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UKC management – an Australasian perspective.

MATTHEW TURNER [1]
PETER O'BRIEN [2]

RESUMEN

Historically UKC management in Australia and New Zealand has been based on empirical static rules. Depending on the port various static UKC rules were in place for example 10% of draft, 15% of draft, or 1m + 5% of draft. The justification of a particular static rule was generally historic use; it had been used previously without incident, but remained unchanged despite significant growth in vessel sizes. A problem with a static rule is that it ignores atmospheric tide, wave and current conditions and the particular conditions and transit speeds of the vessel in question.

Since 1993 the management of UKC has been radically altered by the invention of the Dynamic Under Keel Clearance (DUKC®) system. The DUKC® is unique in the world because it calculates the UKC requirements of any given vessel based on the ambient environmental conditions and the vessel's particular load state and transit speeds. In this way the DUKC® ensures that any vessel transiting a port has sufficient UKC at all times.

To change the UKC rule involved convincing the harbour masters and through them the relevant regulatory authority that the system improved safety. The safety, economic and environmental benefits of DUKC® will be described and illustrated through examples.

A static rule is statistical and therefore there are conditions where the UKC allowance specified by a static rule is insufficient and vessels transiting at such times have a higher than acceptable probability of grounding. By actively managing and modelling the UKC of each vessel transiting a port, the DUKC® allowance of each transit is determined match the particular circumstances. At times where the UKC allowance specified by the DUKC® is less than an acceptable amount the program would recommend reducing the vessel draft to a safe level or to delay sailing and await more benign conditions.

This safety benefit of the DUKC® is illustrated by the Capella Voyager disaster in New Zealand. In a 16 April 2003 a fully-laden supertanker struck a shoal on the entrance to Marsden Point in New Zealand. The vessel was sailing under the static UKC allowance and was fortunate not to rupture a tank. The New Zealand maritime authority subsequently recommended that a DUKC® system be installed at Marsden Point. Retrospective analysis revealed that if a DUKC® had been operating during the transit of the Capella Voyager the incident would not have occurred as the DUKC®, having predicted the extreme wave response that caused the grounding, would have delayed the transit.

The DUKC® varies the UKC allowance of each transit for the conditions of the day; the conservatism inherent in the static UKC rule is variable. A direct economic benefit is therefore that the majority of transits are able to sail with a deeper draft (or with larger tidal windows) than under the static rule. This brings huge economic benefits for ports using the DUKC®.

The Port of Fremantle illustrates this economic benefit. Fremantle is a mixed port with import and export of containers, tankers and bulk goods. The installation of the DUKC® has enabled the draft tankers to increase by between 0.29 m and 0.63 m, and for containers the average draft has increased by 0.35 m which is equivalent to about 120 additional TEU. The DUKC® has also enabled operators to optimise terminal operations.

Environmental benefits are possible because the safe increase in vessel draft is made with minimal environmentally damaging capital dredging. The DUKC® methodology can be applied to channel design to determine a channel profile that matches UKC requirements from harbour to deep water, ensuring maximum return in yield for each dollar spent in dredging. By illustration the Port of Taranaki in New Zealand anticipated that required dredge volumes could be reduced by 50% by utilising a DUKC® channel design and system instead of a traditional static design.

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[1] *Ingeniero Civil PhD, MSc – OMC International Pty Ltd*

[2] *Ingeniero Civil, MSc – OMC International Pty Ltd*

The development and introduction of the DUKC® has radically altered the management of the UKC in Australasia leading to significant safety, economic and environmental benefits.

1. INTRODUCTION

A recent study of over 260 maritime insurance claims involving pilot error found that 35% of the costs paid out by maritime insurers were related to grounding, this was in spite of groundings accounting for less than 3% of the claimed incidents (IGPI, 2004). This statistic alone indicates the potential severity of vessel groundings. Such events have a high economic cost and especially in the case of oil tankers may cause enormous environmental damage. For ports where deep draft vessels and shallow water meet the need to manage operations to avoid grounding is self evident.

Effective management of under keel clearance (UKC) is fundamental to the avoidance of groundings. A vessel transiting a port with insufficient UKC is liable to touch the bottom or lose steerage. Due to uptake of advances in technology through the application of a scientific approach to UKC assessment Australia leads the world in the management of UKC through the Dynamic Under Keel Clearance (DUKC®) System.

The application of a scientific approach to the management of UKC has lead to safety, economic and environmental benefits for Australasian ports and the wider community. Now ports in other parts of the world including Europe and Latin America are looking to gain similar benefits by applying the improved UKC management approach developed in Australia to their situation.

