EFFICIENT METHODS FOR GENERATING DIGITAL CHARTS

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Abstract

Near shore hydrographic surveying conducted for engineering works require high accuracy and high throughput because the results from these surveys serve as inputs in the engineering work cycle for cost estimates, design and construction purposes. Increasingly, this engineering work cycle is driven by the integrated process of computer-aided-engineering. Hence, the traditional end product of the hydrographic survey — the paper depth chart — can no longer satisfy the digital demands of many engineering organisations. A new product —the digital database, with the digital chart as a by-product of this digital database — is therefore urgently needed. This paper explains how inexpensive microcomputer-based digital charts can be generated from conventional analogue/digital hydrographic systems.

INTRODUCTION

Computer-Aided-Design (CAD) work processes in many civil engineering organisations now demand digital information on the seabed topography in their work cycle. In addition to the traditional needs of making hydrographic charts for port navigation, these digital data are also needed for engineering contract works. Because these seabed topographic data serve as inputs in the Computer-Aided-Design engineering work cycle, the desired topographic data must be in the format compatible with the installed CAD system of the organisation. This requirement diminishes the role of the traditional paper chart for engineering design.

The most efficient method in the acquisition of digital topographic seabed data is through direct on-line digital charting at source. The digital X, Y, Z

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information of the seabed topography can then be reformatted into the desired CAD format.

However, on-line digital charting like those conducted by the H.M.S. ROEBUCK (May, 1987) is prohibitively expensive. Unlike deep sea and navigational charting, near shore surveys for engineering works often do not have the economies of scale to justify the use of expensive on-line digital systems for hydrographic surveys. The reality of hydrographic surveys for engineering works is that inspite of its importance, it constitutes a miniscule proportion of the total project cost.

The solution to this cost dilemma is to acquire the digital database off-line on the powerful but inexpensive microcomputers. To minimise cost, the off-line techniques should marry the existing methods of analogue/digital near shore surveys with microcomputer-based CAD (microCAD) systems.

The rationale behind this marriage is strictly economic. Although digital hydrographic equipment are now readily available in the market, they are still expensive. Furthermore, many of the analogue instruments used in near shore surveys — conventional echo-sounders, theodolites, and mini-rangers — are still in perfect working order and need not be consigned to the junk yard. And many organisations like the one described by CONNALLY (1986) are still using these equipment to advantage. The useful lives of these analogue hydrographic equipment can easily be extended in the digital age through creative software solutions.

THE HYDROCAD SYSTEM — AN OVERVIEW

HYDROCAD (for **HYDRO**graphic position fixing through Auto**CAD**) is one such *hybrid* hydrographic system developed for near shore hydrographic surveying. The word hybrid is emphasised because HYDROCAD is a system born of a marriage between conventional hydrography and microCAD technologoy. Such a hybrid system allows analogue/digital output from existing analogue/digital hydrographic systems to migrate from a dumb analogue environment into the intelligent and interactive world of CAD (Fig. 1).

The HYDROCAD hybrid system performs, among other useful functions, two essential tasks. First, it extracts, correlates and processes the mass of disparate raw analogue/digital hydrographic survey data into digital X, Y, Z co-ordinates. This it does in the most economical and efficient method consistent with the available near shore hydrographic equipment.

Second, the HYDROCAD hybrid system encodes and reformats the extracted digital data into the format of the selected CAD system. These two essential functions are illustrated schematically in Figure 2.

