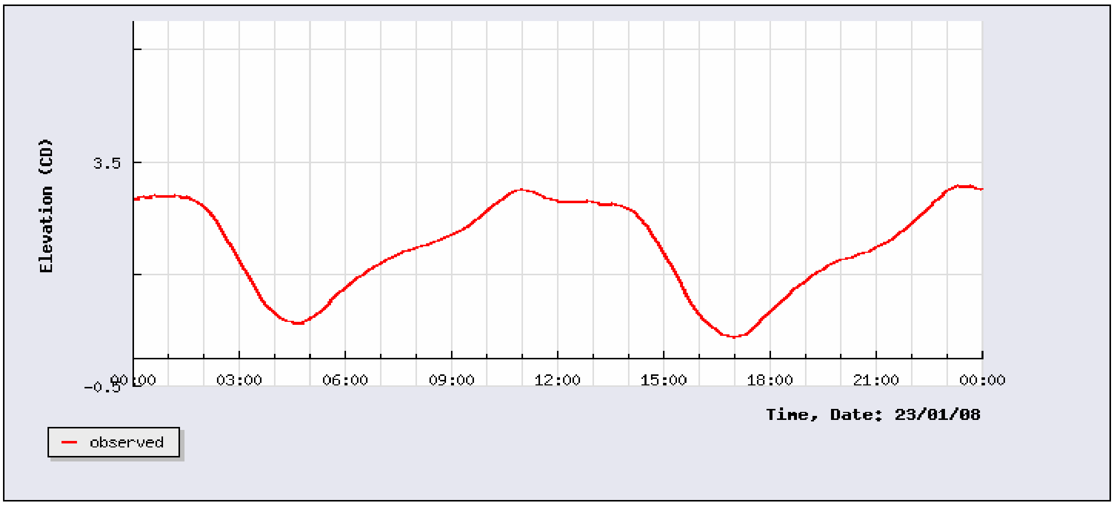


Figure 3: Measured Tide at Lymington on 23 January 2008

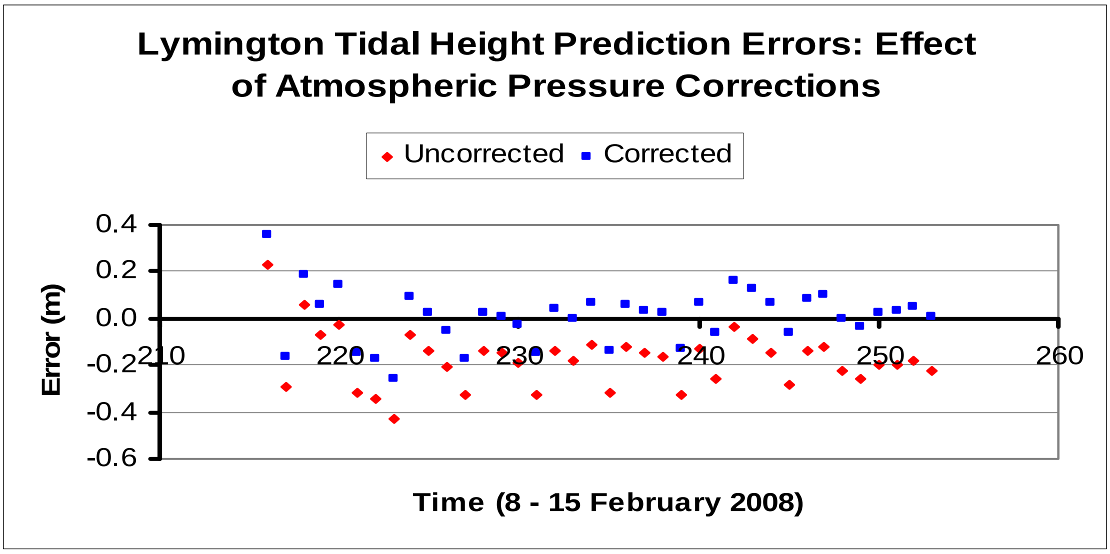


Figure 4: Effect of Atmospheric Pressure on HW and LW Prediction Errors at Lymington

5.6 Ferry Operations

Over the main season it has been the practice to operate a three boat service on a half hourly schedule. In the winter months a two boat operation is used on a schedule which is a mix of half and one hourly departures (referred to here as a "mixed" schedule).

The ferries are required to adhere to a statutory 6 knot through-the-water speed limit in Long and Short Reaches, after which there is an advisory 4 knot limit in Horn Reach. LHC have been able to monitor speed over the ground by means of AIS signals transmitted by the ferries.

The consequence of this operational profile is that the ferries pass in the river when on a three-boat operation, or on the half hour component of the mixed schedule. The reasons for this are illustrated in Figures 5 and 6

These Figures show time/distance plots of ferries operating a shuttle service from Lymington to Yarmouth and back; time is in hours and distance in nautical miles from the Lymington terminal. The frequency of the service is set at the appropriate value and the speed profile matches the speed limits in the river with, in the cases shown, 8 knots allocated for the Solent passage, in accord with observations made on a number of ferry crossings and common practice with the C-class for the past 35 years. Figure 5 shows a three boat operation on a half-hourly schedule with each boat's time/distance line shown by a different colour, blue for the first, then red, then green. The model predicts a dwell time of about 10 minutes at the berth at both Lymington and Yarmouth, and a journey time of about 36 minutes.

This "perfect world" model accords reasonably well with observations and timings made on a number of crossings, although the start-to-stop time is usually close to 32 minutes in reality with a dwell time of around 13 minutes, including about 2.5 minutes for ramp operation on arrival and departure.

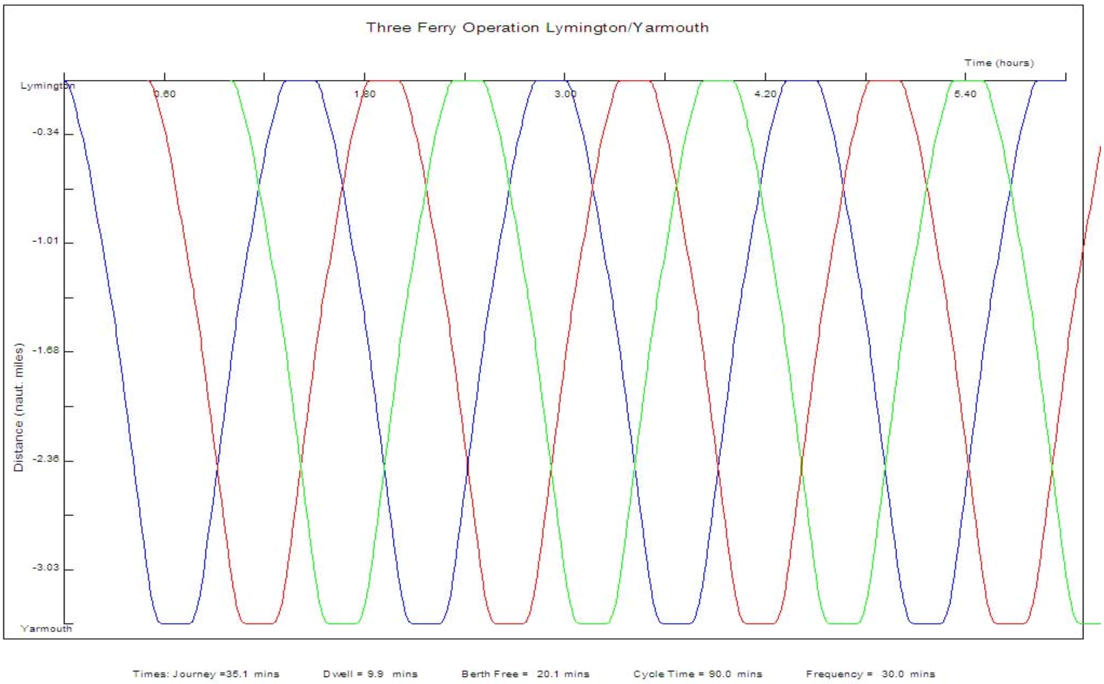


Figure 5: Three Boat Ferry Operation

Where two time/distance lines of different colours cross indicates the time and distance from the Lymington terminal at which two vessels are in nominally the same patch of water: in such a circumstance, they must pass each other.

It is seen immediately from Figure 5 that a consequence of the operation of a three-boat, half-hourly schedule is an unavoidable need to pass twice, once in the Solent (some 2.4 nautical miles from the Lymington terminal) and once some 0.6 nautical miles from the terminal, near the location of the Pylewell navigation post, in the designated passing area. Observations show that when the mixed schedule is in use, the half hour sections again lead to passing in the river.

For illustration, Figure 6 shows a two-boat operation on a 45 minute schedule with the speed profiles used for Figure 5; passing is predicted to take place only in the Solent, just off the mouth of the river. Journey and dwell times are the same as for a three boat service as a consequence of the same speed profile being used. It may be noted that a strict half hour schedule cannot be maintained with a two boat service running with the speed profiles common on the Lymington/Yarmouth route.

The conclusion to be drawn from these plots is that the passing locations are a consequence of the:

- Number of ferries
- Schedule
- Route length
- Speed profile
- Required dwell time at the berth.

If, however, other operational matters intervene to delay the departure or arrival of a ferry at Lymington, the schedule may be disrupted. The consequence of this is that the inbound boat may arrive in the river too early, so that it will be at the

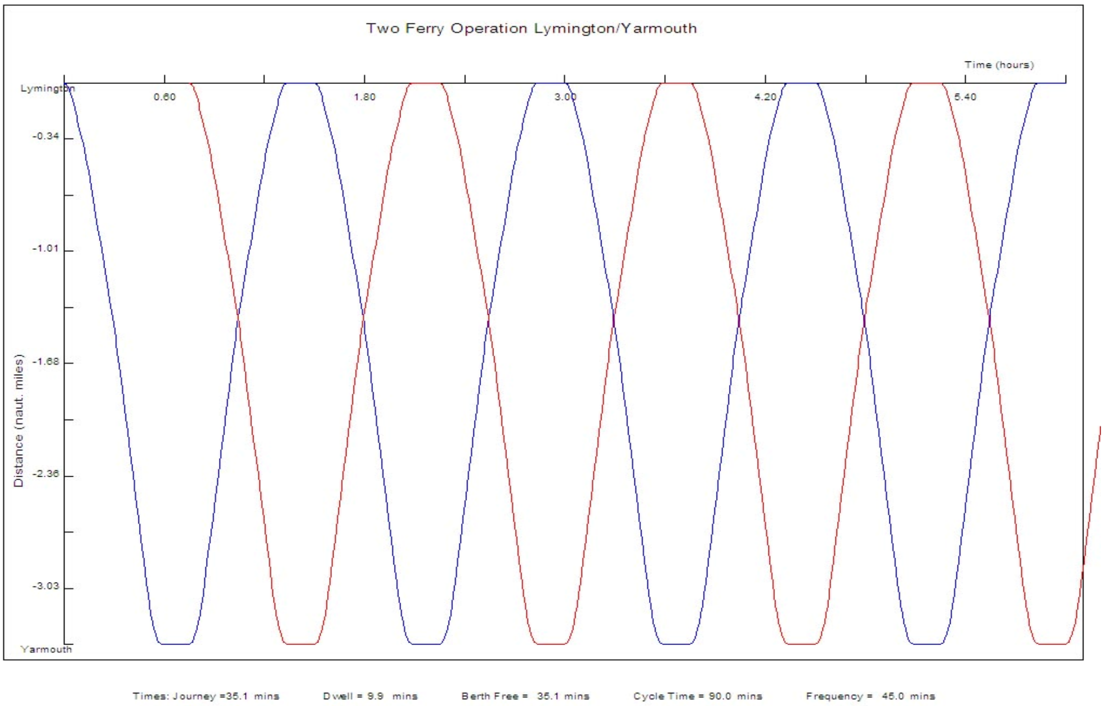


Figure 6: Two Boat Ferry Operation

designated passing place too early. When this happens, the inbound ferry has to wait and hold station in the river by what is essentially dynamic positioning using its Voith thrusters. The consequence of this is that the thruster slipstreams are directed into the river at one location for a period of time and may impact directly on any small craft in their immediate vicinity. However, it is often a consequence of prolonged use of propulsors in confined waters that the whole body of water is set into a motion characterised by a series of large eddies. These, once formed, may take some time to disperse and will therefore have a greater effect when the natural river currents are low, for example when the tide is turning. They will have a greater effect if the water volume is limited, as at low water, when it will be more likely that a significant proportion of the water body will be set in motion. Finally, prolonged use of the thrusters is more likely when the winds are stronger and the ferry has to counter their effect.

The overall effect of this behaviour on small craft could be to move them bodily in the river, thereby making it more difficult to keep station near the waiting ferry.

This, and other operational matters raised above, will be discussed further below.

5.7 Other Operations on the River

Other users of the river number fishing vessels, work boats, dredge barges and leisure users. In terms of numbers, the leisure users far outweigh all the others.

A number of clubs operate in the river and notable among these are the Royal Lymington Yacht Club (RLYC), the Lymington Town Sailing Club (LTSC), the 9th Lymington Sea Scouts, Lymington Rowing Club and Sailability, an organisation dedicated to helping disabled people to sail.

The two sailing clubs run a large number of events on the river among which are those specifically aimed at teaching young people to sail. The younger learners use a water area roughly bounded by the wave screen at one end, and the ferry terminal at the other. This, of course, is a stretch of water they share with the ferries and the clubs have developed comprehensive control measures to ensure the safety of the children when sailing. In essence, a ferry at the terminal uses a sound signal to warn the organisers that it is about to sail and the children are then escorted by safety boats to the side of the waterway, well away from the ferry. The ferry departs and the children are then escorted back to their sailing area. In a similar manner an inbound ferry on the way to the terminal may give a sound signal when in the region of the Cocked Hat navigation post and the procedure is repeated. If it is not common practice to give such sound signals when inbound, then it is recommended that this should become the norm when junior sailing activities are in progress.

When the children are more experienced, they sail near the mouth of the river. To do so, they are escorted down river in “crocodiles”, clear of the ferry routes and outside the trot moorings in Long Reach when there is sufficient water. Below half tide, however, the available water space outside the channel diminishes and there are occasions when the Junior Sailing boats cannot avoid using the channel. This is especially true when the boats have to beat to windward.

Comprehensive risk assessments (Reference 3) have been carried out for all aspects of safety connected with these junior sailing events and the organisation is impressive. Similar considerations are made for the Sea Scout sailing events which may include a large number of kayaks in the river. Once again their main sailing activities are held clear of the ferry routes, but it is necessary occasionally for sailing dinghies to cross the channel, in the company of safety boats.

Sailing regattas for all ages are organised on a frequent basis and this involves many sailing craft in the river and intense activity at and near the public slipway, an area that is also busy when the Wednesday Junior Sailing activities are in progress. All regattas are run in accordance with an agreed Code of Practice developed by LHC in consultation with the clubs. Clubs are required to work in accordance with the provisions of the Code of Practice to satisfy Byelaw Regulation 12 *“All races and similar events shall when within the Harbour be conducted with the conditions previously approved by the Commissioners”*.

The Sailability yachts are, in the main, stable multihulls which must keep to the channel. These are broad-beamed and escorted by safety boats which may, on occasion, act as tugs.

There are also some large motor yachts which use the river. Their lengths substantial (often 15 to 25 metres) and they are clearly major vessels. However, all spoke well of their skippers and it is clear that they operate these vessels safely, often following the ferries up or down river. Some other motor cruisers, however, have poor low speed manoeuvring characteristics and having to hold station or manoeuvre very slowly in the river can be a problem for them.

A large number of moorings are located at the side of the main channel in Horn Reach and Short Reach. In Short Reach these are swinging moorings, whereas fore-and-aft moorings are to be found in Horn Reach near the sailing clubs. Vessels picking up, or letting go, moorings, especially to the east of the wave screen to the river mouth, are at the mercy of any wave action from other vessels, or from natural, ambient waves.

In addition to this local population of leisure craft using the river, visiting vessels also add to the mix. These may include users with variable ranges of nautical ability, who will find themselves sharing the river with other users, including the ferries. One ferry master's experience was that most visitors keep well clear of the ferries and do not pose a significant problem, but there are presumably those of less ability and experience for whom marine risk on the river is greater.

Operations on the river are governed by the International Regulations for Preventing Collisions at Sea (the "ColRegs"), and by the local bye-laws which are readily available on the LHC website. Further useful information and advice is given in the LHC booklet (Reference 4).

The overall impression gained of the leisure activity on the river is that it is extensive, and the water is often very busy over the length of the river. However, it is clear that this activity is generally well run with a large number of risk control measures in place; as a result, the present situation is one that is satisfactorily safe and meets the ALARP (As Low as is Reasonably Practicable) criteria.

6. Local Concerns

The study team met a number of organisations representing the leisure users of the Lymington River as well as the Yarmouth Harbour Master. In addition, a number of individuals, mainly from Yarmouth and the Royal Lymington Yacht Club, have been in contact via e-mail. All were encouraged to express their concerns about the proposed ferries and a good deal of information was passed on.

The concerns are summarised here, grouped under a number of broad headings, the order of which has no particular relevance. It may be noted that the level of concern was considerably higher in Lymington than Yarmouth, a general acceptance of the new ferries being voiced in the latter town.

6.1 Ferry Speed on the River

This concern centred on the possibility that, should the speed of the new ferries have to be reduced in the river from the present levels, sailing activities, especially those of the younger club members, would be curtailed.

6.2 Wind Shadow

The concern was that the effect of the ferries in taking the wind of passing sailing yachts and dinghies would be worse with the new ferries due to their increased windage. This effect may be worse in light winds.

6.3 Junior Sailing

Wednesday and Saturday Junior Sailing works round ferry operations in Horn Reach (as described in Section 5.7) so that any reduction in ferry speed in this region would disrupt Junior sailing more than is presently the case. The Scouts and other young sailors also sail in Short and Long Reaches and worries about marine safety in the presence of the new ferries were expressed.

6.4 Ferry Passing and Waiting in the River

Concern seemed to be aimed more at ferry waiting and the effects this has on other users of the river. Visitors unfamiliar with the ferry operations were, it was claimed, not always sure whether to wait astern of the ferry or pass, slipstreams of the ferry thrusters affected nearby boats and wind shadow created problems and inconvenience for sailing vessels, especially those without power who have to tack or reach in the river. Passing manoeuvres limit waterspace.

6.5 Thruster Effects

Concern about thrusters related to scouring and accretion at Yarmouth, the proximity of the thrusters to the water surface endangering anyone in the water near a ferry (capsizes in the channel are not uncommon), the inability of the ferries to de-clutch the engines from the thrusters and uncertainties as to whether the thrusters can be stopped in an emergency.

A further concern related to ferries moving off or on to the layby berths at Lymington. The breasting manoeuvres apparently used for this can create strong flows at nearby moored vessels.

6.6 Handling and Manoeuvring on the River

There was general concern as to whether the increased size of the new ferries would affect their handling and manoeuvring on the river. Especial concerns were whether the vessels would have good stopping ability in an emergency, should someone be in the river.

6.7 Interaction Effects

Interaction effects in which the passing ferry draws moored vessels toward it and away again were of some concern, especially with regard to boats on the trot moorings alongside the channel.

6.8 Waterspace Limitations

When the river is congested in the sailing season, water space is limited. Concern about the effects of the larger ferries being able to deal with such situations was voiced.

6.9 Fields of View from the Wheelhouse

Fields of view from the wheelhouse on the new ferries were questioned. From a safety perspective, it was of concern that any obstructions to a good all-round view should be avoided; it seemed from the available drawings for the new vessels that the centreline blind spot would be greater on the W-class than that on the C-class.

6.10 Fait Accompli

Worries were expressed that after the trials on the new ferries, other users on the river would be presented with a *fait accompli* in that the new ferries would simply be introduced on completion of the trials without further discussion.

6.11 Ferry Size and Design

There was confusion and uncertainty among some users as to the correct dimensions of the new ferries and details of their design.

6.12 Increase in Road Traffic at Yarmouth and Lymington

Although outside the remit of this study, concern was expressed to the study team about a perceived increase in road traffic at Yarmouth and Lymington due to the additional vehicle capacity of the W-class.

6.13 Wash and Drawdown

The effects of ferry wash on boats and yachts (especially those on moorings when large roll motions can be induced) and drawdown on the river banks were of concern.

6.14 Overall Level of Marine Risk

An over-riding concern was that the overall level of marine risk should not increase with the introduction into service of the new ferries.

7. Present and Proposed Ferries

In this Section, the designs of the C- and W-class ferries are described and compared. This is done not only to provide information relevant to the overall study and on which to base its findings, but also with a view to understanding why the vessels are as they are and as a prelude to estimates of W-class performance.

However, before discussing the designs of the two ferry classes in more detail, it is important to mention a fundamental point about ferry design. By the nature of the “cargo” they carry, ferries are “volume” rather than “deadweight” carriers. Passengers are not a heavy load, but their accommodation needs sufficient (and sometimes substantial) volume; when considering the volume allocated to each passenger, they may be said, therefore, to be a low-density cargo. On the Lymington/Yarmouth route, the demand to transport vehicular cargo has come to dominate the service and consequently the ferries must accommodate this demand by providing the required stowage volume, probably increased due to the size of present day vehicles and any changes in traffic mix (such as an increase in the number of road freight vehicles) to satisfy present and future demands.

When the volume required to stow a vehicle is considered in the density calculation, it is found that vehicular cargo also is of low stowage density compared to the bulk cargoes of “deadweight” carriers, as indicated in Table 1.

It is seen that most types of modern road vehicle have stowage densities about a tenth that of bulk cargoes, together with increased stowage volumes. This implies that, when vehicular cargoes are to be carried on ferries, the design must be geared to provide enough volume, rather than deadweight, capacity. It is of course possible that very heavy, dense, loads will be carried on occasions, in which case sufficient spare deadweight capacity must be available.

Cargo	Type	Stowage Density (kg/m^3)
Crude oil	Bulk (Deadweight)	920-980
Crushed iron ore	Bulk (Deadweight)	2100-2900
Coal	Bulk (Deadweight)	1500
Loose sand	Bulk (Deadweight)	1440
Wet gravel	Bulk (Deadweight)	2002
Maize	Bulk (Deadweight)	760
40’ Container	Bulk/volume?	400
Town car	Volume	120
Large 4wd car	Volume	180
SUV	Volume	130-150
Medium van	Volume	130-150
Articulated trailer lorry	Volume	220-250
Coach	Volume	190

Table 1

7.1 Design

7.1.1 The C-Class

The C-class was designed around 1974 and built in Aberdeen at the yard of Robb Caledon Shipbuilders. Its profile is shown in Figure 7 and its body plan in Figure 8.

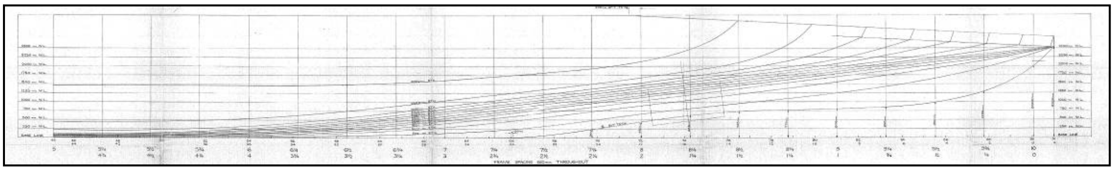


Figure 7: C-Class Hull Profile

The first thing to be seen in the body plan is that the extreme beam is not that at the waterline. The vehicle deck is cantilevered out above water to a beam of about 16 metres, whereas the water line beam at 2.3 metres draught (taken here as the draught at maximum load) is 12.45 metres.

The other notable feature in the body plan is the batter on the parallel middle body, which means the maximum waterline beam changes with immersion. The reason for this design feature is may be an attempt to get as much deck area as possible, thereby reducing the deck overhangs, together with better statical and damage stability characteristics, stability being an important design requirement of vehicle ferries of the ro-ro type. This subject will be revisited below.

The vessel is double-ended with body sections having slack bilges and a flat deadrise, a consequence of the combined need for a large beam to accommodate vehicles and a shallow draught to operate in the shallow waters of the Lymington River. At the centreline, the sections are formed into a keel which has more depth at the bow/stern than amidships and provides a centreline strength member which could take the ground when the vessel is using a slipway, the original method of loading/offloading these vessels. This feature of the body section design also provides some directional stability for the vessel, as no keel or skegs are appended to the hull. When steered by thrusters, rather than a rudder, there is no directional stability obtained from the rudder "fin", a feature that is useful in conventional ships when running a straight track and reduces the need for continual correction by the helmsman or autopilot. However, too much directional stability would be a disbenefit when sailing in the river, so the "skegs" designed in to the body sections fore and aft provide a compromise between straight line stability and turning ability.

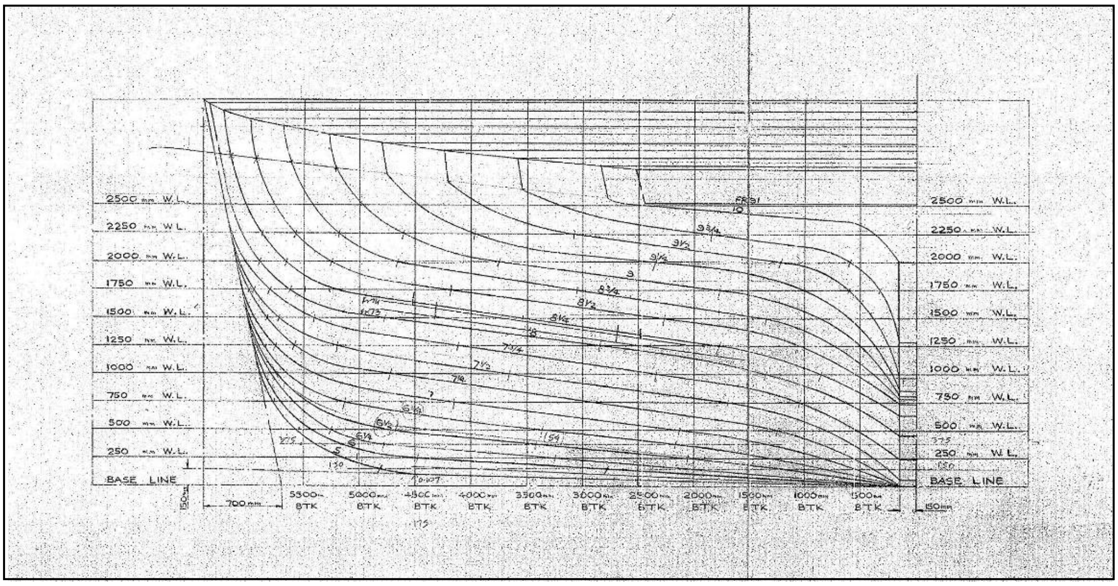


Figure 8: C-Class Body Plan

It may also be noted that the deckline has a reverse sheer, a design feature used to

- Provide additional strength to the hull girder
- Provide the required amount of freeboard amidships
- Provide a low enough freeboard at the bow/stern for shallow ramp angles when using a slipway for loading.

The vessels are propelled and steered by Voith cycloidal thrusters situated on the underside of the hull at each end, diagonally opposed port and starboard. They are located between stations 8 and 8.25 and are angled some 8^{o} to the horizontal in the lateral plane and about 7.8^{o} to the horizontal in the longitudinal plane. They are positioned in such a way that the whole of the thruster envelope is contained within the hull envelope both laterally and longitudinally. This is for thruster protection from grounding, a rather more likely event on a vessel moving in a shallow river with bends and having to pass other ferries on reciprocal courses. It is also a rather more important requirement for Voith thrusters than other propulsors because of the vulnerability to damage of the expensive and delicate parts of their complex propulsion and control mechanisms.

Although Voith thrusters are less efficient than conventional screw propellers, they have the distinct advantage of giving fine control of both the magnitude and direction of thrust, thereby making them an ideal choice for use on the Lymington River. Indeed the first marine use of Voith thrusters was on the ferry

"Lymington", purpose-built for the Lymington/Yarmouth service and introduced in 1938. She also had two Voith thrusters located diagonally opposite each other at each end of the vessel and a significant reverse sheer, similar to the C-class.

Each thruster is powered by a single engine and, although there is an emergency stop button on the bridge, the engines and thrusters are kept running when the vessel is stopped, the latter generally being set to neutral pitch. The fact that the thrusters remain in motion when the engines are running is a consequence of the fact that they cannot be de-clutched from the engines. A corollary of this is that, should an engine fail, its thruster will stop.

7.1.2 The W-Class

The loss of the ro-ro passenger ferry Herald of Free Enterprise in 1987, followed by that of the Estonia in 1994, and the consequential huge loss of life, drastically changed the mandatory safety requirements of ro-ro vessels. Their vulnerability to large quantities of water on the vehicle deck, and its effect of reducing stability, led to significantly more stringent requirements for damaged stability, including the ability to survive with significant side damage and a quantity of water on the subdivision (i.e. vehicle) deck (Reference 5). These requirements are likely to become even more stringent for vessels designed and built after 2009.

The regulations from maritime safety agencies require designers to find more damage stability and, in broad terms, this is done by:

- Increasing damage freeboard, thereby requiring an increase in freeboard in general
- Increasing the buoyant volume of the hull when damaged. This leads to an overall increase in buoyant volume in the hull below the subdivision deck.
- Increasing the amount of subdivision below the subdivision deck (i.e. providing more watertight compartments below this deck so that if one or more are damaged and flooded, the others will provide a "lifebelt" and keep the ship afloat long enough to get the passengers off). This also implies an increase in displacement.

The W-class has to satisfy these modern survivability regulations, even though the vessels are likely to be vulnerable to damage from crossing ships for only part of each journey. The consequence on hull design can be seen in the profile plan in Figure 9 and the body sections in Figure 10. An above-water elevation is shown in Figure 11.

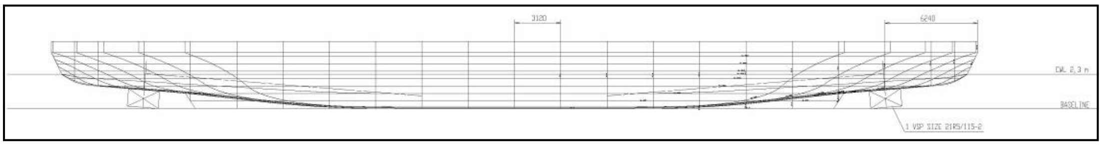


Figure 9: W-class Hull Profile

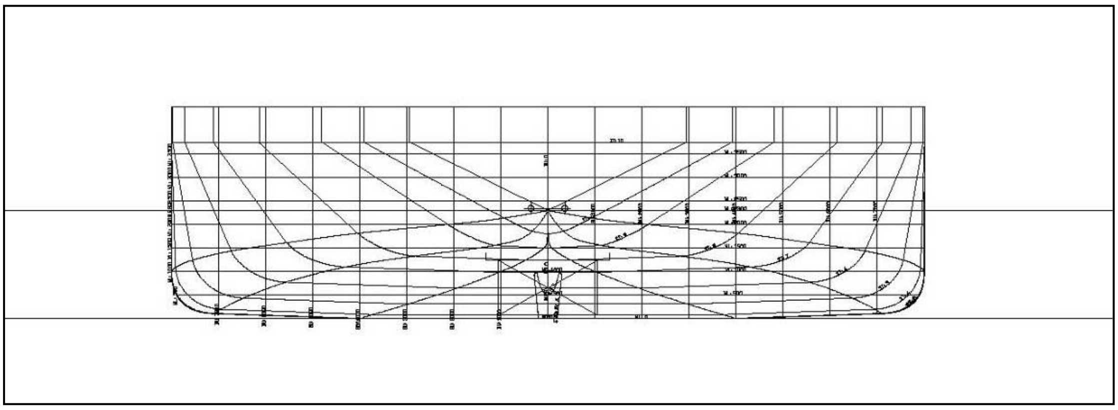


Figure 10: W-class Body Plan

It is seen that there is, of necessity, much more volume in the underwater hull, with the beam at a draught of 2.3 metres increased from 12.43 metres to 16, harder bilges and no batter in the parallel middle body. While there is flare in the forebody, the hull lines are more reminiscent of a conventional merchant ship than those of the C-class. The hard bilges are a notable feature; these may well be beneficial by increasing roll damping on the Solent crossing.

This is not to say that the hull will be hydrodynamically inefficient. It is in essence a “flat” hull, the flow passing under it rather more than around it. Although its free wave pattern contains waves higher than those of the smaller (by volume) C-class (see Section 7.3 below), it is still a comparatively low-wash hull.

