Vessel effects as a result of a deeper channel in the Lower Otago Harbour

Prepared for

Port Otago Ltd

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December 2009

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Executive Summary

This report presents an assessment of the effects of vessel movements resulting from use of the proposed 15 m deep shipping channel in the Lower Otago Harbour.

The assessment is based on analysis of:

- The existing wake environment as derived from tide gauge records at the Spit tide gauge,
- Observations of wake events at Te Rauone Beach,
- Examination of photographs of vessels in transit along the shipping channel, and
- Studies carried out for the Ports of Melbourne comparing wake from container ships in Port Phillip Bay.

Not all wake is discernable at the shore or at the tide gauge. This is because the wake is sometimes not large enough to register visually at the shore or on the gauge, or is not able to be distinguished from the background wave environment. Of the wake that is discernable, the wake from the 4100 TEU vessels is more likely to be larger than the wake from other vessels. However, the greatest number of large wake events that were observed, arise from small container ships and cruise ships. This is because there are many more transits of these types of vessels per year than the 4100 TEU vessels.

The wake events that are more likely to be adverse at the shore are those that occur within an hour or two either side of high tide. The effects on the water are limited to within two or three boat lengths away from the sailing line. As the shipping channel is “one way”, the interaction of boats with wake does not occur between ships, and smaller vessels are advised to sail at a distance from larger ones.

The deeper channel will result in reduced wake from the vessels that use the channel at present due to the greater channel depth and a reduction in the blockage ratio. There will also be a reduction in bed scour from these vessels.

It is likely that larger container vessels such as the 6000 TEU ships will have a wake in the order of 10 -15% greater than the current 4100 TEU vessels. However when these vessels are introduced to the harbour, there will be fewer vessel movements due to the greater vessel capacity and would be a replacement service for the 4100 TEU service.

The cumulative effect of the deeper channel on wake wave effects in the Lower Otago Harbour will be a net benefit, in that there will be an overall reduction in wake energy from container ship movements.

1. Introduction

1.1 Background

This report is part of a collection of reports addressing progressing Port Otago Limited (POL) operations to expand the capacity to service large container ships of 6000 to 8000 TEU (twenty-foot equivalent units). These ships have 50% more capacity and are longer and wider than existing ships that come to the harbour. Port Otago proposes dredging the approaches to Port Chalmers and the berth area, deepening the channel to a minimum of 15 metres below chart datum.

This report considers the effects vessels transiting the shipping channel in the Lower Otago Harbour may have on the surrounding environment after the completion of the proposed channel-deepening project.

Identification and assessment of the effects of larger vessels using the proposed deeper channel on the physical coastal environment has used an approach consistent with international practice (for example PIANC 2003), the requirements of the RMA (1991) and NZCPS (1994 and 2008 proposed).

1.2 The proposal

A full description of the proposed dredging activity is presented by POL (2010) in the Channel Design Report and associated drawings. In summary, the minimum depth of the main shipping channel between the Fairway Beacon and Port Chalmers will be increased from 13.0m below chart datum to a minimum of 15.0m with the entrance channel deepened to 17.5m from the Fairway Beacon to the mole. Figure 1.1 shows the proposed final bathymetry for the harbour channel. (Source: Figure 3.8, Bell et al. 2009).

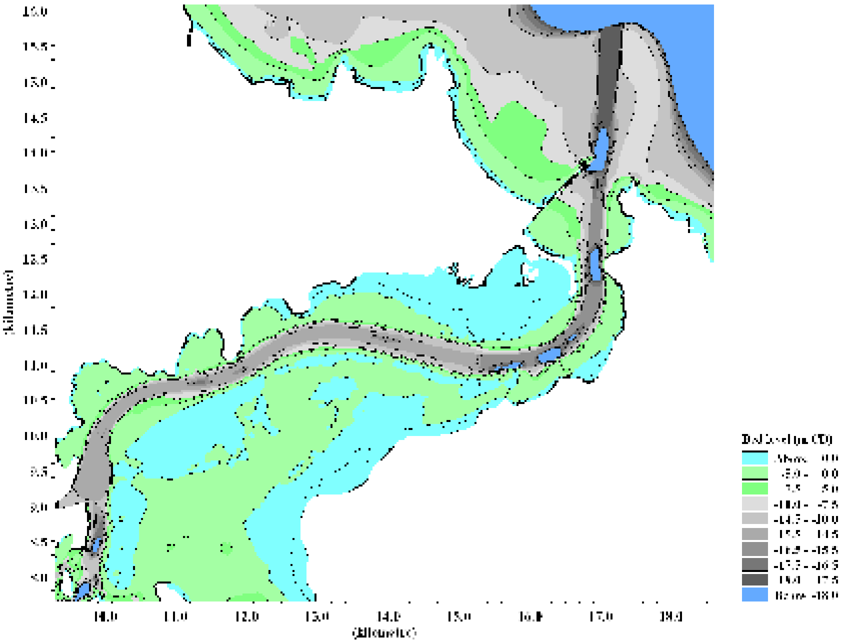


Figure 1.1 Proposed Bathymetry of Lower Otago Harbour

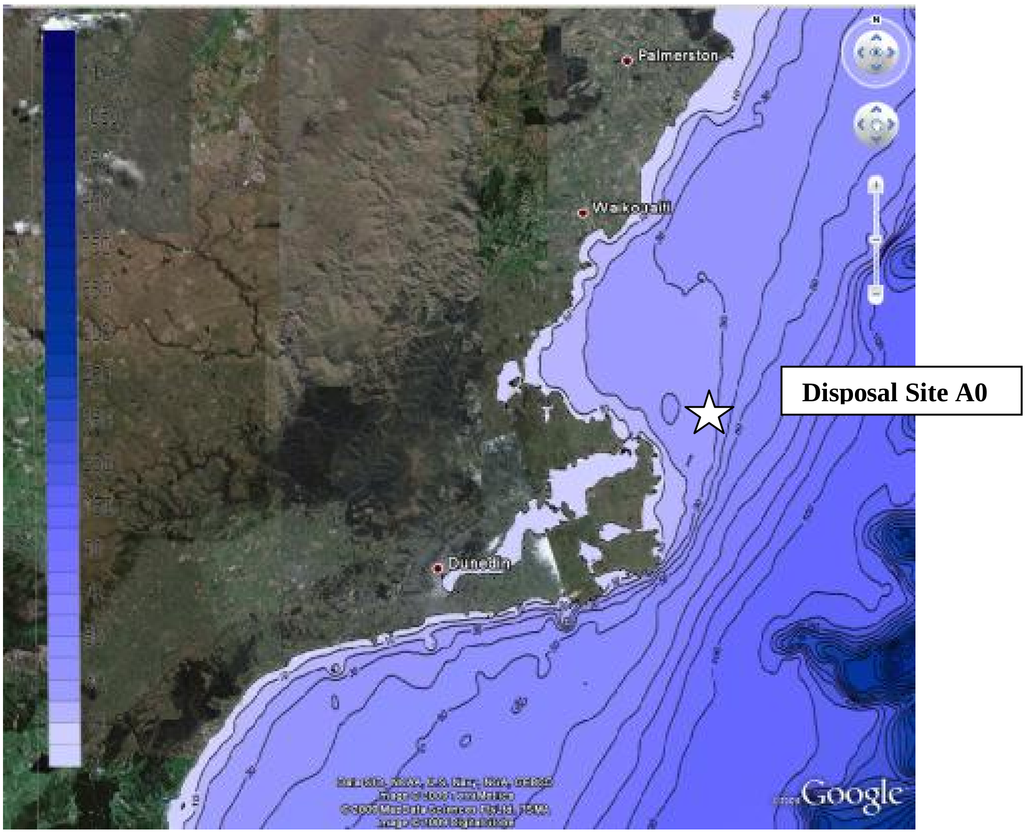


Figure 1.2 Proposed dredge disposal site A0.

The Otago Peninsula and bathymetry in Figure 1.2 shows the position of the area to be used as an offshore dredged material disposal site, known as site A0. The centre of selected site is located approximately 6.3km off the Landfall Beacon (Background image source: Google Earth, 2009).

Figure 1.3 shows the general extent of dredging required within the channel to achieve the harbour bathymetry shown in Figure 1.1. The shipping channel is deepened, and the channel margins are widened at the main bends (Harington Bend and Tayler Bend), while the size of the swinging basin at Port Chalmers is increased. The banding shows the cut depth required from the existing bathymetry to achieve the final channel profile.

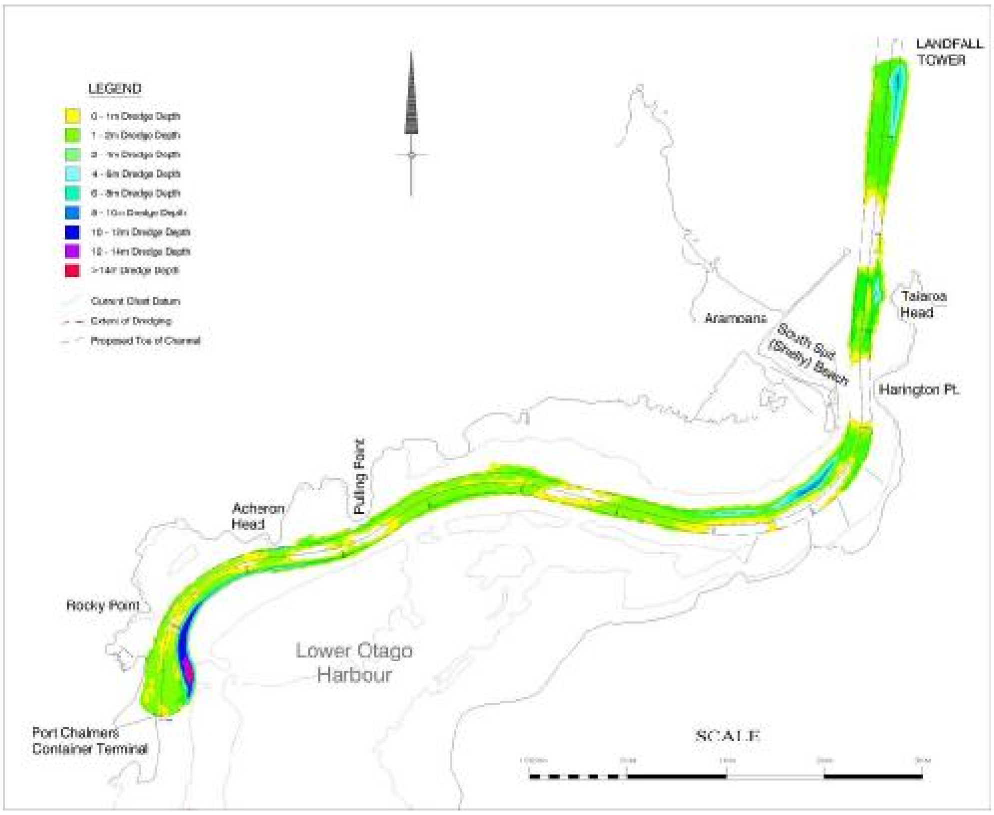


Figure 1.3 Proposed dredging depths within Lower Harbour

1.3 Existing container vessel size

To consider the effects the proposed channel deepening will have on vessel calls at Port Chalmers it is relevant to discuss the existing vessel usage including maximum vessel size. The largest vessel currently calling at Port Chalmers is the 4100 TEU weekly Maersk service. The 4100 vessel fleet, Albatross Class, is generally 281m LOA, 32.2m beam and design draft of up to 12.60m. Actual drafts based on recorded historical data at Port Chalmers are shown in Figure 1.4.

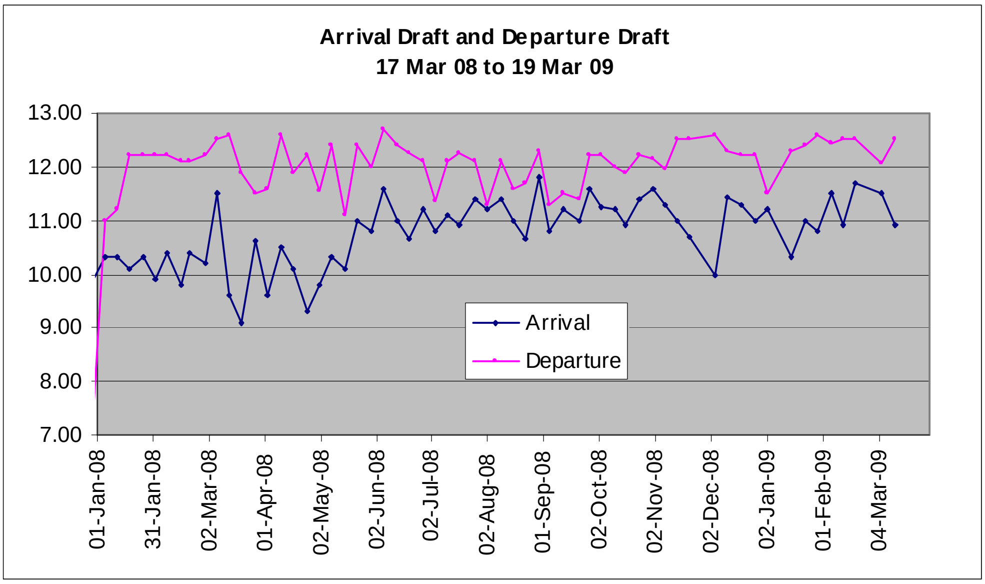


Figure 1.4 Vessel draft of weekly Maersk Service calling at Port Chalmers.

Figure 1.4 shows the variance in vessel draft in the 4100 Class vessel where, without exception, all departures have a deeper draft than on arrival due to Port Chalmers being predominantly an export port. There is also seasonal variability in the draft with a larger variation between arrival and departure drafts during the export meat season, which starts in November and finishes between January and May.

Due to the existing declared channel depth of -13.0m CD (chart datum), and the requirement for a minimum of 10% underkeel clearance (UKC), there are Pilot imposed tidal restrictions on vessels with a draft greater than 11.8m. This concept is covered in more detail in the Port Otago Ltd channel design report.

Even though the 4100 TEU vessels are currently the largest in terms of displacement tonnage to call at Port Chalmers there are also a number of other smaller commercial vessels using the Lower Otago Harbour channel. A large percentage (approximately 40%) of additional vessel calls are smaller container ships used as either feeder vessels for the 4100 weekly call or deep-sea vessels in their own right. These smaller container vessels typically range from 180 to 225m long with drafts between 9.0 and 11.0m

1.4 Port Otago ship calls

As noted in Section 1.3 the number of commercial vessels using the Lower Harbour is not restricted to container vessels. Table 1 provides an indication of the total ship calls for 2008 and the predicted number for 2010.

Table 1 Actual ship calls for 2008, and predicted ship calls for 2010

Vessel Trade	2008 Actual	2010 Predicted
4100 TEU Maersk South East Asia service	52	52
Container Trade - Other	215	234
Cruise ships	39	50
Log and woodchip	16	17
Oil tankers	27	27
LPG Tankers	37	30
Cement trade	13	18
Fertiliser	14	12
Other vessels	43	40
Fishing Vessels	95	70
TOTAL	**551**	**550**

1.5 Potential vessel size

The increased channel depth and alignment will enable ships of greater tonnage to call at Port Chalmers on a regular basis albeit tidally restricted at deeper drafts. Table 2 provides examples of vessels expected to be capable of navigating the proposed channel and for comparison an example of the current Maersk vessel calling at Port Chalmers.

Table 2 Design vessels for Port Chalmers

Nominal Size	Design Draft	LOA	Beam	Displacement Tonnage	Typical Ship
4100 TEU	12.5m	281m	32.2m	53,081	*Maersk Damascus*
6000 TEU	14.0m	318m	42.8m	84,900	*Maersk Karlskrona*
6000 TEU	14.5m	300m	40.0m	84,771	*Maersk Kendal*
8000 TEU	14.5m	347m	43.2m	104,696	*Sovereign Maersk*

Figure 1.5 6000 TEU Vessel *Maersk Kendal*.

It is anticipated that initially the 6000 TEU vessels, as shown in Figure 1.5, *Maersk Kendal* or similar, will call at Port Chalmers with the 8000 TEU not expected to call in the next 20 years. The vessel allocation depends wholly on the shipping lines and trade route requirements. Even with the proposed deeper channel Port Otago Ltd will be required to impose tidal restrictions on the 6000TEU vessels. However the current restrictions on the 4100TEU vessels will be removed following incremental depth improvement to 13.5m below CD.

It is unlikely that there will be increases in the size of other types of vessels such as LPG and oil tankers, bulk carriers such as fertiliser, log and chip carriers or cruise ships. Although LPG tankers and log carriers are generally not restricted by draft it is unlikely there will be demand for larger vessels for the predicted trade volumes. Other vessels such as oil tankers and cruise ships are restricted by draft at other ports of call and in the case of oil tankers restricted by the Victoria Channel in the Upper harbour.

1.6 Types of effects

The increase in vessel size and the changes to the harbour bathymetry are likely to result in changes to the vessel generated waves associated with ship passage along the channel. This report identifies the extent and possible effects of these vessel-generated waves on the surrounding environment of the channel sides, the inter-tidal sand flats and beaches near to the channel.

The environmental effects considered in this report include those resulting from waves generated by vessels such as wake and Bernoulli waves, seabed scour and any potential safety impacts. Figure 1.6 and Figure 1.7 show typical examples of wake generated by container vessels arriving and departing Port Chalmers. The vessels are similar in size and travelling at about the same speed, and although the pattern of the wake is similar between the two vessels, the waves are different in size and in the effect in relation to the background wave conditions. Further examples are presented in Appendix A. The size and effects of the wake is dependent on a large number of variables such as vessel speed and length, climatic conditions and water depth, this discussed further in Section 2.

Figure 1.6 Wake from the container vessel *MSC Basel* departing Pulling Point.

(Source: Leonard Muir, Otago Maritime Society, 2009)

Figure 1.7 Wake from the container vessel *Patricia Schulte* departing Harington Point.

(Source: Leonard Muir, Otago Maritime Society, 2009)

1.7 Area of effects

The area potentially affected by waves associated with vessel movements along the proposed channel in relation to this application is limited to the Lower Otago Harbour.

Any effects are likely to be within 500 m of the channel. However the potential effects of wake waves through the entrance Channel to Harington Bend and at Te Rauone Beach are examined in more detail. These areas are the most dynamic in terms of coastal environment and exhibit greater sensitivity to environmental and climatic change in addition to being adjacent and closer to the channel edge in an area of higher vessel speed.

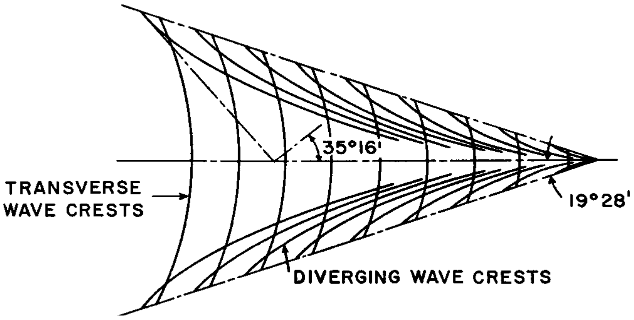
2. Vessel generated waves

2.1 Wave types

All vessels, from a self-propelled canoe to the largest container ships, generate disturbance in the water. Behind the nature of the disturbance are complex wave patterns that can be divided into three principle wave types plus a solitary surge wave as described below:

1. **Wash;** is the high energy turbulence at the stern of the vessel generated by the propulsion mechanism of the vessel and hull friction,

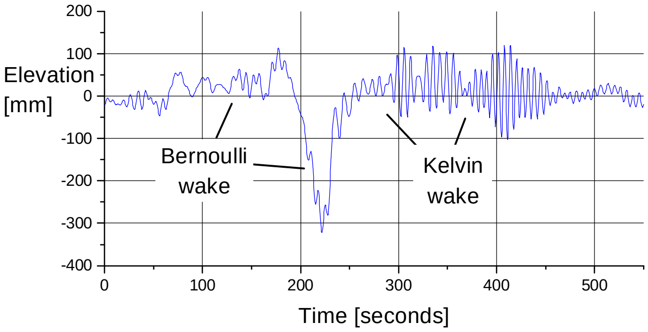
2. **Kelvin Waves or Wake;** are waves formed at the bow (divergent) and the stern (transverse) of the vessel and spread away from the sailing line combining at a location perpendicular to the bow at a distance approximately ⅓ the length of the vessel (as shown in Figures 1.6, 1.7 and 2.1). These waves are generated at sub-critical speeds typical of conventional container ships,



(Source: PIANC, 2003)

Figure 2.1 Steady state Kelvin wave pattern

3. **Bernoulli Waves;** (Figure 2.2) are waves generated by the displacement of water from the passage of the vessel hull. Bernoulli waves are capable of traversing large distances and are also described as surge waves or far field waves.



(Source: PIANC, 2003)

Figure 2.2 Bernoulli wave and Kelvin wave generated by a large container vessel

4. **Solitary surge wave;** There is a fourth type of wave that large displacement vessels in shallow water can generate. This is described as a solitary surge wave capable of

travelling several boats lengths ahead of the vessel when travelling at close to critical speed. The generation of this wave is not possible for a container vessel in the proposed Otago Harbour channel due to speeds of approximately 30 knots required. This wave type will not be discussed in any further detail, as it is not relevant for Otago Harbour.

Of the four wave types described above, wash and the Kelvin wake are visible to the naked eye and disperse relatively quickly with only comparatively minor disturbance in localised areas close to the vessel. Maximum wave height is reduced by half in the first four boat-lengths away from the sailing line. The decrease in wave height is primarily due to wave diffraction (i.e. the spread of wave energy along the wave crest). However in very shallow water, such as across intertidal sands in Lower Otago Harbour, wave decay will also be caused by bottom friction.

Potentially the largest wave heights at shore are generated by the long period displacement wave, the Bernoulli wave. Bernoulli waves are not visible in deep waters and break suddenly on shore potentially affecting smaller moored vessels and users of nearby beaches. This is particularly relevant for large vessels in confined waters but can be produced by any vessel (PIANC 2003).

2.2 Factors determining wave size

The magnitude of wave generated by the passage of a vessel is a combination of the following factors:

- Vessel speed;
- Hull form;
- Vessel size - length and draft;
- Vessel displacement – load and trim;
- Vessel course - distance from shore (sailing line), straight or turning;
- Channel size and water depth, i.e. bathymetry.

As referenced in the Port of Melbourne Channel Deepening documentation (Maunsell 2006) Bernoulli waves are most affected by vessel speed, vessel size and displacement, and channel bathymetry. Kelvin waves are largely dependent on vessel speed and channel bathymetry, in addition to hull form and the existence of a bulbous bow.

Due to the number of dependent factors for the generation of both Bernoulli and Kelvin waves it is highly unlikely any two vessels will produce the same height of wave for the passage of the same channel. Additionally the effects of climate, current and wave conditions also affect wake generation and in turn wave energy dissipation.

Port Otago undertook a review of over 3,000 photographs provided by Mr Leonard Muir of the Otago Maritime Society, and established that wake generated by the same vessel generally varies with each transit depending on a multitude of factors. This is illustrated in Figure 2.3 below.

Figure 2.3 Wake from the container vessel *Nele Maersk*

(Source: Leonard Muir, Otago Maritime Society, 2009)

2.3 Vessel speed

As detailed above, vessel speed is one of the dominant factors in vessel-generated waves for the large container vessels under consideration. The current maximum speed in the Lower Harbour is restricted to 12 knots with vessel speed approaching the Swinging Basin progressively reducing from 12 knots at Cross Channel down to 6 knots at Acheron Point for berthing at Port Chalmers. The changes in speed for the inbound vessel are shown in Table 3.

Table 3 Vessel speed in Lower Otago Harbour navigation channel (Data from Port Otago Ltd 2009)

Channel Reach	Vessel Speed (knots)
Harington Bend	12
Tayler Bend	10
Pulling Point	8
Acheron Point	6

These speeds have been determined from years of experience within the Lower Harbour by the Pilots Group at Port Otago and are applied to maintain safety requirements whilst maintaining vessel manoeuvrability.

Depending on the state of the tide and wave conditions it may be necessary, at the Pilots discretion, to increase vessel speeds passing through the channel entrance, both inward and outward, to enable safe navigation through those sections of the channel. For example vessel speeds past the Mole End may need to be greater than 12 knots for arrival of the 4100 Class vessel during mid spring ebb tide to “punch” through the current.

2.4 Proposed vessel speeds

Following extensive vessel simulation at Devonport Naval Base it was determined that vessel speed for the proposed channel would not be any greater than the speeds shown in Table 3, irrespective of vessel size. This is detailed further in the Channel Design Report (Port Otago Ltd, 2010).

2.5 Existing wave climate and vessel wake generation

Numerous studies have been completed on beach erosion at Te Rauone beach, including recently Single (2007) and Goring (Mulgor Consulting Ltd 2007). Both studies referenced wake or surge at the beach being observed following passages of vessels with Goring correlating vessel berthing and departure times against water level wave readings at the beach.

Goring concluded that "*...Ships appear to generate waves, but they are small and fall within the normal wave climate of Te Rauone Bay…*" . The wave environment of Te Rauone beach was stated as having 86% of waves less than 5cm high.

Goring further concluded that "*…the height of the surge does not appear to be correlated with the ship's size, but there is a weak dependence on their draught…*". The incoming shallower draft vessels were found to create a higher surge than the departing deeper draft vessels (the relation between drafts is shown in Figure 1.4). As noted in Goring 2007 this is likely to be due to Te Rauone Beach being perpendicular to the bow of the incoming vessel and, as noted above, the potentially higher vessel speed as it approaches Harington Bend from the open sea.

As shown by Single (2007) the wave climate at Te Rauone beach is varied, "*The shore is subject to a range of wave conditions. Waves generated by winds on the harbour are small, steep and generally erosive….The dominant strongest winds are from west-southwest (Goring 2007). Breaking waves of about 0.5m have been observed during south-westerly storms*".

Figure 2.4 Te Rauone Beach showing south-westerly wind generated waves.

It should be noted that vessel generated wake lasts for a relatively short time (observed average of 5.5 minutes), whereas swell and wind generated waves can last significantly longer and have the potential to cause substantial damage to the dune system for periods up to 1.5

hours either side of high tide. This concept is discussed in further detail below with data from the Spit Tide gauge assessed to determine the extent of vessel-generated waves.

2.5.1 Wave climate and tidal analysis

During an examination of the Spit tide gauge tracing, it became clear that the wake pattern generated by vessel passage was noticeable on the trace recorded by the data logger. Figure 2.5 shows the short-term deviation of the water level trace about the predicted tidal curve. This deviation is the result of waves being recorded by the tide gauge. However those waves may be wind-generated waves, infragravity waves or vessel-generated wake waves.

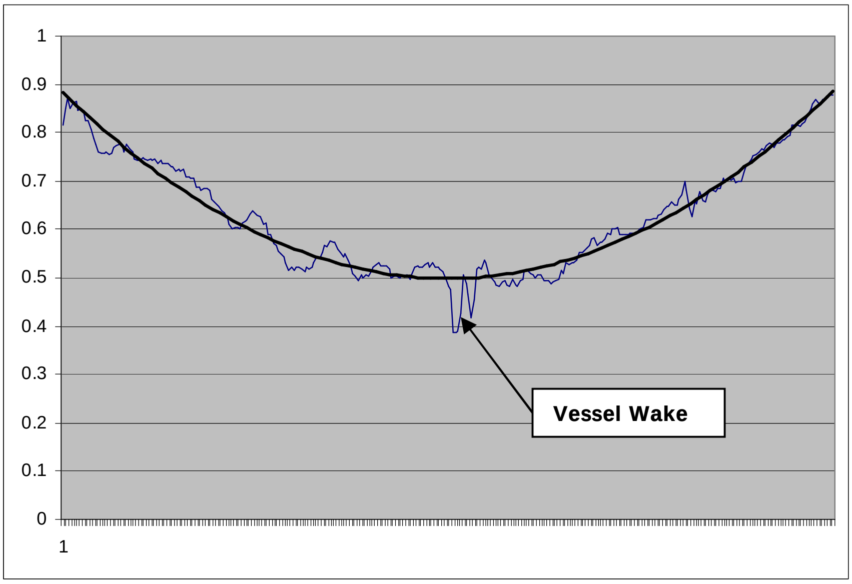


Figure 2.5 Typical Spit Tide gauge recording showing vessel passage

Tide height readings are recorded at 1-minute time intervals and provide the opportunity to carry out a statistical analysis of the readings from the Spit tide gauge. Information was assessed for the 6-month period from 1st January to 30th June 2008. The aim of the analysis was to identify any correlation between commercial vessel visits and recorded wake events and also to put the magnitude and duration of these events into context with background natural meteorological events. The full analysis is included in Appendix B.

Deviations in water level about the tidal curve were identified as event signatures. During the six months studied there were 683 events observed. The times of known commercial vessel passages past the Spit tide gauge were also available and were assessed against the observed events. There were 298 events (44% of the total) that corresponded with commercial vessel visits over the 6-month period. It was inferred that the observed events that coincided with vessel passages were related to wake waves from the vessel. This means that over 50% of the events observed are likely to have been created by either vessels such as the *Monarch* scenic cruises, non-piloted fishing vessels, the dredge *New Era* and the *Aramoana* pilot vessel or by background natural events.

The analysis provided for classifying the wake events into four classes where Class 0 relates to no discernable wake, Class 1 relates to barely discernable wake, Class 2 relates to readily distinguished wake waves and Class 3 relates to large wake waves. Each wake event was attributed to a vessel where possible, and the vessel type was coded with the data for analysis. The types of vessels were small capacity container ships, cruise ships, 4100 TEU container ships, LPG tankers, oil tankers, timber carriers, cement carriers, other (generally smaller vessels or one-off visitors) and unknown. Table 4 shows the results of the tide gauge analysis.

Table 4 Frequency of vessels in each wake grade and in each trade group from 1st January to 30th June 2008. The percentages represent the proportion of vessels in each wake grade in each trade group.

Trade Group	**Wake magnitude class & percentage in each trade**								**Total vessels in each trade**	
	0	% Trade	**1**	% Trade	**2**	% Trade	**3**	% Trade	**Total**	%
Container Ships (<4100 TEU)	54	(23%)	69	(29%)	70	(30%)	41	(18%)	234	(51%)
Cruise Ships	21	(39%)	9	(17%)	10	(19%)	14	(26%)	54	(12%)
4100 TEU Container Ships	4	(8%)	5	(10%)	19	(37%)	24	(46%)	52	(11%)
LPG	31	(86%)	4	(11%)	1	(3%)	0	(0%)	36	(8%)
Oil	10	(42%)	7	(29%)	6	(25%)	1	(4%)	24	(5%)
Forestry	6	(33%)	4	(22%)	5	(28%)	3	(17%)	18	(4%)
Cement	9	(82%)	1	(9%)	1	(9%)	0	(0%)	11	(2%)
Other	18	(82%)	2	(9%)	1	(5%)	1	(5%)	22	(5%)
Unknown	9	(100%)	0	(0%)	0	(0%)	0	(0%)	9	(2%)
Total	162	(35%)	101	(22%)	113	(25%)	84	(18%)	460	(100%)

This analysis shows that although the largest percentage of large (Class 3) wakes per vessel type comes from the 4100 TEU Container ships, there are a greater number of large wake events from smaller container vessels. The analysis of ship visits also showed that there were 162 commercial visits (35% of the total over the 6 months) that were not identified on the tide trace due to either high background “noise” on the trace, or no discernable deviation from the smooth tidal curve during the time when the vessels passed the Spit gauge.

In addition, the analysis of the tide gauge data showed that the maximum 1 minute deviation in the water level trace was + / - 110mm with 99% of the discernable events (Class 1 or above) being less than 40mm deviation.

2.5.2 Vessel wake observation programme

During preparation of this report it was determined that a visual observation programme would be valuable in providing further background information on vessel generated effects away from the shipping channel, and at the shore. The observation programme did not include instrumented measurements. However detailed observations were carried out at Te Rauone Beach between 17th August 2009 and 19th October 2009. Twenty-two vessel passages were observed. Estimates of wake wave heights were made, and the time of wake onset after the vessel had passed the beach, and the duration of the wake event was recorded. The field observation programme also included recording a number of features relating to the vessel transit, the state of the wave environment prior to the wake, and the observed effect of the wake waves at the beach. Further information about the state of the tide and the vessel loading were added to the recorded notes following the field observations.

The results of the observations are summarised in Table 5 and are contained in full in Appendix C. A number of transits were also recorded by video.