HYDROCAD is compiled in QuickBasic and comes in five co-operative modules (Fig. 3). **EDITCON** and **EDITDAT** are the data managers of HYDROCAD. Essentially, these two modules allow the user to capture the raw survey data into the microcomputer. **SEAFIX** is the module which processes the

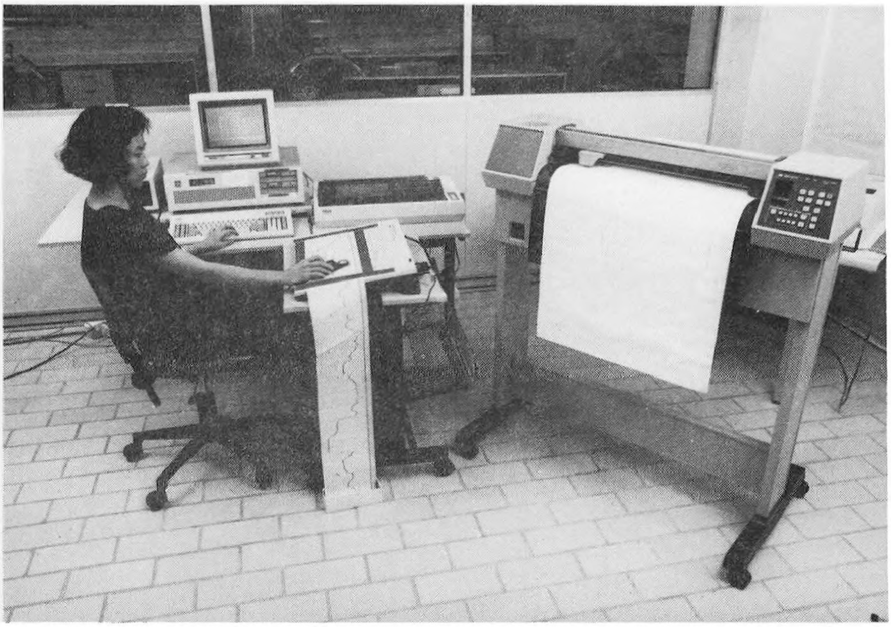

FIG. 1.— Using HYDROCAD to generate digital hydrographic charts on the PC workstation.

raw survey data into position fixes (X, Y). The fourth module, **SEADEPTH**, is the heart of the HYDROCAD system. It performs three essential functions. First it extracts digital depths (D) from the analogue echo trace. Second, it creates the tidal file and corrects the measured digital depths to chart datum. Finally, it correlates the position fixes with their corresponding depths at the prescribed intervals along the track line. The product at the end of the SEAFIX work cycle is the correlated X, Y, D_{chart} file. This file is then processed in **SEAPLOT** for graphics display in AutoCAD.

AutoCAD — THE MICROCAD PARTNER OF HYDROCAD

The production of paper charts by conventional analogue methods is tedious, labour intensive and time consuming. Turnkey systems for the automated production of paper charts, both off-line and on-line, are extremely expensive. With the advent of inexpensive and powerful microcomputers, the production of paper charts for engineering works can be automated economically with the help of microCAD systems.

In the information age, the paper chart is really one by-product of the work cycle. The paper chart contains useful information but these must be extracted by the reader. There are, of course, many other limitations the most serious of which is the necessity to compromise between the need to avoid 'clutter' on the paper and the need to preserve the density of soundings. This compromise means that

