UKC AND DREDGING MANAGEMENT AT PORTS THROUGH DUKC® METHODOLOGY

Peter W O'Brien, GM, OMC International Pty Ltd, Australia, peter@omc-international.com.au
Dr. W. T O'Brien, Director, OMC International Pty Ltd, Australia, terry@omc-international.com.au
Ken Wahren, SE, OMC International Pty Ltd, Australia, ken@omc-international.com.au

1. INTRODUCTION

The Dynamic Underkeel Clearance System (DUKC®) discussed in this paper has a 12 year track record as the leading UKC system, assisting more than 25,000 vessel movements without incident and directly generating in excess of $2 billion dollars in decreased freight costs and increased cargo throughput to port users and stakeholders. These gains have been achieved at a small fraction of the cost involved in gaining equivalent improvements by dredging.

Recent trends in the size of ships, together with increasing pressure on shippers to maintain tight schedules, have seen intense demands placed on ports to match vessel growth requirements in an efficient and timely manner. Increasing port capacity to cater for vessel growth is an expensive and lengthy exercise.

This paper focuses on how ports have utilised DUKC® methodology to provide optimal solutions to these growth requirements through short and long term maximisation of channel capacity in the most cost-efficient manner.

2. DUKC® SYSTEM FOR PORT OPERATIONS

The DUKC® System is a real time underkeel clearance (UKC) system used by ports to maximise port productivity and safety. The DUKC® System considers all factors that affect the UKC of a vessel transiting a channel to determine the minimum safe UKC requirements.

The DUKC® has been, and will continue to be, progressively developed and improved through innovative research and development. Latest technology includes incorporation of meteorology forecasts out to 72 hours to provide reliable DUKC® forecast predictions, web-enabling the DUKC® to provide scheduling advice to shippers world-wide and development of the pilot carry-on DUKC® PPU.

In port operation, the DUKC® System is used to increase tidal windows - allowing vessels to maintain/exceed tight schedules - and increase drafts - allowing additional containers/cargo to be loaded onto each vessel. This provides ports with an optimal short-term solution whilst consideration is given to the longer term requirements of the port and the time consuming processes (studies, approvals, and construction) required for deepening channels are undertaken.

3. DUKC® METHODOLOGY FOR CHANNEL DESIGN

In the port's planning for expected long-term vessel growth, traditional channel design methods are generally fairly generic with little regard for the operational practices at the port. A port that has an operating DUKC® System has the opportunity to utilise DUKC® methodology in the design process. DUKC® methodology provides an optimal dredging solution through targeted design that is consistent with the port's operational practices, as opposed to a blanket approach.

DUKC® quantifies the UKC requirements of each section of a transit; this information is used to create an optimal channel depth profile which matches the specified channel capacity whilst minimising the dredging requirements. Because the use of DUKC® technology enables a realistic simulation of future port operation, all access percentages determined reflect future operating outcomes.

4. CASE STUDY – PORT OF FREMENTLE, WESTERN AUSTRALIA

The case study demonstrates how the DUKC® System has provided the Port of Fremantle with significant gains in the maximum drafts (30-50cm) and tidal windows (2-3 hours) of container vessels transiting the port since 1994.

The Port is expecting significant growth in the container trade, and the case study demonstrates how DUKC® methodology has been utilised in the optimisation process to produce a substantial reduction in the port's dredging requirements in comparison to the volumes that would have been obtained through traditional channel design.

UKC AND DREDGING MANAGEMENT AT PORTS THROUGH DUKC® METHODOLOGY

1 INTRODUCTION

Ever increasing demands on ports to accept larger deeper vessels on a frequent tight time schedule have required ports to become smarter in their under keel clearance (UKC) management. Yesterday's approaches in both operation, based on conservative rules with little scientific basis, and in blanket capital dredging, are not acceptable in today's world of accountable spending budgets and increased emphasis on minimising environmental impacts. There is today a much more sophisticated approach to UKC management which both maximises the efficiency and safety of a port in today's environment, and optimises the dredging requirements in tomorrow's.

This approach utilises DUKC® methodology, and has already been applied at a number of ports around Australia and New Zealand for both efficient and safe port operation and smart designer dredging.

