EXPERIENCE USING A DYNAMIC UNDERKEEL CLEARANCE SYSTEM AT PORT TARANAKI, NEW ZEALAND[1]

by

Captain Ray Barlow, Operations Manager/Chief Pilot, Westgate Transport Ltd. (Port Taranaki), New Zealand

Dr. Terry O'Brien, Director, OMC International Pty. Ltd., Melbourne, Australia

Peter Atkinson, Manager, Duffill Watts & King Consulting Engineers, New Plymouth, New Zealand

CONTACT DETAILS:

Name:	Captain Ray Barlow	Dr. Terry O'Brien	P N Atkinson
Address:	Westgate Transport Ltd Breakwater Road New Plymouth New Zealand	OMC International P/L 2/2 Walmer Street Abbotsford, Victoria Australia	Duffill Watts & King P O Box 6017 New Plymouth New Zealand
Phone:	+64 6 751 0200	+61 3 9428 6222	+64 6 759 8457
Fax:	+64 6 751 0886	+61 3 9428 6900	+64.6.759 8467
Email	rbarlow@westgate.co.nz	terry@omc-international.com.au	dwk.newplymouth@duffillwatts.com

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SUMMARY

The paper describes the studies that have been undertaken and the experience that has been gained since December 1999 in the development and operation of a Dynamic Underkeel Clearance (DUKC) system at Port Taranaki, New Zealand.

The major topics covered in the paper include:

- The influence of new deep-draught container services on Port Taranaki's traditional role of providing port facilities for New Zealand's offshore oil and gas industry, with particular emphasis on the need to deepen the approach channels and berth pockets to meet these new demands;
- Preliminary studies undertaken to assess UKC requirements for the new container liners, as well as for existing methanol and crude tankers using the port;
- Wave climate and transformation studies, combined with ship motion modelling studies, to assess the potential benefits of installing a DUKC system at the port;
- Customisation, testing and implementation of OMC's DUKC system for the wave and tide conditions, channel configuration and shipping at Port Taranaki;
- Assessment of the benefits which are available to container lines and petrochemical exporters at Port Taranaki using dynamic UKC methods for calculation of maximum vessel draughts and tidal windows, as compared with those obtained using existing static UKC rules;
- The application of meteorological and wave forecasting models to provide forecasts of wave conditions and their use in the DUKC system to predict the effect on maximum vessel loadings and tidal windows out to 36 hours prior to channel transit;
- The positive effects on safety by the use of the DUKC system in contrast to previous Static UKC rules;
- Use of DUKC technology to optimise the bed profile of the approach channel at Port Taranaki, thereby minimising the amount and cost of capital dredging operations.

1.0 INTRODUCTION

1.1 Port Taranaki - National & Regional Context

Port Taranaki is one of twelve ports handling New Zealand's international trade and the second largest export port by volume. It is a small breakwater harbour situated on the West Coast of the North Island of New Zealand, halfway between Auckland and Wellington serving the business of the city of New Plymouth and the surrounding area.

1.2 Environment

The breakwaters provide protection from the swells of the Tasman Sea and the Southern Ocean assisted by the position of the offshore islands.

The entrance channel is 200m wide with a controlling depth of 10.6 metres below chart datum and has a 70 degree turn between the breakwaters and 330 metre turning circle. The dredged channel is short with the natural 12 m contour occurring some 400 m from the port entrance

The port experiences semidiurnal tide with a spring rang of 3.09 m and a neap range of 1.74 m

Immediately offshore of the port in a water depth of 25 m significant wave heights of 1.0 -1.5 m occur 25% of the time and wave heights greater than 2.0m occur for 19% of the time.

With the swell waves generally approaching the main breakwater from a north westerly direction and being diffracted/refracted by the end of the main breakwater vessels receive beam seas throughout their turn into the harbour and so can experience significant rolling and pitching increasing their effective draft during this passage.

Wave heights decrease very rapidly once the shelter of the breakwater is reached.

To manage the safe passage of vessels through the port approaches and entrance channel the port has historically adopted a static underkeel clearance rule of 2.5 m.

