'How deep will the water be?'

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Topic J: accurate hydrodynamics

INTRODUCTION

To date ENCs have done very little to help answer this question. Contours and spot depths indicate how far the seabed is below chart datum; tables allow the prediction of tidal height at some specific locations. The uncertainties involved in manually estimating water depth at a certain position and time are essentially unchanged from paper navigation. This may be considered an omission given the crucial significance of the question.

Chart data and tide tables between them are intended to represent a genuine physical environment. In principle this can be modelled and interpolations made by using the same sort of assumptions that a mariner would use. Computer based calculations and interpolations are enormously faster than manual techniques and this opens the door to new methods of displaying and using the information. The resulting accuracy of the predictions can be tested against real world measurements.

We present some initial results from a study into techniques that support computer based 3D interpolation of charted depths and the integration of time varying tidal heights from commercially available data. The aim of this study is to make better use of readily available information by presenting it in ways that can directly assist the mariner's decision making process. In effect, this is extracting more useful information from the ENCs.

A better mechanism for predicting water depth allows safety margins to be defined with more confidence. Reducing the uncertainty in shallow water operations can contribute greatly to reducing the risk of grounding while at the same time potentially extending operational parameters.

DATA SOURCES

A key theme of this project is to use standard, commercially available data. We require bathymetric information and tidal height predictions.

There are currently many projects using high density precision bathymetry. These include S-102, bENC and others. Coverage of this sort of data is sparse, availability is limited and updating can be uncertain. We have attempted to develop techniques which give useful results from ordinary ENC cells. Data that is possibly already in use on a vessel. This does not preclude the use of higher quality data and where available this would probably give more accurate results.

Tidal predictions come from Admiralty TotalTide. This provides good coverage, uses full harmonic predictions and supports programmatic access to the predictions. Other tidal prediction sources could be equally useful. In general the closer tidal stations are then the more accurately it is possible to interpolate between them. Use of SHM systems can be nearly as good as full harmonics in places with a simple tidal regime.

So our starting point is pretty much the same information as a navigator would use.

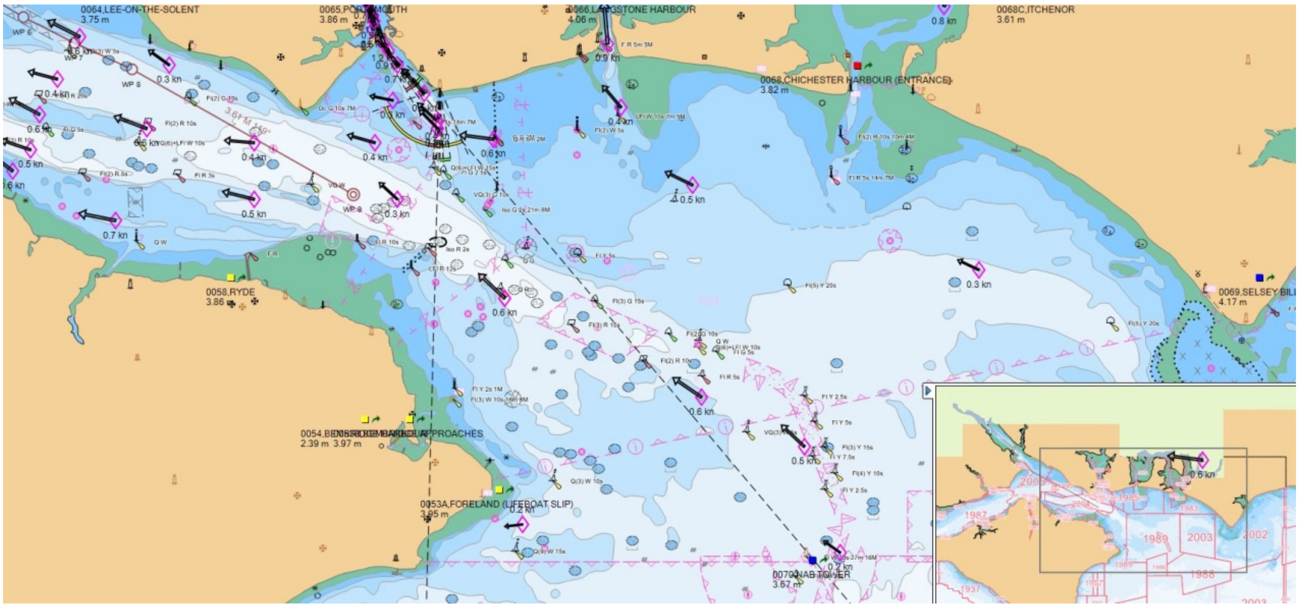

Figure 1 Standard chart data: ENC, Tides, Streams

PREDICTING WATER DEPTH

Water depth is the charted depth plus the predicted tidal height.

