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DATA MANAGEMENT OF SWATH SOUNDING SYSTEMS

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INTRODUCTION

Over a number of years, hydrographers have felt a need for a swath sounding system in place of the traditional single beam echo sounder giving more or less random information from the sea floor. A major predicament of the surveyor has always been the uncertainty inherent in a single track of information. A nagging suspicion remains that in spite of the most scrupulous survey, an outcrop of rock, a boulder or a wreck may pass undetected. It is highly desirable to have a system that could cover a whole area in one sweep, revealing all the features and describing the total sub-sea topography without an enormous amount of time being spent on running close survey lines. The designers of surveying equipment have applied themselves diligently to this problem over recent years and have come up with working solutions. Recently hydrographers have been presented with swath echo sounding systems of considerable sophistication giving high resolution presentations of the sea floor. Breakthroughs have also been achieved using airborne laser bathymetric sounding systems providing large amounts of data in hours which previously took years of survey time. The new systems will have a profound impact on the surveying community.

Survey managers, be they from the private sector or from national Hydrographic Offices, will have to re-think their operations in view of the new possibilities offered by the systems. A considerable challenge is also to be met by custodians of the survey data as well as those engaged in chart production when the transition is made from purely analogue to electronic digital data. In the brief time that high resolution swath echo sounding systems have been in use, detailed presentations have been made of sea floor features. Perhaps the most revealing ones have been the detailed charting of some continental shelf areas done in connection with pipelaying operations. By the 1 m contour intervals on the chart shown in Figure 7, iceberg scourings are shown in detail and, perhaps less expectedly, pockmarks are also clearly identifiable. Figure 1 shows an area

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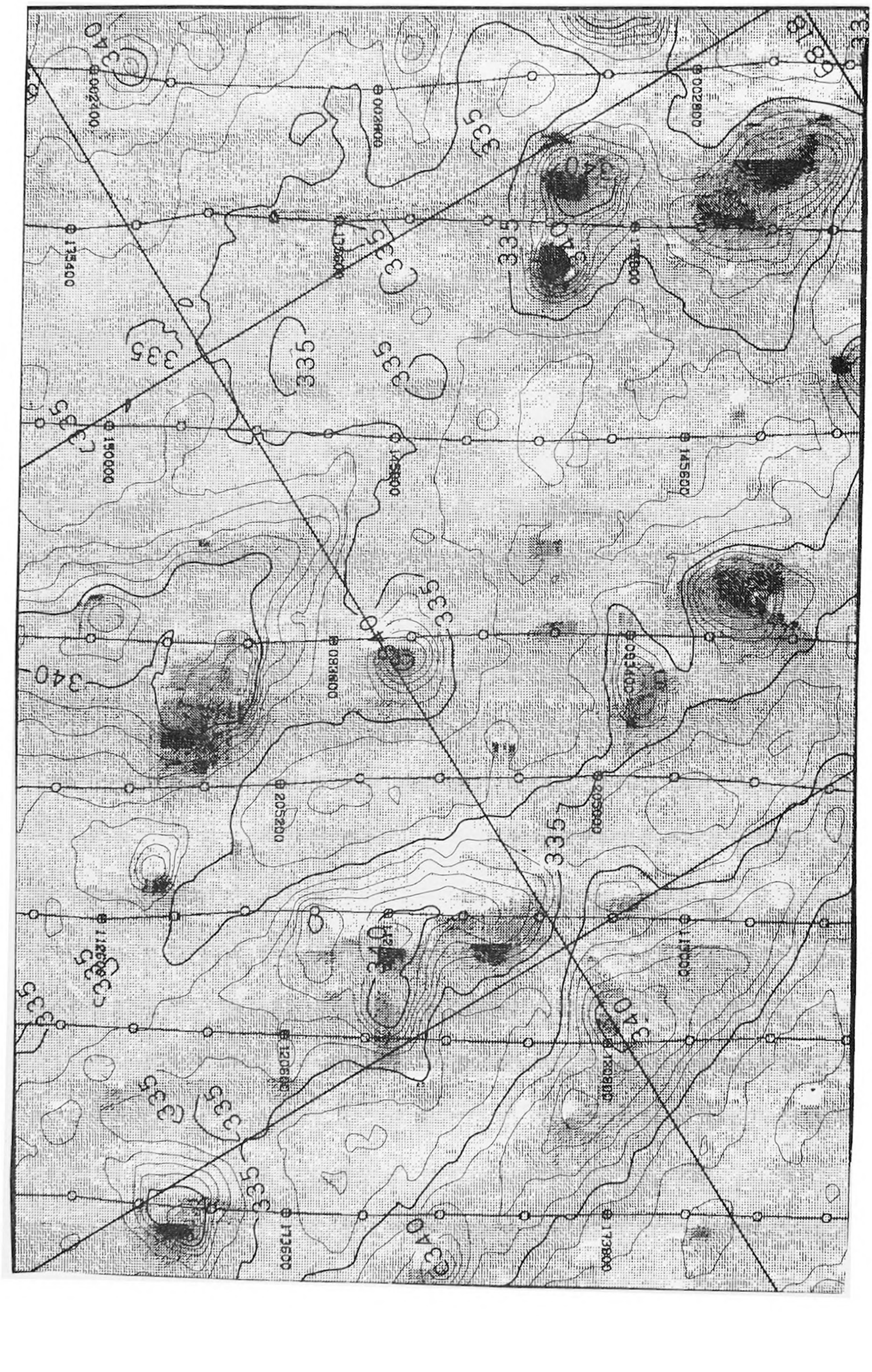

FIG. 1. — Sea floor bathymetry surveyed by EM100 swath system superimposed by sidescan sonar.

surveyed by a multibeam echo sounder superimposed by a sidescan sonar record on which pockmarks can be clearly identified.

National Hydrographic Services are facing a growing demand for information other than depth data intended for navigational purposes. It is only natural that such Services place great emphasis on their traditional tasks of catering for the needs of the navigator, perhaps tending to disregard the old view that navigation is not an end in itself, but is more the means to an end. The development of equipment and systems like sidescan sonars and multibeam echo sounders allow hydrographers to grow out of their traditional role and venture into another realm. Charts produced on the basis of sidescan coverage will not only provide fishermen with the means of avoiding obstacles, but also allow them to relate their catches, fish types and behaviour against the bottom texture as shown on the chart. Swath sounding systems applied over large sea floor areas will form a basis for planning offshore pipelaying operations and the siting of offshore structures.

It can be safely assumed that the majority of Hydrographic Services in some way or other have already ventured into giving information beyond the purely navigational in their portfolio of charts. The decision whether to engage more deeply into this policy will force itself upon Hydrographic Offices with the advent of the new technology. As with so many new devices put to use, the first euphoric reception of the swath sounding system was soon followed by a growing awareness of the problems arising from the application of the equipment. One of the major problems which has to be addressed on implementing a swath sounding system is the management of the prodigious amounts of data ensuing from the survey operations.

For a commercial survey company, the average survey task is very often limited in time and size, thus the amount of data might be manageable. For a national Hydrographic Service, on the other hand, the problem is more daunting. In principle, the utilization of a shipborne swath surveying system is a continuous on-going task, limited only by the size of the area where the system is applicable. For Norway, as for many other nations, this would comprise the whole continental shelf area. A steady volume of data to be handled, both on board and ashore in the Hydrographic Offices, can therefore be expected.

The 'raison d'être' of the shipborne swath sounding system lies in its potential for giving detailed information over large areas in a short period of time. The more detail, the larger amount of data. A twenty-four hour operation may result in several million soundings. How are we to cope, being torn between the wish to make the detailed information available to those who need it, and the data reduction required to make the information readable?

This paper addresses some of the problems and questions that arise when processing a large number of randomly distributed data points forming a digital terrain model. In principle, the discussion applies to shipborne swath sounding systems, to data ensuing from laser bathymetry, or for that matter to digital depth data from any source.

The various processing steps will be described from initial gridding, through elimination of noisy data and filtering, to contouring for chart production. The contour chart is just one output from the process. The terrain model may be used for different tasks such as volume calculations, adding or subtracting of other terrain models, minimum or maximum depth calculations and cross section presentations. Some results that have been obtained are shown. The last part of the paper discusses some aspects of data reduction techniques, a relevant separation between onboard and post survey, onshore processing and concludes with a few general thoughts on managing electronic digital data from various sources — of which a swath sounding system is one.