Table 5 Vessel observations at Te Rauone Beach (Speed shown is calculated from time taken to pass a fixed point)

Date	Vessel	Vessel Trade	DWT (tonnes)	Wave Height (mm)	Tide Height (m)	Draft (m)	Vessel Speed (knots)
18/08/09	Kakariki	Oil tanker	46,724	200	1.50	6.45	7.6
20/08/09	Maersk Damascus	4100 Container	53,081	140	0.08	10.30	11.3
18/08/09	MSC Kiwi	Container	14,367	150		8.30	8.2
20/08/09	Peregrine	Log	50,895	220	1.28	7.90	11.1
23/08/09	Amattal Atlantis	Fishing Vessel	1,255	200	1.78	7.30	8.3
07/09/09	Townsend Cromwell	Research vessel	309	100	0.32	4.00	7.7
07/09/09	Vega Gotland	Container	13,806	100	0.22	7.60	10.9
07/09/09	Townsend Cromwell	Research vessel	309	150	0.66	4.00	7.0
14/09/09	Maersk Radford	Container	13,819	200	1.96	7.70	8.0
25/09/09	Maersk Duffield	4100 Container	53,171	220	0.43	10.80	10.2
28/09/09	Torea	Oil tanker	37,069	150	1.62	6.40	11.3
01/10/09	Maersk Dunafare	4100 Container	53,452	350	1.77	11.30	9.6
05/10/09	Maersk Radford	Container	13,819	150	1.36	7.10	10.9
08/10/09	Maersk Denton	4100 Container	53,115	500	1.10	10.60	11.1
09/10/09	Milburn Carrier II	Cement	8,465	150	1.52	5.30	11.5
12/10/09	Rehua	Fishing Vessel	2,483	120	1.56	7.10	13.1
13/10/09	Maersk Fukuoka	Container	11,815	150	0.44	7.30	11.3
16/10/09	Crimson Jupiter	Woodchip	48,205	150	2.19	8.40	8.7
16/10/09	Maersk Damascus	4100 Container	53,081	200	2.12	12.30	8.1
19/10/09	Vega Gotland	Container	13,806	100	0.25	7.90	11.9
19/10/09	Crimson Jupiter	Woodchip	48,205	100	0.20	11.03	9.3
19/10/09	MSC Sardinia	Container	43,270	100	0.22	9.10	9.3

An assessment of the relationship between wake height and a number of variables was carried out. Data for the Maersk Denton was excluded due to complex wave reflection contaminating the data. It was found that there was a weak correlation between wake height and tide height (as shown in Figure 2.6). This positive relationship is to be expected as deeper water in the nearshore allows for less shoaling effect and bigger breaking waves.

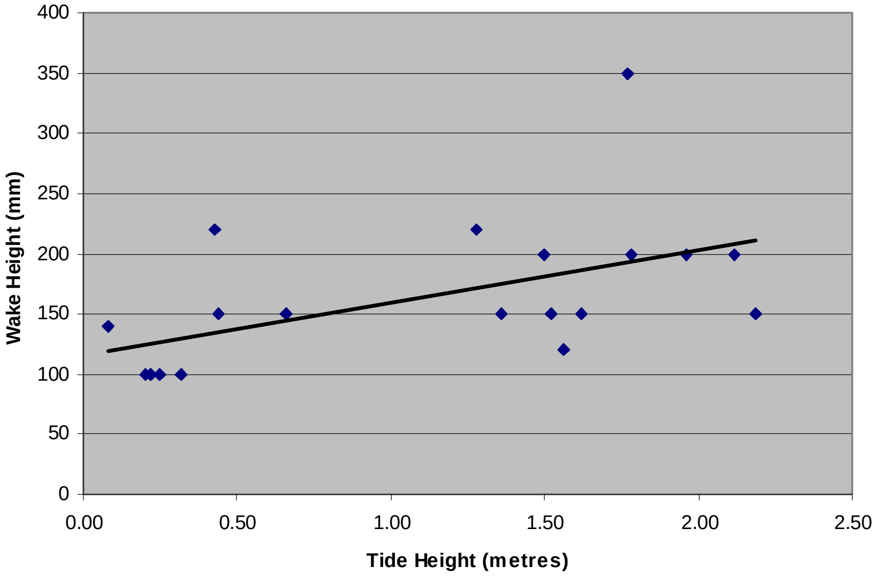


Figure 2.6 Observed wake height versus tide height

As shown in Figure 2.7, there appeared to be little correlation between wave height and vessel speed through the water. The vessel speed through water is calculated by measuring the time taken for the vessel to pass a fixed point and applying an estimated current velocity. The environmental and vessel factors that influence wave height are complex and vary over time. The sample size is too small to show all this variability and subsequently there is no clear relationship between vessel speed and wake height for the data set.

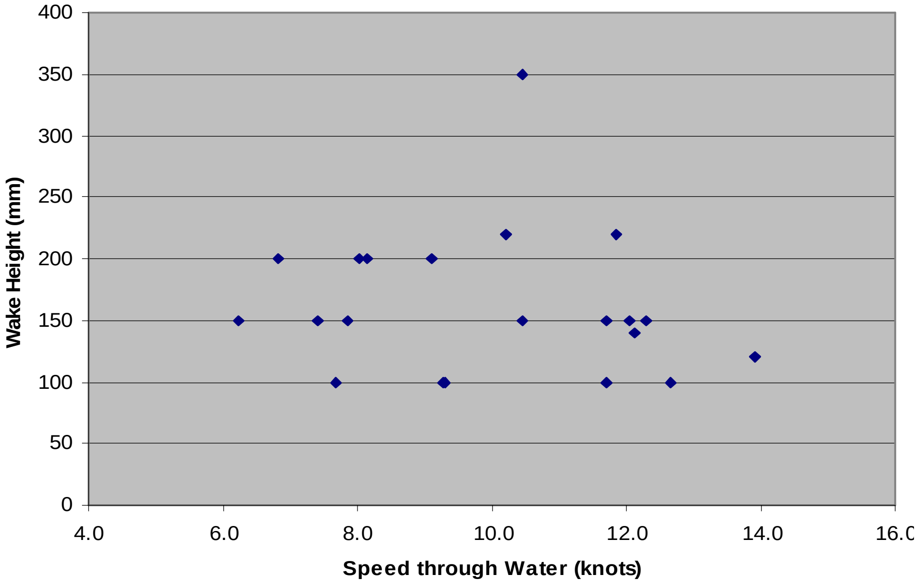


Figure 2.7 Observed wake height versus vessel water speed

There were six occasions when the wake reached the dune face, on each of these occasions the vessel transits were at, or near, high tide with the water level already at a level near the base of the dunes. Sand was observed in motion at the dune face as a result of wake on one occasion (*Maersk Damascus*, 16/10/2009).

The passage of the *Maersk Denton* on the 8th October was particularly interesting not only because of the wake breaker height, estimated at 500mm, but also because of the wake wave characteristics observed offshore and in the nearshore. Over the years, residents at Te Rauone have reported to Port Otago Ltd anecdotal descriptions of "rogue" wakes associated with the passage of larger vessels in certain conditions. There had been no measurements of such waves, and no pattern recorded to the circumstances behind their occurrence due to the apparent randomness of the events. Fortunately, with the passage of the *Maersk Denton*, a video of such an event was recorded, enabling the wave generated to be studied in more detail.

The recorded event occurred with a tide height of 1.10m. From the review of the video, the vessels bow waves, or diverging waves, approached almost parallel to the beach. Due to a combination of the steepness of the beach face at this tide height and the relatively calm conditions the wave crests were reflected back off the beach back towards the channel. These wave crests then intersected with the transverse wave crests from the stern of the vessel creating considerably larger waves than either of the diverging or transverse waves. This is caused by the combination of the energy of both waves effectively adding the crest heights together to create a larger and potentially more energetic wave.

This condition is sometimes referred to as "standing waves" and although apparently linked to reflection of the leading waves off the shore, it could also be related to phenomena known as "cusp loci", where the divergent and transverse waves intersect as they are travelling in slightly different directions at slightly different speeds. Details of the wake waves from the passage of the *Maersk Denton* are illustrated in Figure 2.8, taken from the video footage and subsequently marked up.

This complex wave effect can also occur where large vessels pass each other in confined channels travelling in opposite directions. However, this cannot happen in Otago Harbour due to the shipping channel having one-way traffic only.

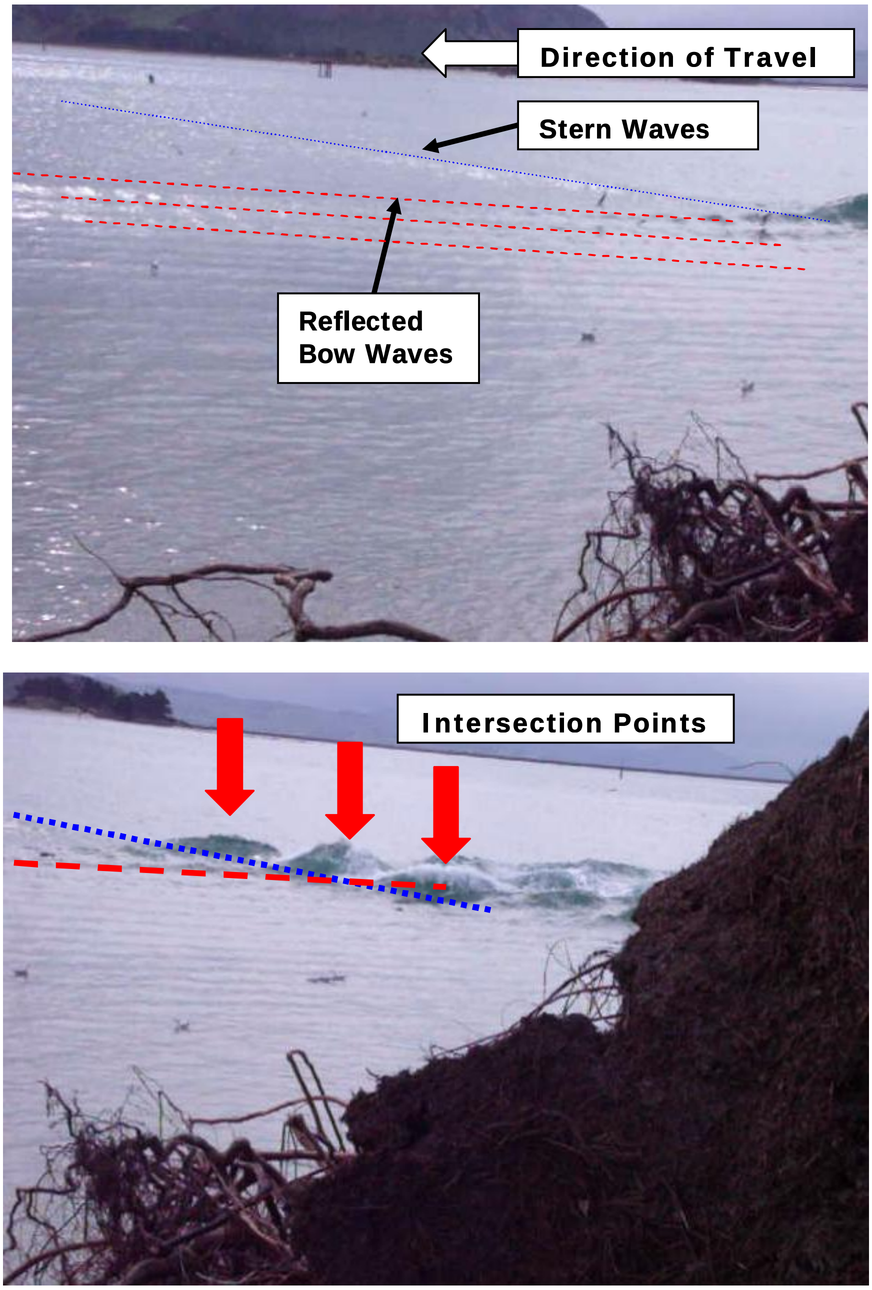


Figure 2.8 Wake generated by the passage of *Maersk Denton* 8th October 2009

Observations of the transit of the *MSC Basel* and the *Maersk Denton* were undertaken on 5th November 2009 following the recognition of this complex wave effect. Both vessels arrived within 30 minutes of each other so weather, tide and current conditions were largely unchanged between the transits. The observed effects showed that the reflection, and subsequent complex wave conditions, occurred for both vessels with a bigger wave height witnessed for the *Maersk Denton*. The *Maersk Denton* is a larger vessel (53,115 DWT, 4,112TEU) than the *MSC Basel* (45,696 DWT, 2,680TEU).

These observations and discussion with local residents confirm that this complex wave pattern does not occur on all passages, but is very much dependent on the vessel, the climatic conditions, the tide height and the state of tidal flow.

2.6 Determination of vessel wake generation with a deeper channel

As noted in numerous publications including PIANC (2003), accurate computer-modelling techniques do not currently exist to determine breaking wave height and beach run-up as a result of vessel wake, and are likely to be decades away from becoming readily available. This is in large part to the numerous variables associated with the passage of vessels and the constantly changing natural environmental conditions (wind, wave and currents), and the complexity of the bathymetry of navigable channels and adjacent shorelines.

Empirical studies carried out as part of the Channel Deepening Project (CDP) for Port of Melbourne Corporation by Maunsell Australia (Maunsell 2006) using vessel speed and draft as the variables, indicate that an increase of approximately 15% in Kelvin wave height could be expected from the larger vessel at speeds of 20 knots. It should be noted that these speeds are much higher than would be allowable for safe passage of the Lower Otago Harbour, although the changes in channel depth currently being constructed in Port of Melbourne are very similar to those proposed by Port Otago Ltd.

Of relevance to Otago Harbour are the results of studies of vessels with speeds of 8 knots in the Port of Melbourne channel. Conclusions from this work indicate that a deeper draft (14m) vessel in the proposed channel will create slightly smaller waves, approximately 5 – 10% reduction, than the 12.1m draft vessels in the existing channel. The reasons for the reduction is explained as being due to the increased water depth and cross sectional area of the new channel being the dominant factor rather than the deeper vessel draft. This effect is described as the blockage ratio and is the wetted cross section of the ship in relation to the cross section of the channel, This is illustrated in Figure 2.9. Table 6 provides estimated cross sectional dimensions of the existing and proposed channels with batter slopes shown conservatively at 1 vertical to 3 horizontal.

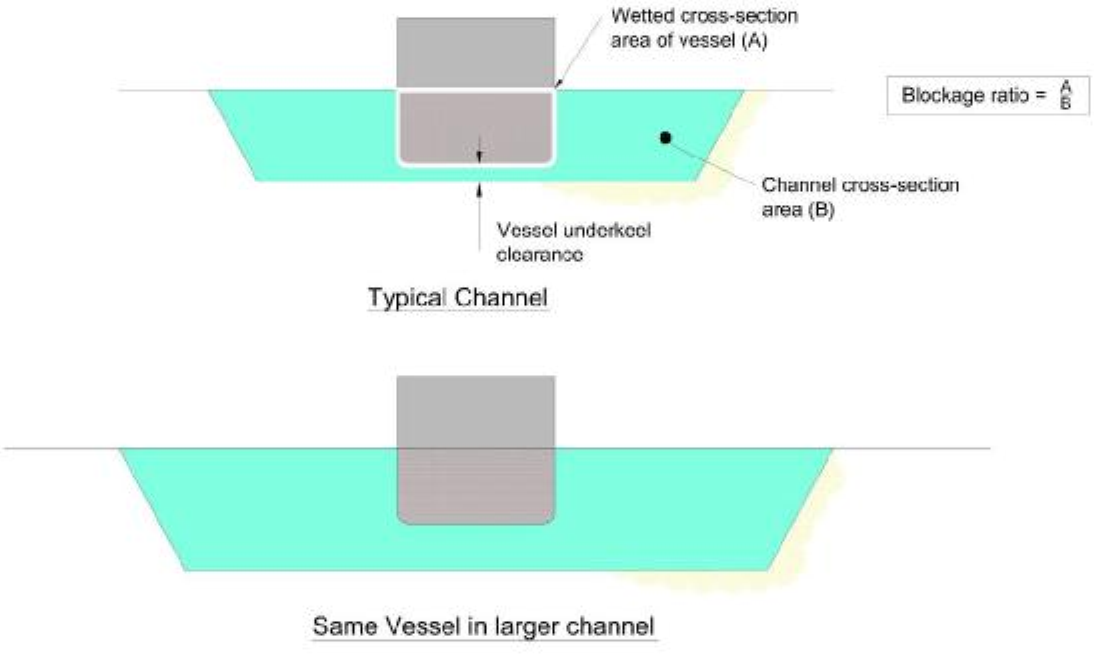


Figure 2.9 Blockage ratio

Table 6 Channel dimensions in the Lower Otago Harbour

	Width (m)	Depth (m)	Min Batter Slope	Cross Sectional Area (m²)
Existing Channel	183	13	1v:3h	2,890
Proposed Channel	200	15	1v:3h	3,675

Table 7 illustrates the significant reduction (approximately 21%) in blockage ratio of the 4100 TEU vessel in the proposed channel and a 22% increase in the blockage ratio for 6000 TEU in the new channel over 4100 TEU vessels in the existing channel. It should be noted that the blockage ratios' are calculated at 0m of tide.

Table 7 Vessel dimensions and blockage ratio (note that a smaller blockage ratio indicates a smaller degree of blockage)

	Beam (m)	Draft (m)	Squat (m)	Cross Sectional Area of Vessel (m²)	Blockage Ratio Existing Channel	Blockage Ratio Proposed Channel
Existing 4100 TEU Vessel	32.2	12.7	0.5	425	0.147	0.116
Proposed 6000 TEU Vessel	43.0	14.5	0.76	656	(0.227)	0.179

Based on the information on blockage ratios above and the Port of Melbourne studies, it is expected that the wake and wave effects of all existing vessels using the proposed deeper channel in Otago Harbour will be reduced due to the deeper and wider channel. The proposed channel provides a larger cross sectional area with the subsequent reduction in blockage ratio for existing size vessels. As an example of magnitude of the wake, a fully loaded 4100 TEU vessel could be expected to produce a maximum wake wave of around 205mm high in the current channel configuration. This would be reduced to 187mm in the new channel, a reduction of 9%. A similar reduction could be expected to apply to all vessels currently using the channel. This agrees with the findings from Melbourne and studies by the US Army Corps of Engineers (Maynord 2006).

There is an expected increase in the order of 10 to 15% from the current observed wake heights from the 4100 TEU vessels (ranging from no discernable effect to Class 3 wake events) for the passage of 6000 TEU vessels in the proposed channel under similar tidal conditions. The relative increase in wave height between the 4100TEU and 6000TEU vessels will be very small and well within the variability of wake observed in the existing environment.

A positive effect of the introduction of the 6000 TEU vessels is the greater container capacity of the larger vessels. This will result in an overall reduction in the number of vessel visits required to carry the same volume of containers. The cumulative effect of this will be an overall reduction in the number of vessel wake occurrences, and subsequently, a reduction in the wake wave energy generated from container vessels in the harbour.

3. Safety Impacts

With passing vessels of any size, safety impacts on nearby environments need to be considered. General impacts can be grouped under the following sections:

1. People;
2. Vessels underway or moored; or,
3. Structures.

3.1 People

With the passage of any vessel there is the possibility of safety impacts on people using the Lower Harbour from vessel effects. Like wake, the magnitude of these impacts are dependent on a number of factors including vessel size and speed but also relevant to consideration are additional factors such as the channel topography and any special shoreline features.

The majority of safety issues associated with vessels are as a result of high or excessive speed for the conditions. PIANC 2003 states "*…In general, impacts involving people on or near the shoreline are primarily associated with transverse waves generated by vessels operating at or near critical speed and the long-period waves that comprise the first group of waves generated by vessels operating at super-critical speeds.*"

While vessels within the Lower Harbour are generally not operating at super critical speeds, in particular container vessels, the statement is still relevant for shorelines close to the shipping channel.

Table 8 summarises wake impacts associated with uses of the shore and provides examples of locations within the Otago Harbour where these impacts may be experienced. The potential risks detailed in Table 8 can be managed to reduce potential adverse effects. Management measures are discussed in greater detail in Section 7.

Table 8 Impacts related to the safety of people based on shoreline characteristics (after Kofoed-Hansen, 1996; MCA, 1998)

Shoreline Characteristics	Otago Harbour Example	Potential Risk	Probable Cause
Shallow sloping beach	Te Rauone Beach	People may be caught in water or knocked down	Rapid inundation of large areas from run up of long-period waves
Moderate / steep beaches, boat ramps	Careys Bay boat ramp	People knocked down Damage to boats and vehicles on ramp	Plunging and breaking waves
Shorelines with sea walls	Deborah Bay shoreline	People on narrow beaches trapped against sea wall	Rapid inundation of exposed beach from run up of long-period waves Breaking waves that overtop the seawall

3.2 Vessels underway or moored

Where vessels generate wake they could potentially cause damage to moored vessels or manoeuvring difficulties to other vessels underway. If moored, the extent of any potential damage is clearly dependent on the size of the wake, how well the vessel is secured and the vessel size and shape. If the other vessel is underway the skipper’s skills and experience is also a factor in the case of limiting the extent of yawing and rolling. This is particularly relevant to yachties and recreational users of the Harbour.

The Otago Harbour channel has been designed as one-way access for deep draft vessels. Therefore vessel-to-vessel suction forces are not considered in any further detail. These forces can lead to a loss, or partial loss, of steerage with the resulting safety concerns being either channel impact or collision with other vessels.

The risks to moored vessels and smaller vessels outside of the channel can be managed to reduce potential impacts. Management measures are discussed in greater detail in Section 7.

3.3 Structures

A number of structures lie adjacent to the shipping channel of the Lower Harbour. These include, but are not limited to the following:

- Boathouses, wharves and jetties (for example at Weller’s Rock),
- Protective rock walls along the harbour edge (for example Carey’s Bay to Waipuna Bay, the northern section of Te Rauone Beach and Omate Beach),
- Revetments, groynes and moles (for example in the Harbour entrance and offshore of Te Rauone Beach).

The key impact on these structures is the drawdown and surge associated with the passage of a large displacement vessel. This can result in a sudden change in water level leading to undermining of the foundation of such structures over time.

There have been limited examples of impact on structures in the Lower Otago Harbour as generally existing drawdown and surge wave magnitudes are small with a low likelihood of occurrence. As the likelihood of occurrence is minimal this is not considered further.

4. Effects on Ecology

As the size of the wake waves from existing vessels using the deeper shipping channel in Lower Otago Harbour are likely to be smaller than at present, the effects of these waves on the harbour ecology are likely to be no different or may be lesser than the present effects. James *et al.* (2008) describe the ecological situation and the effects of the proposed dredging activity in detail.

The potentially larger Bernoulli wave from larger vessels (6000 to 8000 TEU vessels) may disturb surficial sediments and biota near to the channel margins, but to no greater degree than wind waves and tidal currents. However the larger surge effect of these waves at the shore may have an effect to a higher elevation than the Bernoulli waves from the existing 4100 TEU vessels using the harbour. This effect is primarily only of concern when the shipping movement is at or about high tide. It is likely that the wave will affect the shore biota to a similar spatial extent across the shore as wind waves during storms, but as there are only one to three waves associated with this effect, the magnitude of the effect is less than during a storm.

James *et al.* (2008) also discuss the effects on bird foraging and roosting, with the expected impact from vessel wake to be minimal. James *et al.* (2008) note *"Birds in the Harbour are acclimatised to regular ship movement and maintenance dredging and showed little response to ship movement during observations at Aramoana (Sagar 2008)."*

This is further evidenced by study of video footage taken during the vessel wake observation programme whereby foraging and roosting birds either "rode out" the waves or simply flew out of the way of incoming waves and settled back once the event has passed.

5. Sandbank and Beach Stability

The sandbanks of the Lower Otago Harbour are relatively stable sedimentary units. There has been some accretion of sediment in areas of Aramoana and south of the shipping channel opposite Aramoana. However the main secondary channels on the eastern side of the harbour towards Omate Beach and Te Rauone have been stable in location and in depth. There is no indication that there has been an effect of wake waves modifying the sandbanks or disturbing the ecology and habitats of the inter-tidal areas. Surveys of the cross-section of the dredged channel also show that there has been little change to the stability of the channel sides.

The minor changes expected in the magnitude of the wake waves from larger vessels using the deeper channel are not likely to have any additional effect on the sandbanks or channel sides. Natural processes, wind waves, will influence these areas and tides, as they are now, so will remain as dynamic environments. They will not be adversely affected by changes to the vessel traffic in the deeper shipping channel.

The beaches potentially directly affected by wake waves due to close proximity are Te Rauone Beach, the harbour side of Aramoana Spit / Shelly Beach, small pocket “low-tide” beaches and along Omate Beach. As the wake wave is likely to be smaller for the existing vessels and for larger vessels in the deeper channel, the effects at shores at a distance from the shipping channel is likely to be reduced from the present effect.

6. Seabed Scour

Suspension and redistribution of seabed material, or seabed scour, is a common phenomenon associated with the passage of vessels in close proximity to the seabed. It is a function of the return of water to an at rest state following the passage of the vessel with the extent of scour largely influenced by the return velocity of the displaced water.

The return water velocity is dependent on a number of factors including underkeel clearance, shape and size of channel, vessel blockage ratio and vessel speed. There is also scour generated by the action of the propeller jet. Information gained from a literature review is clear in that high return velocities and scour are prevalent when the underkeel clearance is very low or there is a high blockage ratio.

As shown in Table 9, the current blockage ratio for the 4100 TEU vessels is greatly reduced following the proposed channel deepening and widening. This indicates a reduction in the current return velocities for the 4100 TEU vessel and all other existing vessels transiting the channel. The largest vessels expected to use the proposed channel, 6000 TEU, do show an increase in the blockage ratio over the present 4100 TEU vessels in the present channel, and correspondingly an increase in return velocities can be expected.

Table 9 Vessel blockage ratios (note that a smaller blockage coefficient ratio indicates a smaller degree of blockage)

	Cross Sectional Area of Channel (m^2)	Cross Sectional Area of Vessel (m^2)	Blockage Ratio	Percentage Change from 4100 in current channel
4100 TEU Vessel	2,890	425	0.147	0
4100 TEU Vessel	3,675	425	0.116	-21.1%
6000 TEU Vessel	3,675	656	0.179	+21.8%

The critical velocity for sand entrainment in locations where higher vessel speeds will occur is estimated to be about 0.5m/s. It is likely there is suspension already occurring under the present channel conditions through passage of the 4100 TEU vessels. However, the rate of sediment entrainment and scour may be higher in the proposed channel with the passage of the 6000 TEU vessels due to slightly greater return velocities.

As indicated above the seabed sand and silt will be susceptible to scour during the passage of 6000 TEU vessels. However Bell *et al.* (2009) recorded naturally high current velocities within the channel of between 1.00 and 1.55 m/s during the peak spring flood tide. That work indicates that sediment suspension and transport occurs naturally within the channel under tidal flows. The result of the combined processes of tides and the smaller number of larger ships acting on the seabed in the proposed deeper channel will not change the potential mobility of the sediments to a large degree.

7. Wake Management

7.1 General

Wake will almost always be an effect of the passage of vessels using the navigable channel of the Otago Harbour. These effects cannot be avoided due to the requirement to maintain vessel speed to ensure safe navigation of the channel. Physically there is little that can be done to reduce the magnitude of vessel wake. Instead, increasing public awareness and knowledge about potential wake, and modifying the effects at the shore are appropriate management options.

7.2 Management Options

A key phase of management into the effects of vessel wake will be a campaign to increase community awareness and communication to Harbour users of the potential impacts of waves associated with vessel passage in the shipping channel. Options for management could be as follows:

1. Awareness or reminder to the Port Otago Ltd pilot staff to keep speed to a practical minimum,
2. Pilots sounding the horn during daytime hours on bends prior to navigating to warn of vessel approach.
3. Media promotion, radio and newsprint,
4. Signs on beaches and boat ramps to advise users of possible risks associated with passing vessels,
5. Communication with user groups, such as
    a. Yacht Clubs,
    b. Commercial users (Monarch Cruises, etc),
    c. Rowing Clubs,
    d. Port Environment Committee.
6. Implementation of beach profile monitoring on affected shores at Te Rauone beach and the distal end of the Aramoana spit.

It is anticipated that an education and advertising programme into the safe passage of vessels within the lower Otago Harbour would be implemented as part of the capital dredging campaign and preceding the arrival of larger vessels.

7.3 Te Rauone Beach

Port Otago are currently in discussions with the Otago Regional Council, Dunedin City Council, Te Rauone Coast Care Committee and residents in regard to the ongoing erosion issues at Te Rauone Beach. As part of these discussions a number of mitigation measures were suggested by Single (2007), and are summarised as follows:

1. Do nothing,
2. Managed retreat

3. Beach re-nourishment
4. Construction or destruction of shore groynes
5. Seawalls, revetments and bulkheads
6. Nearshore structures, i.e. artificial reef, submerged short parallel structure, etc

It was concluded that *"It is likely that a combination of options will need to be employed to achieve a sustainable managed coastal resource, and that different sections of the bay will require different types of management. Beach nourishment in combination with structures to encourage sand retention is identified as the most likely successful option."*

The process to instigate the above mitigation measures for Te Rauone has commenced and will continue irrespective of the channel deepening and widening project. This work is an ongoing interest for Port Otago Ltd as a harbour user, and the company will encourage the project to be fostered in a partnership with other users.

It is anticipated that work completed as part of Te Rauone beach, in particular the construction of a rocky groyne and beach re-nourishment, will reduce the incidents of standing wave generation. This incident reduction is expected as the likelihood of bow diverging wave fronts being reflected off the beach is significantly reduced due to the energy dissipation characteristics of the rock groyne and the sand beach seaward of the dunes. Re-nourishment of the beach will also reduce the beach face angle, which in turn will dissipate wave energy due to friction, again minimising the likelihood of reflection.

8. Summary and Conclusions

Vessels moving through water generate wake. The character (size, period, direction of travel, number of waves and duration of the event) of wake waves are dependent on a large number of variables including vessel shape, vessel speed, vessel displacement, bathymetry of the channel and surrounding water body and the climatic conditions including wind, wave and tide.

Port Otago's proposal to deepen and widen the existing navigable channel in the Lower Otago Harbour will enable vessels of a larger size and displacement to transit the channel. Concerns have been raised that this could potentially lead to increased magnitude and instances of wake from vessels that cause public nuisance and create safety concerns for fellow users of the Harbour.

It has been shown that wake generated by commercial vessels is of limited duration (on average 5.5 minutes per vessel) and is a small component (<1%) of the total wave environment of the entire harbour system. Swell and wind generated waves can persist for considerably longer durations. An examination of waves evident on the Spit tide gauge readings showed that larger vessels generally created larger wakes than smaller vessels. However, wake events from large vessels occurred much less often than from smaller vessels and often could not be discerned from the natural background waves.

An observation programme of wake waves was carried out at Te Rauone Beach. It was found that wake waves arrived at the beach from inbound and outbound vessels, and that the wake only reached the backshore and dunes within one to two hours of high tide. Complex wave events were also observed at Te Rauone. These waves appeared much larger than straightforward wake, and included a large reflected wave and a series of "standing waves" just offshore of the beach following the passage of a 4100 TEU vessel. The wave train was generated by bow waves being reflected from the beach face and other shoreline features and intersecting with the stern transverse waves. This results in a wave of combined energy and amplitude. This complex wave event, which rolls along the beach, does not occur on all passages and is very much dependent on the vessel, the climatic conditions, and the state of the tide.

It is likely that the proposed deepening and widening of the Lower Otago Harbour channel will result in a reduction in the magnitude of wake generated by commercial vessels currently transiting the channel. This is due to the reduction in blockage ratio of the vessels in relation to the channel depth and cross-sectional area. There will also be a reduction in the seabed scour beneath the vessels due to the lower blockage ratio and the greater clearance beneath the existing vessels and the proposed base of the channel.

The wake waves created by 6000 TEU vessels will be potentially larger than those from the 4100 TEU vessels due to the greater displacement and blockage ratio of the larger vessels on a typical transit of the harbour channel. It is difficult to quantify this increase with any certainty although based on vessel observations and studies in Port Phillip Bay in Melbourne it is likely to be in the order of 10 – 15%, this range is well within the natural variability within the existing wave environment.

With the introduction of a service utilising 6000 TEU vessels, the number of transits of container vessels will be less than at present due to the larger capacity of the vessels. This will mean that the same volume of containers will be moved for less container vessel transits. Therefore the cumulative effect of wake waves in the harbour will be reduced.

There are no documented effects on the harbour ecology from wake generated by the passage of the present vessels using the harbour channel. This situation is not likely to change following the deepening and widening of the channel. Any effects from existing vessels that may exist are likely to be reduced. The wakes of the 6000 TEU vessels may disturb surficial sediments and biota but to no greater degree than current wind waves or tidal currents.

The physical occurrence of wake cannot be eliminated. However, management measures recommended during and following channel deepening and widening can improve personal safety by increasing the community awareness and educating the general public and users of the harbour to the effects of vessel traffic even though most of these effects are likely to be reduced. Likely methods of increasing awareness may be through media promotion, signs and continued communication with user groups.

With strong support from the community and other partners the consenting and construction of a rock groyne at Te Rauone beach and subsequent sand re-nourishment will continue irrespective of the channel deepening and widening project. The potential effects of vessel wake, including reflected and standing waves will be taken into consideration for the final design of any works at Te Rauone Beach.

In conclusion, the effects of vessel passage following widening and deepening of the existing navigable channel will be similar or less than that currently existing. The cumulative effect of vessel wake, both current and in the future, is likely to be much less than the effects of natural waves and tidal currents occurring in the dynamic environment of Otago Harbour.

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Acknowledgements

Port Otago would like to offer our appreciation to Mr Leonard Muir of the Otago Maritime Society who provided his time and photographic catalogue of vessel transits to Port Otago to study, some of which are contained in Appendix A.

Ms Amy Shears was tasked with interpreting 6 months of tidal data from the Spit tide gauge and cross-referencing this with vessel movements. A task requiring attention to detail and no shortage of patience, we thank Amy for her efforts and the results are included in Appendix B.

It must also be acknowledged the efforts of Mr Fraser Cameron who spent many an hour at Te Rauone Beach observing and recording the passage of vessels. His observations are presented in Appendix C.

Appendix A

Photographic collection of vessels transiting Otago Harbour

Appendix B

Wave climate and tidal analysis at Spit Wharf tidal gauge, Aramoana

This Appendix is a copy of a short report completed by Amy Shears, a Masters student at Otago University, on the basis of a brief from Port Otago. Amy undertook analysis of the “Spit” tide data for the period 1 June 2008 to 30 June 2008.