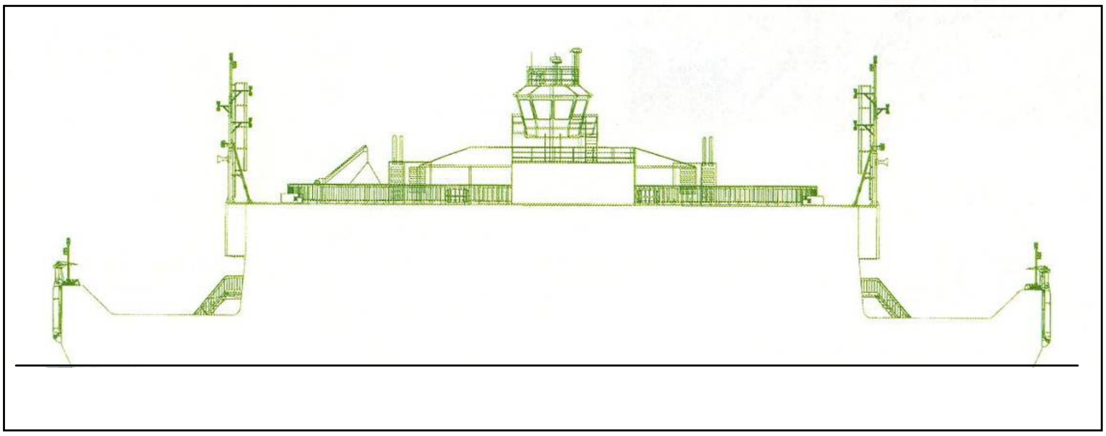


Figure 11: W-class Above-Water Profile

This may also be the result of a further feature of the hull design whereby the forward/aft section is lifted clear of the baseline to accommodate a Voith thruster on the centreline at each end. These are still kept within the “longitudinal” hull envelope, although they are more deeply-set than those on the C-class. The mean depth of the thrusters is some 1.7 metres below the at-rest waterline at 2.3 metres draught, compared to 1.3 metres for the C-class. Furthermore the outboard extremity of the thrusters on the W-class are some 4.9 metres in from where the local body section cuts the water surface, compared to 1.4 metres with the C-class. (This is a minimum value for the C-class; obviously the clearance to the other beam is much greater and separated by the intervening hull structure). Each thruster has two engines, mounted in parallel, with uptakes to exhausts carried to, and above, the upper deck on one side.

The thruster engines will be stopped when the ship is berthed or at rest for any other reason; furthermore, the thrusters can be de-clutched from their respective engines. This will significantly reduce scouring when the vessels dwell in the terminals. Anchors are to be fitted at bow and stern.

Voith thrusters must be mounted on a flat surface and this is worked in to the local hull sections fore and aft, the sections ahead/astern of the thrusters having more shape for a cleaner entry/run and better behaviour in a head sea. Small skegs are added to the hull at the point at which the keel rises and these will help both with directional stability and strength, should the vessel take the ground.

The low freeboard at bow and stern for slipway loading/unloading seen in the C-class has gone, as has the reverse sheer, indicating that these vessels are designed principally for linkspan loading. The vehicle deck is flat laterally and longitudinally with a constant freeboard of 2.24 metres at 2.3 metres draught, compared to 1.13 metres amidships, the maximum for the C-class.

The outboard profile in Figure 11 reflects the fact that these vessels are volume rather than deadweight carriers. The volume enclosed by the superstructure is larger than that of the existing ferries with the drawing showing that the lower vehicle deck has been given more shielding from wind and spray by the superstructure sides. There is a mezzanine deck to one side which has sections fore and aft that can be raised and lowered for vehicle access. On the other side, and located above the accommodation deck head, is a movable garage deck. This is capable of holding 15 car equivalent units (CEUs), and is lifted to an enclosed housing at the passenger deck level. Above this is a sun deck with the wheelhouse and bridge surmounting a small block accommodating crew's quarters. The wheelhouse has enclosed wings which extend to, and beyond, the extreme beam of the vessel.

7.2 Comparison

The principal particulars of the two classes are compared in Table 2. Where possible, these have been independently checked by BMT using drawings provided by the designers.

The following should be noted in relation to the information in Table 1:

- Dimensions have been taken from drawings
- Hydrostatic features (displacement, and form coefficients) are as calculated by BMT
- Windage area differs from "profile area". The former is the area above the water; the latter comprises that area, plus the underwater area.
- The "laden" condition for the windage areas assumes two high-sided vehicles have been loaded at the ends of the vessel, as shown in Figure 12. A constant draught has been assumed in both conditions, and it should be noted that the areas shown in the Figure are the *profile* areas.
- Various values have been given in the past for displacement mass, ranging from 1495 to 1520 tonnes. BMT calculations suggest the hull volume to be 1453m^3 with appendages, which is close to the value of 1465m^3 given by Voith from the same lines. The BMT value is used in the Table.
- As mentioned in Reference 1, there is some variance in the values for the installed power of the C-class given in the past. The values shown in the Table are those given in Lloyds Register of Ships (Reference 6). The smaller value is for Cenred, the larger for Cenwulf and Caedmon.

Particular	C-class	W-class	% Change
Length Overall	55.51m	62.40m	12.4
Length on Waterline at 2.3m draught	55.29m	61.00m	10.3
Waterline Beam at 2.3m draught	12.43m	16.00m	28.7
Overall Beam	15.2m	16.00m	5.3
Reference draught	2.3m	2.3m	-
Displacement Volume at reference draught	847m^3	1453m^3	71.5
Displacement in water of density 1025 kg/m^3	868.2 t	1489.3 t	71.5
Block coefficient	0.536	0.647	20.5
Prismatic coefficient	0.585	0.669	14.2
Midship section coefficient	0.915	0.967	5.7
Waterplane area coefficient	0.872	0.814	-6.7
Tonnes per cm immersion at reference draught	6.17	8.14	31.9
VCB above base	1.425m	1.303m	-8.6
End-on windage area – unladen - laden	173.8m^2 188.1m^2	213.2m^2 243.1m^2	22.7 29.2
Side-on windage area – unladen - laden	297.9m^2 365.3m^2	611.5m^2 665.7m^2	105.3 82.2
Installed power	618/728kW	2544kW	249.5

Table 2

The changes in a number of the particulars in Table 2 are now discussed in more detail.

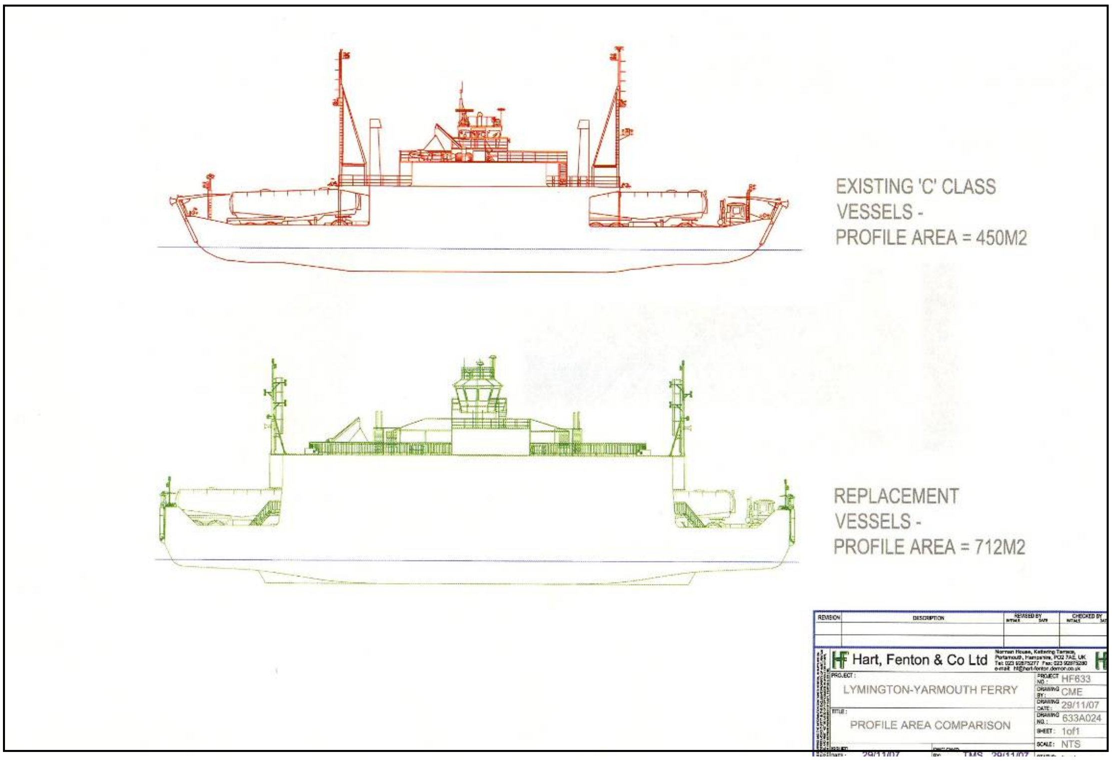


Figure 12: Comparison of W- and C-class Laden Profiles

Main Hull Dimensions

While length overall, beam and draft are subject to increases of about 12% or less, the waterline beam is increased by about twice as much in percentage terms. This is almost certainly due to the increased stability requirements mentioned above. The large increase in displacement is for the same reason.

Form Coefficients

Block, prismatic and midship area coefficients are all increased to a greater or lesser degree, but waterplane area coefficient is reduced in the new vessel design. The block coefficient is not increased as much as was feared at one time, and the confusion over the relevant dimensions which led to this has now been resolved. Although both block and prismatic coefficients are increased, they are still of a size comparable to those seen on container ships and cruise liners, indicating that the form is still relatively easily-driven and further suggesting that free waves, although likely to be increased in size, will not be as big as might have been feared at one time.

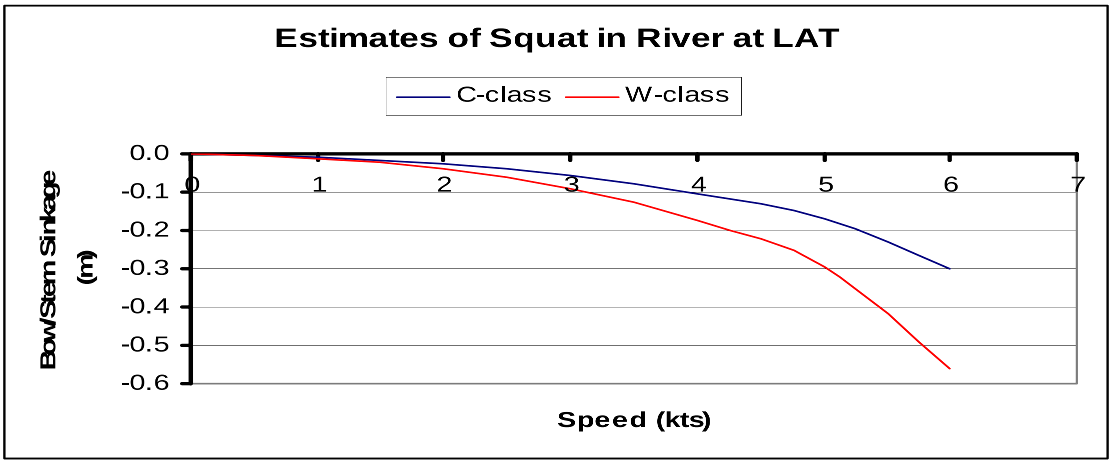


Figure 13: Squat Estimates

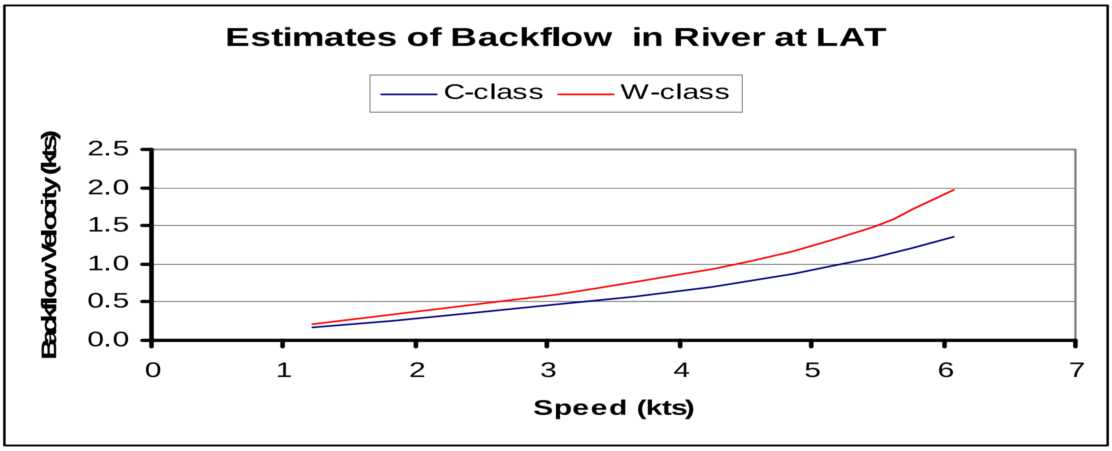


Figure 14: Backflow Estimates

Drawdown and squat will increase, however, and Figures 13 and 14 show comparisons of predicted squat at 6 knots in the river (which will be similar to drawdown at the ship) at LAT and the estimated backflow velocity increase at the ship. These estimates give values *at the ship* for a water depth of 4 metres; at greater depths, values of squat and backflow at a given speed will diminish.

Immersion Coefficients

The “tonnes per cm” immersion coefficients give an indication of the change in draught for a given load. As might be expected, the new ships, with greater buoyancy, will increase their draught somewhat less than the existing ships.

Windage

The increase in lateral windage is significant, especially when the ships are unladen, or so lightly loaded that the vehicles are contained within the covered central portion of the vehicle deck. It may be noted that the mezzanine deck side of the new vessels is provided with two large openings, but the other side, on which stairwells and other compartments are located, apparently does not. Although the openings may be of some help in shiphandling by dispersing the wind load, the fact that both sides of the superstructure are not treated in the same way means that, for all practical purposes, the new ships will present an increased effective windage area of the size given in Table 2.

The increase in windage of these ships is due in part to the greater longitudinal coverage of the cargo (which will give more uniformity to the way they handle in a cross wind), and the greater height of the superstructure. Although the superstructures of the old and new vessels are comparable in height up to the underside of the passenger deck, the new ferry has a higher passenger deck space (due, presumably, to the needs of the garage deck, the result of which is more volume in the passenger spaces) and the crew’s quarters beneath the bridge on the new ship which have no counterpart on the existing vessels. Apart from providing the crew with its own quarters, this deckhouse serves to raise the wheelhouse high enough to give a reasonable field of view ahead of the long sun deck.

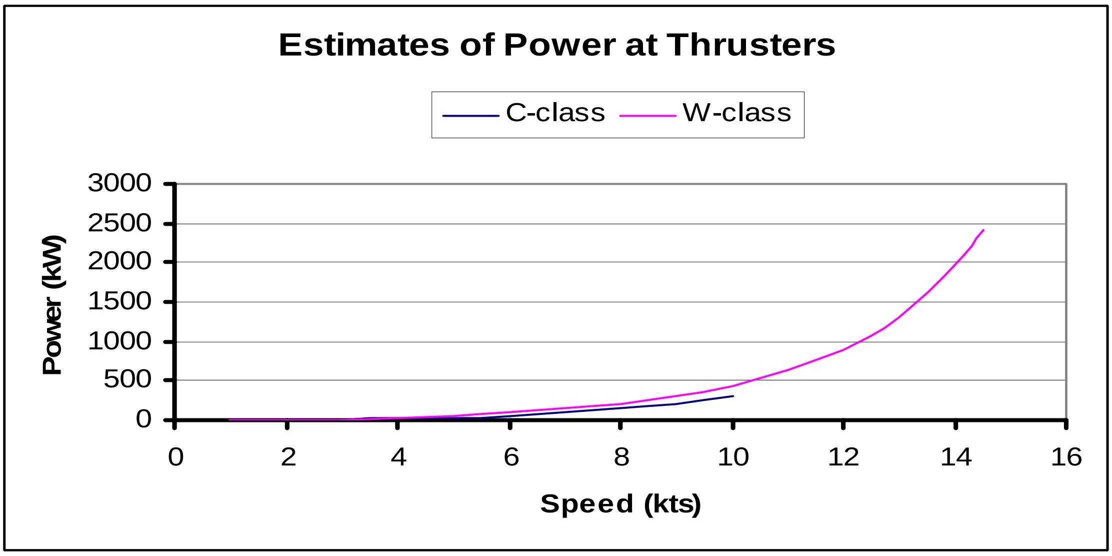


Figure 15: Power Estimates

Installed Power

The total power installed in the new vessels is significantly greater than that in their older counterparts. The consequence of this is seen in the stated maximum speed of 14.5 knots, compared to its stated service speed of 10 to 12 knots. Figure 15 shows estimated powers to propel both ships up to their maximum speeds and it is clear that the increase from about 11 to 14.5 knots puts a high premium on power. However, the increase in installed power is probably more to do with redundancy with two engines per thruster. It is understood that normal service will use one engine per thruster, thereby significantly increasing the mechanical reliability of the new ships compared to the old. It is also understood that the engines will be de-rated for normal use.

The magnitude of the installed power on the new ships, is however, not unusual for ferries, as demonstrated in Figure 16. In this plot power coefficients (defined as power/(g*displacement*speed) in compatible units) are shown for a number of conventional ferries of various sizes. It is seen that the C and W class ferries have service powers similar to the norm for their size, although the full power of the W-class certainly places it at the high end of the range. It may also be noted that the power of the C-class, in relation to its size and speed, is not dissimilar to the norm, although defining the lower end of the range.

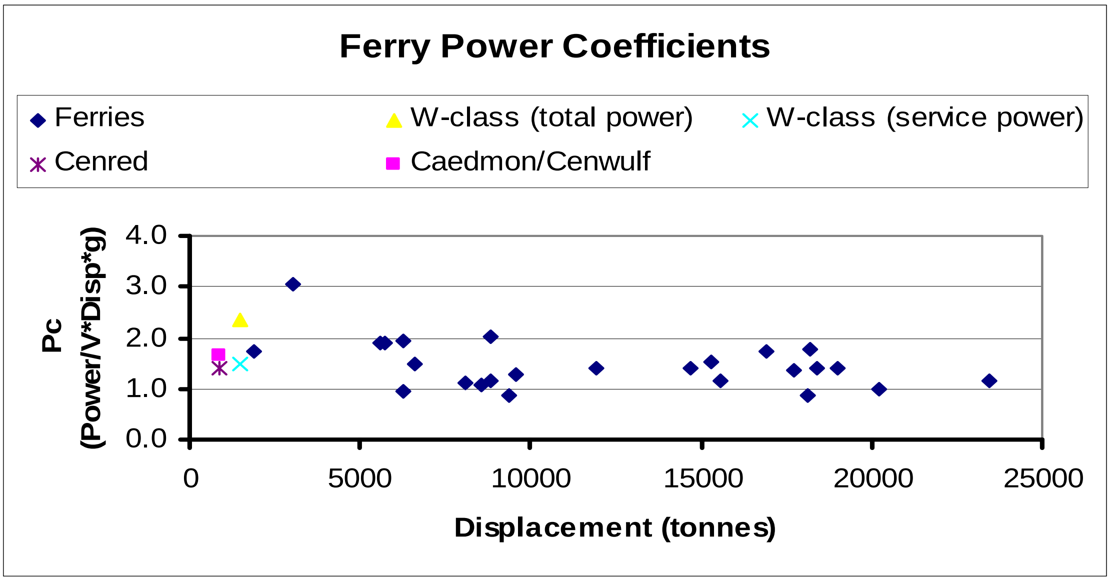


Figure 16: Ferry Power Coefficients

7.3 Effect of the New Ferry Design on Operations

It is clear from Section 6 that many concerns of the leisure users of the river relate to operational aspects of the new ships.

In this section therefore, the effect of the design differences between the ferries on their operation and the possible consequences for leisure and other users, as well as the river itself, are discussed. Although the operational effects of the new ferries are presently unknown (and will be assessed in Phase 2 of this study), it is possible to make some estimates; these used in the discussion which follows.

7.3.1 Thrusters

For leisure users of the river, the thrusters on the ferries have the potential to affect them in the following ways:

- Direct slipstream effects
- Indirect slipstream effects
- Proximity to the water surface and their potential hazard to anyone in the water
- Use in ferry manoeuvring and stopping

These are considered in turn.

Direct Slipstream Effects

By direct slipstream effects is meant the effect from the jet itself striking a nearby moored boat or the keel and canoe body of one that is sailing past. This is most likely to be experienced when the slipstream is directed at an angle to the ferry centreline, as would occur when navigating a bend, holding station (waiting) in a cross wind or breasting out from, or in to, an overnight berth.

In its simplest terms, the slipstream may be thought of as an underwater jet whose velocity depends on the thrust required and the cross-sectional area of the jet itself. As an example, the case of a ferry holding station in cross winds of Beaufort (BF) 4, 6 and 9 (taken as 13, 24 and 44 knots respectively) is addressed. Estimating the beam-on wind loads from aerodynamic data for a ferry with a broadly similar superstructure and using the laden windage areas given in Table 2, gives the total side loads and mean slipstream jet velocities of Table 3 where the jet cross-sectional areas of the thrusters have been taken as the product of the thruster diameter and the blade length.

	C-class			**W-class**		
	BF4	BF 6	BF 9	BF4	BF 6	BF 9
Total side load (kN)	8.1	27.5	92.3	14.7	50.0	168.2
Mean Jet Velocity (m/sec)	1.6	2.9	5.3	1.7	3.2	5.8

Table 3

It is seen that the computed mean slipstream velocities are about 10% greater in the W-class ferries in both wind speeds. This suggests that, in spite of an increase in side-on windage of some 80% to 100%, this translates into a possible increase in slipstream velocity at the thruster of the order of 10%. This is in part explained by the fact that water is a fluid some 800 times more dense than air, so the force it produces when in motion (which is proportional to the square of its velocity) is large, and in part by the increased “jet” area of the larger thrusters on the W-class vessels.

Therefore, although the new vessels will have increased slipstream velocities, the increase will not be proportional to the increase in windage area.

Attenuation downstream of the thrusters will also have its part to play. The location of the thrusters on the existing ferries aligns them with the deadrise so that, in certain circumstances, their jets will adhere to the local hull surface and, after a comparatively short distance, break the water surface, as shown in Figure 17. Thrusters in the W-class are deeper set by about 0.4 metres and on the centreline and, although their jets are still likely to adhere to the local hull surface to some extent, the distance to the water surface, port and starboard, is the same at 4.9 metres compared to 1.4 metres (minimum) with the C-class as mentioned in Section 7.1.2 above. This means the thruster jet velocity will have a longer distance to attenuate on the W-class than the worst case on the C-class, so that direct slipstream effects may not be a significantly greater problem than at present. Computations from Voith suggest that attenuation of the slipstream velocities at about the quarter span length of the blades from the hull surface (where slipstream velocities are high) is about 30% to 60% for both the C-class and W-class at 4 diameters downstream of the thrusters. At greater depths the

Figure 17: Slipstream from Stern Thruster Breaking Surface

local slipstream flow is less. For the W-class, this distance is 8.4 metres and for the C-class, 6.4 metres. This suggests that the direct effect of the slipstream will be noticeably reduced at these distances from the ferry; whether with the new ferries the attenuation from the deeper-set thrusters will offset some of the increased jet velocity is not at present clear.

This suggests that the direct effects of the thruster jets on leisure users and the river banks will be similar to those presently experienced, but it is not clear at present whether they will be worse with the new ferries or not. Further assessment must await the full scale trials, but this aspect of the new ferry operation will be one of those to be paid particular attention.

Finally, any possible suction effects upstream of the thrusters will be observed. To date, no effect of this type has been observed on the existing ferries where it would be expected to be accompanied (and revealed) by ventilation ("air-drawing"). Each thruster on the new ferries will probably find most of its inflow from the surrounding water at the thruster depth, but observations of any upstream effects will be made from the river level, probably during waiting trials.

Indirect Slipstream Effects

By indirect slipstream effects is meant the tendency of a waiting vessel, holding station with its thrusters, ultimately to set the surrounding waterspace in motion. This is common when the waterspace is confined in depth and width and so, in the context of the Lymington River, this means low water conditions. Prolonged use of thrusters will tend to set up large, slowly-moving eddies, progressing slowly through the waterspace containing low density energy and with very little tendency to attenuate. This is a common problem when, for example, tug bollard pull tests are undertaken in an enclosed dock when the disturbance generated in the water surrounding the tug soon becomes unacceptable; similar effects are found in the Suez Canal as a convoy passes through.

Once such eddies have been set in motion, they will move small vessels in an apparently random manner, thereby making their station-keeping near to a waiting ferry difficult, especially if the tide is convecting the eddies on to them. The effects will extend underwater as well as on the water surface, and leisure users may well experience these effects at present when their yachts and motor vessels are moved towards, or away from, nearby waiting ferries.

This effect will depend on the mass flow of water produced by the ferry thrusters when holding station in the river during periods of waiting. In spite of the probably small increases in slipstream velocity for the W-class compared to the C-class discussed above, the mass of water moved by the thrusters is likely to be larger with the W-class than the C-class. Estimates are shown in Table 4 for the wind conditions of Table 2.

	C-Class			**W-Class**		
	BF4	BF 6	BF 9	BF 4	BF 6	BF 9
Total side load (kN)	8.1	27.5	92.3	14.7	50.0	168.2
Mean Mass Flow (m^3/sec)	2.5	4.6	8.5	4.2	7.7	14.1

Table 4

The estimated increases in mass flow are of the order of 65% suggesting that more disturbance to the local waterspace may be caused by a W-class waiting in the river than a C-class.

This will also receive attention during the trials.

Proximity of the Thrusters to the Water Surface and their Potential Hazard to People in the Water

It is not impossible for people to be in the water when a ferry approaches. This may arise from a number of causes, capsize and falling overboard being the two most probable.

Clearly one hazard for a person in such a predicament is to be caught in a thruster of the nearby ferry and this will depend on:

- Whether the thruster is rotating at the time
- Thruster proximity to the water surface.

Regarding the first of these points, both classes have the ability to stop the engines and thruster immediately using the Emergency Stop Button on the bridge, while the W-class has the additional ability of de-clutching the thrusters from the engines.

Regarding the second point, the thrusters of the W-class are deeper set and are located further, laterally, from the free surface than those of the C-class. However, it must be remembered that the disposition of the thrusters on the C-class means that one of the two will be well clear of anyone in the water; the other of course, will not.

Thruster use in Ferry Manoeuvring and Stopping

Thruster use in manoeuvring can inconvenience small craft users nearby, largely from direct and indirect slipstream effects.

As discussed above, the deeper-set thrusters on the W-class should help in this regard, but breasting manoeuvres performed by the new vessels close to moored vessels will still have an effect from the increased mass flow. When turning, the vectored slipstreams from the W-class may have no worse an effect on the water surface than the C-class due to its deeper thrusters, helping in slipstream attenuation which will offset some of the increase in thrust due to vessel size. Again, the full-scale trials should allow this to be assessed.

Controlled emergency stopping in the river by the W-class should be adequate due to larger thrusters and access to more power. However, the greater inertia of these vessels from their increased displacement, as well as passenger safety considerations, both have to be taken into account. Again a final assessment has to await Phase 2 of the study.

7.3.2 Wash, Drawdown and Squat

Wash and drawdown have been measured with the C-class at Lymington as described in Appendix 2. In general terms, both local and free waves were found to be comparatively small and there was no sign of severe breaking waves on the river banks as the ferry passed at speeds up to 6 knots, even at low water. As an example, Figure 18 shows the measured water level change as two ferries and a dredger passed Pylewell Boom navigation post around low water on 22 January 2008. The results have been corrected for the tide (which was flooding at the time) and free waves have been removed in order to show the longer period movements more clearly. The drawdowns in the Figure are all less than 50mm. Most of the other measured drawdowns were similar to those shown in the Figure, but one, from a ferry inbound just before low water and passing close to the Pylewell and Enticott measurement locations, produced a drawdown around 150mm to 170mm. For further discussion on these and other measurements, including those of the natural waves, see Appendix 2.

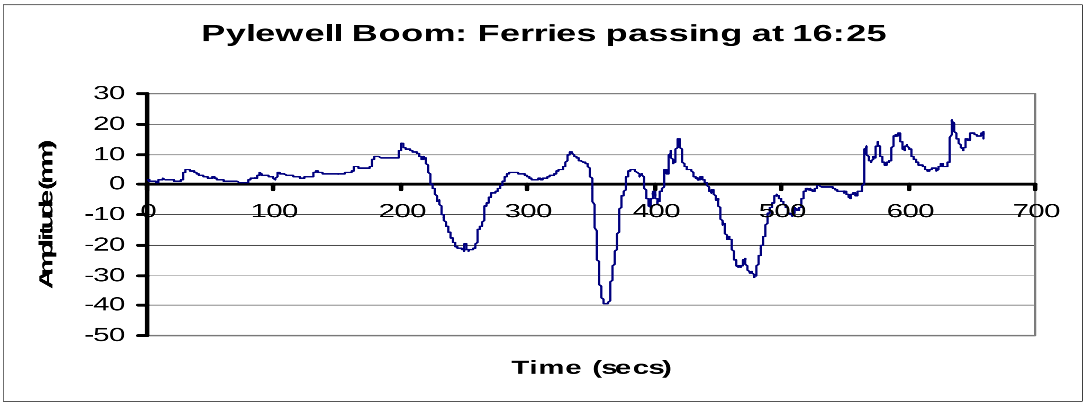


Figure 18: Water Surface changes Measured at Pylewell Boom Post.

Bearing in mind that drawdown and squat have similar magnitudes, estimates of squat for both the C-class and W-class vessels may be used at this stage to give an indication of the expected drawdown, the greater displacement of the W-class vessels and their fuller hull forms being expected to give rise to greater squat and hence greater drawdown. Estimates for squat made at BMT using the method described in Reference 7 gave reasonable agreement with drawdown magnitudes measured for the C-class and suggest that the squat (and hence drawdown) of the W-class at 4 and 6 knots through the water may be about 70% to 90 % greater than that of the C-class, all other things being equal. Measurements in Phase 2 of this study will be used to check this.

The free wave component of wash can affect all boats in the river, but of interest are its effects on those that are moored. In such cases, the frequencies of the free waves from any other vessel are of importance. This is because it is often found that some of the frequencies in vessel wave systems can be close to the natural roll frequencies of boats. When this occurs, roll motions can be large and, should those on board the moored boats not be expecting such an event, they may be exposed to risk. Such effects have been observed on the river by the study team; they arose from vessels of different types, not only the ferries. Whether the W-class will cause more severe effects remains to be seen; tank model test results showing the bow and stern wave amplitudes in a water depth equivalent to 4.8 metres full scale are shown in Figures 19 and 20; unfortunately the frequency components of the free waves are not known, but Figure 21 gives some idea from calculations made by Voith for the W-class hull form. Compared to the C-class free wave system, it is seen that the heights from the bow wave system of the W-class model were very much the same, whereas those from the stern system were similar at 4 knots but increased from the C-class value of 60mm (full-scale) at the measuring location to between 100mm and 150mm at 6 knots.