Make sure both these values are to the same vertical datum.

To determine the water depth at an arbitrary location you need to estimate the charted depth from nearby soundings and you need to estimate the height of tide from one or more nearby tidal height stations.

When you actually arrive the measured water depth will likely be a little different from the prediction for several reasons including:

- Accuracy of the echo sounder
- Effects of air pressure, wind and other climatic factors
- Nature of the seabed and variations in the water column

At the moment we can't help in managing the residuals (although we have some ideas) but we can attempt to make a better prediction.

INTERPOLATING CHARTED DEPTH

To determine the charted depth at an arbitrary location we need to first build a 3D model of the seabed from the ENC data. Depth data is available from contours, soundings and the coastline. A Triangulated Irregular Network (TIN) is constructed from this information. Use of a TIN is a fairly standard technique for creating 3D models in GIS applications. Creating one from ENC data presents a few challenges. These mostly come about because the data is not intended to represent a genuine physical surface but only to create a 2D chart image. So, for example, contour lines join each other in a few places and occasionally just stop.

Another issue is that the density of available depth information can vary significantly across the charted area. Ideally (for our purposes) we would have a fairly even spread of data with maybe some more detail in locations where there were rapid changes in the seabed. In practise we see two broad categories of ENC:

- Many appear to use soundings off the paper chart. These often follow tracks and can be very sparse in some areas.
- Others contain evenly spaced soundings which seem a lot more like they have come from a model, possibly from a modern multi-beam survey.