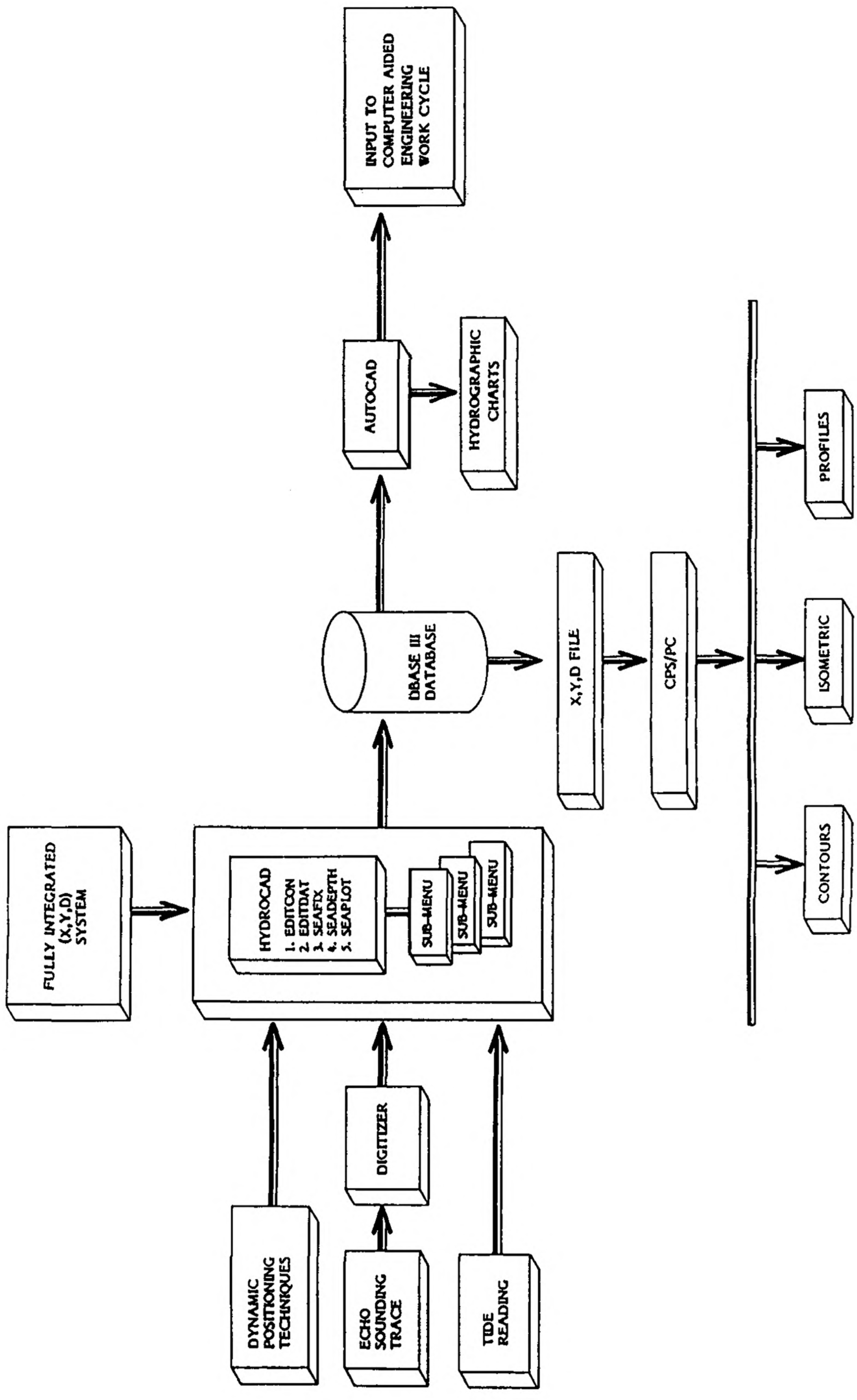

FIG. 2.— The concept of HYDROCAD — a schematic representation.

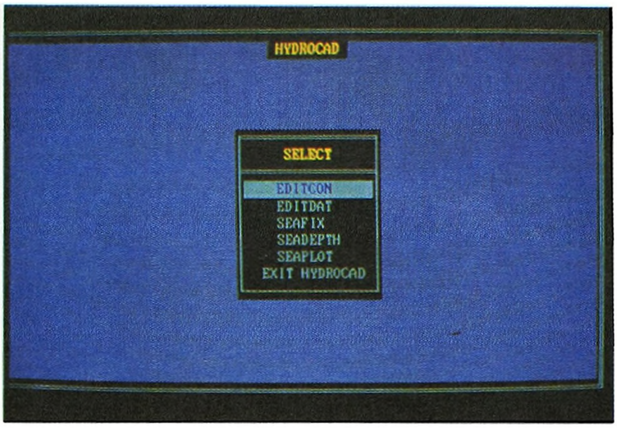

FIG. 3.— User friendly windows allow the user to access the five modules of HYDROCAD.

useful information collected during the hydrographic survey may not be represented on the chart.