The Dynamic Underkeel Clearance System (DUKC®) has been around for over 12 years, assisting more than 25,000 vessel movements without incident and directly generating vast financial, safety and environmental benefits to port users and stakeholders. However the application of DUKC® methodology to optimise dredging depths to achieve specified outcomes is a relatively new concept.

This paper will outline how DUKC® methodology has been used by ports to provide optimal solutions to port growth requirements through short term and long term maximisation of channel capacity in the most cost efficient manner. A case study is given and the short and long term associated benefits presented.

2 DUKC® SYSTEM

2.1 Background

OMC is the inventor and sole international supplier of the DUKC® system which is a **unique** real-time under keel clearance management system for use in depth restricted waterways. First installed at Hay Point, Queensland, in 1993, the technology is now operational at eleven (11) ports around Australia and New Zealand. Systems are currently under development at three additional ports, including the Port of Lisbon, Portugal.

A DUKC® System provides a scientifically sound, risk based tool around which quality assured procedures can be developed for ensuring UKC safety. Specifically, it offers a decision support tool for assessment of UKC for conditions of the day, using an internationally recognised and proven methodology for managing UKC both before and during transit.

The DUKC® System has an impeccable track record spanning more than 12 years as the only fully dynamic UKC system in the world, directly generating in excess of $2 billion dollars to port users and stakeholders.

Benefits are delivered through:

1. Increased tidal windows allowing greater throughput of vessels. Downtime of infrastructure is reduced. Vessel demurrage costs are also reduced.
2. Increased drafts allowing additional cargo to be loaded onto each vessel. As expected available drafts are increased, arrival and departure drafts for long term planning can also be increased.

These benefits are obtained at a fraction of the dredging costs that would be required to yield equivalent increases in productivity.

The economic benefit to ports and shippers using DUKC® has been achieved whilst *improving the certainty, and therefore the safety, of shipping transits*. *There have been now over 25,000 DUKC® sailings at all the DUKC® ports without incident.* In 2003, the Maritime Safety Authority of New Zealand (MSA) imposed significant draft limits on the Port of Marsden Point following the groundings of two 100,000+ dwt oil tankers under their static rule – these restrictions were not lifted until they implemented a DUKC® System.

DUKC® environmental benefits stem not only from safety benefits reducing the risk of marine accidents, but also in reducing the costs and adverse effects on the environment associated with dredging.

The DUKC® has been, and will continue to be, progressively developed and improved through innovative research and development. Latest technology includes incorporation of meteorology forecasts out to 72 hours to provide reliable DUKC® forecast predictions, web-enabling the DUKC® to provide scheduling advice to shippers worldwide both short term through the DUKC® and long term through the scheduling tool Q-DUKC® and development of the pilot carry-on DUKC® PPU.

2.2 DUKC® Methodology

Traditionally, ports have operated under fixed rules which govern the minimum underkeel clearance (UKC) to permit safe transit along port approach channels. To ensure safety, these fixed UKC rules are determined by requirements in extreme swells and negative tidal residuals. It is essential that UKC requirements include not only vessel squat and the effect of wind and atmospheric pressure changes on predicted tides, but also the dynamic motions of vessels of varying size and stability characteristics.

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.

Dynamic UKC (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 UKC.

The DUKC® system has two major functions:

- *Maximisation of vessel drafts for the tide, or for a specified sailing time* (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).

DUKC® modelling guarantees accuracy and applicability. UKC requirements are determined based on the actual vessel and its stability parameters, real time metocean conditions (wave height, period and direction, current, tidal plane, wind), vessel transit speed and waterway configuration, including detailed bathymetry, at the time of sailing. 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.

DUKC® systems determine the minimum safe under keel clearance along the complete transit from berth to deep water, taking advantage of favourable conditions and ensuring safety during unfavourable conditions. These systems allow ships to be loaded to greater draft or use wider tidal windows than is possible using fixed UKC rules.

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.

Reducing the risk of a serious marine incident is an obvious environmental benefit of DUKC® systems. In most applications, DUKC® modelling reduces the costs and adverse effects on the environment associated with dredging through:

1. Ensuring the most efficient use is made of available depth, allowing dredging to be postponed.
2. When dredging is required, DUKC® methodology can be used to identify the optimum volume of material to be removed from each channel section, ensuring that unnecessary dredging is not undertaken.

