

# HOW A NAUTICAL DEPTH CHART IS PRODUCED

## Silt Density Measurements in IJmuiden

IJmuiden (The Netherlands) is sometimes called "the gateway to Amsterdam". IJmuiden also accommodates a large fishing harbour and the Corus steel factory. Due to tidal currents and the shape of the breakwaters, continuous sedimentation of silt occurs in the waterway between breakwaters. The local waterway authority (the North Sea Canal Department, Dienstkring Noordzeekanaal) uses Nautical Depth Charts to supervise the contractor that carries out maintenance dredging. These charts are also sent to the pilot service to ensure the safe passage of deep draught vessels. To guarantee a detailed description of the most recent situation, every two weeks the Survey Department of Rijkswaterstaat IJmuiden produces a new Nautical Depth Chart.

Silt is made up of very fine fragments of rock and organic particles. In the North Sea the transport of silt in suspension is considerable. Several sources/origins of North Sea silt have been defined e.g.:

- Atlantic Ocean
- English Channel
- Rivers
- Seabed erosion
- Coastal erosion

Silt plays a significant role in the North Sea ecosystem. The organic part of silt serves as food for many different kinds of organisms. A great variety of xenobiotic (hydrophobic) substances are also involved in the transport of silt, creating possible environmental problems in areas where accumulation occurs. This article focuses on another important characteristic of silt: deposition.

As, depending on the density of local water, the specific mass of silt exceeds that of salt water, gravity will cause the particles to move slowly downwards. Along the Dutch coast, bottom currents point towards the coast. Therefore the highest concentrations of silt are found in coastal waters.

The overall current along the Dutch coast moves water and silt in a northerly direction due to the fact that the tidal current towards the north (rise) is stronger than the tidal current towards the south (fall). Turbulence caused by the breakwaters at IJmuiden forces the deposition of silt in the relatively sheltered navigational channel between the breakwaters. Once deposited, this silt will accumulate and, after a while, consolidate. The increase in silt deposition is affected by seasonal factors such as storms and a sudden increase in organic materials (e.g. at the end of a seasonal algal bloom). These dynamics urge the need to monitor the thickness of the silt layer in the navigational channel on a regular basis.

### Nautical Depth

Nautical Depth is defined as the depth above which the density of the silt in suspension (muddy water/fluid mud) is sufficient to ensure safe navigation. The physical properties of silt in suspension vary throughout the world. Nautical Depth has to be established for each port individually. Research has shown that a density of 1,200kg/m<sup>3</sup> applies for IJmuiden. The same value is used in Rotterdam. The Survey Department of Rijkswaterstaat IJmuiden determines the Nautical Depth every two weeks, carrying out an echosounder survey and a series of 75 silt density measurements. The data from both surveys is processed and combined to produce a Nautical Depth Chart. The two surveys are preferably done on the same day to minimise uncertainties.

### The Early Days

The Survey Department Rijkswaterstaat IJmuiden began investigations into the production of Nautical Depth Charts in the early nineties. One of the first methods of determining the thickness of the silt layer was by means of an in-house developed 'Nautical Pipe'. The Nautical Pipe consists of a Plexiglas tube (length approximately 2m, with taps at a fixed interval of 2dm). By dropping the pipe onto the seabed a soil sample is collected. After recovery, the density of the soil/silt/muddy-water at the different levels was determined by means of a handheld density-meter. The offset of the 1,200kg/m<sup>3</sup> level relative to the top of the instrument was then calculated. Combining this with the amount of "cable-out" and the tidal height resulted in a Nautical Depth. The locations of the silt density measurements were determined by interpreting the results of a combined 33kHz / 210 kHz echosounder survey. Although this method is straightforward and easy to apply, its accuracy is not very high. Strong currents (or a drifting survey vessel) will result in unreliable 'cable-out' values. Also, the silt layer may not be penetrated perpendicularly. With the increase in techniques came a

growing need for more accurate and reliable data. It was therefore decided to look for more sophisticated sampling methods. In the period 1995-1998 the production of the Nautical Depth Chart of IJmuiden was a joint effort between the Survey Departments of Rijkswaterstaat IJmuiden (echosounding) and Rijkswaterstaat Directorate North Sea (silt density measurements). Since 1998 the Survey Department of Rijkswaterstaat IJmuiden has been completely self-supporting in producing the Nautical Depth Chart of IJmuiden.