Appendix C

Te Rauone Beach vessel wake observation programme data

Appendix A1 - Asian Trader 2 arriving Harrington Point

Appendix A2 – Cabo Negro arriving Harrington Point

Appendix A3 – Cape Race departing Pulling Point

Appendix A4 – Cap Byron departing Pulling Point

Appendix 5 – CGM Melbourne arriving Harrington Point

Appendix A6 – Challenge Pioneer departing Harrington Point

Appendix A7 – Forest Wave departing Pulling Point

Appendix A8 – Maersk Josephine departing Pulling Point

Appendix A9 – Maersk Damascus Departing Pulling Point

Appendix A10 – Maersk Damascus arriving Harrington Point

Appendix A11 – Maersk Damascus arriving Harrington Point

Appendix A12 – Maersk Denia arriving Harrington Point

Appendix A13 – Maersk Denton departing Pulling Point

Appendix A14 – Maersk Dominica departing Harrington Point

Appendix A15 – Maersk Fuji arriving Pulling Point

Appendix A16 – Maersk Dunafare arriving Pulling Point

Appendix A17 – Maersk Niigata departing Pulling Point

Appendix A18 – Mercury departing Pulling Point

Appendix A19 – MSC Basel departing Pulling Point

Appendix A20 – MSC Canberra departing Harrington Point

Appendix A21 – MSC Clorinda arriving Pulling Point

Appendix A22 – MSC Canberra departing Harrington Point

Appendix A23 – MSC Denisse departing Harrington Point

Appendix A24 – MSC Edith arriving Pulling Point

Appendix A25 – Dredge New Era spit wharf

Appendix A26 – Patricia Schulte departing Harrington Point

Appendix A27 – Patricia Schulte arriving Harrington Point

Appendix A28 – Rhapsody departing Harrington Point

Appendix A29 – Rehua arriving Pulling Point

Appendix A30 – SP Endurance arriving Harrington Point

Appendix A31 – STX Pioneer arriving Pulling Point

Appendix A32 – UTE Oltmann arriving Pulling Point

Appendix A33 – Vega Gotland departing Harrington Point

Appendix A34 – Wellington Express arriving Pulling Point

03/09/2009

Dear Lincoln

Re: Spit Tide Gauge Analysis for Ship Wake and Weather Effects

Purpose of Work: To provide some factual data and analysis to show what the effect vessels passing the spit tide gauge have. To put the magnitude and duration of these events in context with natural meteorological events.

The following results were calculated in Excel file - Visits Jan 2008 to 16 March 2009_modified (attached). Vessel wakes were observed in the Spit tidal height gauge data over 6 months (1st January 2008 to 30th June 2008). Visual wake observations were recorded and later cross referenced with the POL record of vessel arrivals and departures.

To aid identification of wakes and look at the context of wake heights in the tide trace, the difference in tidal height between every minute interval of recordings was calculated and graphed with the tide trace (Fig. 1). The change in tidal height in each minute was collated in Figure 2 to show most of the height variation in a minute was within 20 mm but maybe due to waves tidal change was often up to 30 mm in a minute. As much as 110 mm in tidal height change in a minute was rarely observed, but are assumed to be due to vessel wakes.

Figure 1: Example of wake observations in the tidal height trace (m) (dark blue line) on the 1st and 2nd of January 2008 at Spit gauge (minutes are shown on the x-axis). The bright blue line is the difference in tidal height over each minute. White circles refer to a wake that corresponds to a vessel passing, whereas a red circle was observed possible wakes that did not correspond to a vessel passing. The larger yellow circle covers an area with undulating tidal heights, which is later cross-referenced for an explanation with wind speed and direction data at Taiaroa Head.

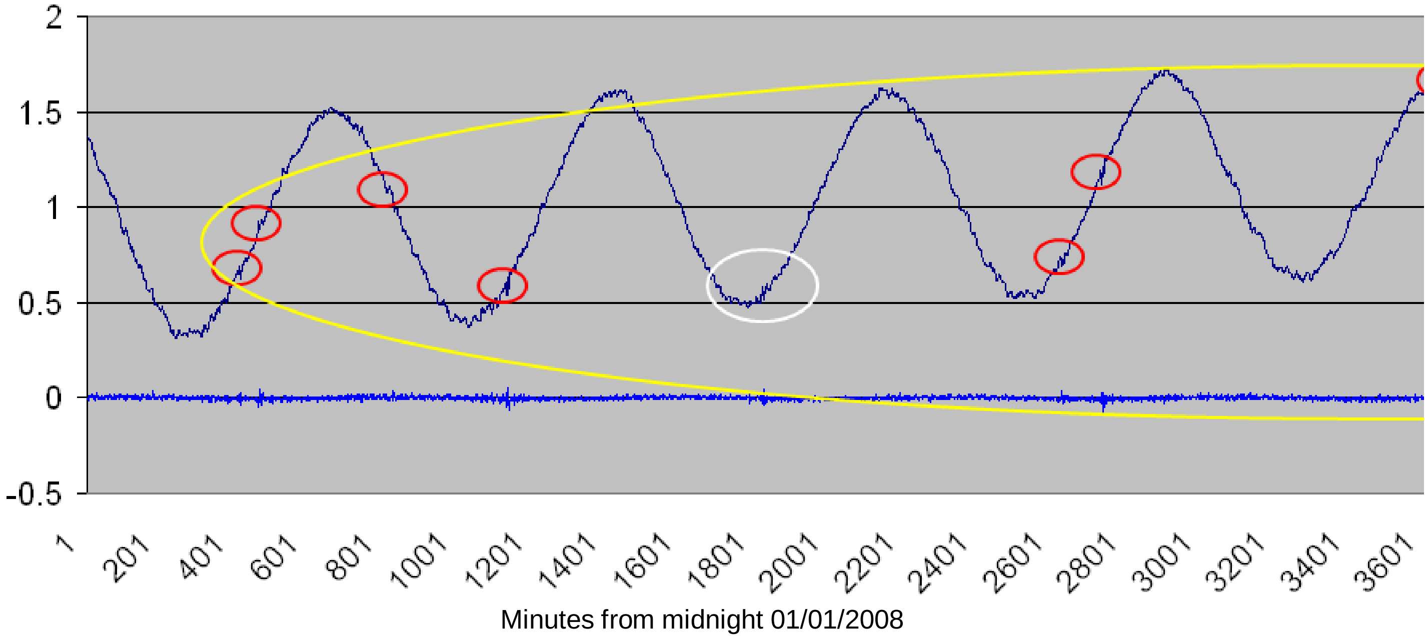
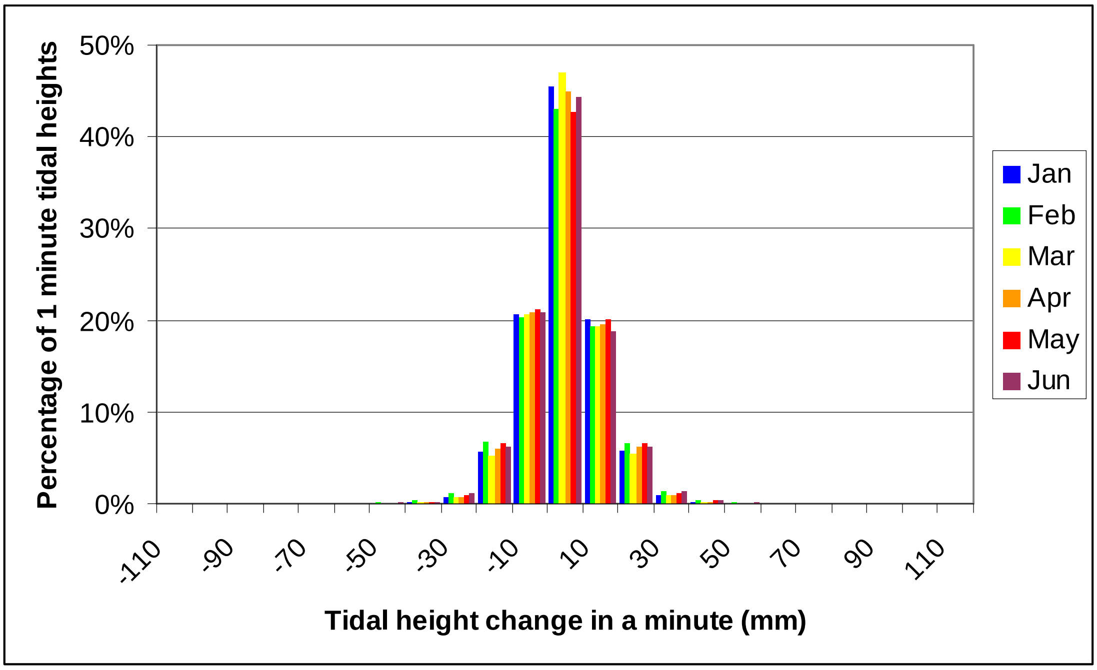


Figure 2: Frequency of tidal height changes in a minute for January to June in 2008. For all six months over 40% of the minute tidal change was near 0 mm.



The first aim of the wake observation exercise was determining the "hit rate" – how often possible wakes appeared on the Spit tide gauge that could actually be cross-referenced to a recorded vessel passing the gauge at that time (Tab. 1). Over the six months of tide gauge data, 683 possible wakes were visually observed, of which 44% were cross-referenced back to recorded vessels passing the Spit gauge at the same time (298 vessels). The 385 misinterpreted observations can be explained by either waves that appeared like wakes in the tide trace or unrecorded vessel movement through the harbour entrance (e.g. fishing boats and Monarch scenic cruises).

Table 1: Visual wake observations at Spit tide gauge and their correlation with recorded vessel arrivals and departures in January to June, 2008.

Month	Observed Wakes	Vessel Recorded	No Vessel Recorded	Correct Wake Observations
January	81	43	38	53%
February	106	55	51	52%
March	123	57	66	46%
April	109	39	70	36%
May	129	51	78	40%
June	135	53	82	39%
TOTAL	683	298	385	44%

But more vessels visited Otago Harbour than what was visually observed in the Spit tide gauge data. Generally, the wakes of most large vessels were observed in the tide data and the smaller vessel wakes were not identified. Six months of tide gauge data were examined for vessel wakes and the magnitude of each wake was recorded (on a scale from 0-No identifiable wake to 3-Large wake) and matched with a recorded vessel (or no vessel as already shown).

JANUARY 2008

82 vessels passed the Spit tide gauge in January 2008, of which 43 vessels can be observed in the tide gauge records (52%) and only 11 vessels created “large” (wake grade 3) wakes (13%). The average wake grade was 1.04. Half of the 4100 liners produced grade 3 wakes. Large wakes were also produced by other liners and cruise ships.

Table 2: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in January, 2008.

Trade Group	Wake magnitude (0-no wake to 3-large wake)				Total vessels in each trade
	0	1	2	3	
Liner	13	6	12	3	34
Cruise	9	5	4	4	22
4100 Liner	1		3	4	8
LPG	3		1		4
Oil	2				2
Forestry	1	1			2
Cement	2				2
Other	4				4
Unknown	4				4
Total vessels in each wake grade	39	12	20	11	82

FEBUARY 2008

Out of the 92 recorded vessels that passed the Spit gauge in February 2008, 59% had identifiable wakes (55 vessels) and 19 vessels created large (grade 3) wakes (21%). Table 3 shows that the vessels producing the large wakes were mostly liners, then cruise ships and 4100 liners. Overall the average wake grade for February was 1.22 (barely identifiable small wakes).

Table 3: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in February, 2008.

Trade Group	Wake height grade (0-no wake to 3-large wake)				Total vessels in each trade
	0	1	2	3	
Liner	7	10	9	10	36
Cruise	6	4	4	6	20
4100 Liner	2	1	3	3	9
LPG	7	1			8
Oil	3	1	2		6
Forestry	2				2
Cement	2		1		3
Other	8				8
Total vessels in each wake grade	37	17	19	19	92

MARCH 2008

Out of the 84 recorded vessels that passed the Spit gauge in March 2008, 68% had identifiable wakes (57 vessels). Table 4 shows 19 vessels created large (grade 3) wakes (23%) and the vessels producing these large wakes were mostly liners, then equally cruise ships and 4100 liners. Overall the average wake grade for March was 1.42 (barely identifiable small wakes).

Table 4: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in March, 2008.

Trade Group	**Wake grade (0-no wake to 3-large wake)**				**Total vessels in each trade**
	0	**1**	**2**	**3**	
Liner	9	9	13	10	41
Cruise	4		2	4	10
4100 Liner		1	4	4	9
LPG	4				4
Oil	1	3	1	1	6
Forestry		1	3		4
Cement	2				2
Other	4		1		5
Unknown	3				3
Total vessels in each wake grade	27	14	24	19	84

APRIL 2008

Out of the 60 recorded vessels that passed the Spit gauge in April 2008, 65% had identifiable wakes (39 vessels) and 7 vessels created large (grade 3) wakes (12%) (Tab. 5). The vessels producing the large wakes were mostly from liners, then 4100 liners. Liners are the most frequent vessel past the spit gauge but the average wake grade for liners is only 1.43, however, 4100 liners have an average wake grade of 2. Overall the average wake grade for April was 1.20 (barely identifiable small wakes).

Table 5: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in April, 2008.

Trade Group	**Wake height grade (0-no wake to 3-large wake)**				**Total vessels in each trade**
	0	**1**	**2**	**3**	
Liner	7	11	12	5	35
Cruise	2				2
4100 Liner	1		5	2	8
LPG	6				6
Oil	2	1	1		4
Forestry	1		1		2
Other	1	1			2
Unknown	1				1
Total vessels in each wake grade	21	13	19	7	60

MAY 2008

Out of the 63 recorded vessels that passed the Spit gauge in May 2008, 81% had identifiable wakes (51 vessels) and 15 vessels created large (grade 3) wakes (24%). Table 6 shows the vessels producing the large wakes were mostly from liners, then 4100 liners. Liners are the most frequent vessel past the spit gauge (60%) but the average wake grade for liners is only 1.68, however, 4100 liners have an average wake grade of 2.3. Overall the average wake grade for May was 1.54 (identifiable small wakes).

Table 6: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in May, 2008.

Trade Group	Wake height grade (0-no wake to 3-large wake)				Total vessels in each trade
	0	1	2	3	
Liner	3	15	11	9	38
4100 Liner		2	3	5	10
LPG	4	2			6
Oil	1	1	2		4
Forestry	1			1	2
Cement	2				2
Unknown	1				1
Total vessels in each wake grade	12	20	16	15	63

JUNE 2008

Out of the 79 recorded vessels that passed the Spit gauge in May 2008, 67% had identifiable wakes (53 vessels) and 13 vessels created large (grade 3) wakes (17%). The vessels producing the large wakes were mostly from 4100 liners, then liners and forestry vessels (Tab. 7). The average wake grade for 4100 liners in June 2008 was of 2.6 but these vessels only made up a small proportion of the total vessels past the Spit gauge (10%). Overall the average wake grade for June was 1.19 (barely identifiable small wakes).

Table 7: Frequency of vessels with wakes observed at Spit tide gauge in each wake grade and from each trade group in June, 2008.

Trade Group	Wake height grade (0-no wake to 3-large wake)				Total vessels in each trade
	0	1	2	3	
Liner	15	18	13	4	50
4100 Liner		1	1	6	8
LPG	7	1			8
Oil	1	1			2
Forestry	1	2	1	2	6
Cement	1	1			2
Other	1	1		1	3
Total vessels in each wake grade	26	25	15	13	79

SIX MONTHS

The problem with the visual method we chose is that as I have gone through identifying wakes I have (inadvertently) got better at picking them. All together 65% of the vessels create wakes that can be observed (Tab. 8). Generally, most of the wakes from liners, cruise vessels, oil vessels and forestry vessels could be observed. 18% of the vessels produced grade 3 (large) wakes, half of which were from liners and a quarter from 4100 liners. But a total of 234 liner vessels passed the Spit gauge and only 18% produced large grade 3 wakes. The trade group with the greatest percentage of large wakes was by far the 4100 liners with 46% (Tab. 8). Overall the average wake height grade for the six months sampled is 1.26 (barely distinguishable wakes).

Table 8: Frequency of vessels in each wake grade and in each trade group from 1st January to 30th June, 2008. The percentages represent the proportion of vessels in each wake grade in each trade group.

Trade Group	**Wake magnitude grade & percentage in each trade**								**Total vessels in each trade**	
	0	% Trade	**1**	% Trade	**2**	% Trade	**3**	% Trade	**Total**	%
Liner	54	(23%)	69	(29%)	70	(30%)	41	(18%)	234	(51%)
Cruise	21	(39%)	9	(17%)	10	(19%)	14	(26%)	54	(12%)
4100 Liner	4	(8%)	5	(10%)	19	(37%)	24	(46%)	52	(11%)
LPG	31	(86%)	4	(11%)	1	(3%)	0	(0%)	36	(8%)
Oil	10	(42%)	7	(29%)	6	(25%)	1	(4%)	24	(5%)
Forestry	6	(33%)	4	(22%)	5	(28%)	3	(17%)	18	(4%)
Cement	9	(82%)	1	(9%)	1	(9%)	0	(0%)	11	(2%)
Other	18	(82%)	2	(9%)	1	(5%)	1	(5%)	22	(5%)
Unknown	9	(100%)	0	(0%)	0	(0%)	0	(0%)	9	(2%)
Total	162	(35%)	101	(22%)	113	(25%)	84	(18%)	460	(100%)

WIND

I have also attempted to correlate observed tidal height fluctuations with wind data in January and February. Unfortunately these don't match as well as we had hoped (Fig. 3-6). But certainly during these times of tidal height fluctuations, observing vessel wakes was almost impossible and as a result either many potential wakes were observed or barely any were observed. But using 6 months worth of data should reduce the effect of visual wake observation method.

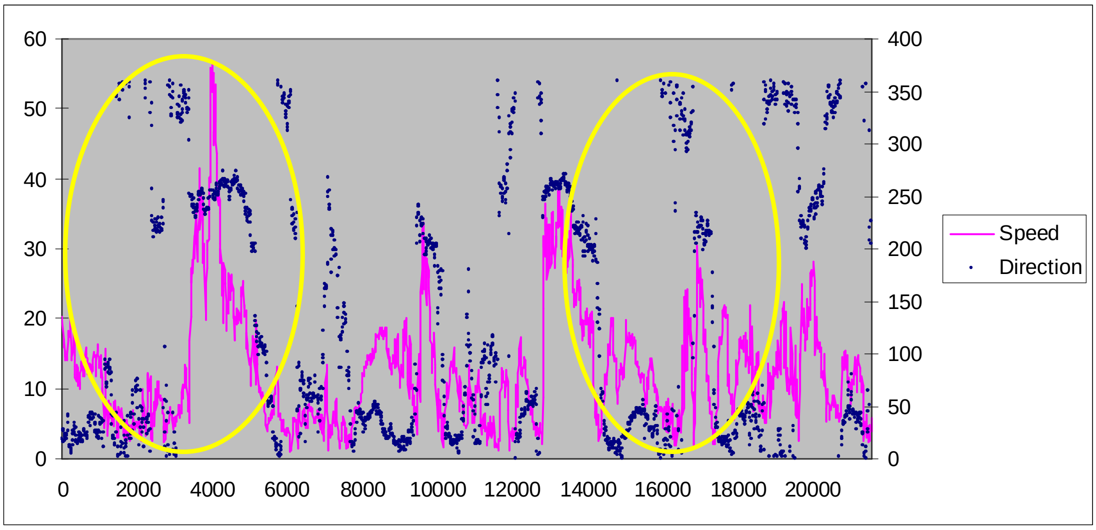


Figure 3: Correlation between observed periods of Spit tide gauge height fluctuation (yellow circles) and wind speed (pink line) and direction (blue dot) recorded at Taiaroa Head on January 1st -15th, 2008. Time on the x-axis is minutes from the start of the month.

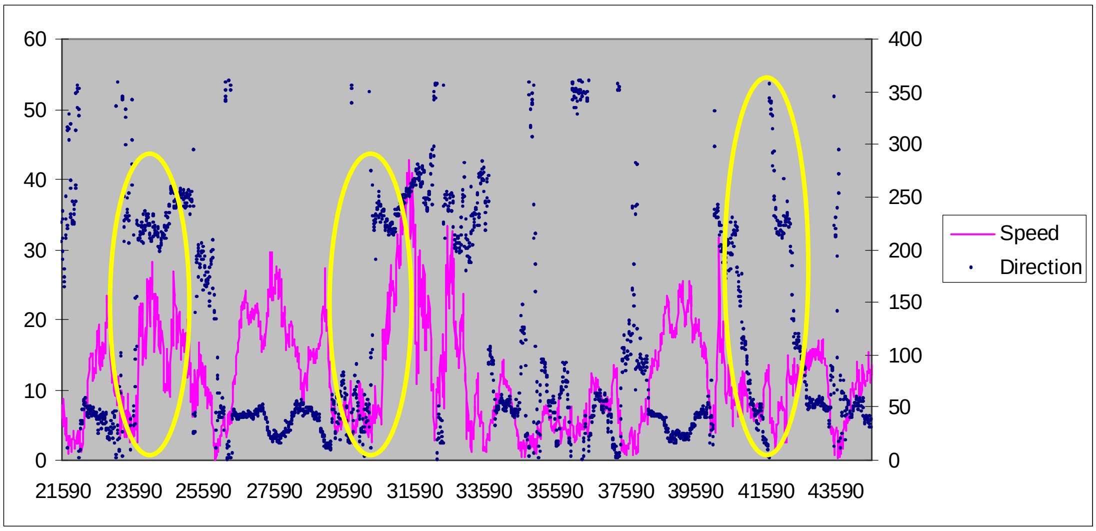


Figure 4: Correlation between observed periods of Spit tide gauge height fluctuation (yellow circles) and wind speed (pink line) and direction (blue dot) recorded at Taiaroa Head on January 16th- 31st, 2008. Time on the x-axis is minutes from the start of the month.

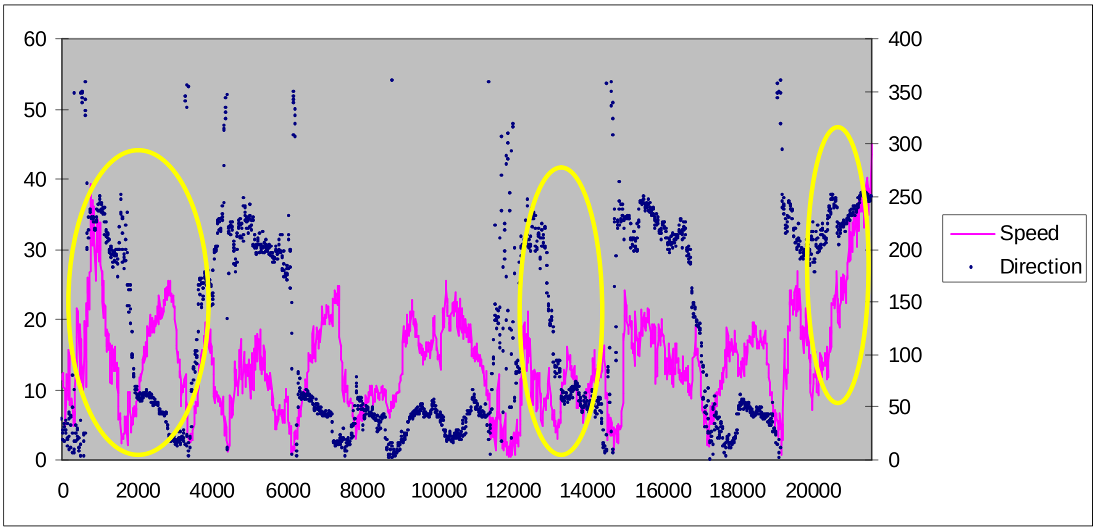


Figure 5: Correlation between observed periods of Spit tide gauge height fluctuation (yellow circles) and wind speed (pink line) and direction (blue dot) recorded at Taiaroa Head on February 1st -15th, 2008. Time on the x-axis is minutes from the start of the month.

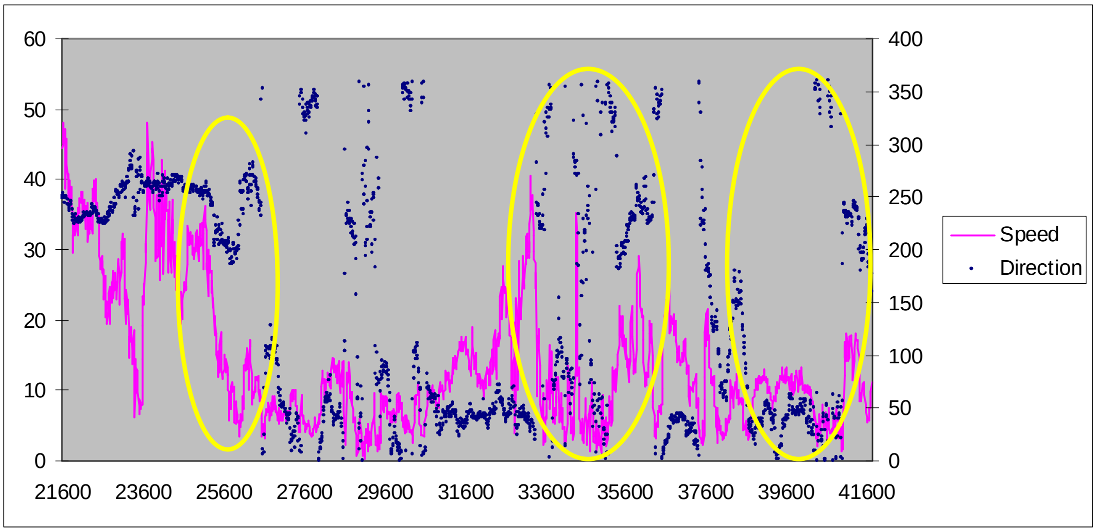


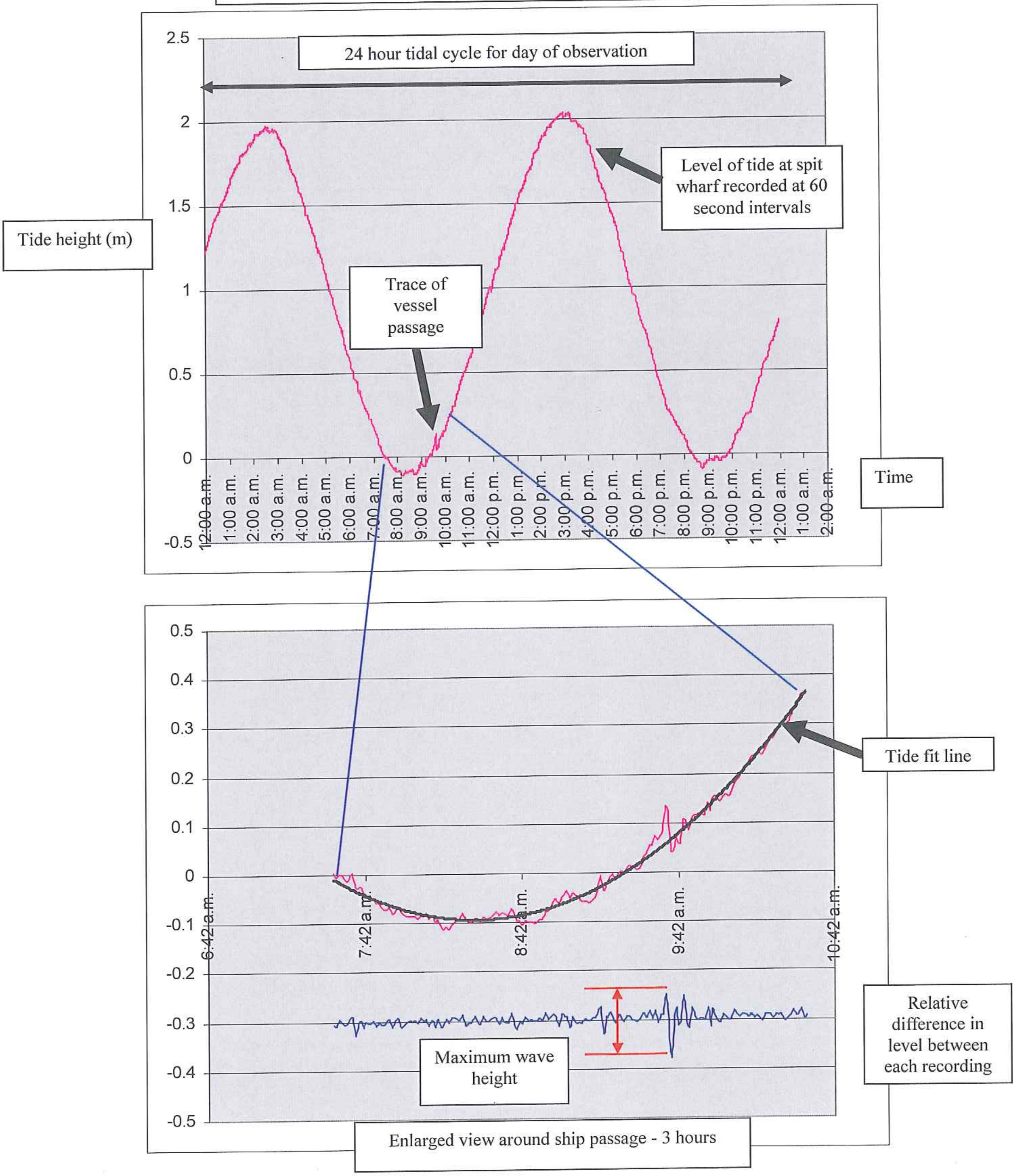
Figure 6: Correlation between observed periods of Spit tide gauge height fluctuation (yellow circles) and wind speed (pink line) and direction (blue dot) recorded at Taiaroa Head on February 16th - 29th, 2008. Time on the x-axis is minutes from the start of the month.

Generally, the six months collated into Table 8 shows that most vessels have observable wakes. What Table 8 doesn’t show is that when waves are present, vessel wakes blend in remarkably and many waves begin to look like vessel wakes on the tide trace. Throughout the six months of observations my thoroughness in identifying wakes may have varied. Particularly in windy periods where the wakes were more difficult to identify, as a result, either far too many potential wakes were observed or far too few observations were made, therefore, affecting the results of Table 1.

Let me know if there is anything else you would like me to work on.