Full-scale field tests using highly accurate dual-frequency Differential GPS have been undertaken on over 140 vessels to provide unparalleled validation of the predictive models used in the DUKC® systems.

2.3 Operational DUKC® System

The DUKC® System consists of three components:

1. DUKC® SIV
2. Q-DUKC®
3. DUKC® PPU

2.3.1 DUKC® SIV

DUKC® SIV is the most recent version of the land based DUKC® System. DUKC® SI was developed in 1993 for Hay Point. Since this first installation, research, development and refinement of the DUKC® land based systems has continued assisted by interaction between Harbour Masters, Pilots, port users and the OMC design team.

DUKC® SIV is designed to provide predictions up to 36 hours (and even up to 72 hours where reliable meteorology forecasts are available) prior to sailing based on real time metocean conditions and is customised for the vessel type, speeds through the transit and channel configuration. This is used to assist vessel loading and sailing scheduling. In the final hours before departure the DUKC® SIV 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 to the ship handlers.

2.3.2 Q-DUKC®

The Q-DUKC® is a scheduling tool that can be used for long term planning of vessel sailings through the internet (up to 1 year in advance). It optimises the long term draft planning for vessels visiting ports with an operational DUKC® System. Access to the system can be provided to any authorised Scheduler with an internet connection.

The Q-DUKC® utilises DUKC® methodology in providing the Scheduler with a picture of the relationship between the arrival/departure draft of a specific vessel and how long that vessel will be delayed according to a user-selected confidence limit. This relationship is illustrated by Figure 1, below.

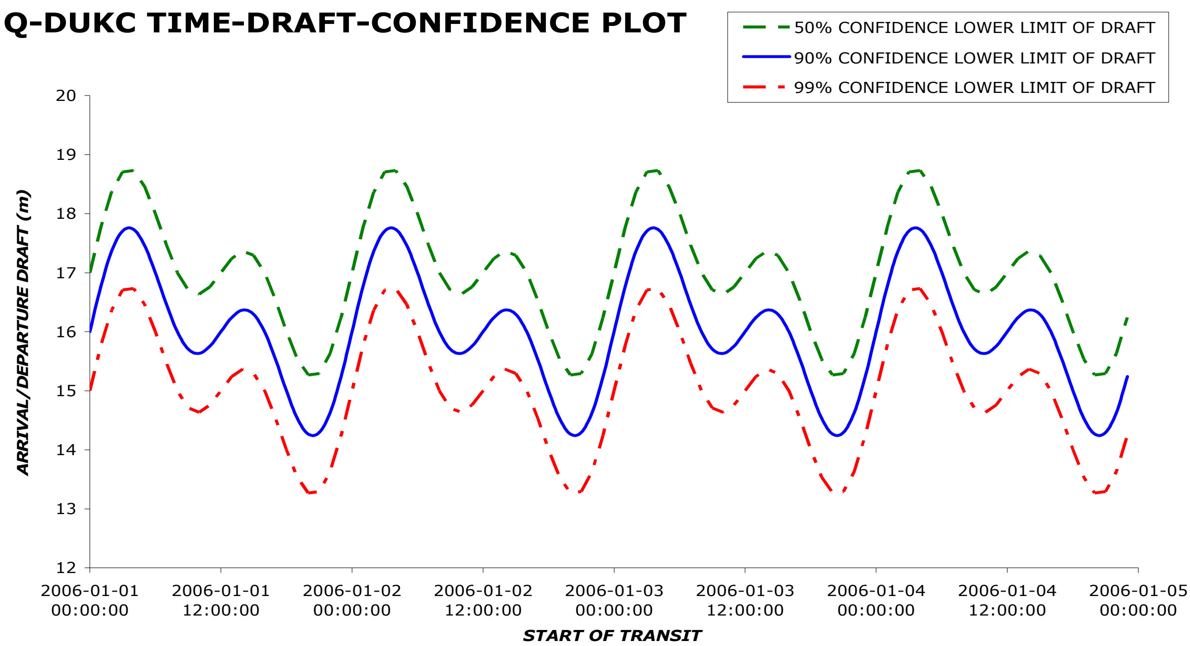

Figure 1 – Q-DUKC® TDC Plot

The principal difference to the DUKC® System is that environmental information is based upon probabilistic estimates of conditions, *seasonally based*, rather than real-time measurements. The Q-DUKC® concerns only scheduling, whereas the DUKC® is always used for the actual transit so as to incorporate conditions of the day.