1.3 Historical Trades

Developed for servicing the Taranaki region's agricultural industry in the late 19th century it was the world's largest cheese export port in the 1960's. The agricultural trades gradually became containerised and a trend developed for them to be shipped through alternative New Zealand ports over the last 30 years. The major imports have been fertilizers over most of the period.

The discovery of oil and gas in the area in the 1970's and subsequent development of down stream processing caused, by the mid 80s, a change of focus from a predominantly agricultural into a mainly petrochemical port. Tonnages increased from 400,000 tonnes per annum in 1970 to more than 5,500,000 tonnes per annum today.

A significant dredging programme to support new petro-chemical volumes was undertaken during 1985-1988 to increase the operating draft to 11.0m. The seabed is an agglomerate of lahar laid volcanic debris containing a wide variety of randomly distributed materials from sands to mega-boulders. Unfortunately, the necessary depth was not achieved in the key entrance area as dredging had to be stopped because of a combination of cost overruns and structural changes in the New Zealand ports industry. The operating draft was consequently limited to 10 metres. This depth allowed 2.5m static under keel clearance at MHWN.

The petrochemical business is conducted over the Newton King Tanker Terminal, a two berth finger pier, and occupancy of the Terminal runs at approximately 53% on each berth, with at least one vessel occupying a berth 73% of the time. Various improvements in operating procedures have been put in place over the past 10 years and despite ship visits and total cargo volumes having increased nearly 40%, occupancy has only increased 5%.

The Tanker Terminal has a strategic importance in the New Zealand economy in that all the reticulated gas for the country has a significant amount of associated liquids produced with it and the only outlet for these liquids is the terminal (approximately 2,000,000 tpa). If the Terminal or port is out of commission with the limited storage full, then gas production has to cease, with the same consequent effect on the downstream 5000 tonne per day methanol plant.

Until recently, container trades have been a small part of the Port's business. Container vessels have been first load port calls, and have been easily accommodated within the existing controlling depths.

1.4 Emerging Trends

From time to time over recent years the port has received a number of enquiries from all its major market sectors about the possibility of either increasing depth for larger vessels or increasing the available operating windows for vessels at maximum draft.

With changes to the shipping contracts for dairy products, Port Taranaki became a prospect for larger container volumes provided it could handle vessels with departure drafts of up to 11.0 m. This was an excessive draft under the static underkeel clearance rules and could only be contemplated on MHWS tides in ideal conditions.

It has been the history of dredging in this port that such works have been difficult and expensive. Notwithstanding this fact, trends in shipping and the prospect of requiring increased depth for deeper draft vessels (both tankers and container vessels) raised the issue of further deepening being required in the near future. Studies on this subject revealed that the lead time for a dredging project would be long and the cost would be high.

The advent of DUKC provided an opportunity to achieve additional effective depth without significant quantities of capital dredging at very low cost (relative to capital dredging) and with a very short lead time. The only downside was that increased draft was variable according to the severity of wave conditions in the entrance.

Accordingly Westgate commissioned OMC to conduct a desk top study to assess the potential advantages of the system at Port Taranaki. Following that study (which is outlined below) the port commissioned the installation of a DUKC system in mid 2001

1.5 Implications For New Trades Of Underkeel Clearance Requirements

Starting in September 2001 Maersk-Sealand established new services with weekly calls at the port of ‘N’ Class vessels and similar, with drafts up to 11.0 metres on departure and 10.5 metres on arrival.

A new trade in refrigerated LPGs is planned to commence in 2005 which may well, with the implementation of DUKC for all vessels using the Terminal, be able to be accommodated on the existing berths and obviate the need for investment in a new facility.

These drafts could not have been contemplated without the DUKC system and some associated dredging that flowed out of the desk study commissioned from OMC.

While the above benefits are immediate and obvious a very significant benefit is anticipated in the long term. It is highly likely that the port will require deepening at some time in the future. The ability to manage ship transits with DUKC is expected to reduce capital dredging requirements by the order of 50% which represents a potential saving in development cost of the order of fifteen million dollars.