This paper presents an overview of UKC management especially the recent technological advances that have been developed in Australia. The first section of the paper presents a review of the traditional approach to UKC management as well as a discussion of its limitations and the need for a different paradigm. Later sections introduce the DUKC® System employed at most major Australasian ports and illustrate the benefits its introduction has brought. These benefits will be presented though case studies.

2. BACKGROUND

To avoid groundings ports predetermine a sufficient level of under keel clearance. Fundamental to this management is that ports define an area within which a minimum depth (relative to a vertical datum) is declared, having been precisely determined through detailed surveying – this value is known as the declared depth. Within this defined area, masters and pilots can calculate the water depth with confidence as the declared depth plus the tide level at that location.

With the water depth known, there are then conceivably two ways a vessel can ground transiting a port, i) leaving the bounds of the declared section (due to navigational errors or engine failure) where a shallower section may be encountered, or ii) grounding within the declared depth section due to a failure to anticipate the depth of water required to safely complete a transit and to ensure sufficient UKC during the transit.

For the purposes of navigation it is convenient to define two types of UKC. Gross UKC is the distance between the keel and the sea bed for a static vessel in calm seas: the vessel's static draft subtracted from the water depth. Net UKC is the distance between the vessel's keel and the sea bed of a vessel moving through the water and subject to wave action. Grounding will occur when the allowance for Net UKC is inadequate.

Historic approaches to UKC management have been to assign or calculate a Gross UKC amount under the assumption that this will ensure sufficient Net UKC. This approach to UKC management can be considered as management via a static rule: a fixed rule that does not vary with the ship or the environmental conditions. The reason for applying a Gross UKC amount to ensure an adequate Net UKC amount may simply be its convenience. In ``Approach Channels: A Guide For Design'' (PIANC 1995) the section on conceptual channel design states:

A simpler way to allow for squat, draft and sounding uncertainties (and also to give a margin for safety) is to set a minimum value on water depth/draught ratio. In many parts of the world a value of 1.10 has become accepted *although a value of 1.15 can be found. These values are for calm water only and greater values would be necessary if the channel is subject to wave action, where figures of 1.3 or more may be used.*

These depth on draft ratios are often presented as gross UKC requirements being a fraction of static draft. For example the depth on draft value of 1.1 is frequently quoted as a Gross UKC requirement of 10% of draft. This means that for a vessel with a 10m draft, 1m of gross UKC must be allowed. For sailing to be permitted the water depth must therefore be at least 11 m.

The use of static UKC recommendations is widely applied. The recently published American channel design guidelines, USACE (2006) reported initial planning guidelines of entrance channels exposed to waves and listed several sources of recommendations PIANC-ICORELS, IAPH, and PIANC (quoted above). All three recommending sources differentiated between channel regions exposed to strong or long swell, and channel regions less exposed to long swell. The values varied but generally less exposed section were accorded a UKC of 10-15% of draft, and more exposed sections were accorded a UKC recommendation of between 15 and 30% of draft.

Like the rest of the world the use of static Gross UKC requirements have been standard for Australasia. The static rules that have been in place have been expressed in one of three forms, a fixed UKC amount, a UKC that varied with draft, or a maximum draft vessel that is allowed to enter a port. To illustrate each of these The Port of Taranaki had a fixed 2.5m UKC rule applied to all vessels transiting the port. The Deep Water Channel at Fremantle had a 15% of draft UKC limit, and the less exposed Success and Parmelia Channels had a seasonally variable 13/14%. At Melbourne the maximum allowable drafts that a vessel can enter at any time is 11.6m, with tidal assistance 12.1m is allowed.

While static rules are simple to apply there are a number of consequences associated with their use:

- loss of context over time,
- inefficient,
- unquantifiable risk of grounding, and
- loss of UKC control.

The worrying consequence of these simplistic expressions of UKC is that the values are memorable, but the context is important. The 10% of draft as expressed in PIANC (1995) is expressly for calm waters only. Yet in operational rules the 10% may be adopted without thought of the prevailing conditions potentially leading to a misinterpretation of the guidelines. An example of this is from a Maritime New Zealand Investigation Report (MSA, 2005) into a fishing trawler grounding where it is stated *" As a broad rule of thumb a 'safe' minimum static under keel clearance is usually taken to be 10% of a vessel's maximum draft..''* . While this statement includes the term *minimum* to indicate that under certain circumstances 10% is insufficient, it can be seen that the context of calm waters and the absence of wave response has been lost. With the context of the value missing it is conceivable that it may be applied in the future to situations where it may be unsuitable. Another example of this is a BP Shipping insurance policy clause where the need to maintain 10% of static draft is stated without any reference to environmental conditions (Intertanko, 2006).

