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Recent Developments and Applications of DUKC® Technology in Channel Design and Operation

By

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ABSTRACT

The Dynamic Under Keel Clearance System (DUKC®) has been the leading real-time UKC system in the world for more than 15 years. It has assisted more than 35,000 vessel movements without incident and has directly generated for shippers and stakeholders many billion of dollars in decreased freight costs and increased cargo throughput, while increasing port safety. These gains have been achieved at a small fraction of the cost involved in gaining equivalent increases in productivity by dredging, without incurring any adverse environmental effects.

OMC has continued to tailor the DUKC® system to better meet the under keel clearance needs of its customers. The resultant products provide integrated vessel management and monitoring tools from port of origin to port of destination.

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This presentation first describes recent innovations and applications which allow DUKC® technology to be taken onboard ships by pilots equipped with the DUKC® Portable Pilot Unit (PPU) and to be integrated into Vessel Traffic Services (VTS) with DUKC® VTS. Both applications allow monitoring and control of under keel clearance by management of vessel speed during transit. Both applications are configured to provide a seamless transition from the shore-based DUKC® Dynamic Passage Planning System.

The presentation then summarises the application of DUKC® technology to optimise dredging profiles for deepening the approach channels for container vessels into the Port of Fremantle, Western Australia. This methodology has been applied at a number of other ports around Australia and New Zealand to minimise channel deepening costs.

The presentation concludes with a summary of the author's involvement in recent activities by PIANC and IALA with regard to concept and detailed design of channel depths, use of hydro/meteo data in channel operation and provision of analysis tools for management of under keel clearance. A brief description is also given of the use of DUKC® PPU technology as a key component in the MarNIS (Maritime Navigation and Information Systems) Project being undertaken by the European Union.

1. INTRODUCTION

Traditionally, ports have operated under fixed rules which govern the minimum under keel clearance (UKC) to permit safe transit along port approach channels. To ensure safety, these fixed UKC rules are determined by requirements under extreme swells and negative tidal residuals.

If the requirements are too conservative, ships carry less cargo than they could, and the operation is not as cost-effective as it might be. At the other extreme, inadequate criteria could jeopardise safety and cause a grounding to occur.

The Dynamic Under Keel Clearance System (DUKC®) developed by OMC uses customised numerical models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time.

DUKC® modelling guarantees accuracy and applicability. UKC requirements are determined based on the actual vessel and its stability parameters, real-time met-ocean conditions (wave height, period and direction, water levels, currents, 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, including the effect of temporal and spatial variation of tidal currents.

The accuracy of the numerical models used in the DUKC® System has been validated by undertaking more than 200 ship transits to obtain full-scale measurements of vessel speed, track and vertical displacements. These validation tests have been undertaken for a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.

The system has also been rigorously and independently tested by specialist risk management consultants to ensure that it satisfies internationally-accepted levels of risk for safely managing the UKC of vessel transits.

DUKC® has assisted more than 35,000 ship transits over the past 15 years, without incident. It is now used by 15 ports in three countries and by piloted vessels transiting Torres Strait. The Port of Lisbon installed DUKC® in 2007 for their deep draft container vessels. By the end of 2008 it will be extended to the Outer and Lower Weser River in Germany as a pilot project of the Waterways and Shipping Directorate, Aurich, and will be operational in the VTS centres at Bremerhaven and Bremen.

On average, there is now a DUKC®-assisted ship movement every two hours, somewhere in the world.

DUKC® is supported 24/7 by an experienced staff of engineers, naval architects and software engineering/IT personnel, employed full-time on the development, implementation and support of DUKC® systems, including ongoing system maintenance, training of operators and regular audits.

What are the benefits?

The three key areas of benefit from an operational DUKC® system are safety, environmental protection and economic gain.

Safety – DUKC® systems greatly reduces the risk of ships running aground. Some examples of groundings that might have been avoided with DUKC® include two large tankers that grounded in the channel leading to New Zealand's only oil refinery at Marsden Point in 2003 where it was later shown that a DUKC® would have prevented both these near environmental disasters. The Maritime Safety Authority of New Zealand imposed significant draft limits on the port following these groundings – these restrictions were not lifted until a DUKC® System was implemented at the Port in a record time of 4 months!