2.0 WAVE STUDIES

2.1 Wave Climate Analysis

Being situated on the West Coast of New Zealand, the wave climate of the port is dominated by the west to east movement of weather systems across the Tasman Sea. The port is open to an essentially unlimited fetch (ie the generation of waves from this quarter are time limited not fetch limited) over a wide sector from due west to the north. Wave fields directed towards the port are generated:

1. Around an anticyclone ahead of an oncoming front. (Northerly airstream). Following these fronts the wind backs to the westerly quarter
2. Within depressions in which winds are sometimes from the northerly direction
3. By the west to east passage of mid-latitude depressions in which long fetches from the westerly quarter are evident.

Generally the passage of these mid-latitude depressions is of such speed that wave fields reach a fully arisen sea state only occasionally. (Harris 1988)

Since 1983 a great deal of wave data has been collected by a NBA Controls wave gauge mounted on a structure (wave tower) just outside the port entrance. In recent years further studies in support of environmental investigations have included the collection of directional data over a sixteen-month period at a site west of the port in 24 m water depth (L1 in fig 1) and at an inshore location outside the port entrance.(L2 in fig 1) These data enabled the derivation of reliable wave height ratios between the offshore site and the port entrance channel and the port's long term record from the wave tower. This provided good quality information for the desk study.

In general the offshore wave climate is dominated by long period (12-14 seconds) swell from the westerly quarter. The joint probability distribution of significant wave height (H_s) and peak wave period (T_P) indicates that the larger waves events (i.e $H_s > 2.0$ m) are associated with peak periods of approximately 10 seconds and with wave directions of around 125 degrees. In fact, because of diffraction, the direction of wave advance varies across the port entrance channel through a narrow sector between 100 and 140 degrees. (McComb, 1999)

2.2 Real-time Wave Measurement, Analysis and Display

Westgate installed a replacement environmental monitoring system, (emSYS), in 1998. This system was developed by Buxton Tudor and Waugh, a local New Plymouth company, in conjunction with Westgate. The new single system was designed to record wind, wave, tide, sea temperature and barometric pressure.

The system is very versatile and allows the presentation of real-time as well as historical data. It can display data ranging from a single tide gauge to a full meteorological system. The displays are totally customisable to allow charts, dials or digital information. It allows for comparisons between real time and predicted data, or historical and current data as well as the assessment of tidal residuals. Data is recorded in the Dbase III format and can thus be easily viewed and imported into a number of software packages.

The whole system comprises six components. The first three are data retrieval, the next is the data logging computer and the last two parts are for data broadcasting.

Wave data and sea temperatures are recorded by a unit on the wave tower. Digital data packets are sent every minute via radio to the logging unit. Wind speed , direction and pressure are recorded at the lee breakwater and also sent via radio to the logger. These signals are received via a dedicated receiver /modem. Finally the tide gauge is hardwired to the logger through its own serial port.

The main logging unit is a Pentium 2 Linux Samba server with a shared data folder, connected to the main Westgate NT network. Initially Windows was used but was found to be unstable and prone to crashes when one of the sensor signals was lost. Generic device drivers are used and can be interfaced to most devices but customised drivers can be created. The Linux software also lends itself to external support via a dial up modem. Time keeping is crucial and Tardis software is used to synchronise the whole system, via the Internet, every hour. Tides and wind data is processed every minute, wave and spectral data every twenty minutes. The data is recorded in a number of daily databases, but others of longer time frames have been created for the DUKC systems requirements.

The broadcasting of data is over the network and any person on the network can view the data. Two computers however play a special role in broadcasting wind and tide data to external sources; one for the availability of data via telephone and the other via VHF. The latter is used by the pilots who can activate the system remotely from their VHF to retrieve real time data.

The emSYS system is still evolving and the next step is to create a warning system over specific spectral data frequencies to forewarn us of possible dangerous surge in the harbour.

2.3 Wave Transformation Modelling for DUKC system

Wave transformation modelling is carried out in the DUKC system from the real-time wave measurement location to all points along the transit. At Port Taranaki, wave refraction and friction are the dominant influences on the propagation on the offshore waves through the harbour entrance.

Relationships for the wave attenuation and direction at all points of the transit have been developed using the relationships provided in References 2 & 4.

