

# ENHANCED SAFETY THROUGH THE USE OF REAL-TIME DYNAMIC CHARTS OVERLAYS

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## ABSTRACT

In today's economic climate, ports need to maximise their efficiency while ensuring safety of passage. As vessels increase in size, the dilemma facing many ports is that their existing static underkeel clearance (UKC) rules are inflexible, thus deeper vessels cannot transit without compromising safety.

As static rules do not change with the environmental conditions, the actual clearance and the potential of vessel grounding varies on any given day; for this reason static rules need to be conservative.

In contrast, dynamic UKC systems, calculate the required UKC depending on the prevailing environmental and vessel conditions; this ensures every transit satisfies appropriate risk standards. With safety assured, economic and efficiency benefits are realised when conditions allow deeper draughts and/or extended tidal windows.

This dynamic information can now be relayed to the pilot, via a chart overlay, to provide real-time 3D displays of the safe navigational areas, thereby ensuring continued safety of navigation.

## STATIC V DYNAMIC SYSTEMS

The majority of authorities' in the world use static rules to determine the safe underkeel clearance of a vessel. These static rules often use the vessel's draught as the baseline to determine the underkeel clearance; however it is contended that this method can be erroneous as they are based on the assumption that this clearance is sufficient

regardless of the prevailing environmental conditions.

In practise, the actual safety clearance is determined by the conditions on the day, and under static rules, the clearance for a vessel varies for every transit. Most of the time the static rules will be conservative, but evidence shows that up to five percent of transits are marginal, even unsafe<sup>1</sup>.

By contrast, a dynamic under keel clearance system (DUKC®)<sup>2</sup> calculates real time under-keel clearances in ports and shallow waterways to maximise channel safety and also productivity. The DUKC® considers all factors that affect the UKC of a vessel transiting a channel to determine the minimum safe UKC requirements. The system does not use the vessels draught as the baseline, but a pre-determined safety limit which must not be breached; added to this limit are the vessel's dynamic movements which are modelled using the predicted environmental conditions and this gives the minimum water level that is required to ensure safety at all times throughout a planned transit.

The methodology behind dynamic underkeel clearance has been internationally recognised, and the improved certainty and information that dynamic systems can deliver, has seen regulatory bodies, i.e. IALA and PIANC<sup>3</sup>, regarding such systems as an essential Aid to Navigation (AToN).

These bodies are now developing standards for dynamic underkeel clearance systems because of the significant benefits, which dynamic determination of underkeel clearance provides, as a risk mitigation tool. They have identified DUKC® as a

core e-Navigation concept, which is available and operational today. For the same reasons many authorities' have become increasingly interested in installing DUKC® for safety and risk management purposes.

However, DUKC® systems have also been widely recognised for the enormous economic benefits provided to waterway owners and users by reducing the inefficiencies inherent in the static rules, which is a result of the conservatism, when allowed; Therefore benefits can be realised when environmental conditions allow, and safe transits outside the restrictive static rule boundary can be undertaken.

## STATIC RULES

Traditionally, authorities' have utilised static rules to govern the minimum under keel clearance (UKC) to ensure the safe transit of a

vessel. These static rules were devised when vessels were smaller, their speeds lower, ship/shore communications poor and technology generally unavailable to determine ship motions accurately.

Therefore, there needed to be a simple method of calculating a safe underkeel clearance, and the accepted practise, was/is to calculate the underkeel clearance as a proportion of the vessels draught. The most common clearance ratio is "ten percent of draught", which is unfortunate as the PIANC<sup>4</sup> guidelines state that this is a minimum suggested safety clearance and is for calm waters only, and that twenty, even fifty, percent may be better, especially for areas that are subjected to wave motions, but this fact is often forgotten.

1.- OMC's historical records show approximately 95% of vessels are conservative, 4% marginal and 1% potentially unsafe

2.- DUKC® is the trademarked product of OMC International to determine dynamic underkeel clearances.

3.- International Association of Lighthouse Authorities and Permanent International Association of Navigation Congresses.