The Q-DUKC® presents the Scheduler with various level-of-risk scenarios (eg 99%, 90%, 50%) for a particular vessel over a particular time period, and also with a graphical representation of the likely yield over following tides such that the risk associated with missing one tide can be made considering subsequent tides, as shown in Figure 2. The lower the selected risk level, the greater the predicted yield curves however the greater the risk the vessel will get caught out at the time of sailing under DUKC®. Drafts can be scheduled such that the probability of delaying a transit due to adverse environmental conditions is consistent with the economic viability of the trade.

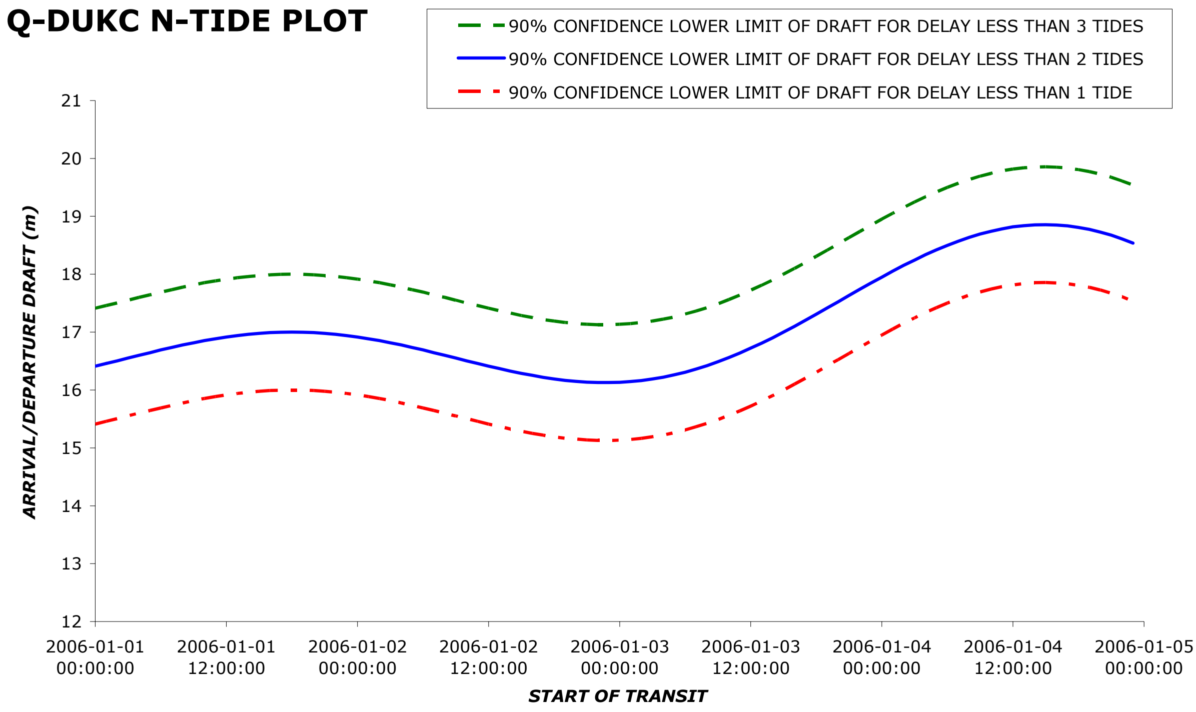

Figure 2 – Q-DUKC® N-Tide Plot

Q-DUKC® has the advantage of allowing some of the additional draft benefits a DUKC® System offers to be realised in long term vessel planning, and provides the Scheduler with the ability to plan long term vessel sailings with a known level of risk determined very accurately. Drafts required for scheduling trades such as container or tanker arrivals at an inbound port are determined with a methodology consistent with that used immediately prior to the vessel's arrival/departure. There is after all little logic in loading a vessel's arrival draft to a DUKC® port considering the static UKC requirements at that port, and then finding the tidal windows are very large, or even continuously open, for the actual transit with the DUKC® System. Clearly draft opportunity is lost.