For an outgoing vessel, the wave directions vary from on the head in the inner harbour to 70^o off the head in the vicinity of the critical UKC control point near the wave tower

3.0 UKC DESK STUDY

OMC International was commissioned by Westgate Transport Ltd. in late 1999 to conduct a desk study to assess the UKC requirements at Port Taranaki and the potential benefits of installing a Dynamic Underkeel Clearance (DUKC) system at the port.

A site visit was conducted between 7 – 12 December 1999 and involved undertaking five vessel transits inbound and outbound from Port Taranaki.

The major purpose of the desk study was to compute the UKC for each vessel on which transits were undertaken, using modelling techniques similar to those used in DUKC systems. These results were then compared with the values required under the existing UKC rules at Port Taranaki.

In addition to the results from the actual transits, comparisons between DUKC results and the existing port rules were made for a variety of swell conditions from very poor to very good. These comparisons provide a realistic indication of the benefits that a DUKC system could provide at Port Taranaki.

The major conclusions arising from the study were:

1. While the wave conditions at Port Taranaki can be severe, and in such conditions the existing UKC rules provide appropriate UKC margins, for the majority of the time the existing rules result in the loss of considerable tonnage and tidal windows.

2. A DUKC system at Port Taranaki would provide increases in maximum drafts in the order of 1.0m to 2.0m for export vessels and increase the width of tidal windows for import vessels by several hours, except when swell conditions were near operating limits for the port. In such conditions, the safety requirements built into a DUKC system would ensure that maximum drafts or tidal windows were consistent with international safety standards.

3. A real-time environmental system, including quality assurance of data, should be installed to continuously measure wave, tide and wind data and transfer such data in an appropriate format to the proposed DUKC system at 20 minute intervals. An appropriate backup of hardware and software should be provided to maintain continuity of DUKC service.

4. The study results should be used by Westgate Transport Ltd in planning future capital dredging works for Port Taranaki. The combined use of a DUKC system and capital dredging should be optimised to maximise port efficiency at minimum total cost.

4.0 DREDGING

4.1 Dredging Optimisation Study

Following acceptance of the findings of the UKC desk study, Westgate Transport commissioned OMC International to undertake two further desk studies during 2000/01:

1. Using the models developed during the UKC desk study, determine the optimum bed depth profile along the transit to minimise dredging volumes for a range of ship draughts and entry conditions.
2. For a selected bed depth of 10.6m in the critical outer section of the approach channel, analyse the downtime conditions due to swell for a Maersk "N" class container vessel of 11.0m draught entering or leaving the port within the hour of any high water.

The results of the above studies were used by Westgate Transport to increase the declared depths of the outer entrance channel and at the container vessel berths, as described below.

4.2 Capital Dredging Works

The sea bed in the harbour is of volcanic origin and has a difficult and expensive dredging history. After the '80's dredging campaign there remained a number of 'high spots' in the entrance channel in particular, these were mainly nests of boulders up to 2.0m in diameter. An assessment by diver of those spots controlling the depth in the channel showed that with minimal drilling and blasting the controlling depth could be increased by 0.6m.

This was executed in the summer of 2001 and debris removed by a barge mounted backhoe in the spring of the same year.

The berth pocket at the container terminal which was originally dredged by a bucket dredge in the late 1960's also required deepening from 10.5 metres to 12.0metres to accommodate the new container services this was accomplished by the backhoe and significant drilling and blasting of a sandstone ridge during the winter and spring of 2001.

Some clean up work was also carried out on one berth of the Tanker Terminal to provide depths of 12.0 metres alongside the berth.

5.0 DYNAMIC UKC SYSTEM AT PORT TARANAKI

5.1 DUKC Background

The **Dynamic UKC (DUKC)** concept and Australian applications up to early 2000 were summarised in a paper presented by Dr. O'Brien to the Second IHMA Congress in Dubai in April 2000 (Reference 1).

DUKC is a near real-time underkeel clearance prediction system for use at ports which have draft limitations on import or export ships. The DUKC system takes into account all of the major factors affecting underkeel clearance, including tidal residuals (measured height – predicted height), squat, heel and dynamic motions in waves, as described in O'Brien (1).