Regards,
Amy Shears

Interpretation of Vessel Trace records on following pages


24 hour tidal cycle for day of observation

Level of tide at spit wharf recorded at 60 second intervals

Trace of vessel passage

Tide fit line

Maximum wave height

Relative difference in level between each recording

Enlarged view around ship passage - 3 hours

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			**Vessel Data**		
LOCATION:	TE RAUONE	obs	NAME:	Kakariki	obs
DATE:	18/8/09	obs	TRAVEL DIR.	**ARR / [✓ DEP]**	obs
TIME START:	10:25	obs	DRAFT:	6·45	POL
TIME END:	11:07	obs	TONNAGE:	46724	POL
WEATHER:	Overcast	obs	LENGTH	172·4	POL
WIND:	light to moderate WSW	obs / POL	SPEED:	7·6 kN	POL
WAVE:	small waves 100mm	obs / POL	TIDE HGT:	1·5	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	10:55	hh:mm:sec	Maximum Height	200	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	44	sec	Estimate of max travel up beach	2	m
Time of 1st Wake Wave	2:32	mm:sec	Duration of event	6:00	sec
Height of 1st Wake Wave	200	mm	Time for Wave to Reach Shore	2:32	sec
Time of Last Wake Wave	6:00	mm:sec			

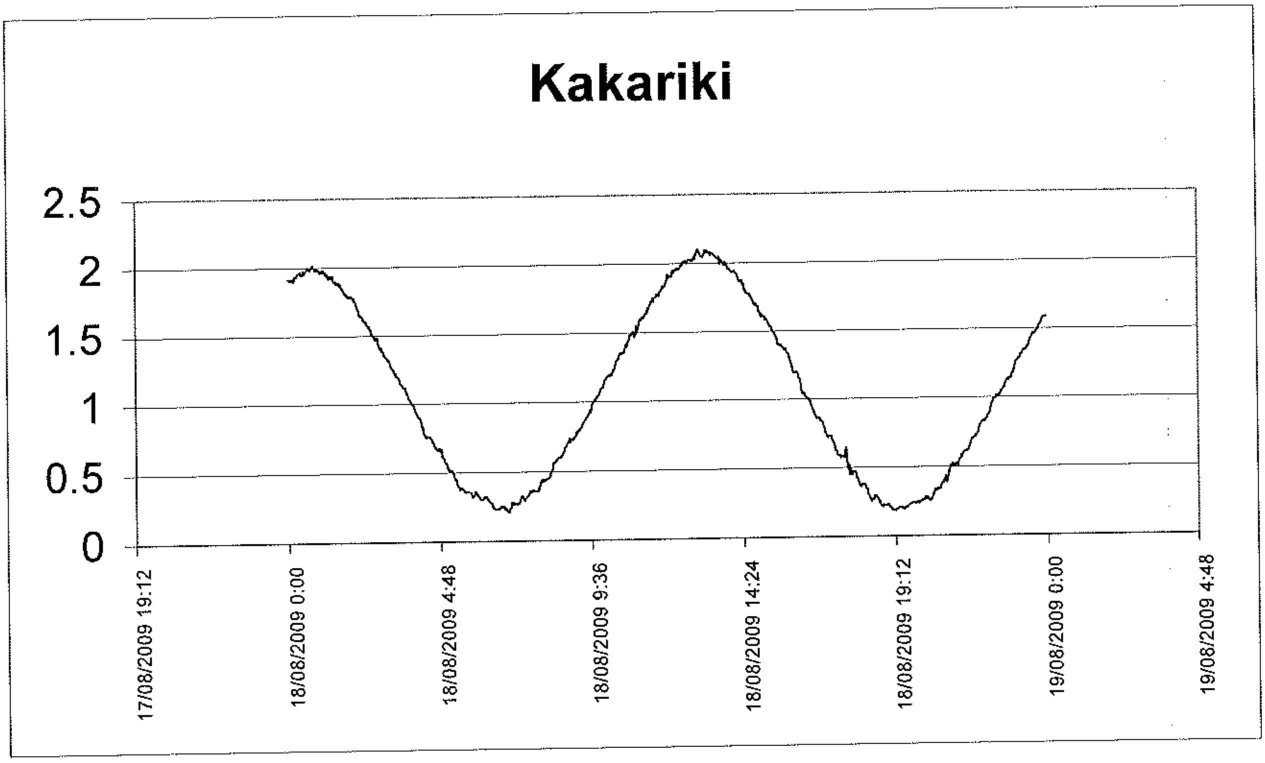
Observed Wake Data

		Comments
Change in wave period	**[✓ YES] / NO**	Wind and waves Same quarter
Change in approach angle	**YES / [✓ NO]**	
Does the wake create sand in motion	**[✓ YES] / NO**	Very little
Does the wake reach the base of the dunes	**YES / [✓ NO]**	Reached undergrowth.
Does the wake cause any noticeable dune erosion	**YES / [✓ NO]**	
Photos taken	**YES / [✓ NO]**	
Video taken	**[✓ YES] / NO**	

DISCUSSION / COMMENTS:

Observed by:

Observed by: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2
1.5
1
0.5
0
17/08/2009 19:12
18/08/2009 0:00
18/08/2009 4:48
18/08/2009 9:36
18/08/2009 14:24
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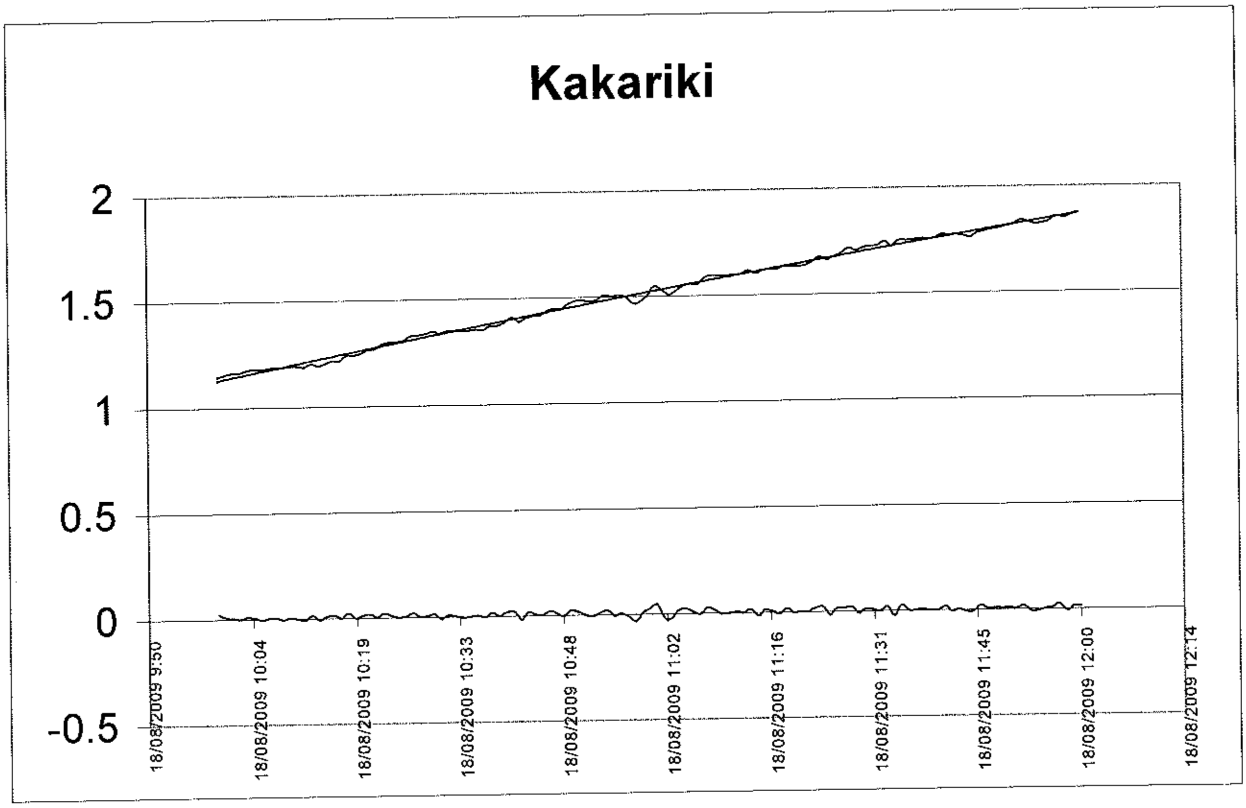
19/08/2009 0:00
19/08/2009 4:48


Kakariki
2
1.5
1
0.5
0
-0.5
18/08/2009 9:50
18/08/2009 10:04
18/08/2009 10:19
18/08/2009 10:33
18/08/2009 10:48
18/08/2009 11:02
18/08/2009 11:16
18/08/2009 11:31
18/08/2009 11:45
18/08/2009 12:00
18/08/2009 12:14

PORT OTAGO LIMITED

Site Observation Form

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Maersk Damascus	obs
DATE:	20/8/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	9.30	obs	DRAFT:	10.30	POL
TIME END:	12.45	obs	TONNAGE:	53081	POL
WEATHER:	Sunny / patchy cloud	obs	LENGTH	268.0	POL
WIND:	very little NNE	obs / POL	SPEED:	11.3 kN	POL
WAVE:	very small 80mm	obs / POL	TIDE HGT:	0.08	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	9:39	hh:mm:sec	Maximum Height	140	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	didn't notice	m
Stern Past Fixed Point	46	sec	Estimate of max travel up beach	30 very flat	m
Time of 1st Wake Wave	0:50	mm:sec	Duration of event	7:00	sec
Height of 1st Wake Wave	140	mm	Time for Wave to Reach Shore	50	sec
Time of Last Wake Wave	7:00	mm:sec			

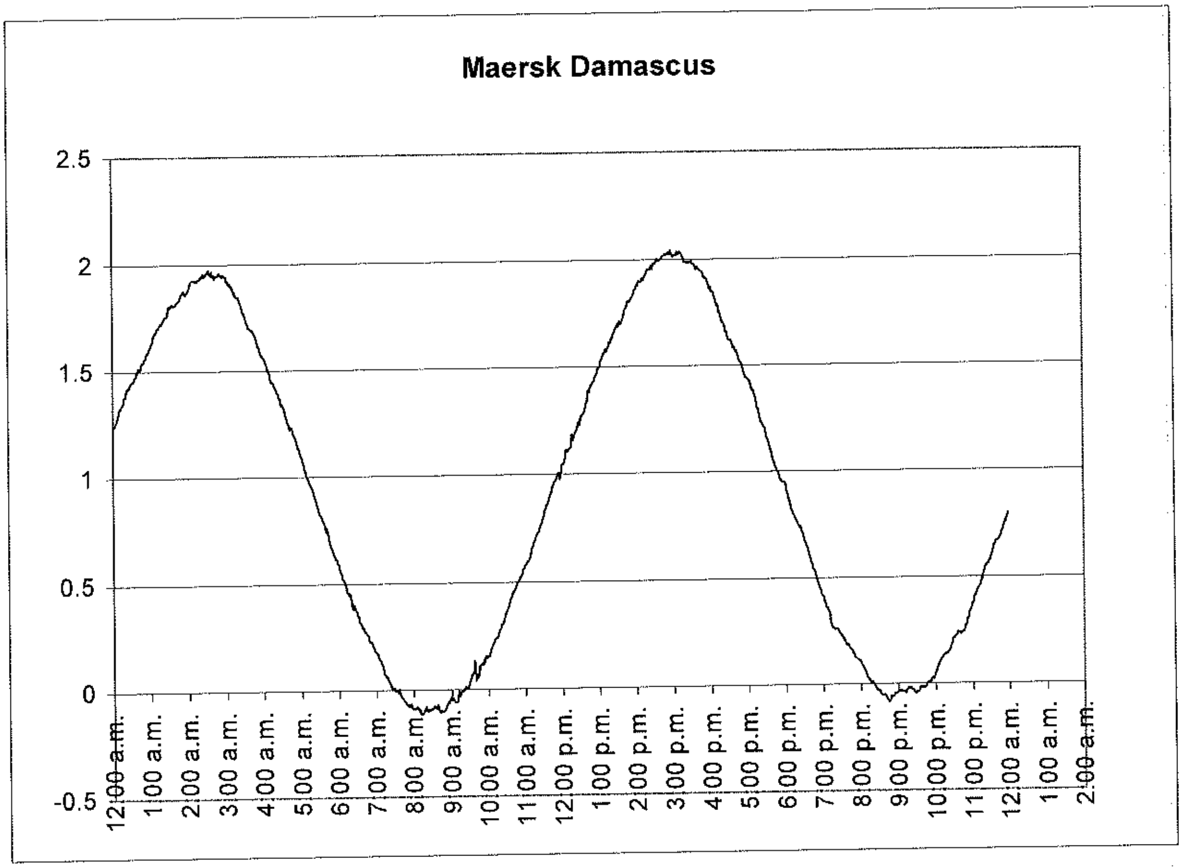
Observed Wake Data

		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	YES / [✓ NO]	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by: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2
1.5
1
0.5
0
-0.5
12:00 a.m.
1:00 a.m.
2:00 a.m.
3:00 a.m.
4:00 a.m.
5:00 a.m.
6:00 a.m.
7:00 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
1:00 p.m.
2:00 p.m.
3:00 p.m.
4:00 p.m.
5:00 p.m.
6:00 p.m.
7:00 p.m.
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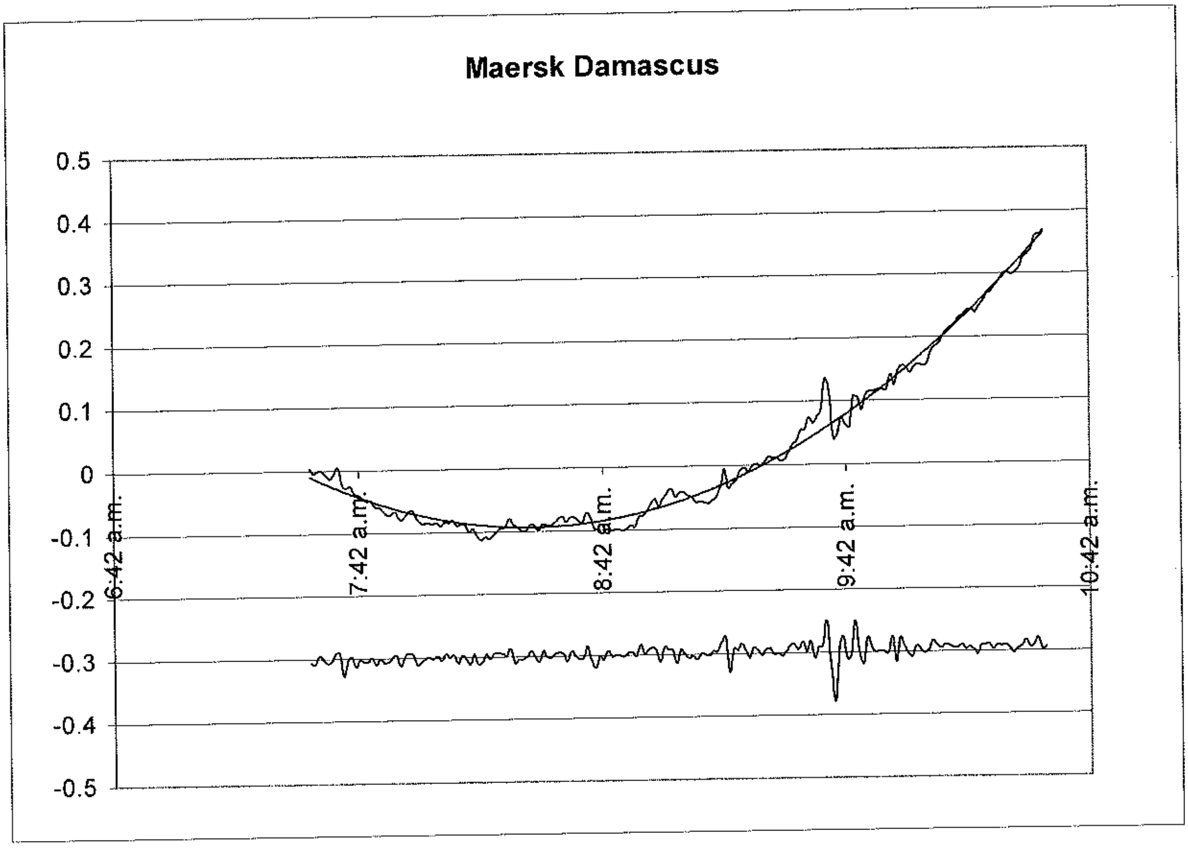
1:00 a.m.
2:00 a.m.


Maersk Damascus
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0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
6:42 a.m.
7:42 a.m.
8:42 a.m.
9:42 a.m.
10:42 a.m.

Site Observation Form

PORT
OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	MSC Kiwi	obs
DATE:	20/8/09	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:	11:30	obs	DRAFT:	8·30	POL
TIME END:	12:45	obs	TONNAGE:	14367	POL
WEATHER:	Sunny w/clouds	obs	LENGTH	198·74	POL
WIND:	light - moderate NE	obs / POL	SPEED:	8·2 kN	POL
WAVE:	100mm	obs / POL	TIDE HGT:		POL
			TIDE STATE:	Flooding	POL

Measured Wake Data

Time of vessel pass	11:53	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	0·5	m
Stern Past Fixed Point	47	sec	Estimate of max travel up beach	0·5	m
Time of 1st Wake Wave	2:43	mm:sec	Duration of event	6:47mins	sec
Height of 1st Wake Wave	120	mm	Time for Wave to Reach Shore	2·43 mins	sec
Time of Last Wake Wave	6:47	mm:sec			

Observed Wake Data

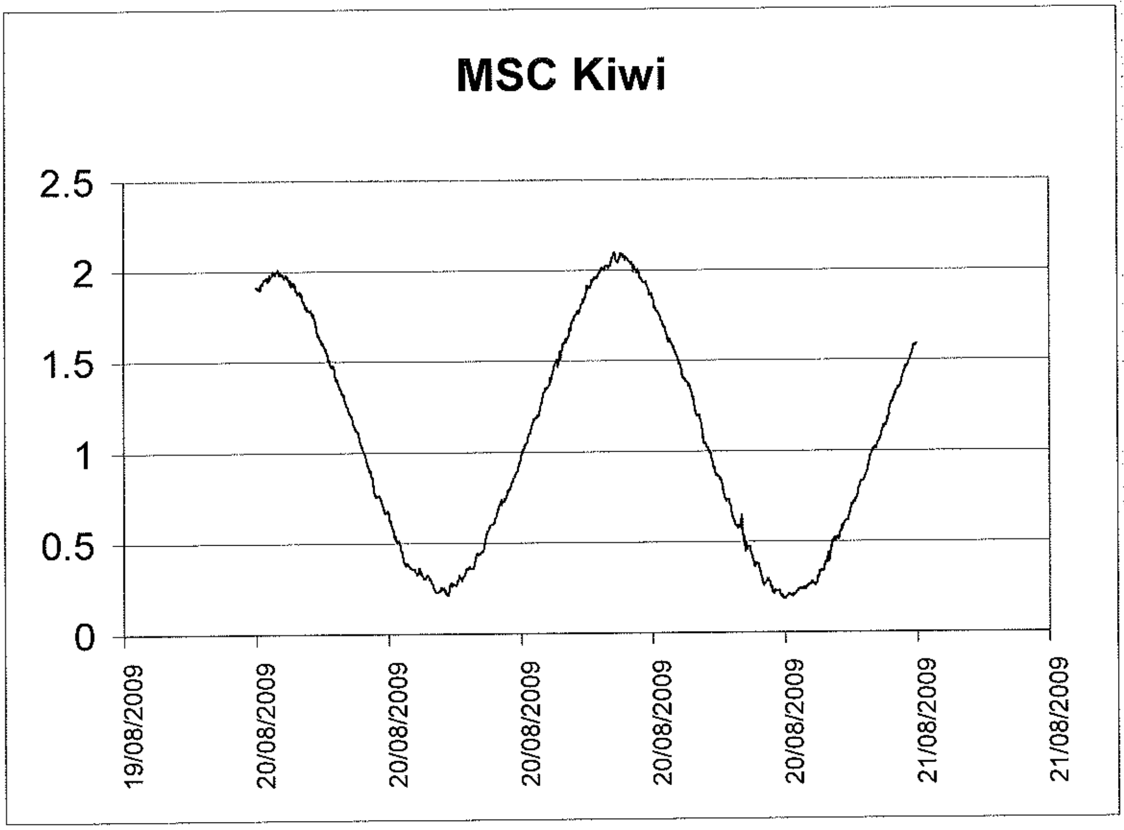
Change in wave period	[✓ YES] / NO
Change in approach angle	[✓ YES] / NO
Does the wake create sand in motion	[✓ YES] / NO
Does the wake reach the base of the dunes	YES / [✓ NO]
Does the wake cause any noticeable dune erosion	YES / [✓ NO]
Photos taken	YES / [✓ NO]
Video taken	[✓ YES] / NO

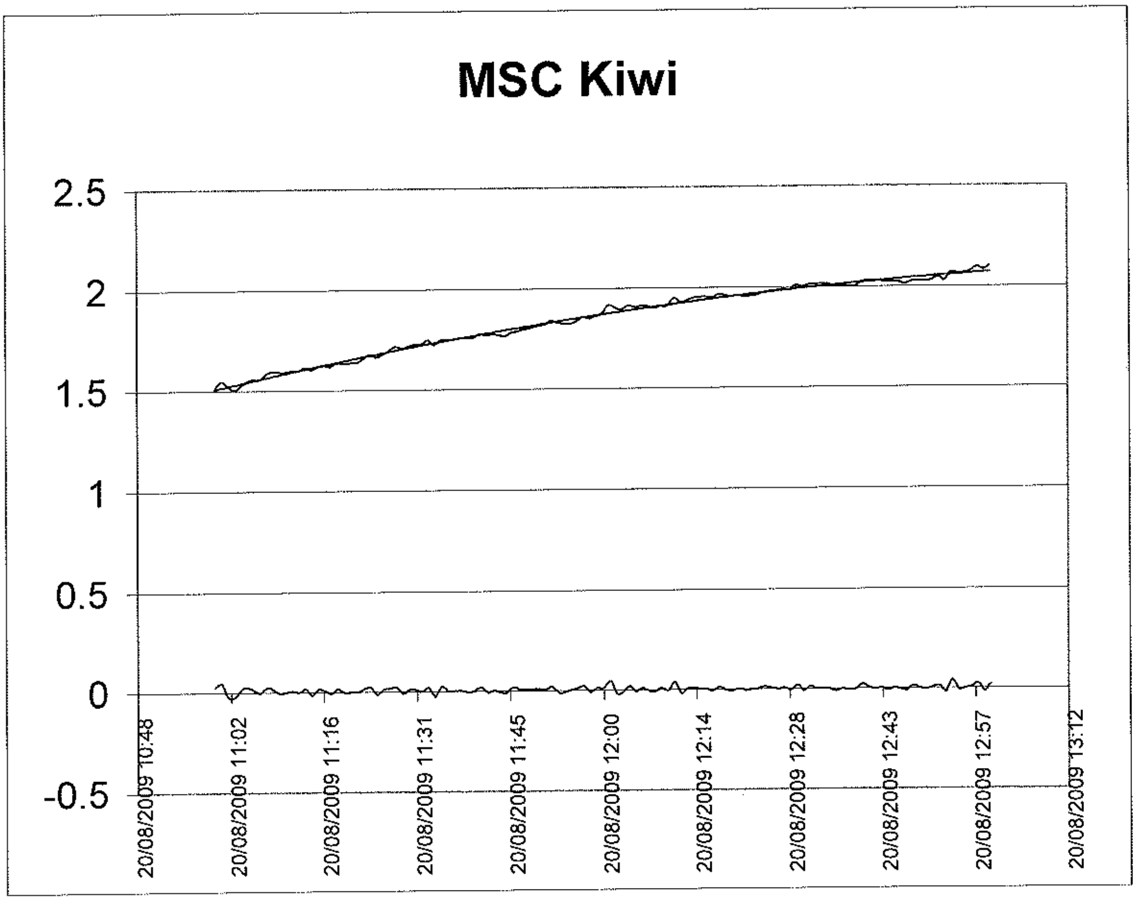
Comments

DISCUSSION / COMMENTS:

Observed by:

Observed by:


MSC Kiwi
2.5
2
1.5
1
0.5
0
19/08/2009
20/08/2009
20/08/2009
20/08/2009
20/08/2009
20/08/2009
21/08/2009
21/08/2009


MSC Kiwi
2.5
2
1.5
1
0.5
0
-0.5
20/08/2009 10:48
20/08/2009 11:02
20/08/2009 11:16
20/08/2009 11:31
20/08/2009 11:45
20/08/2009 12:00
20/08/2009 12:14
20/08/2009 12:28
20/08/2009 12:43
20/08/2009 12:57
20/08/2009 13:12

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Peregrine	obs
DATE:	20/8/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	12:10	obs	DRAFT:	7.90	POL
TIME END:	12:45	obs	TONNAGE:	50895	POL
WEATHER:	Sunny w/clouds	obs	LENGTH	182.0	POL
WIND:	light NE - moderate	obs / POL	SPEED:	11.1 kn	POL
WAVE:	100mm	obs / POL	TIDE HGT:	1.28	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	12:29	hh:mm:sec	Maximum Height	220	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance		m
Stern Past Fixed Point	32	sec	Estimate of max travel up beach	0.5	m
Time of 1st Wake Wave	2.40	mm:sec	Duration of event	7.30	sec
Height of 1st Wake Wave	200	mm	Time for Wave to Reach Shore	2:40	sec
Time of Last Wake Wave	7:30	mm:sec			

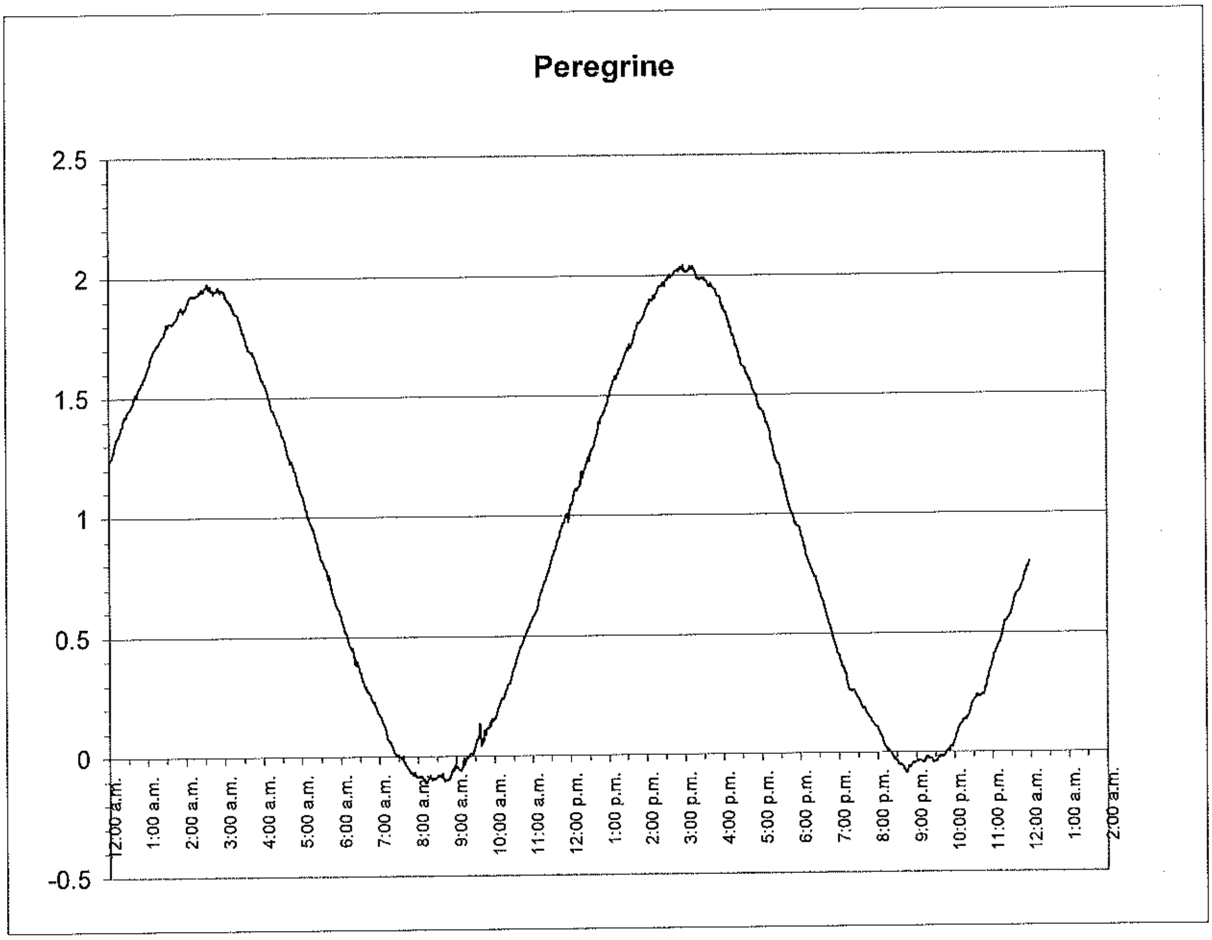
Observed Wake Data

		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	wind boat same quarter
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	close to undergrowth
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Peregrine
2.5
2
1.5
1
0.5
0
-0.5
12:00 a.m.
1:00 a.m.
2:00 a.m.
3:00 a.m.
4:00 a.m.
5:00 a.m.
6:00 a.m.
7:00 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
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3:00 p.m.
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5:00 p.m.
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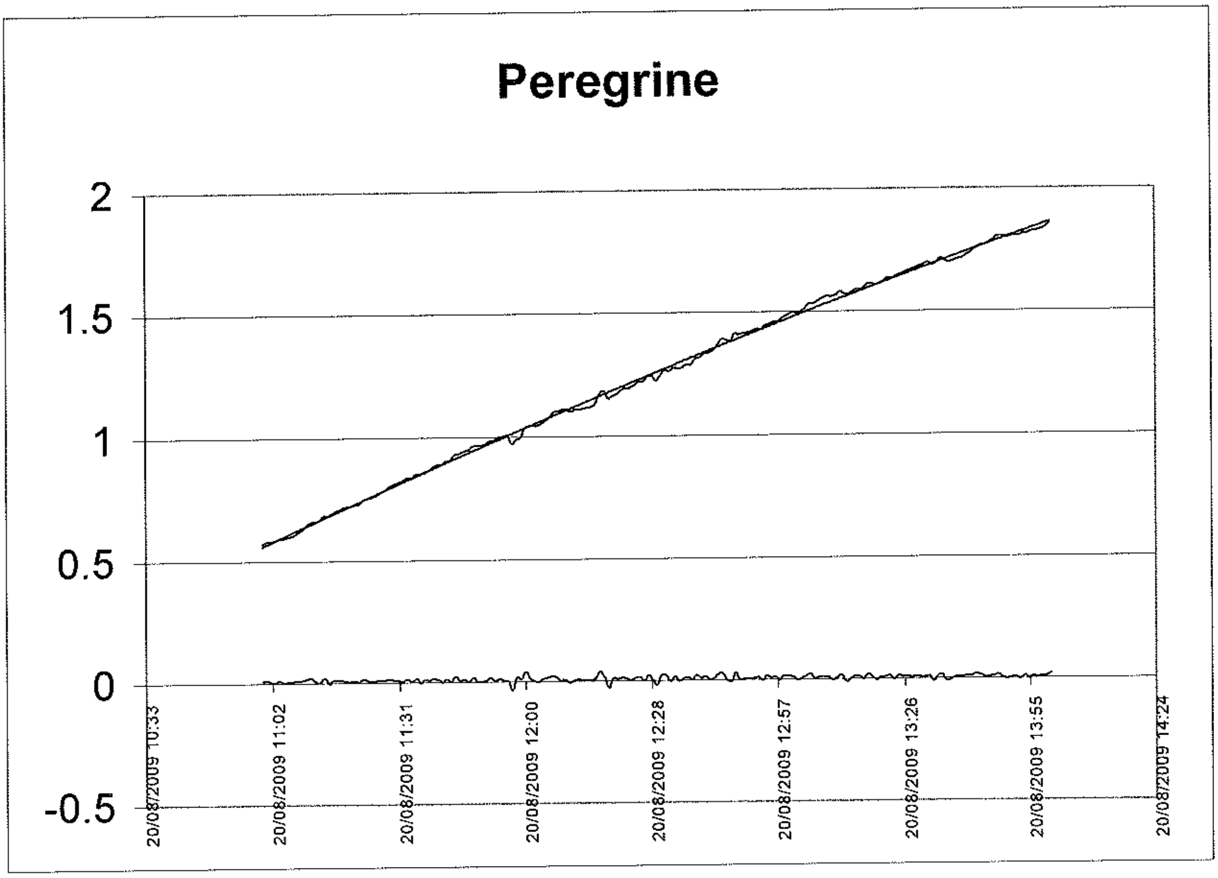
1:00 a.m.
2:00 a.m.