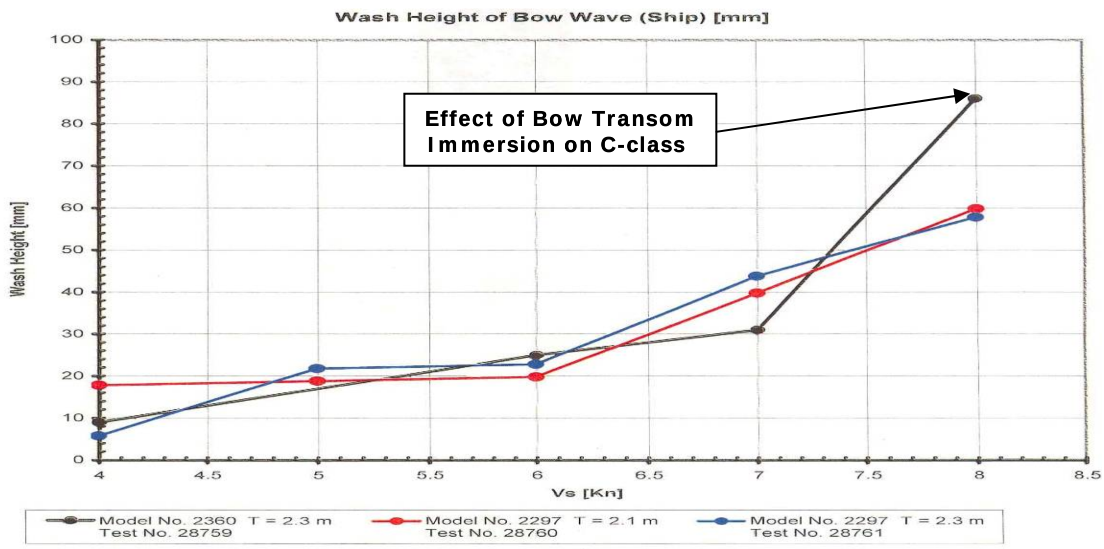


Figure 19: Tank Measurements of Bow Wave Heights (Model 2360 C-class, model 2297 W-class)

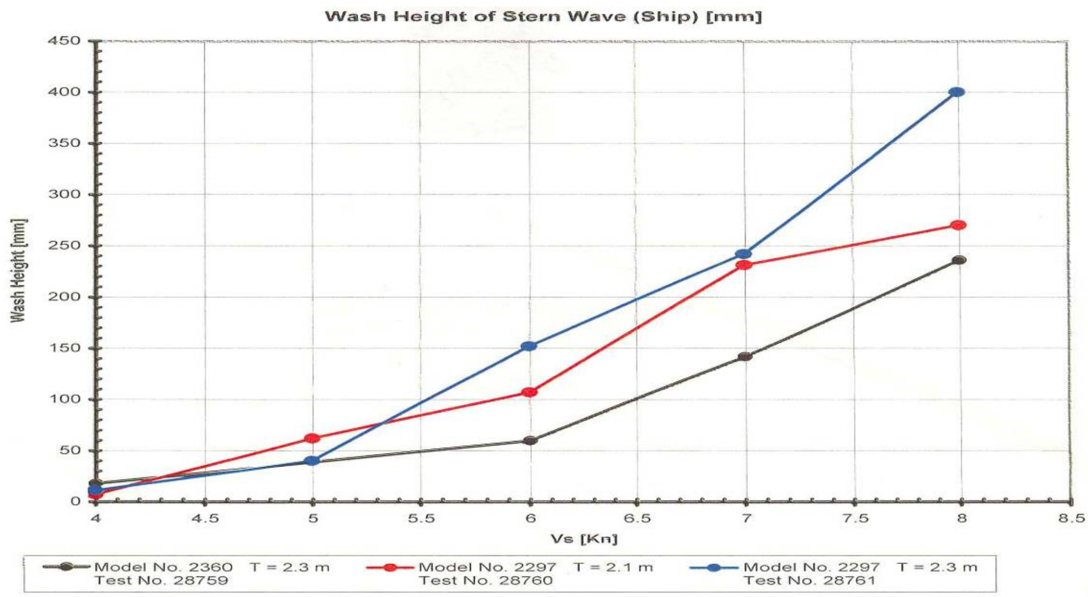


Figure 20: Tank Measurements of Stern Wave Heights (Model 2360 C-class, model 2297 W-class)

Although the results for the stern wave at 6 knots represent an increase over the present situation, it should be borne in mind that, they are less, or at least no worse, than vessel waves and drawdown tolerated in other parts of the world where wash is of concern. Indeed, as mentioned in Reference A1 of Appendix 2, a wash height of 300mm is considered acceptable by the Danish Maritime Authority in areas where wash from high speed ferries is a significant concern. Indeed, measurements of natural waves in the region of the Pylewell post have shown that they can have heights around 250 to 300mm on a day when the wind was not from the prevailing direction and the fetch was consequently restricted. (see Appendix 2) Nevertheless, the effects of the expected change in wash will be monitored in the Phase 2 trials.

The result at 4 knots suggests that, from a wave height perspective, there will be no need to reduce the speed of the new ferries from the advisory 4 knots in Horn Reach, the location of some of the Junior Sailing events.

7.3.3 Speed in the River

As mentioned above, the speed in the river of the new ferries is a cause for local concern because of the effect it would have on sailing activities. It has been also mentioned that the W-class ferries will probably produce higher free waves at the stern that the existing vessels, but the frequency components are unknown.

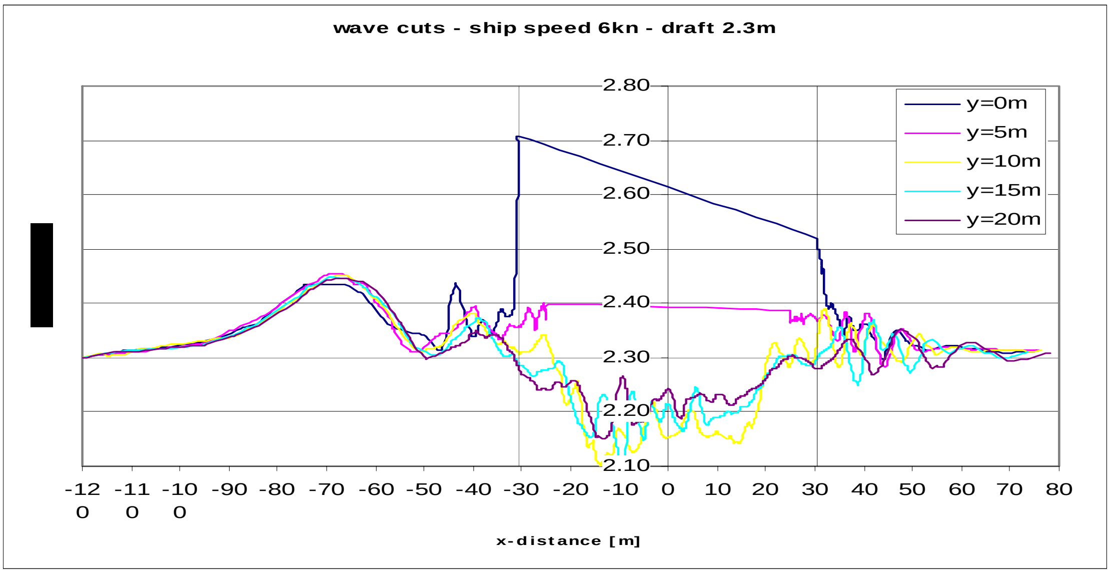


Figure 21: Wave Cuts for W-class Computed by Voith

The need to revise the speed of these ferries in the lower reaches of the river must await the outcome of the live trials, but it appears that at the 4 knot advisory speed in Horn Reach, the free waves of the new ferries should be no worse than those of the existing ferries.

However, ferry speeds will also be related to the ease with which they can be handled and the power requirements to maintain 4 and 6 knots in all conditions on the river. Figures 22 (a truncated version of Figure 15) and 23 show estimates of the power required for a range of speeds in deep and shallow water for both the C and W classes.

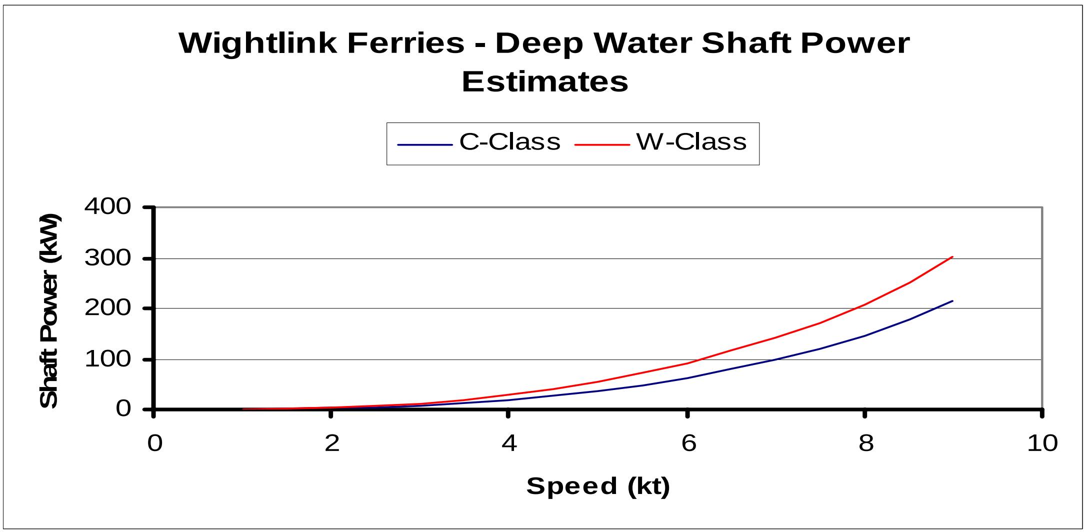
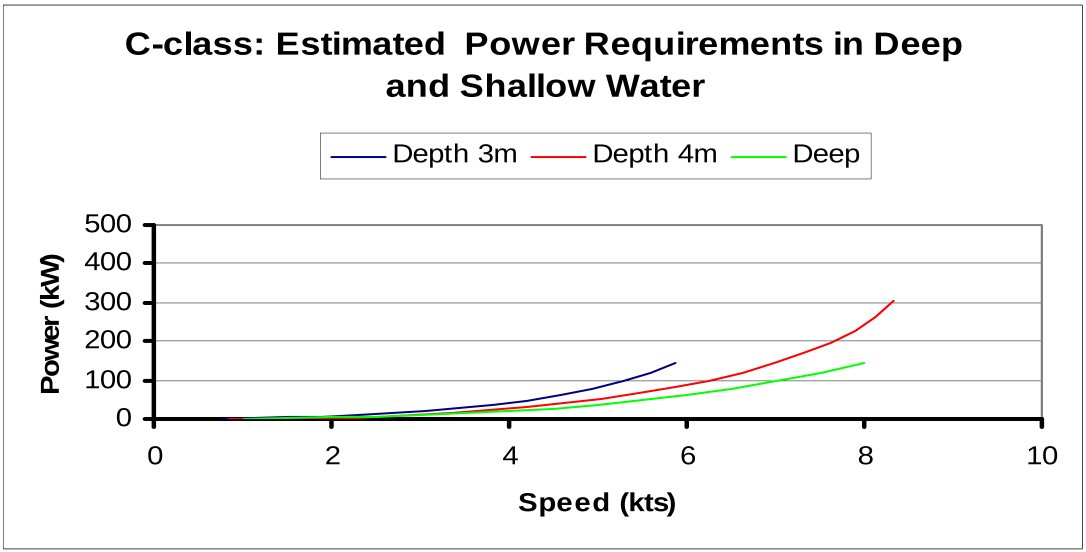


Figure 22: Estimates of Thruster Power for C- and W-class in Deep Water



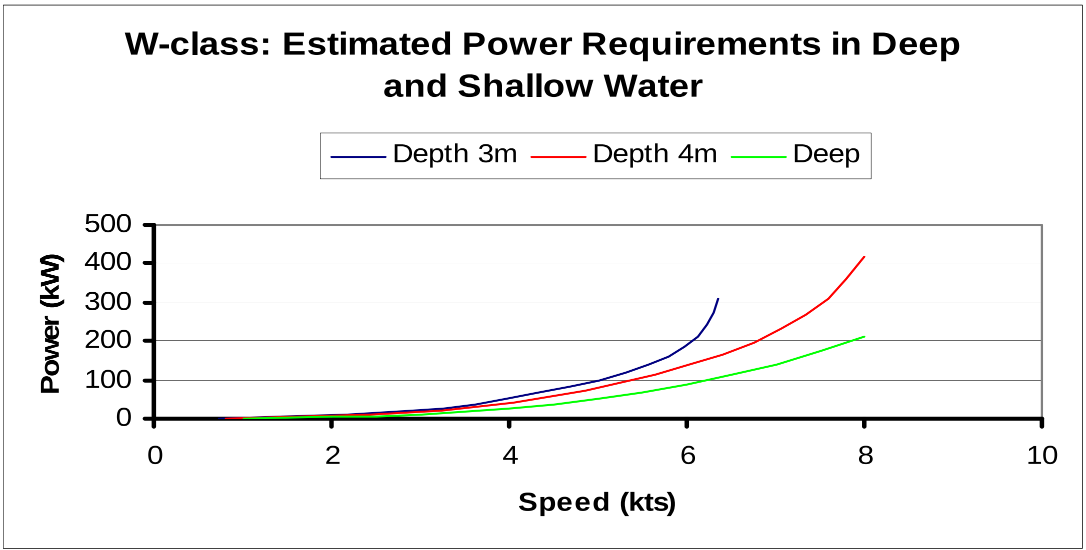


Figure 23: Estimated Thruster Power Requirements for Both Vessels in Deep and Shallow Water

It is seen that the power requirements for deep water at speeds up to 9 knots are greater for the W-class, as might be expected, the increase being of the order of 42%. It may be noted however that the shaft power requirement is well below the installed power of both vessels, thereby giving a reserve for emergency stops as well as the hotel load and the ability to deal with wind and waves on the Solent crossing. It also shows that the W-class is unlikely to need its full reserves of power in normal deep water operations and should be able to operate on one engine per thruster as planned, with the other in reserve thereby increasing reliability.

In the shallow waters of the river however, Figure 23 shows estimates for both vessels in 3.0 and 4.0 metres of water, the lower of which is possible at LAT (a not uncommon occurrence in the river), and the larger is more typical of low water springs. It is seen that the thruster power requirement is noticeably higher for both vessels, but is still within their overall power capability. The steep rise in power above 6 knots indicates the penalty of driving a ferry too fast in the river, and also shows how the vessels themselves will be limited in speed by the shallowness of the river at low water.

7.3.4 Windage Effects

The increased windage of the W-class ferries results in concerns in the following areas:

- Increased thruster activity to hold station in strong cross winds
- Increased wind shadowing effects causing problems for sailing vessels near to the ferries.

Increased Thruster Activity

It has been shown above that the increase in thruster slipstream velocity needed to hold station in cross winds up to BF9 is around 10% for the W-class, compared to the C-class. Attenuation of the slipstream should reduce this somewhat by the time it impinges directly on any nearby small vessel, but it would be nevertheless prudent for such vessels to keep as far from the ferries as possible.

A ferry waiting in the river for the other to pass, however, will still be likely to set the surrounding water in to an eddying motion, as described above.

Wind Shadowing Effects

Wind shadowing occurs in many instances on land and sea and is commonly met when sailing. Indeed, in some sailing situations “taking another’s wind” a well-known racing tactic. However, common experiences of wind shadowing in other contexts include bringing a large vessel alongside a berth dominated by large buildings which can be difficult in winds because of shadowing, and inland water dinghy sailors having to contend with loss of wind and changes in wind direction due to shadowing effects.

Wind shadow is most likely to cause problems for leisure users of sailing craft without any alternative means of power while passing ferries at low water (especially low water springs) when the available water space is reduced.

Shadowing is due to the downstream wake of the bluff body which is the ship’s superstructure. In the absence of flow visualisation data for both Wightlink ferries under discussion, Figure 24 shows the sort of flow which might be expected as the wind blows across the ferry's upperworks; the view looks along the "ferry" from bow to stern or vice versa.

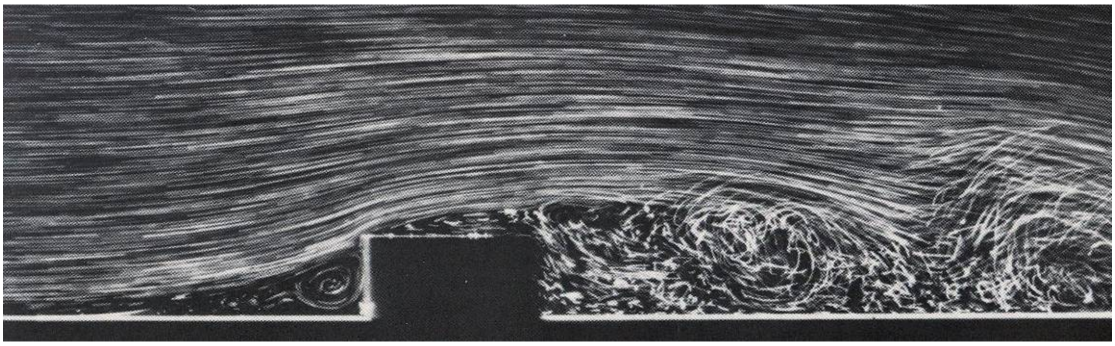


Figure 24: Flow Around a Bluff Body on a Surface. (from "An Album of Fluid Flow", The Parabolic Press, Stanford, California)

Several features may be noted:

- There is an area of "dead" flow immediately in the lee of the "ferry", after which eddying flow dominates.
- The downstream disturbance is a confused, eddying flow whose effects extend above the "ferry".
- Flow directions and strengths are continually changing with some of the flows reversed.
- There is some evidence of a trapped eddy on the upstream side of the "ferry". However, the photograph is of a two-dimensional flow and would be modified as flow leaked round the ends of a real three-dimensional superstructure. This would cause the upstream eddy to dissipate to a certain extent.
- The eddying flow gradually dissipates as it flows downstream and mixes with the main flow.

The last point means that, the further downstream of the ferry a boat is located, the less disturbance it will feel; it is usual to assume that some 10 times the body height downstream is the area where the wind flow is back to normal and the shadowing has disappeared. For the C-class, the effective superstructure windage height is about 8.5 metres and that of the W-class is about 11.8 metres. (It should be noted that this is not to the highest point above water - the "air draught" – but rather the height of the main part of the superstructure blocking the wind). From these values, it may be deduced that the wind shadow would extend some 85 metres abeam the C-class vessel and some 118 metres for the W-class. For a ferry waiting near Pylewell, these regions are outside navigable water for all but the smallest boats. Most leisure users' boats will in fact be within the eddying region for both ferries when navigating in the river; end effects will, however, make the longitudinal extent of the very disturbed flow less than the full longitudinal extent of the main windage area.

Nevertheless, it is true that the new ferries, when passed by a small boat, will cause a disturbance for a greater period of time due to the increased windage length of the new vessels. Rough estimates of such times for a range of relative passing speeds are given in Table 5.

Relative Passing Speed (knots)	Disturbance Times (secs)		Difference (secs)
	C-class	W-class	
2	21.4	39.4	18
4	10.7	19.7	9
6	7.1	13.1	6
8	5.3	9.8	4.5

Table 5

Apart from the longer disturbance time with the new ferries, it would seem that the effects of their disturbance will be similar in practice to the present situation. This will receive consideration in Phase 2 of the study when recommendations are considered and activities on the congested river have been witnessed.

7.3.5 Ferries Passing and Waiting in the River

It has been shown in Section 5.6 that a consequence of a three boat operation is a passing manoeuvre in the river. This will have effects:

- On both ferries as they interact with each other when passing
- On other river users due to the loss of available water space for a time during passing
- On the river waters should an inbound ferry have to hold station in Short Reach for some reason.

Interaction

When ships pass they interact with each other. In a river or canal they may also interact with the banks of the waterway. Both effects can be significant and cause the vessels to sheer off course into the paths of others, or to run aground.

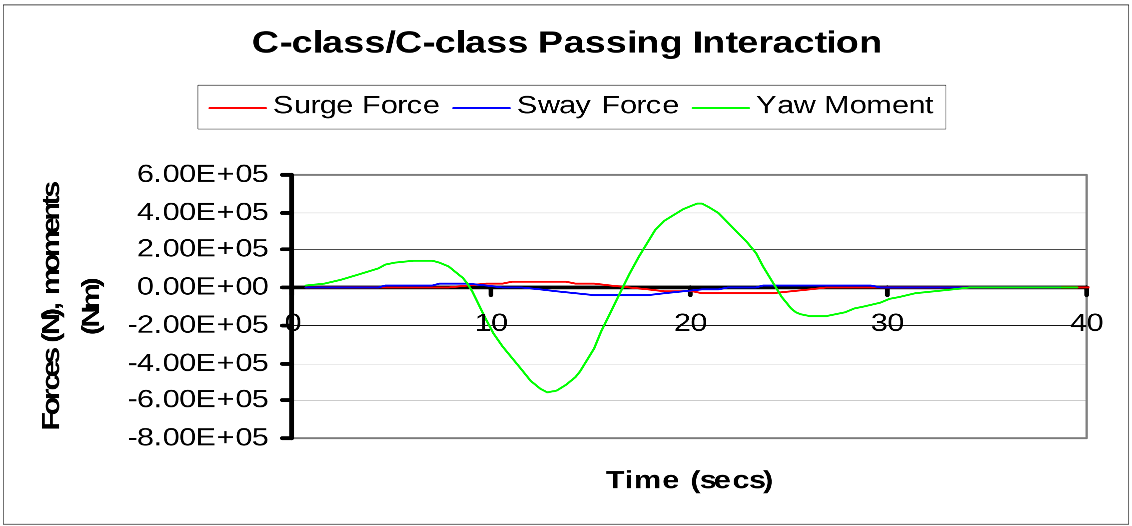
In reciprocal passing the relative velocity is such that ship-ship interaction effects are over comparatively quickly before they have time to act, but there could be an effect after passing. However, interaction effects depend strongly on relative speed and at low speeds they can generally be handled satisfactorily, especially with ships having good control and manoeuvrability. This is the case with the C-class vessels and presumably will be so with the W-class (see below). The study team has been unable to find any evidence of serious navigational incidents on the river which have been ascribed to passing interaction. Bank effects are certainly felt by the ferries at low water, but they are well within the control capabilities of the C-class. At this stage, there seems to be no reason to believe that the W-class will be any different in this regard.

Rough estimates of the interaction forces and moments in reciprocal passing for two W-class vessels passing each other compared to those on two C-class vessels passing are shown in Figure 25 from which it is seen that the main differences are confined to the predicted yaw moments.

Available Waterspace

The width of waterway for passing vessels may be determined from guidelines given in Reference 8. These have been derived from best practice in ports world wide, but have been developed with large ocean-going ships in mind and not those fitted with propulsion and control devices which make them very manoeuvrable. Applying these guidelines to passing in the Lymington River between two ferries, purpose-built for the river passage, should therefore be done with caution. Further caution should also be exercised when it is realised that; although the waterline beam of the C-class is some 12.5 metres, its actual beam for the purpose of passing is around 16 metres: that of the W-class. As the overall beam of the new ferries is virtually the same as that of the present vessel, additional loss of waterspace width for other users will be negligible.

The PIANC guidelines from Reference 8 indicate a 67 metre wide navigable channel at LAT for the C-class vessels; the navigable width is in fact about 64 metres near Pylewell from Reference 2. For two W-class vessels passing, the guidelines suggest a navigable width of some 86 metres; this occurs at a tide height of about a metre.



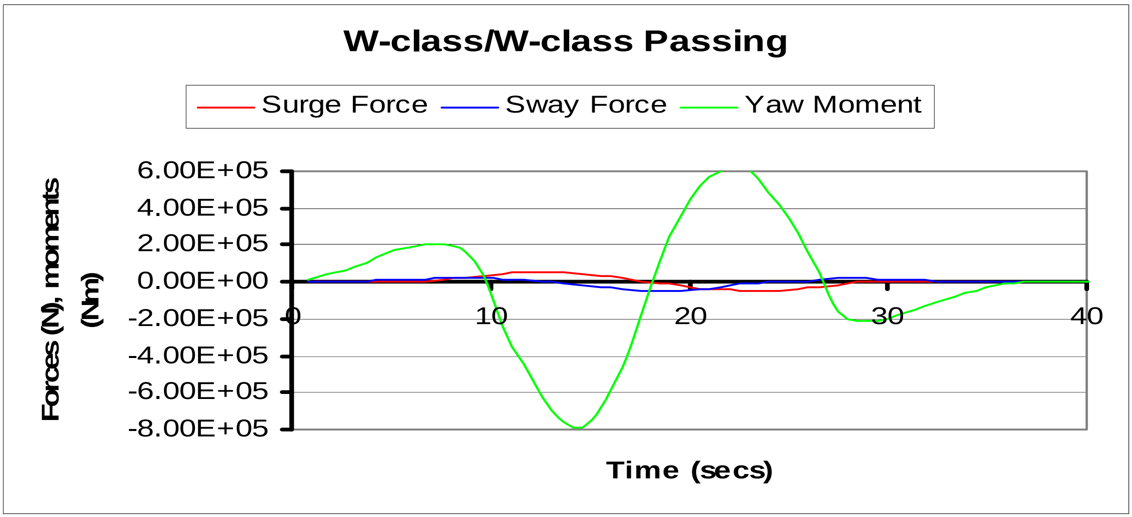


Figure 25: Estimates of Ship-Ship Interaction in Reciprocal Passing

It should be understood that the PIANC recommendations are guidelines only, developed for ocean-going vessels. The guideline channel width figures given above have been developed from the “Concept Design” part of Reference 2. In a typical channel design exercise, where it is difficult to obtain the recommended width, or the vessels in question differ significantly from those upon which the guidelines are based, a more detailed assessment of the channel design would be made after the initial channel width figures have been obtained. This is good (and quite common) practice, and would usually involve computer modelling in which both the ships and the channel would be modelled. In the present case at

Lymington, the ships in question have specialised designs and the modelling of a channel through mud would be less than straightforward. It is therefore proposed, in this case, to "model" at full scale and pay close attention to the behaviour of the new ferries while passing; any significant signs of interaction which could compromise safety will be noted and used in the final recommendations of Phase 2.

Waiting

On a three-boat service, an inbound ferry should not have to wait if the schedule is maintained, as demonstrated above. On a two-boat service, a 45 minute schedule would eliminate passing in the river, again if the schedule is maintained and satisfaction of demand ignored.

But there are inevitably events which will disrupt any schedule and this can lead to waiting in the river. The disruption this causes to other river users, not to mention the ferries themselves, has been discussed above and it is clear that it should be avoided if at all possible; on a three-boat service, uninterrupted passing on the river should be the norm. Should there be a disruption in the schedule, it should be possible to communicate between inbound and outbound ferries so that the inbound vessel can adjust its speed in the Solent to avoid the need to wait. Obviously, this will not be the solution in all cases and at certain times waiting in the river will be inevitable. However, it is suggested that the culture on the ferries, old and new, be such as to avoid waiting in the river in all but exceptional circumstances.

7.3.6 Reliability

The use of redundant engines on the W-class vessels should increase their reliability considerably compared to the present vessels. The latter have shown a reduction in reliability over the years and the loss of a thruster which accompanies the loss of an engine is a shortcoming which should be effectively eliminated with the new vessels.

This should be a benefit to other river users and the possibility of a ferry drifting or delayed through mechanical problems should be much reduced, if not eliminated. In this regard, it may be noted that a mechanical failure while the vessel is berthed can upset the schedule and lead to inbound ferries having to wait.

7.3.7 Handling on the River

The hull shape of the new should help manoeuvrability in the river. This is due to the fact that most of the displacement is concentrated in the middle two thirds of the hull, with raised portions at either end to accommodate the thrusters. This will aid turning, but, by the same token, may make the vessels a little less directionally stable. With the fine control possible on Voith thrusters, this should not be a major problem and is most likely to be felt on the Solent crossing, rather than in the river.

The inherent manoeuvrability of the new vessels on the river should therefore be no worse, and possibly better, than the C-class ferries. This would benefit users in that there should be no need for the ferries to reduce speed because of day-to-day handling problems.

7.3.8 Fields of View from the Wheelhouse

Figure 26 shows the field of view from the wheelhouse of a C-class ferry. The following are the dominant features obstructing the view:

- The loading ramp on the centreline, hiding anything dead ahead in part of the view.
- Tripod masts
- The forward portion of the deckhouse upon which the wheelhouse stands
- A hand-rail

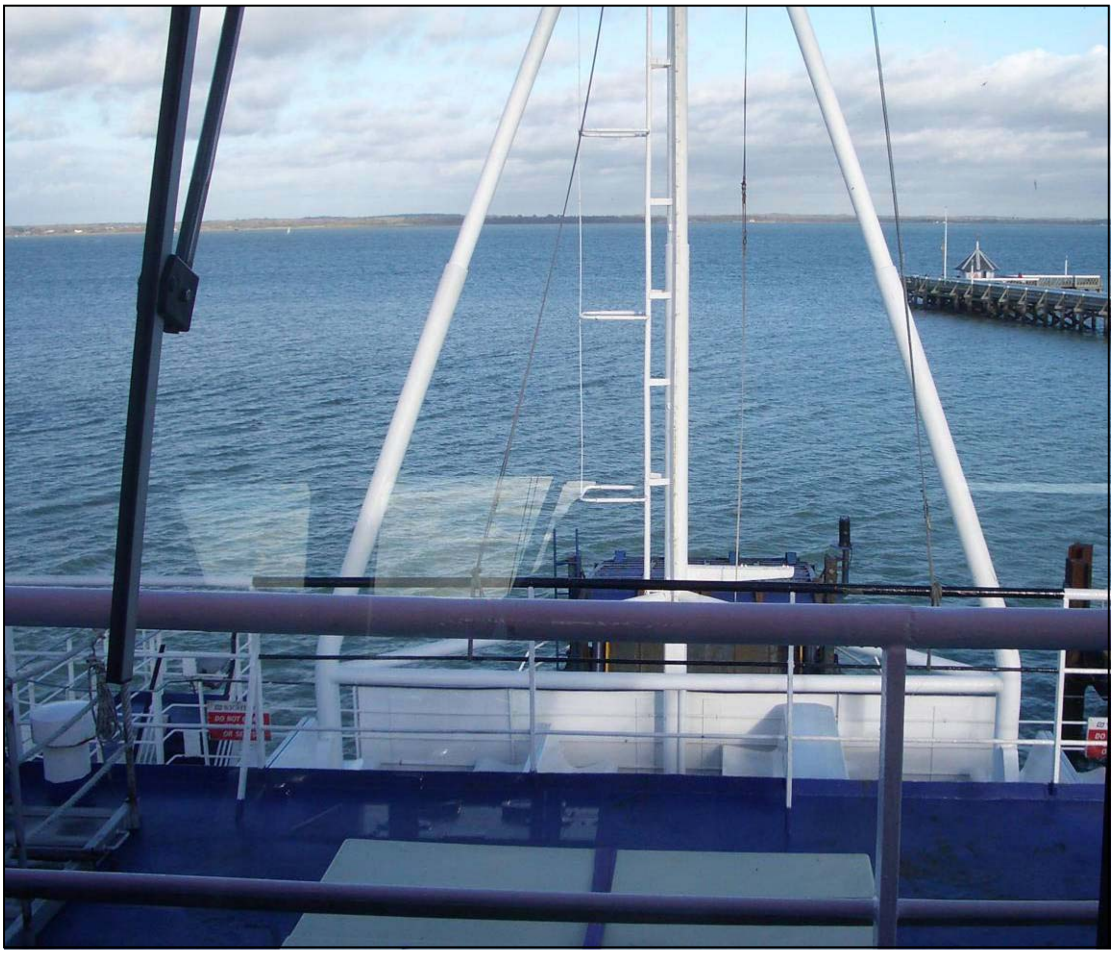


Figure 26: Field of View from Wheelhouse of C-class Ferry

The field of view from the wheelhouse of the W-class ferries will eliminate the obstruction of the wheelhouse hand-rail, but will still see that on the forward part of the sun deck and the sun deck itself. A tripod mast obstruction will be present on the centreline, and there will be two short masts either side of the stored ramp. The obstructed field of view dead ahead will be about 34 metres on the centreline, compared to about 22 metres for the C-class vessels.

However, it should be remembered that the wheelhouse on the W-class vessels extends to and beyond the lateral extremities of the beam, giving a wide lateral field of view. Observations on the C-class vessels shows that, in spite of the view dead ahead on the centreline being partially obscured by the bow ramp, moving to the bridge wings gives a lateral view of part of that obscured area. This suggests that when the risk of people or objects in the water being obscured is high, the sensible practice of posting lookouts at the extremes of the bridge wings, as suggested by the masters, be instigated, especially when operating in dense river and Solent traffic conditions, and before leaving the terminals at Lymington or Yarmouth. This would not only effectively improve the field of view but would also improve the ability to see a situation ahead of the vessel developing. However, the use of CCTV will be considered in Phase 2, if it is concluded that this would have additional safety benefits.

8. Risk Assessment

In this section, an attempt is made to assess the present marine risk on the route, with particular attention being paid to the Lymington River. A Risk Register has been compiled in which the main marine risks identified by the study team for the present situation are listed. This will be used as a benchmark against which to judge the performance of the new ferries on completion of their trails on the river. The risk control measures needed to keep any increase in risk in line with the ALARP concept will then be based on the revised risk register.