The system has two major functions:

- Maximisation of vessel drafts (export vessels)
- Determination of the earliest and latest times for entry into the port approach channel(s) (import vessels and export vessels sailing at less than maximum draft for the tide)

Traditionally, most ports in Australia and elsewhere have operated under fixed rules which govern the minimum under keel clearance (UKC) to permit safe transit along port approach channels. UKC requirements are generally calculated to cover a broad range of environmental conditions and vessel parameters. If the requirements are too conservative, ships carry less cargo than they could, and the operation is not as economic as it might be. At the other extreme, inadequate criteria could jeopardise safety. Because of their geographical situation on the coastline of an island continent, the approach channels of most Australian ports are subject to ocean swells generated by tropical cyclones or Southern Ocean storms.

Port Taranaki is in just such a situation and Fig 2 demonstrates the gains to be made by the application of DUKC technology as well as the limitations of relying on assessed static underkeel clearance rules.

In addition to knowledge of the ship dimensions and its stability parameters for the particular cargo and load condition, the following factors are essential to the UKC requirements of a vessel:

- Real-time tide levels along the transit, at the time of passing each critical UKC control point;
- Real-time wave heights, periods and directions along the transit and the associated UKC wave motion allowance for the particular ship and wave conditions, at the time of passing each critical UKC control point;
- Real-time current speed and direction along the transit and the associated effect on UKC wave motion allowances for the particular ship and wave/current interaction conditions, at the time of passing each critical UKC control point;
- Bed depth profiles across and along the channel, especially near each critical UKC control point, and effect of abrupt changes in bottom topography on vessel squat and heel;
- Vessel trim and its effect on squat and heel;
- Vessel speed through the water and over the ground (as affected by current speed and direction) and its effect on squat and heel;
- Vessel acceleration or deceleration through the water and its effect on squat and heel;
- Vessel position in the channel, heading and COG (course over ground).

DUKC systems utilise all the above factors using real-time tide, current and wave measurements taken prior to transit to determine the minimum safe under keel clearance along the complete transit from berth to deep water, thus taking advantage of favourable conditions and ensuring safety during unfavourable conditions.

Wave spectra, ship speed and water depths vary along the transit and the effect of these variations is computed by the numerical ship motion model used in each DUKC system. In addition, wave spectra and tidal residuals will change over time, and these effects are accounted for in each system. With respect to squat, individual ships and the pertinent characteristics of the complete approach channel are modelled in each DUKC system.

By measuring tide and wave data and using the actual measured values, as opposed to predictions, UKC calculations can be performed with a much greater degree of certainty for the conditions of any given day.

These systems allow ships to be loaded to greater draft or use wider tidal windows than is possible using fixed UKC rules, which are determined by safety requirements in extreme swells and negative tidal residuals. DUKC systems thus increase port productivity without the need for new port infrastructure or capital dredging and without compromising safety standards (all DUKC systems operate in accordance with internationally accepted safety criteria for bottom clearance and manoeuvrability requirements). This translates into significant savings to exporters, shipping companies and port authorities.

DUKC systems are customised for the vessel type, hydrography, tides and wave climate at each port. The system is designed to provide predictions up to 36 hours ahead to assist vessel loading and sailing scheduling. In the final hours before departure the DUKC system operates a Windows Monitor, which continuously updates sailing times and maximum drafts prior to sailing, enabling shippers to maximise cargo loadings while providing up-to-the-minute information for the ship handlers.

Since the first installation in 1993, research and development of the DUKC has continued and has been greatly assisted by continuing interaction between Harbour Masters, Pilots, port users and the design team. Full-scale field tests using highly accurate dual-frequency Differential GPS have been undertaken on over 70 vessels around Australia and abroad. These provide further validation of the predictive models used in the DUKC systems

The vessels tested have included bulk carriers, up to Cape size, tankers and container vessels. A six week field measurement program on over 10 container vessels has recently been undertaken at the Port of Melbourne, where swells up to 5m significant height interact with currents up to 7 knots at peak ebb tides. Further real-time testing targeting container vessels has also been undertaken in Auckland and New York/New Jersey.

The range of conditions at each of these ports varies considerably, including narrow channels, undulating sea floors and variations in tide and wave conditions. Each study has highlighted the sensitivity of squat to the local conditions and individual channel configuration.