MULTIBEAM ECHO SOUNDER

Swath covering, multibeam echo sounders have now been in use for some years. A new device on the market is the high resolution, high accuracy EM100 sounder produced by SIMRAD Subsea A/S of Horten, Norway. This equipment has recently been bought by the Norwegian Hydrographic Service and was installed on board the survey vessel *Lance* in May 1987. We find it natural to use Simrad's multibeam echo sounder EM100 as the basis for this paper, since it is the use of this equipment which has made it necessary for us to find solutions to the different data management problems. The sensor produces high volumes of depth soundings relatively uniformly distributed over the sea floor. It would be possible, in theory, to plot the soundings on a fair sheet manually and, subsequently, draw the contour lines by hand, but certainly this is neither a practical nor an economically feasible way to process the survey data. The EM100 has been in commercial use in the North Sea area since June 1986, in combination with computerized post processing. Charts have been produced for oil companies, typically at a scale of 1:2,500, with a 1 metre contour line interval allowing for a detailed presentation. It is inevitable that swath systems like EM100 will be used extensively in the future by Hydrographic Services for their charting tasks, and that digital processing of the surveyed data is a prerequisite. The authors would like to share some of their experiences in computerized post processing using such a system, and also to try to shed some light on the processing rules that can be applied to the data. Perhaps, then, the concept of digital chart processing might be accepted by the hydrographic community, as it is already for many private surveying companies.

Sensor properties of the Simrad EM100 multibeam echo sounder

The EM100 is a sea floor mapping sensor, sampling 32 points across a swath of sea floor for each acoustic pulse. The pulse rate varies from three per second in shallow water to one per second for the maximum depth of 600 metres. The swath width varies from 2.4 times the water depth in shallow water down to 0.7 times the water depth at the maximum working depth.

Data density

At a depth of 25 metres, the swath will be approximately 50 metres wide, assuming a transducer mounting depth of 3 metres. The cross-track distance between the individual soundings is then approximately 2 metres, and along the track, with a vessel speed of 8 knots, the distance between soundings will be 1.3 metres. This implies that the sensor generates in the order of 385,000 individual soundings per square kilometre.

In a depth of 400 metres, the swath width is 680 metres (wide mode), giving a cross track sounding distance of 21 metres. The along track distance between soundings is 3 metres. This gives a data density of 16,000 soundings per square kilometre. In the narrow mode the data density will be 38,000 soundings per square kilometre.

Noise content in data

The depth data from the sensors is available as 32 number pairs for each pulse, namely cross-track coordinate (y') and depth (z') in the vessel's coordinate system. Measurements of the variations of the soundings with the vessel lying still over a flat sea floor indicate a 'white noise' content with a standard deviation of approximately 0.3% of the water depth. The noise level is about the same for all beams. Due to real-time compensation for acoustic ray-bending (the system has an input for a sound velocity profile sensor), there are no evident systematic errors for the outer beams of the fan, and when comparing the depth values of soundings made with different beams at a given spot on the sea floor, the discrepancies found are in the same order of magnitude as the noise content of each beam.

Data recording

Figure 2 shows a typical block diagram for a survey ship installation of the EM100 system. Processing the data for a bathymetric chart requires sufficient recorded data to calculate the exact coordinate value of each individual sounding, normally as x-y coordinates. This implies recording:

— vessel position and time of fix
— depth data (32 depth values expressed in ship coordinates per pulse) with time and vessel heading.

The sounder produces 1·2 Mbytes of data recorded for each hour of operation. In order to maintain the best possible accuracy, it is necessary to synchronize the time references for position data and depth data, and to ensure that processing delays in the position fixing equipment are accounted and compensated for. Synchronization errors exceeding 0.3 second will lead to clearly

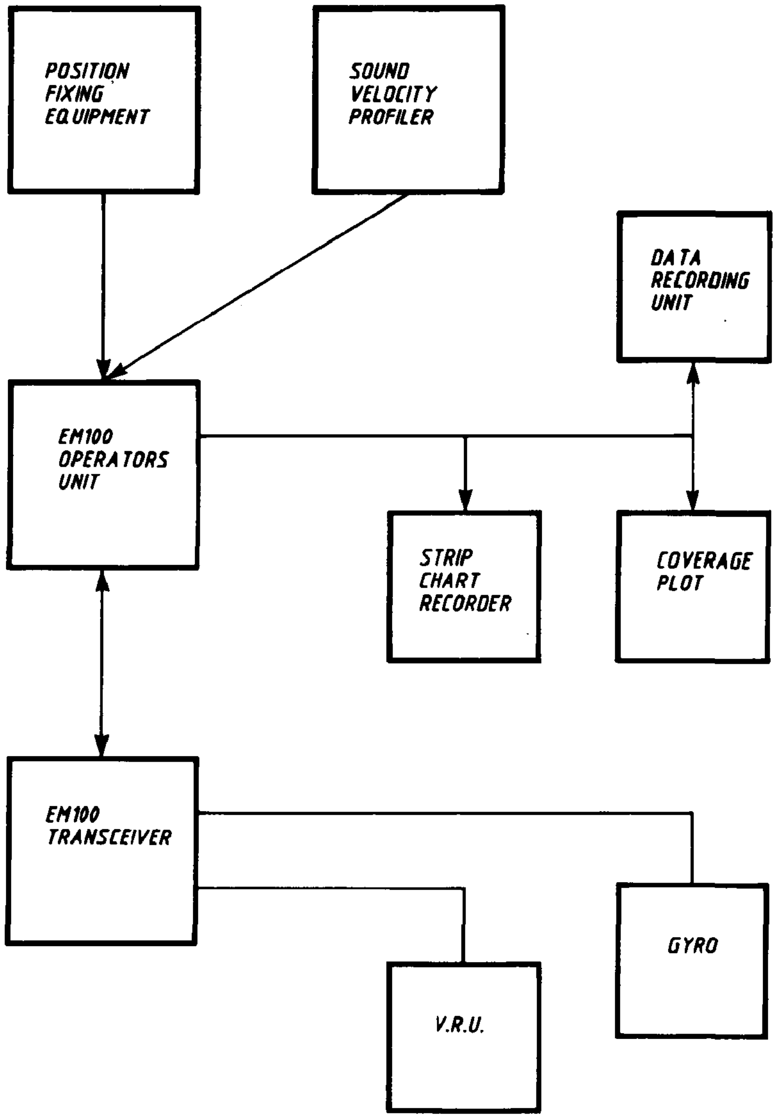

FIG. 2. — Survey ship installation of EM100.

visible inaccuracies in the final chart, at least in shallow water.

Data recording on a single medium is achieved either by feeding position data to the EM100 and recording the combined data stream coming out of the sounder (see Fig. 2), or, alternatively, by merging depth and position data in a data recording computer.

Data pre-processing

Before being processed into final chart products, the data recorded from the

EM100 has to be pre-processed to form a list of positioned, tide-corrected sounding values. Each element in this list is a set of three values:

x — easting coordinates
y — northing coordinates
z — depth values.

The processing is specific for EM100, and other sensors will need different processing algorithms to produce the same data list format.

Figure 3 shows a functional block diagram for SC100 (Simrad Conversion module for EM100).

The processing is as follows:

A. Data is read from the recording medium and split into separate files for depth data and position data.

B. Position data, describing the ship's track, is processed separately. Data spikes may be removed, smoothing may be applied, track may be displayed and plotted. In case an error has been made during the real-time calculation of UTM positional values, the whole position file may be exchanged with a corrected file.

C. A file of tide level values with time references is established, either manually by use of an editor or entered from some recording device.

D. The x-y-z data are calculated in the following way:

- The position of the vessel at the time of each sounding is calculated by interpolation in the position file.
- The UTM coordinates for each individual sounding are calculated making use of the vessel's position and the soundings position relative to the vessel.
- The depth value is corrected for the tide level by interpolating in the tide-level file.

E. In case the survey covers an area too large for processing into a single chart-sheet, it is possible at this stage to sort the data into separate files, one for each chart-sheet.

A software program for terrain modelling

The traditional way of presenting depth information is by depth digits and contour lines. While the depth digits are relatively easy to process and present, the drawing of contour lines requires more sophistication if they are to be generated by an automatic system. The same may be said about other products that can be derived from survey data.