Peregrine
2
1.5
1
0.5
0
-0.5
20/08/2009 10:33
20/08/2009 11:02
20/08/2009 11:31
20/08/2009 12:00
20/08/2009 12:28
20/08/2009 12:57
20/08/2009 13:26
20/08/2009 13:55
20/08/2009 14:24

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Amattal Atlantis	obs
DATE:	24/8/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	4:20	obs	DRAFT:	7·30	POL
TIME END:		obs	TONNAGE:	1255	POL
WEATHER:	Sunny	obs	LENGTH	55·55	POL
WIND:	reasonably light	obs / POL	SPEED:	8·3 kN	POL
WAVE:	100mm	obs / POL	TIDE HGT:	1·78	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	4:32	hh:mm:sec	Maximum Height	200	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	6	m
Stern Past Fixed Point	13	sec	Estimate of max travel up beach	0·3	m
Time of 1st Wake Wave	1·30	mm:sec	Duration of event	5:05	sec
Height of 1st Wake Wave	150	mm	Time for Wave to Reach Shore	1:30	sec
Time of Last Wake Wave	5:05	mm:sec			

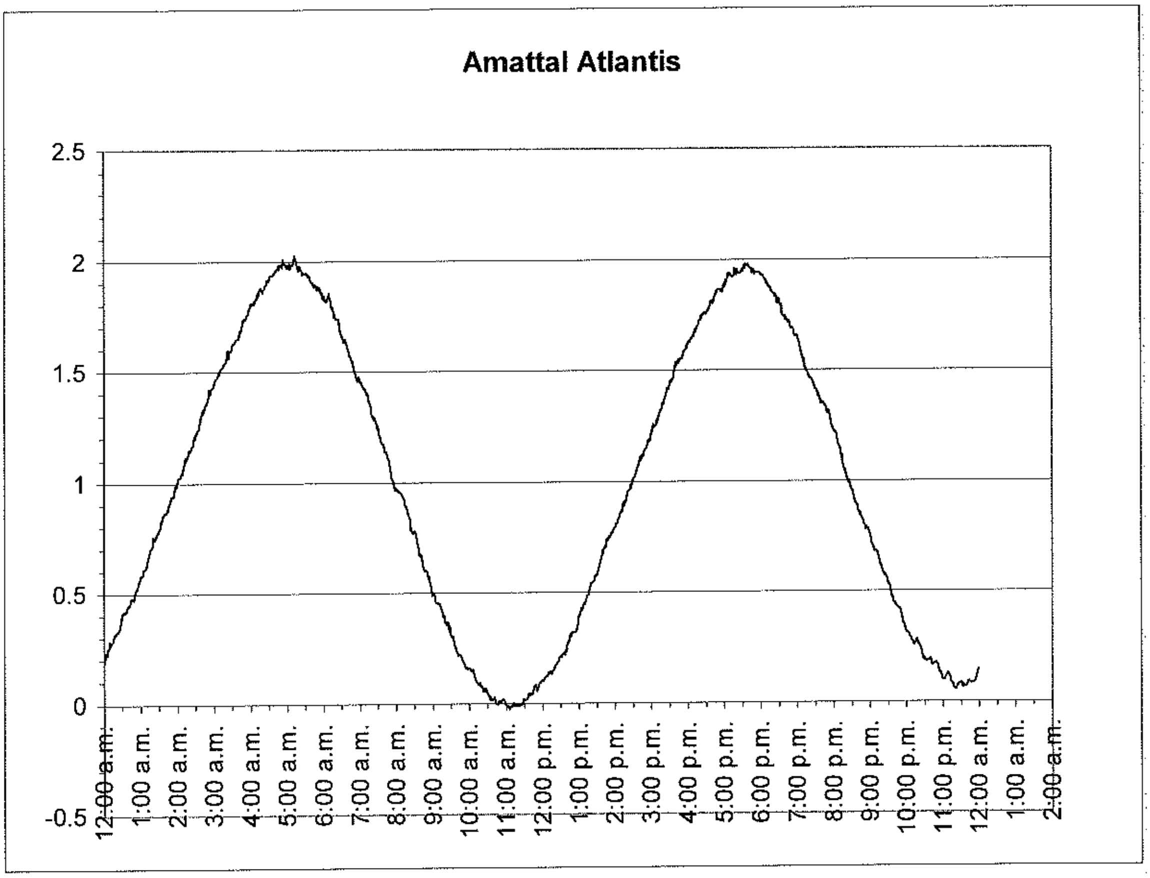
Observed Wake Data

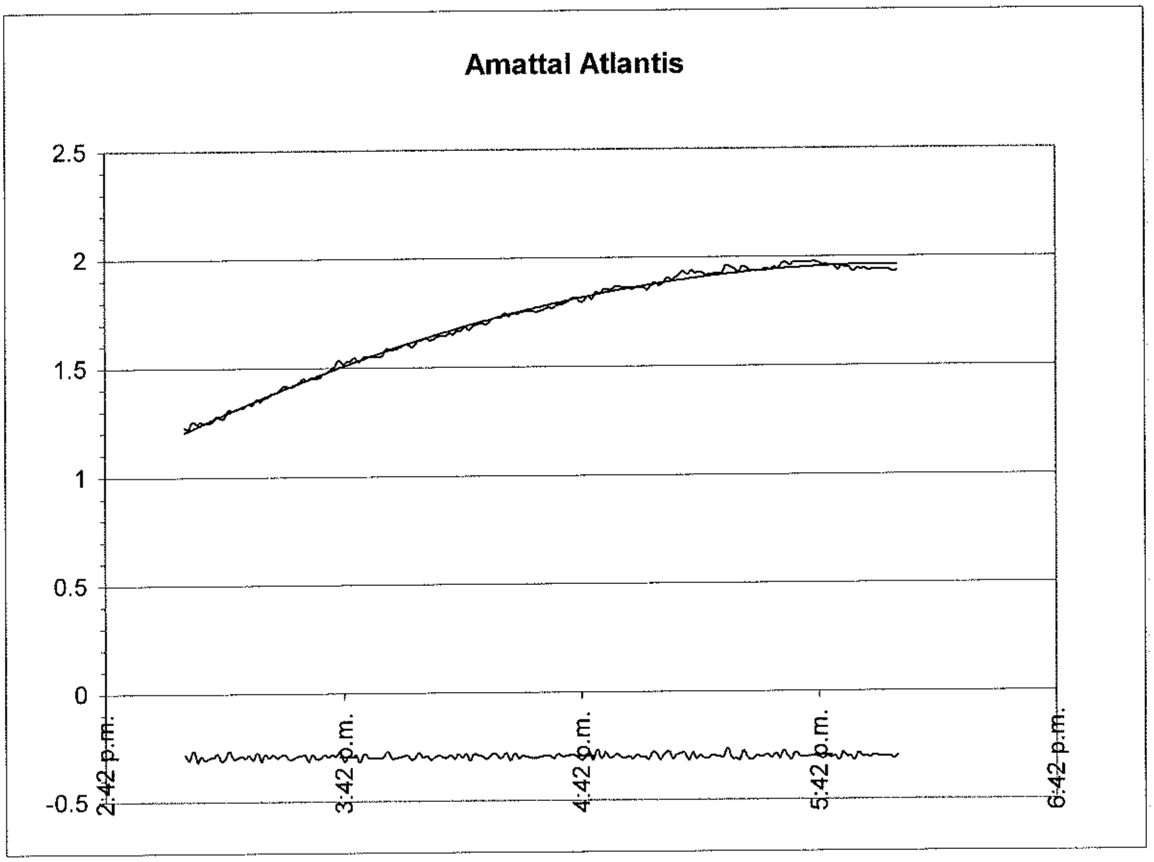
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	Reached undergrowth but
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	tide was already there.
Photos taken	YES / [✓ NO]	
Video taken	YES / [✓ NO]	lens wouldn't open
		properly

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Amattal Atlantis
2.5
2
1.5
1
0.5
0
-0.5
12:00 a.m.
1:00 a.m.
2:00 a.m.
3:00 a.m.
4:00 a.m.
5:00 a.m.
6:00 a.m.
7:00 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
1:00 p.m.
2:00 p.m.
3:00 p.m.
4:00 p.m.
5:00 p.m.
6:00 p.m.
7:00 p.m.
8:00 p.m.
9:00 p.m.
10:00 p.m.
11:00 p.m.
12:00 a.m.
1:00 a.m.
2:00 a.m.


Amattal Atlantis
2.5
2
1.5
1
0.5
0
-0.5
2:42 p.m.
3:42 p.m.
4:42 p.m.
5:42 p.m.
6:42 p.m.

Site Observation Form

PORT
OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			**Vessel Data**		
LOCATION:	Te Rauone	obs	NAME:	Townsend Cromwell	obs
DATE:	7/9/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:		obs	DRAFT:	4.00	POL
TIME END:		obs	TONNAGE:	309	POL
WEATHER:	Overcast	obs	LENGTH	43.46	POL
WIND:	light	obs / POL	SPEED:	7.0kN	POL
WAVE:	100mm	obs / POL	TIDE HGT:	0.66	POL
			TIDE STATE:	flooding	POL

Measured Wake Data

Time of vessel pass	1:00	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point		sec	Estimate of draw down distance		m
Stern Past Fixed Point		sec	Estimate of max travel up beach	0.2	m
Time of 1st Wake Wave	1:33	mm:sec	Duration of event	5:12	sec
Height of 1st Wake Wave	150	mm	Time for Wave to Reach Shore	1.20	sec
Time of Last Wake Wave		mm:sec			

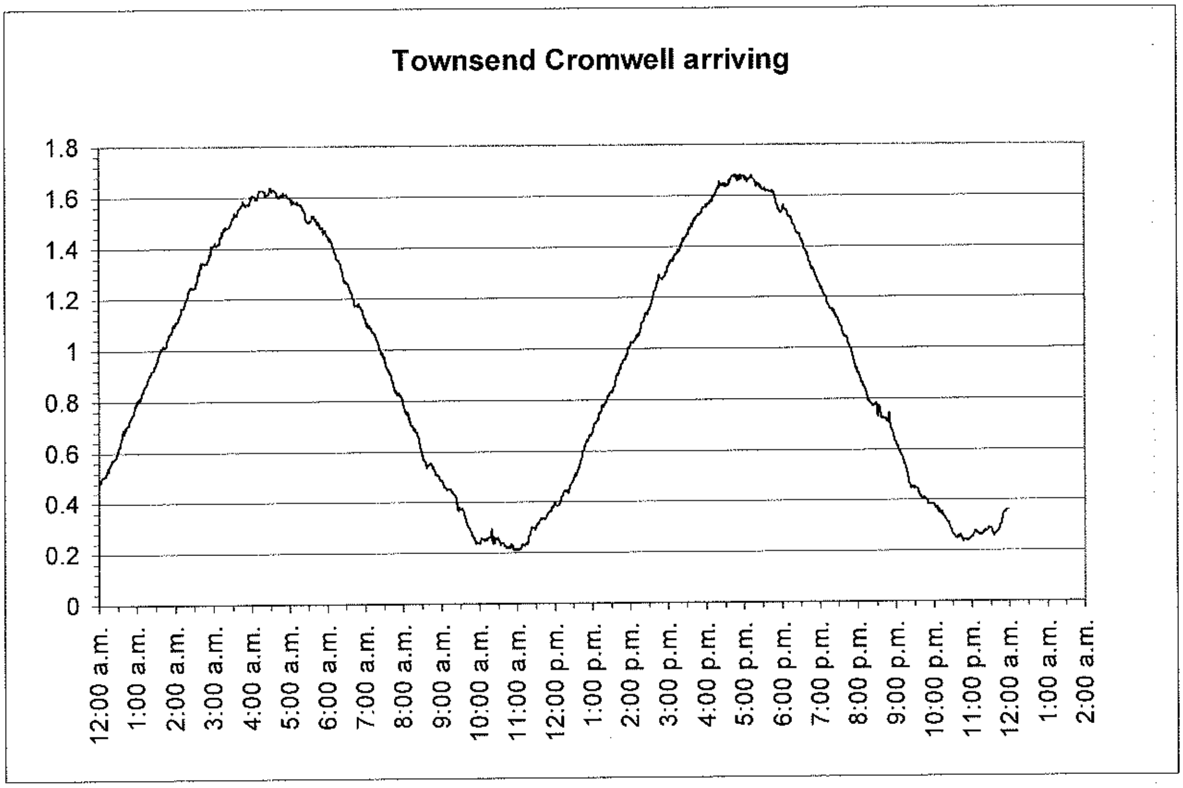
Observed Wake Data

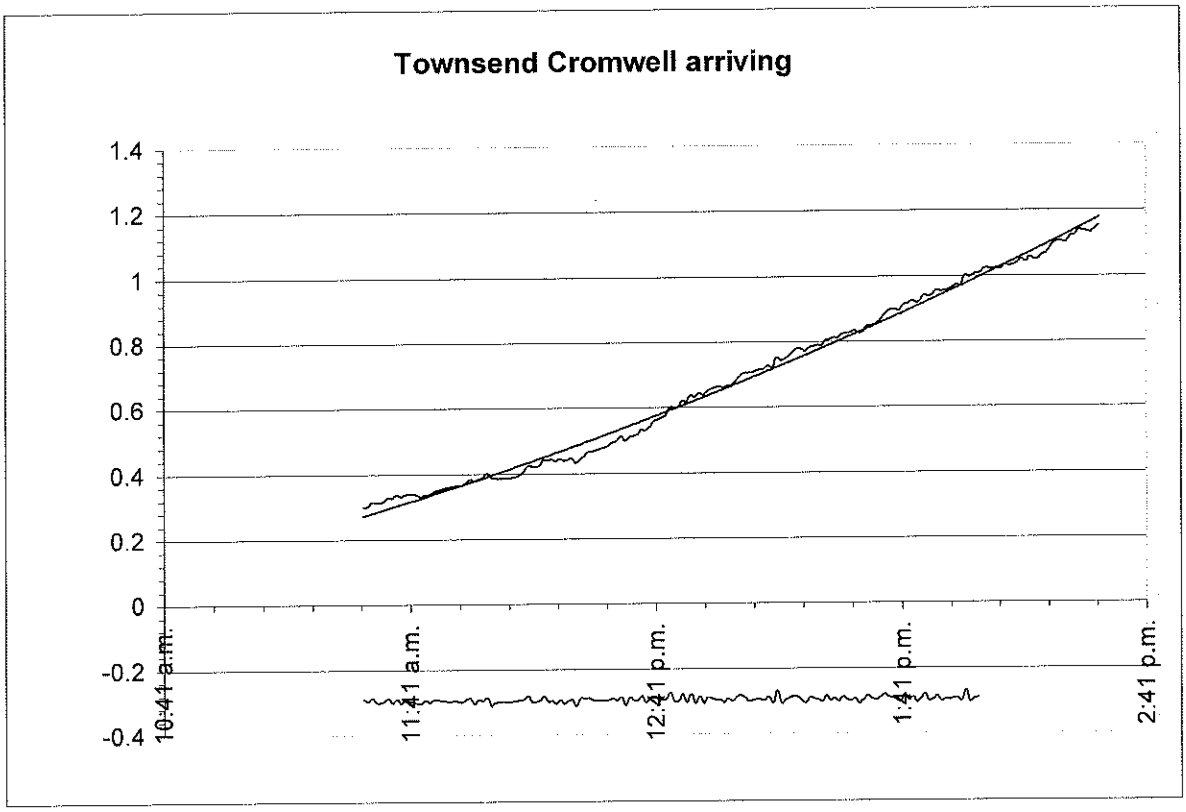
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / NO	
Does the wake create sand in motion	YES / [✓ NO]	
Does the wake reach the base of the dunes	[✓ YES] / NO	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	YES / [✓ NO]	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Townsend Cromwell arriving


Townsend Cromwell arriving

Site Observation Form

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Vega Gotland	obs
DATE:	7/9/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	10:00	obs	DRAFT:	7.60	POL
TIME END:	10:29	obs	TONNAGE:	13806	POL
WEATHER:	Overcast	obs	LENGTH	140.3	POL
WIND:	None-very little	obs / POL	SPEED:	10.9	POL
WAVE:	Tiny ripples	obs / POL	TIDE HGT:	0.22	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	10:20	hh:mm:sec	Maximum Height	100	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	0	m
Stern Past Fixed Point	25	sec	Estimate of max travel up beach	6	m
Time of 1st Wake Wave	30	mm:sec	Duration of event	7:20	sec
Height of 1st Wake Wave	100	mm	Time for Wave to Reach Shore	5	sec
Time of Last Wake Wave	7:20	mm:sec			

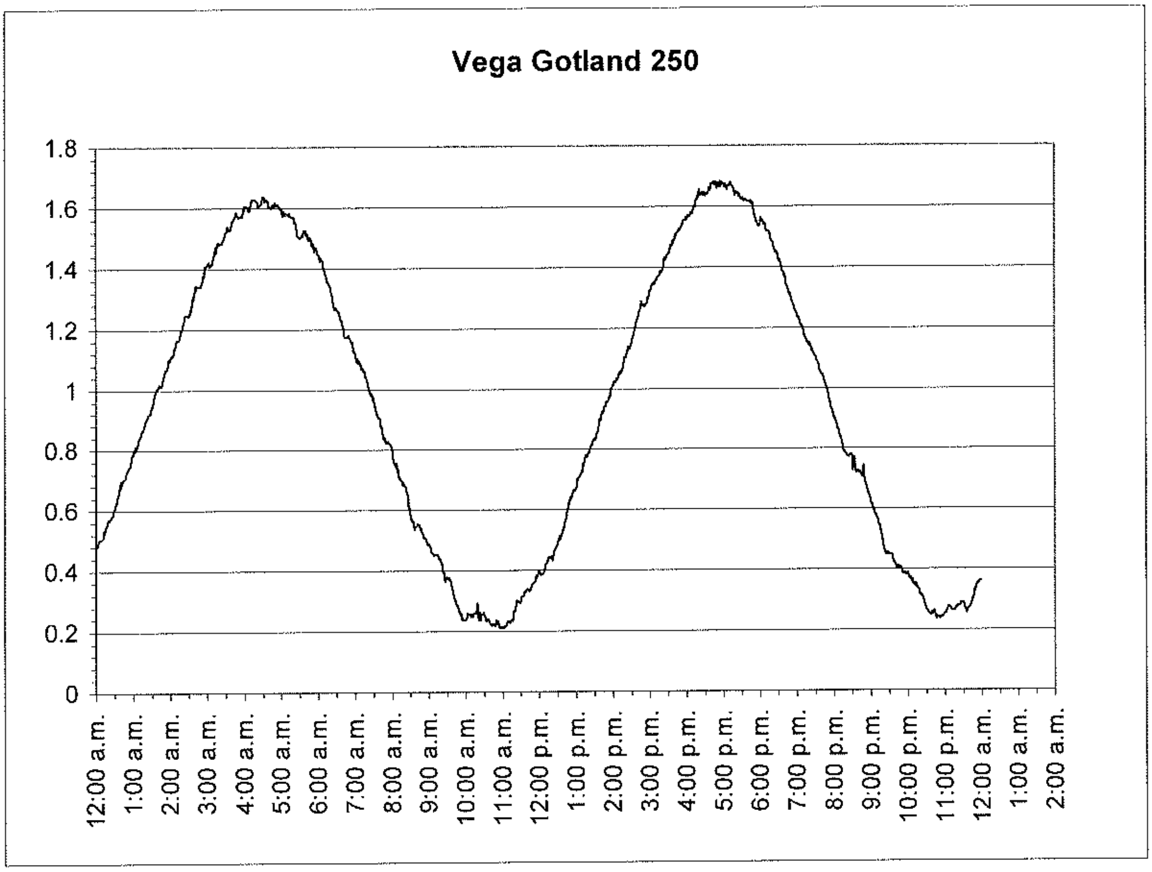
Observed Wake Data

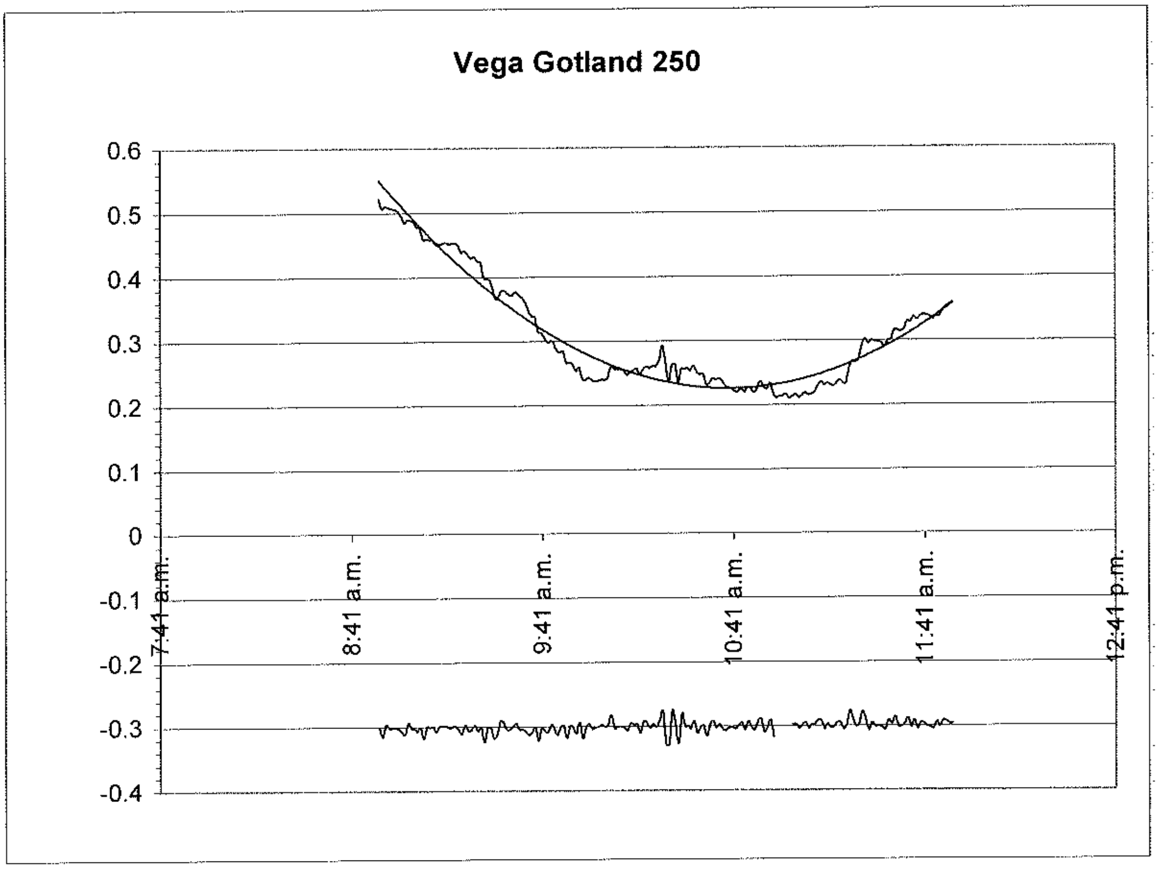
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	Wind and boat same quarter
Does the wake create sand in motion	[✓ YES] / NO	very little
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	Camera Broken.
Video taken	YES / [✓ NO]	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Vega Gotland 250
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 a.m.
1:00 a.m.
2:00 a.m.
3:00 a.m.
4:00 a.m.
5:00 a.m.
6:00 a.m.
7:00 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
1:00 p.m.
2:00 p.m.
3:00 p.m.
4:00 p.m.
5:00 p.m.
6:00 p.m.
7:00 p.m.
8:00 p.m.
9:00 p.m.
10:00 p.m.
11:00 p.m.
12:00 a.m.
1:00 a.m.
2:00 a.m.


Vega Gotland 250
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
7:41 a.m.
8:41 a.m.
9:41 a.m.
10:41 a.m.
11:41 a.m.
12:41 p.m.

Site Observation Form

PORT OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			**Vessel Data**		
LOCATION:	Te Rauone	obs	NAME:	Townsend Cromwell	obs
DATE:	7/9/09	obs	TRAVEL DIR.	**ARR / [✓ DEP]**	obs
TIME START:	10:30	obs	DRAFT:	4.00	POL
TIME END:	11:50	obs	TONNAGE:	309	POL
WEATHER:	Overcast	obs	LENGTH	43.46	POL
WIND:	light ENE	obs / POL	SPEED:	7.7 kN	POL
WAVE:	Small 50mm	obs / POL	TIDE HGT:	0.32	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	11:44	hh:mm:sec	Maximum Height	100	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	0	m
Stern Past Fixed Point	11	sec	Estimate of max travel up beach	5m v.flat	m
Time of 1st Wake Wave	1:30	mm:sec	Duration of event	4:50	sec
Height of 1st Wake Wave	100	mm	Time for Wave to Reach Shore	1:30	sec
Time of Last Wake Wave	4:50	mm:sec			

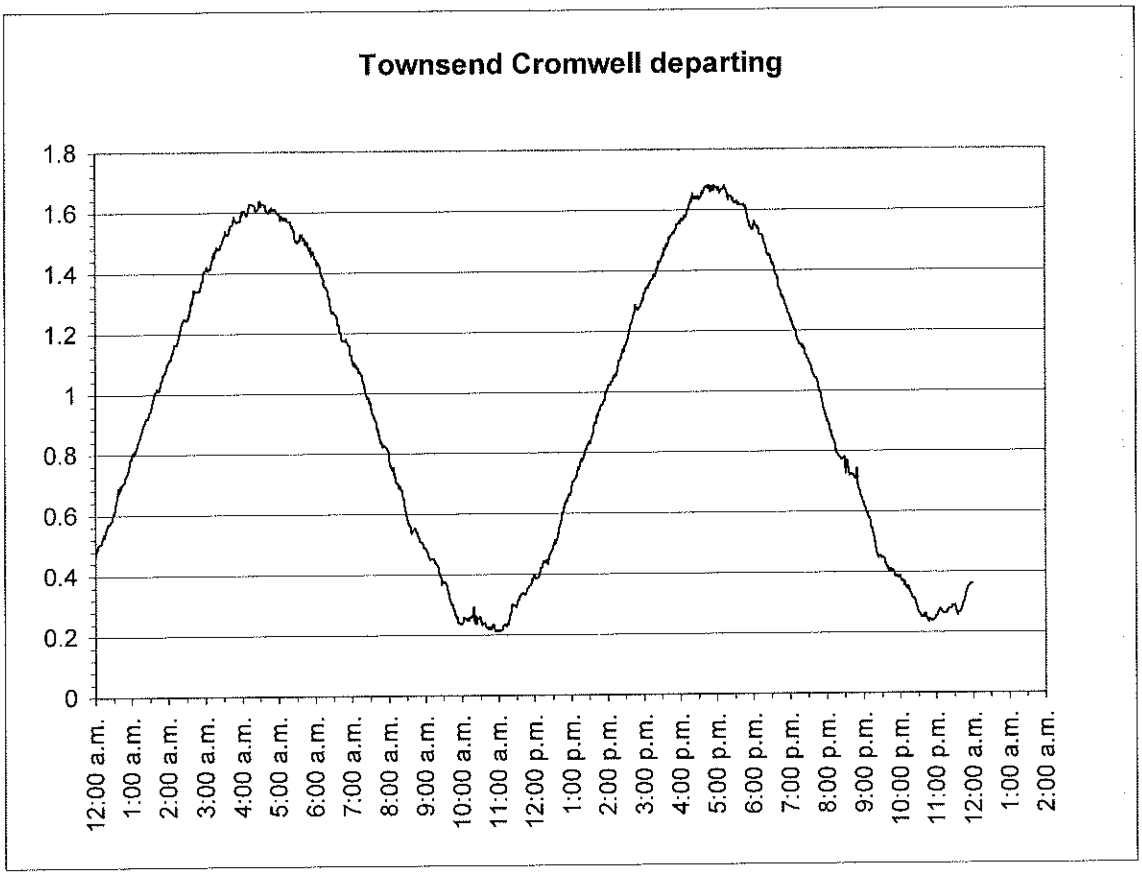
Observed Wake Data

		Comments
Change in wave period	**[✓ YES] / NO**	faster
Change in approach angle	**[✓ YES] / NO**	
Does the wake create sand in motion	**[✓ YES] / NO**	very little
Does the wake reach the base of the dunes	**YES / [✓ NO]**	
Does the wake cause any noticeable dune erosion	**YES / [✓ NO]**	
Photos taken	**YES / [✓ NO]**	Camera Broken
Video taken	**YES / [✓ NO]**	

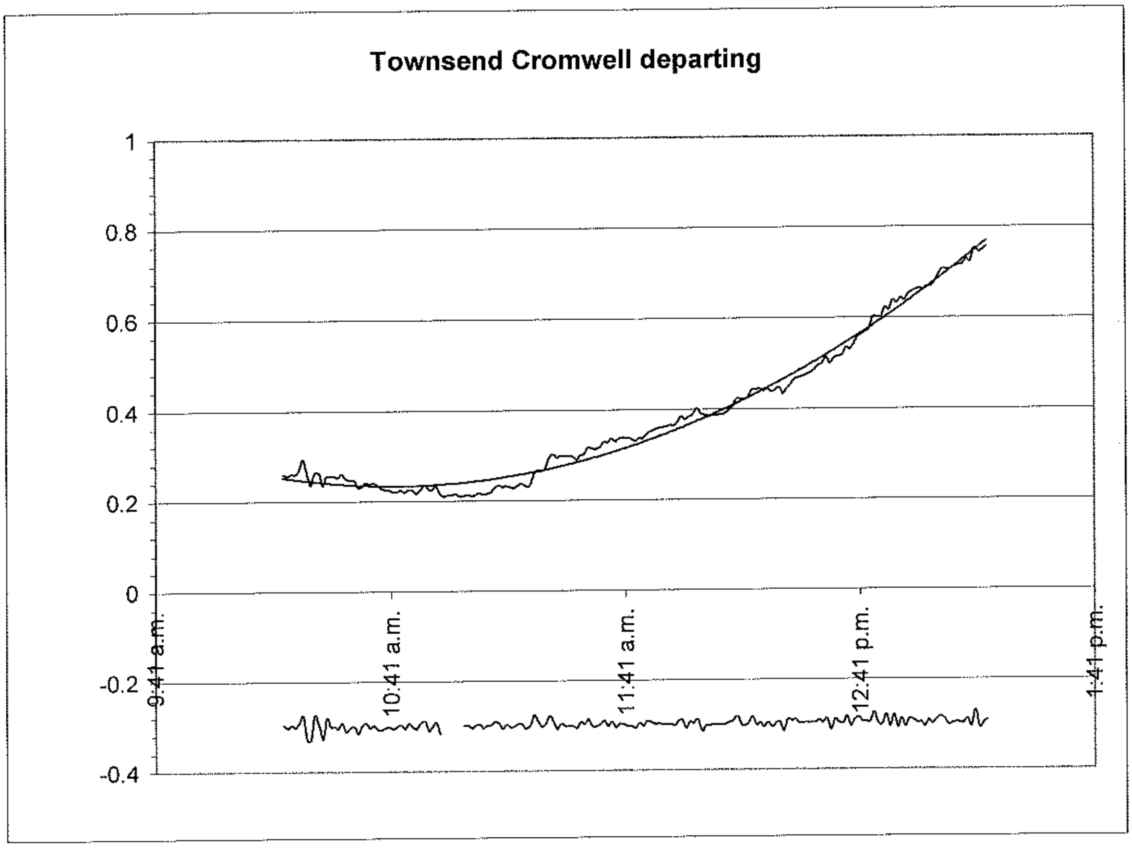
DISCUSSION / COMMENTS:

Observed by:

Observed by:



Townsend Cromwell departing



Townsend Cromwell departing

Site Observation Form

PORT
OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data

LOCATION:	Te Rauone	obs
DATE:	14/9/09	obs
TIME START:	10:50	obs
TIME END:	11:30	obs
WEATHER:	Overcast	obs
WIND:	light E	obs / POL
WAVE:	small 70mm	obs / POL

Vessel Data

NAME:	Maersk Radford	obs
TRAVEL DIR.	[✓ ARR] / DEP	obs
DRAFT:	7.70	POL
TONNAGE:	13819	POL
LENGTH	140.3	POL
SPEED:	8.0	POL
TIDE HGT:	1.96	POL
TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	11:22	hh:mm:sec
Bow Past Fixed Point	0	sec
Stern Past Fixed Point	34	sec
Time of 1st Wake Wave	2:32	mm:sec
Height of 1st Wake Wave	150	mm
Time of Last Wake Wave	6:40	mm:sec

Maximum Height	200	mm
Estimate of draw down distance	1.5	m
Estimate of max travel up beach	1	m
Duration of event	6:40	sec
Time for Wave to Reach Shore	2:32	sec

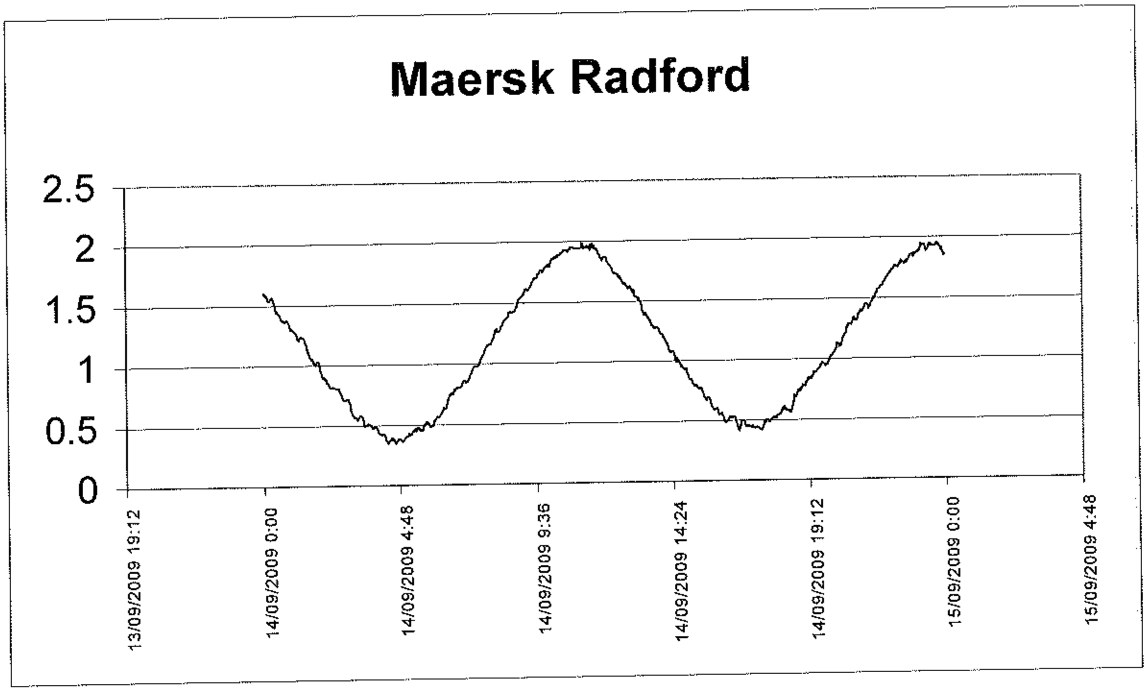
Observed Wake Data

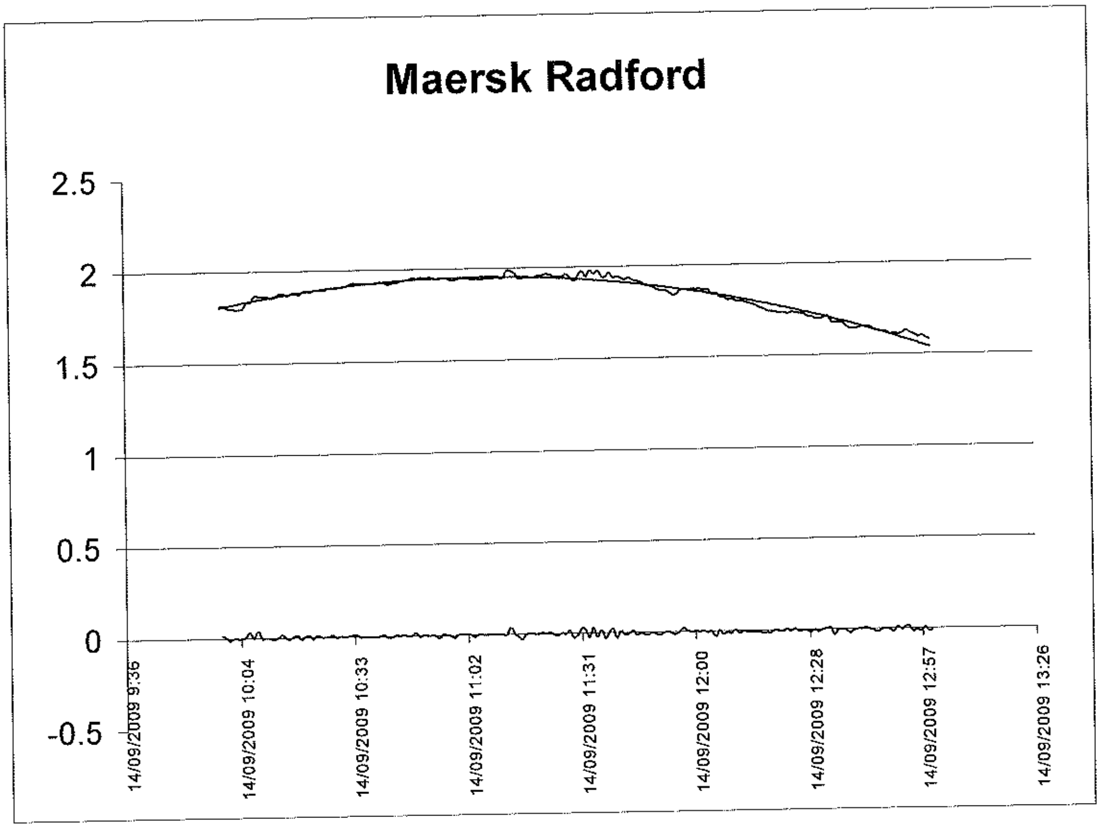
		Comments
Change in wave period	[✓ YES] / NO	faster
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	YES / [✓ NO]	Broken Camera