Environment – DUKC® has been developed and is currently being trialled to ensure adequate under keel clearance for piloted ships transiting through Torres Strait and the Great Barrier Reef, one of the great natural marine wonders of the world. The ecological consequences of a ship running aground here, or anywhere, are clearly serious.

Economic – In port operations, the estimated economic benefits of DUKC® in increased vessel drafts, widened tidal windows and reduced demurrage charges exceeds US$5 billon to date.

2. DYNAMIC PASSAGE PLANNING

The core functions of DUKC® systems have always been to provide ports and users with dynamic passage planning advice on:

- maximum draft for tides
- earliest and latest sailing times (tidal windows)
- UKC for specific transits

These core functionalities remain but user needs in specific waterways often drive new developments in the way in which they are computed for those waterways; sometimes these developments find general application for all waterways.

3. DYNAMIC PASSAGE MONITORING AND CONTROL

Recent innovations allow DUKC® technology to be taken onboard ships by pilots equipped with the DUKC® Portable Pilot Unit (PPU) and to be integrated into Vessel Traffic Services (VTS) with DUKC® VTS. Both applications allow monitoring and control of under keel clearance by management of vessel speed during transit. Both applications are configured to provide a seamless transition from the shore based DUKC® Dynamic Passage Planning System.

DUKC® PPU and DUKC® VTS Systems provide Pilots and Vessel Traffic Operators, respectively, with look-ahead predictions of minimum under keel clearances during transit from berth to deep water (or vice versa).

The DUKC® PPU provides marine pilots with real-time under keel clearance management advice through vessel speed optimisation.

Specifically the DUKC® PPU allows the pilot to:

- Monitor that the actual speeds are within the speed envelopes generated by the DUKC® Passage Plan.
- Determine where it is safe to travel at speeds outside those generated by the DUKC® Passage Plan and to what extent it is safe to do so.
- Investigate alternative speed/sailing options in situations where the passage does not proceed as planned. This could include situations such as vessel breakdowns, vessel delayed leaving the berth, vessel loaded in excess of its planned passage draft, vessel not performing as expected or deterioration in the environmental conditions.
- Identify speeds that will maximise UKC or minimise transit time without exceeding safe UKC limits.

The DUKC® VTS System provides VTS Officers with a tool to monitor the effect of vessel speed on under keel clearance during transit. If shore-based pilots have access to this system, they can use it to advise on-board pilots (who may not have access to a DUKC® PPU unit) to adjust speed as necessary, especially when problems develop with maintaining planned passage speed.

The VTS application has been operational at Port Hedland, Western Australia, since mid-2007. It was used on at least three occasions during the first four months of operation to help on-board pilots determine the best option in dealing with UKC issues arising from engine breakdown during transit.

Both PPU and VTS applications are currently being implemented at several ports where DUKC® Dynamic Passage Planning systems are in place.

4. INTEGRATION OF DYNAMIC PASSAGE PLANNING AND CONTROL FOR MULTIPLE VESSELS AND PORTS

An integrated DUKC® system for Dynamic Passage Planning and Control is currently under development for the Waterways and Shipping Administration (WSA) in North-West Germany. The project is being undertaken as a pilot project of the Waterways and Shipping Directorate, Aurich.

This system is being configured for the Outer Weser and Lower Weser River, between Bremerhaven and Bremen to assist safe and efficient movement of deep-draft container vessels into the Port of Bremerhaven (4.9 million TEU's in 2007) and bulk carriers into the ports of Nordenham, Brake and Bremen on the Lower Weser.

The integrated system will be operated at the VTS centres at Bremerhaven and Bremen (as shown in Figure 1) for UKC management of vessels in their respective traffic control segments on the Outer and Lower Weser It will provide Vessel Traffic Operators with the capability to monitor and predict minimum under keel clearances of vessels as they pass through the two VTS control zones on the Weser and as they enter or leave one of the four ports on the river and its estuary.

Figure 1 – Outer and Lower Weser River, Major Ports and VTS Centres

5. OPTIMISATION OF CHANNEL DESIGN

Ever increasing demands on ports to accept larger and 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 channel operation, based on mostly static rules with little scientific basis, and using blanket capital dredging, are becoming increasingly less acceptable in today's world of accountable budgets and increased emphasis on minimising environmental impacts.