The objective of Q-DUKC® is to load such that the vessel arrives at the port shortly before a tidal window. The operational DUKC® System will then determine the actual window.

2.3.3 DUKC® PPU

A recent major innovation has been the development of a DUKC® Portable Pilot Unit system (DUKC® PPU). This provides a seamless transition from the shore based DUKC® SIV prediction system, which operates from 36 hours up until a vessel's transit, to a system operated aboard a vessel during transit through port approach channels and shallow waterways.

Whereas the shore-based DUKC® system is operated by port authorities and shippers, the ship based DUKC® PPU is operated by the pilots during an actual transit. DUKC® PPU optimises a vessel's speed during transit to ensure adequate UKC will be maintained based upon the prevailing environmental conditions. The DUKC® PPU enables pilots to shorten transit times through port channels to the minimum possible without exceeding acceptable safety criteria.

The DUKC® PPU is the only tool in the world providing marine pilots with real-time underkeel clearance management advice through vessel speed optimisation.

Specifically the DUKC® PPU allows the pilot to:

- Monitor that the actual speeds are proceeding within the DUKC® SIV assumed speed envelopes.
- Determine where it is safe to travel at speeds outside the DUKC® SIV assumed envelope and to what extent it is safe to do so.
- Investigate alternate speed/sailing options in situations where the passage does not proceed as planned. This could include situations such as vessel break-downs, last lines outside of the predicted window, an over-loaded vessel or a vessel not performing as expected.
- Identify speeds that will maximise UKC or minimise transit time.

2.3.4 DUKC® Components in Operation

There is a seamless transition between each of the DUKC® components. Following is a typical scenario where the three components are utilised to provide the port with optimal operational UKC management:

1. A shipping line scheduler, using the Q-DUKC®, predicts the maximum draft or tidal window for a scheduled vessel transiting to a DUKC® port up to several months ahead.

The Q-DUKC® will provide a user selected level of probability that the result will be achieved, i.e. should the 95% probability be selected, there is a 5% probability that the vessel will be delayed transiting the port on that selected tide. This Scheduler has the confidence to know that the selected level of probability is accurate, based on scientific determination utilising the port's operational system. The Scheduler is able to further ascertain the risk of missing that particular tide, based on the predicted Q-DUKC® yield on following tides.

2. Within 36 hours of the scheduled transit, the Scheduler updates the predicted maximum draft and tidal windows using real-time data through the DUKC® SIV System. Unless a high level of risk has been selected in the Q-DUKC®, the DUKC® maximum draft or tidal window should be greater than the Q-DUKC® maximum draft or tidal window, this effect generally increasing as the time to transit reduces. The scheduler is therefore able to continually fine tune the proposed vessel draft/tidal window for say 30, 24, 12, 8, and 4 hours before departure using the DUKC® SIV system.

3. For the time of sailing, the pilot takes the DUKC® PPU on board. The pilot is able to optimise transit speeds and, for the occasional periods where unusual circumstances arise; eg the environmental conditions deteriorate rapidly, the vessel is late leaving the berth or the actual draft is different to that assumed in the DUKC® SIV, the pilot is able to control speeds in critical sections to ensure safe UKC at all times.

2.4 DUKC® Methodology for Channel Design

The most efficient design is one that has full regard to operational practices. For a port operating under a DUKC® System there is considerable potential to optimise a channel profile through simulations replicating port operations. In addition the port has the confidence that the determined gains will correspond to operational gains because the designs were generated and analysed using simulation models subject to actual operational constraints.

DUKC® determines the UKC requirements in each section of a channel for a particular vessel transit. Because the factors reducing UKC vary greatly throughout a transit, an optimum non-uniform channel design can be determined which matches the specified channel access criteria.

Traditional channel design based upon assumptions of static UKC requirements results in unnecessary dredging and a channel profile that does not match operational requirements. In the cases where a DUKC® is not used at the port, UKC is a matter of pilot judgment. That judgment cannot be reliably replicated (often varying from pilot to pilot), and as a result is becomes impossible to accurately simulate port operation.