First, however, it is of value to discuss the reported incidents on the river to get an impression of the overall marine risk from a historical perspective.

8.1 Historical Incidents

Incidents reported to the Lymington Harbour Commissioners February 1998 to December 2007 have been collected and analysed by the LHC. These concern all incidents involving ferries in the river (including near misses) and are believed to be a comprehensive record. No incidents in the Solent or at Yarmouth are included.

The incidents have been categorised and Figure 27 summarises the results. The categories used are as follows:

- Striking a navigation post or pile
- Collision with a leisure craft
- Collision with a commercial craft
- Close quarters situation with a leisure craft
- Close quarters situation with a commercial craft
- Obstruction of the ferry
- Wash due to speed
- Thruster slipstream effects
- Mechanical failure on a ferry
- Oil spill from a ferry
- Grounding
- Wind shadow
- Other

A total of 58 incidents have been recorded in this time period and, with 225,000 ferry movements over the same period, this amounts to 0.26 incidents per 1000 ferry movements.

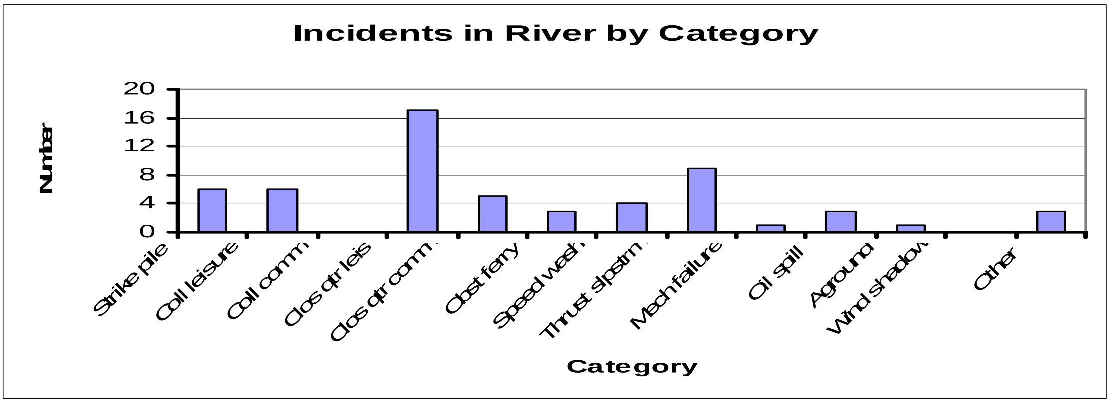


Figure 27: Historical Ferry-related Incidents on the Lymington River

An alternative incident rate figure takes the movements of all craft in the river into account. In this regard, an attempt to determine movements of leisure craft has been made by LHC and their values for visiting craft are summarised in Table 6. Note that "Off Peak" refers to the periods March-May and September-November inclusive (but excluding Bank Holidays), and "Peak" refers to June-August and all Bank Holidays.

Period	Movements in Period
Off peak weekday	44-52 (mean 48)
Off peak weekend	86-90 (mean 88)
Peak weekday	140-164 (mean 152)
Peak weekend	434-478 (mean 456)

Table 6

No records exist for the number of movements from resident river users in the same period, so a rough estimate had to be made. Knowing the number of moorings available to residents to be 1600 it may be assumed that in peak times about 20% to 25% will be on the water on any day with the higher value for weekends and Bank Holidays. (These percentage values have been obtained for a typical marina, but not one of those at Lymington.) Further, assuming that ratios similar those used in Table 6 for weekdays and weekends in peak and off-peak times apply, and allowing for some craft to leave the river and go elsewhere, the movements in Table 7 have been obtained.

Period	Movements in Period
Off peak weekday	150
Off peak weekend	270
Peak weekday	470
Peak weekend	1400

Table 7

Annualising these figures gives an approximate number of leisure craft movements in the river over 10 years of just under 1,060,000. Adding this to the ferry movements reduces the incident rate to 0.045 ferry-related incidents per 1000 vessel movements of all types. This value is compared with benchmarks of incidents/1000 movements other ports and harbours world-wide given in Table 8, meaned over the period 1995 to 2000.

Ports	Mean Incidents/1000 movements
Hong Kong	1.7
Australia	0.7
UK	0.7
Korea	2.3
Rotterdam	Ranges from 4 to 12 from 1987 to 1995

Table 8

Even if only the figure of 0.26 per 1000 ferry movements alone is considered, the incident level compares very favourably with these international benchmarks. Indeed, it confirms the statement made in Reference 1 that ferries and leisure users at Lymington have co-existed satisfactorily over the years with very little marine risk, bearing in mind the amount of traffic on the river.

Before leaving this topic, it is of some interest to look at details of the reported incidents. The following observations may be made:

- There is no record of any wind shadow-related incidents
- The most frequent incident types are :
  - Effect of adverse weather (12%)
  - Effect of ferry movements at or near the Lymington berth (12%)
  - Effect of ferry thrust when in the Lymington berth (8.6%)
  - Effect of ferry waiting in river (8.6%)
  - Effect of excessive ferry speed and wash on moored boats (5%)
- There is no record of any collision between two ferries or between a ferry and a commercial vessel, but collisions between a ferry and a leisure craft amounted to 10% of the total.
- The most common incidents were close quarters situations between a ferry and a leisure craft
- The next most common related to thruster slipstream effects.
- Incidents related to some form of mechanical problem on the ferries (failure and oil spill) together amounted to 7% of the total.
- Many of the incidents occurred before the statutory and advisory speed limits were inaugurated on the river.

8.2 Risk Register

A risk register is included as Table 9. This has been compiled for the present situation and will be re-visited in Phase 2 of the study, after the trials of the W-class ferries have been completed, to assess the change in marine risk likely as a result of their operation.

The two components of risk (probability and consequence) have been shown and have each been allocated a ranking on a scale of 1 to 5, based on the existing situation. These are simply multiplied together to gain an idea of the overall risk of each entry in the register.

The register starts with what might be considered the most important hazards for consideration: those that relate to injury or loss of life. First among these is the only hazard so far identified which could involve multiple injury and loss of life and that is a collision between a ferry and another vessel on the Solent crossing. If the other vessel is large, such a collision could lead to ferry damage and capsize, so it is understandable that the ferry design and operation must comply with the statutory requirements of the MCA and the IMO as well as safe operation as required by various regulations such as the International Regulations for

Preventing Collisions at Sea. These, of course, are requirements which drive the design and operation of all ro-ro ferries and have done so for the W-class. There is therefore no question that the new ferries must comply and this accounts for their increase in displacement.

It is also clear that the Lymington River must be operated safely and this is the main responsibility of the LHC. The remaining hazards in the Register therefore relate to operations in the river, some being of greater weight than others.

8.3 Risk Control Measures

The fact that the number of historical incidents involving ferries is so low indicates that operations on the river have been carried out at very low risk. This is no doubt due to the control measures put in place by the Lymington Harbour Commissioners together with the local yacht clubs and other leisure craft organisations, as well as the competence and seamanship of the Wightlink ferry crews.

The Codes of Practice for Junior Sailing events are, as far as is known, adhered to closely in Horn Reach and a safe sailing environment is provided for the young sailors in an area of the river regularly traversed by ferries. It is doubtful if better control measures can be devised for this particular activity and the young sailors are clearly well looked after.

Codes of Practice for other sailing events mention ferries (although many of the concerns listed in Section 6 above are not specifically referred to) and Reference 4 provides sensible advice to all users regarding the ferries.

In season, other users are also guided when appropriate by the Harbour Master's patrol launches. However, it is noted that harbour patrols are weighted toward the upper reaches because of the need to manage the visitor mooring area. (See Recommendations in Section 10.2)

In view of the possibility that waiting ferries could set the river waters in motion in Short Reach to the detriment of other users in or near the passing area, it would seem that further control measures here would be beneficial. It would seem that the ideal solution would be to avoid the need for a ferry to wait in the river, but it is accepted that there will be times when it is unavoidable. When it does occur, an additional presence by the Harbour Master's river patrols would be useful downriver to ensure that any congestion or other problems caused by the waiting ferry were dealt with swiftly and competently. Whether ferries are waiting or not, the additional patrols would be a useful safety feature in times when the lower reaches of the river are congested.

Nevertheless, ferry waiting in the river should be the exception rather than the rule and it would seem that proper communication between ferries would allow the inbound ferry to adjust its speed on the Solent crossing to arrive at the passing place at the same time as the delayed outbound vessel. If the delay is likely to be protracted, then the inbound vessel should wait in the Solent near the mouth of the river (as they do in bad weather), or delay their departure from Yarmouth. Perhaps before leaving Yarmouth or Lymington, the ferry masters, as well as checking that they are keeping to schedule, could routinely call up their opposite number at the other terminal to see if any delay is likely; they will then be forewarned. If the delay is likely to be very protracted, the service may have to continue using the emergency slips. In this case, it is understood that the new ferries will use small bespoke floating pontoons between ferry ramp and slip for docking.

Other control measures listed in the Risk Register are a combination of common sense and the tenets of good seamanship, many of them to be found in the "Safety & Navigation" section of Reference 4.

9. Discussion

It is unfortunate that Phase 1 of this study was carried out off-season when there was very little leisure traffic on the river. Congestion has not therefore been witnessed, especially in the lower reaches, in the passing area. This, naturally, makes it very difficult to draw any early conclusions about Phase 2 with the new ferries because, although users have been very helpful in describing activities on the river, it is essential for the study team to witness them in reality.
This state of affairs will, of course, be remedied in Phase 2 which is likely to be carried out in a period of peak sailing activity. It will also be the period of peak demand for the ferry services so it will be possible to witness the co-existence of ferry and leisure traffic at first hand.

Nevertheless, it is clear that the river is well-operated and the marine risk level is very low. It is important that the introduction of the new ferries keeps any change in marine risk as low as reasonably practical (ALARP) and the trials of the new vessels will be crucial in assessing whether any further control measures are necessary. As mentioned above, it would seem that a combination of common sense and good seamanship will go far to resolving any problems, but some operational aspects have been highlighted for attention.

The need for ferries to wait in the river has been mentioned several times above. Having witnessed ferry operations in the virtual absence of any leisure traffic in the river and with a 2-boat, 3-boat or mixed service in operation, it is clear that, in such ideal circumstances, waiting can be all but eliminated. It would therefore seem that the off-season period is a time when any modifications to ferry operating practices could be tried out and, if necessary, refined in order to be ready for the more congested peak times of operation. It is therefore recommended that means to avoid waiting with a 3 (or mixed) boat service are developed.

Significantly reducing the need for waiting would also reduce the congestion in the passing area (especially at low water springs), to the benefit of the leisure users. It would also lessen the possibility of the new ferries stirring up the waters in the passing area rather more significantly than at present, the increased mass flow from their thrusters while holding station being the source of this disturbance.

Clearly, a 3-boat half-hourly service leads to passing and waiting on the river while a 2-boat service need not, depending on schedule, as demonstrated in Section 5.6 above. It might be thought that a 2-boat service should be recommended to avoid any need for passing on the river at all. Clearly such a change would have to consider demand, but it is understood that the demand cannot be satisfied in peak season by a 2-boat service. Presently, we do not see a case for abandoning the 3-boat service, provided waiting in the river can be made the exception, and unhindered passing the rule. In this regard, it is noted that no incidents from ferries passing in the river appeared in the historical records; this is in contrast to a small number of incidents due to ferries waiting in the passing area.

No	Hazard	Probability	Ranking (a)	Consequence	Ranking (b)	Risk (a)x(b)	Risk Control Measures	Risk after Control Applied
1	Ferry capsize in Solent after sustaining damage	low	2	Multiple injury and/or death	5	10	Ferry damage stability to conform to IMO/MCA requirements; operation of the ferry to conform to ISM/STCW requirements	Low if compliance obtained; high if not. New ferries will comply
2	Person in water hit by ferry	low	1	Injury and/or death	4	4	Keep clear of ferries as advised in LHC booklet; ferries keep lookout; ferries able to stop rapidly	Low. Applies to existing and new ferries
3	Person in water sucked into thrusters	low	1	Injury and/or death	4	4	Keep clear of ferries as advised in LHC booklet; ferries keep lookout; ferries able to stop thrusters immediately	Medium with existing vessels; low with new vessels
4	Boat (moored or moving) hit by ferry	Low	1	Damage to boat; possible injury and/or death	3	3	Curtail extended presence of people on vulnerable boats on single point moorings close to the fairway; keep good lookout on ferries; keep clear	Applies to both existing and new ferries

							of ferries	
5	Sailing vessel passes into ferry wind shadow in river	high	4	Short loss of steady wind; possible capsize for dinghies	1	4	Keep clear of ferries as advised in LHC booklet;	Low for existing and new ferries.
6	Junior sailors pass into wind shadow in Horn Reach	low	1	Loss of steady wind; possible capsize for dinghies	3	3	Juniors moved to sides of water space as ferry passes.	Low for both existing and new ferries
7	Need for low ferry speeds in the river due to the probability of excessive wash	low	1	Loss of leisure sailing time; damage to river banks; ferry scheduling problems	3	3	Ferry hull design and speed to minimise wash while maintaining control	Low with existing ferries and advisory and statutory speed limits. To be determined with new ferries, but likely to be low in Horn Reach.
8	Erosion and accretion at terminals due to thruster action	high	4	Loss of water depth at Yarmouth, scour pits at Lymington	1	4	Place thrusters in neutral pitch; Turn off thrusters	Medium with existing ferries; low to negligible with new ferries
9	Thruster slipstream and mass flow effects	High	4	Boats moved; river eddies produced at low water when ferry waiting	2	8	Avoid waiting in river; keep clear of ferries as advised in LHC booklet; set thrusters in neutral pitch in berth	Low if waiting avoided for both existing and new ferries
10	Ferry waiting in river	Medium	3	River eddies produced at low water when ferry waiting; inconvenience to	2	6	Avoid waiting in river	Low if waiting avoided for both existing and new ferries

				other craft; grounding of leisure craft				
11	Congestion	Medium	3	Collision/grounding; transit speed reduced with effect on schedule	2	6	Adhere to sailing CoPs to limit boat numbers, increase LHC patrols in lower reaches. Keep out of the main channel if possible	Low to medium with both existing and new ferries
12	Limitations in the Field of View	High	3	Striking, collision	2	6	Maintain lookout, use extent of bridge wings on ferries, check around ferry before departure	Low for both existing and new ferries
13	Grounding	Medium	3	Blocking river, navigation hazard, damage to vessels	2	6	Use ferries designed for the river, with good controllability at all water depths, thrusters contained within hull envelope and competent crew. Design in ability of hull to take the ground. Ensure navigation marks correctly positioned; maintain lookout; proceed with caution; provide visual tide height gauges on	Low for both existing and new ferries

							navigation posts; ensure river does not silt; make bathymetry plots available.	
14	Mechanical failure and oil spill on ferry	Medium	2	Loss of control, hazard to navigation, damage to other vessels	3	6	Provide redundant machinery, upgrade machinery and seals	Remains medium on existing ferries, low to negligible with new ferries.
15	Severe weather (wind and fog)	Medium	3	Loss of control, use of more waterspace, grounding, damage to vessels and navigation posts	3	9	Improve ferry control, use radar-conspicuous and "handrail" visual navigation marks which clearly define the channel, allow masters to cease ferry operations if they consider situation unsafe	Medium to low with both existing and new ferries.
16	Wash	Medium	3	Damage to river banks, inconvenience to other users, causes moored boats to roll.	2	6	Control speed, use low wash hull forms, be aware of other users on the river and slow down if necessary.	Low with existing ferries; possibly low to medium with new ferries.
17	Interaction effects on moored vessels	Medium to high	3	Moored vessels (especially those on single point moorings) pulled into the main	2	6	Ensure boats moored near the channel cannot swing into the path of passing ferries	Low for both existing and new ferries.

				channel.			and other large vessels.	
18	Navigation posts out of position.	Medium	2	Grounding, blocking channel (see 13 and 15 above)	2	4	Ensure navigation posts correctly located.	Low for both existing and new ferries.
19	Two ferries colliding when attempting to pass in Short Reach	Low	1	Multiple injury, grounding, blockage of navigation channel	5	5	Adhere to ColRegs, use leading marks in good visibility radar in poor visibility, and the master's judgement as to whether to pass at all in bad visibility	Low for existing ferry

Table 9

Note: Ranking 1 to 5 with 1 low and 5 highly likely/catastrophic

The ability to stop the thrusters on the new ferries while berthed will help eliminate much of the bottom scour in these regions, but care should be taken to avoid excessive thruster use when breasting off and on to the overnight layby berths. Nearby moored small craft can be affected by both the thruster slipstreams and interaction from the ferries and, while the resultant movement of the small craft may be inconvenient at best, it could be dangerous if someone is working on deck or moving from one boat to another.

The general effects of the ferries on moored vessels arise from interaction and wash. The new ferries have hulls with some low wash characteristics, but it appears that their stern wave system may be larger than that of the present vessels. If this is borne out on the trials and the frequencies of some of the wave components are such as to cause severe rolling of vessels on single point moorings in Short Reach, then consideration should be given to ensuring that people on board such vessels are aware of the risks of moving about on deck when the ferry passes.

Collisions between ferries and moored vessels are statistically low, so the need to avoid populating moored boats for extended periods in vulnerable areas does not seem to be pressing, although staying for long periods on some of the more vulnerable moored boats should be discouraged.

Having said this, however, it is clear that safety issues related to the increased wind shadow, changes to wash, passing in the river and the effects of the larger thrusters on the new vessels are matters of serious concern to the leisure users. Some background information and estimates relating to these effects have been given above, but no firm conclusions as to the altered magnitudes of these effects brought about by the introduction of the new ferries can be given until the Phase 2 trials have been carried out. In these trials special attention will be paid to passing (as already highlighted above), wash (by repeating the water level measurements carried out for Phase 1 with the new ferries and other vessels), thrusters (by observation, and measurement if possible) and wind shadow by using an anemometer located at a suitable height on one of the navigation posts close to the ferry track. This will measure the change in wind speed and direction as the ferries pass.

The Phase 2 trials are therefore crucial to the outcome of the risk assessment. Because of this, it is important that a structured trials programme be carried out. A possible form is suggested below, on the assumption that initial handling and familiarisation trials have been completed satisfactorily with the new vessels:

- Both classes of ferry at representative draughts
- High water spring arrival and departure with no passing or waiting
- Mid-tide arrival and departure with no passing or waiting. Tide level to be compatible with mid-ebb on 22/23 January 2008
- Low-tide (spring) arrival and departure with no passing or waiting. Tide level to be compatible with the 0.45m level measured at 16:10 on 22 January 2008
- Repeat the above with W-class/W-class and W-class/C-class passing
- Emergency stopping under control and stop-and-hold on the river for both W-class and C-class ferries.
- Waiting in the passing area at or near low water to determine the extent to which the thrusters cause the river to be set in motion. If this is serious, then the recommendation to avoid waiting will be endorsed.

In these trials the following items, mentioned above, should be checked:

- Wash and drawdown
- Evidence of increased ship-ship interaction (and therefore increased risk) when passing in the river using the existing leads
- Whether the speed limits in the river remain satisfactory
- The effect of speed through the water on wash
- Thruster slipstream effects on the river and other users, with observations of effects upstream as well as downstream of the thrusters.
- Effect of the ferries on moored vessels from interaction and wash
- Control of speed profile on the route to avoid waiting in the river
- Fields of view from the wheelhouse when the river is busy, to compare with present vessels
- Effect of the ferries on the wind, to provide evidence of the magnitude of wind shadow.

Ideally, initial trials should be undertaken in the absence of river traffic congestion; later trials should certainly be carried out with congestion normal for the season.

Based on observations made to date, together with estimates and calculations made for the new ferries, it would appear that the wash from the new ferries at 4 knots through the water will be very much the same as that from the existing ferries. Bearing this in mind and the fact that the new ferries are likely to have excellent control, there would seem to be no reason that operations in Horn Reach with the new ferries should differ from those presently in place. Wind shadow should not be a problem for Junior Sailors there because they are moved aside as the ferries pass, and the evidence on wash from, and control of, the new ferries suggests that they should not need to go any slower than the advisory 4 knots.

The present risk controls on the river are clearly working well; many are outlined in the Risk Register and, with the information presently to hand, would appear to be suitable for operations with the new ferries. However, any firm conclusions on this, changes to the Risk Regisiter and recommended new measures must await the outcome of the Phase 2 trials.

In conclusion, it is clear that the river as operated at present is a safe environment where ferries and leisure users co-exist satisfactorily. It is also clear that the introduction of the new ferries must not upset this situation.

10. Conclusions and Recommendations

Phase 1 of a two-phase study, dealing with the present ferry and related operations on the Lymington River, has been completed. As a result the following conclusions are drawn and recommendations made.

10.1 Conclusions

- The present level of marine risk on the river, as measured by the number of ferry-related incidents over the past 10 years, is low, with suitable risk management measures in place for sailing and other activities.
- Commercial ferries and leisure users have been able to co-exist on the river satisfactorily for a large number of years
- The new ferries are larger in several respects than the existing ferries. Much of the increase in displacement and changes in hull shape are a

result of the survivability requirements now mandatory for all ro-ro passenger ferries. Some of the increase in above water enclosed volume is probably due to the greater stowage volume required by present traffic demand.

- Passing in the river is a consequence of a 3-boat 30 minute service or a mixed service run with 2 boats.
- Waiting in the river is disruptive to leisure users and prolonged use of the thrusters to hold station, especially at low water, may cause large eddies to form in the river. These are disruptive to leisure craft and other users of the river.
- The drawdown from the present ferries is low, generally of the order of 40mm to 50mm or less near the banks in Short Reach. On one occasion, however, a drawdown between 150mm and 170mm was measured as a ferry passed close to the measurement location. No breaking waves were witnessed as a result of drawdown or water level recovery. Free wave heights and frequencies from the ferries are similar in magnitude to those caused by some smaller vessels.
- Natural ambient waves at the Pylewell measurement location can be noticeably higher than the free waves produced by the ferries.
- Boats affected by wash in the river react to wave frequency rather more than wave height.
- Maximum tidal stream values in an ebbing spring tide are of the order of a knot in Short Reach. In Horn Reach on a similar tide, they are much less at about 0.33 knot. Over most of the tidal cycle the flow velocities were considerably less than these values, however, implying that overground speed in Horn Reach will be very similar to the through-water speed for most of the tidal cycles and close to ground speed for much of the time in Short Reach.
- There should be no need for the new ferries to navigate Horn Reach any differently from the existing ferries.

10.2 Recommendations

- Make ferry waiting in the river the exception and unhindered passing the rule
- In peak season, increase the Harbour Master's patrols in Short Reach, especially in the region of the passing place
- Ensure that ferries continue to make sound signals on leaving the terminal when junior sailing is in progress, and make it common practice to give similar signals when inbound at the Cocked Hat navigation post.
- Ensure that the navigation posts in the river mark the limits of the navigable channel and provide a visual indication of the channel in all conditions, including fog.
- Install visual tide boards on navigation posts
- Ensure that a structured programme of trials is undertaken with the new ferries. (A preliminary template for such trials is suggested in the report)

11. References

1. "Wightlink Ferries: Lymington Harbour Navigational Review" Eagle Lyon Pope Report No: ELP-55272-1206-57219-Rev 1, December 2006

2. "Lymington River Channel Bathymetric Survey" PRO Surveys Ltd, 2006

3.	LHC Code of Practice for Organised Events produced in consultation with the Royal Lymington Yacht Club and the Lymington town Sailing Club, 2007. Also various supporting risk assessments, policies, plans and procedures produced by the clubs themselves.
4.	"Lymington Harbour 2008. Harbour Facilities and Local Services including Tide Tables" Lymington Harbour Commissioners, 2008
5.	Merchant Shipping (Passenger Ship Construction: Ships of Classes 3 to 6(a)) Regulations 1998. Statutory Instrument 1998, No 2515
6.	Lloyds Register of Ships 1992-1993
7. Dand I W and Ferguson A M	"The Squat of Full ships in Shallow Water" Transactions of the Royal Institution of Naval Architects, vol 11, 1973, p.237→
8.	"Approach Channels: a Guide for Design" Final Report of the Joint PIANC and IAPH Working Group PTC II-30 (in conjunction with IMPA and IALA). Supplement to Bulletin 95, June 1997.

Appendix 1

Terms of Reference

Terms of Reference

Lymington Harbour Commissioners

Terms of Reference for Ferry Operations Risk Assessment

Introduction.

This document is intended to provide a set of terms of reference for an independent consultant with relevant experience in marine risk assessment to be employed to undertake a full risk assessment of the operation of the new ferries proposed by Wightlink for the Lymington to Yarmouth route. The assessment shall include the verification of the ELP Report (December 2006), the provision of an appropriate agreed methodology for measuring impacts during live sea trials, and a risk assessment to define any necessary reasonably practicable risk mitigation measures that may be required to enable the LHC to meet the requirements of the Port Marine Safety Code. The work will require liaison with all river user groups. The exercise will necessarily be conducted in several parts.

Part 1. Review of Previous Study Work

As part of their own investigations, Wightlink have had two reports produced, one relating to the navigational characteristics of the new vessels within the river, and the second to consider possible environmental impacts.

The appointed consultant shall review the Navigation Report (Ref 1), and following a new analysis of the existing data, provide an opinion regarding the likely accuracy of its conclusions. This information (in combination with that developed from Part 2) will then be used to inform the Appropriate Risk Assessments in Part 3.

The framework for any further assessment of environmental impacts is currently being considered by the Marine Fisheries Agency, Natural England and the Environment Agency. We understand that these regulators are taking legal advice on how/if any further assessment should proceed. LHC will be guided by the outcomes of these considerations which must be set within the legal framework for assessing projects of this nature. Hydrodynamic data captured to help inform this study will be available to help inform environmental considerations.

Part 2. Provision of Methodology for Measuring Impacts during Live Sea Trials

LHC and Wightlink have developed a draft methodology (Annex 1) to quantify the present and potential future hydrodynamic effects of both the existing and proposed larger ferries through a series of “live” sea trials. The appointed consultant will be required to review this methodology and offer an opinion on whether it is fit for purpose, can reasonably be achieved, and where necessary provide reasoned recommendations for improvement. The appointed consultant will be responsible for sourcing the necessary equipment and for monitoring and recording the results of the trials in co-operation with LHC personnel. LHC will provide the necessary marine logistical support.

Part 3. Risk Assessment

The objective of Part 3 is firstly to attempt, based on the validated conclusions from Ref. 1, and further desk/field based work to undertake a full risk assessment that will meet the requirements of the PMSC. This assessment will have regard for the safety of all craft using or moored on the river including the ferries themselves. The assessment will include (but not be limited to); an assessment of bridge operating procedures on the new vessels - to include an assessment of bridge visibility; an assessment of manoeuvrability; an analysis of historic incident records; an assessment of the impact of the hydrodynamic effects including some quantification of what those effects are (see Annex 1); an analysis of the navigation of the new vessels including the effect of windage, thruster power and direction when transiting the reaches of the river in all operating wind speeds and direction; an analysis of passing in the river; and an analysis of the effects of increased wind shadow on sail powered boats. Based on the assessment of risk, the consultant will need to identify reasonable and practical risk mitigation measures that may be required to enable LHC to meet the requirements of the PMSC. This may also require the suggestion of mitigation and control measures for leisure users.

Once the sea trials (Part 2) are complete, the consultant will be required to verify the earlier (desk based) risk assessments and proposed mitigation measures against the trial results. At this stage it may be necessary to modify the control measures predicted from the theoretical work.

Methodology

The consultant will be required to liaise in detail with all the interested user groups, to include (but not necessarily limited to) the Yacht Clubs, Rowing Club, Sea Scouts, Lymington Sailability and Wightlink. The objective of these meetings will be to allow the consultant to understand from each group what activities they consider are likely to be impacted by the proposed ferries. The Lymington Harbour Commissioners will also be represented at these discussions.

Reporting and Implementation

The Consultant will prepare a report for the consideration of LHC and a draft will be circulated to all participating groups for comment/discussion prior to publication of formal conclusions.

The final decision regarding any necessary mitigation measures will rest with LHC, in accordance with the Port Marine Safety Code.

Where appropriate, LHC will then seek to codify any new measures within existing or a revision of the Harbour Byelaws.

06/11/07 ver 3
Ref 1. Wightlink – Lymington Harbour Navigational Review
Report No. ELP-55272-1206-57219-Rev 1
Annex 1. Attach Risk Identification and Measurement Criteria.

Appendix 2

Field Measurements

FIELD MEASUREMENTS AT LYMINGTON IN JANUARY AND MARCH 2008

1. Introduction

Measurements of water level change and flow velocity in the Lymington River were carried out on 22 and 23 January 2008. These dates were chosen because a spring tide with a large range was due with, importantly, one low water occurring before all daylight was lost. Measurements of natural waves in Short Reach were made on 12 March 2008.

The results of this exercise are intended to form baseline measurements of wash and drawdown (together with the implied backflow) in the present situation. It is against these that similar measurements, to be made when the new ferries are trialled on the river, will be compared. This will provide an important part of the information needed to determine the change, if any, in marine risk due to the introduction of the new ferries.

The natural wave measurements provide a comparison with the vessel-generated waves.

In this report the results obtained are presented and discussed and some conclusions drawn.

2. Aims and Scope

2.1 Aims

The main aims of this exercise were as follows:

- To measure wash and drawdown in calm weather as ferries and other vessels carried out their normal operations on the river.
- To measure these parameters in the passing place and near the Public Slipway. The former was chosen because it was thought to be where most wash, drawdown and backflow would be experienced and the latter because of the amount of leisure user activity, including junior sailing, which takes place there.
- To measure river flow in the same areas together with, if possible, the backflow induced by the ferries.
- To measure ambient wave activity in Short Reach when a typical (preferably, prevailing) wind was blowing.

2.2 Scope

The scope of the measurement study was limited to:

- As large a tide as possible within the time constraints of the study, preferably during the ebb when the river flow would be high, combined with as small a low-water level as possible.
- Two locations, chosen to give a reasonable representation of conditions elsewhere on the river. One day was to be spent at each location.
- Three water level probes and one velocity probe used as the main measurement devices, with a small hand-held velocity probe for some additional measurements.

3. Equipment

3.1 Water Level Probes

The water level probes were capacitive devices consisting of a single 6 mm diameter stainless steel rod some 1.5 metres in length. They were encased in a plastic coating to form the dielectric, and excited with an AC oscillator. As the water level changed, so did the dielectric, thereby affecting the oscillator, whose current change was sensed to provide a measure of change.

Each probe was supported in a tubular steel frame to which was attached a splash-proof box containing a small data logger. This was turned on or off manually at the start or finish of a measurement run and the results subsequently downloaded on to a computer for analysis.

Each probe was attached to a suitable river navigation post by means of adjustable straps which allowed easy fixing and adjustment. As the probe length was less than the tidal range, ease of adjustment was essential as they had to be moved as the tide changed to ensure adequate water coverage.

Figure A1 shows a probe in position on the “green” post near the ferry terminal.

Figure A1: Water Level Probe Mounted on “Green” Post

The probes were calibrated in the river water using a simple calibration jig; a linear calibration resulted. Results from all probes were obtained at 20Hz sampling rate for later primary and secondary analysis.

3.2 Water Velocity Probes

Water velocity measurements were carried out under sub-contract by ABPmer using an acoustic doppler current profiler (ADCP). This is shown being deployed near the public slipway in Figure A2.

Figure A2: Deploying ADCP

As can be seen, the instrument was mounted in a frame which stood on the river bed, the profiler looking up through the water column. It was used to determine the dominant flows in the river and did so by operating for a fixed, active, period between periods of dormancy. Deployed in this way it was able to produce mean velocity vector measurements throughout the water column, as well as the overall mean value at the location. A smaller hand-held device was also used to measure local flow velocities and other parameters.

4. Methodology

4.1 Water Level Data

The water level probes were deployed as shown in Table A1.

Day	Area	Probe	Location (post)
22 Jan 2008	Passing Area	1	Enticott
22 Jan 2008	Passing Area	2	Bag of Halfpence
22 Jan 2008	Passing Area	3	Pylewell Boom
23 Jan 2008	Public Slipway	1	Harpers
23 Jan 2008	Public Slipway	2	"Red" near RLYC
23 Jan 2008	Public Slipway	3	"Green" near Ferry Terminal
12 March 2008	Passing Area	3	Pylewell Boom

Table A1

Results were obtained in January for the whole of the ebb, from the high water stand on the day (see Figure 3 in the main report) to low water. Unfortunately Probe 2 was not operating for early part of day 1, but operated satisfactorily that afternoon and the whole of the following day. In the exercise in March, most of the ebb was used for measurement.