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

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

Because the use of DUKC® technology enables a realistic simulation of future port operation, all access percentages determined reflect future operating outcomes.

The following presentation summarises the application of DUKC® technology to optimise dredging profiles for deepening the approach channels for container vessels into the Port of Fremantle, Western Australia. This methodology has been applied at a number of other ports around Australia and New Zealand to minimise channel deepening costs.

Case Study in Use of Dynamic Under Keel Clearance (DUKC®) Technology at Fremantle Ports

OMC installed a DUKC® System for Dynamic Passage Planning at the Port of Fremantle in April 1994 for the import of crude oil in Post-Panamax tankers. 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.

In 2004, Fremantle Ports began detailed planning for a major increase in waterway capacity for the next generation container vessels, involving capital dredging of their channels to provide access for 14.0m draft post-Panamax vessels. Currently the port is restricted to 4,100 TEU container vessels loaded to approximately 12.5m draft.

Given the importance of minimising the environmental impacts from dredging, an innovative technological process using Dynamic Under Keel Clearance (DUKC®) technology was developed to optimise the depths of the approach channels and harbour swing basin area for the Inner and Outer Harbour proposals. This optimisation process resulted in a substantial reduction in the dredging requirements in comparison to the volumes that would have been obtained through traditional channel design.

The channel design study was undertaken utilising DUKC® methodology. Many thousands of simulations were performed representing the range of vessel characteristics, manoeuvres, speeds and environmental conditions to which the vessels will be exposed under the Fremantle Ports operational rules, in this case DUKC®.

Simulations were performed for two possible channel alignments, an eastern channel alignment option and a western channel alignment option, using several years of recorded wave and tide data. A plot of the preferred eastern alignment option is given in Figure 2.