The use of a Gross UKC allowance is inherently conservative. This is because for the allowance to be safe it should cover the worse possible case. For a particular port using a static rule most vessels will transit the port less than optimally from a safety point of view, but this is necessary to avoid the riskiest vessel in the most adverse conditions grounding. By applying a static UKC rule the draft of the fleet of vessels transiting the port is limited by safety concerns of the transits that are at high risk. The economic concern of lost opportunity for the fleet is unduly limited by the safety concerns for an individual vessel or environmental condition.

Additionally applying a static UKC rule does not eliminate the chance of a failure. Groundings have occurred in ports where the static UKC was found to be insufficient. The case study in the later sections will illustrate such an example.

Finally from a UKC management perspective, a more fundamental concern is that by expressing the UKC allowance in terms of gross UKC, control over net UKC is unquantifiable. When using a conservative Gross UKC most transits should be safe, however some will be safer than others and the knowledge of which vessels are more at risk of having insufficient UKC is lost when using a static UKC. From a safety perspective this means that there is no knowledge of which vessels are at risk of insufficient UKC, how at risk they are and what net UKC margins are being applied. From an economic perspective there is no information on how much opportunity is being missed through the use of a static UKC rule.

The original thrust to change the management from UKC in Australia came from mineral export ports where the conservative UKC rules were leading to many hundreds of millions of dollars worth of potential exports being lost. These ports wished to increase their export drafts while maintaining or enhancing the safety of their vessels. This led to a paradigm shift in the management of UKC. Rather than the applying a broad static rule to all vessels the UKC requirements of each individual vessel would be assessed and the sailing draft of each vessel determined individually dependent on the vessel, its loading, transit, and the prevailing environmental conditions.

3. UKC FACTORS AND DUKC®

In order to assess the UKC requirements of an individual vessel the factors that affect net UKC need to be determined and calculated. The main factors that contribute to UKC are illustrated in figure 3-1. The factors coloured in blue determine the total amount of water available. After subtracting the draft the remaining distance is the gross UKC. Gross UKC is then (subject to operational testing) mostly composed of a series of assumed independent phenomena that cause a downward movement of the vessel's keel: squat, wave response and heel. The remaining part of gross UKC is from the contribution of factors that specify an allowance for uncertainties in the measurement or prediction of the other processes: tidal residual allowance, static draft allowance, change in water density, and survey tolerance and siltation allowance. If for a given transit the factors that contribute to gross UKC can be calculated and summed together, the net UKC can be determined as the difference between the gross UKC determined from the available water minus the draft and the combined UKC components. When this amount is greater than a specified safety factor the transit would be considered safe and conversely if the computed net UKC of a proposed transit is less than a specified safety factor the transit is clearly risky. This calculation made for at all points along a channel for the predicted time of sailing is the essence behind the DUKC® system.

First installed at Hay Point in 1993 and now operational at 13 Australasian port (plus 1 European port), the Dynamic Under Keel Clearance or DUKC® system is a software tool that combines information about the prevailing sea state with vessel information to predict the net UKC of a proposed vessel transit. Because the net rather than gross UKC is being predicted this technology has enabled ports to more directly and actively manage the UKC of visiting vessels.

In essence the DUKC® operates by combining environmental (wave, tide, and current) forecast models with ship wave response, squat and heel models to calculate the UKC requirements of a particular vessel under a specific load. The DUKC® is so called because the gross UKC requirements of each transit are adjusted dynamically rather than fixed via a static UKC rule.

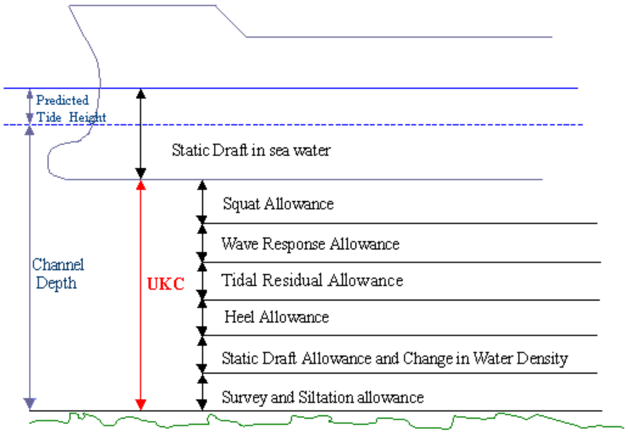

Figure 3-2: Diagram of the main factors that influence gross UKC

While a simple idea, the power of this dynamic approach is that the gross UKC allowance of each proposed vessel transit is adapted to match the conditions. In adverse conditions the gross UKC allowance can be increased to accommodate the larger downward vessel motions that may be expected, while in calm conditions with large predicted tide the gross UKC allowance can be reduced. In effect the DUKC® operates conversely to the static rule in that for the DUKC® the gross UKC allowance varies for each transit while the net UKC required remains fixed whilst the opposite applies for a static rule. Clearly to optimise efficiency and maximise safety it is the net UKC that must be maintained at a constant safe level.