During the measurement periods in January, notes were taken of traffic movements in the river with special attention to the times at which vessels passed the probes. As the logger results contained the time of day and date, it was possible, therefore, to find, on the overall record, the section of data relevant to the disturbance of a given vessel.

All results were subject to primary (i.e. converting to engineering units) and secondary analysis. The secondary analysis was carried out in a bespoke computer program developed for the study and comprised:

- Screening and correcting data where necessary
- Searching for the appropriate section of the data
- Weeding and smoothing
- Removing tidal effects.
- Initial plotting

Screening the data showed that Probe 1 had produced results in a format which differed from that for Probes 2 and 3. Accordingly a separate program was written to correct the offending files so that they could be read by the main analysis program.

Searching the data was straightforward because each data field was uniquely defined by the date and time of day. Knowing when vessels had passed, it was possible to find the data range which straddled this period and check it on the screen. If it showed the effects a vessel passing the probe, it was saved.

Weeding and smoothing In order to limit each file to a manageable size, the data was weeded so that every fifth sample was used, giving an effective sampling frequency of 4 Hz. Smoothing was used on the January measurements in order to show more clearly the effect of drawdown and other low frequency effects in the absence of the higher frequency free waves.

Figures A3 and A4 show data before and after smoothing, but they also show another effect which required further removal before the data could be assessed.

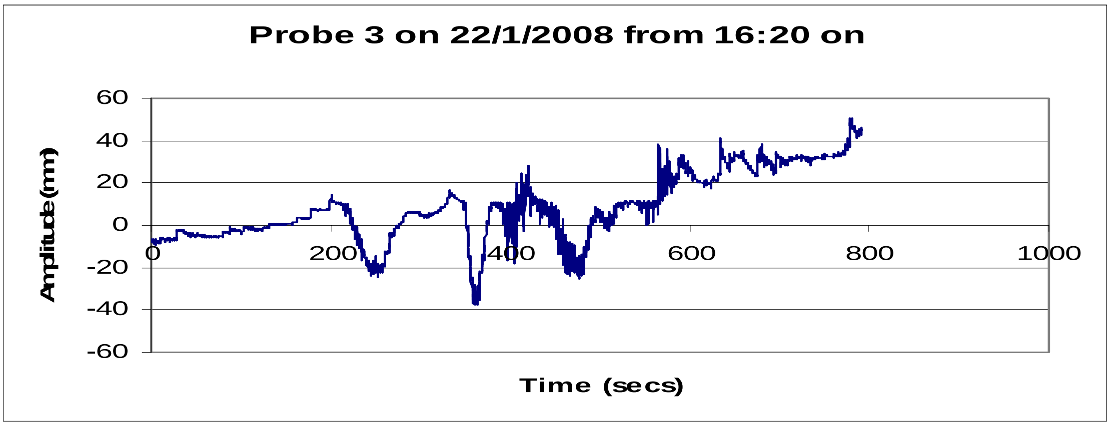


Figure A3: Raw Data Weeded to 4 Hz, including Free Waves

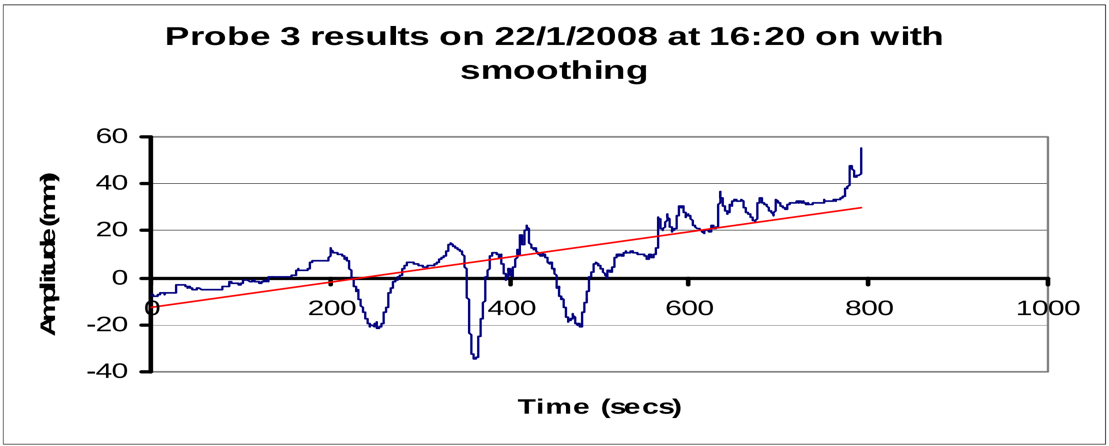


Figure A4: Data smoothed

After smoothing it was immediately apparent that, due to the rapid rise and fall of the tide over the period of interest, the datum level of the measurements changed with time. This was removed by determining a trend ("zero") line, using a least-squares method (as shown in red on Figure A4) and subtracting this from every data point. In most cases, apart from when the tide was turning, this gave reasonable results and Figure A5 shows the process completed for the data set under consideration.

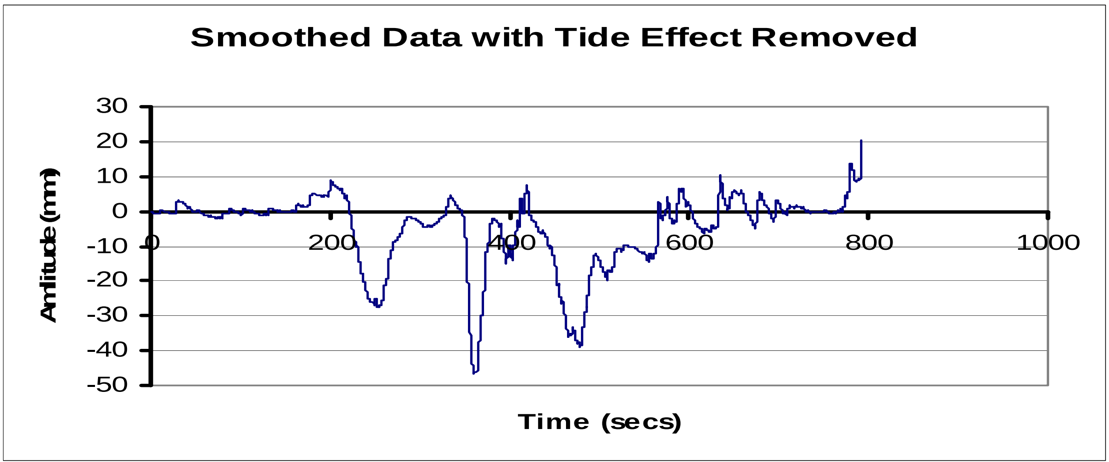


Figure A5: Smoothed Data with Tide Effect Removed

The analysis software was modified to include smoothing (if required) and automatic tide removal, with the addition of the ability to plot the selected data immediately on the screen for assessment. A listing of all results was also produced for each run and these were used for final plots, produced on a spreadsheet.

In what follows, all tidal effects on water level measurements have been removed.

4.2 Water Velocity Data

Water velocities were measured on the January exercise only. The ADCP was positioned on the edge of the navigation channel about 12 metres west of the Pylewell Boom navigation post where it stood on the river bed. It was left there for the duration of the ebb on 22 January and the remaining tidal cycle until about 11:00 the following morning. It was then deployed off the Harbour Master's Pontoon, again on the edge of the dredged channel, at about 11:45 on the second day. Water velocity results were obtained by ABPmer using standard analysis methods. Velocities and tide heights were obtained at both locations, thereby allowing the results to be corrected to a standard tide.

The smaller hand-held device was unable to record any change in velocity when ferries passed, but heading changes due to movement of the workboat from which it was deployed were sensed on the second day.

5. Results Obtained

In this section the measurements are presented and discussed.

5.1 Water Level Changes: January

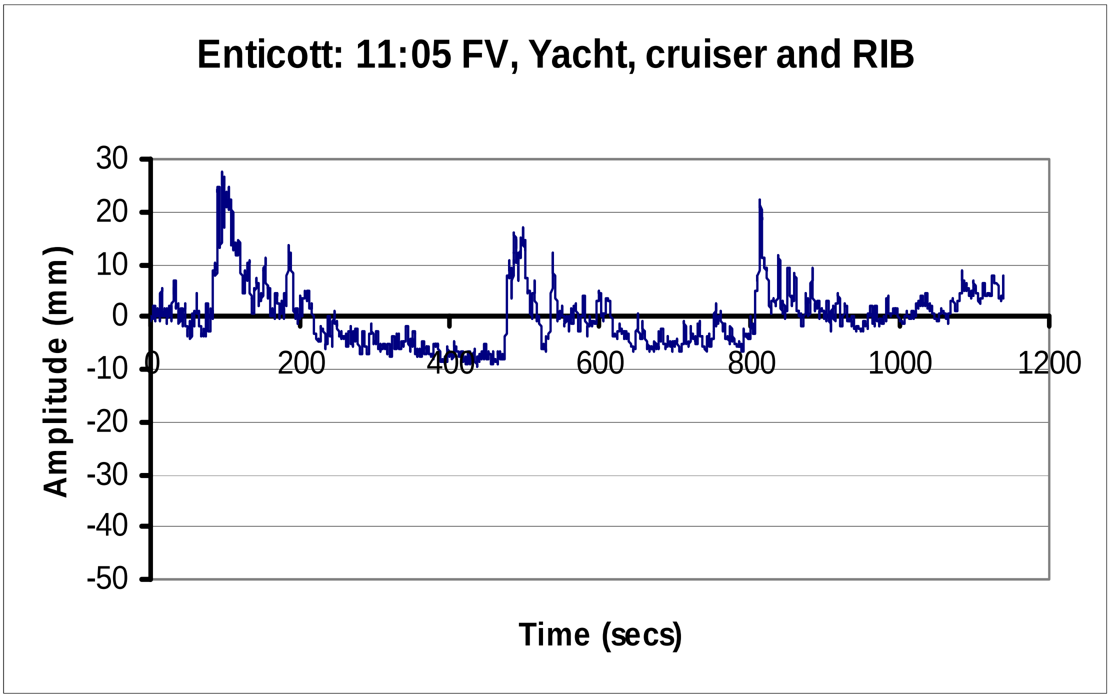
The weather was good on both days, with very little wind and a calm water surface. This was ideal as it allowed the water level movement due to the ferries and other vessels to be defined without contamination from natural wind-driven waves.

Measured water level changes are discussed for the two measurement locations. The discussion centres around plots of results, the passing vessel(s) being indicated on the relevant plot. Where possible the plots have been made to the same vertical scale for ease of comparison, although in some cases it was necessary to change the scale to encompass the measurements, especially those showing the free waves. Finally, it should be mentioned that "FV" stands for "Fishing Vessel" and "RIB" for "Rigid Inflatable Boat".

5.1.1 Passing Place

Measurements were obtained from high water on the day to just after low water, thereby covering the whole of the ebb. Three probes covered each measurement area, but, as mentioned above, Probe 2, on the Bag of Halfpence navigation post, did not work on the morning of the 22 January and for some of afternoon it was out of the water.

Figure A6 shows small boat activity in the area during high water as measured at Probes 1 and 3. The tidal elevation was 3.2m giving a water depth around 7 metres in the channel. The data has been smoothed to show the underlying behaviour of the water surface and it is seen that most amplitudes are of the order of 10 mm with the higher bow wave systems showing up clearly.



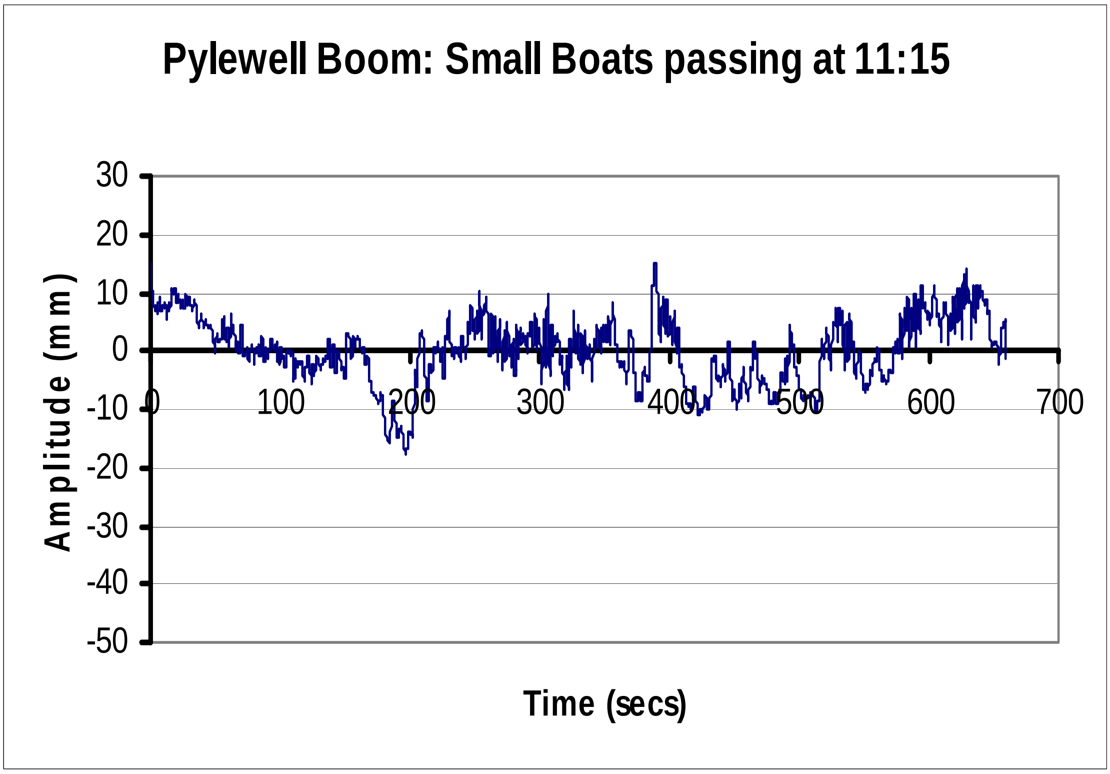
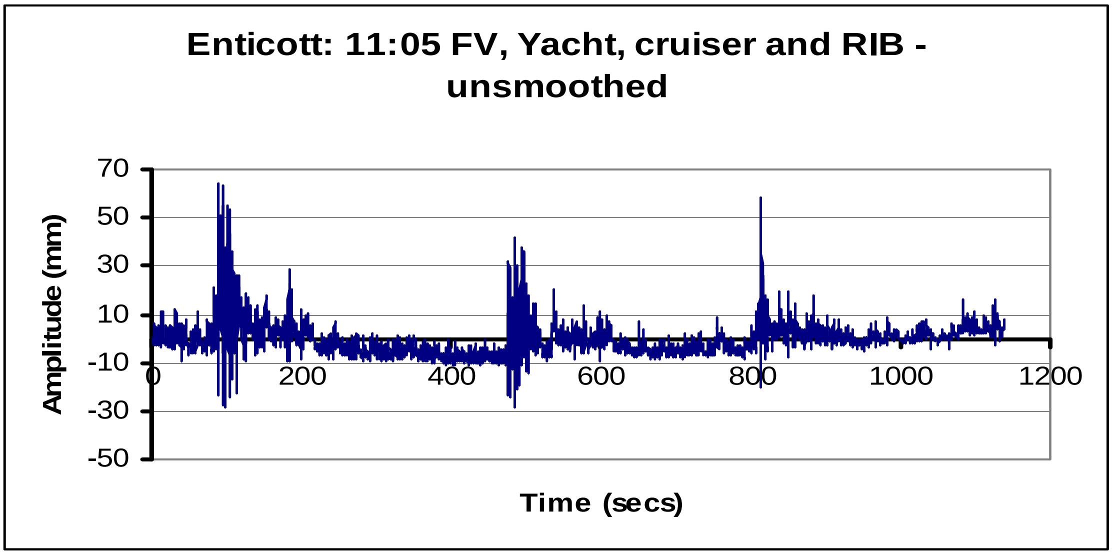


Figure A6: Fishing and Leisure Craft at High Water. Smoothed.

Figure A7 shows the same plots but with all the free waves included. The different vertical scales should be noted.



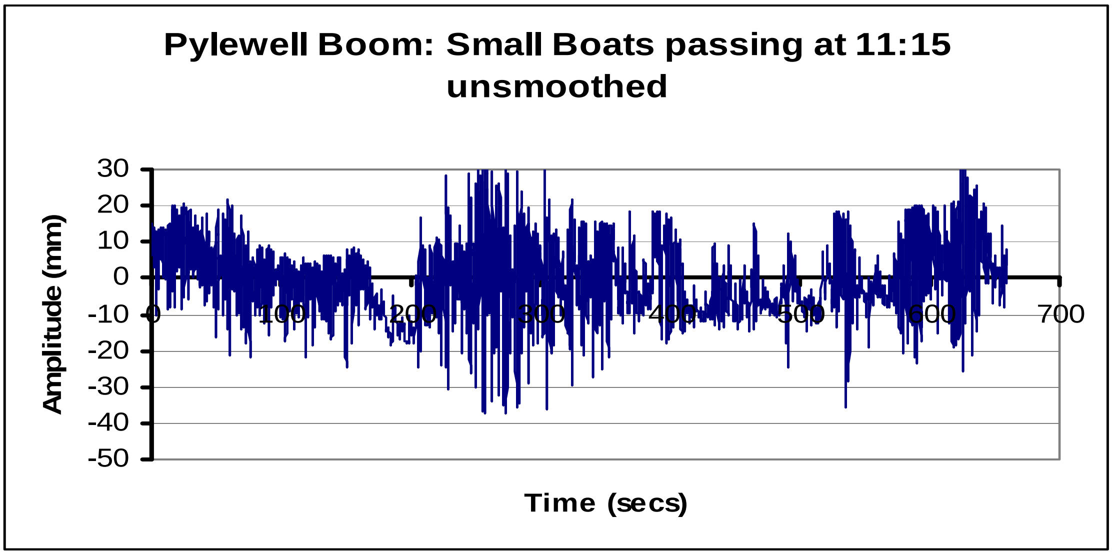
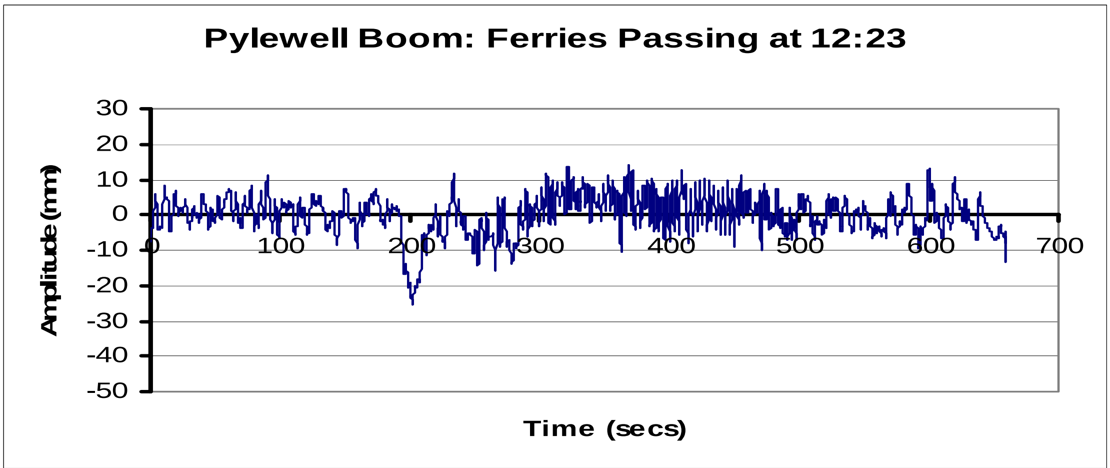


Figure A7: Fishing and Leisure Craft at High Water: All waves included

The difference is notable with free wave heights approaching 70 to 90mm.

Figure A8 shows ferries passing both Probes 1 and 2 just before the ebb began to flow. The tidal elevation was 3.1m, again giving a water depth around 7 metres.



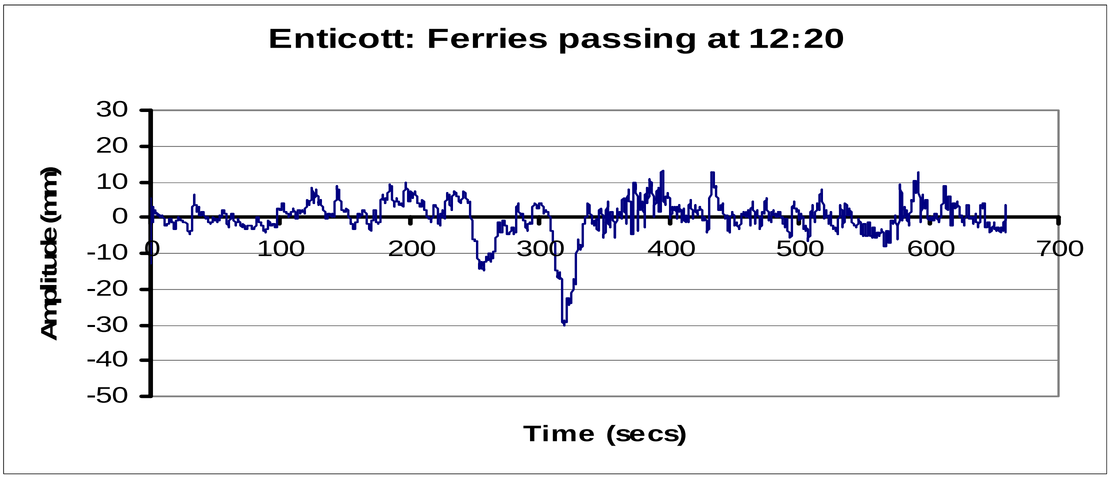


Figure A8: Ferries Passing at High Water.

The smoothed data in the Figure shows clearly the effect of as the ferries pass. At a time of about 200 seconds, the drawdown is clear, showing a value of around 25 mm. The outbound ship passed Enticott first, with the inbound ship passing a little later, the latter showing a rather larger drawdown. This may be due to the fact that the inbound ship passed closer to the measuring probe at Enticott.

Figure A9 shows the same plots, but with the free waves included.

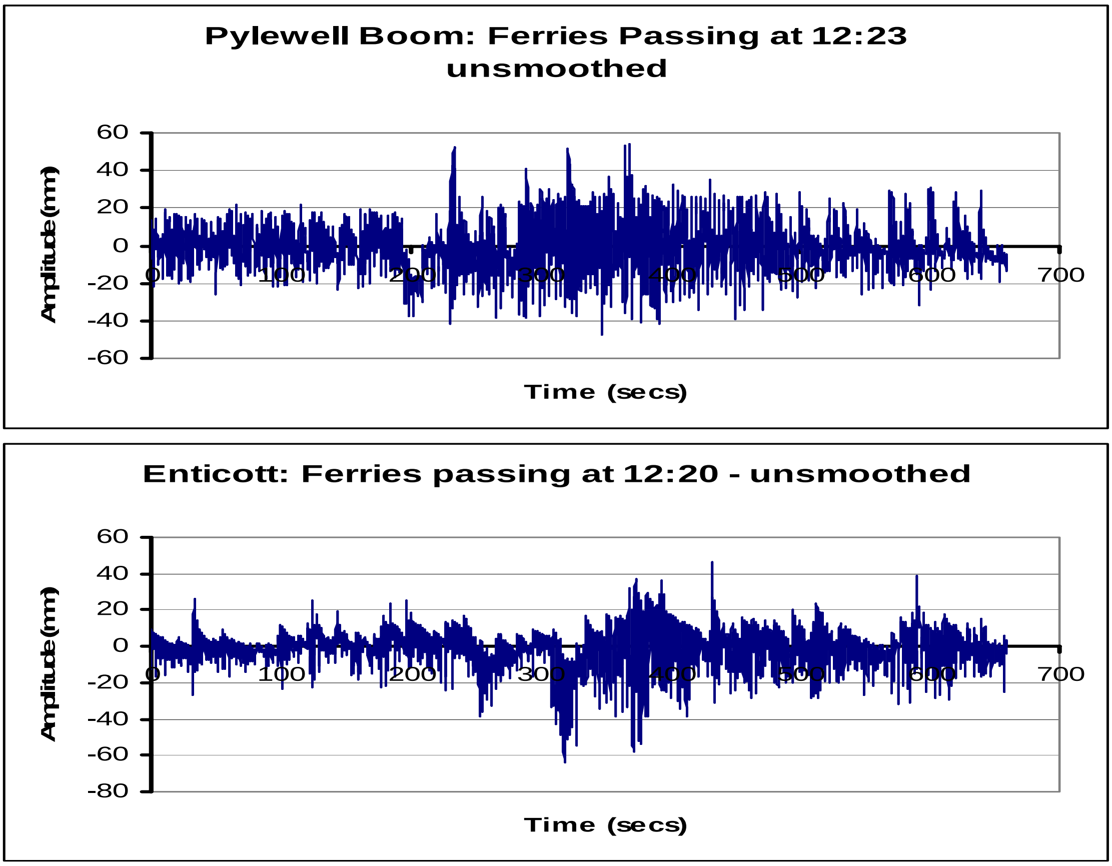


Figure A9: Ferries Passing at High Water: All Waves Included

It is seen that the free waves add to the disturbance with heights up to a maximum around 100mm, occurring after the vessels passed the probe. However, most free waves are less than this in height.

Figure A10 shows smoothed data for a ferry, dory and an empty dredger barge passing inbound at around 14:20. At this time the ebb had started and the tide height was 1.9m, giving a water depth just under 6 metres. Free wave effects were similar to those shown above and are not included here.

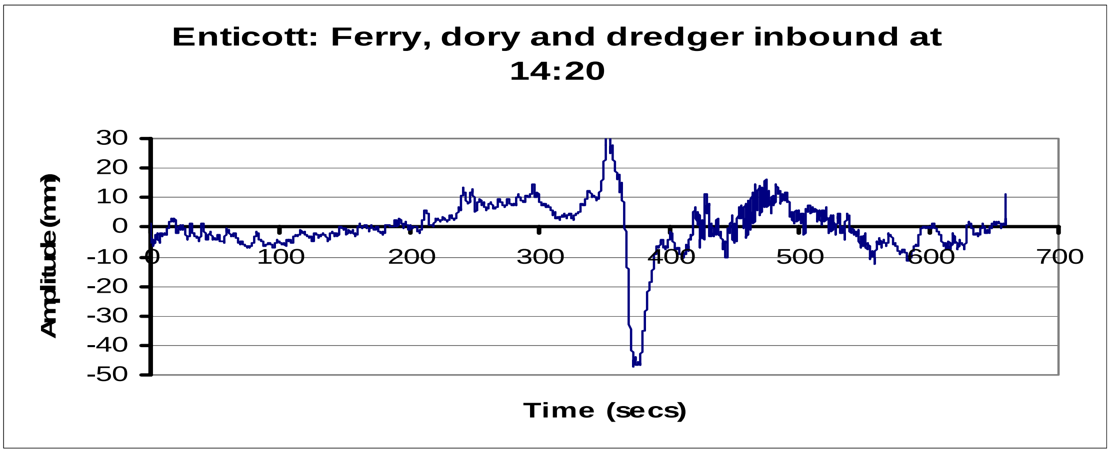
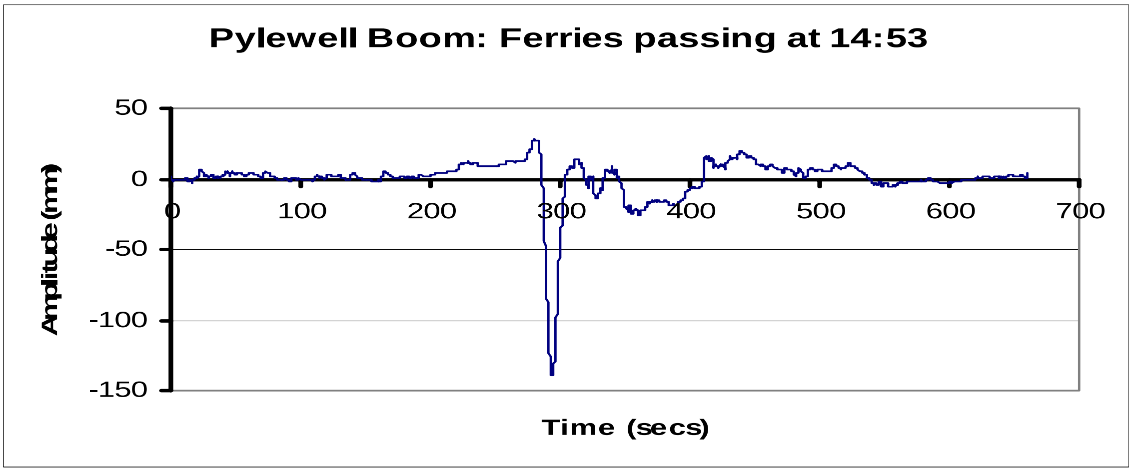


Figure A10: Various Vessels passing inbound on the Ebb

The ferry drawdown is now more marked, reaching a peak of just under 50mm. It may be noted that the swell-up as the ferry approaches is now more noticeable as is the “hump” in the curve after it has passed. These features were common to most of the ferry profiles and appear to be shallow water effects; the free wave system is superimposed on these longer period variations.

At around 14:53 with a tidal elevation of 1.2m and a depth around 5 metres, the results in Figure A11 were obtained.



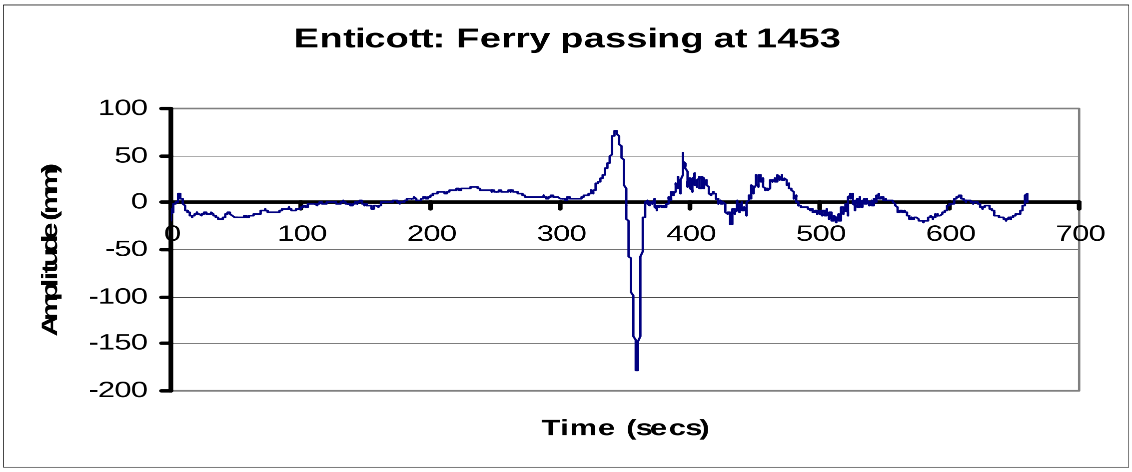


Figure A11: Ferries passing just before Low Water

Two ferries passed in the region of Pylewell measuring location and two drawdowns can be seen in the record for this probe, one at about 300 seconds and the other around 350 to 400 seconds. It is apparent that one was around 140mm, greater than any other drawdown measurement obtained on the two days. The same effect was repeated at Enticott as the inbound ferry passed and on the trace for this ferry can be seen the evidence of the enhanced transverse waves often seen in the river in the wake of the ferries, shown in Figure A12. It is possible that these waves were enhanced by the inbound ferry initiating its turn to port into Horn Reach.