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Maersk Radford
2.5
2
1.5
1
0.5
0
13/09/2009 19:12
14/09/2009 0:00
14/09/2009 4:48
14/09/2009 9:36
14/09/2009 14:24
14/09/2009 19:12
15/09/2009 0:00
15/09/2009 4:48


Maersk Radford
2.5
2
1.5
1
0.5
0
-0.5
14/09/2009 9:36
14/09/2009 10:04
14/09/2009 10:33
14/09/2009 11:02
14/09/2009 11:31
14/09/2009 12:00
14/09/2009 12:28
14/09/2009 12:57
14/09/2009 13:26

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			**Vessel Data**		
LOCATION:	Te Rauone	obs	NAME:	Maersk Duffield	obs
DATE:	25/9/09	obs	TRAVEL DIR.	[✓ **ARR**] / **DEP**	obs
TIME START:	1:30	obs	DRAFT:	10·80	POL
TIME END:	2:15	obs	TONNAGE:	53171	POL
WEATHER:	Overcast	obs	LENGTH	268	POL
WIND:	Moderate NW	obs / POL	SPEED:	10·2	POL
WAVE:	150mm	obs / POL	TIDE HGT:	0·43	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	2:02	hh:mm:sec	Maximum Height	220	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	51	sec	Estimate of max travel up beach	3	m
Time of 1st Wake Wave	30	mm:sec	Duration of event	7·21	sec
Height of 1st Wake Wave	200	mm	Time for Wave to Reach Shore	30	sec
Time of Last Wake Wave	7·21	mm:sec			

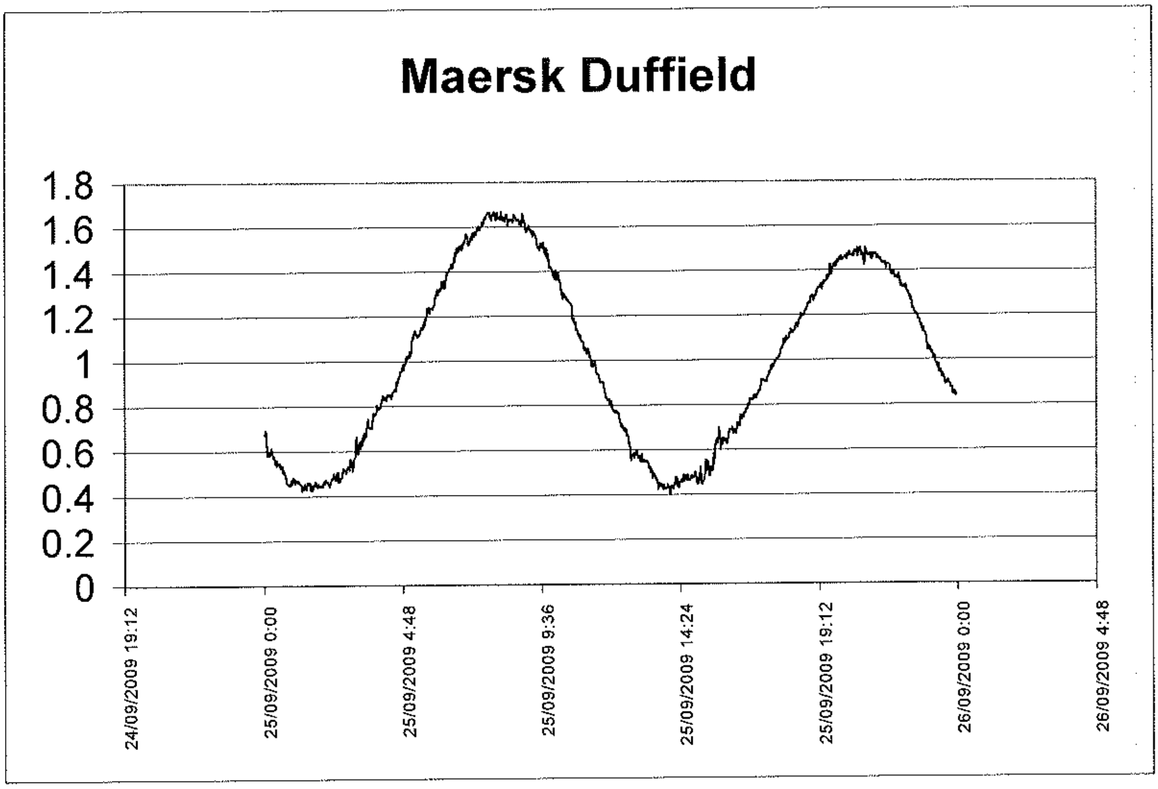
Observed Wake Data

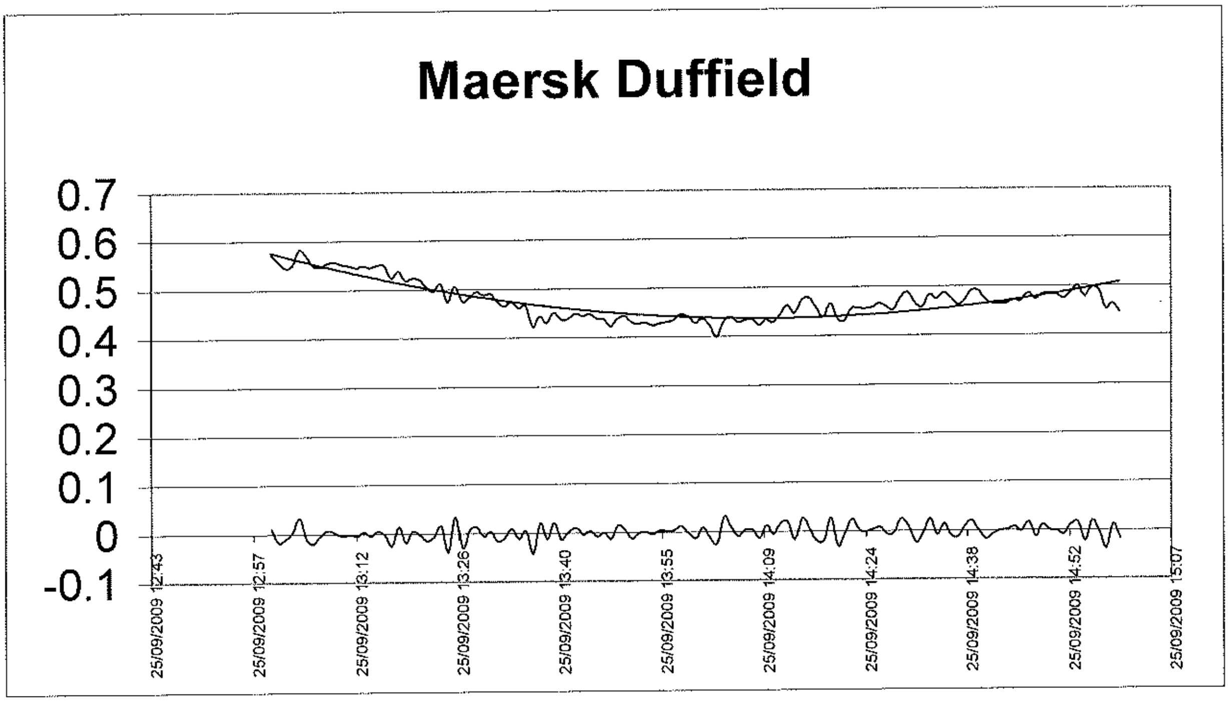
		Comments
Change in wave period	[✓ **YES**] / **NO**	
Change in approach angle	**YES** / [✓ **NO**]	Same Quarter
Does the wake create sand in motion	[✓ **YES**] / **NO**	
Does the wake reach the base of the dunes	**YES** / [✓ **NO**]	
Does the wake cause any noticeable dune erosion	**YES** / [✓ **NO**]	
Photos taken	[✓ **YES**] / **NO**	
Video taken	[✓ **YES**] / **NO**	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Maersk Duffield
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
24/09/2009 19:12
25/09/2009 0:00
25/09/2009 4:48
25/09/2009 9:36
25/09/2009 14:24
25/09/2009 19:12
26/09/2009 0:00
26/09/2009 4:48


Maersk Duffield
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
25/09/2009 12:43
25/09/2009 12:57
25/09/2009 13:12
25/09/2009 13:26
25/09/2009 13:40
25/09/2009 13:55
25/09/2009 14:09
25/09/2009 14:24
25/09/2009 14:38
25/09/2009 14:52
25/09/2009 15:07

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Torea	obs
DATE:	28/9/09	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:	9:45	obs	DRAFT:	6·40	POL
TIME END:	11:00	obs	TONNAGE:	37069	POL
WEATHER:	Overcast / Intermittent rain	obs	LENGTH	168	POL
WIND:	light S	obs / POL	SPEED:	11·3 kN	POL
WAVE:	Ripples	obs / POL	TIDE HGT:	1·62	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	10:42	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	29	sec	Estimate of max travel up beach	1	m
Time of 1st Wake Wave	2:40	mm:sec	Duration of event	6:04	sec
Height of 1st Wake Wave	50	mm	Time for Wave to Reach Shore	2:40	sec
Time of Last Wake Wave	6:04	mm:sec			

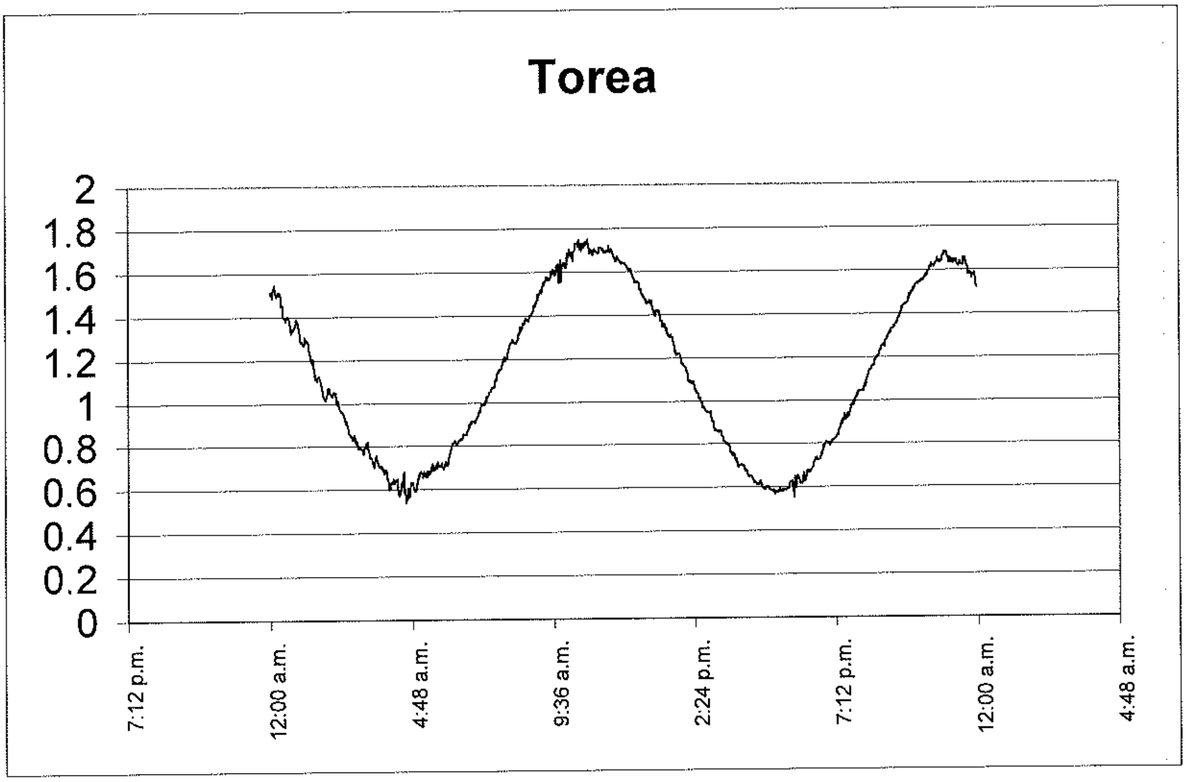
Observed Wake Data

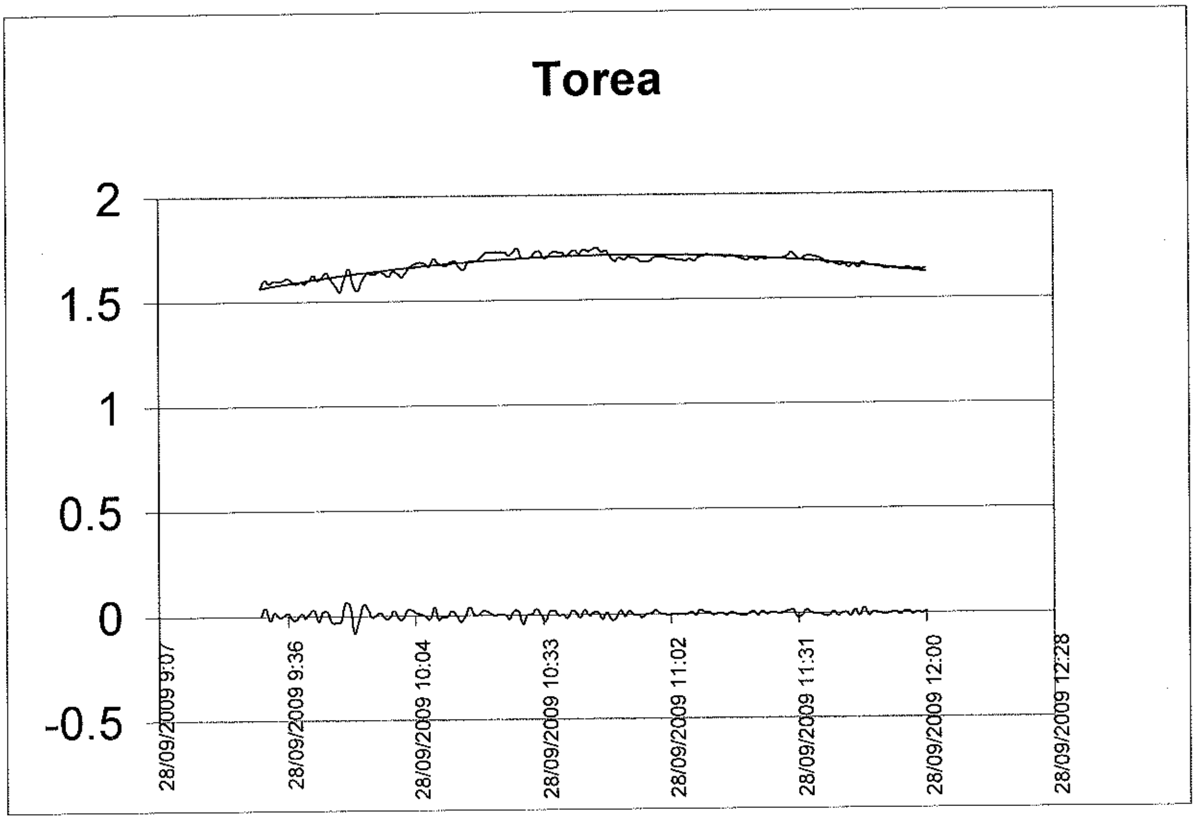
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	Started at undergrowth
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Torea
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
7:12 p.m.
12:00 a.m.
4:48 a.m.
9:36 a.m.
2:24 p.m.
7:12 p.m.
12:00 a.m.
4:48 a.m.


Torea
2
1.5
1
0.5
0
-0.5
28/09/2009 9:07
28/09/2009 9:36
28/09/2009 10:04
28/09/2009 10:33
28/09/2009 11:02
28/09/2009 11:31
28/09/2009 12:00
28/09/2009 12:28

Site Observation Form

PORT OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data

LOCATION:	Te Rauone	obs
DATE:	1/10/09	obs
TIME START:	1:00	obs
TIME END:	1:35	obs
WEATHER:	Sunny, Patchy clouds	obs
WIND:	light SW	obs / POL
WAVE:	50mm	obs / POL

Vessel Data

NAME:	Maersk Dunafare	obs
TRAVEL DIR.	[✓ ARR] / DEP	obs
DRAFT:	11·30	POL
TONNAGE:	53452	POL
LENGTH	268	POL
SPEED:	9·6	POL
TIDE HGT:	1·77	POL
TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	1:26	hh:mm:sec
Bow Past Fixed Point	0	sec
Stern Past Fixed Point	54	sec
Time of 1st Wake Wave	2:15	mm:sec
Height of 1st Wake Wave	100	mm
Time of Last Wake Wave	7:44	mm:sec

Maximum Height	350	mm
Estimate of draw down distance	1	m
Estimate of max travel up beach	3	m
Duration of event	7:44	sec
Time for Wave to Reach Shore	2:15	sec

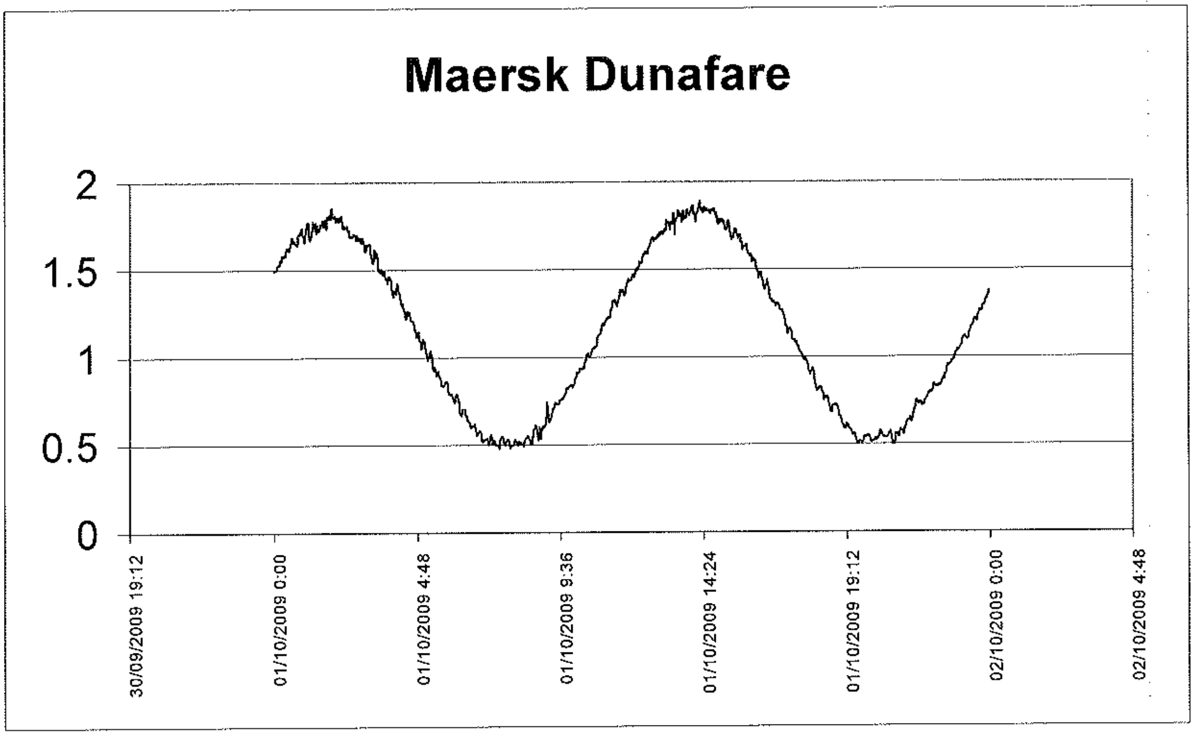
Observed Wake Data

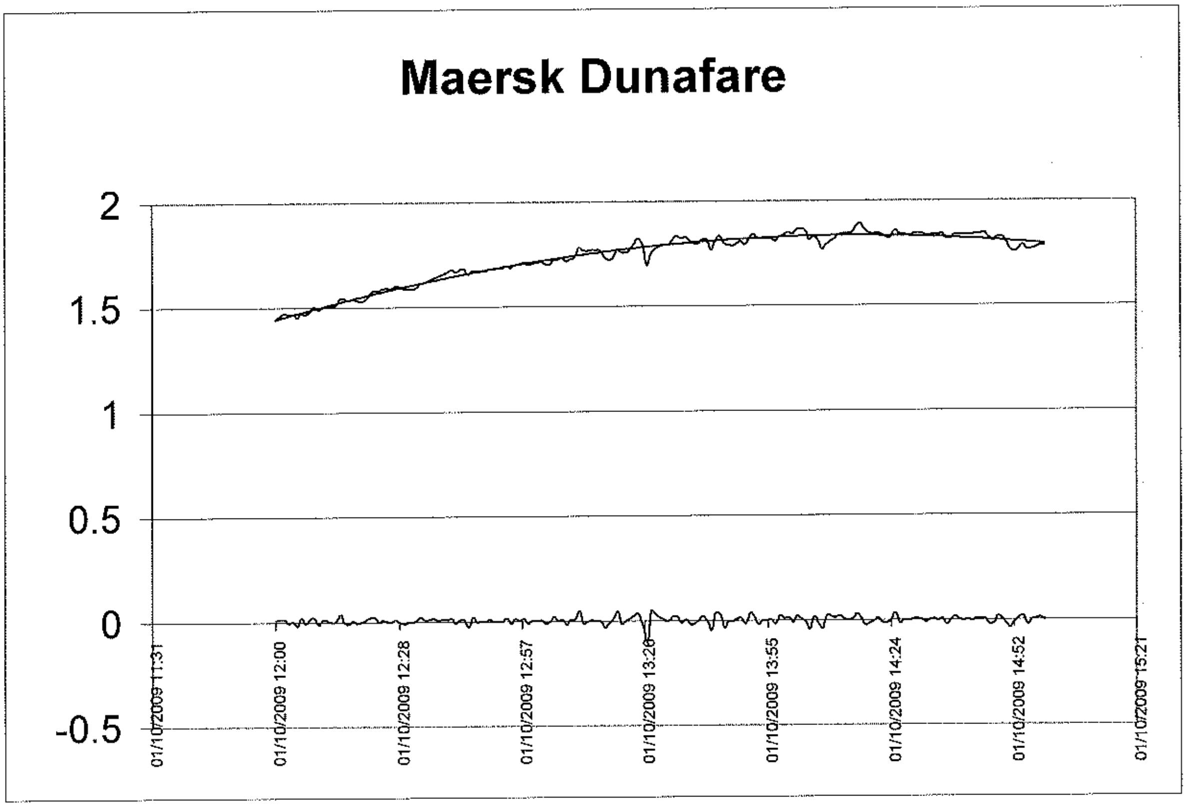
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	Started at undergrowth
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Maersk Dunafare
2
1.5
1
0.5
0
30/09/2009 19:12
01/10/2009 0:00
01/10/2009 4:48
01/10/2009 9:36
01/10/2009 14:24
01/10/2009 19:12
02/10/2009 0:00
02/10/2009 4:48


Maersk Dunafare
2
1.5
1
0.5
0
-0.5
01/10/2009 11:31
01/10/2009 12:00
01/10/2009 12:28
01/10/2009 12:57
01/10/2009 13:26
01/10/2009 13:55
01/10/2009 14:24
01/10/2009 14:52
01/10/2009 15:21

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Maersk Radford	obs
DATE:	5/10/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	3:02	obs	DRAFT:	7.10	POL
TIME END:	3:20	obs	TONNAGE:	13819	POL
WEATHER:	Sunny	obs	LENGTH	140.3	POL
WIND:	light NW	obs / POL	SPEED:	10.9	POL
WAVE:	small 50mm	obs / POL	TIDE HGT:	1.36	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	3:10	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	25	sec	Estimate of max travel up beach	0.5	m
Time of 1st Wake Wave	2:55	mm:sec	Duration of event	6:29	sec
Height of 1st Wake Wave	100	mm	Time for Wave to Reach Shore	2:55	sec
Time of Last Wake Wave	6:29	mm:sec			

Observed Wake Data

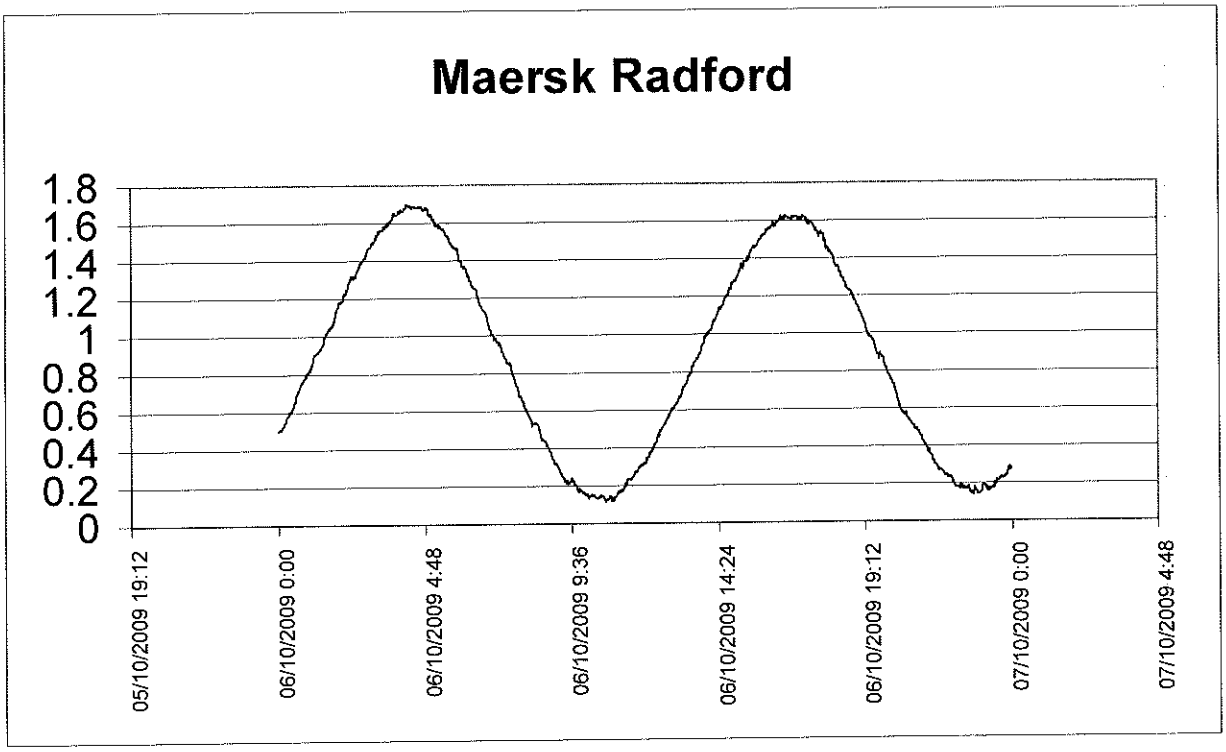
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	Boat/Wind Same Quarter
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	Started at undergrowth
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

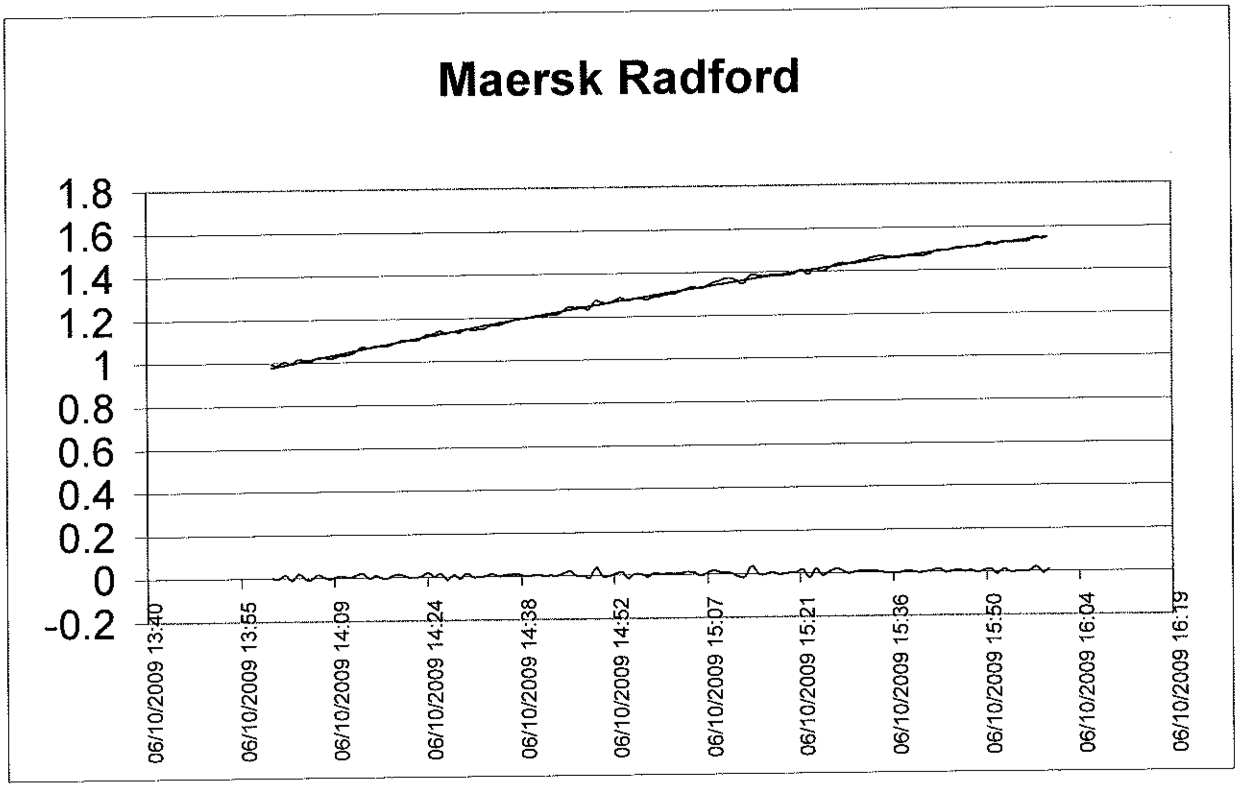
DISCUSSION / COMMENTS:

Waves at start look bigger than 50mm because a medium sized yacht had just gone by (photo included) which actually made more wake than the 400.