In a dredge optimisation study using DUKC® methodology the UKC profile is produced based upon statistical analysis of environmental conditions as well as the range of possible vessel types and speeds. The profile created allows for the full range of conditions under which a vessel may be required to transit the channel.

Optimisation with DUKC® can significantly reduce the financial cost of dredging as well as its environmental effects. The intended aim of increasing allowable sailing drafts and tidal windows is delivered at a greatly reduced cost and with minimal environmental effects.

As testament to the value of applying DUKC® methodology to channel design, the following case examples are provided:

Case 1: In 2003 OMC completed a study for Harwich Haven Authority to determine the UKC and depth requirements for the approach channels to the port of Felixstowe.

"The work done by OMC International has highlighted the non-optimal profile of the existing channel which has followed use of conventional channel design methods for the most recent (Yr 1999) capital dredging program. OMC was commissioned by HHA in 2003 to undertake a study of UKC requirements along the length of the transit. This study demonstrated to our satisfaction that, if DUKC® technology had been employed for channel design at the time of capital dredging, significant savings in dredging volumes and cost (in the order of 15%) could have been achieved, for the same channel yield. The results of this study, and of the ongoing DUKC® trials, are now being used to support reductions in maintenance dredging costs in areas where excessive capital dredging was undertaken." (Captain David Shennan, Harwich Haven (HHA) Harbour Master, UK).

Case 2: In 2002 OMC completed analysis for the Geraldton Port Authority using DUKC® methodology to determine optimum depths for the port approach channels.

"*Such use of DUKC® methodology to determine the design channel profile has resulted in a stepped profile ... effectively optimising the channel at a number of discrete locations considering specific UKC requirements at each location. Such a stepped profile has resulted in a significant reduction in the dredging volumes, and therefore dredging costs, time and environmental impacts, over that which would be achieved using traditional channel design methods."* (Captain David Murgatroyd, Harbour Master, Geraldton Port Authority, WA).

Case 3: In 2003 OMC undertook a study on behalf of Pilbara Iron to determine optimum volumes and locations for dredging in the Port of Dampier approach channels.

"Recently, we have employed OMC services to apply DUKC® methodology to determine optimum depths in the Dampier departure channels. By applying the results of this analysis in recent capital dredging operations, Pilbara Iron have been able to achieve draft gains in the order of 0.2m by dredging only isolated critical locations in the channel." (Julian Carr-White, Marine Technical Officer, Pilbara Iron, WA)

Case 4: In the Port of Taranaki, New Zealand, OMC was able to reduce the port's planned dredging costs by approximately 50% through the introduction of the DUKC® and analysis to determine optimum dredging locations and volumes:

"if we were to achieve the aims we had set we had a clear choice; spend $15m on dredging or adopt DUKC® plus minimal dredging and spend <$1.5m." (Captain Ray Barlow, Harbour Master, Westgate Port Taranaki, NZ)

3 CASE STUDY – THE PORT OF FREMANTLE, WESTERN AUSTRALIA

3.1 Background

The Port of Fremantle is located in the South-West of Australia. Port trades include imports of crude oil, exports of alumina as well as a busy container trade. The port consists of an inner and an outer harbour. There are three main deep draft approach channels to the port.

3.2 Operational DUKC® System

OMC installed a DUKC® System in March 1994 for the import of crude oil in Post-Panamax oil tankers. DUKC® was introduced at the time a major dredging project for the approach channels had been completed.

The DUKC® System enabled the Gross UKC for import tankers to be reduced by 3% of vessel draft (approximately 42 cm), with additional draft increases up to 1.0 m for tankers with beams in excess of 40 m. Considering tankers with a TPC of approximately 100 tonnes, this represents a significant increase in freight.

In addition, the system allowed ships to berth earlier, optimise terminal operations and clear the berth earlier than would have been possible without use of the system.

Following the success of the DUKC® for the crude tankers, the system was extended to include container ships entering the Inner Harbour and Panamax bulk carriers sailing from the Alumina berth in the Outer Harbour. For the container vessels, the DUKC® has provided increases in the maximum draft of 30-50cm and widened the tidal windows 2-3 hours depending on the conditions of the day.

Through continuing interaction with the Harbour Master and other stakeholders, the Fremantle DUKC® system has been upgraded and extended in stages since its initial installation in March 1994.