Digital terrain modelling is a process by which a number of x-y-z data points within an area may be used to create a numerical model. From this model, a variety of presentations derived from the x-y-z data may be presented. To gain

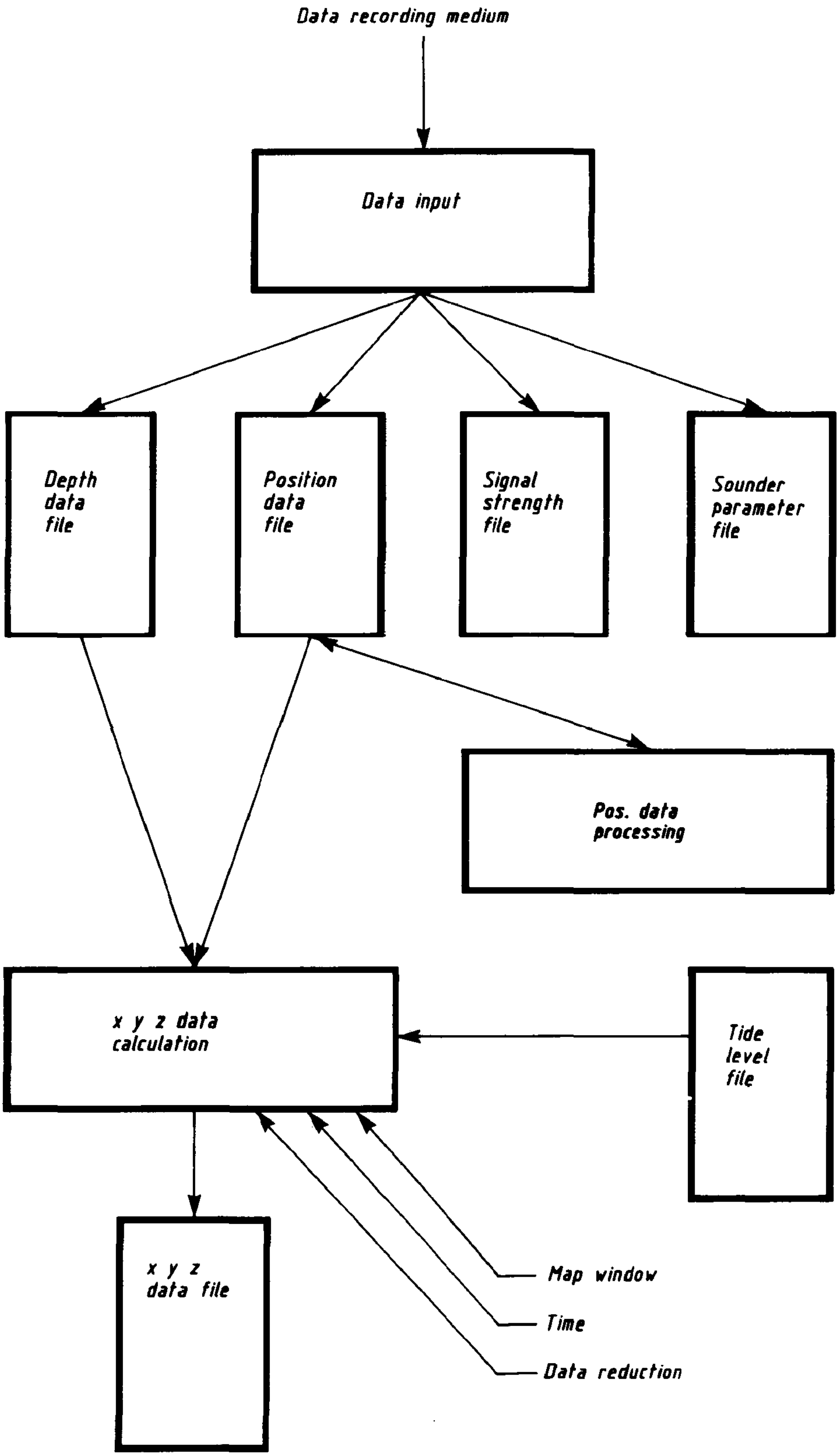

FIG. 3. — Simrad conversion module for EM100 (SC100).

the full advantage of the data gathered by the swath sounding system, a digital terrain model is therefore necessary.

The software system CP100 (Contouring Package for EM100) is based upon IRAP, a software system which was originally developed for analysis and mapping of oil reservoirs under the sea floor, but which has also proved to be very useful for sea floor charting. It is now used by most of the oil companies in the North Sea, both for oil reservoir analysis and for producing the detailed sea floor charts which are required for oil field exploration and planning of pipeline routes. The sea floor charting module is the one dealt with in this paper.

A simplified structure of the software module is shown in Figure 4. The processing is executed as a sequence of operations on the different representations of the data, and can be controlled by an operator via commands or a menu system, or alternatively, by executing files with command sequences. A high resolution graphic display is used for presenting results to the operator, and plot files are generated as required. Internal data representations are FORTRAN 77 data structures in virtual memory, and input/output operations are to disk files. A typical equipment configuration is a 32 bit computer (ex: HP9000/350, VAX) with minimum 8 Mbytes of RAM, 300 to 1000 Mbytes of disk storage space, UNIX or VMS operating system, and necessary peripherals.

Random points representation

As shown on Figure 4, the processing starts by reading a file of x-y-z data from disk. The data is randomly positioned within a given area. In our application, each data triplet of x-y-z corresponds to one depth sounding with its calculated position. A window corresponding to the area which one wants to process is defined. From this random data form, plot files and displays of the 'raw' sounding data can be prepared in a straightforward manner.

Grid representation

Most of the processing is performed on a grid representation of the surface which is being charted. A grid is a mesh of lines with a specified line spacing in the x and y directions, superimposed on the window area. Each line crossing defines a grid point, and the input data can be represented to any desired accuracy by the values of the z variable in each grid node. A dense grid gives a very detailed data representation, while a larger spaced grid gives a more generalized presentation, where small details are lost or smoothed out. The dense grid requires greater computer storage space compared to a more open grid. The grid is an approximate representation based upon interpolation. It is clearly preferable to the alternative approach, which is to draw contours by triangulation techniques in the original data set. The main reasons for this preference are:

- the ability to filter noisy data (see earlier discussion on noise content in data),
- the speed of computations,
- the flexibility of operations which may be performed.

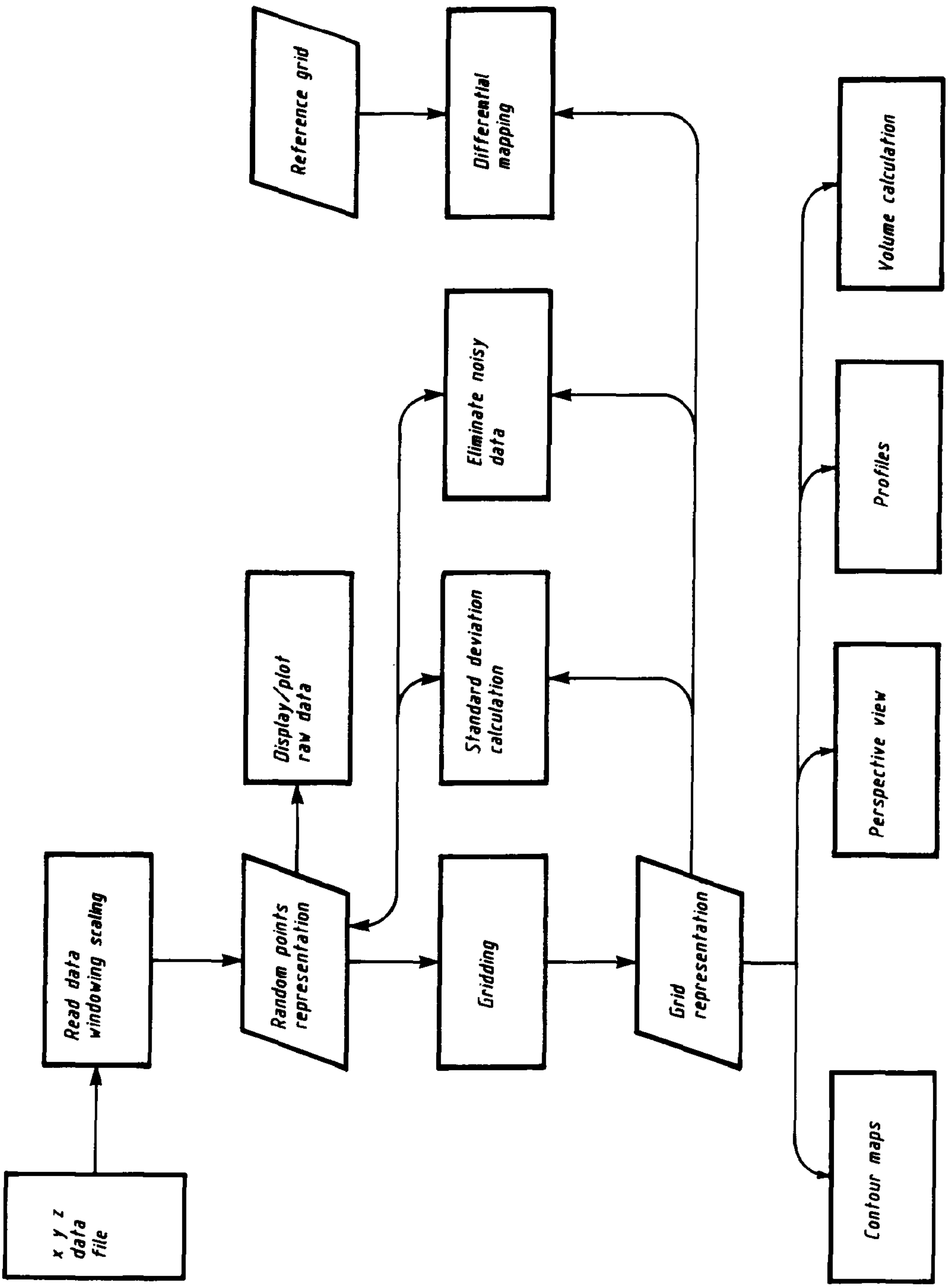

FIG. 4. — Software block diagram for processing bathymetry.