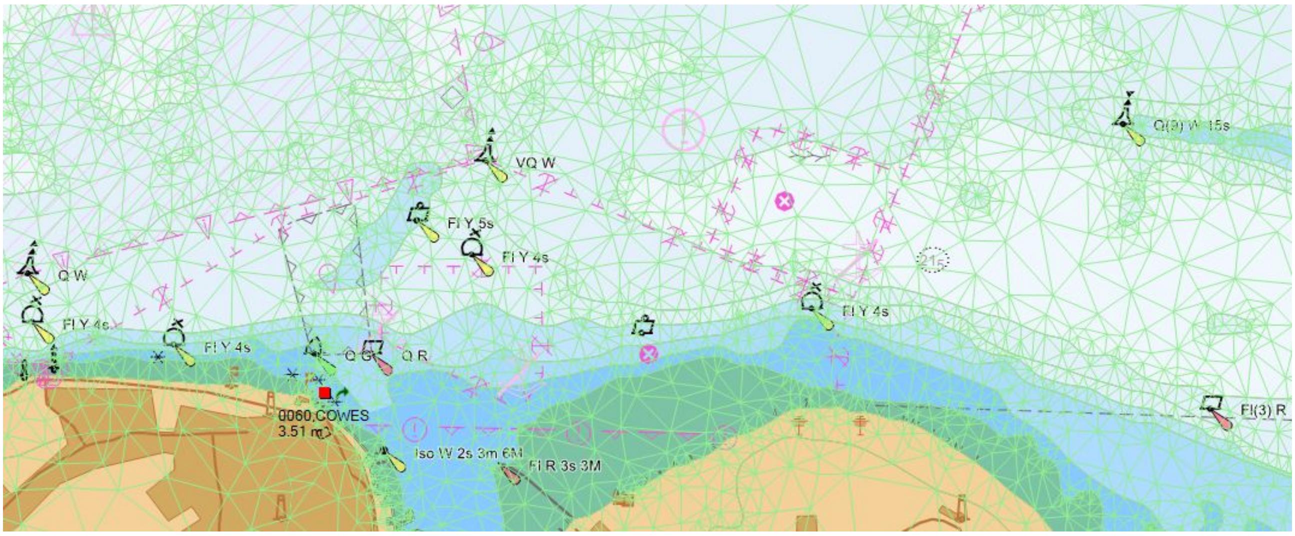

Figure 2 Creating a Triangulated Irregular Network (TIN) from ENC data

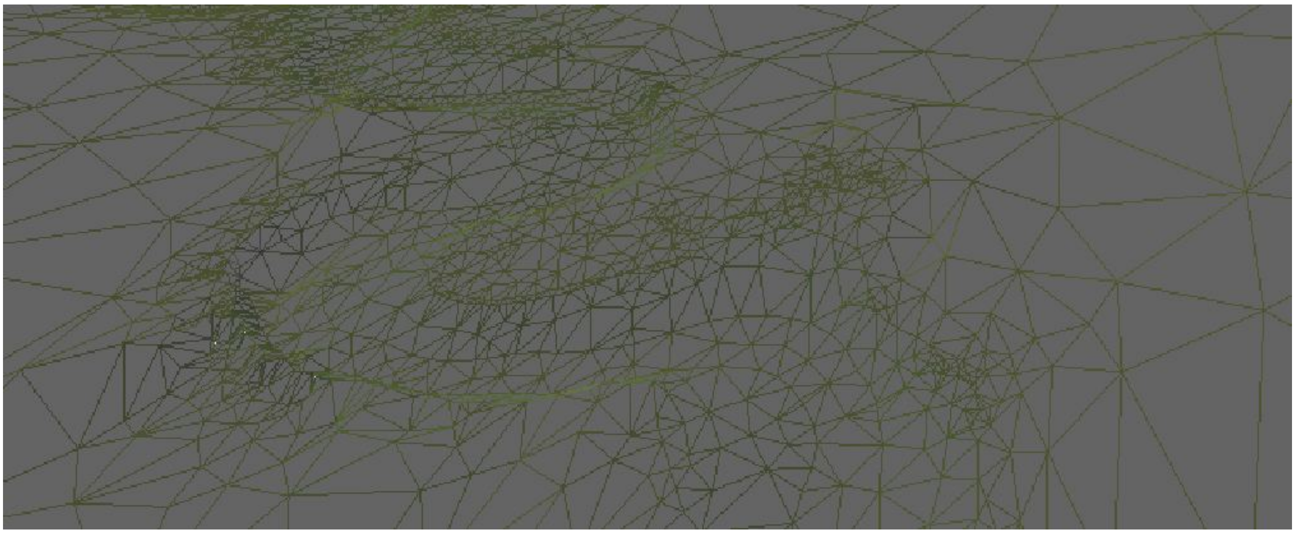
Figure 3 A 3D view of the TIN representing a river estuary

INTERPOLATING TIDAL HEIGHT

A different type of TIN is used to create a mesh that links all the tidal stations. However the periodic nature of tides means that there is no single parameter which can map directly to the height value of the TIN. One approach would be to map each harmonic separately however the linear summation of harmonics works least well where there are shallow water effects. These tend to be the places that water depth is most important. We have tried several techniques for creating a time invariant description of the relationship between tidal stations and currently use two surfaces; one representing amplitude and the other a phase delay. In many ways these values are like the surfaces implied by the contours on a co-tidal chart.

From the tidal TIN we can intermediate virtual tidal stations at each of the nodes of the bathymetric TIN which are then close enough that a simple linear interpolation is sufficient.

ACCURACY

A useful technique for assessing accuracy in interpolation is to remove the known data for a point in the model and then compare the interpolated values with the actual ones. We found this technique particularly effective in helping us develop the tidal models.

We've done some sea trials. We focussed on shallow water areas with rapidly changing depth. Results so far look quite promising.

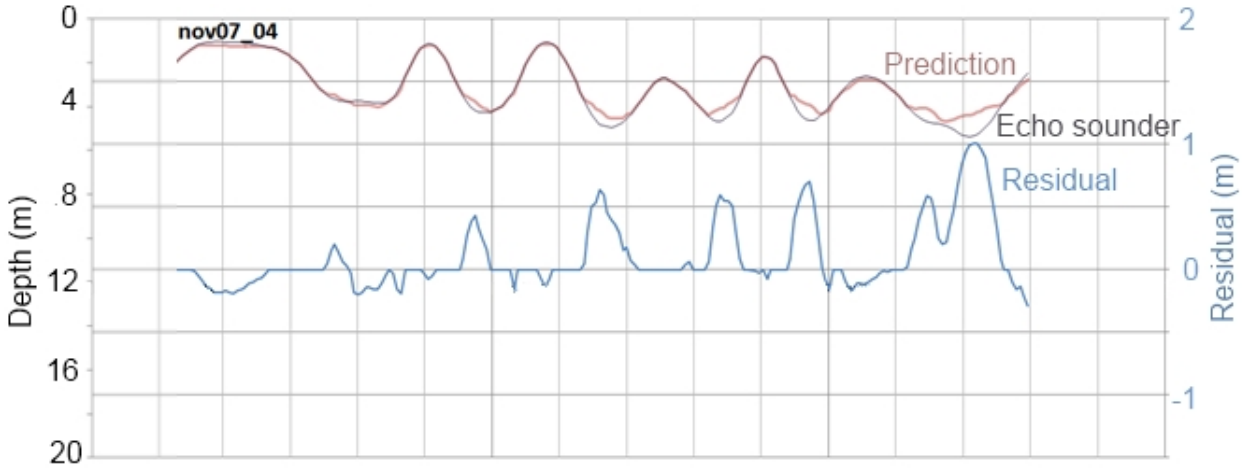

Figure 4 A twenty minute except from one of the trials. This data is typical rather than specially selected

We noticed that charts tend towards safety. They often indicate shallower water than we measured and this accounts for some of the residual.