Observed by:

Observed by:


Maersk Radford
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
05/10/2009 19:12
06/10/2009 0:00
06/10/2009 4:48
06/10/2009 9:36
06/10/2009 14:24
06/10/2009 19:12
07/10/2009 0:00
07/10/2009 4:48


Maersk Radford
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
06/10/2009 13:40
06/10/2009 13:55
06/10/2009 14:09
06/10/2009 14:24
06/10/2009 14:38
06/10/2009 14:52
06/10/2009 15:07
06/10/2009 15:21
06/10/2009 15:36
06/10/2009 15:50
06/10/2009 16:04
06/10/2009 16:19

Site Observation Form

PORT OTAGO
LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data

LOCATION:	Te Rauone	obs
DATE:	8/10/09	obs
TIME START:	4:01	obs
TIME END:		obs
WEATHER:	Overcast	obs
WIND:	light NW	obs / POL
WAVE:	small 50mm	obs / POL

Vessel Data

NAME:	Maersk Denton	obs
TRAVEL DIR.	[✓ ARR] / DEP	obs
DRAFT:	10.60	POL
TONNAGE:	53115	POL
LENGTH	268	POL
SPEED:	11.1 kN	POL
TIDE HGT:	1.10	POL
TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	4:14	hh:mm:sec
Bow Past Fixed Point	0	sec
Stern Past Fixed Point	47	sec
Time of 1st Wake Wave	2:18	mm:sec
Height of 1st Wake Wave	150	mm
Time of Last Wake Wave	4:24	mm:sec
Maximum Height	500	mm
Estimate of draw down distance	2	m
Estimate of max travel up beach	4.5	m
Duration of event	4:24	sec
Time for Wave to Reach Shore	2:18	sec

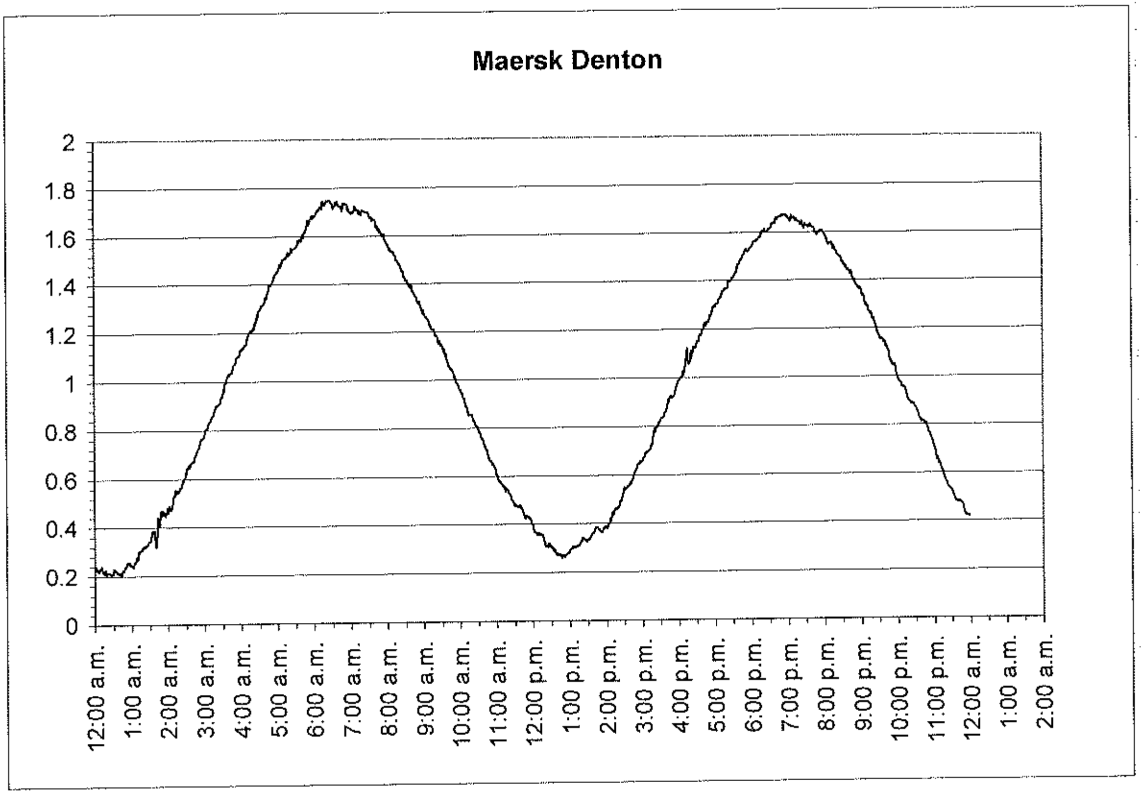
Observed Wake Data

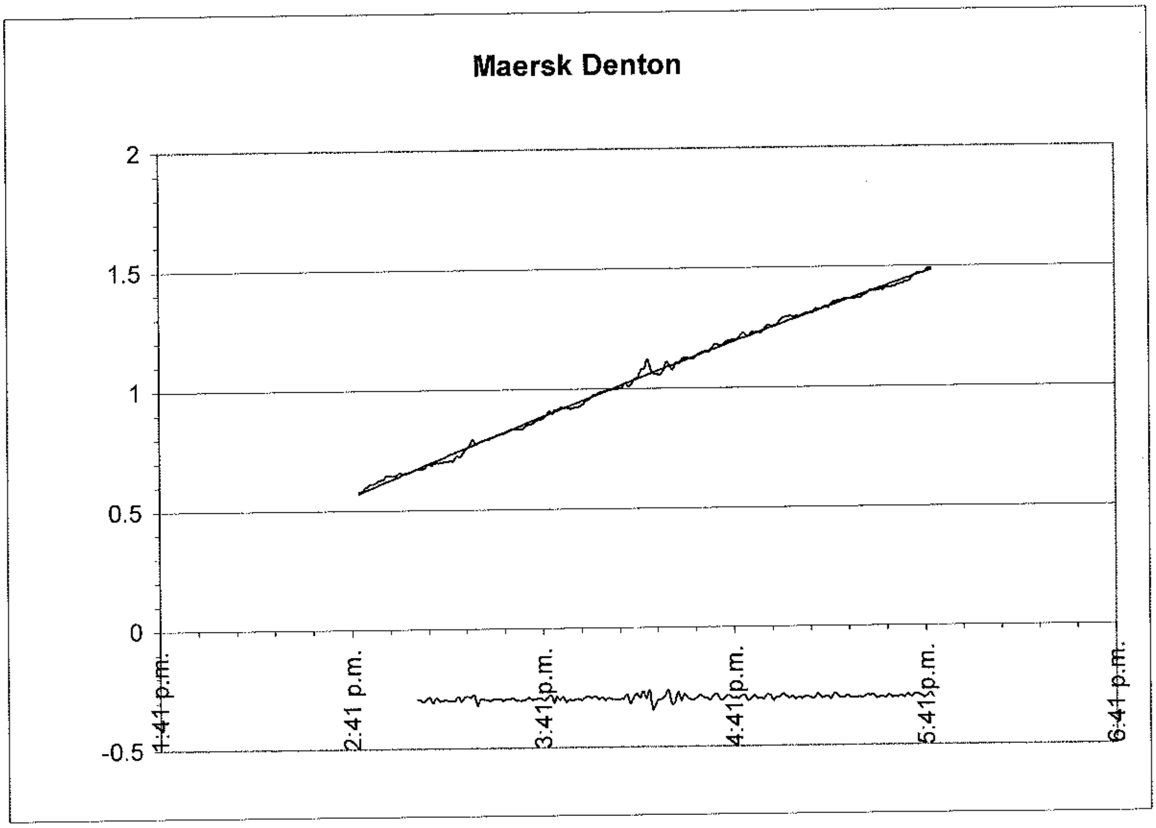
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Maersk Denton
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 a.m.
1:00 a.m.
2:00 a.m.
3:00 a.m.
4:00 a.m.
5:00 a.m.
6:00 a.m.
7:00 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
1:00 p.m.
2:00 p.m.
3:00 p.m.
4:00 p.m.
5:00 p.m.
6:00 p.m.
7:00 p.m.
8:00 p.m.
9:00 p.m.
10:00 p.m.
11:00 p.m.
12:00 a.m.
1:00 a.m.
2:00 a.m.


Maersk Denton
2
1.5
1
0.5
0
-0.5
1:41 p.m.
2:41 p.m.
3:41 p.m.
4:41 p.m.
5:41 p.m.
6:41 p.m.

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data

LOCATION:	Te Rauone	obs
DATE:	9/10/09	obs
TIME START:	9:15	obs
TIME END:	9:35	obs
WEATHER:	very cloudy	obs
WIND:	light NW	obs / POL
WAVE:	small 50mm	obs / POL

Vessel Data

NAME:	Milburn Carrier II	obs
TRAVEL DIR.	ARR / [✓ DEP]	obs
DRAFT:	5·30	POL
TONNAGE:	8465	POL
LENGTH	112·4	POL
SPEED:	11·5	POL
TIDE HGT:	1·52	POL
TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	9:23	hh:mm:sec
Bow Past Fixed Point	0	sec
Stern Past Fixed Point	19	sec
Time of 1st Wake Wave	2:12	mm:sec
Height of 1st Wake Wave	70mm	mm
Time of Last Wake Wave	6·50	mm:sec

Maximum Height	150	mm
Estimate of draw down distance	1	m
Estimate of max travel up beach	1	m
Duration of event	6:50	sec
Time for Wave to Reach Shore	2:12	sec

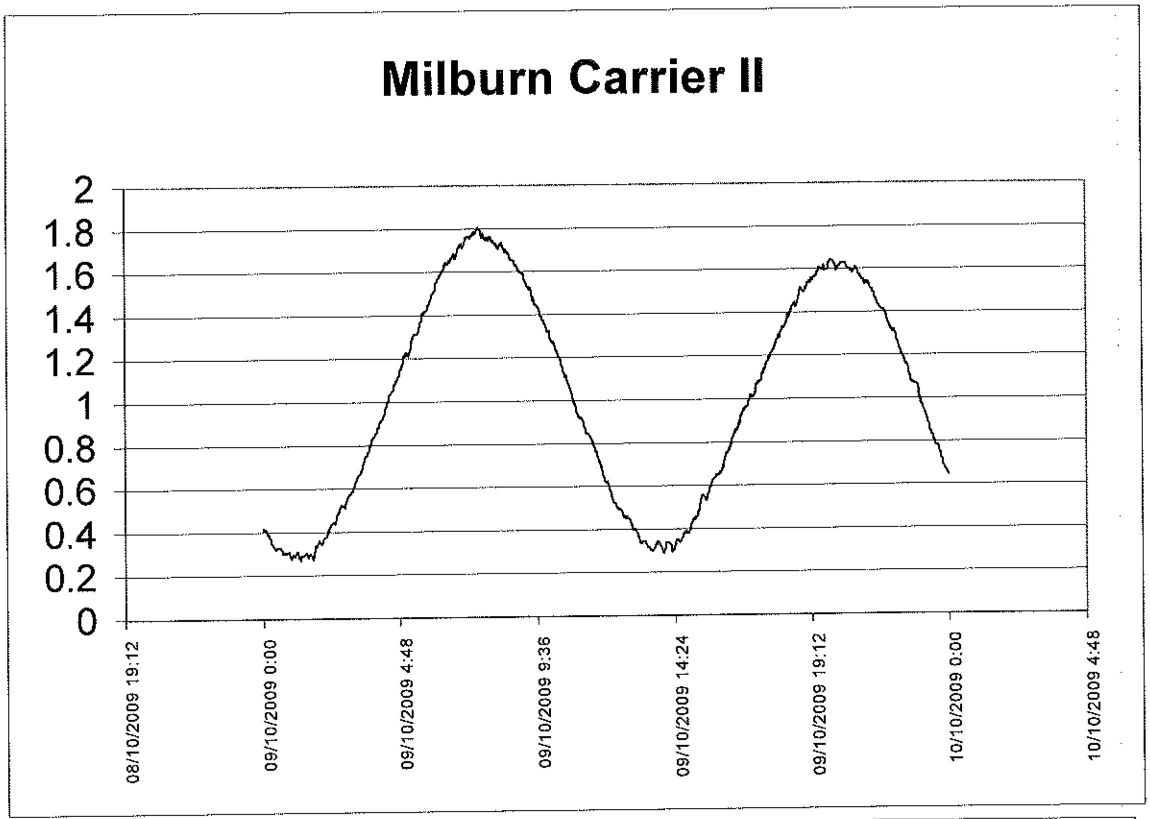
Observed Wake Data

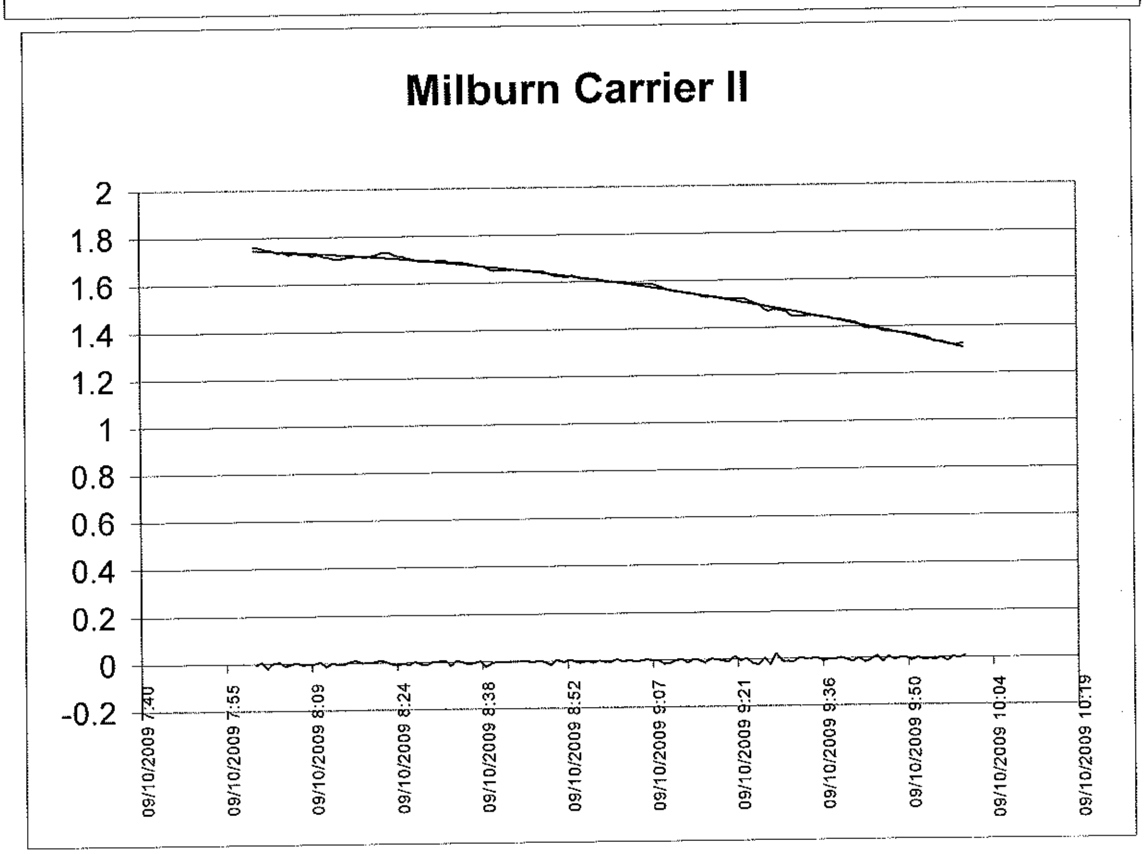
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Milburn Carrier II
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
08/10/2009 19:12
09/10/2009 0:00
09/10/2009 4:48
09/10/2009 9:36
09/10/2009 14:24
09/10/2009 19:12
10/10/2009 0:00
10/10/2009 4:48


Milburn Carrier II
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
09/10/2009 7:40
09/10/2009 7:55
09/10/2009 8:09
09/10/2009 8:24
09/10/2009 8:38
09/10/2009 8:52
09/10/2009 9:07
09/10/2009 9:21
09/10/2009 9:36
09/10/2009 9:50
09/10/2009 10:04
09/10/2009 10:19

Site Observation Form

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Rehua	obs
DATE:	12/10/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	9:00	obs	DRAFT:	7.10	POL
TIME END:	9:20	obs	TONNAGE:	2483	POL
WEATHER:	Sunny w/clouds	obs	LENGTH	60.77	POL
WIND:	light - none	obs / POL	SPEED:	13.1 kN	POL
WAVE:	small 70mm	obs / POL	TIDE HGT:	1.56	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	9:08	hh:mm:sec	Maximum Height	120	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	9	sec	Estimate of max travel up beach	2.5	m
Time of 1st Wake Wave	1:27	mm:sec	Duration of event	7:30	sec
Height of 1st Wake Wave	70	mm	Time for Wave to Reach Shore	1:27	sec
Time of Last Wake Wave	7:30	mm:sec			

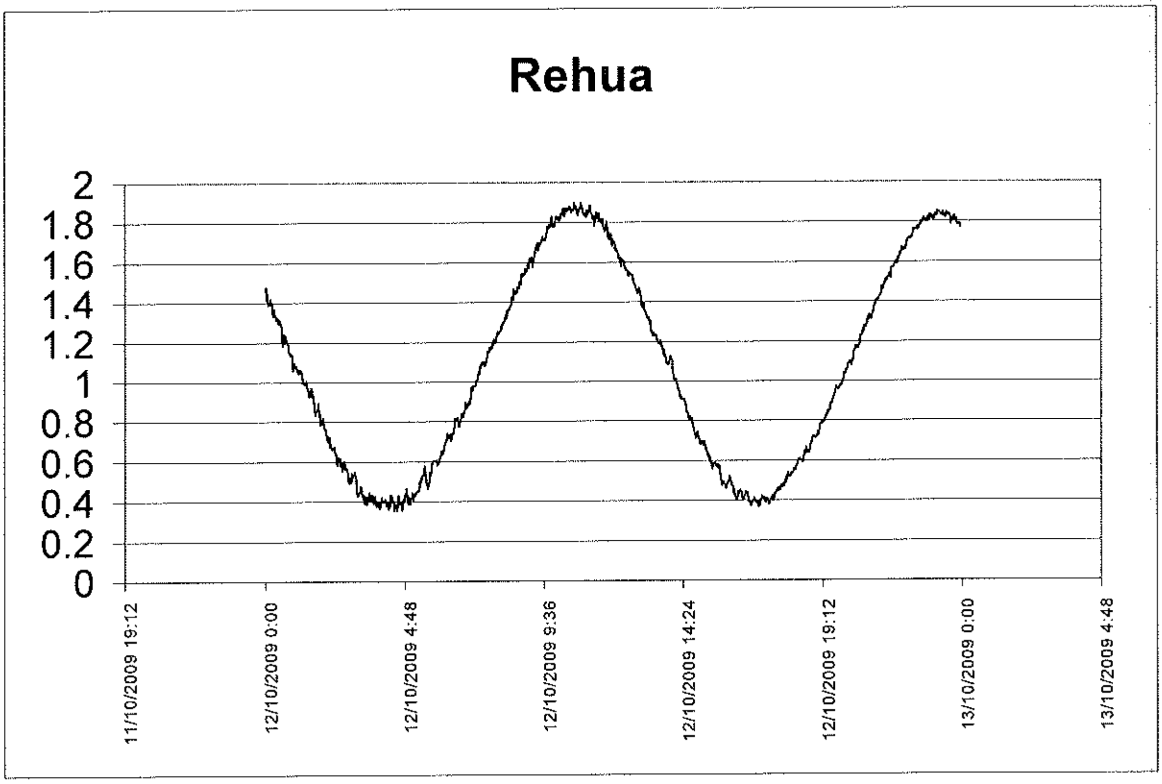
Observed Wake Data

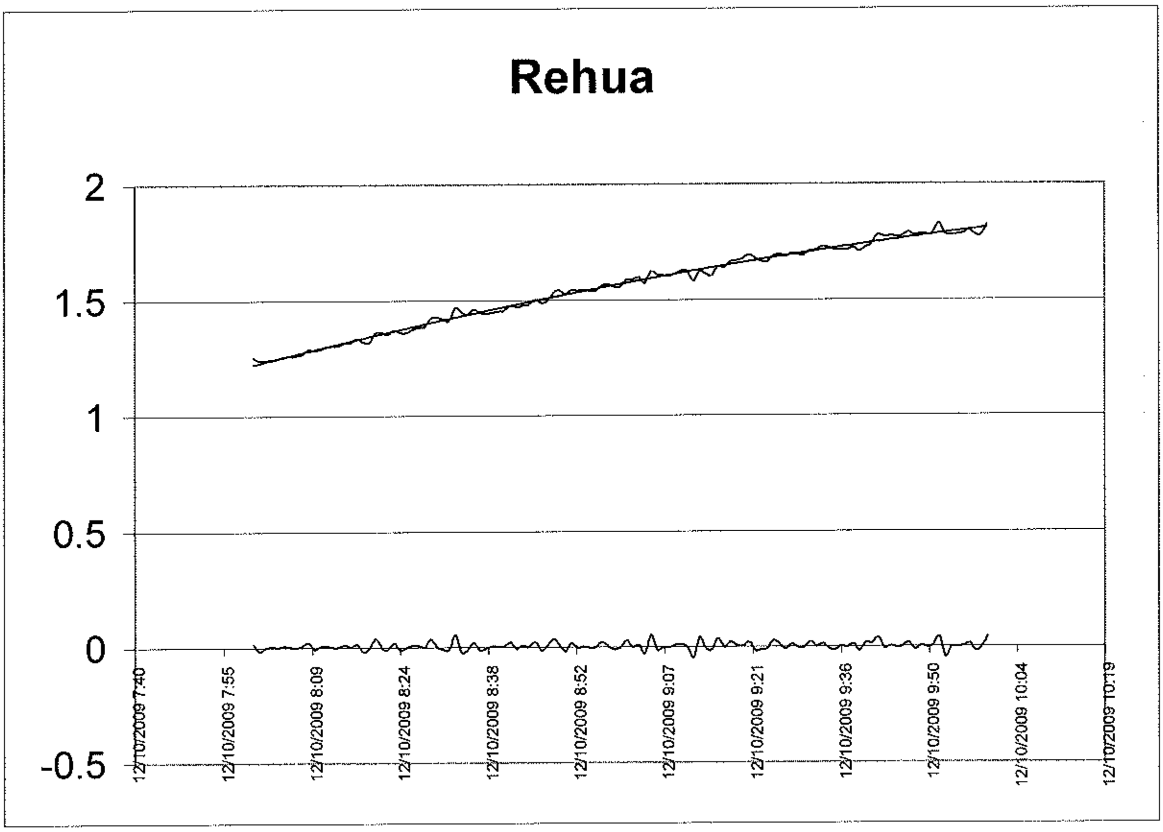
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	Started at undergrowth
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Rehua
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
11/10/2009 19:12
12/10/2009 0:00
12/10/2009 4:48
12/10/2009 9:36
12/10/2009 14:24
12/10/2009 19:12
13/10/2009 0:00
13/10/2009 4:48


Rehua
2
1.5
1
0.5
0
-0.5
12/10/2009 7:40
12/10/2009 7:55
12/10/2009 8:09
12/10/2009 8:24
12/10/2009 8:38
12/10/2009 8:52
12/10/2009 9:07
12/10/2009 9:21
12/10/2009 9:36
12/10/2009 9:50
12/10/2009 10:04
12/10/2009 10:19

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Maersk Fukuoka	obs
DATE:	13/10/09	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:	4:10	obs	DRAFT:	7.30	POL
TIME END:		obs	TONNAGE:	11815	POL
WEATHER:	Sunny w/clouds	obs	LENGTH	139	POL
WIND:	none	obs / POL	SPEED:	11.3	POL
WAVE:	50-100mm	obs / POL	TIDE HGT:	0.44	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	5:00	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	5	m
Stern Past Fixed Point	24	sec	Estimate of max travel up beach	2.3	m
Time of 1st Wake Wave	50sec	mm:sec	Duration of event	6:00	sec
Height of 1st Wake Wave	100-120	mm	Time for Wave to Reach Shore	50	sec
Time of Last Wake Wave	6:00	mm:sec			

Observed Wake Data

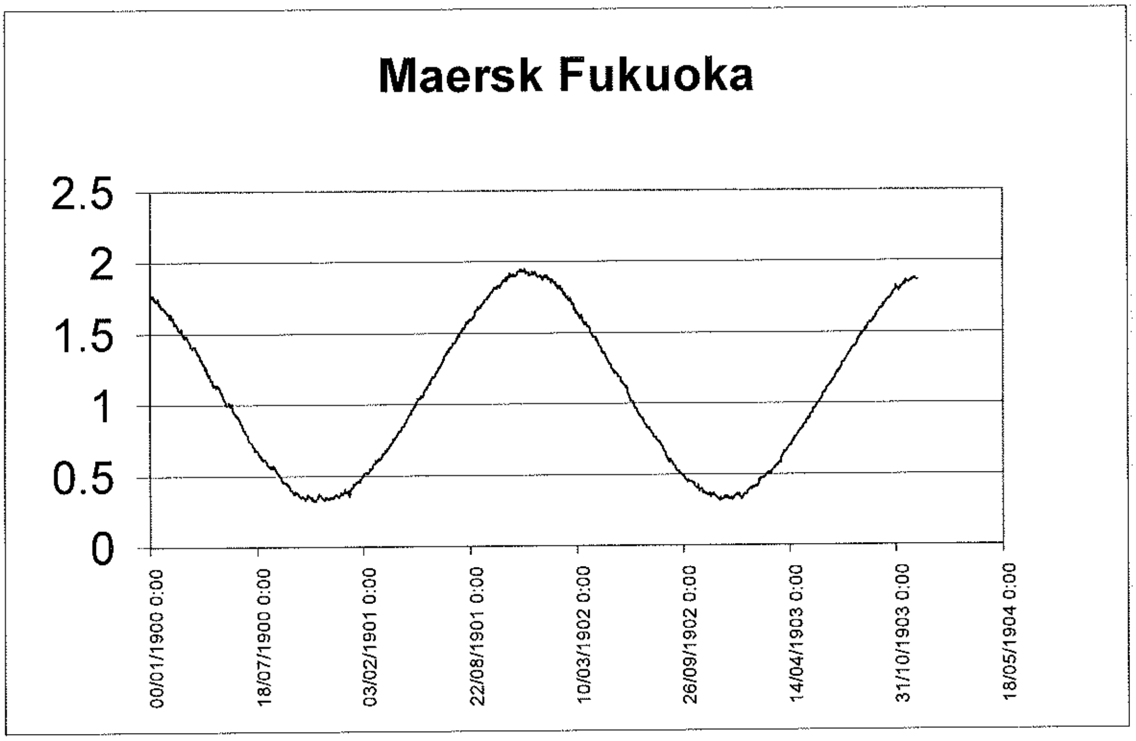
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

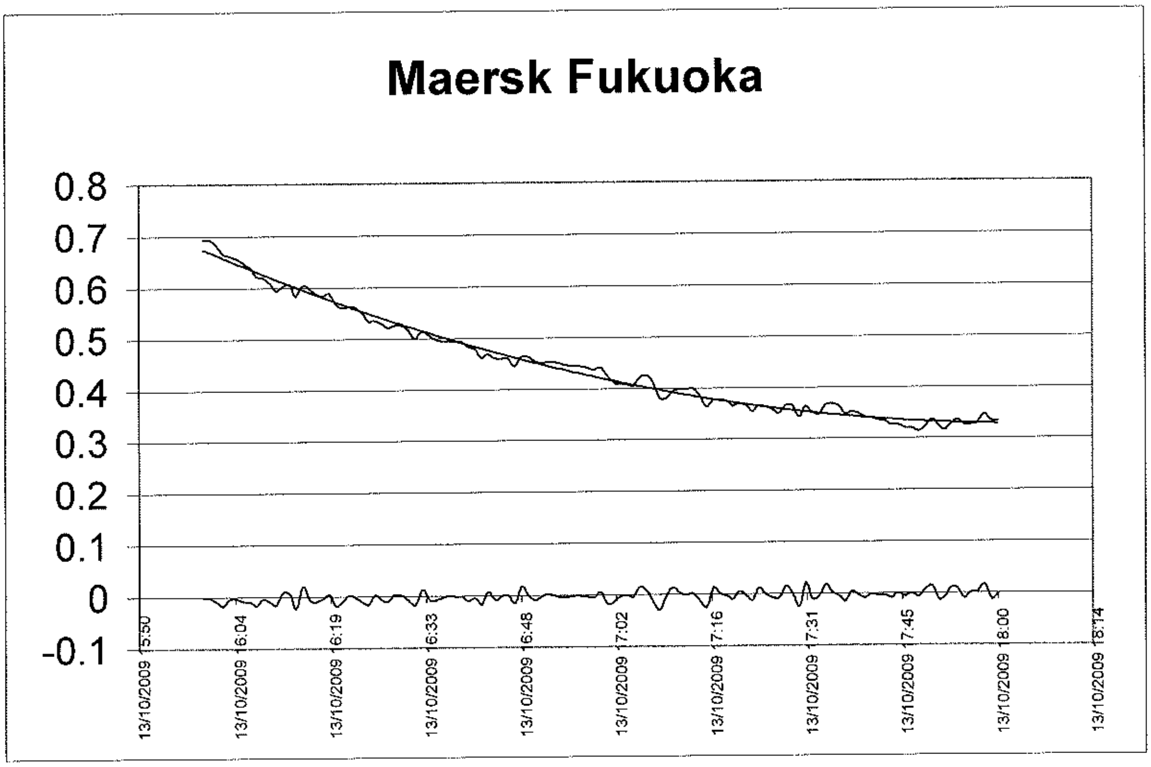
DISCUSSION / COMMENTS:

Hard to tell when wake actually stopped as wake was very small and did not have a hugely different pattern to regular waves.

Observed by:

Observed by:


Maersk Fukuoka
2.5
2
1.5
1
0.5
0
00/01/1900 0:00
18/07/1900 0:00
03/02/1901 0:00
22/08/1901 0:00
10/03/1902 0:00
26/09/1902 0:00
14/04/1903 0:00
31/10/1903 0:00
18/05/1904 0:00


Maersk Fukuoka
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
13/10/2009 15:50
13/10/2009 16:04
13/10/2009 16:19
13/10/2009 16:33
13/10/2009 16:48
13/10/2009 17:02
13/10/2009 17:16
13/10/2009 17:31
13/10/2009 17:45
13/10/2009 18:00
13/10/2009 18:14

Site Observation Form

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PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	TE RAUONE	obs	NAME:	CRIMSON JUPITER	obs
DATE:	16-10-2009	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:	1:58	obs	DRAFT:	8.40	POL
TIME END:	3:20	obs	TONNAGE:	48205 DWT	POL
WEATHER:	SUNNY / CLOUDY	obs	LENGTH	191.5	POL
WIND:	LIGHT / MOD SE	[✓ obs] / ~~POL~~	SPEED:	8.7 KN	POL
WAVE:	50 - 100 mm	[✓ obs] / ~~POL~~	TIDE HGT:	2.19	POL
			TIDE STATE:	HIGH - EBB	POL

Measured Wake Data

Time of vessel pass	15:00	hh:mm:sec	Maximum Height	150	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	1	m
Stern Past Fixed Point	43	sec	Estimate of max travel up beach	2	m
Time of 1st Wake Wave	1:51	mm:sec	Duration of event	8:51	sec
Height of 1st Wake Wave	100 mm	mm	Time for Wave to Reach Shore	1:51	sec
Time of Last Wake Wave	8:51	mm:sec			

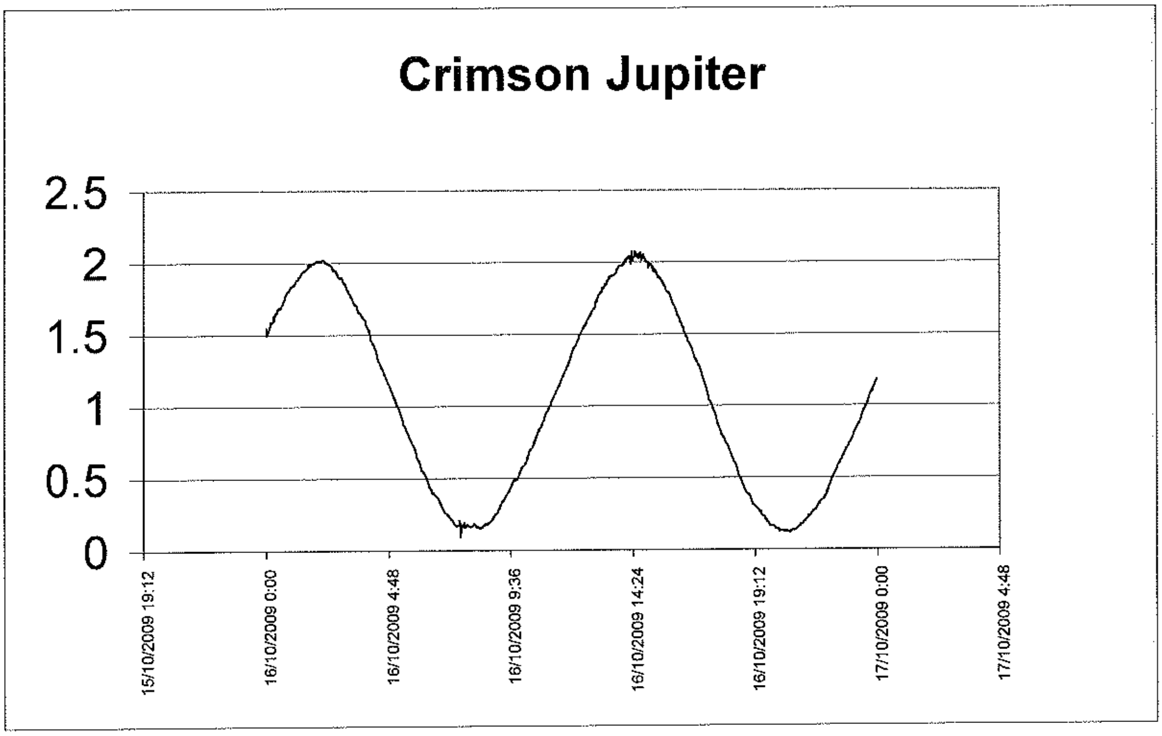
Observed Wake Data

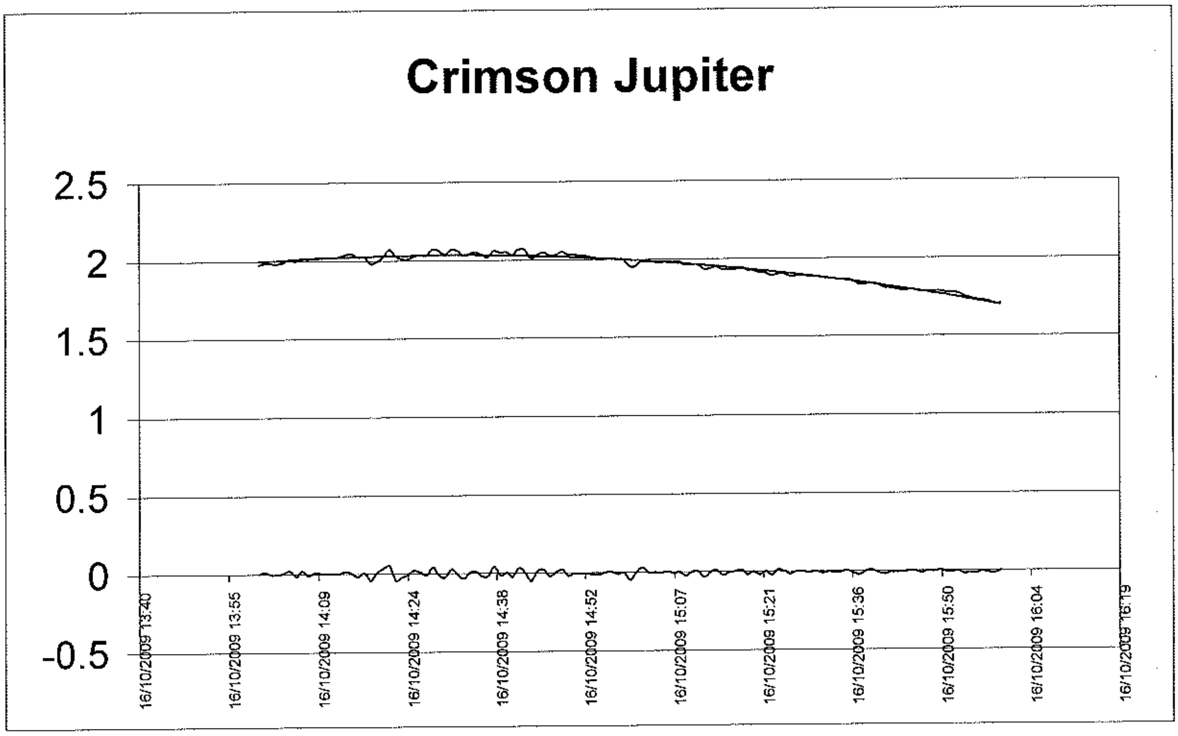
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	STARTED AT UNDERGROWTH
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by: FRASER CAMERON