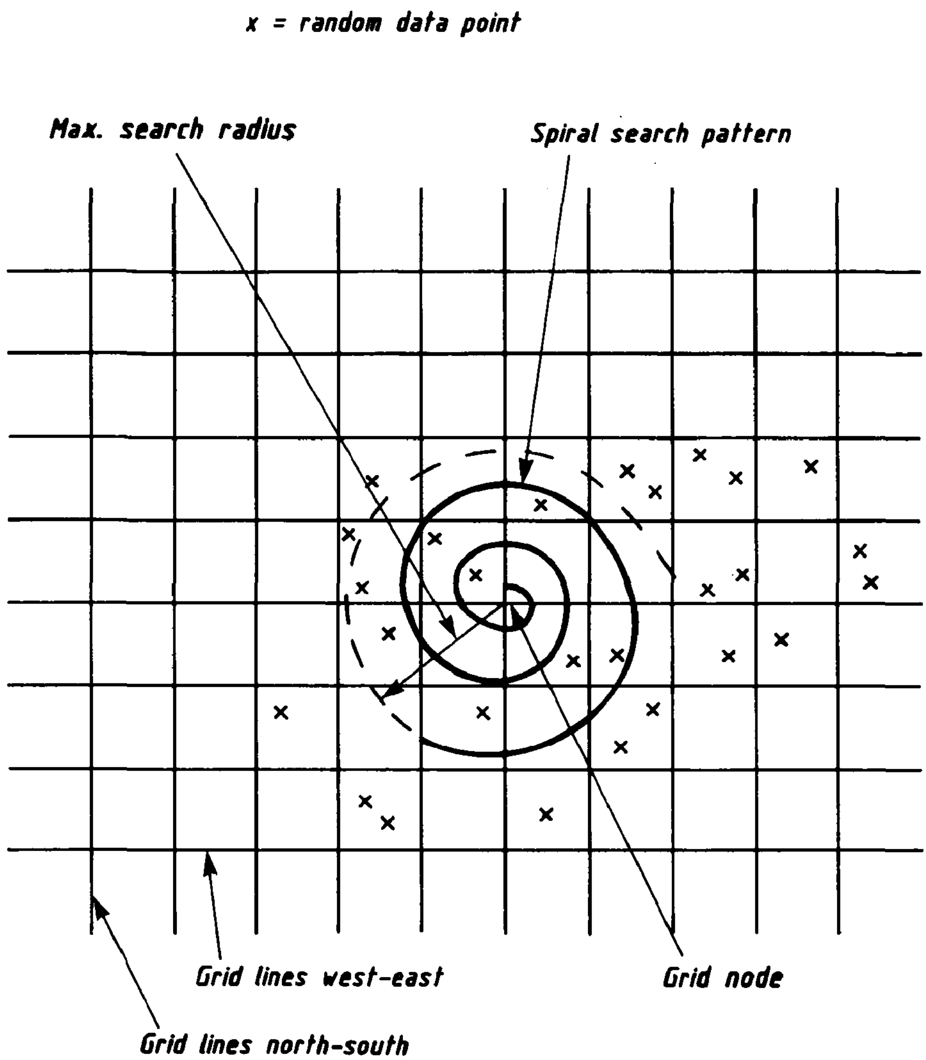

FIG. 5. — Process of going from random data to grid representation.

Figure 5 illustrates the process of going from the random data representation to grid representation. The z value of a grid node is calculated from all data points in the proximity. First, a spiral search locates all data points to be used until sufficient data has been found. Then an interpolation is performed to calculate the value. The process is called gridding. The algorithms have been refined extensively to give the optimum result, yet allowing for the processing of up to 2 million depth soundings for each chart.

Digital terrain model

The grid representation of a given area is often referred to as a 'digital terrain model'. It is an ordered file of depth values, with additional data describing the grid cell size, the global position of the area and so on. The digital terrain model is a product by itself. It can easily be stored and retrieved for later processing, it can form the reference to compare with later surveys and a grid with high resolution can easily be converted to a lower resolution and merged with other grids to produce charts of a larger area at a different scale.

Elimination of noisy data

The raw data is a representation of the sea floor, as mentioned earlier, with a noise content of approximately 0.3% of water depth. The noise is about equally distributed around a mean value which approximates the true sea floor depth. Should a few spikes be found in the data due to obvious (very large) errors in particular samples, these can be eliminated. The charts produced will consequently suffer a little in richness of detail, but they will gain considerably in consistency and accuracy. The EM100 produces a very dense set of data, and elimination of a small fraction of erroneous data carries virtually no penalty at all. It is possible to spot the bad data visually by inspecting the display, but this is not practical for routine processing of large data sets in the order of 0.2 to 2 million soundings. A 2-step procedure has been developed as a more or less standard process (see Fig. 6.) In step 1, each raw data point is compared with a mathematical surface which runs through all grid node values. A standard deviation value over the whole window area is calculated for the difference between raw values and grid surface. This standard deviation is a measure for the consistency of the raw data, although it also varies with the grid

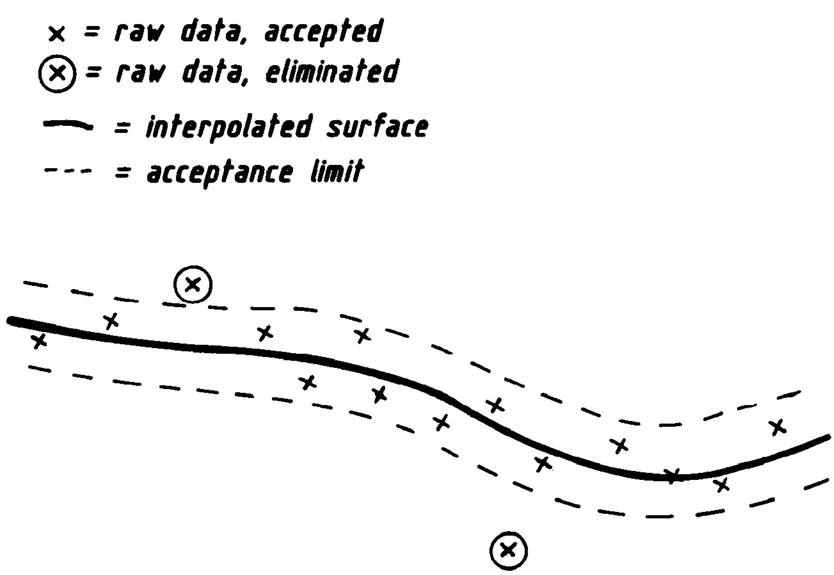

FIG. 6. — Smoothing of data and elimination of noisy data.

cell size, the terrain type and a number of other parameters. The second step involves elimination of all data points which deviate from the grid surface by more than say two times the standard deviation (depending on grid size, terrain and the object of the survey operation). This operation reduces the original data set by 5 to 10%. The reduced data set is gridded again, and the procedure can be repeated, if required.

Processing products

From the gridded representation of a data set where most of the noise is eliminated, it is relatively straightforward to produce a number of 'products' that may be of interest.

The contour chart

Figure 7 shows a section of a contour chart with 1 metre contour intervals, produced by the Norwegian survey company Geoconsult using the EM100 sounder. The contour lines are computed by cubic spline polynomials. An alternative presentation form is the colour coded contour line chart where the area between each contour line is filled with a colour that corresponds to the depth. This presentation requires a colour raster plotter.

Perspective view

Figure 8 shows the same area as in Figure 7 in a perspective view. The perspective view gives a more intuitive impression of the terrain formations than the contour chart, but less precise information.

Profile

It is possible to define a straight or curved line in the chart, and have the depth profile along the line calculated from the grid presentation. Figure 9 is an example of this option. The x-axis represents the distance along the line, the y-axis represents the depth.