4.- Underkeel clearance for large ships in maritime fairways with hard bottom; Supplement to Bulletin No51 (1985);

The static rule tries to capture all anticipated factors<sup>5</sup> in a single allowance. Essentially the only controllable factors are the tide height (and therefore transit time) and speed (which determines the amount of squat<sup>6</sup>). Therefore, where depths are critical and conditions more variable, there may be times when the allowance is marginal.

It could be suggested that *the “static rule” approach is a “top-down” approach*, where the gross clearance is determined from the draught and the actual net underkeel clearance is unknown.

Some ports do try to assess some of the factors, and this could be viewed as an advanced static rule. But whilst some of these factors can be pre-calculated, predicted wave response (in real time) is impossible to calculate without significant processing power and access to envi-

ronmental data; so in practical terms wave motions are undeterminable once a transit commences. To address this issue, these ports apply a pre-determined roll/pitch angle to give the ship-handler an indication of loss of underkeel clearance due to wave motion<sup>7</sup>.

Speed is an absolutely critical element in maintaining safe UKC. Evidence has shown that vessels’ do not always maintain the planned, or proceed at an appropriate speed for the transit. If the transit is too fast, the ship will squat, and heel, in excess of the predicted amounts; both effects are approximately proportional to the square of the speed. By contrast if the vessel transits slower than planned, it will not reach way points at required times and, in tidal waterways, may have less water than predicted and the transit may now be unsafe.

Once underway these elements can be difficult to assess and can often be overlooked. Most authorities’ use a single squat formula, but there are many formulae in existence and the most appropriate formula will depend on the bathymetry, channel design and the type of vessel. Often the navigator will calculate the squat for a single critical point, but in practise the vessels squat is continually changing throughout the entire length of the transit.

The biggest drawback with static rules is that the actual clearance is wholly reliant on the environmental conditions. If they are too optimistic, safety could be jeopardised; too conservative, and they become uneconomic; so they are blunt compromise, and for safety reasons need to be derived for the worst case scenario<sup>8</sup>. The actual net clearance is proportional to the environmental and transit conditions, but at the same time unresponsive to change; this means an authority cannot maximise efficiency when conditions allow. More worryingly, an authority will not be aware when conditions are actually unsafe<sup>9</sup>, because when static rules are used, the level of risk is variable and the net underkeel clearance on any particular transit is unknown.

**DYNAMIC ALLOWANCE**

By contrast, dynamic underkeel clearances 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.