Observed by:


Crimson Jupiter
2.5
2
1.5
1
0.5
0
15/10/2009 19:12
16/10/2009 0:00
16/10/2009 4:48
16/10/2009 9:36
16/10/2009 14:24
16/10/2009 19:12
17/10/2009 0:00
17/10/2009 4:48


Crimson Jupiter
2.5
2
1.5
1
0.5
0
-0.5
16/10/2009 13:40
16/10/2009 13:55
16/10/2009 14:09
16/10/2009 14:24
16/10/2009 14:38
16/10/2009 14:52
16/10/2009 15:07
16/10/2009 15:21
16/10/2009 15:36
16/10/2009 15:50
16/10/2009 16:04
16/10/2009 16:19

Site Observation Form

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PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data | Vessel Data

LOCATION:	TE RAUONE	obs	NAME:	MAERSK DAMASCUS	obs
DATE:	16-10-2009	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:	13:58	obs	DRAFT:	12.30	POL
TIME END:	15:20	obs	TONNAGE:	53081 DWT	POL
WEATHER:	SUNNY W/CLOUDS	obs	LENGTH	268	POL
WIND:	LIGHT SE	[✓ obs] / ~~POL~~	SPEED:	8.1 KN	POL
WAVE:	SMALL 30-50	obs / POL	TIDE HGT:	2.12	POL
			TIDE STATE:	HIGH - SLACK	POL

Measured Wake Data

Time of vessel pass	14:14	hh:mm:sec	Maximum Height	200	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	2.5 - 3	m
Stern Past Fixed Point	1:04	sec	Estimate of max travel up beach	2.5 - 3	m
Time of 1st Wake Wave	1:49	mm:sec	Duration of event	12:40	sec
Height of 1st Wake Wave	50-80	mm	Time for Wave to Reach Shore	1:49	sec
Time of Last Wake Wave	12:40	mm:sec			

Observed Wake Data

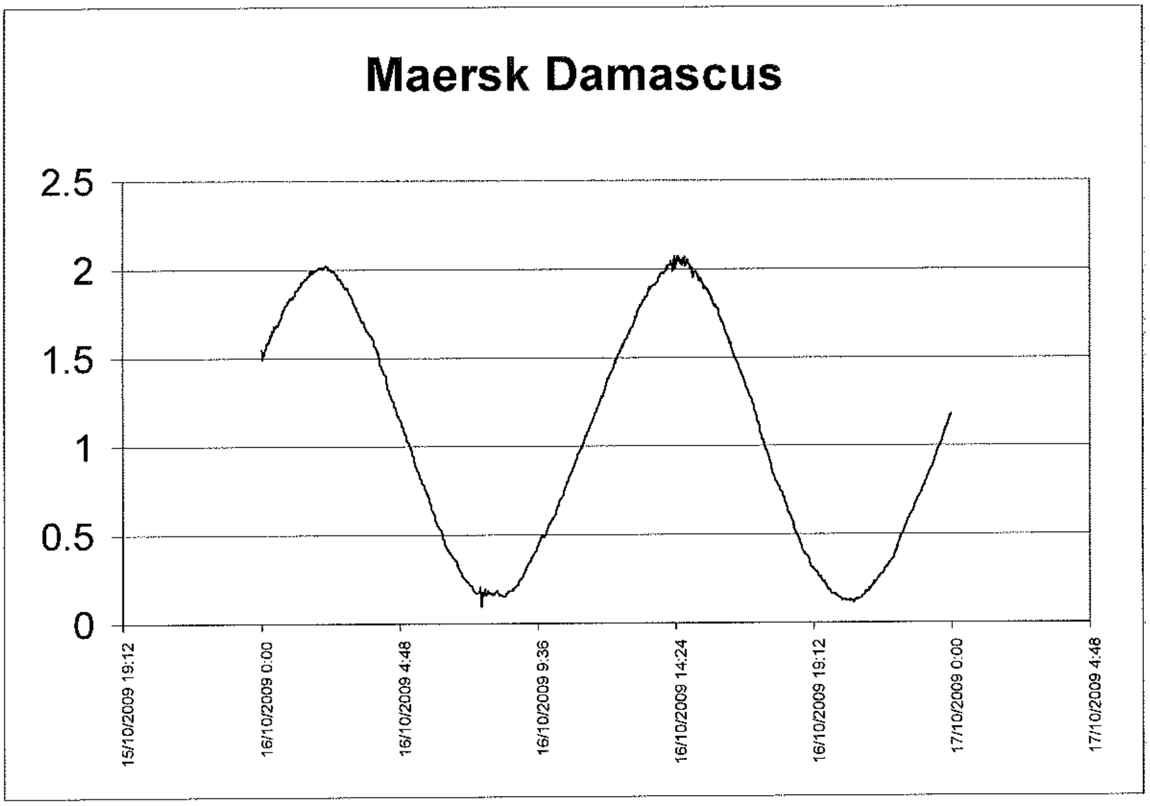
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	YES / [✓ NO]	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	[✓ YES] / NO	STARTED AT UNDERGROWTH
Does the wake cause any noticeable dune erosion	[✓ YES] / NO	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

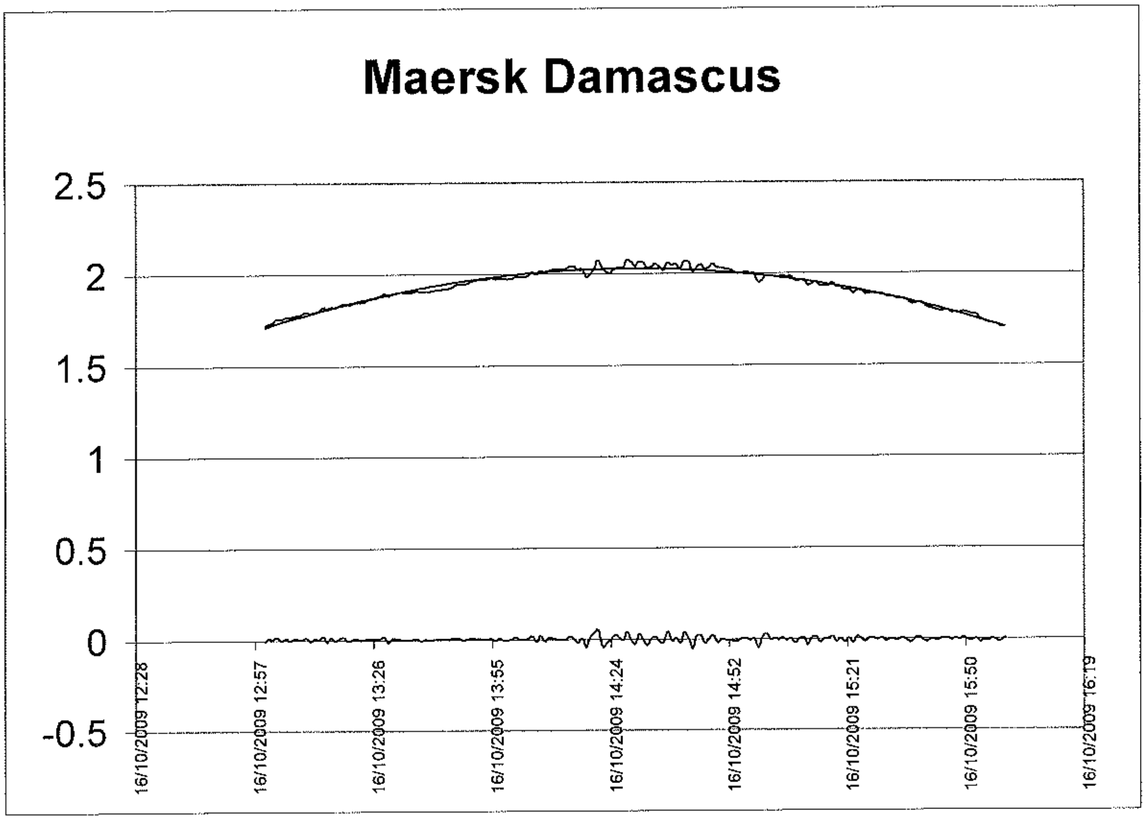
DISCUSSION / COMMENTS:

WHEN MAIN WAKE HAD PASSED IT WAS HARD TO TELL WHETHER WAVES HAD INCREASED IN SIZE (AS I DID NOTICE WIND PICKED UP) OR IF IT WAS JUST THE END OF THE WAKE. BECAUSE OF THIS DURATION OF THE EVENT COULD HAVE BEEN AS LOW AS 9 MINUTES.

Observed by: FRASER CAMERON

Observed by:


Maersk Damascus
2.5
2
1.5
1
0.5
0
15/10/2009 19:12
16/10/2009 0:00
16/10/2009 4:48
16/10/2009 9:36
16/10/2009 14:24
16/10/2009 19:12
17/10/2009 0:00
17/10/2009 4:48


Maersk Damascus
2.5
2
1.5
1
0.5
0
-0.5
16/10/2009 12:28
16/10/2009 12:57
16/10/2009 13:26
16/10/2009 13:55
16/10/2009 14:24
16/10/2009 14:52
16/10/2009 15:21
16/10/2009 15:50
16/10/2009 16:19

Site Observation Form

PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	Te Rauone	obs	NAME:	Vega Gotland	obs
DATE:	19/10/09	obs	TRAVEL DIR.	[✓ ARR] / DEP	obs
TIME START:		obs	DRAFT:	7·90	POL
TIME END:		obs	TONNAGE:	13806	POL
WEATHER:	Overcast, Drizzle	obs	LENGTH	140·3	POL
WIND:	Mod NW	obs / POL	SPEED:	11·9 kN	POL
WAVE:	Small 50mm	obs / POL	TIDE HGT:	0·25	POL
			TIDE STATE:		POL

Measured Wake Data

Time of vessel pass	11:05	hh:mm:sec	Maximum Height	100	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance		m
Stern Past Fixed Point	23	sec	Estimate of max travel up beach	40	m
Time of 1st Wake Wave		mm:sec	Duration of event	7:26	sec
Height of 1st Wake Wave		mm	Time for Wave to Reach Shore		sec
Time of Last Wake Wave	7:26	mm:sec			

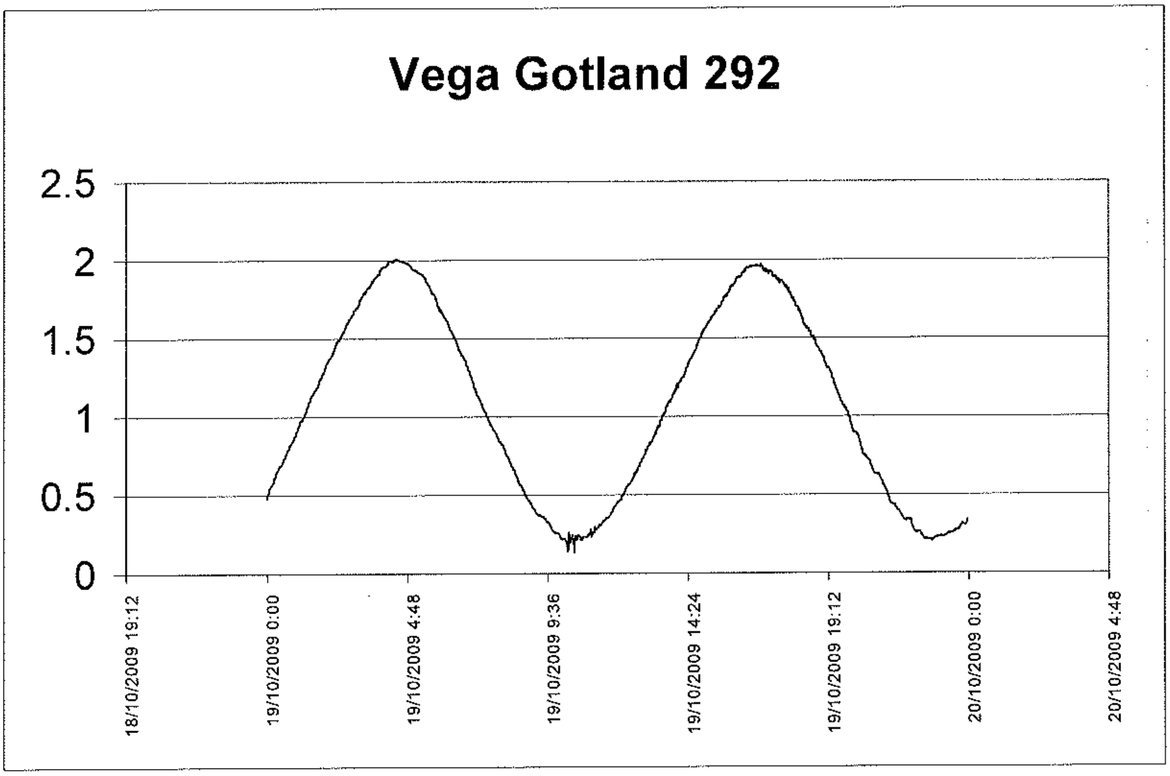
Observed Wake Data

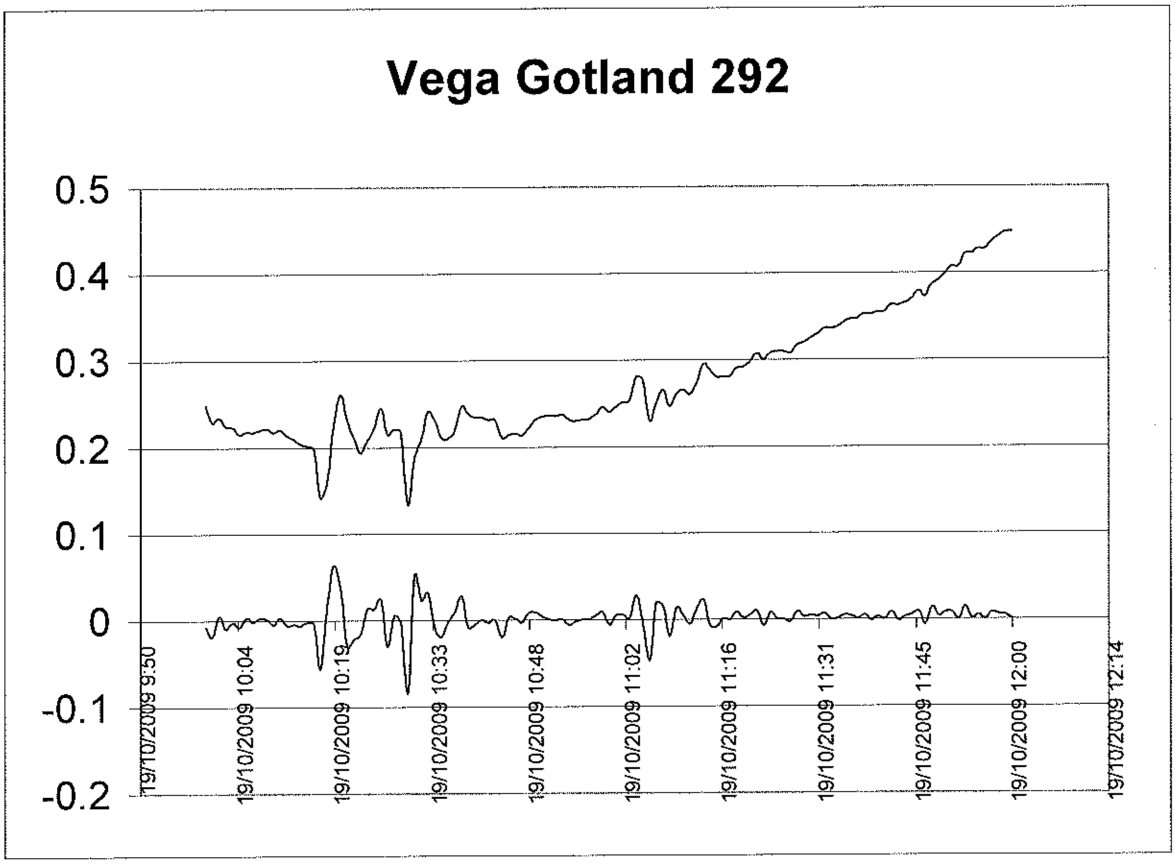
Change in wave period	[✓ YES] / NO	***Comments***
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

DISCUSSION / COMMENTS:

Observed by:

Observed by:


Vega Gotland 292
2.5
2
1.5
1
0.5
0
18/10/2009 19:12
19/10/2009 0:00
19/10/2009 4:48
19/10/2009 9:36
19/10/2009 14:24
19/10/2009 19:12
20/10/2009 0:00
20/10/2009 4:48


Vega Gotland 292
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
19/10/2009 9:50
19/10/2009 10:04
19/10/2009 10:19
19/10/2009 10:33
19/10/2009 10:48
19/10/2009 11:02
19/10/2009 11:16
19/10/2009 11:31
19/10/2009 11:45
19/10/2009 12:00
19/10/2009 12:14

Site Observation Form

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PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	TE RAUONE	obs	NAME:	CRIMSON JUPITER	obs
DATE:	19-10-2009	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:	10:00 am	obs	DRAFT:	11.03	POL
TIME END:		obs	TONNAGE:	48205 DWT	POL
WEATHER:	OVERCAST / DRIZZLE	obs	LENGTH	191.5	POL
WIND:	MOD. N.	[✓ obs] / POL	SPEED:	9.3 KNOTS	POL
WAVE:	30-50mm (SMALL)	[✓ obs] / POL	TIDE HGT:	0.20 m	POL
			TIDE STATE:	LOW FLOOD (START)	POL

Measured Wake Data

Time of vessel pass	10:13	hh:mm:sec	Maximum Height	100	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	N/A	m
Stern Past Fixed Point	40	sec	Estimate of max travel up beach	30-40	m
Time of 1st Wake Wave	0	mm:sec	Duration of event	11:43	sec
Height of 1st Wake Wave	100	mm	Time for Wave to Reach Shore	—	sec
Time of Last Wake Wave	11:43	mm:sec			

Observed Wake Data

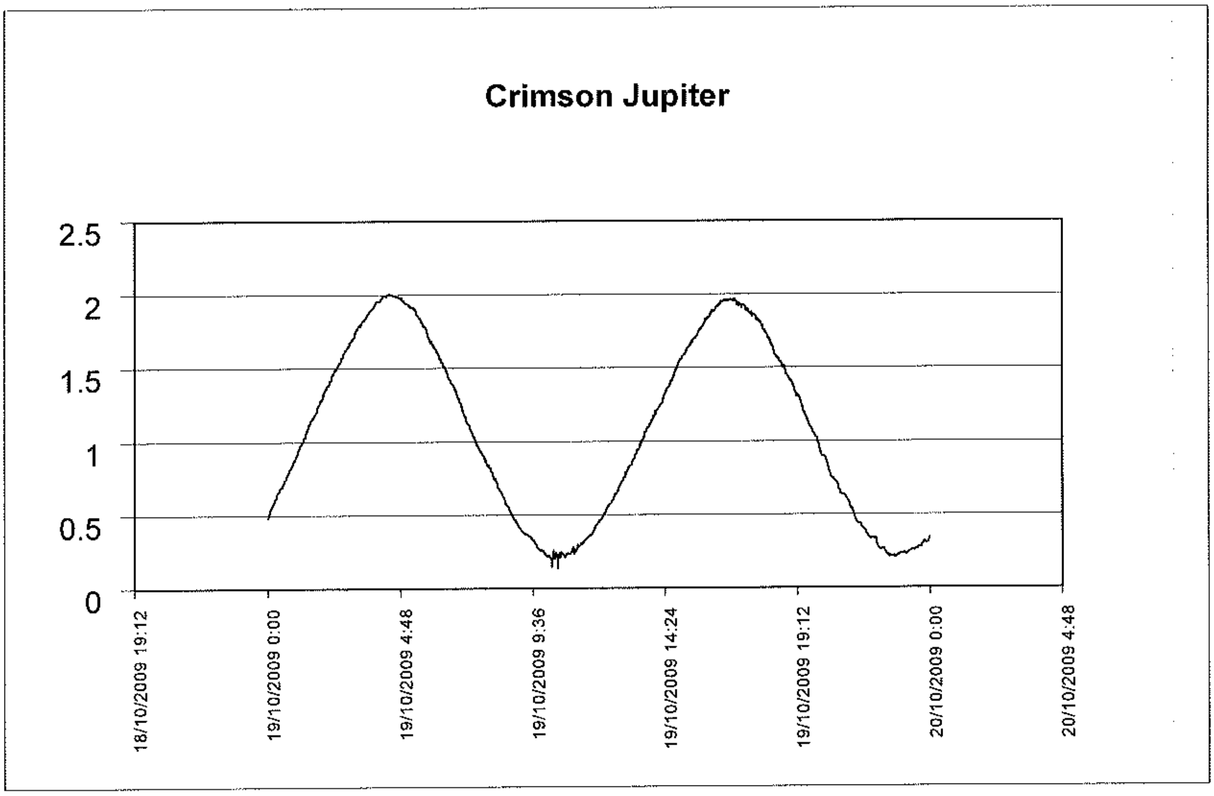
		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

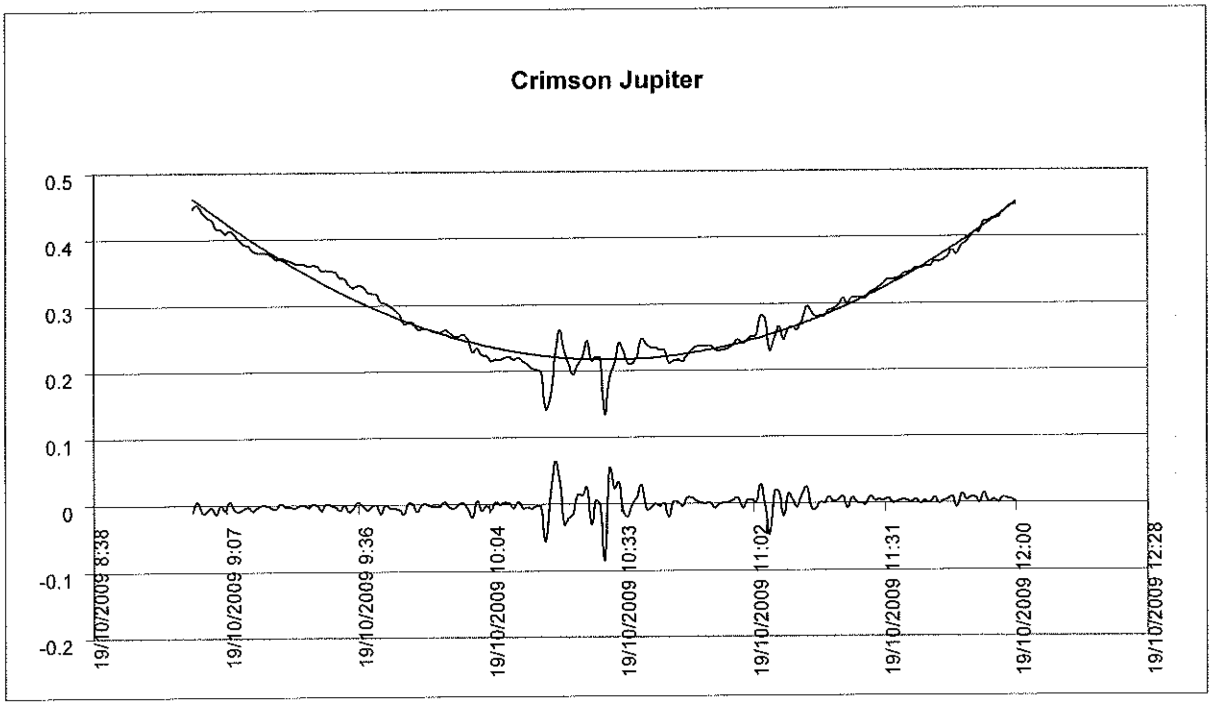
DISCUSSION / COMMENTS:

WITH THE TIDE SO LOW WAKE HIT SHORE BEFORE BOAT HIT MARKER

Observed by: F. CAMERON

Observed by:


Crimson Jupiter


Crimson Jupiter

Site Observation Form

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PORT OTAGO LIMITED

PROJECT NEXT GENERATION - VESSEL WAKE MEASUREMENTS

Physical Environment Data			Vessel Data		
LOCATION:	TE RAUONE	obs	NAME:	MSC SARDINIA	obs
DATE:	19-10-2009	obs	TRAVEL DIR.	ARR / [✓ DEP]	obs
TIME START:		obs	DRAFT:	9.10	POL
TIME END:		obs	TONNAGE:	43270	POL
WEATHER:	OVERCAST/DRIZZLE	obs	LENGTH	224.01	POL
WIND:	MOD. N.	[✓ obs] / ~~POL~~	SPEED:	9.3 KN.	POL
WAVE:	30-50mm	[✓ obs] / ~~POL~~	TIDE HGT:	0.22	POL
			TIDE STATE:	LOW - FLOOD	POL

Measured Wake Data

Time of vessel pass	10:26	hh:mm:sec	Maximum Height	100	mm
Bow Past Fixed Point	0	sec	Estimate of draw down distance	–	m
Stern Past Fixed Point	47	sec	Estimate of max travel up beach	30-40	m
Time of 1st Wake Wave	0	mm:sec	Duration of event	9:43	sec
Height of 1st Wake Wave		mm	Time for Wave to Reach Shore		sec
Time of Last Wake Wave	9:53	mm:sec			

Observed Wake Data

		Comments
Change in wave period	[✓ YES] / NO	
Change in approach angle	[✓ YES] / NO	
Does the wake create sand in motion	[✓ YES] / NO	
Does the wake reach the base of the dunes	YES / [✓ NO]	
Does the wake cause any noticeable dune erosion	YES / [✓ NO]	
Photos taken	YES / [✓ NO]	
Video taken	[✓ YES] / NO	

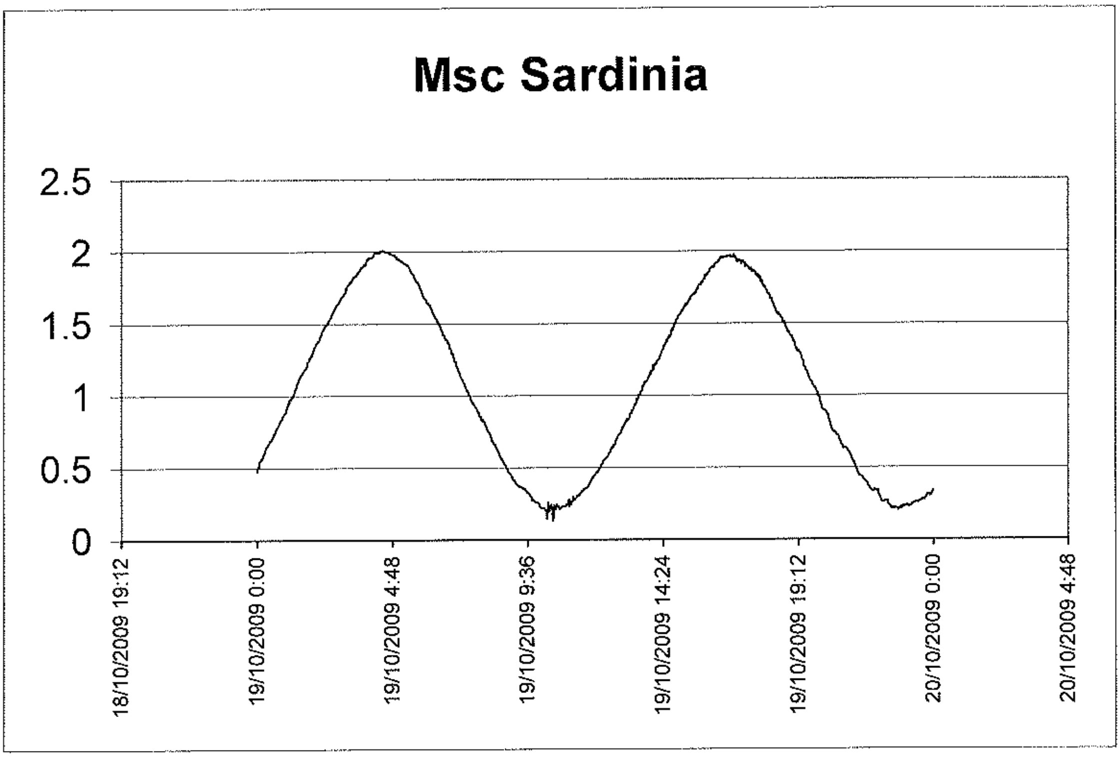
DISCUSSION / COMMENTS:

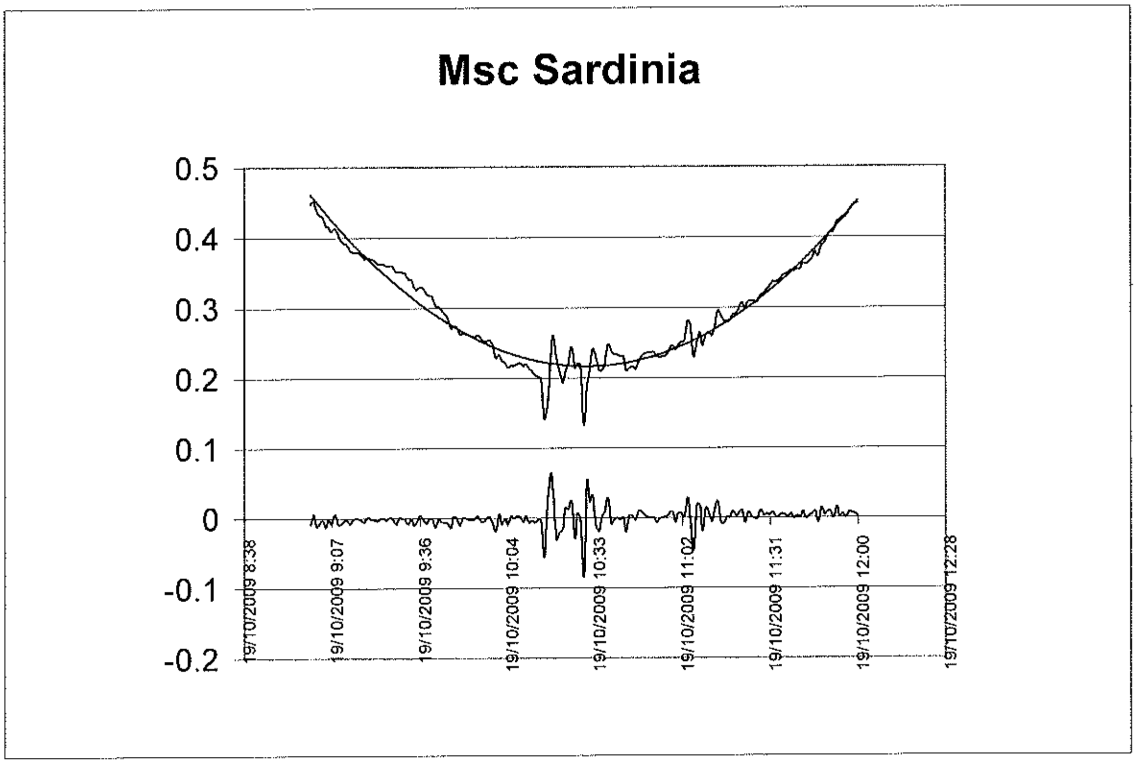
WITH LOW TIDE WAKE ARRIVED BEFORE BOAT EVEN HIT MARKER.

CRIMSON JUPITER WAKE WAS STILL GOING WHEN PASSED.

Observed by: F. CAMERON.

Observed by:


Msc Sardinia
2.5
2
1.5
1
0.5
0
18/10/2009 19:12
19/10/2009 0:00
19/10/2009 4:48
19/10/2009 9:36
19/10/2009 14:24
19/10/2009 19:12
20/10/2009 0:00
20/10/2009 4:48


Msc Sardinia
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
19/10/2009 8:38
19/10/2009 9:07
19/10/2009 9:36
19/10/2009 10:04
19/10/2009 10:33
19/10/2009 11:02
19/10/2009 11:31
19/10/2009 12:00
19/10/2009 12:28