Differential charts

The system offers full flexibility for grid to grid operations. The most useful application of this is to subtract two grid representations of the same area. The result of the subtraction is a grid representation of the difference between two surveys of a certain area, and it can be presented as a contour chart, either in perspective view or as numbers. Figure 10 is an example of the latter, used to check the consistency of the EM100 sensor in shallow water. The numbers are diffe-

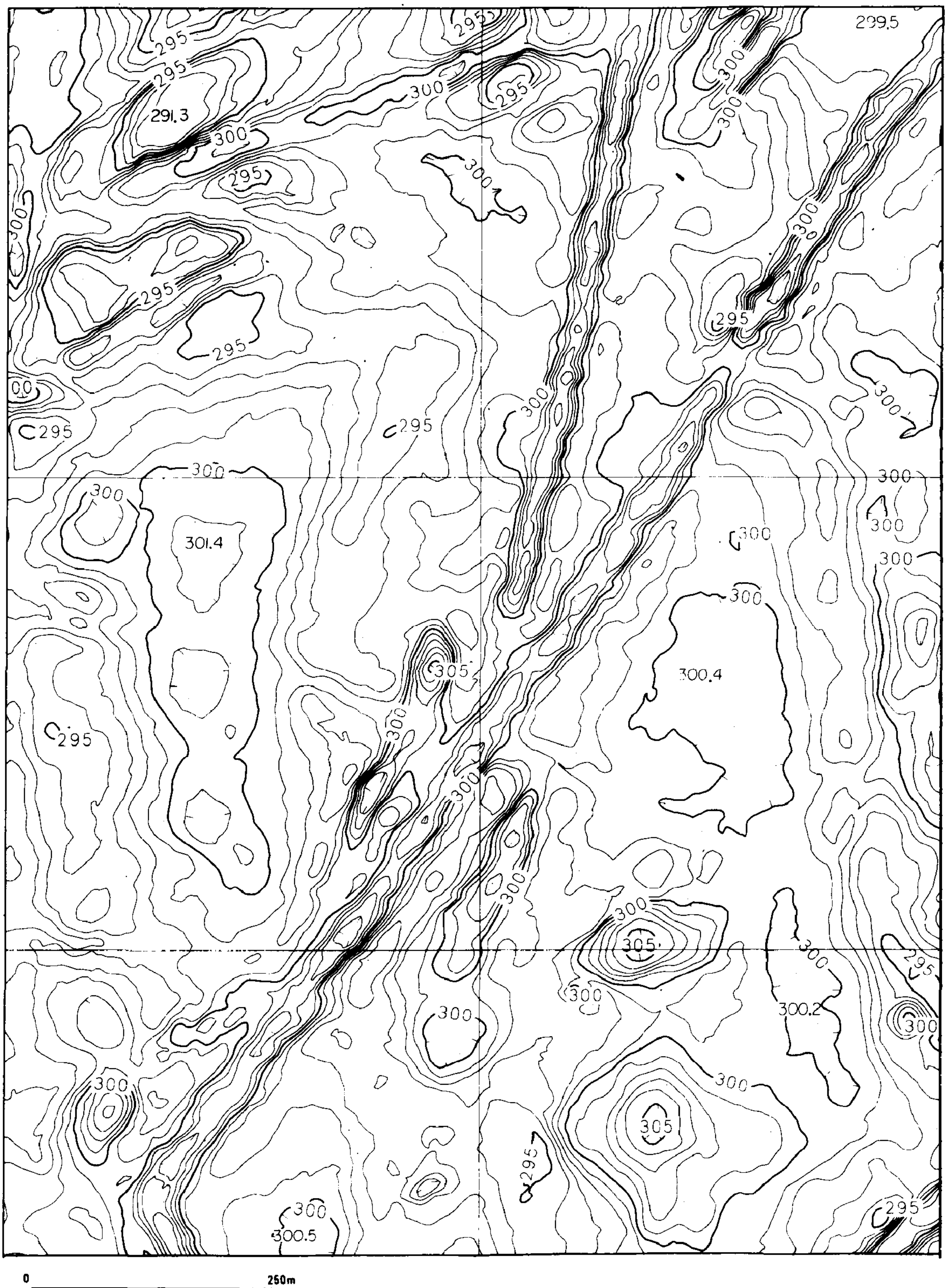

FIG. 7. — Sea floor bathymetry showing iceberg scours and pockmarks. Contour interval 1 metre. Surveyed by A.S. Geoconsult using Simrad EM100.

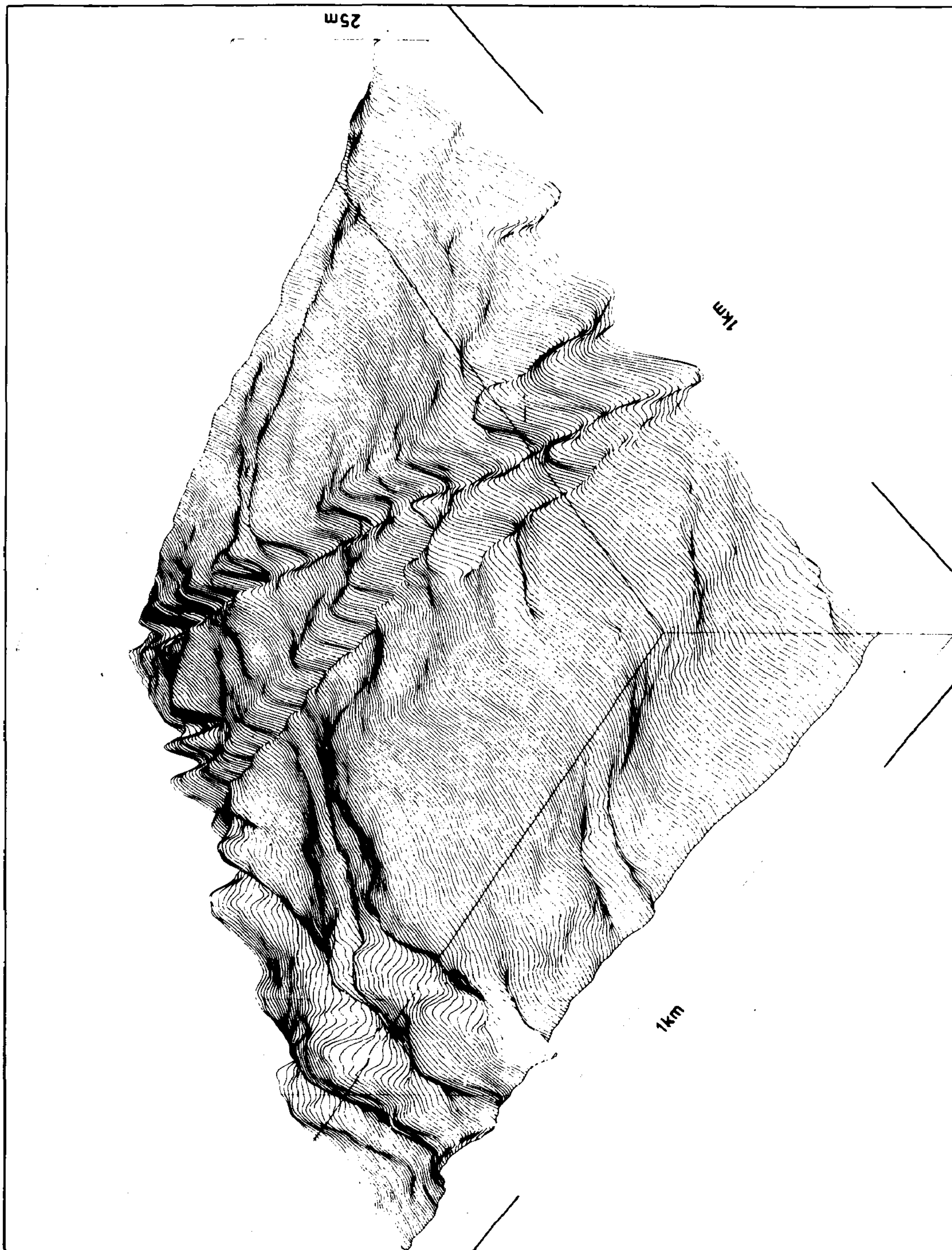

FIG. 8. — Perspective view of data shown in Figure 7.

