THE NETHERLANDS HYDROGRAPHIC SERVICE

Optimisation of Survey Frequency

The Netherlands Hydrographic Service tries to optimise its bathymetric survey planning by interpreting archived surveys of the sea floor on The Netherlands Continental Shelf. This allows survey capacity to be used as efficiently as possible. This article presents the statistical method applied by the Netherlands Hydrographic Service, using an example area in a southern North Sea sand-wave field.

The Netherlands Hydrographic Service is responsible for charting The Netherlands Continental Shelf. Two ships survey the sea floor, according to the plan shown in Figure 1 in the magazine. Shallow and busy areas are surveyed more frequently than deep or quiet areas. The Hydrographic Service also tries to optimise the survey plan with respect to sea-floor dynamics, interpreting series of archived bathymetric surveys of an area in a statistically correct way. These surveys are archived at the Hydrographic Office in the Bathymetric Archive System (BAS). Charts are produced from the Representative Bathymetric File (abbreviated in Dutch as RBB), which is a representative selection of these archived depths. This way, several sets of depth data are digitally available for many areas. Although surveys have been recorded digitally since the early eighties, the older ones have usually not all been loaded into the BAS. Although the RBB has not yet fully covered The Netherlands Continental Shelf, several areas exist where more than four surveys are available. This is due to the survey priorities expressed in the survey plan.

Critical Area
We take a critical area for shipping as an example: the northern part of the northernmost category 1 area, west of The Netherlands. Sets of surveyed depths and their accuracies are digitally available in the BAS for 1991, 1995, 1998, 2000, 2002 and 2003. We interpolate these surveys to grids with an azimuth of 30° east of north. This way, the two grid directions x and y equal the average direction of sand-wave pattern and the crest direction, respectively. The interpolation method is chosen such that we obtain not only depths, but their accuracies as well.

Time Series
It is possible to automatically compare a series of surveys in time using the accuracy information of surveyed depths, a procedure called Deformation Analysis. This can decide whether differences between surveys are small enough to be likely to have been caused by measurement and interpolation noise or so big that the cause was probably real differences between surveys. Of course, such a difference may be due both to a change in the sea floor and/or error in the survey process.
Applying deformation analysis to the sea floor we specify two kinds of dynamic behaviour: a linear trend and a single outlying survey. A survey is said to be 'outlying' if it deviates from the others. The sea floor representation begins as static: a sloping plane, or, if a clear sand-wave pattern is present, as a sloping plane superimposed by a sine wave. Extensions are consecutively added to the representation to model differences. These extensions 'are' the trend, and the outlying surveys, and are formulated both for planar behaviour and sand-wave behaviour. The addition of extensions continues until the representation adequately fits the dynamic behaviour of the series of surveys.
Such analysis may be performed on various scales, for instance per grid node or the area as a whole. If we consider the example again for the 2003 survey shown in Figure 3, results are as presented in Figures 4 and 5. The nodal analysis in Figure 4 does not enable accurate analysis: per node there are a maximum of six depths available to estimate depth, and possibly depth dynamics. But it does give us high-resolution insight into the dynamics within the area. In contrast, the analysis results in Figure 5 give an accurate insight into the average behaviour within the area.
Maximum nodal dynamics are up to 0.28m/yr downward for a trend, and deviations exist of up to 5m. The trends have 95% accuracies of 0.03m/yr, and the deviations have a 95% accuracy of 1m. This deviation can be estimated only so poorly because the node is situated at (x,y)=(950,150), which is at the boundary of the area. Figure 3b indicates that the interpolation value in 2003 is of low quality at that node. In fact, no depth estimate is available there at all for some surveys. The fastest descending node is at (x,y)=(850,550). It is striking that both these nodes are approximately at the crests of the sand-wave pattern.
The estimated trends of the area analysis show a yearly change of 0.01m, -0.01m/km, and -0.02m/km for depth, slope in x-direction, and slope in y-direction. Their 95% accuracies are 0.03m, 0.01m/km and 0.02m/km a year, respectively. Figure 5 shows that the trend in depth is significant, but the trends in both the slopes are of about the same size as the accuracy intervals. It may be concluded that the depths in the area are, on average, increasing.

Sand-wave Behaviour
By its nature, it is impossible to estimate sand-wave parameters from nodal analysis. The area analysis does allow this, but the pattern of the example area is too irregular. Sand-waves in shallow seas with wavelengths of several hundreds of metres are often dynamic and may

occur in areas with intensive traffic, like the North Sea. It is therefore desirable to find an additional method of analysis able to deal with less regular sand-wave patterns. This is possible by defining a third scale: analysis of cross-sections corresponding with grid lines. This is performed in both the grid directions x and y, resulting in the Figures 6 and 7. The results in Figure 6 show that estimates of amplitude and crest position are available for this scale. The sand-wave pattern is superimposed on a sloping straight line.

Although the one-dimensional sand-wave patterns do not demonstrate a clear sine shape, they are regular enough to find significant amplitudes. Keep in mind that it is not our goal to calculate an accurate description of a cross-section of the sea floor, but to detect and estimate changes at the cross-sections. Experiments have shown that changes in the sand-wave pattern are effectively found, also in areas with only limited sand-wave regularity.

Figures 6 and 7 consist of a range of similar graphs as the ones of results per area in Figure 5. Every grid line has been analysed. All the results are shown in the direction of that grid line. Comparison of the coordinate of a grid line to the coordinates of the analysis results per node, in Figure 4 will show that the first and last grid lines are not analysed in either case, as they consist of very few grid nodes. The first and last couple of grid lines are often shorter than are the others, which cause artefacts in the graphs. These are visible in Figures 6 and 7. Note that the representation is extended for the straight line as a whole, or the sand-wave as a whole. Therefore the slope always shows the same kind of behaviour as the depth, and the crest position shows the same kind of behaviour as the amplitude of the sand-wave. The most significant trend in the pattern direction x is 0.08m/yr downward, having a 95% accuracy of about 0.01m. The outlying grid lines have sizes up to 0.50m, and a 95% accuracy of about 0,1m. In crest direction y the greatest trend is 0,14m downward, with the same accuracy as in the x-direction. The single outlying grid line has a size of 0.07m, again with the same accuracy as in the other direction. The results of the grid-line analysis do not show systematic behaviour, confirming the impression given by the nodal analysis: many dynamics are present at small scales. Depth estimations in crest directions (see Figure 7a) reveal that both the crests show an average downward trend.

Applying Results
The results of the Deformation Analysis have already led to a decrease in survey frequency for several areas of The Netherlands Continental Shelf, allowing for an increase in survey frequency for other areas. The procedure is being implemented in a stand-alone computer program that enables a feedback to the survey plan when a new survey is received at the Hydrographic Office. In this way The Netherlands Hydrographic Service tries optimise the efficiency of its available survey capacity.