5.2 Customisation, Testing and Implementation

Implementation of a DUKC system at Port Taranaki involved customisation of the DUKC software for the wave and tide conditions, channel configuration and bathymetry, ship motion models and other UKC related factors specific to the port. This work also involved development of software to input real time data from wave and tide measurement devices, as well as software to enable system operation to be maintained and monitored from OMC's office in Melbourne. Installation and testing of the total DUKC system was completed by OMC in August 2001.

Westgate Transport undertook extensive monitoring of the DUKC system during September – December 2001, during which period the system was fine-tuned by OMC on the basis of operational advice provided by Westgate.

The impetus for the installation of the system, and the initial focus was principally on increasing the operating window for sailing fully laden vessels and thereby freeing the berth for following vessels earlier or importantly increasing opportunities for maintenance without disrupting customer schedules. It was also expected that maximum draft could be increased, but this was not the principal objective at the time as one major user had recently built five ships specifically tailored for 10.0 metre loaded draft and was not likely to replace them.

It was recognised right at the beginning of planning that a full understanding and acceptance of the theory and implementation parameters by the port's pilots was essential to the success of the system and its operation. Their enthusiasm and dedication to achieving increased productivity and safety has been invaluable in the successful trialling and implementation of DUKC at Port Taranaki.

Pilots have been fully involved from day one in setting bottom clearance and manouevring margins for various parts of the channel and advising on specific manouevres.

An experienced pilot was appointed as project manager and liaison and coordinated the upgrade of the environmental monitoring system and its links with the DUKC software as well as developing analytical programmes for reviewing system performance and marketing support.

The pilots also developed detailed operating procedures for DUKC and are 'owners' of the system.

A site visit to the Port of Fremantle together with the project manager to view their system in operation and the procedures that had been set up to support it was invaluable in setting Westgate on the right path. Fremantle pilots also assisted in passing on their experiences and comments on using DUKC at both Fremantle and Bunbury, Western Australia.

The system was installed in August 2001 and finally implemented commercially from January 1st 2002 after extensive trialling, proving and some modification of the environmental software links

The trialling was assisted by the pilots installing a portable GPS receiver on the bridge to match track against echo sounder traces. These were played back after each transit and subjected to detailed evaluation. This process had two substantial benefits. It proved the accuracy of the system and by increasing pilot's understanding of the ships track it led to a significant improvement in the accuracy of navigation under pilotage.

5.3 Swell Forecasting

Nowcast and 12-hour, 24-hour and 36-hour forecasts of directional wave spectra at deep water sites offshore from each DUKC installation are generated twice daily by the Bureau of Meteorology in Melbourne, using global and regional wind and wave generation models.

The nowcast and forecast wave spectra are downloaded automatically from the Bureau FTP site and transformed using site-specific relationships to obtain predicted spectra at the wave measurement sites at Port Taranaki. The transformed nowcasts are compared with the corresponding measured data and these comparisons are used to adjust the 12-hour, 24-hour and 36-hour forecasts. The adjusted forecast data are then used in the Port Taranaki DUKC system for the generation of 36-hour, 24-hour and 12-hour forecasts for maximum draft or tidal window applications. In ports with semi-diurnal tides, as occur at Port Taranaki, such forecasts provide scheduling information for shippers to use up to three high water levels prior to channel transit.

6.0 SUMMARY OF DUKC BENEFITS

The major benefits that the DUKC system is providing users at Port Taranaki can be summarised as follows:

- Positive improvements in operational efficiency and safety at an affordable cost
- By using the DUKC system operating windows are nearly always increased, in some conditions it can be by as much as 100%.
- By using the DUKC system maximum transit drafts are nearly always increased, in some conditions it can be by more than 2.0 metres.
- By using the DUKC system it is readily evident when conditions are such that a more conservative approach should be taken than under the existing static rules.
- The DUKC system adds science to experience and rule of thumb, in determining safe operating limits.
- The trialling and implementation of the system has given the practitioners a far greater understanding of the issues of under keel clearance and ship motions.
- The trialling and track review process has put a new discipline and emphasis on navigational accuracy
- Significant commercial gains to customers and the port.
- Potential to significantly reduce long term development cost by the optimization of dredged depths