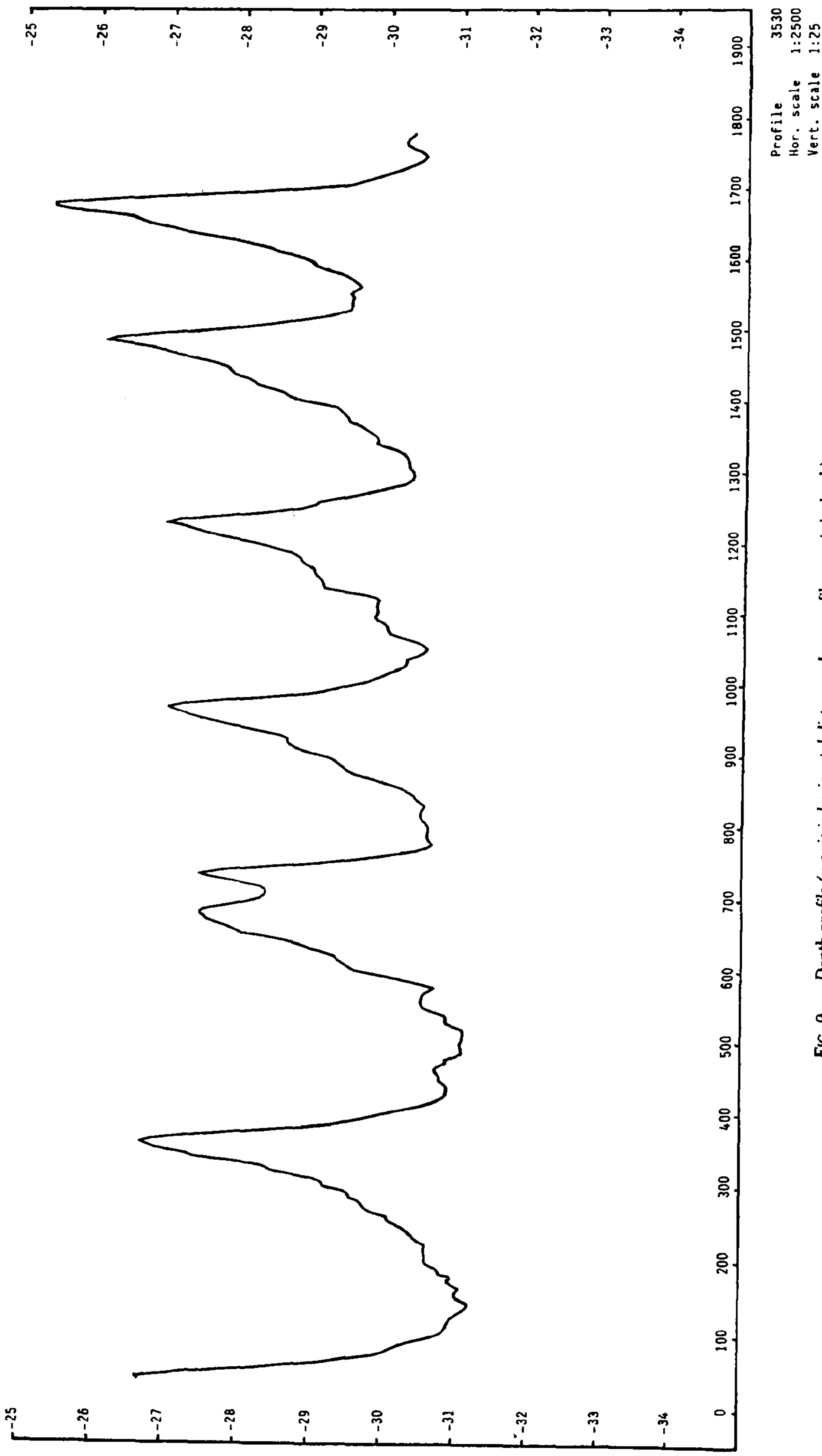

FIG. 9. — Depth profile (x-axis is horizontal distance along profile, y-axis is depth).

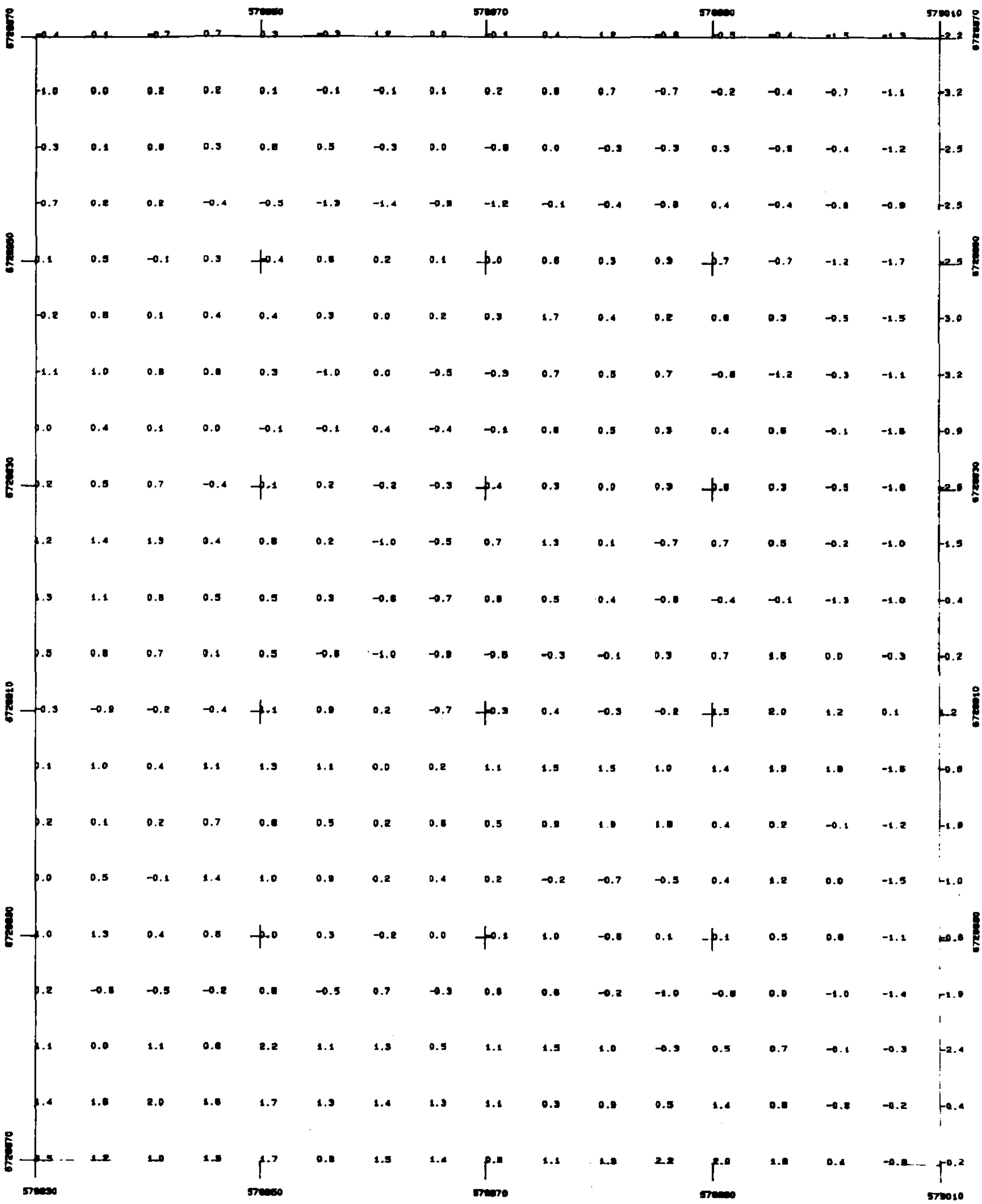

FIG. 10. — A grid of difference values at nodes.

rence values at grid nodes, printed as decimetres with centimetres after the decimal point. The same method can obviously be used to monitor slow changes of an area caused by silting or pollution, or the presence of some new object or removal of an existing one in the area.

Volume calculations

The system offers several algorithms for calculation of volumes. Applications for this are dredging operations planning or, in combination with differential charting, calculation of the volume of material which has been dredged, or volume of deposits caused by silting or dumping of material.

Finding extreme depth values

In a hydrographic context, it is essential to be able to identify shoals and troughs with their correct depths. The system allows for an automatic search and saving of such values.

DATA REDUCTION AND PRESENTATION

The classical problem over which all hydrographers and cartographers have had to ponder since the start of systematic depth sounding has been data reduction. How much data to retain and still have the chart readable, and how much data to discard and still have the chart give the necessary information?

A traditional approach to the problem would be as follows:

1) The chart must provide the navigator with a set of depth values positioned as accurately as possible, showing the navigational limitations of the area, i.e. least depth over shoals, in channels, fairways, etc., and in many cases the greatest depths.

2) In addition, to convey a general picture of the sub-sea topography, this being obtained by a set of depth values, each giving a representative description of the area adjacent to the particular depth digit.