The direct benefits of introducing a predicted UKC system such as the DUKC® can be categorised in terms of safety, economic and environmental benefits. Vessel safety can be improved because the UKC requirements of each individual transit are tailored to the specific conditions and loading conditions of the vessel. Unsafe transits that may have been missed under a static UKC rule are identified and the transit is adjusted or delayed to ensure sufficient net UKC is maintained throughout the transit. Economic benefits also flow from actively managing the net UKC of vessel. In benign conditions where gross UKC can be safely reduced (relative to a static rule) the reduction can be balanced by an increase in vessel draft or an earlier sailing in a tidal window. Increasing vessel draft has clear economic benefits in terms of more cargo transported per ship or less ship visits required where annual throughput is fixed by the landside. Increased tidal windows means greater port profitability and throughput. The reduction of unnecessary gross UKC and the subsequent increase in draft and tidal windows can be seen as reducing the conservatism inherent in the use of a static UKC rule. Environmental benefits are also possible from the introduction of a dynamic UKC rule. In many ports the net UKC is restricted at only a few particular shallow locations. The DUKC® can identify these controlling points and dredging operations can be targeted to only remove the areas that will directly impact on critical UKC. This ensures that every dollar spent towards dredging results in a draft benefit, typically resulting in significantly less dredging being required to achieve a similar level of draft increase under a static rule based dredging design. By reducing dredge volumes the environmental damage caused by dredging can be reduced.

More recent applications of DUKC® technology have been in the implementation of real time management of vessel UKC by linking a DUKC® engine with Vessel Traffic Management Information System (VTMIS) information. This adds the vertical, or UKC, dimension to these systems that would otherwise only consider the horizontal, or x and y, dimensions, and enables port operators and regulators to actively monitor the UKC of all vessels operating in the port in real time. When dealing with unforeseen situations – a vessel being delayed or slowed down due to engine failure, or deteriorating environmental conditions – the direct management of UKC enables port operators to enact strategies to avoid potentially hazardous situations.

The benefits that a dynamic UKC rule brings in the management of UKC are outlined in the following section by means of case studies.

4. IMPROVED SAFETY

The Port of Marsden Point is located on the east coast of New Zealand's North Island, approximately 17km from Auckland. It is the location of New Zealand's only oil refinery, which is serviced by a two-berth terminal for import and export tankers. Approximately weekly the port is visited by aframax and suezmax tankers (100,000 DWT) arriving from the Middle East with crude oil. Smaller tankers transport refined petroleum products to other destinations in New Zealand.

The approach channel at Marsden Point is indicated in Figure 4-1. The channel is approximately 8km long and its seaward end is highly exposed to swell arriving from the east and south-east. Such swell incident on the stern of import tanks has the potential to induce large pitching and rolling motions. Also at the seaward end of the channel is a shallow sand bar that incoming vessels must pass over when they are most exposed to swell.

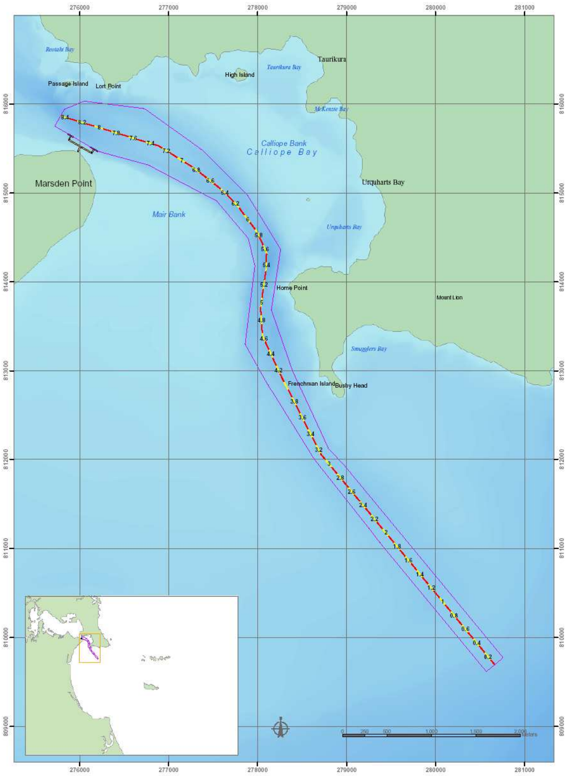

Figure 4-1: Location of Marsden Point approach channel.