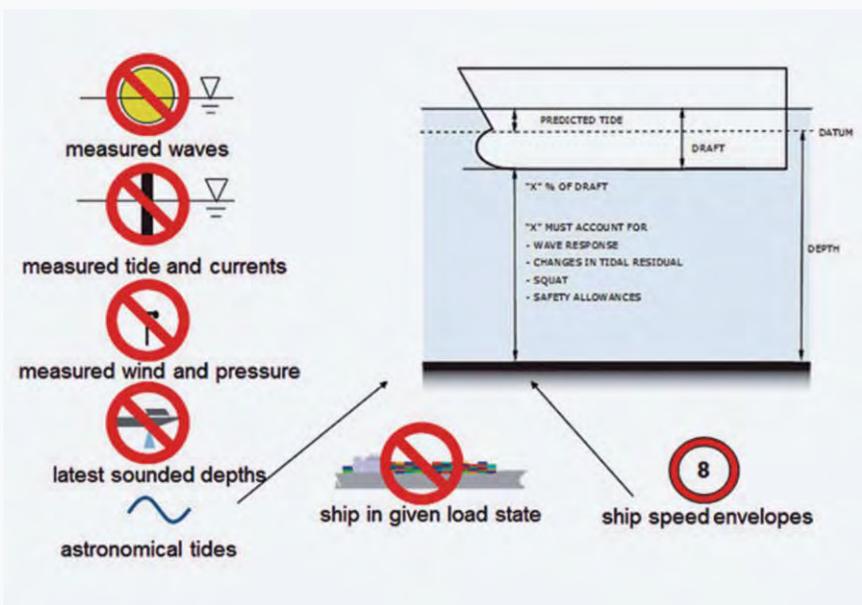


Figure 1 Static Rule components

- 5.- Factors include: Tidal residual (difference between predicted and actual tides); Tidal change during transit; Allowance for unfavourable metrological conditions; Water density; Squat (from ship speed); Wave response; Sounding errors; Sedimentation, Localised phenomena such as standing waves.
- 6.- Squat is a hydrodynamic phenomenon by which a vessel moving through water creates a localised area of lowered pressure that causes the vessel to “apparently increase in draught” and be closer to the seabed than would otherwise be expected. It is approximately proportional to the square of the speed of the ship. [http://en.wikipedia.org/wiki/Squat\\_effect](http://en.wikipedia.org/wiki/Squat_effect) .
- 7.- Loss of UKC = Tan Roll \* Beam. However it should be remembered that two vessels, of the same dimensions, but with differing stability will react differently in the same environmental conditions.
- 8.- The probability that ship-bottom contact in the long term results in the loss of a ship, or large contamination of the marine environment or the beaches, should be virtually zero. PIANC (1985).  
The chance that a vessel touches the channel bottom during its transit must always be less than 1% for all (weather) conditions (Save-nije RPhAC 1996. Probabilistic admittance policy deep-draught vessels)
- PIANC (1997) grounding probability studies show risk of grounding is in region of 3x10<sup>-5</sup> (one ship per 33000 movements)
- 9.- Whangarei, 2003. Two vessels “Capella Voyager” and ‘Eastern Honour’ ground under existing static rules, which were considered safe.

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 the system.

With respect to squat, individual ships and the pertinent characteristics of the complete approach channel are modelled in each dynamic system, using the most appropriate squat formula, and include the effect of temporal and spatial variation of tidal currents during the transit.

Dynamic systems can be considered as a “bottom up” approach and the system has, at its core, minimum limits<sup>10</sup> that must not be breached. Each of the factors are computed in real time, and then added until the minimum tide height is found that ensures a safe transit. Thus when the conditions are favourable vessels may have greater tidal windows and/or can sail with a deeper draught; but when conditions are not then tidal windows are reduced, and may even be closed, or a vessel may be able to proceed but with a reduced draught.

The systems are predictive, so if a navigator wishes to adapt his transit plan (especially the transit leg speeds), or if there is an unforeseen event (e.g. an engine issue or berth congestion), or there is a change in the environmental conditions the system will automatically update the safe transit windows.

Integration of the sophisticated numerical calculations (the “engine”) with real time environmental data (wave, current and tide) ensures

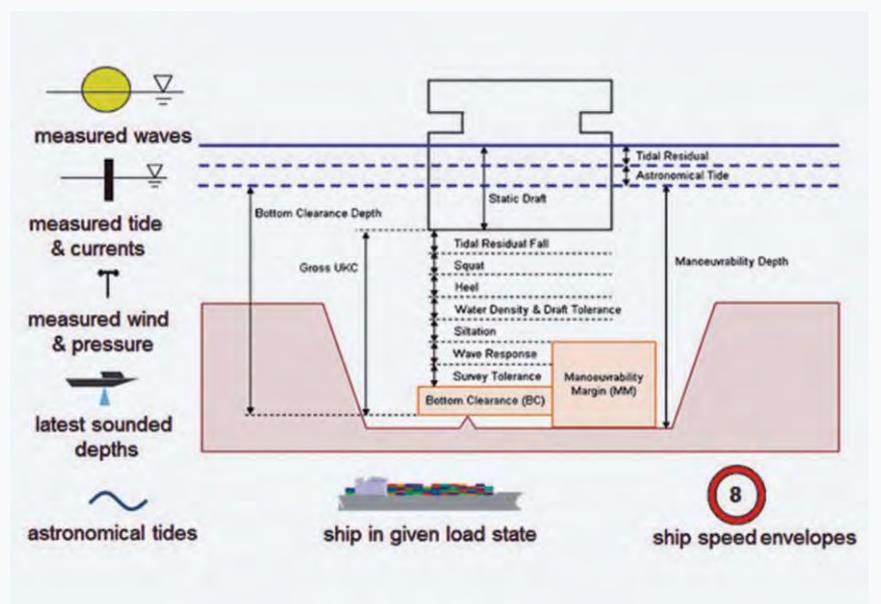


Figure 2 Dynamic Allowance components

integrity and quality at the critical interface between the UKCM system and the dynamic data. Validated accurate numerical models<sup>11</sup> are used to ensure accurate vertical displacements for any vessel type, size and stability condition and vessel speed, in any channel width, configuration, lengths and wave condition, tidal regime and current speed. Each installation is customised using these numerical models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time. For this reason a dynamic system satisfy and often exceeds the internationally-accepted levels of risk for safely managing the UKC of vessel transits<sup>12</sup>.