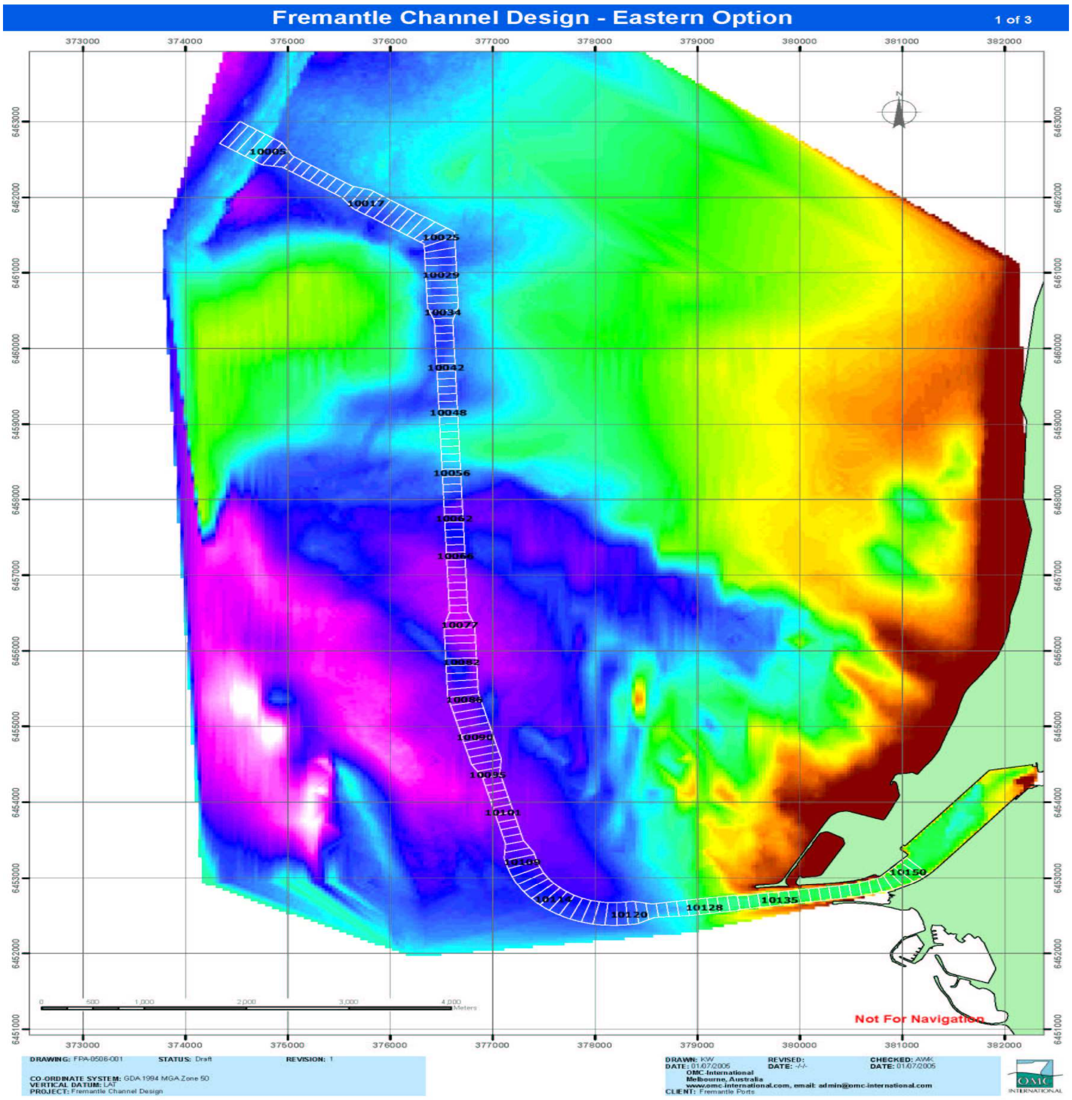

Figure 2 - Eastern Alignment Option (Port of Fremantle)

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 channel profiles determined for the range of access targets for one of the channel alignment options. This Figure shows that the optimal 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 compared to blanket dredging to a uniform depth.

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

The results also enabled a cost-effectiveness relationship to be determined for varying access targets and alternative channel widths, as shown in Figure 4. This allowed an assessment of the relative gains of each potential new channel design.

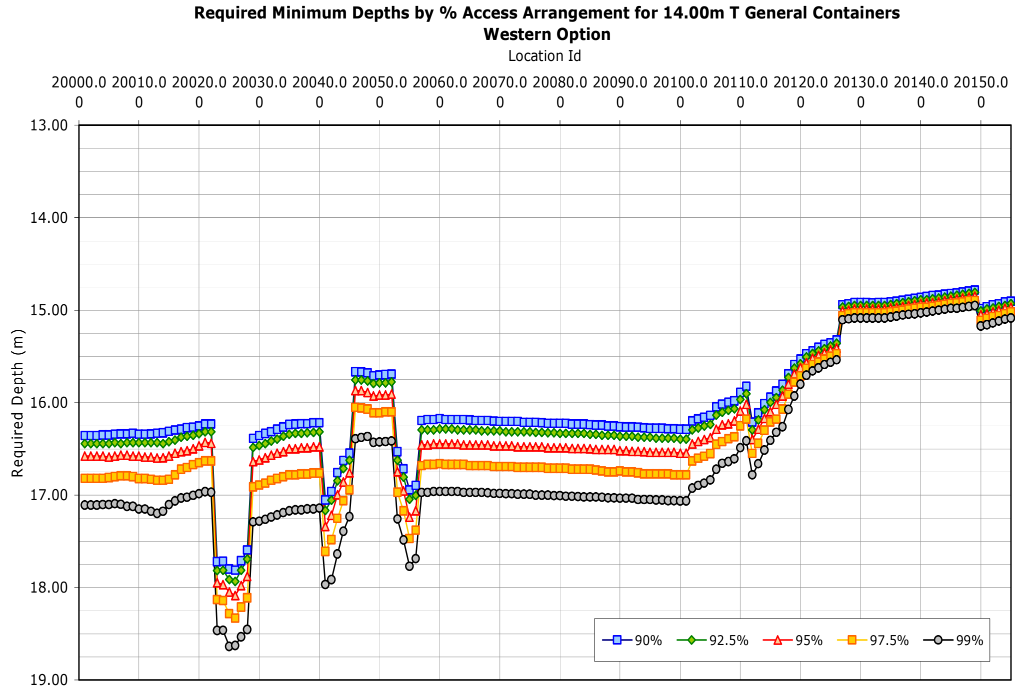

Figure 3 – Channel Profile using DUKC® Methodology for Range of Channel Access Targets