Historically a static rule of 10% draft as gross UKC up to a maximum draft of 15.24 m was in place subject to pilot judgement. As no wave measuring instruments were located at the port, it was customary for pilots to board import vessels 2 miles to the south-east of the entrance channel and to assess the safety of a transit and likely vessel motions over the intervening approach.

In 2003 the inherent risk of this static approach to UKC management was proven when two groundings of inbound fully laden super tankers occurred at the sand bar within 3 months. On April 14th 2003 the Capella Voyager carrying 108,000 tonnes of crude oil hit the sand bar. The hull was split and the vessel took on several thousand tonnes of water. Heavy seas were reported at the time. On July 27th 2003 Eastern Honour carrying over 100,000 tonnes of crude oil scraped the bottom of the shoal. Again heavy seas were reported.

Following the two groundings, the Maritime Safety Authority (MSA) of New Zealand imposed significant draft limits on the port and recommended they implement a DUKC® System. This endorsement of the safety benefits obtained through DUKC® System is highlighted in recommendation 5.1 of the MSA report (MSA, 2003) on the grounding of the first tanker, the Capella Voyager.

In 2004, a DUKC® system at Marsden Point was commissioned. After its installation MSA commissioned the generation of retrospective DUKC® runs for the 61 import tankers that had arrived over the previous year. A summary of these runs is shown in Figure 4-2. The vessels on the figure have been ordered based on indicative net UKC (i.e. net UKC minus the safety margin: less than zero indicates the DUKC® would not allow the transit to occur) predicted by the retrospective DUKC® analysis. For example, the vessel on the extreme left arrived on 8/12/2002 with a draft of 10.9 m. This vessel was calculated to have had an indicative net UKC of approximately 4.75 m during the transit.

Subsequent vessels have decreasing amounts of net UKC. The final two vessels on the figure are the Eastern Honor and the Capella Voyager. These vessels were estimated to both have in excess of -2.5 m indicative net UKC. These vessels essentially had no chance and their proposed transits were destined to result in groundings. Interestingly the draft of the Capella Voyager was by no means the deepest draft vessel over the year: at 14.4 m draft it was the 23rd deepest draft and much less than the 15.24 m draft limit. The gross UKC of the Capella Voyager was estimated at 18.75% of draft much greater than 10% allowance used at the port (TAIC, 2003).

This observation indicates that vessel safety is not merely a function of draft but also other factors such as environmental conditions and load state are can equally as important. Had the DUKC® been operational prior to the transits of the Capella Voyager and the Eastern Honor the incidents would have been avoided.