By conducting extensive comprehensive geospatial analysis of raw sounding data<sup>13</sup> the system can accurately quantify minimum depths

and manoeuvrability depths on a much finer resolution than a standard DUKC calculation. High resolution multi-beam survey data is primarily used to describe the sea bed in much greater detail than is typically available from a standard ENC or navigational chart.

This allows vessels to load deeper when performing dynamic passage planning analyses based upon actual channel depths derived from raw sounding data rather than from a usually conservative estimate of channel depths. For channels that have major siltation issues and require regular sounding, these can now be readily input the DUKC® as soon as they are made available. The DUKC® is therefore always operating on the latest available hydrographic depths, with an allowance for siltation where appropriate from the date of the latest survey.

10.- The limit/s can be found in PIANC, 1985 (Underkeel Clearance for Large Ships in Maritime Fairways with Hard Bottom. Report of a Working Group of the Permanent Technical Committee II. Supplement to Bulletin No. 51 (1985)). The limits used in a dynamic system are the PIANC's Bottom Clearance and Manoeuvring Margin limits, but any stipulated minimum limit could be used.

11.- Accurate, and validated, numerical models are fundamental to the assured safety of a DUKC® system. This is done through full-scale measurements of vessel speed, track and vertical displacements, using survey grade DPGS units. OMC has undertaken on more than 300 ship transits in a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.

12.- 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. The Port of Melbourne also undertook two independent risk assessment studies and these extensive risk management studies concluded that the full complement of DUKC® software would significantly reduce the risk of large vessels grounding in port approach channels.

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## DYNAMIC UNDERKEEL CLEARANCE SYSTEMS (DUKC®)

DUKC® is a proven safety and risk management technology and is a recognised core e-Navigation concept, which is available and operational today. OMC, the developers, created the first DUKC® system for Hay Point coal terminal in 1993. The technology has now been installed in over 20 ports and has ensured the safety of over 100,000 transits to date and the day-to-day operation of DUKC®, in preference to static rules for UKC, has moved the system from academic theory into a best practice in the real world.

The system is customised for every port and implements the “dynamic allowances” mentioned above. 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

The system provides comprehensive reports for ports and pilot’s which improves the decision making process and enhances the master pilot information exchange. It also serves as a historical database for auditing and risk analysis purposes. The system is now at Version 5 and is a fully interactive cross-platform web based system.

Examples of the information from the voyage planning service, which provides advice and maximum draughts and tidal windows, can be seen in Figure 3, and the transit planning service which allows for speed (squat) adjustment and information on calculated keel elevations in Figure 4.

Whilst these functionalities remain at the core of the DUKC system, specific user needs and how they want their results computed and delivered often drive new developments, which have universal application for all waterways. One such development was the delivery of dynamic information to the pilot (and vessel), in a format that is readily understandable, and did not