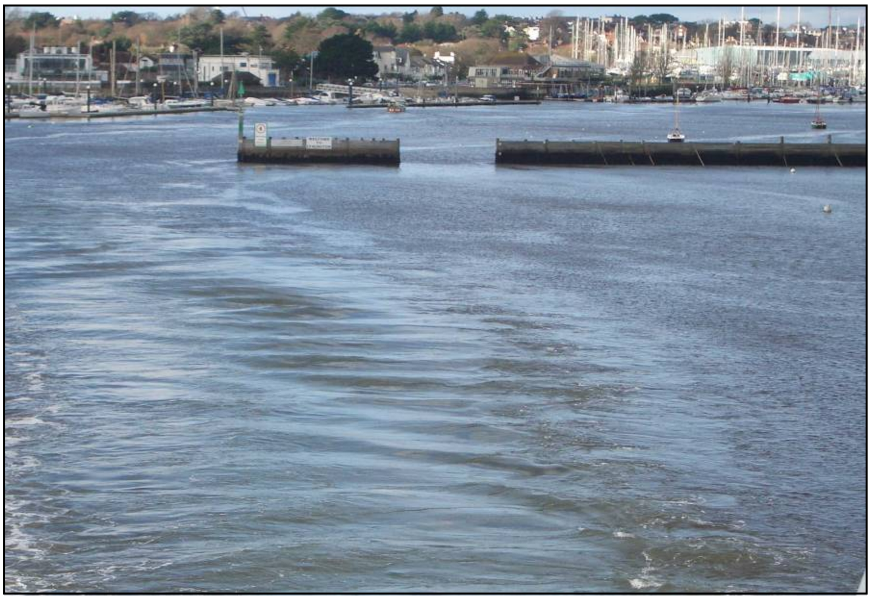
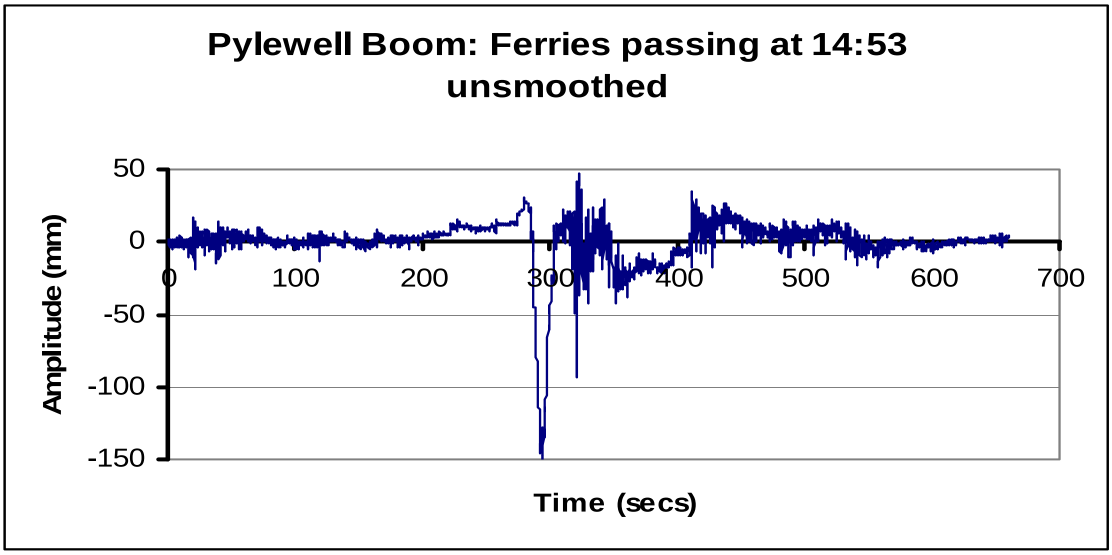


Figure A12: Transverse Waves Astern of a Ferry

It is possible that the wave disturbance made by the outbound ferry is that at the start of the Enticott trace shown in the figure.

Figure A13 shows the same two plots, but with the free waves included. It is seen that the free waves were generally small at this state of the tide and depth of water, having more of an effect at Enticott.



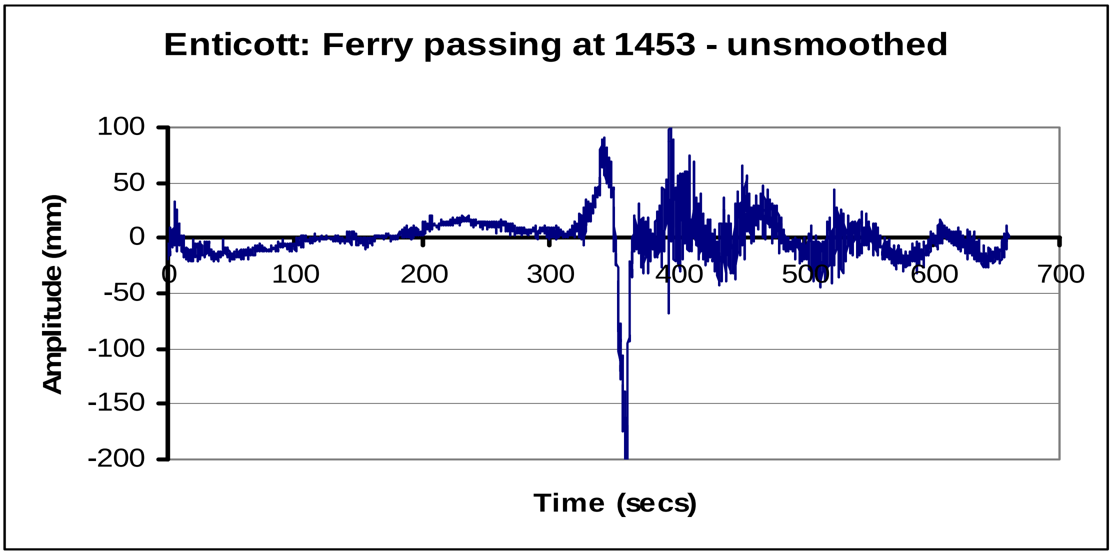
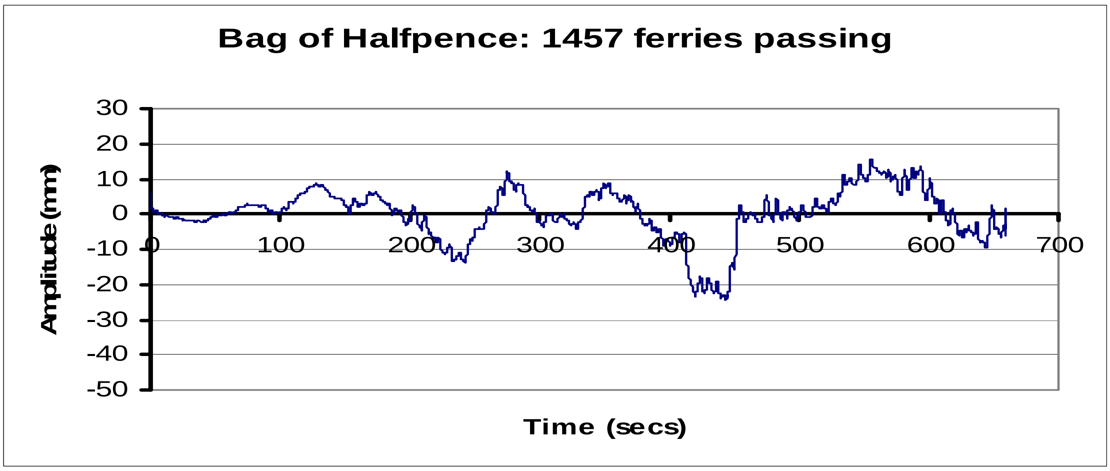


Figure A13: Ferries Passing just before Low Water. All Waves Included.

Interestingly, this event was logged on probe 2 at the Bag of Halfpence location and the resultant traces (without and with free waves) are shown in Figure A14.



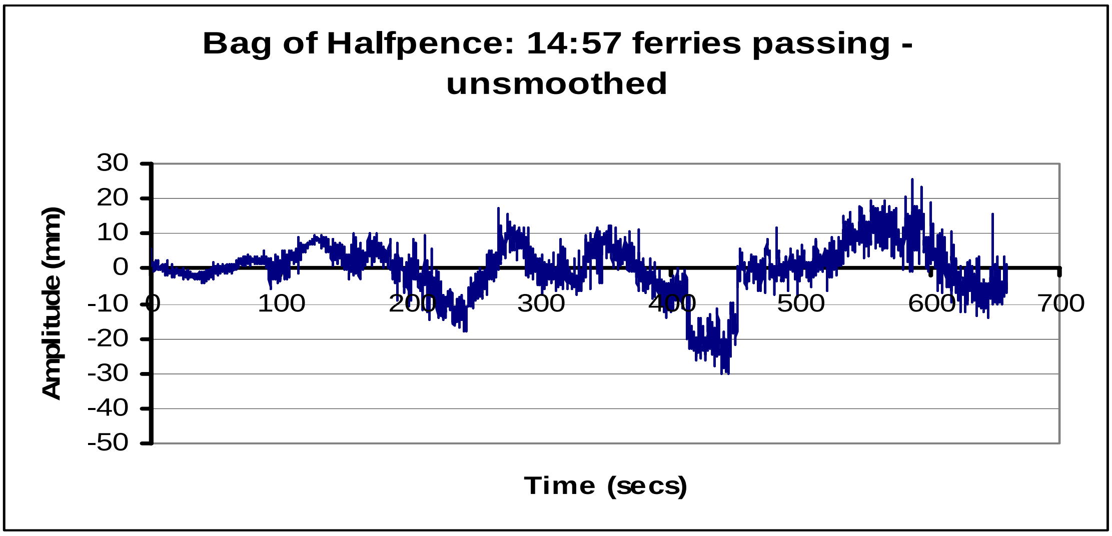


Figure A14: Ferries Passing, Probe 2.

Although evidence of two drawdowns can be seen, they are not as severe as those measured at the Enticott and Pylewell locations; the free waves are also small. The reasons for this apparent discrepancy is assumed to be due to the fact that the inbound vessel passed much closer to the Pylewell and Enticott posts than to the Bag of Halfpence.

The final plot in this series was obtained a low water at the Pylewell location and is shown in Figures A15 and A16. The tidal elevation was 0.45m giving a water depth around 4 metres. Two ferries passed off the Pylewell post and their drawdowns can be seen clearly. The outbound (distant) ferry was moving at around 6 knots, but the inbound vessel was accelerating up to speed after a significant ease down to ensure passing occurred at the correct location. The faster ferry caused the middle drawdown and the inbound ferry the first, but it is clear that there are three drawdowns on the trace, the third coming from another vessel, the laden dredger outbound. Interestingly, the peak drawdowns were low, at less than 40mm, even though the water level was at its lowest of the day.

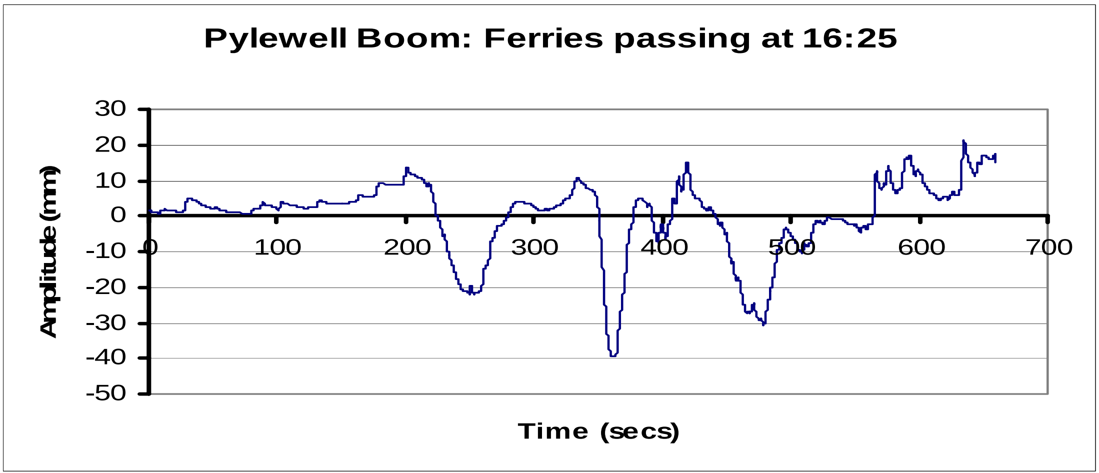


Figure A15: Ferries Passing and Dredger at Low Water

Free waves are included in Figure A16 from which it is seen that, at low water where waves are likely to be damped by the exposed banks and natural waves will have a much reduced fetch due to the limited water space, the unsmoothed data is very similar to the smoothed data.

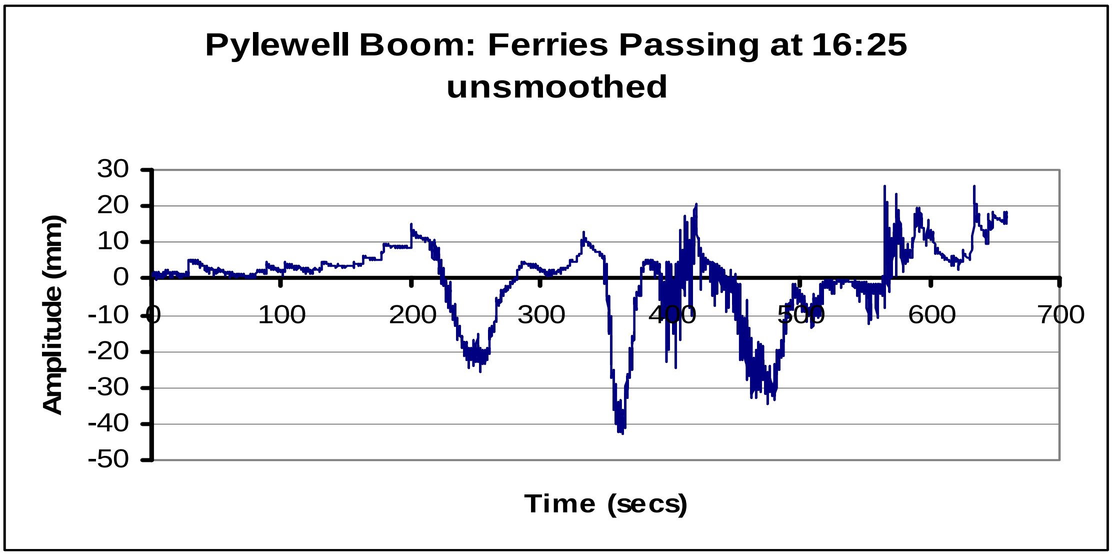
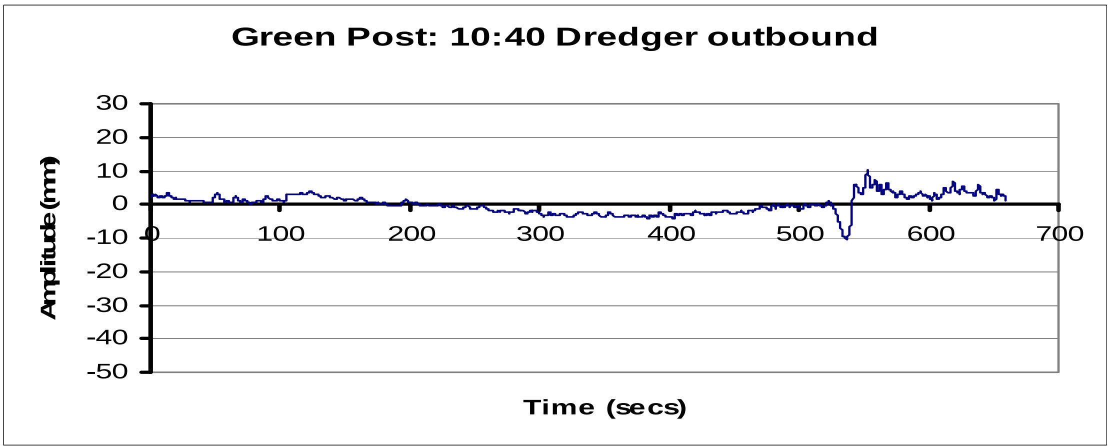
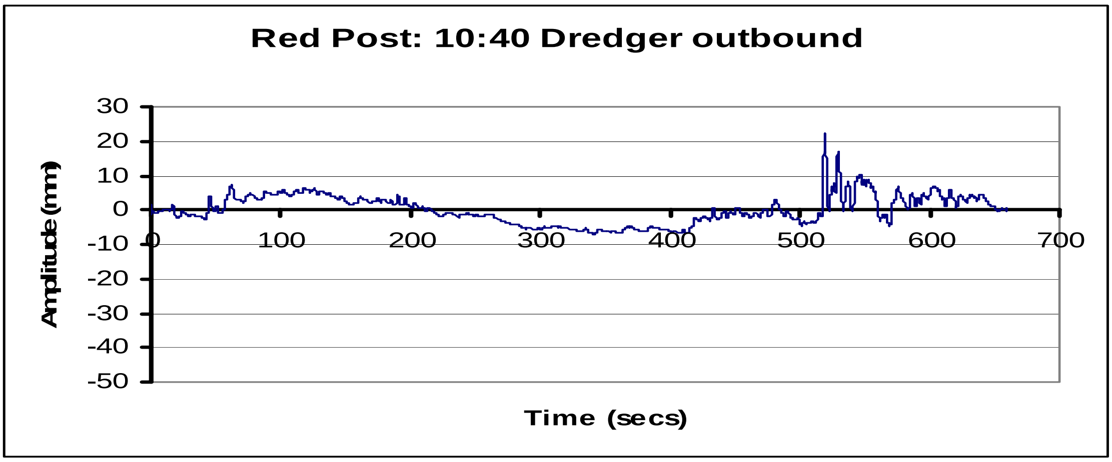


Figure A16: Ferries Passing and Dredger at Low Water. All Waves Included.

5.1.2 Horn Reach

Vessel velocities in Horn Reach were lower than those at the passing place, but the mix of traffic was similar. For example, Figure A17 shows the laden dredger outbound at high water as measured at the Green Post (near the ferry terminal), the Red Post (near the RLYC) and Harpers Post (near the wave screen).





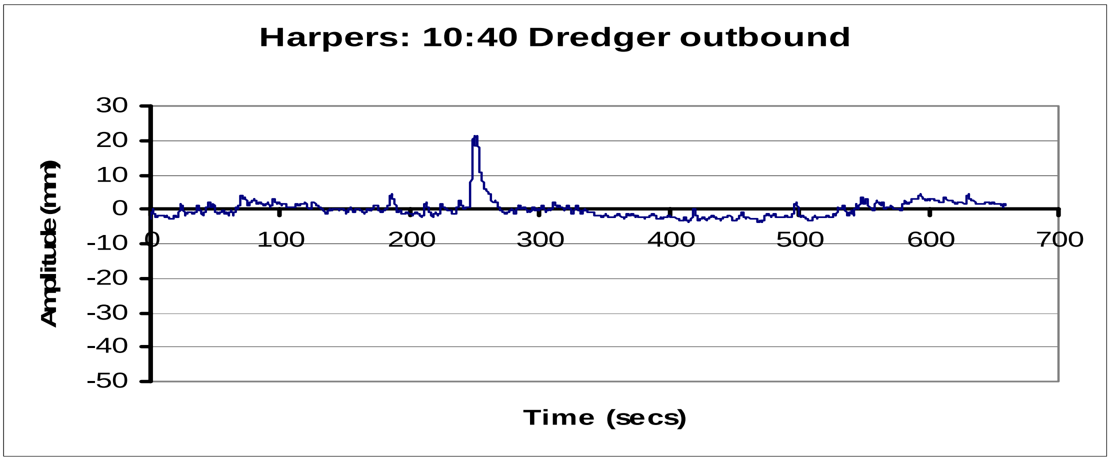


Figure A17: Dredger outbound in Horn Reach

It is of interest to note the lowering of the water level in the more confined waters near the ferry terminal and the yacht club, prior to the characteristic drawdown. This is also apparent at the wave screen (Harper's Post), preceded by the equally characteristic trace of a small RIB.

Figure A18 shows the "Green Post" trace without smoothing from which it is clear that, on the day, the free waves in the Horn Reach were very small in relation to the overall longer-period water movements. As a result, unsmoothed data will not be shown for all cases here.

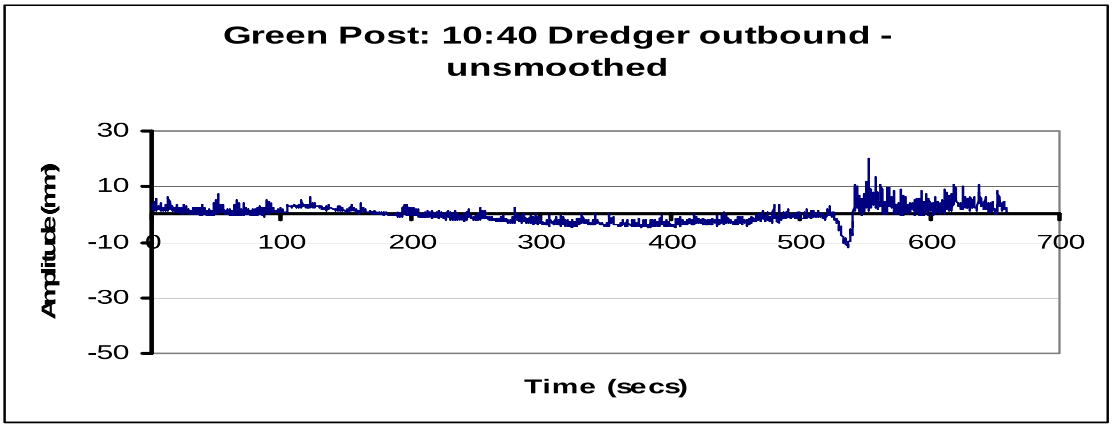
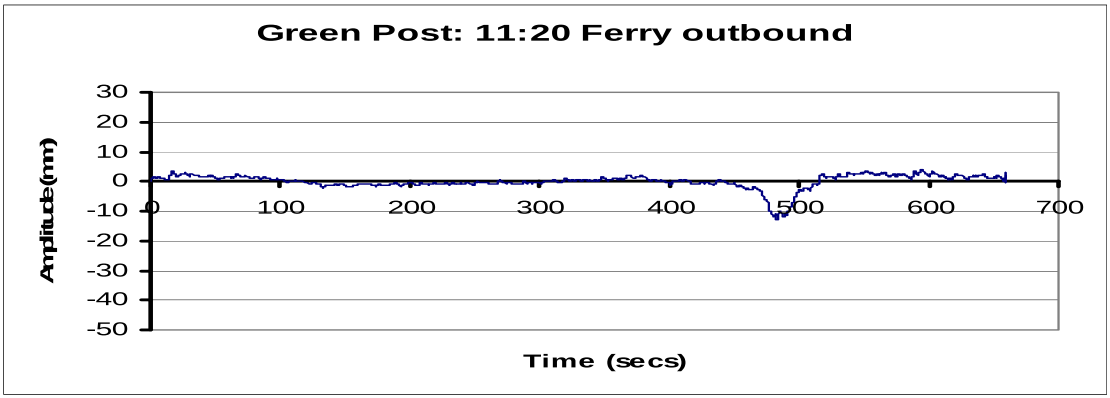


Figure A18: Dredger outbound in Horn Reach. All Waves Included.

Figure A19 shows the smoothed traces of a ferry outbound at high water, measured near the ferry terminal and the wave screen. As with the dredger, the major change in water level is small, around 10mm to 15mm, with the ferry stern wave and perhaps some effect of the stern thruster apparent near the wave screen when it had built up speed to 4 knots.



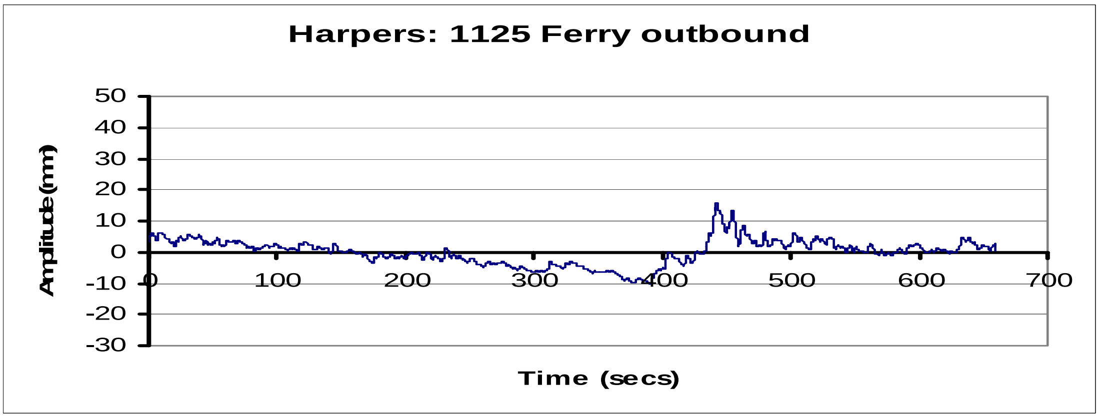


Figure A19: Ferry outbound in Horn Reach

These features are also apparent on an inbound ferry passing the wave screen shortly after, leaving the trace of Figure A20.

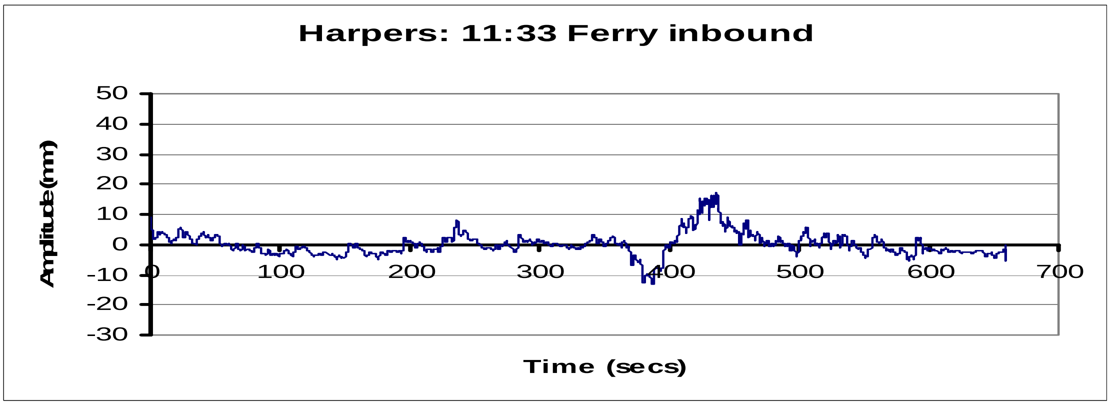
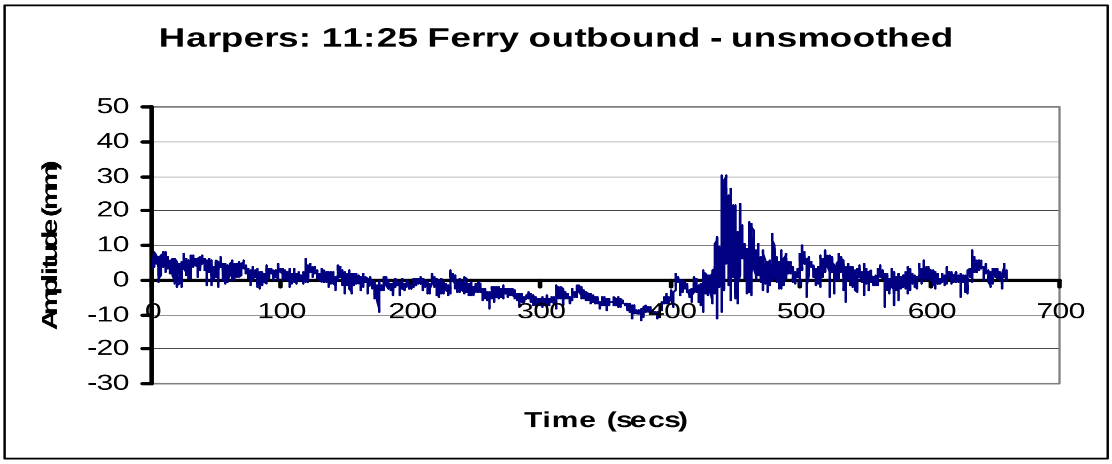


Figure A20: Ferry inbound at the Wave Screen

These observations at Harper's Post are confirmed by the unsmoothed results in Figure A21.



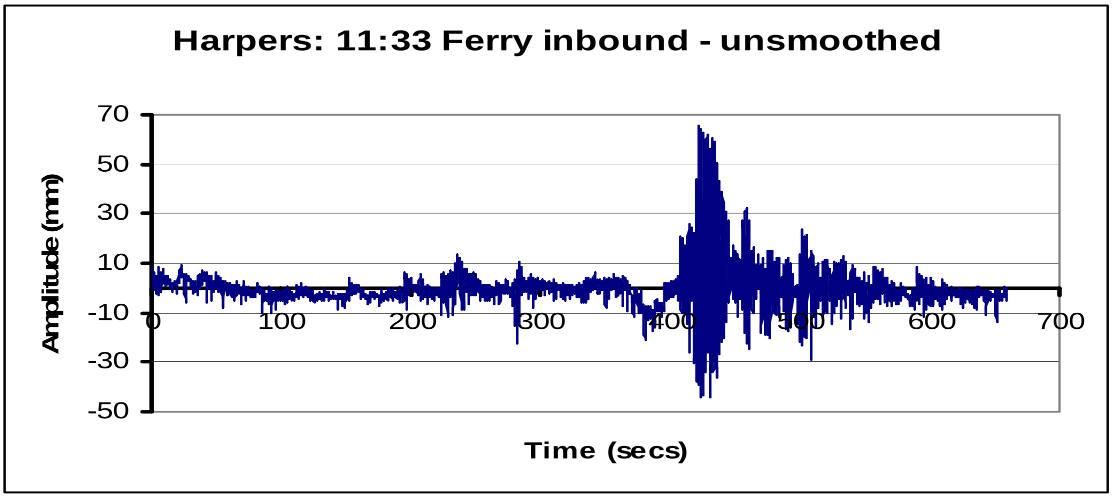
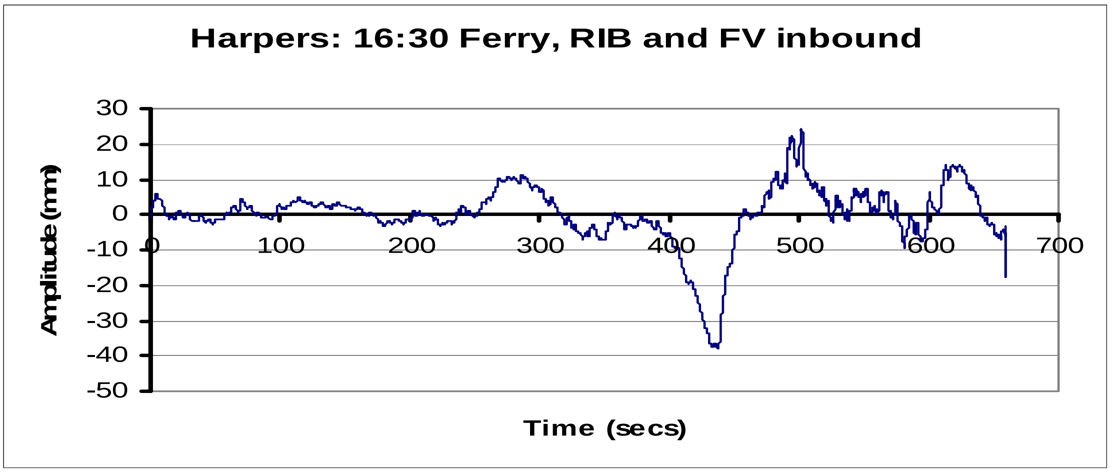


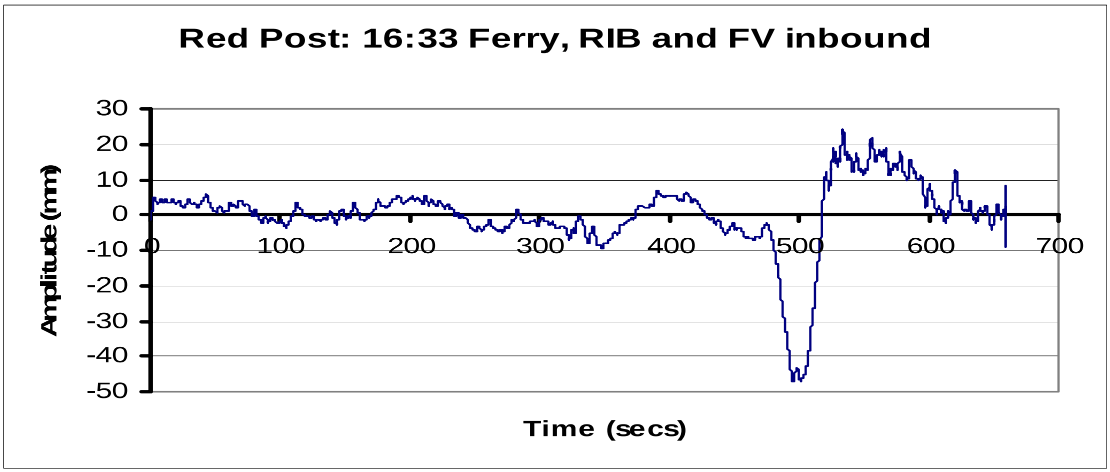
Figure A21: Ferry Disturbance at Harpers Post. All Waves Included.