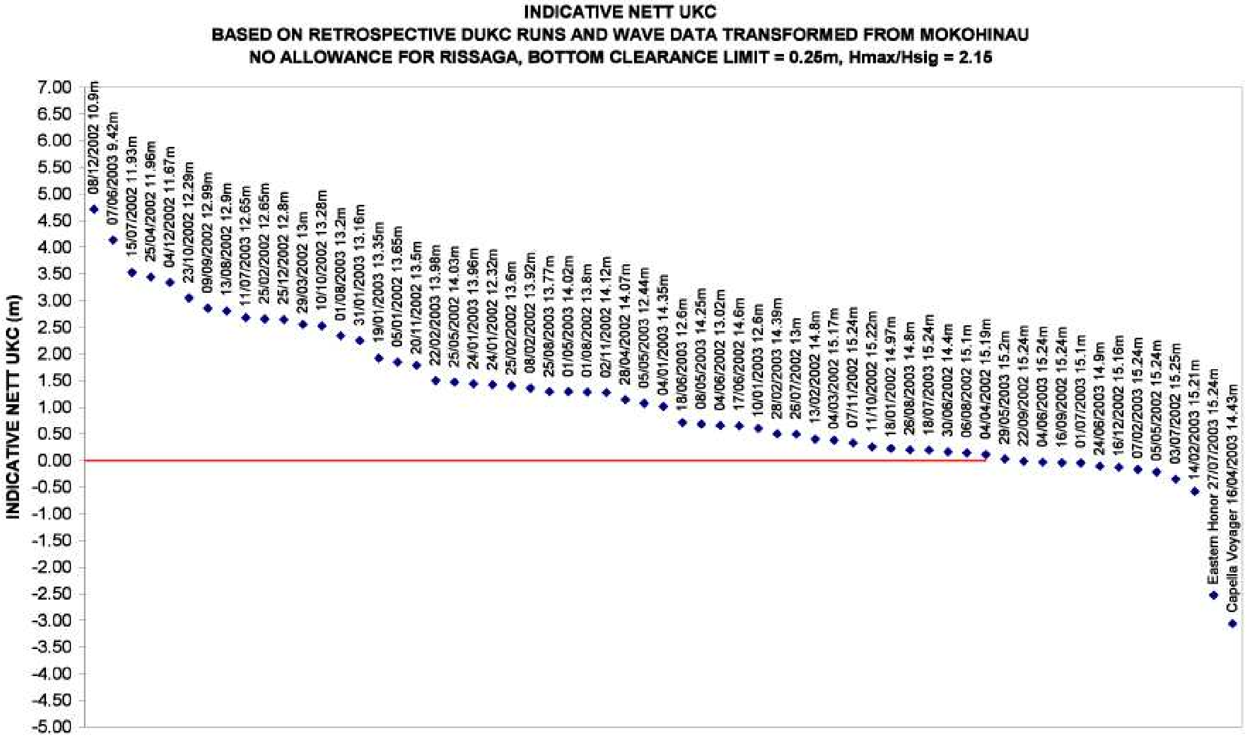

Figure 4-2: Retrospective analysis of import tanker transits in the year prior to the Capella Voyager and Eastern Honor incidents.

A further point to note from Figure 4-2 is that the 11 transits preceding the Eastern Honor also have a predicted net UKC of less than zero. These vessels would also have been identified by the DUKC® as unsafe. This indicates that the calculation of indicative net UKC less than zero does not indicate that grounding is imminent, rather that the risk of grounding is unacceptably high. Conversely if the left hand side of Figure 4-2 is considered more than half the vessels arriving at Marsden Point have an indicative net UKC of greater than 1 m. A significant opportunity exists for these vessels to safely transport more cargo. This example summarises well both the safety and economic benefits a dynamic UKC rule provides.

5. ECONOMIC BENEFITS

The Port of Fremantle is located on the west coast of Australia, approximately 14 km from Perth. The Port of Fremantle operates from two locations: the Inner Harbour at Fremantle and the Outer Harbour, 15 kilometres south at Kwinana. The Inner Harbour handles mainly container trade, while the Outer Harbour handles bulk cargo of which grain, petroleum, and various minerals are major contributors. The port is a major importer of crude oil from the Middle East to service the BP refinery.

The access channel configuration for Fremantle is indicated in Figure 5-1. To reach the inner harbour deep draft vessels must transit the Deep Water Channel, while to reach the Outer Harbour vessel must additionally transit successively the Success, Parmelia and Stirling Channels. Prior to the introduction of the DUKC® the Deep Water Channel at Fremantle had a 15% of draft UKC limit, and the less exposed Success and Parmelia Channels had a seasonally variable 13/14% of draft UKC limit.

In 1994 the Port of Fremantle adopted the DUKC® for managing its UKC. A major interest for the port in introducing the DUKC® was the potential benefits for the importation of crude oil. The ports perception was that DUKC® technology would allow increased draft balanced against wider tidal windows. It later established that both container trade and bulk trade benefited economically from the DUKC's introduction.

Figure 5-1: The channels of Fremantle Source: (PoF 2008)

It had been established at the coal terminal at Hay Point that DUKC® could bring significant benefits to bulk export ports. This was brought about because the DUKC® enabled the terminals to optimise the export draft to the prevailing conditions avoiding any lost opportunity. At Fremantle for the importation of crude oil this technique could not be applied as the sailing draft is determined weeks prior on leaving the Middle East when the prevailing environmental conditions could not be predicted with any degree of accuracy.

To be of benefit to Fremantle for the importation of crude oil the DUKC® needed to bring about an increase in the Maximum Economic Draft (MED). The MED is a draft that a vessel can load to with only a small risk that on arrival at the destination port it must wait no longer than the time to the next high water. An important point here is that it is not known which high water this will be and so the available water will vary with the spring-neap tidal cycle as well as the variation in wave and tidal residual conditions.

The actual value of the MED is determined as a balance between the economic benefit gained by shipping companies as they can load their vessels deeper carrying more cargo against the risk of not having sufficient net UKC on arrival at the destination port at the next high water and the economic consequences associated with that delay (demurrage etc).