When applied to the management of data from a swath sounding system, the primary considerations will be that the remaining data is sufficient for a reconstruction/presentation of the topography to a defined accuracy within the given chart scale. To keep a firm control over processing costs and data storage capacity, it is equally important that no more data than necessary is retained. It is also necessary to be aware of the limitation of the graphic reproduction technique that is used, in particular the line thickness and the minimum size of letters that are readable. Since the swath sounding system produces such an enormous amount of detail, particular attention is needed in judging how much small detail can be put into a chart before it becomes too cluttered to read. Experience in charting with the EM100 system so far seems to show that charts of approximately 70 cm times 1 m, processed from 1·2 million individual soundings, will be close to the limitations mentioned above. At present it does not seem to be practical to process a chart from 10 or 100 million soundings. If we compare these numbers with the data density numbers given earlier in this paper, we see that a 1:5,000 scale chart can be produced without data reduction at 400 metres water depth, but in 25 metres of water we would need to process some 6·7 million soundings, and in this case, data reduction should be considered. One should bear in mind that, although direct processing of a large number of input points may be possible, it will cost a lot of computer storage capacity, man-hours and money, and be without obvious benefits.

Simple data reduction

A simple way of reducing data would be to disregard a certain percentage of the data and retain the rest, without doing any optimization of the process. The SC100 software package has a facility for processing every n'th pulse, and skipping the others. The number *n* can be any chosen number. Alternative simple schemes are easily implemented, and can make it possible to apply a sensor such as EM100 with a resolution which sometimes is higher than necessary for the task in hand. Once this simple data reduction has been applied, the possibilities for later elimination of noisy measurement samples are more or less lost, since the soundings adjacent to the noise spike are eliminated, leaving nothing to check against. To conclude, the simplest approach is not the optimal one.

Controlled, automated data reduction

Having discarded the simple data reduction method, the hydrographer will have to address the problem: 'How can one best represent all measurements within a defined area by a reduced data set?' Reducing data of the magnitude provided by the swath sounding system has to be done automatically by computer to be of practical use. Figure 11 illustrates a suggested scheme for this.

1. The survey area is divided into a number of quadratic cells of a defined size.
2. All data points gathered inside a cell are to be represented by three data points:
   - the minimum depth,
   - the maximum depth,
   - the average depth.

   By preserving and processing these variables, it is possible to meet the requirement for a good descriptive chart presentation, and combine it with the requisite true and reliable indication of shoals and deepest values.
3. It is important that the extreme values are not selected among the noise spikes which may be present in the data. This is avoided by first gridding the data points in the cell to an interpolated surface, making use also of data in the adjacent cells, then by eliminating noisy raw data as previously described.
4. From the remaining data, a selection is made of the shallowest and the deepest soundings. These are written on separate files. The average value

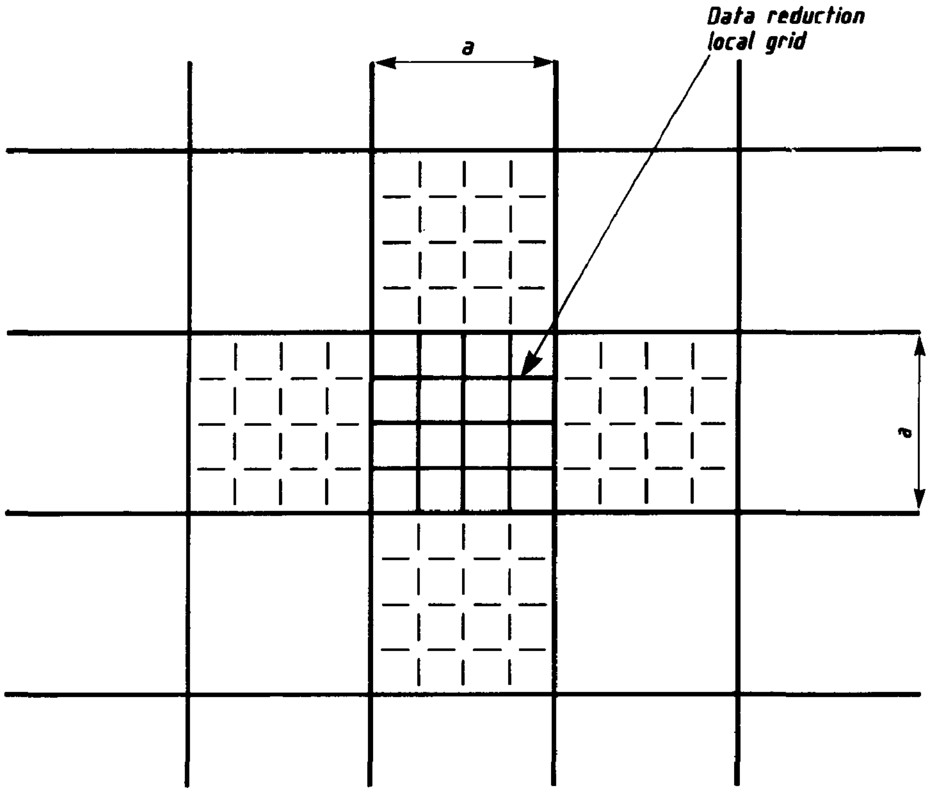

FIG. 11. — Technique for reducing data within a grid.

can either be the grid node value in the center of the cell, or, alternatively, selected from the raw data points as the value which is closest to the arithmetic mean.

The procedure above is relatively fast, because only small, local areas are gridded, and it is well suited to run continuously without human intervention.

PROCESSING CHAIN

With the hardware and software available today, it is preferable to split the processing of the surveyed data into separate on-board operation, and on-shore processing.

On board

The result of the survey operation will be a laser disk containing all the collected data from which the hydrographer can generate a file containing the accepted, quality controlled basic data in an on-board process.

This file will then be the precious basic data that will be kept in the Hydrographic Office along with the fair sheets and analogue records of old surveys. From the basic data, the hydrographer may also prepare a list of such recognizable features as the scrutiny of the data will reveal. Such items, be they wrecks, pock marks, etc., will be written to separate files. He will also obtain the information needed for conducting the progress of the survey in an efficient way. Figure 12 illustrates what seems to be a realistic model for processing multibeam echo sounder data. It is expected that a system of this type will be in operation within the 1988 to 1989 time frame. The on-board quality control and data reduction are performed on a work station with a powerful 32 bit computer. The computer is interfaced to the laser disk data recorder of the EM100. Tactical application of the swath sounding system is, of course, done in the same way as with an ordinary echo sounder, by running lines of soundings. It is recommended that a certain overlap between each swath is achieved. The amount of overlap depends on a number of considerations, such as beam width, the nature of the task in hand, etc. A practical way of keeping abreast of the post-processing work is by processing previously run lines, while running new ones. To overcome problems of discontinuance of contour lines between two swathes, swathes 1 and 2 are processed while running swath 3, resulting in the contour chart for swath 1. Swathes 2 and 3 are processed while running swath 4, resulting in the contour chart for swath 2, and so on. (Fig. 13).

On-shore processing

Even though the development of computer technology is advancing by leaps and bounds, it will still be very impractical, and indeed undesirable to process the basic survey data every time a new product is to be compiled. It is obvious that considerable data reduction is necessary when the data set from the survey vessel is to be used in compiling nautical charts and other products in the necessary variety of scales. In fact, to meet requests for different scale charts and other products, it is necessary to produce a set of standard products available for contouring, perspective views, profiles, or whatever presentation is required. These products could be organized in a series of pertinent scale levels. These may be 1:2,000, 1:10,000, 1:50,000 and 1:100,000, each with its own grid surface to which the depth data is organized. A grid size of 1 mm at the scale of the chart seems to be reasonable for a sufficiently detailed picture of the sea floor on an average. A standard size chart might then contain slightly less than one million depth data points, a figure within the capacity of the system to handle in an acceptable time.

For shallow areas, that number of data points would suggest a scale of 1:2,000 for the total mass of depth information from the EM100. For deeper waters, a scale of 1:10,000 could suffice.

With a 'chart scale-to-number of data point' ratio of 1:5,000 to one million, a chart of 1:50,000 will contain 100 million depth digits to store and handle, 1:100,000, 400 million. The total Norwegian EEZ surveyed by EM100 would result in 100 billion data points! — which underlines the necessity for data reduction.