It is seen that the free wave disturbance from the ferry is small, except as the stern passes the measurement location when it is possible that the effect of a thruster slipstream causes amplitudes over 60mm for a short time before settling down to amplitudes less than 10mm.

Turning to events during the ebb when water levels were lower, Figure A22 shows a combination of vessels inbound. Smoothed results are shown for the wave screen, the yacht club and the ferry terminal, all near low water when the tide height was 0.51m giving a water depth around 4.2 metres at the wave screen and 3.8 metres near the yacht club and ferry terminal.

The drawdown from the ferry is clear and its increase in the shallower waters near the yacht club is apparent. Reduction in speed on approach to the terminal reduced the drawdown from around 50mm to just over 10. The stern disturbance from the ferry is apparent in all traces.





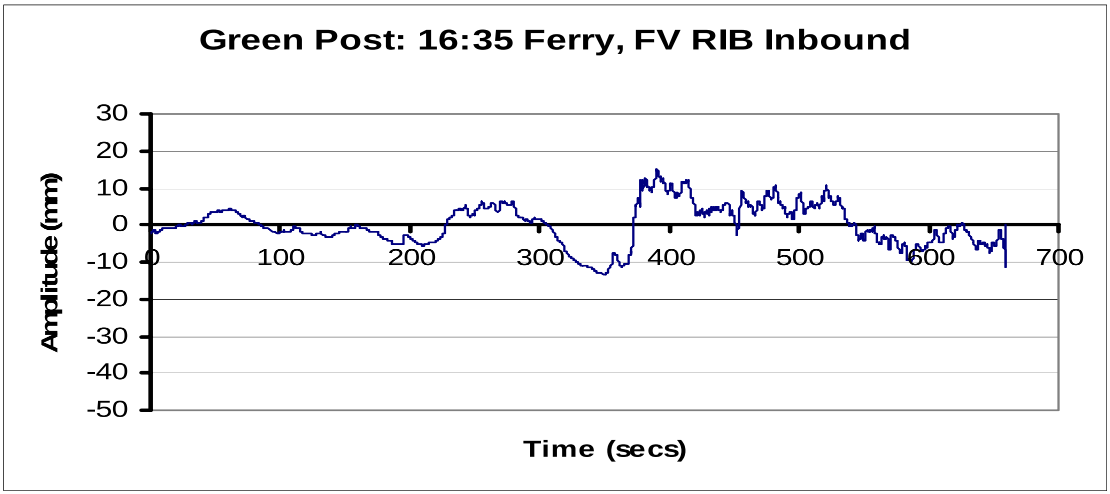
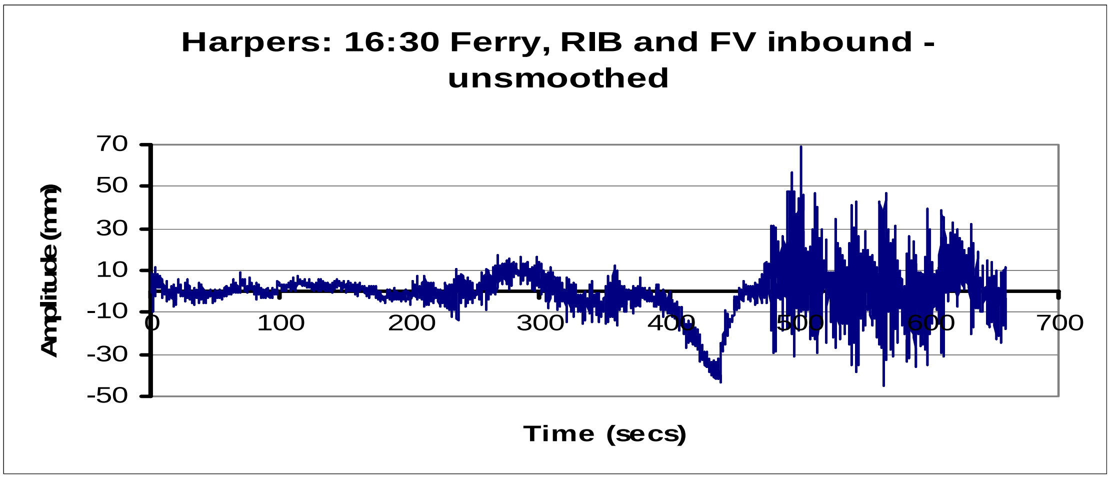
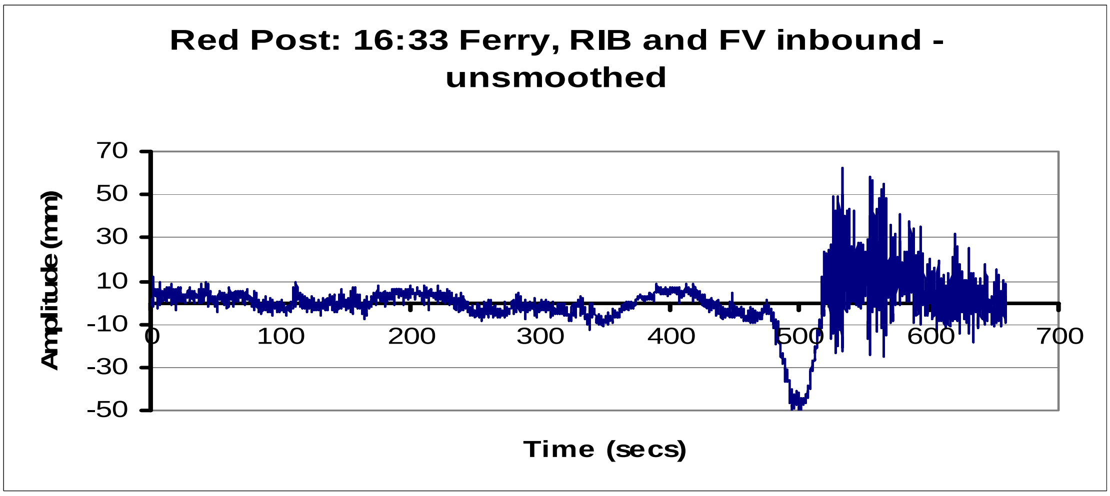


Figure A22: Ferry and other Vessels inbound in Horn Reach





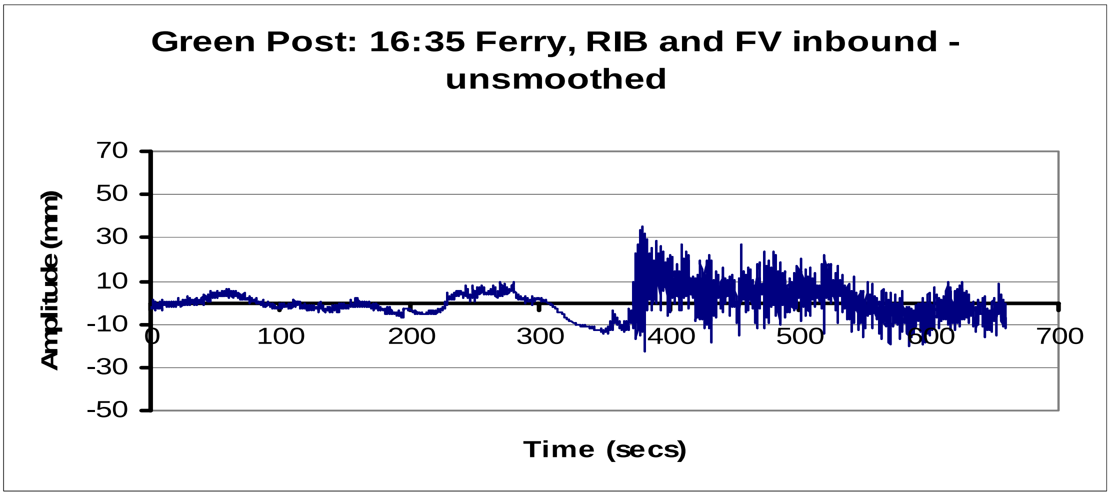


Figure A23: Ferry and other Vessels inbound in Horn Reach. All Waves Included.

Figure A23 shows the three traces of Figure A22 without smoothing from which it is apparent that the ferry's free waves in the vicinity of the terminal and the RLYC building can have amplitudes up to about 50 to 60mm. Overall wave height in this region can reach values of around 80mm.

Finally, Figure A24 shows smoothed results obtained for a ferry departing at low water when the tide height was 0.37m giving a water depth near the yacht club and terminal around 3.7 metres and about 4.1 metres at the wave screen.

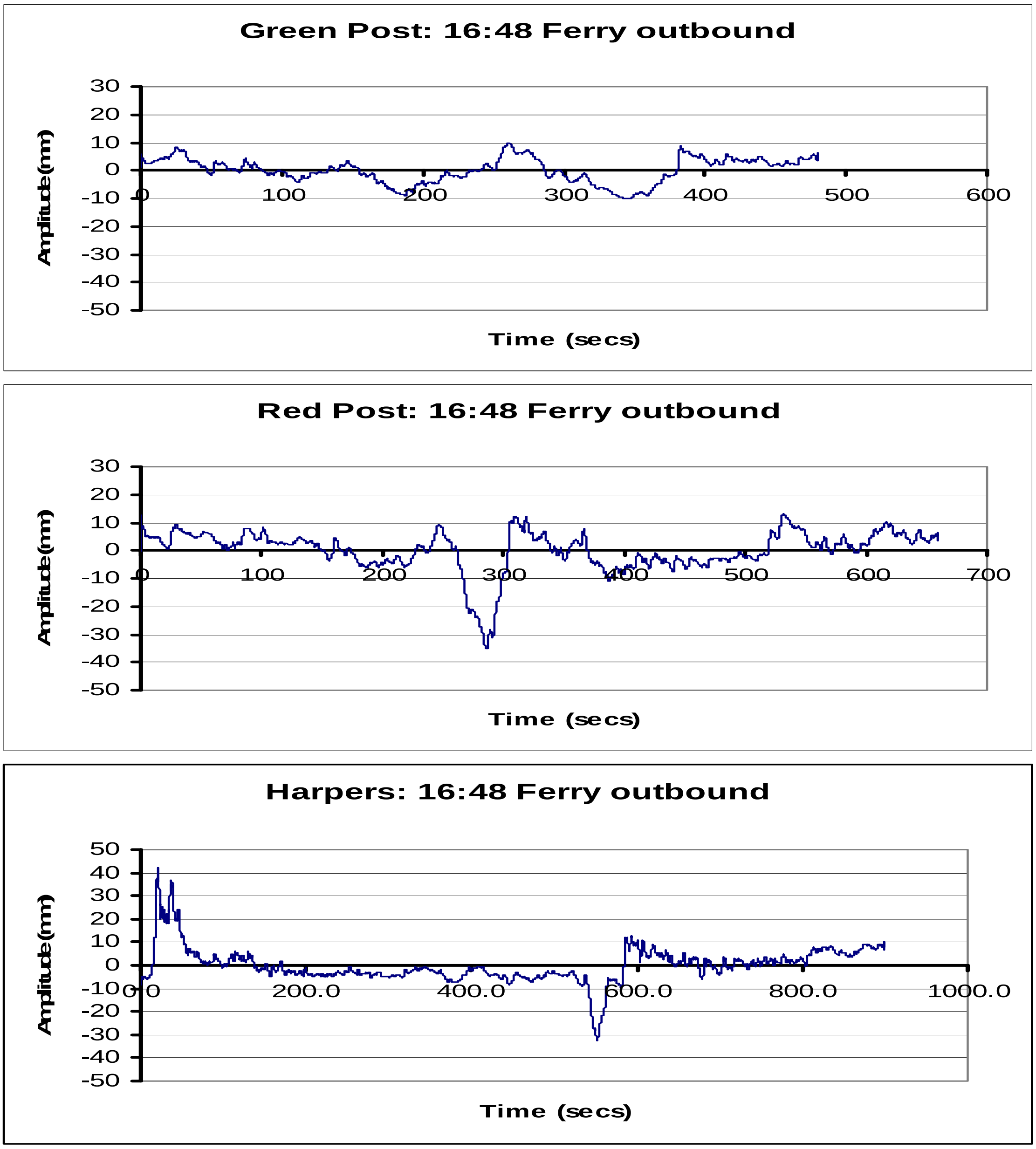


Figure A24: Ferry outbound at Low Water, Horn Reach

It is of interest to note that the ferry drawdown was around 30mm at the most, but a fishing vessel which passed through the wave screen just before the ferry, had what appeared to be a large wave system as shown in the "Harpers" trace. Figure A25 confirms this by showing the unsmoothed trace from the Harpers Post probe from which it is seen that the free waves from the fishing vessel (early in the trace) had significantly greater wave amplitudes than those of the ferry.

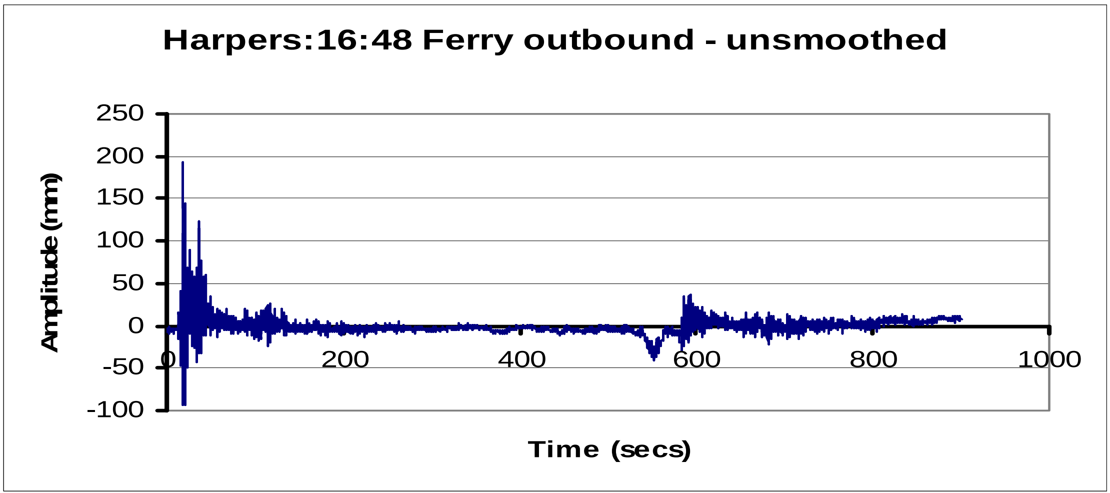


Figure A25: Ferry and Fishing Vessel. All Waves Included

It may be mentioned that interaction with the outbound ferry was experienced in the launch used as a base by the study team, moored close to the Red Post. The change in heading was measured by ABPmer and is shown in Figure A31.

5.2 Water Level Changes: March

Water level changes were measured on a day when the wind was blowing from north of west with mean velocities ranging from about 28 knots at the start of the measurement period (about 1100) to about 20 knots at the end (about 1530). The wind speeds and directions are shown in Figure A26.

Measurements are shown for four periods through the day in Figures A27 to A30. No smoothing has been applied and all natural, ambient, waves are shown; a ferry passed the measurement location at Pylewell at about 1236 and there is evidence of drawdown to be seen in Figure A29.

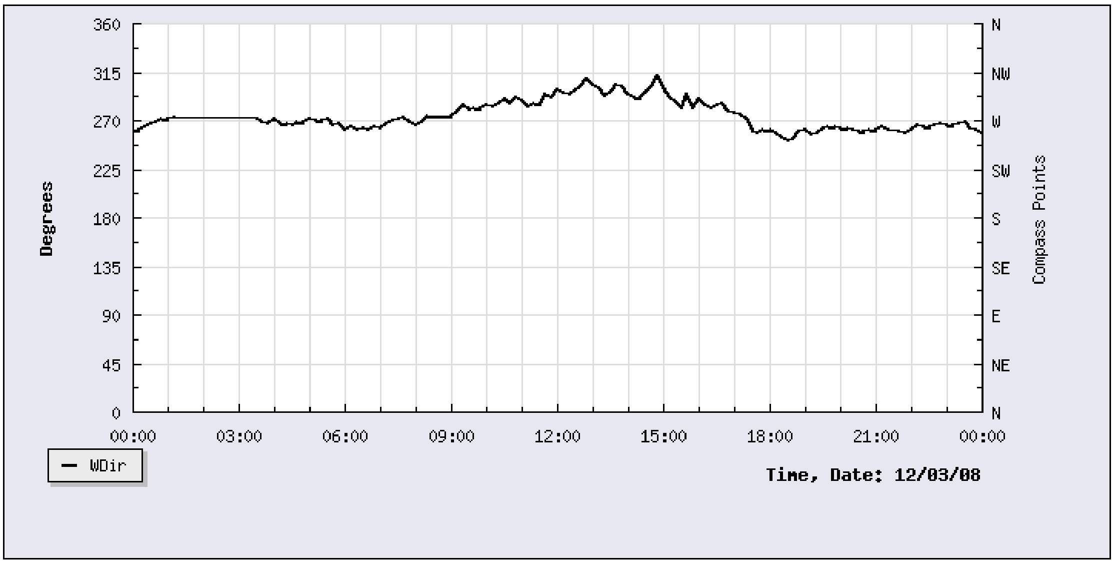


Figure A26: Mean Wind speeds and Directions on 12 March 2008

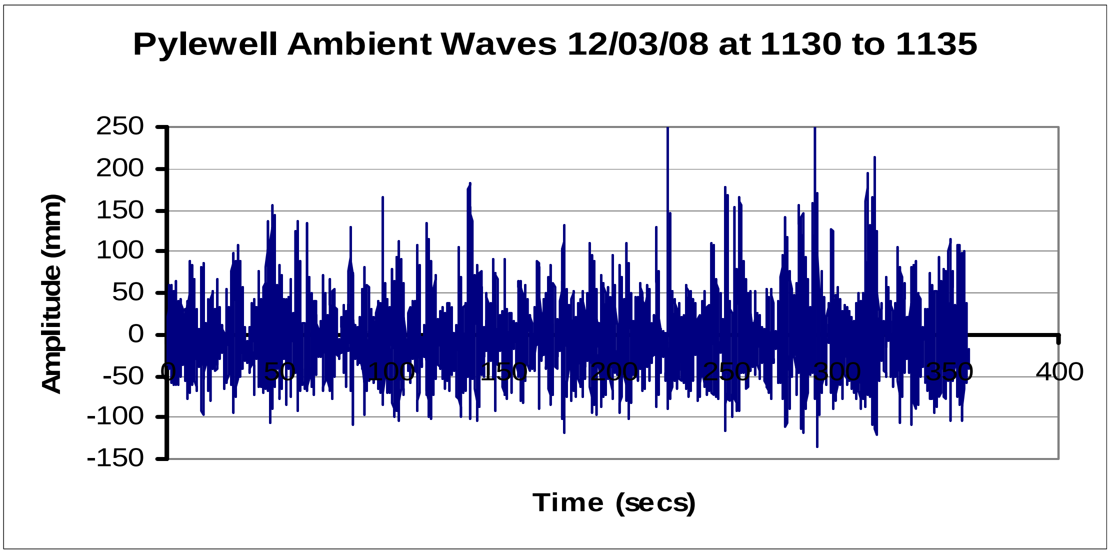


Figure A27: Ambient Waves at Pylewell from 1130 to 1135

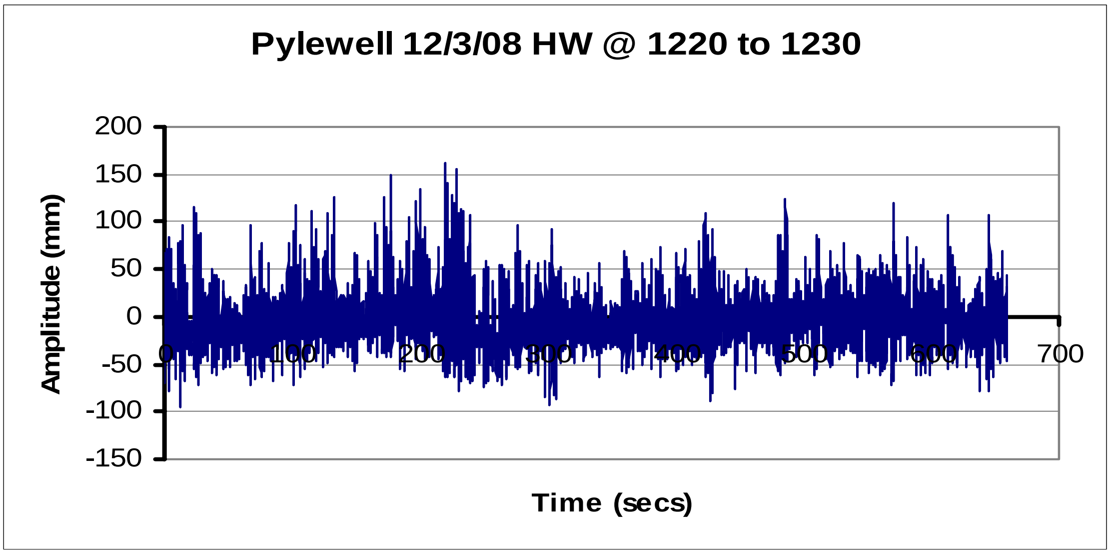


Figure A28: Ambient Waves at Pylewell from 1220 to 1230

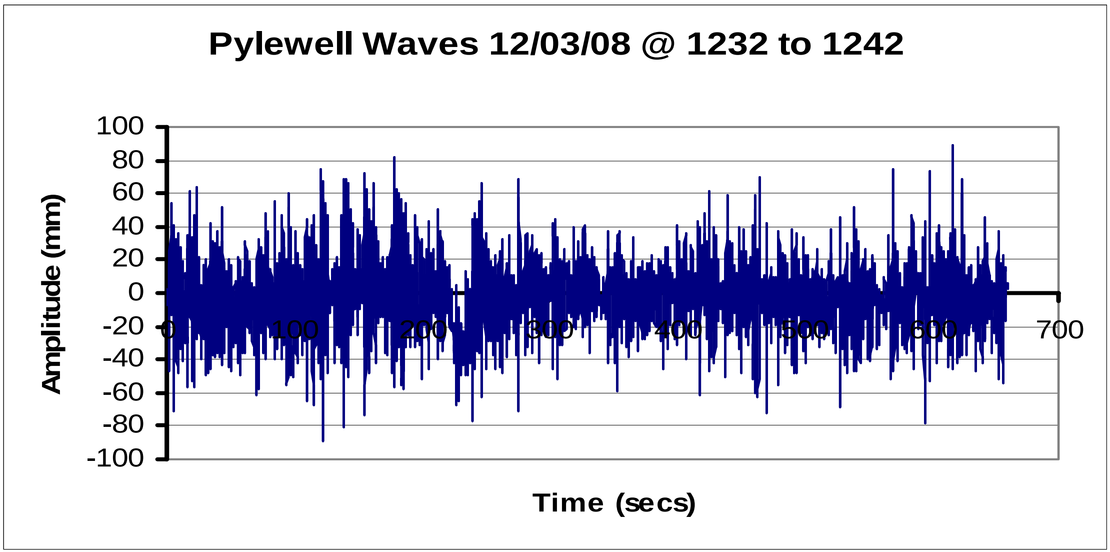


Figure A29: Ambient Waves at Pylewell from 1232 to 1242 with Ferry Passing

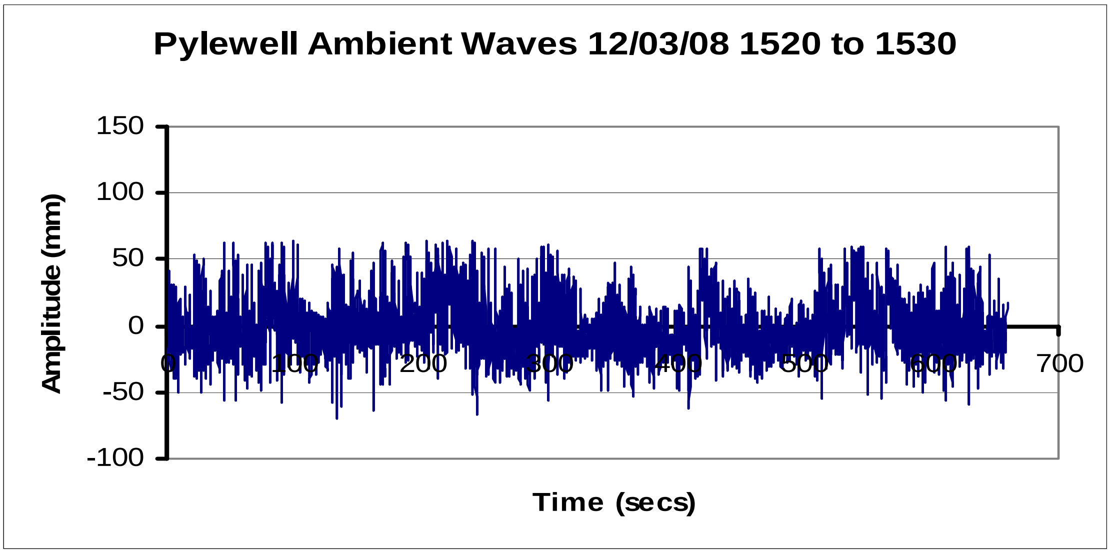


Figure A30: Ambient Waves at Pylewell from 1520 to 1530

It is seen that around 1100 when the wind was at its strongest, natural wave heights were of the order of 250mm with some having amplitudes in excess of this figure. As time progressed, the wind eased, the water level fell and the exposed river banks began to damp the wave activity. As a result, wave heights around 1530 had reduced to about 70mm to 100mm with some amplitudes in excess of 50 mm. It may be noted that the ferry passing around 1236 had little effect on the measured wave heights and frequencies.

Figure A26 shows that the wind direction was between 300^{o} and 315^{o} compared to the more usual 240^{o} shown in Figure 2, indicating that it was rather more to the north than the prevailing direction. This would give these wind-generated waves a shorter fetch than would normally be the case, suggesting that they would have been bigger had the wind been in its prevailing direction.

Comparing the natural wave heights in Figures A27 to A30 with those produced by the ferries and other vessels shows that the natural waves on 12 March were generally larger than those produced by the ferries. The available fetch had some impact on the natural waves, as did the low water effects of increased damping from the exposed banks and greater shelter from the surface wind. Nevertheless it is clear that natural wave heights of around 200 to 300mm can be experienced in Short Reach in a wind from a direction more sheltered than the prevailing.

5.3 Water Velocities

The results for the water flow measurements in both locations are given in Tables A2 and A3. As mentioned in the main report, measurements in the channel at Pylewell were obtained over a complete tidal cycle, whereas those in Horn Reach were obtained over the ebb only. The tidal range was 2.8 metres on 22 January and 2.63 metres in the ebb on 23 January.

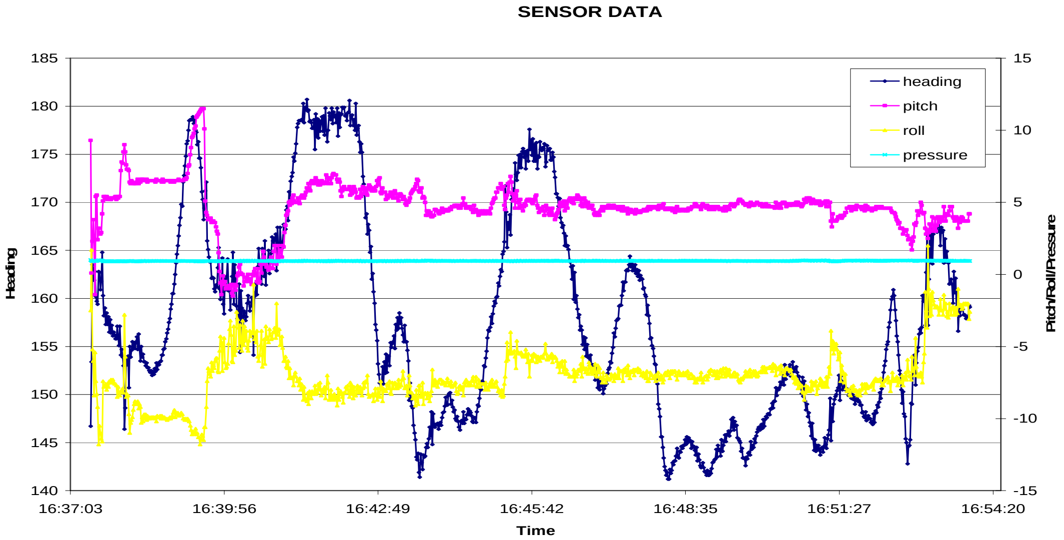


Figure A31: Sensor Data showing Heading Change as Ferry Passed Red Post

Pylewell

Time	Direction (°)	Measured Speed (knots)
HW-6	16	0.36
HW-5.5	348	0.49
HW-5	359	0.28
HW-4.5	350	0.20
HW-4	96	0.20
HW-3.5	271	0.25
HW-3	347	0.33
HW-2.5	1	0.34
HW-2	1	0.37
HW-1.5	360	0.46
HW-1	5	0.76
HW-0.5	9	0.58
High Water	230	0.27
HW+0.5	197	0.22
HW+1	134	0.19
HW+1.5	200	0.16
HW+2	184	0.18
HW+2.5	216	0.17
HW+3	193	0.56
HW+3.5	191	0.79
HW+4	187	0.91

HW+4.5	187	1.11
HW+5	188	0.92
HW+5.5	193	0.56
HW+6	222	0.21

Table A2

Horn Reach

Time	Direction (°)	Measured Speed (knots)
High Water	188	0.23
HW+0.5	117	0.18
HW+1	195	0.20
HW+1.5	161	0.18
HW+2	164	0.16
HW+2.5	176	0.17
HW+3	140	0.15
HW+3.5	155	0.37
HW+4	147	0.38
HW+4.5	151	0.38
HW+5	144	0.37
HW+5.5	142	0.28
HW+6	147	0.17

Table A3

The results are shown graphically in Figures A32 and A33.