Following the introduction the DUKC® at Fremantle the MED increased by between 0.19 and 0.24 m. The figures are presented in Table 5-1. The variation between the summer and winter MED values is due to the average sea level variation of about 0.25 m over the year. Based on Aframax and Suezmax of around 100DWT at current crude prices this accounts to approximately an additional 1 million dollars of additional crude oil that can be imported per vessel.

Table 5-1: Increase in MED following introduction of DUKC® at Fremantle

	Winter MED	Summer MED
Pre DUKC®	13.56 m	13.76 m
Post DUKC®	13.75 m	14.00 m

Additional operational benefits were achieved through measurement campaigns. The MED had been calculated based on a 40m beam vessel, with a reduction factor to account for deeper vertical movement of wider rolling vessels (for the same roll angle). Studies of the seasonal wave climate found that the conditions in summer induced significantly less roll than in winter months and correspondingly the reduction factor could be lessened. Note that this did not reduce the safety of such transits as all must satisfy the net UKC requirements calculated by the DUKC® prior to commencing an import transit.

Further benefits were achieved through more careful planning. It had been standard practice for import tankers to arrive at MED on a static even keel – with the draft at the bow equal with the stern draft. It is well established that full form vessels with large block coefficients (0.82-0.85) will squat preferentially by the bow. When entering the port under speed the bow squat was inducing a dynamic trim by the bow. This bow trim could be compensated by initially statically trimming the vessel by the stern allowing the vessels to enter under an even keel. In total the introduction of the DUKC$^{®}$ resulted in a minimum draft increase of 0.29 m for inbound tankers and potentially 0.63 m draft increase for wide beam vessels arriving trimmed by the stern.

Fremantle is the first and last port on the container trade between Australia and overseas destinations. For this reason it was important for the port to have sufficient depth to avoid lost opportunity with vessel either bypassing Fremantle or refusing cargo at ports like Melbourne to allow draft for commitments at Fremantle.

After dredging the Inner Harbour Entrance Channel (not shown in Figure 5-1) in 1989 from 11 to 13 m the port container vessels could enter with a maximum draft of 12.5m. However with increased trade and new services Fremantle was pressured to further increase the depth to 12.8 m. Further dredging was ruled out on engineering grounds and the DUKC$^{®}$ system was extended to be applied to the channels used by container vessels. This resulted in an increase in the achievable safe vessel draft of 0.3 to 0.35 m. Ironically the introduction of the DUKC now required vessels to lighten at Fremantle to achieve a draft sufficient to enter the eastern Australian ports reversing the previous situation.

6. ENVIRONMENTAL BENEFITS

Port Taranaki is located on the west coast of New Zealand's North Island. It is the second largest export port in New Zealand by volume. Historically Taranaki served agricultural trades, but since the discovery of oil and gas in the region it has become mainly a petrochemical port. Since 2000 the container trade has increased notably due to changes in the shipping contracts for dairy products. This increase was accompanied by significant pressure to increase its maximum operational draft from 10 to 11 m. The introduction of the DUKC$^{®}$ made the entry of 11 m draft vessel feasible with no dredging but access was still restricted by tide and wave conditions. Therefore some additional dredging was required.

Although the access channel at Taranaki is relatively short (Figure 6-1) the sea bed in the harbour is of volcanic origin making dredging difficult and expensive. Using the DUKC$^{®}$ methodology a channel design study was undertaken to determine the optimal bed profiles for a range of draft and entry conditions. The study found that a series of high points remained after a previous dredging campaign in the 1980's. The analysis indicated that these points were "controlling" the transit and therefore their removal would yield immediate additional draft. Diver assessment found that these localized points were groups of boulders of up to 2 m in diameter that could be removed with minimal effort providing an additional 0.6m of draft.

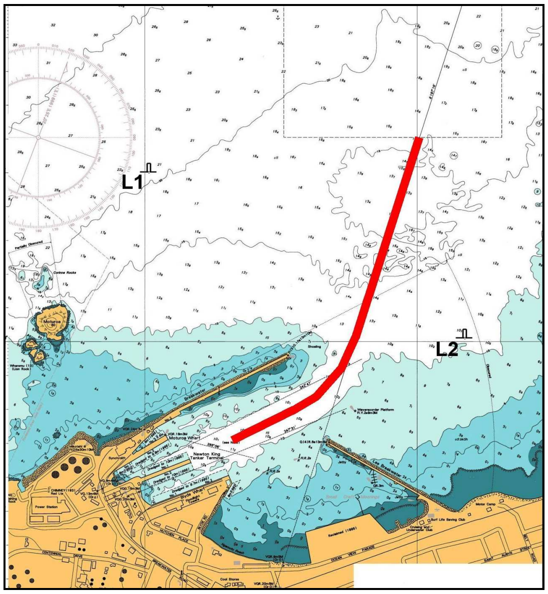

Figure 6-1: Layout of the port and the access channel at Taranaki.