DUKC® SIV has recently been implemented at the port. This latest upgrade offers increased yield by utilising actual soundings through the use of sophisticated GIS technology. In analysing these soundings, DUKC® SIV is able to deliver additional increases in the yield of a channel in the order of 20 to 30 cm while maintaining PIANC guidelines for UKC through a unique methodology that considers separately the manoeuvrability and bottom clearance requirements.

The DUKC® SIV upgrade included extensive wave interaction modelling around Rottnest Island, and full scale DGPS measurements to validate the additional benefits offered with the upgrade.

3.3 Channel Design Utilising DUKC® Methodology

Fremantle Ports is looking to increase its waterway capacity by undertaking capital dredging of their outer channel to provide access to 14.0m draft post-panamax vessels. Currently the port is restricted to 4,100 TEU container vessels loaded to approximately 12.5m draft.

The study was undertaken utilising DUKC® methodology. DUKC® architecture enables OMC to undertake many simulations that represent the range of vessel characteristics, manoeuvres, speeds and environmental conditions to which the vessels will be exposed under the port's operational rules, in this case DUKC®.

Thousands of DUKC® simulations were performed for two possible channel alignments, using several years of recorded wave and tide data.

The simulations were performed using a fleet of post-panamax container vessels retrieved from OMC databases to reflect the vessels that are likely to call at Fremantle, post dredging.

Each simulation calculated the maximum draft available if a ship began the transit at a particular time, or the tidal windows available for that vessel and tide.

Channel profiles targeting 90%, 92.5%, 95%, 97.5% and 99% access for each of the alignment options and at all stages of the tide were designed, and volumes calculated utilising GIS software.

Figure 3 provides a plot of the optimum non uniform channel profiles determined for the range of access targets for one of the channel alignment options. This Figure shows the determined profiles are very non-uniform, matching the UKC requirements throughout the transit. It is shown that there is a substantial reduction in the port's dredging requirements c.f. blanket dredging.

Because the use of DUKC® technology enabled a realistic simulation of future port operation, all access percentages determined reflect real operating conditions – for example, 95% access to the port means that if a vessel were to show up or depart at the quoted draft at a random time, there would be a 95% chance that it would not be delayed for under keel clearance reasons.

The results also enabled a cost-benefit relationship to be determined for the varying access targets, as shown in Figure 4. This enables an assessment of the relative gains of each potential new channel design. Fremantle Ports can have confidence that these potential gains will correspond to operational gains because the designs were generated and analysed using simulation models subject to actual operational constraints.