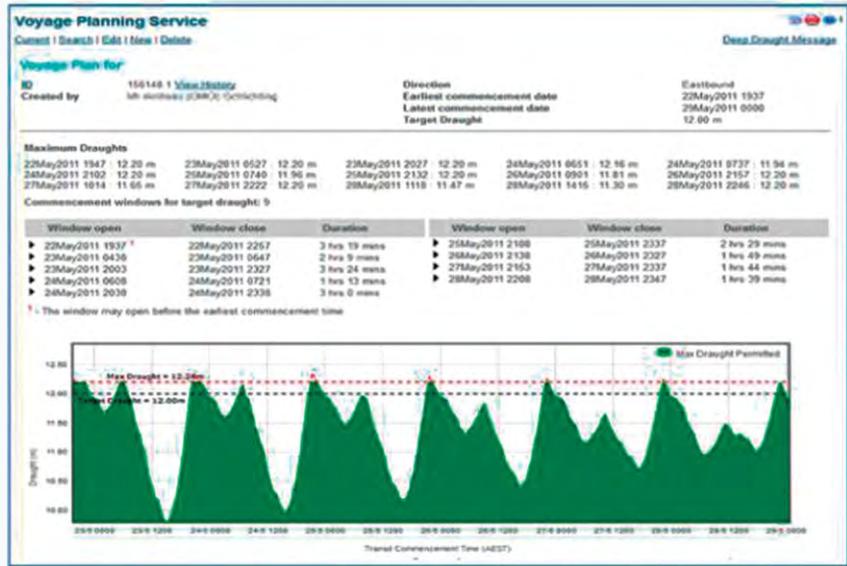


Figure 3 Voyage Planning Service - Max draughts and Tidal Windows

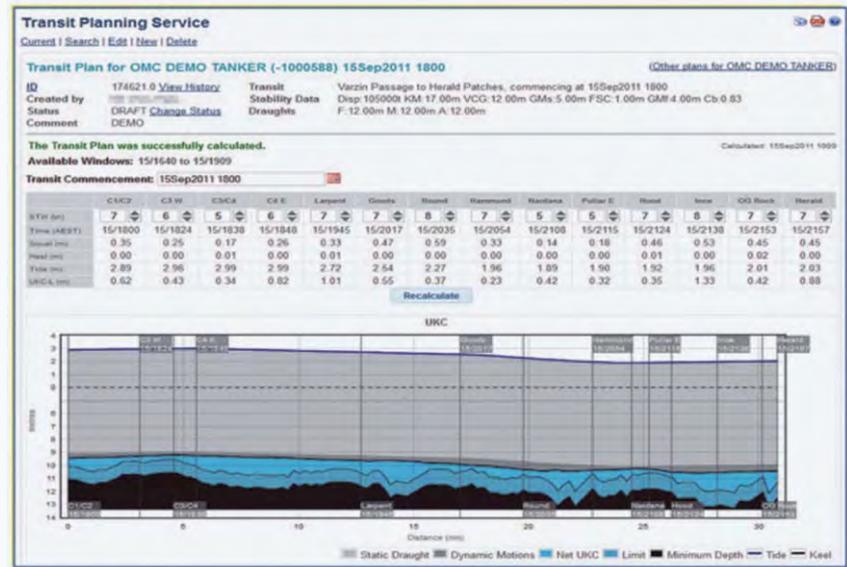


Figure 4 Transit Planning Service - Transit and Speed Assessment

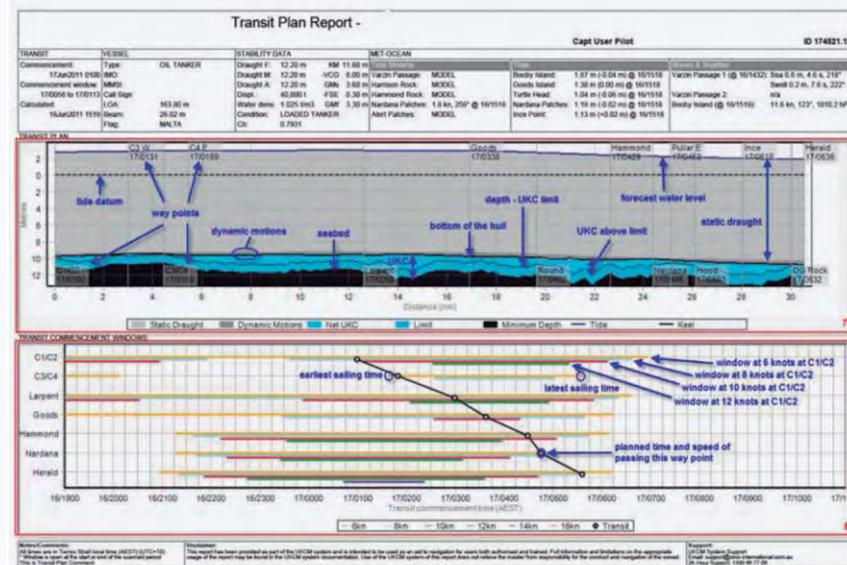


Figure 5 Overview of transit information report

interfere with primary requirement of navigation. Chart overlays were identified as the most appropriate method, which can be readily incorporated into the pilots' portable pilotage unit (PPU). Chart overlays present a simple visual indication on which areas meet UKC limits, and are safe for traversing, and which areas do not meet UKC limits, and should be avoided.