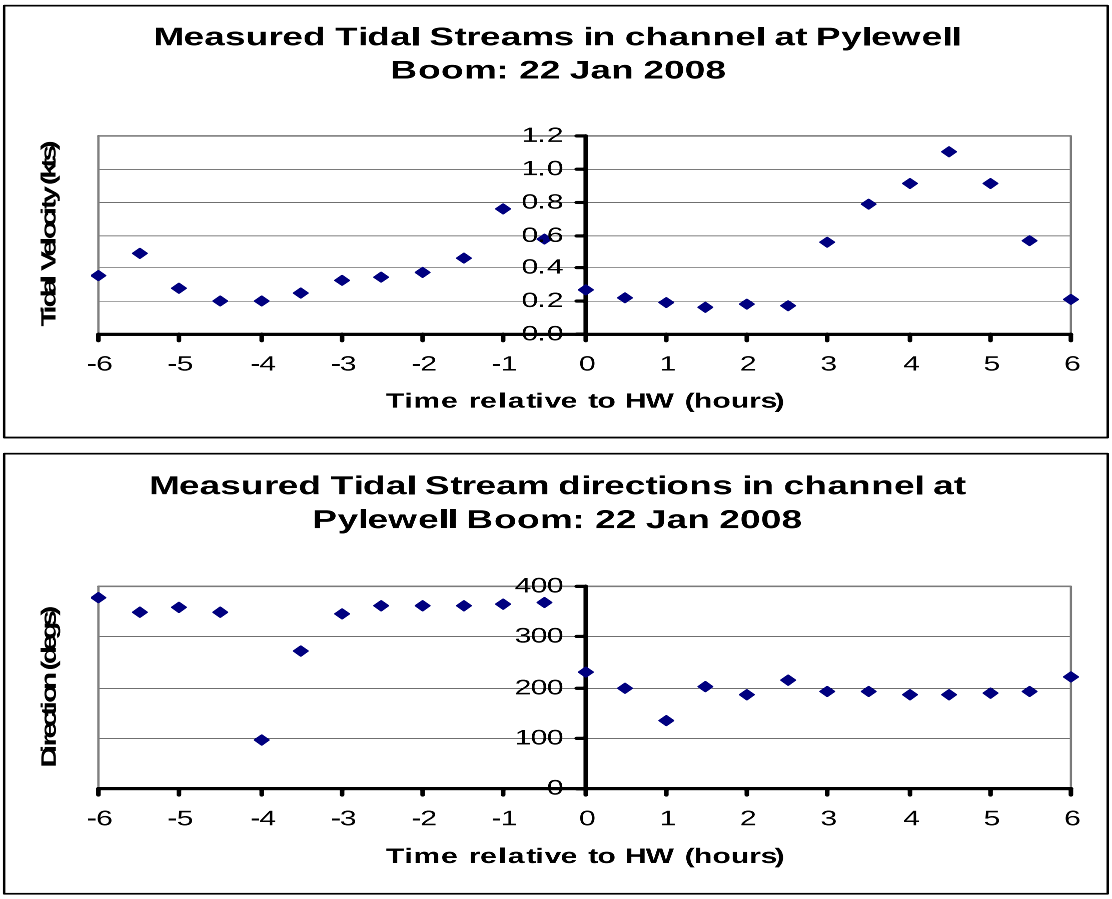
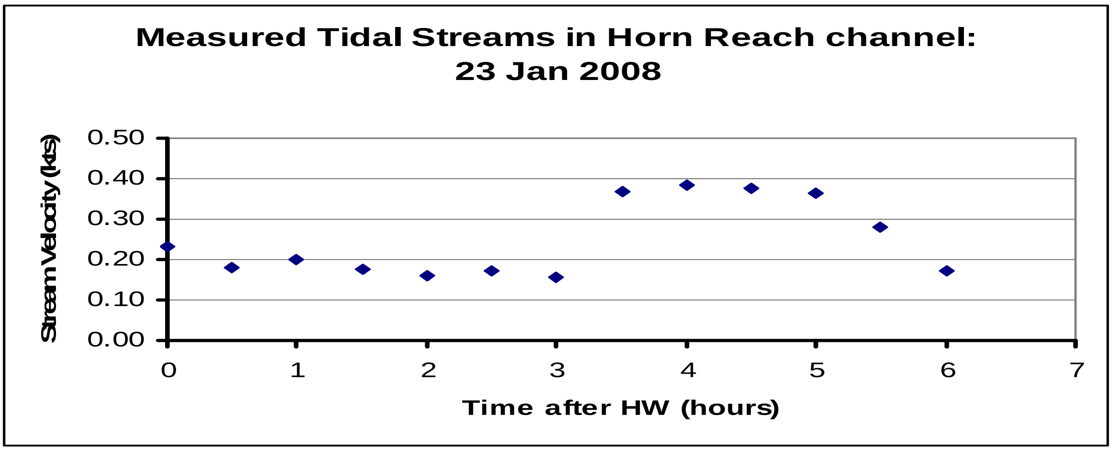


Figure A32: Channel at Pylewell Boom Flow Velocity Measurements

Of note in Figure A32 are the low velocities during the flood and the rapid rise and fall of stream velocity in the ebb. The increase in velocity in the ebb is also noticeable in Figure A33.



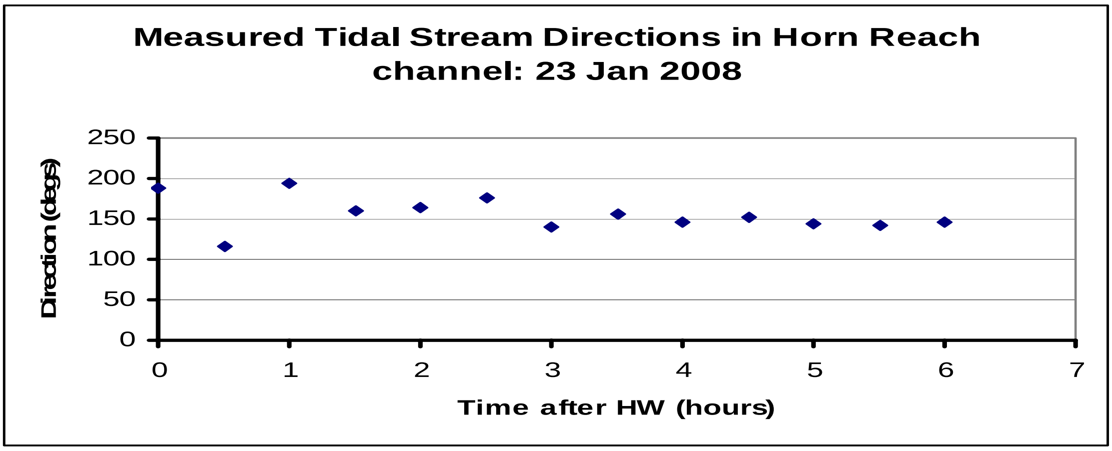


Figure A33: Horn Reach Flow Velocity Measurements

Attempts to measure backflow from the passing ferries with the hand-held device were unsuccessful in that it was not possible to discern any change in flow velocity at the measurement location as the ferry passed.

6. Discussion

The water level and flow measurements carried out in ideal conditions over two days in January 2008 and in windy conditions in March give a good impression of the present hydrodynamic situation on the Lymington River. They have shown the disturbances likely from the existing ferries and some other craft, one of which was a dredger which, when laden, produced disturbances similar to those of the ferries. The characteristic water level changes due to small craft such as RIBs and workboats have also been captured.

Tidal flow velocities in the upper and lower reaches of the river have been measured and the results presented.

These measurements provide a useful description of the base line situation and show the magnitude of the disturbances experienced and tolerated at present. In general the drawdowns have amplitudes of around 50mm at the most, although one measurement on the first day resulting from an inbound ferry, passing close to the measurement location, showed that drawdown could approach 150mm to

180mm. This value is roughly in accord with squat estimates made for the existing ferries, taking account of the change with lateral distance from the measuring location. An indication of this change has been obtained for the W-class from the results shown in Figure 21 in the main text. Drawdown is, of course a wave system feature confined mainly to the ferries and other craft of similar size such as the self-propelled dredge barges.

Ferry free wave heights were of the order of 100 to 150mm at the most, with the majority being far lower than this. Larger waves of nearly 300mm amplitude were measured from a fishing vessel in the region of Harpers Post. It was apparent therefore that the free wave system of the existing ferries produced a water surface disturbance which did not differ significantly from those produced by much smaller craft; Figure A34 gives an example.

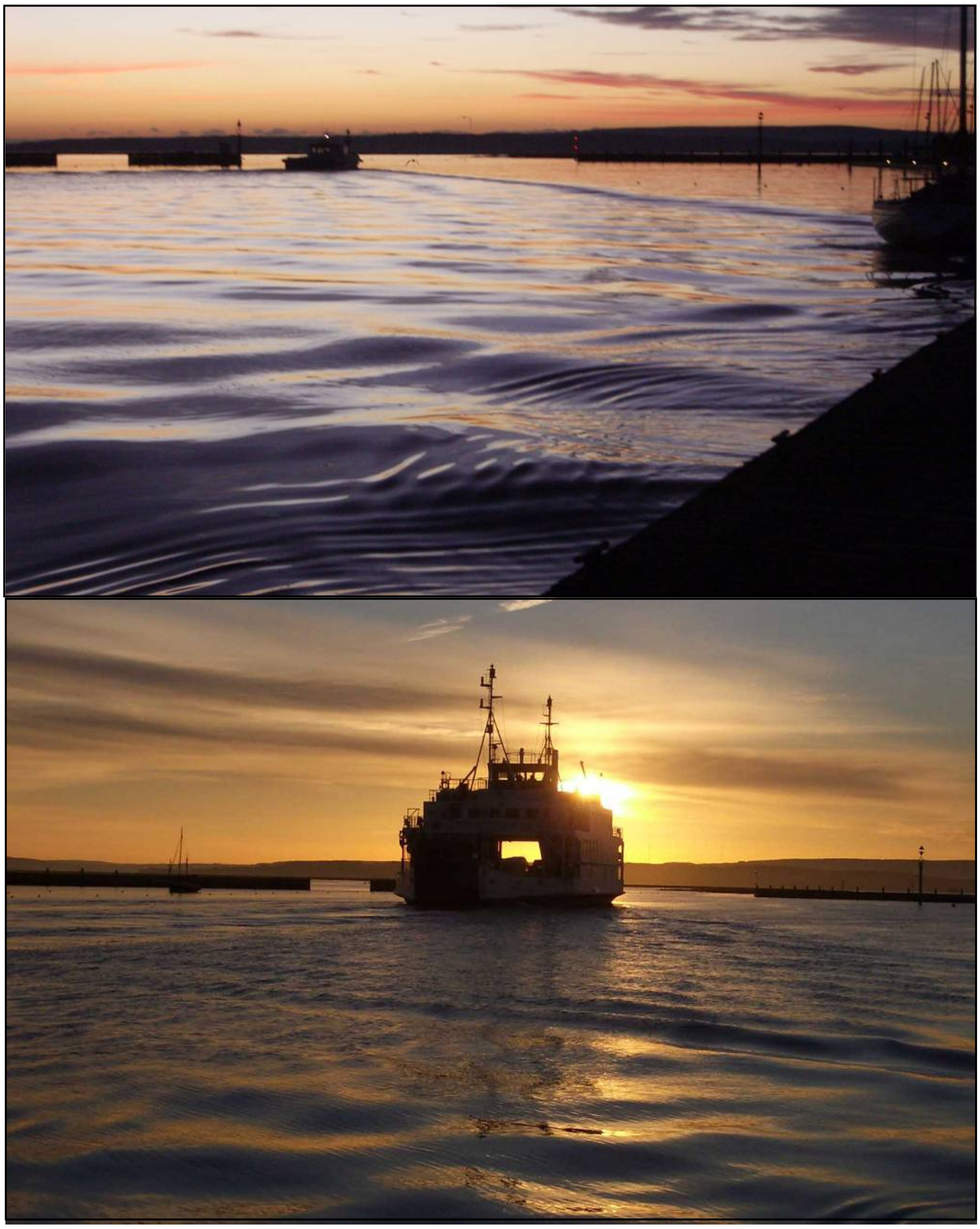


Figure A34: Boat and Ferry Free Wave Systems

Natural waves having heights around 250 to 300mm were measured in March on a day when the wind was not from the prevailing direction, but rather from one likely to produce waves of lower height than normal.

The overall impression gained is that the water disturbance from the existing ferries is less than that tolerated in other ports where vessel wash nuisance is experienced. It is usually assumed that free wave heights no greater than 300mm (±150mm amplitude) are acceptable in about 3 metres water depth. (See, for example, Reference A1).

The flow velocities measured in the river are in accord with estimates made by various people experienced in its ways, and a maximum value of a knot in the lower reaches (with flow velocities at other tidal states being much lower there) should not provide a significant safety issue. The lower velocities in Horn Reach are in accord with what might be expected, bearing in mind the increased water prism in the region resulting from the LHC dredging activities. Maximum tidal flow velocities of the order of 0.4 knots should pose few problems for all vessels using this area.

Attempts to measure the backflow velocities were unsuccessful in that the changes they produced in Horn Reach were too small to measure.

As mentioned above, it was not possible to measure the effect of leisure traffic on water levels. It is intended to remedy this in the Phase 2 trials.

7. Conclusions

Measurements of flow and water level disturbance have been made on the Lymington River, in the absence of leisure traffic, in order to define the present situation. As a result, the following conclusions may be drawn:

- The overall magnitude of the water level disturbances at the measurement locations near the boundaries of the navigation channel was small.
- Tidal flow velocities in the upper and lower reaches of the river peaked at around 0.4 knots and 1.1 knots respectively.
- Ferries and large commercial craft, such as the self-propelled dredge barge, create a drawdown which varies in magnitude with water depth, speed and distance off. The majority of the measurements had a maximum drawdown no greater than 50mm, but on one occasion (when a ferry passed close to the measuring location just before low water) it was over 150mm.
- Boats moored in the vicinity of the RLYC are subject to ship-ship interaction effects as the outbound ferry passes at low water.
- Ferries produce characteristic free wave disturbances whose measured amplitudes are less than those possible in natural waves, similar to those of some of the smaller workboats and apparently less than those from some fishing vessels operating on the river.
- Natural waves can have heights of 250 to 300mm even when the wind is blowing off the land, the most sheltered scenario.

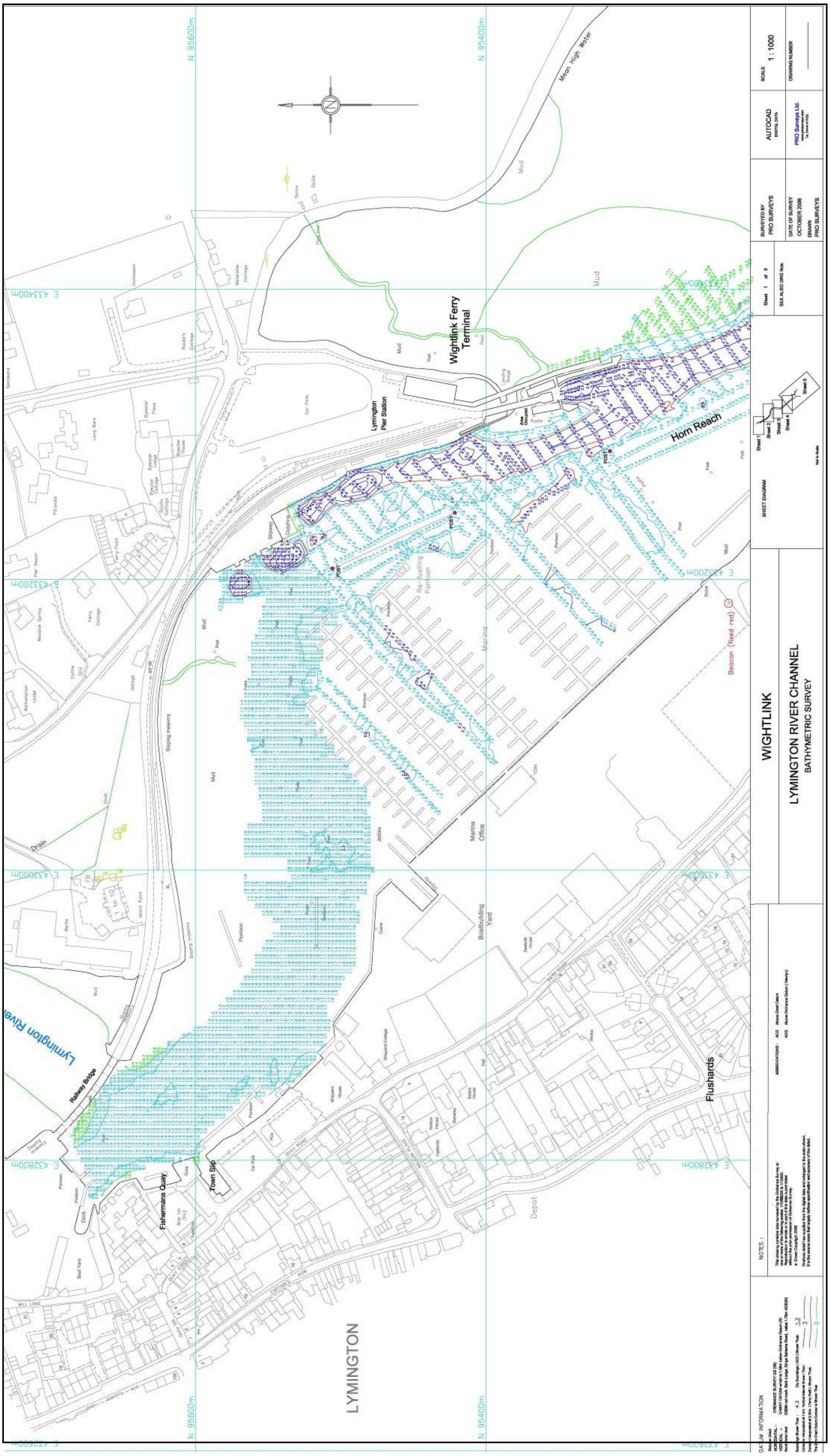
8. Reference

1. “The Impact of High Speed Ferries on the External Environment”, Nautical Division, Dansh Maritime Authority,

1998

Appendix 3

Bathymetry Plots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BATHYMETRIC SURVEY
SCALE
1 : 1000
AUTOCAD
SURVEYED BY
PRO SURVEYS
DATE OF SURVEY
OCTOBER 2006
Wightlink Ferry Terminal
Lymington Pier Station
Horn Reach
Mean High Water
Mud
Re-fuelling Pontoon
Marina
Marina Office
Boatbuilding Yard
Beacon (fixed red)
Lymington River
Railway Bridge
Drain
Fishermans Quay
Town Slip
Flushards
LYMINGTON
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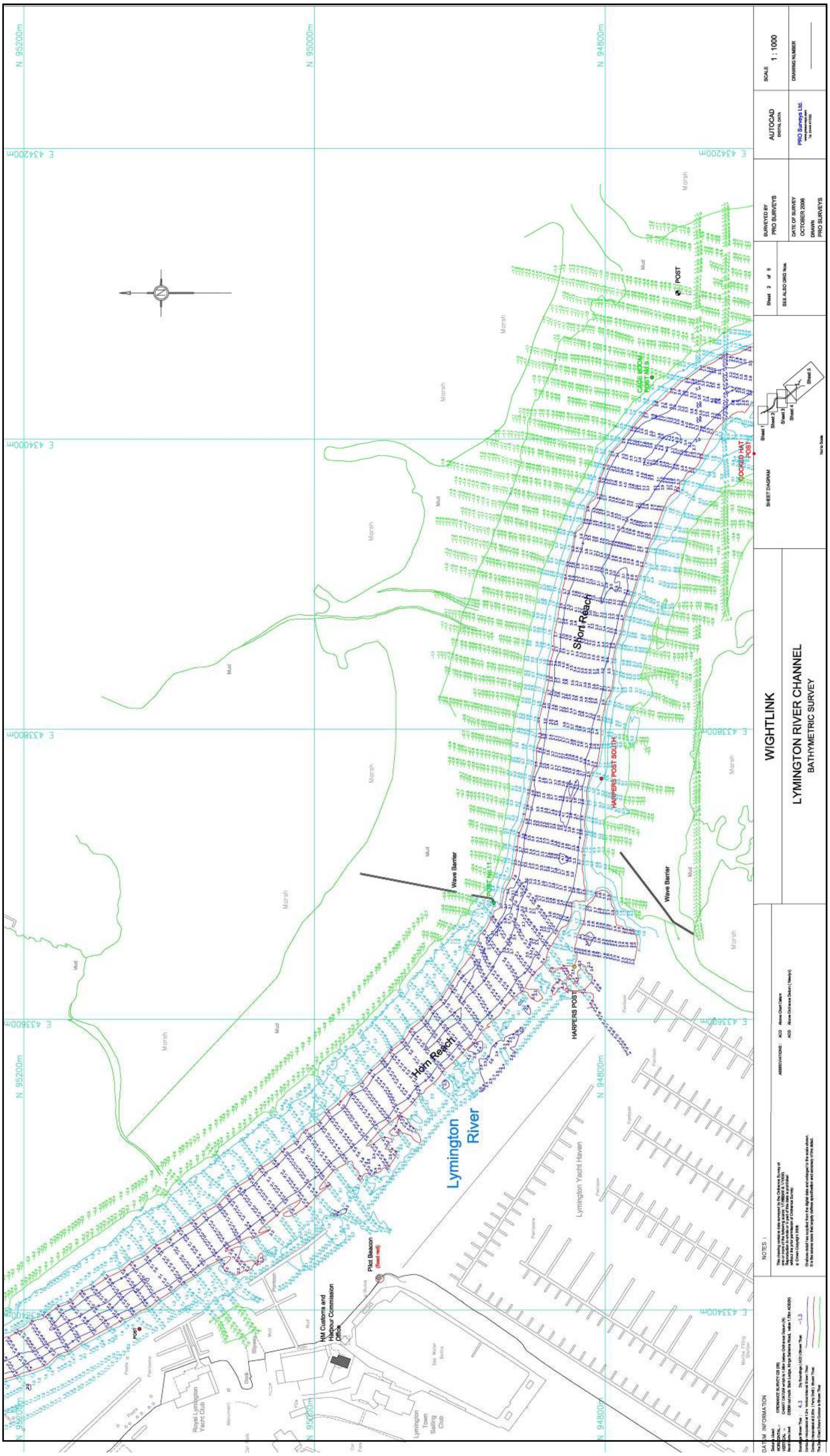
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Short Reach
Horn Reach
Lymington River
Wave Barrier
HARPERS POST SOUTH
HARPERS POST
COCKED HAT POST
POST
Pilot Beacon
HM Customs and Harbour Commission Office
Royal Lymington Yacht Club
Lymington Yacht Haven
Marsh
Mud
N 95200m
N 95000m
N 94800m
E 434200m
E 434000m
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AUTOCAD
PRO SURVEYS
OCTOBER 2008
SHEET DIAGRAM
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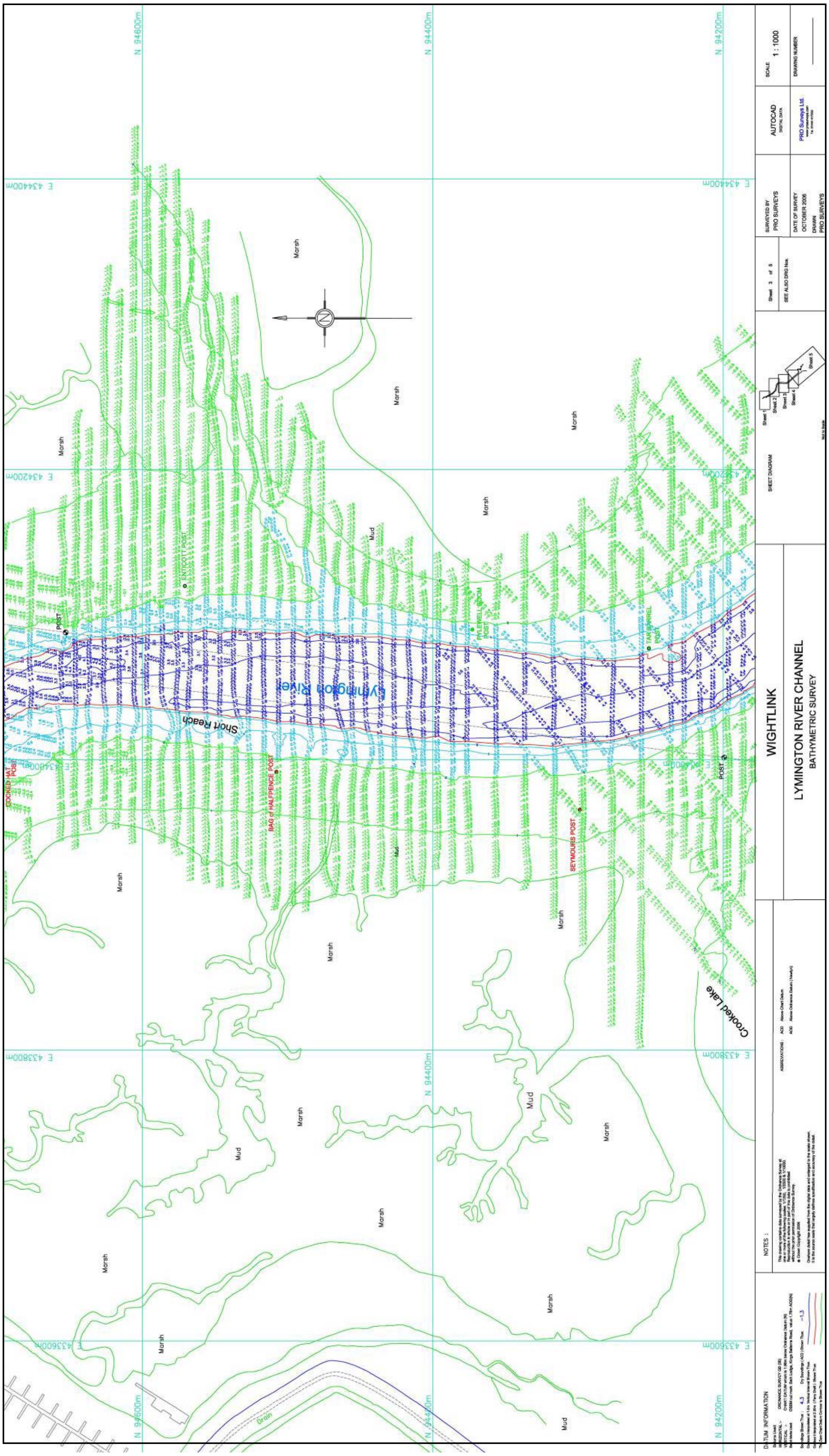
DATUM INFORMATION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Lymington River
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Crooked Lake
Marsh
Mud
Drain
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SEYMOURS POST
POST
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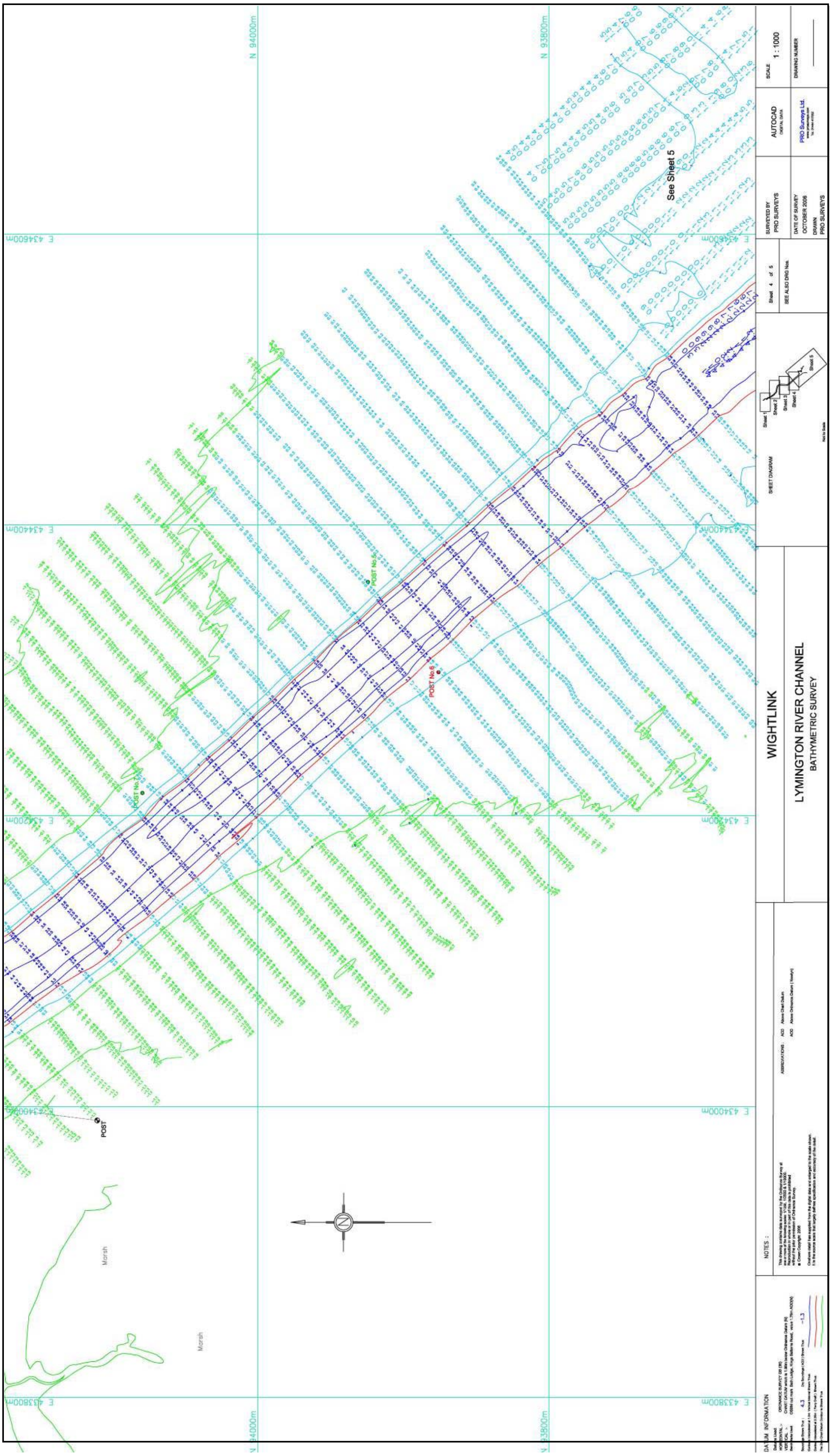
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See Sheet 5
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POST No.6
POST
Marsh
Marsh
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AUTOCAD
PRO SURVEYS
OCTOBER 2006
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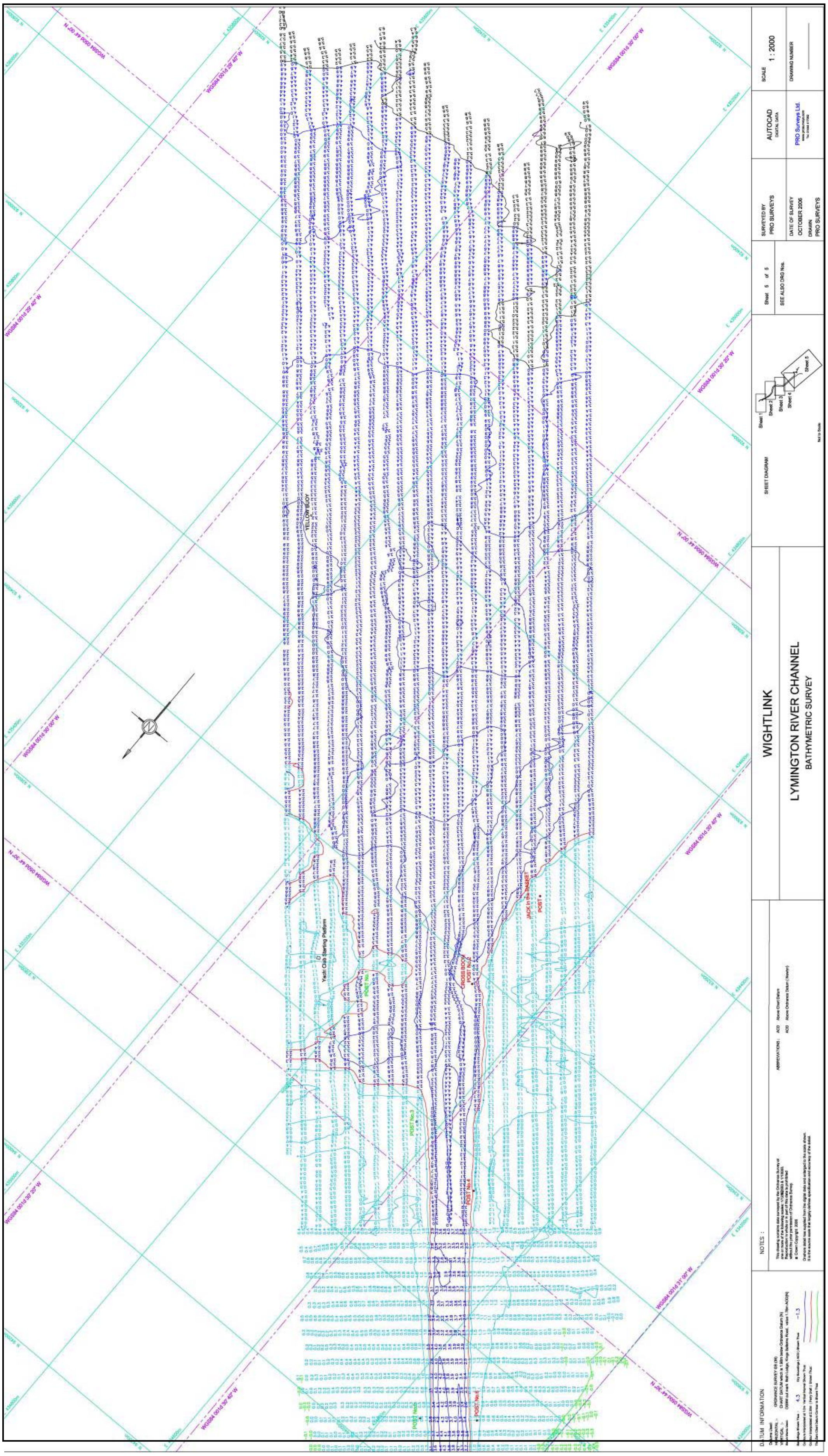
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