Clearly, this restriction is no longer binding, when the paper chart is transformed to its electronic equivalent — the digital chart. With the zoom, search, pan and layering abilities of digital charts, the soundings could be as dense as the accuracy of the survey allows. Therefore, even though the HYDROCAD system can produce paper charts economically and efficiently on the microCAD system, this is not the reason for going digital. Indeed, the main objective of implementing the digital chart in the microCAD environment is to allow users — hydrographers, navigators and engineers — to access and query the graphic data base more quickly, more intelligently and more productively.

The digital chart on the microCAD system, in fact, becomes a pseudo electronic chart. It is pseudo, because it is generally accepted that an electronic chart requires the integration in one system of two essential components: a navigation system and a hydrographic data base system (EATON *et al*, 1986). Since the digital chart is only a hydrographic data base display system, it does not qualify for full electronic chart status. Nevertheless the potential for upgrading the digital chart to full electronic chart status is latent.

The concept of marrying microCAD systems with hydrographic analogue/digital systems to produce digital charts has been documented by KOO (1987). This marriage of convenience is not unique to hydrographic surveying. Other areas in surveying are proving equally fertile grounds for such marriages of conveniences. In a related development, FOOTE (1987) and ROGERS *et al* (1988) have chronicle similar work in photogrammetry. The successful development of a hybrid digital photogrammetric system — the DAT/EM system — for compiling interactive digital maps directly from analogue photogrammetric plotters is now well known. In the case of HYDROCAD, different versions of this software system has been in use for near and inshore hydrographic surveying in and around Singapore since 1985.

Clearly, one important reason for using the microCAD as the backend of the hybrid hydrographic system is cost. But cost alone is not the decisive factor.

There are other equally compelling technical factors. First, there is the reason of not wanting to re-invent the wheel. MicroCAD systems come with their own library of routines: points, lines, text, layers, splines, etc. which more than satisfy the requirements of displaying the digital chart. The entity library of AutoCAD is very comprehensive and entities not available in the microCAD can always be designed.

Second, most microCAD systems come with a comprehensive range of device drivers which make the digital charts drawn in AutoCAD portable across commonly available hardware. In the mix and match environment of the microcomputer hardware world, the tedium of writing graphics routine for specific hardware is, therefore, eliminated.

Admittedly, the database of the microCAD is limited and data searching on large coastal projects will be slow. However, this defect is remedied in HYDROCAD by using an external database (such as DBASE III plus) to work in co-operation with the chosen microCAD. All the topographic information (together with their attributes) pertaining to the seabed are housed in the DBASE III system. Initial enquires and data searches are made in the DBASE III environment. The queried database, which is necessarily smaller than the entire database of the project, can be exported to the microCAD system for display, enquiry and engineering design.

The microCAD system chosen for HYDROCAD is AutoCAD (Autodesk 1987). This choice was made on the merit that AutoCAD is one of the most powerful microCAD system available today. It is in fact the *de facto* standard in microCAD systems by which all other microCAD systems are compared. AutoCAD runs under four of the most used operating systems in the micro and mini worlds: IBM's PC DOS, Apollos' AEGIS, Sun's UNIX and DEC's VMS. The ability of AutoCAD to run under so many operating systems alone puts it in a class of its own because most packages, even those at the high end of the price and performance ratio are still bound to a specific machine environment. With over 100,000 registered users, AutoCAD has become the Lotus 1-2-3 of the microCAD industry. The marriage between HYDROCAD and AutoCAD is therefore not without good reasons.

It is recognised that not all engineering organisations use AutoCAD. Hence it is important to ensure that digital charts created in the AutoCAD environment can be exported to other micro, mini or mainframe CAD systems. AutoCAD comes with the universal IGES (*I*nitial *G*raphics *E*xchange *S*tandards) translator to satisfy this requirement. But graphics data interchange from one CAD system to other is often fraught with problems (KOO, 1988) and the IGES translation service is, therefore, not a panacea for exchanging graphics files from one CAD system to another CAD system.