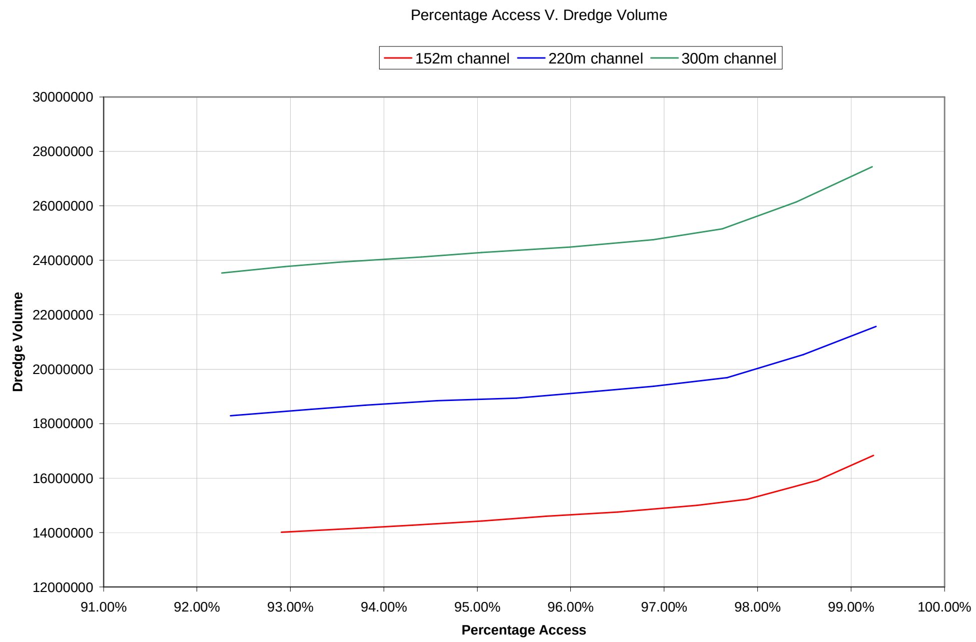

Figure 4 – Cost-Effectiveness Analysis for Range of Channel Access Targets and Channel Widths

A second study was conducted to determine depth requirements for container vessel transits through the proposed 2nd Success & Parmelia (S & P) Channel to the Outer Harbour, as shown in Figure 5.