Overall the accuracy of the system depends on the accuracy of the charts, the tidal data and the suitability of the algorithms used to predict water depth. We think the techniques developed here will prove to be useful in many circumstances but as with all aids to navigation judgment and experience will need to be applied.

Concern about over reliability on technology should never be understated. Consistency, speed and repeatability in the calculations are all very positive factors but really all we are doing here is providing another view, an interpretation, of the existing standard information. Good seamanship is still required.

PRESENTING THE INFORMATION USEFULLY

Our preliminary results suggest that the use of computer models is perfectly workable. The techniques we have developed appear to be at least as capable as a mariner might manage and in many cases much better.

By using computing power to do many predictions in a reliable, repeatable way we can present the information in ways which are more useful than the standard chart + tide tables. For example:

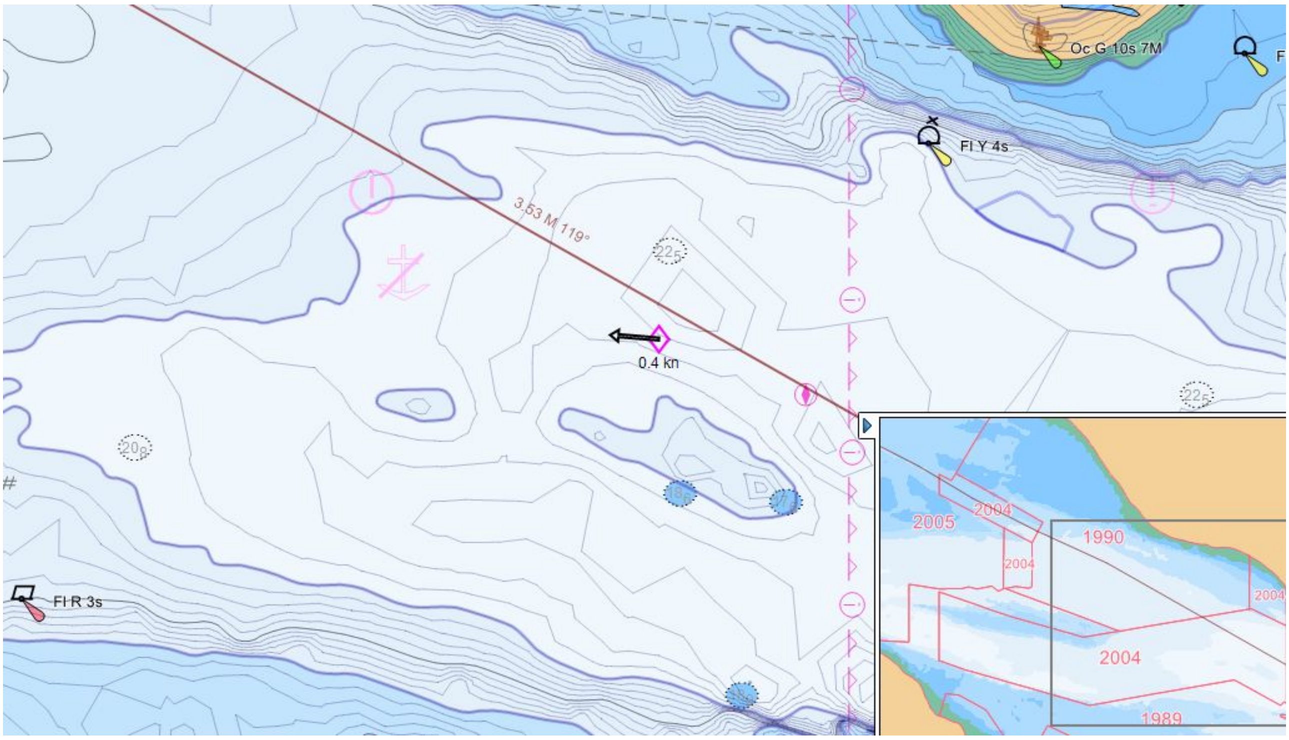

Figure 5 Interpolated 1m contours

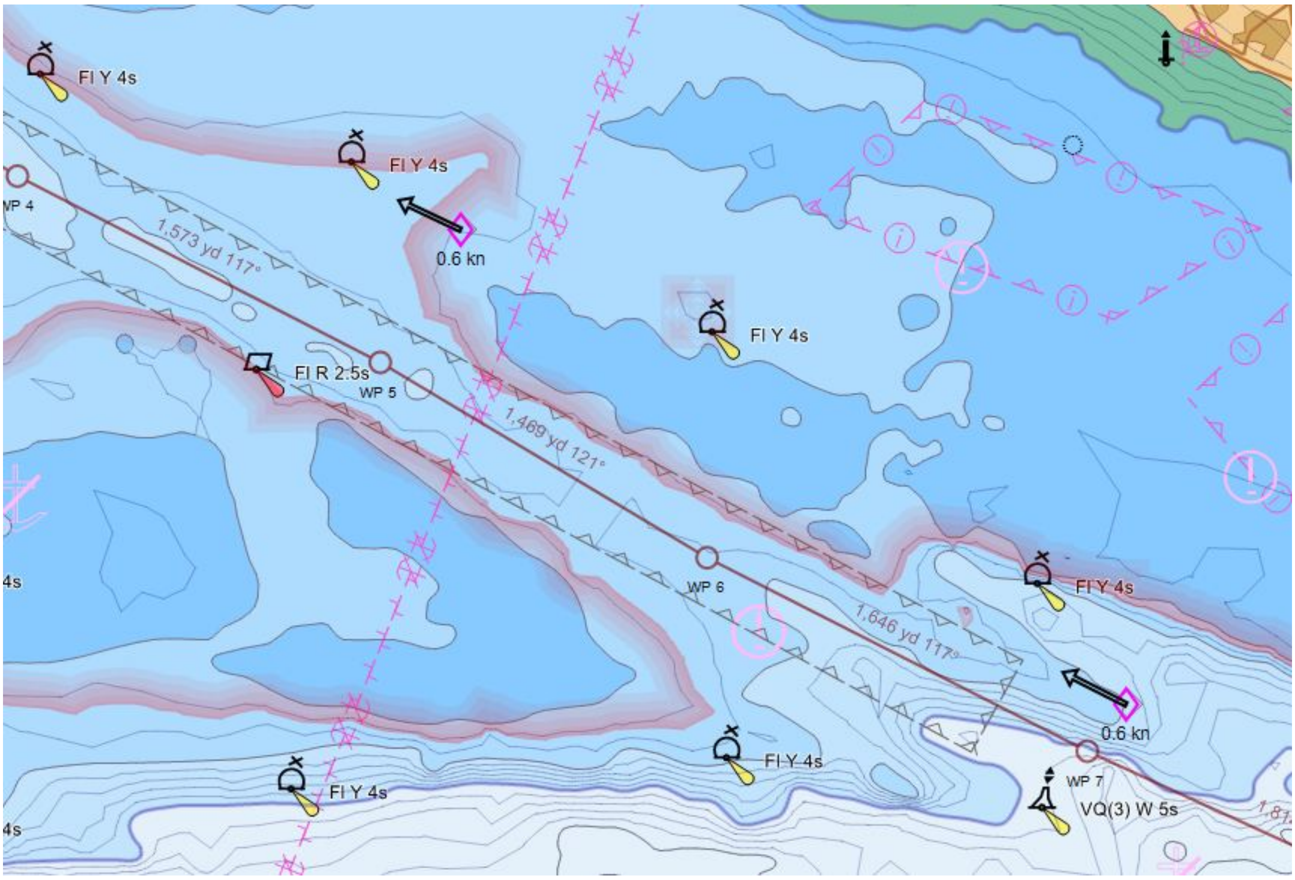

Figure 6 The red line indicates predicted 7m water depth at the arrival time of the vessel. A better safety contour?

CONCLUDING REMARKS

We have attempted to emulate the types of water depth calculations and estimations that a good mariner would use. Using standard commercially available data it appears that this is not only possible but also useful. By taking advantage of contemporary computing and display capabilities we can present this information in a useful way that may give the navigator a better feel as to what the underlying data really means.

These techniques would work even better with higher resolution bathymetric data.

This is a practical solution to an apparent omission in the development of digital navigation systems.

We would like to recommend that chart producers start to consider their data as a model of real surfaces rather simply a chart image.