HYDROCAD — DATA COLLECTION SYSTEMS

Near shore hydrographic surveys are usually carried out by the familiar methods of angular intersection, resection, radiation, and linear intersection (range-range). The front end of the HYDROCAD system has, therefore, been designed to allow easy transfer of the raw survey data from any one of the familiar methods of near shore hydrographic surveying into the HYDROCAD system.

Data files (*.DAT) may be created manually from the survey field sheets or they may come in from data collectors. If the survey data is to be transferred manually, the user can make use of HYDROCAD's data managers to create the necessary input data files interactively. HYDROCAD's data managers — EDITCON and EDITDAT — will literally hold the user's hand and walk him or her through the data creation process. However, if the survey data have already been logged into data collectors, these need to be dumped into the micro-computers. The raw survey data will have to be reformatted into the format of the HYDROCAD data file structure. Since the input format for each of the survey methods are clearly documented in the manuals (KOO, 1988), the reformatting can be easily achieved with a program written in any language.

HYDROCAD — DATA PROCESSING

Once captured, the raw survey data are processed in three stages.

Stage A

Here, the raw survey data are processed into position co-ordinates (X, Y). The SEAFIX module will access the data files (*.DAT), solve the position fixes according to the method of survey and saved it in an output file (*.FIX).

Stage B

The second stage involves the extraction of digital depths from the analogue echo trace. An accurate, inexpensive and universally applicable method of converting analogue depths to digital depths has been developed for this purpose. Code named SEADEPTH, this algorithm allows the user to extract digital depths (D) by simplying tracing the depth curve of the echogram mounted on an A3-sized digitizer with the cursor. Figure 4 shows the digitizing set-up for executing SEADEPTH. The digitizing is done on a fix-by-fix routine. At the end of each tracing cycle, the algorithm correlates the (x, y) digitizer co-ordinates, picked up during the digitizing process, with the position co-ordinates (X, Y),

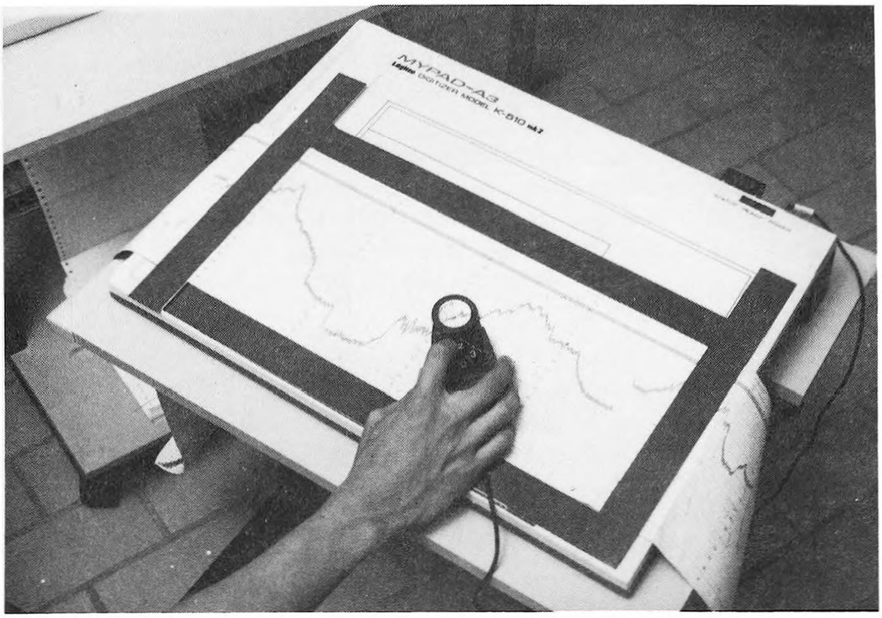

FIG. 4.— SEADEPTH at work. Measured analogue depths are extracted and correlated with the position fixes at the prescribed intervals along the track line.

generated earlier in SEAFIX, to yied X, Y, D triplets. This digitizing and correlation cycle is performed in real-time and is repeated until the end of the echo trace.