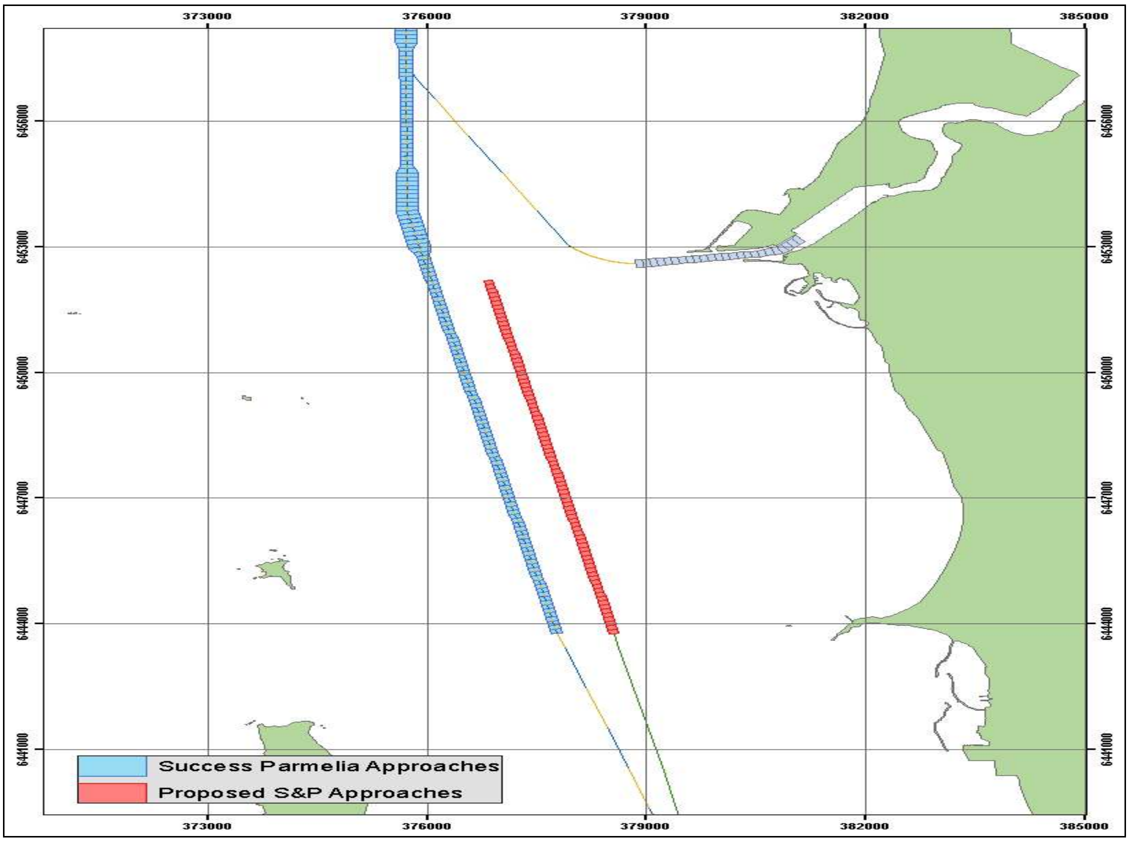

Figure 5 - Proposed Success and Parmelia Channel Approaches

This channel design study was carried out by simulating a vessel, selected at random from a fleet of 14m draft container ships, transiting the eastern Deep Water Channel alignment option, Gage roads, and 2nd S & P channel for every hour of a two year period where wave and tide data were available. Three different channel widths (152m, 220m and 300m) were simulated in the S & P channel to determine the effect on UKC requirements.

The results from the analysis are shown in Figure 6, with the Parmelia bank on the left and the Success bank on the right.

The change in depth between the three channel widths is due to the change in squat. A wider channel will induce less squat in the vessel, as the flow around the hull is less restricted. The greater variance in required depth between the Success and Parmelia sections is due to the influence of surrounding water depths on squat; areas with shallow surrounding banks cause greater squat than open water.

Figure 6 - Channel depth profiles for three optional channel widths

6. INTERNATIONAL DEVELOPMENTS IN UKC MANAGEMENT

Two recent developments in UKC management by international navigation bodies are summarised below.

PIANC has established MarCom Working Group 54 to develop guidelines for the use of hydro/meteo data to optimise safe waterway access and determine the operational limits of navigational channels. This Working Group is being chaired by the author and is well advanced towards meeting its target of providing a draft report by late 2009. The guidelines will address the measurement, prediction and use of hydro/meteo data and give examples of current national approaches to these important tasks.

IALA – A meeting of IALA's e-Navigation Committee in Shanghai in February 2008 produced a Strategy Document and an accompanying paper on User Needs, which specifically include provision of analysis tools for management of under keel clearance and air draft.

These documents are to be reviewed and approved by IALA Council, for submission to IMO Nav 54 in late June 2008. If Nav54 approves the proposed strategy and user needs, the documents will then be referred to MSC (Maritime Safety Committee) of IMO for its meeting in October 2008.

In addition to the above developments, Dynamic Under Keel Clearance Management also forms an important component in the European Union **MarNIS** (Maritime Navigation and Information Services) Project.

MarNIS is an Integrated Research Project in the 6th EU Framework Programme, bringing together 50 partners to develop Maritime Navigation and Information Services on a pan-European basis.

OMC was sole-sourced by the MarNIS Project to integrate its DUKC® technology for Portable Pilot Units (PPU) into the POADSS (Port Approach Docking Support System). The integration of this technology with high precision IMU/RTK vessel motion sensors will be featured at the MarNIS Demonstration scheduled in Lisbon on 15-16 October, 2008.

7. ACKNOWLEDGEMENT

Since installation of the first DUKC® systems in the early 1990's, continued research, development and refinement of DUKC® technology has been undertaken by an expanding OMC team of talented and dedicated engineers, naval architects, software developers and IT personnel. They have been. greatly assisted by interaction with Harbour Masters, Pilots and port users. Without such continuing feedback and interaction, the technology could not have reached its present state of development and widespread application. The author is deeply grateful to all who have contributed their time, knowledge and experience to this innovation in maritime engineering.