#### Silt Density Probe

In the summer of 1997 the survey department of Rijkswaterstaat IJmuiden purchased a D2ART Nuclear Silt Density Probe. D2ART stands for Direct Data Acquisition using Radio-active Technology. The probe is manufactured by Seabed Systems B.V., also located in IJmuiden. Silt density measurements with D2ART are based on absorption by the medium of gamma rays, as radiated by a small Barium 133 source. This source is placed in an H-shaped frame, opposite a so-called 'Scintillation detector', a highly sensitive gamma ray detector. This type of detector gives a quantitative analysis of the amount of gamma rays passing through the medium. For optimum safety, the Barium source is fully encapsulated in a special gamma ray-absorbing material. Besides this density measurement, the probe also holds sensors for the accurate measurement of tilt (in both directions), pressure (depth), temperature and conductivity. The complete D2ART system consists of three main components:

- The nuclear probe
- A data acquisition and interfacing computer that controls the measuring process. The ship's echosounder and positioning system are also interfaced with this
- A computer-controlled winch that holds up to 80 metres of signal/tow cable

The density range of the probe is from 1,000kg/m<sup>3</sup> up to 1,600kg/m<sup>3</sup> with a resolution of 20 kg/m<sup>3</sup>. The accuracy of the density measurement depends on the measuring time and the selected pay-out time of the winch. The settings used in IJmuiden result in an accuracy of three per cent of the measured density.

Calibration of the probe is done on a regular basis, using substances of a known density (prepared in a laboratory). Once every five years the Barium source needs to be replaced because the strength of the signal decreases (half-life).

#### Echosounder Survey

The survey vessel Swalinge is usually responsible for the echosounder survey. The Swalinge is equipped with a standard survey spread consisting of:

- Aquarius LRK GPS positioning system
- Octans heading and motion sensor
- Atlas Deso 25 echosounder (210 kHz)
- Fallmouth CTD probe
- QINSy 6.6 Data acquisition soft-ware

Additionally, a Reson Seabat 8101 multibeam echosounder (240 kHz) is permanently installed.

The survey can either be done singlebeam, using predefined lines at 25m intervals, or multibeam, using a pre-defined grid (matrix) with cells of 2x2m.

The signal of both echosounders reflects at a density between 1,030 kg/m<sup>3</sup> and 1,040kg/m<sup>3</sup> i.e. the top of the silt layer.

The collected data is processed in the office of the survey department of Rijkswaterstaat IJmuiden using the QINSy processing suite. As a final step, the processed data is either interpolated to a 5x5m grid (in case of singlebeam) or dumped in a 5x5m grid (multibeam).

Interpolation is done using the Digipol algorithms. Digipol is an interpolation method developed by The Netherlands Organisation for Applied Scientific Research (TNO). Digipol algorithms have recently been implemented in the QINSy software.

#### Silt Density Measurements (Data Acquisition)

The silt density measurements are carried out from survey vessel Kennemer. The D2ART probe is attached to the crane. The Kennemer is equipped with a DGPS positioning system and a survey gyro compass. The offset position to the tow point is calculated and sent to the D2ART computer, where the WinDart software handles the measurements. The maximum distance between the 75 measurement locations is 100m. For safety reasons, personnel on board are equipped with a small instrument, a so called 'dosemeter' which registers the amount of radiation they receive. Every four weeks the dosimeters are analysed by the Nuclear Research & Consultancy Group (NRG).

#### Silt Density Measurements (Data Processing)

Each individual density measurement is stored in a separate datafile. The filename consists of the survey date, type of data indicator (binary or ascii) and the unique location ID. Using the DartPost processing software developed by Seabed Systems, each measurement is displayed in a profile view. The main profile shows density (horizontal axis) against depth (vertical axis). Depths can be corrected for tides by means of interpolation from a text file with time and tidal height. Three fixed density levels may be defined. The depths of these three levels are automatically fixed by the software but can be altered manually. In IJmuiden, the Survey Department determines the depths of the 1,050, 1,200 and 1,250kg/m<sup>3</sup> layers. The (relative) difference in depth between 1,050 and 1,200kg/m<sup>3</sup> is the thickness of the silt layer. This method does not require tidal values to be applied, since only difference in depth is used.

Once the levels of all 75 profiles are determined, an ASCII file is exported containing Easting, Northing, Silt layer thickness and Location ID. The results are compared to the previous survey and then offered to the Digipol interpolation program.

#### Combination of Data

Both surveys are now available as a regular grid. By simply adding the two a Nautical Depth grid can be created. From this Nautical Depth grid a variety of products may be generated such as charts with (nautical) depth figures, depth contours or spot maps.