Stage C

The third stage consists of correcting each measured depth to its chart datum. The algorithm for doing this is also incorporated in SEADEPTH. The discrete time/tide information is first created on a file. This is done within SEADEPTH and the user is guided on the relevant information to key in. Output from data collectors will need to be transferred to SEADEPTH using the data file structure defined by SEADEPTH. The chart datum corrections to the measured depth (D_i) at time t_i is determined using the GREGORY-NEWTON's second order forward and backward difference interpolation technique. Again, this correlation is performed in real-time.

The final output after the SEADEPTH run is a file of X, Y, D_{chart} co-ordinates. These co-ordinates are then exported to a DBASE III system for attribute attachment. These attributes include dates of survey, standard deviations of the survey co-ordinates, authority of survey, cost of survey, etc.

DATA PRESENTATION

For presentation and engineering design purposes, the X, Y, D_{chart} triplets need to be displayed graphically. First, the relevant information for display are searched in the DBASE III system. A case study of a relevant search for an engineering design project is presented.

Area of interest:	$E_1 < \text{Easting} < E_2$
	$N_1 < \text{Northing} < N_2$
Standard Deviation Specifications	$S_D < 0.15$ m
Date criterion	$t_1 < 31$ Dec 1987
Depths to be shown in 5 layers	$D_i < D_1$ [layer 1, yellow]
	$D_1 < D_i < D_2$ [layer 2, red]
	$D_2 < D_i < D_3$ [layer 3, green]
	$D_3 < D_i < D_4$ [layer 4, purple]
	$D_4 < D_i < D_5$ [layer 5, blue]

The above constraints were imposed on the relevant topographic database in DBASE III. The data base was searched and the required information exported into SEAPLOT using DBASE's SDF format for graphic display. All the layers of the digital chart are switched on in AutoCAD.

SEAPLOT is HYDROCAD's cartographer. With the help of simple menus, the user can specify the exact formats for the digital chart. These include the text font, the size of the text on the paper chart, the position of the depth information, the arrangement of the text — whether the decimal part of the depth should be subscripted or otherwise—, the orientation of the depth text, etc.

The consensus of opinion is that digital charts should, as far as possible, adhere to the cartographic formats of the conventional paper chart (MORRIS, 1987). SEAPLOT attempts to reflect this philosophy but at the same time allows the user the free hand to adopt other formats and symbol types. SEAPLOT also allows the user to filter out the depth information into depth ranges. Each depth range may be assigned a particular colour on a particular layer.

Colour coding and depth filtering by SEAPLOT allows the generation of colour coded depth layers. In effect we can create a 'semi automatic depth contouring' digital chart 'with the change from one colour to the next representing a depth contour line'. This feature is acknowledged by WENTZELL *et al* (1982) to be extremely useful when 'survey track lines are run fairly close together' in engineering works such as in land reclamation and dredging surveys. WENTZELL further elaborates that here the colour effect makes the 'depth contours visible at

Words within quotations are attributed to Hubertus F. Wentzell and W. Buchka in 'Semi-Automatic Depth Contouring Aids Dredging operations.'

a glance. Where the parallel track line distance is greater, it needs just a few second to follow the colour transitions in order to obtain the depth contour lines'. The colour filtered digital chart can also be plotted. However, most plotters can only carry a limited number of colour pens, usually eight, and the effect is therefore not as dramatic as when the chart is displayed on a microCAD system. Figure 5 shows the resultant colour coded digital depth chart of an actual land