Essential to any implementation of chart overlays is the availability of promulgating the raw sounding data, as previously mentioned. This data is required to be up to date, and in recent years, survey techniques, data processing and computing power have progressed to the point where detailed electronic sounding data can be readily analysed and quickly, provided to users.

### CHART OVERLAYS

DUKC® Chart Overlay was specifically designed for pilots and mariners and displays under keel clearance information geospatially through a Marine Information Overlay (MIO) on a compatible Electronic Charting System (ECS) such as one running on a Portable Pilot Unit (PPU) carried on board to monitor the passage in real time. In parallel, the overlays can be displayed on the web within the DUKC portal, allowing a shore station to view the same dynamic overlay that the pilot is viewing.

As every vessel has a unique dynamic UKC plan each overlay is vessel dependant; this is different to a tidal or weather overlay that is generic to all vessels. Thus there may be numerous vessel specific chart-overlays in existence at any one time.

The overlay is based on the latest available high-resolution bathymetry data, prediction of tidal and non-tidal water levels, waves and currents, knowledge of the recorded vessel load state (draft, trim, and stability), the pilot's submitted passage plan (speeds and expected times at waypoints) and predictions of the associated dynamic vessel motions (squat, heel, and wave response). DUKC® overlays are also predictive in nature, therefore tide heights, currents and environmental