While this minor dredging combined with the DUKC$^{®}$ had enabled the port to meet their current operational requirements the port anticipated that additional capital dredging would be required into the future. A major capital dredging program was completed in 2007 again using the DUKC$^{®}$ for the channel design. The port had estimated that the ability to manage vessel UKC dynamically with the DUKC$^{®}$ was expected to reduce the amount of dredging required by about 50%. This obviously brought enormous cost saving, but additionally as dredging is often an environmentally damaging activity the ability to significantly reduce dredge volumes and avoid unnecessary dredging brought additional environmental benefits.

In a typical access channel the drafts at which a vessel may safely enter is controlled at a few specific locations as illustrated by the example above. By identifying and removing these immediate benefits are possible subject to operational testing. Moreover a channel can be designed to ensure that the profile matches the UKC requirements from the harbour to deep water viz. each point along the channel is a potential controlling point. Designing a channel in this way ensures a maximum return in terms of additional draft for every dollar spent on dredging.

7. VERIFICATION

The decision to move from a static to dynamic management of UKC appears obvious from the direct benefits outlined. In the past however there has been reluctance to adopt a dynamic rule especially from those concerned with vessel safety – the Maritime Authority, Harbour Masters and Pilots. Often this is well intentioned: these individuals are responsible to ensure safe passage and it is natural that a degree of caution is taken when a new approach is being proposed. This caution is often connected with unfamiliarity with the system and through training, education, and trialling the utility of the system as an aid to navigation becomes apparent.

To authorise the adoption of a dynamic UKC management regulatory bodies, Maritime Authorities and Harbour Masters require evidence of the safe performance of the system. This is achieved through the use of Full Scale Vessel Motion Analysis (FSVMA) studies. These provide a means to independently verify the sailing advice provided by the DUKC®.

The FSVMA is a technique whereby differential DPS units are attached to key locations of a vessel prior to a transit. During the transit these units record their position in three-dimensional space to sub-decimetre accuracy. By post processing these data at the completion of a transit it is possible to identify the individual UKC components – squat, wave response, and heel – as well as the net UKC. By comparing these values with those values predicted by the DUKC®, the evidence of the safe operation of the system is achieved.

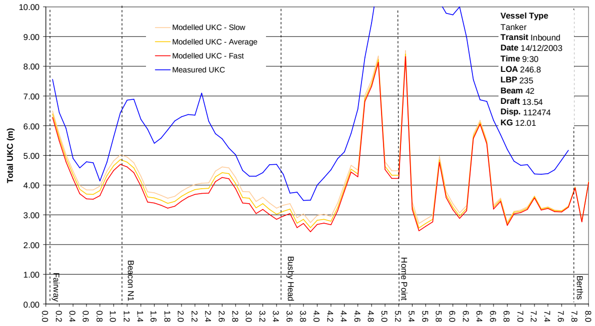

Figure 7-1: Measured and Predicted UKC for the CS Valiant at Marsden Point.

An example of a DUKC® validation is shown in Figure 7-1. This data was collected during the installation of the DUKC at Marsden Point. The plot compares the net UKC measured in the FSVMA study against the net UKC predicted by the DUKC®. The DUKC® safely predicts the UKC for all points in the transit, confirming the performance of the system.

8. CONCLUSIONS

Historically UKC management has been based on static UKC rules. While simple to apply the disadvantages of managing UKC with such rules are: safety risk, conservatism and lack of control. In Australasia many ports have moved towards a dynamic management of their UKC, this has been made possible through the development of the DUKC®. Specifically the benefits that improved UKC management has introduced are safety, economic and environmental.

Retrospective analysis has shown that two super tanker accidents at Marsden Point would have been avoided had a DUKC® been in place. At Fremantle the introduction of the DUKC® allowed inbound tankers to increase draft by between 0.29 and 0.63 m and the container vessels to increase draft by 0.3 m. And at the Port of Taranaki the port estimated that dredging amounts have been reduced by 50% because of the introduction of the DUKC®.

The introduction of the DUKC® has radically changed the way that ports in Australia and other locations manage their UKC. The benefits outlined in this paper are universal and would be applicable to ports operating world-wide.

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