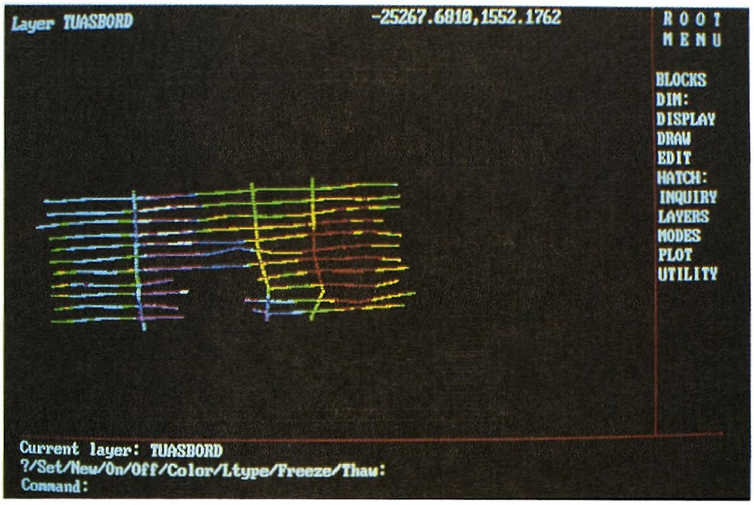

FIG. 5.— An overall view of the colour coded depth chart captured in AutoCAD after the data has been processed by HYDROCAD.

reclamation survey in Singapore. This chart was generated in AutoCAD using HYDROCAD as the pre-processor. All the layers on display in the figure have been switched on for display. Selected layers can, of course, be switched off. Figure 6 is a selected window of figure 5.

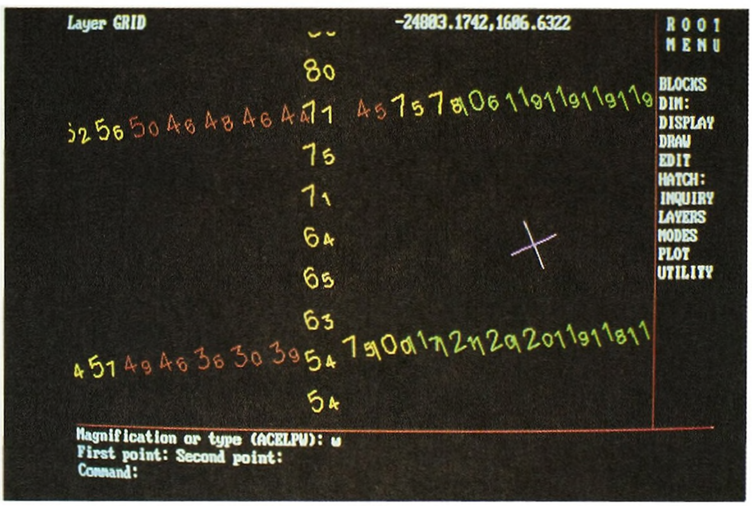

FIG. 6.— A selected window of the colour coded depth chart shown earlier.

DATA EXCHANGE FORMATS

AutoCAD accepts IGES or DXF formatted files. SEAPLOT formats a DXF file for AutoCAD. Since the creation and placement of the DXF exchange format in the public domain by Autodesk almost all microCAD systems have come to accept DXF files as the *de facto* standard for exchanging files. Hence, although SEAPLOT is written to work with AutoCAD, the universal status of DXF makes the SEAPLOT files suitable for migration to other CAD systems.

Digital terrain models can also be generated from the X, Y, D_{chart} triplets through either the IGES or DXF files. In fact, several PC-based software are already available for generating DXF contours and fishnet diagrams. Some examples are CPS/PC of RADIAN, QuickSurf of SCHREIBER INSTRUMENTS and Surfer from GOLDEN SOFTWARE.

CONCLUSION

The successful development and implementation of HYDROCAD debunks the myth that digital chart production systems are necessarily expensive. The ability of HYDROCAD to generate accurate and economic digital charts inexpensively points the way for small hydrographic companies to upgrade their manual chart production systems to digital ones.

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