7.0 REFERENCES

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Captain Gordon Franklin, Senior Pilot
Captain Neil Armitage Pilot

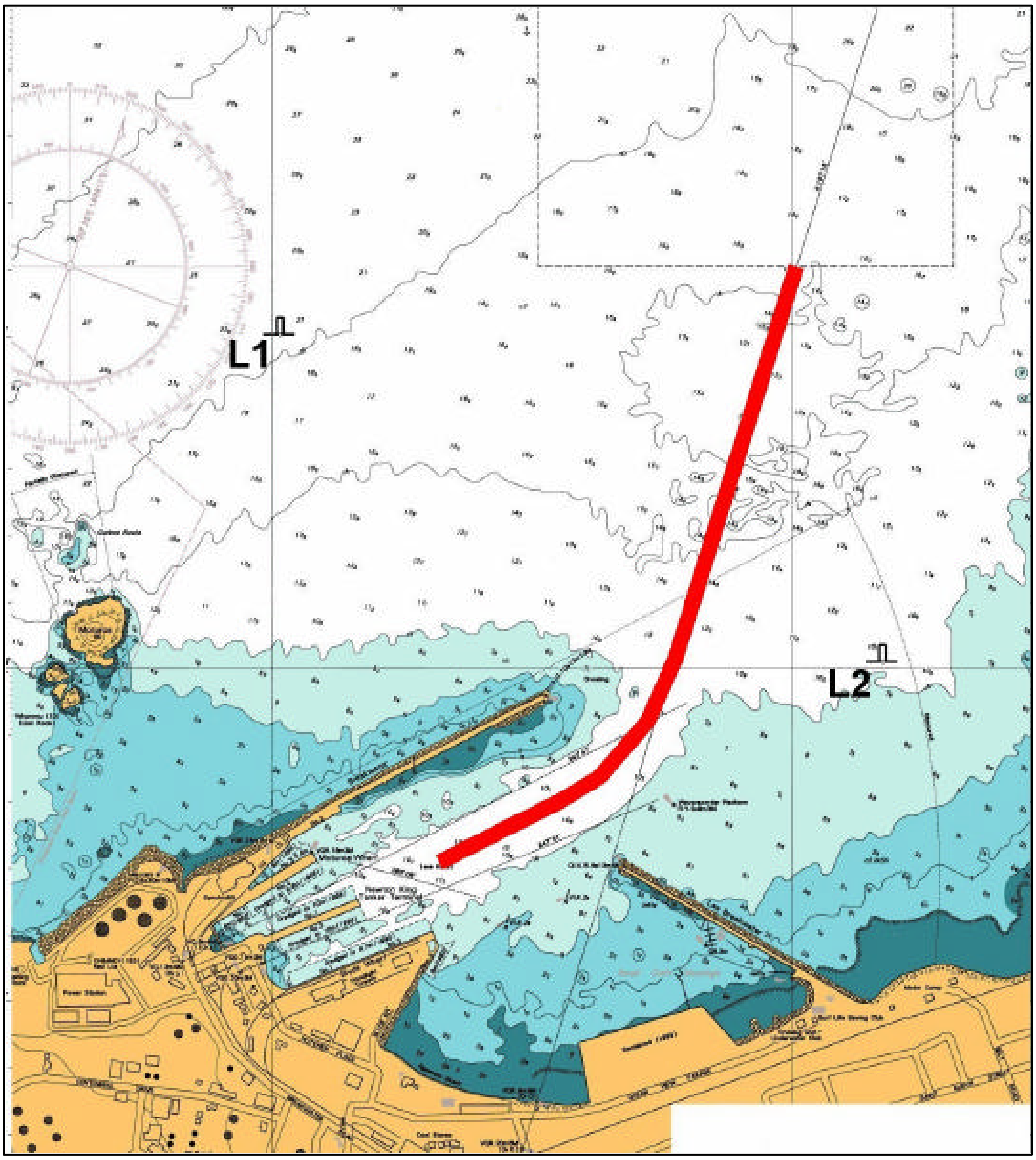

Figure 1 Partial view of Port Taranaki chart showing the line of ship tracks to and from the port and the location of wave recording sites (L1 and L2)