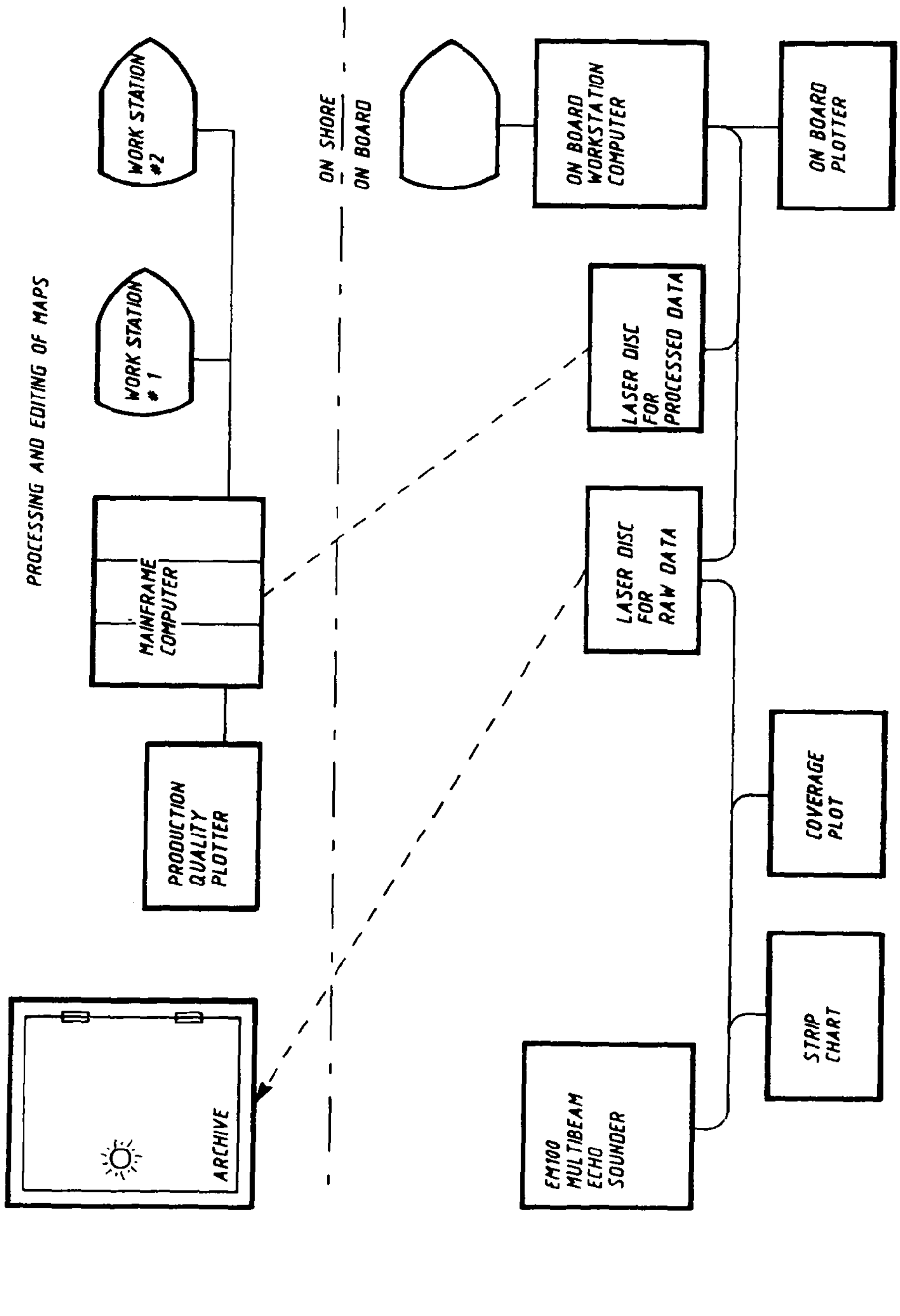

FIG. 12. — A model for processing multibeam echo sounder data.

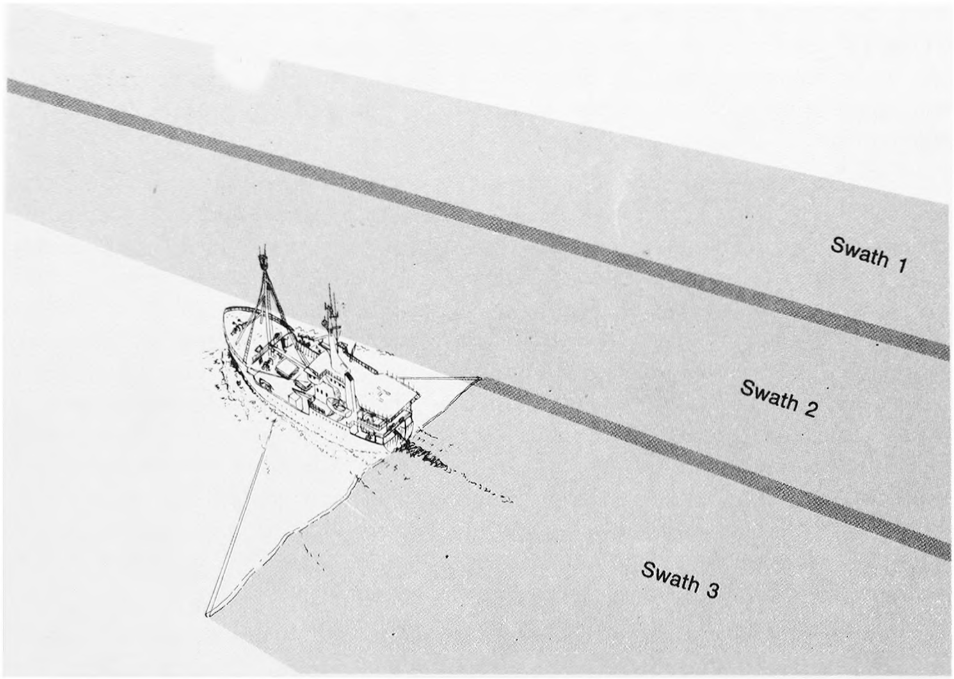

FIG. 13. — Survey method of overlapping swaths.

Having established the data at different scale levels, the various products can be output at intermittent scales. Producing these standard products could imply the use of the same techniques and programs as those applied in the CP100 contouring package previously described. It is a well established fact that the compilation of a nautical chart from the survey data to the finished product is a time consuming process, and well it might be, with all the considerations and technical skills that have refined this product to its present stage of perfection. The product from a swath sounding system, organized as shown above, will, however, make it possible to issue products for other than navigational purposes, more or less directly upon the completion of the actual survey.

CONCLUSION

It is difficult to address the problem of data management of a swath sounding system without taking a broader view of digital data management. With the advent of the digital terrain model and the associated software systems for the products and presentations that may be derived from it, the foundation is laid for a significant development, in many ways a revolution, in the life of a Hydrographic Service. No longer will the nautical chart as we have known it be the sole product springing from our survey effort. A multitude of new concepts in navigation are emerging, the Electronic Chart Display Information System being one. Future navigators, afloat or submerged, might very well come to rely on digital terrain models provided by the Hydrographic Services as a primary source for navigation by 'best fit' methods. As stated earlier, the new technology will open a whole new range of products tailored to fit the customer's requirements.

Having established the tool for the versatile handling of survey data, the next problem to present itself will be the extent of data available to the customers. Swath sounding systems will deliver large amounts of high quality data, but the on-shore processing scheme must be a comprehensive one, taking into account digital data which is becoming available from a number of sources. Many Hydrographic Services have either a capacity for turning out digital bathymetric data from more or less automated survey systems, or are planning to acquire systems giving them this capability. There is a considerable interest in laser bathymetric systems with enormous potentials for generating digital data eminently suited for processing in a digital terrain model. A terrain model will also make it viable to utilize the large amounts of high quality data surveyed in connection with industrial development, particularly that of the offshore oil industry (in Norwegian waters representing a yearly output far in excess of our Hydrographic Service's own offshore surveying capacity).

Once presented with the possibilities of the new systems, our customers' demand for digital data over large areas will soon be far greater than our capacity to survey high quality data fast enough, even with the new sensors in our arsenal of equipment. For most Hydrographic Services, by far the bulk of historic survey data will be found as analogue depths on fair sheets, the fruit of enormous amounts of painstaking toil through the years. When digitized, this data will provide the necessary information for digital terrain models over large parts of our chart coverage area until such time as new surveys are made. Making use of data from various sources will make it necessary to allow for a selective search routine, retrieving data by reference to such parameters as quality of navigation and bathymetry, origins, etc. Applying the same procedure for organizing these data to different scale levels, such as the one used for handling swath sounding data, seems a reasonable approach. The present technological stage has compelled us to organize our data files as geographical areas in order not to be overwhelmed. It is quite possible, however, that new computer technology may allow us to present the data in an uncompromising way in the future. Despite all our trials and tribulations over the data deluge, one thing may be certain: the hydrographic community has hardly ever seen such exiting technological and conceptual developments in its long professional course.

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