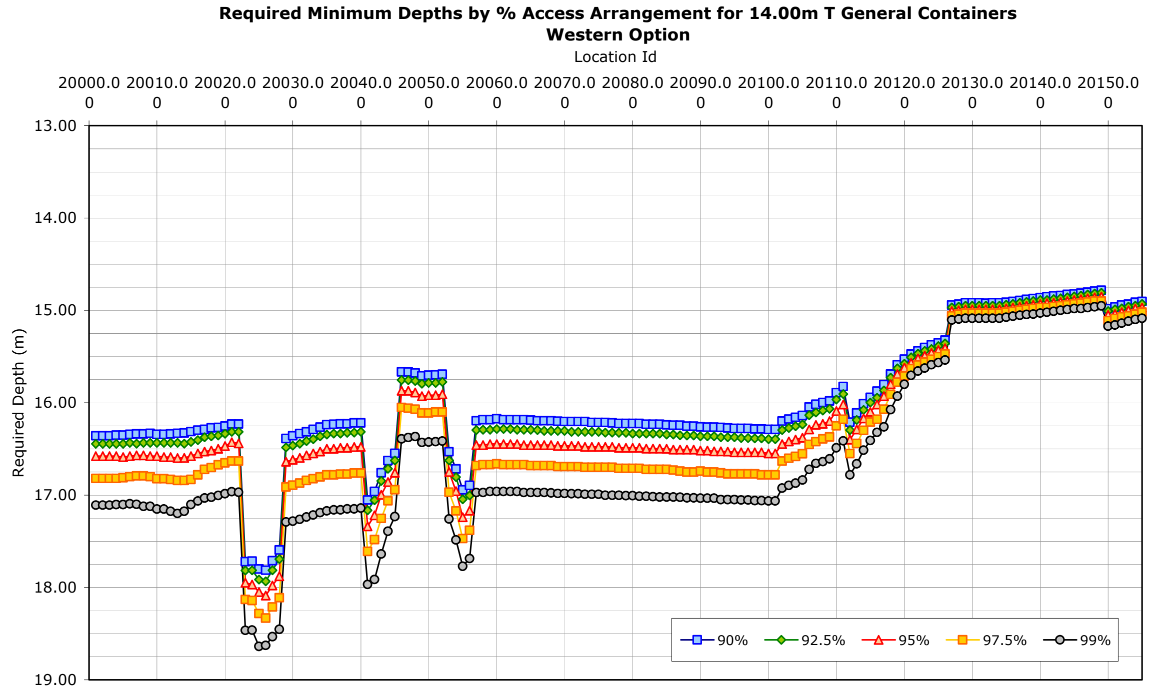

Figure 3 – Channel Profile using DUKC® Methodology for Range of Channel Access Targets

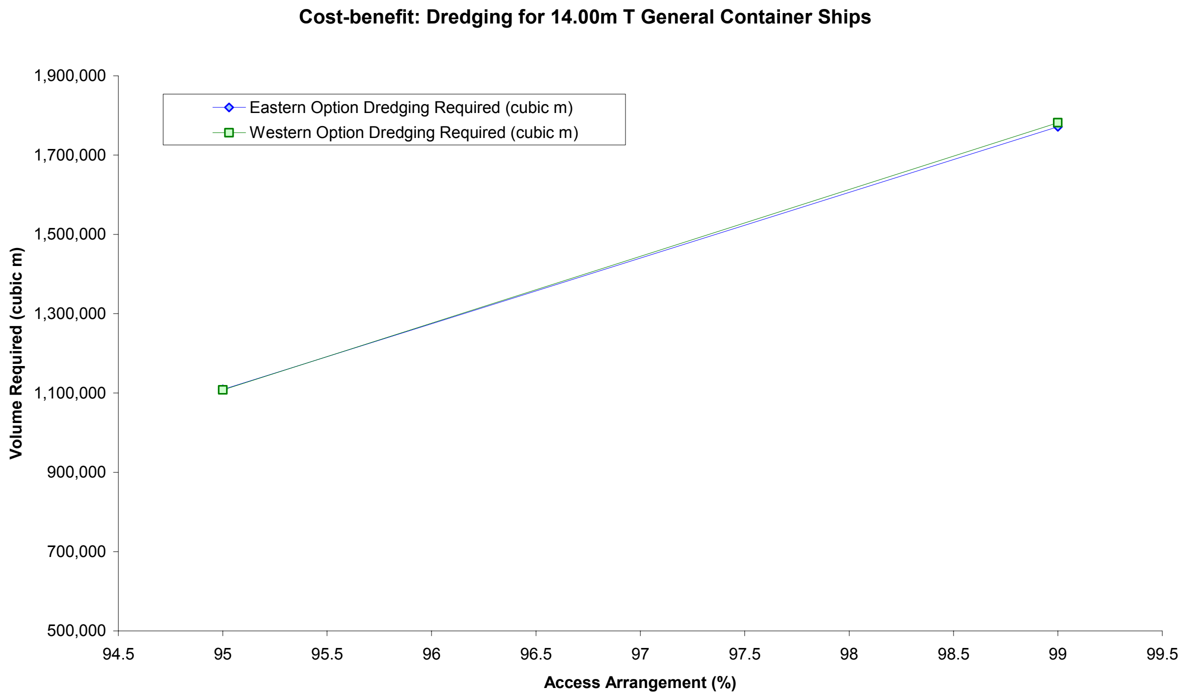

Figure 4 – Cost-Benefit Analysis for Range of Channel Access Targets

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the continued support and assistance provided by the Port of Fremantle, in particular the Harbour Master and Deputy Harbour Master. Without this support, the development, operation and continued improvement of the DUKC system would not have been possible.

Keywords: Underkeel Clearance, Safety, Squat, Draft, Benefits, Dynamic, Dredging, Prediction, Maximum Draft, Tidal Windows,