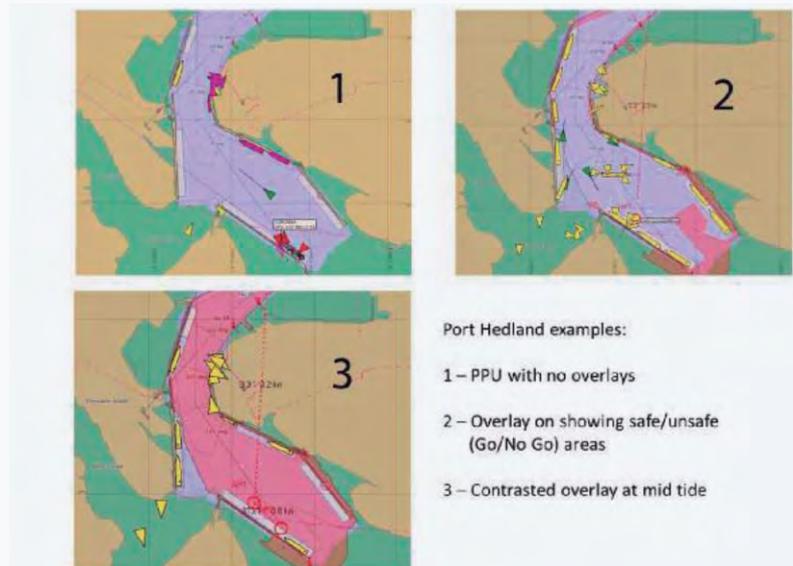


Figure 6 Actual PPU displays with overlays on/off and differing tidal conditions

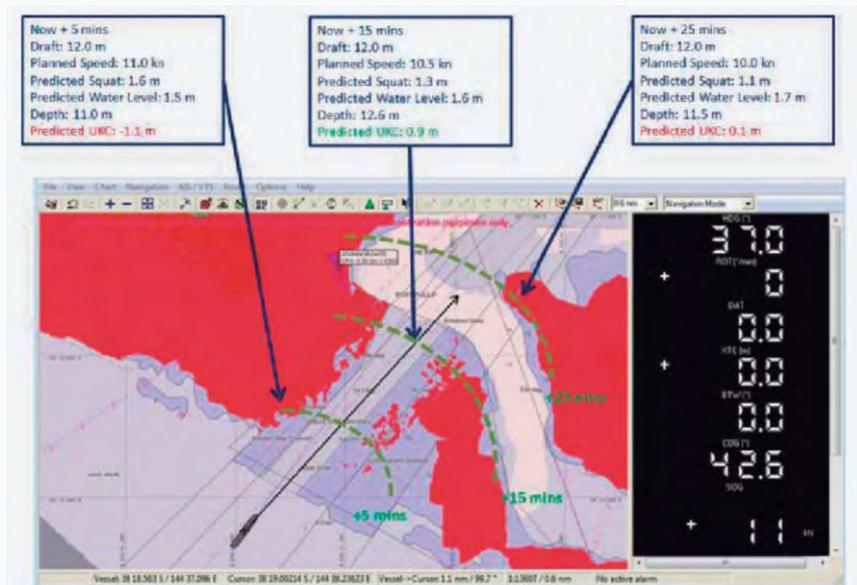


Figure 7 Overlays are predictive as well as dynamic (overlay colour transparency reduced for clarity only)

conditions are being predicted for the actual time of transit (i.e. at a waypoint) which makes DUKC overlays unique when compared to other products.

An example of the chart overlay is displayed in Figure 6. The simple presentation of predicted Go / No Go areas for the time of the vessel arrival in those areas allows the pilot to anticipate required deviations from the transit plan. This anticipation allows time for various options to be considered and enables proactive rather than reactive navigations.

### KEY BENEFITS FEATURES

Dynamic UKC chart overlays, and the predictive capabilities, have a number of key benefits over existing navigational systems.

- It allows rapid identification of channel (or adjacent) areas that must be avoided and allows identification of potential UKC hazards at the passage planning stage.
- It allows pilots and masters to make informed tactical navigational decisions about the vessels route which can be adjusted to ensure

safety of navigation is maintained.

- It offers optional fine-tuning and optimising of passage plans for long or complex passages while underway.
- In emergency conditions it offers informed escape options and lowers the risk of channel blockage. As the same overlay is available to the port user, it allows the Harbour Master (or similar) to assess the situation in parallel. This benefits the pilot/master whose primary priority is to stabilise the situation, whilst contingency plans are assessed.

**THE KEY FEATURES OF THE SYSTEM ARE:**

- Display of safe and unsafe transits (go/no-go areas) at the passage planning stage and whilst underway.
- Updates go/no-go areas automatically based on the latest available met-ocean conditions and actual vessel speed and position (AIS).
- Go/no-go areas are based on dynamic under keel clearance calculations and include the impact of dynamic ship motions on navigational safety.
- Go/no-go areas are computed on-shore by powerful computers and are transmitted to the vessel, allowing relatively lightweight and low spec on-board devices.
- The go/no go areas are predictive, i.e. predicts the conditions ahead of the time of arrival.
- The go/no-go areas can be displayed within compatible ECSSs.

**CHART OVERLAYS DELIVERY**

The delivery of a chart overlay to a pilot required a number of technologies to be integrated. The concept of overlays is not new, but dynamic and predictive UKC content, delivered in real-time, is a world first and true e-Navigation solution. The first live application is at Port Hedland,

Australia, and involved three<sup>14</sup> principal companies, these were:

- OMC International: DUKC® system delivering dynamic chart overlays in real-time.
- QPS BV: Received the chart overlay,

interpret the data and deliver to the PPU via their Qastor Connect server.

- Navicom Dynamics: PPU manufacturers running Qastor navigation software which receives the Qastor Connect data and displays on the PPU.