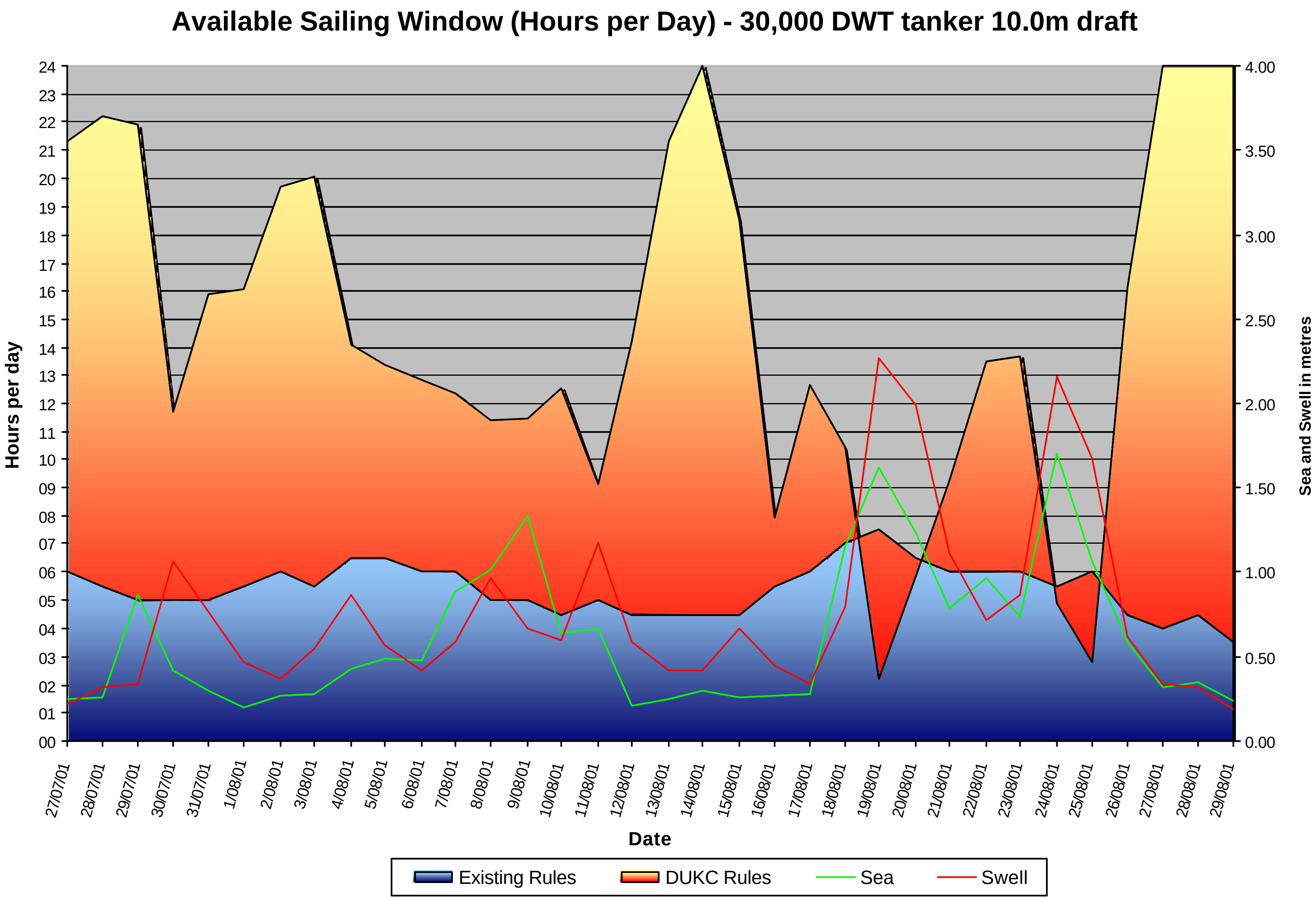

Figure 2 Graph comparing operating windows allowed by the static underkeel clearance rule and the application of DUKC. Note the correlation with swell height and the non-conservative situations with the static rule on the 19th and 25th of August.