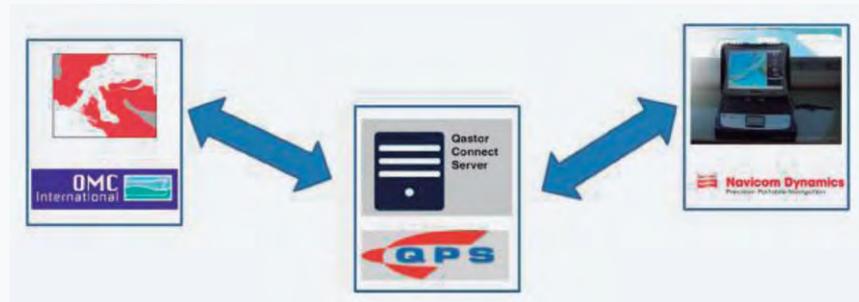


Figure 8: Overview of the Chart Overlay delivery

**THE KEY STEPS TO PRODUCING AN OVERLAY ARE:**

1. At the planning stage, prior to the transit, the administrator calculates a safe transit window for the vessel and the time of sailing, based on a default speed profile, and promulgates this to the pilot organisation. The pilot can then interact with the system (via the web) and customise the transit. In essence this means the pilot can optimise/adjust the speed profile, to match the vessels manoeuvring characteristics and any changes that negatively impact on the safety are visually<sup>15</sup> apparent to avoid unsafe transits.
2. When a DUKC calculation is performed the results are spatially combined with the high resolution bathy grid (as described earlier) and areas of Go/No Go are determined. This data are stored as a single band geotif, and are vessel and transit specific i.e. customised for each vessel using the system.
3. The computed geotifs are placed on a local file server. The chart overlays are now ready for display. For passage planning where pilot has ready broadband access (before departure on land) overlays can be displayed on map server within DUKC® system.
4. The overlays are continually updated and file sizes are reduced by splitting transit into tiles and only updating the required tiles by overwriting. Once a transit commences historical tiles are not recalculated, thus reducing file sizes further (and this significantly reduces data transfer costs). Once transit has commenced the other Chart Overlay partner companies take over.
5. Qastor Connect server regularly pole the OMC file server for new chart overlays. These are pulled down from the local server, interpreted and broadcasted via a dedicated communications channel to a receiver running the Qastor software, normally being the pilot's PPU.
6. The Qastor navigation software has been modified to allow the pilot to load the applicable transit from the server. Once loaded the software continually downloads the revised chart overlays (updated tiles) and these are displayed as a layer on the PPU display by over laying the standard ENC's and other layers used. The chart overlay is on by default but can be turned off if the full chart needs to be viewed.

14.- A fourth company, Telstra, was used for dedicated 3G broadband but newer technologies like marine broadband VDES could be used when available.

15.- At the planning stage, the transit is displayed as a vertical graph of the water column taking into account the dynamic components for the whole transit. See Figure 4.



## FUTURE DEVELOPMENTS

Chart overlays will be an important component of any eNavigation system as it will deliver navigational and safety information in formats that will be readily understandable. The type of data that could be communicated is diverse, and it is probable that it will revolutionise today's navigational practices.

Dynamic UKC chart overlays are already well established, and whilst they are presently being delivered by geotifs via 3G, any recognised overlay format and communication channel could be implemented. Implementation of the S100 standard is very likely to benefit the delivery of this information to a ship's ECDIS, or other navigational systems, rather than just the pilot's PPU, and the proposed VHF Data Exchange System (VDES) will also be an important/necessary development as data requirements increase.

## CONCLUSION

The use of static rules at many ports needs serious consideration about whether they are suitable, and if all factors are understood. The paradox of the static rules is that without an incident a port's static rules may appear validated and considered safe. In reality, where underkeel limits are critical and conditions variable, there may be times when the clearance is marginal and the port has experienced an unknown "near miss".

Dynamic underkeel clearance systems ensure safety through accurate planning and continual monitoring of the UKC of large vessels during transit along shallow waterways. These decision support tools, and the integration into navigation systems, such as a pilot's PPU, also allow the effect of alternative speed/sailing options on UKC to be quickly investigated by pilots and masters in situation where the passage does not proceed as planned. The information that is now available from a dynamic system enhances the decision making processes of all users, and complements the master/pilot information exchange, and the availability of results to both vessel and

shore, in real time, also enhances contingency planning in the event of an unforeseen incident.

Dynamic underkeel clearance systems have a proven track record and its use will only increase throughout the maritime industry. As the methodology builds on the concept of a minimum clearance limits that must not be breached, dynamic underkeel clearance systems effectively controls the risk of a touch-bottom/grounding in-

cident. This level of risk cannot be achieved with static rules because the clearances vary and are determined by the environment present on the day.

Dynamic UKC chart overlays are an evolutionary step in delivering UKC information to the navigator in a visually understandable format. It is an operational and proven eNavigation solution that can only increase the safety of vessels. ■

## NOTES

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