International Hydrographic Review, Monaco, LII (2), July 1975

POLAPLOT : AN AUTOMATIC HYDROGRAPHIC DATA LOGGING AND PROCESSING SYSTEM

by The Hydrographic Service,
Port of London Authority

DEVELOPMENT

For some years the Port of London's Hydrographic Service had been conscious of the fact that a modern survey launch, operating near its base, using an echo-sounder and a continuous position fixing system such as Hi-Fix, could collect more data than could reasonably be processed by the conventional methods of recording and plotting by hand. It was fairly obvious that the data-loggers which were then coming on the market could adequately record hydrographic data either on paper or magnetic tape and that these tapes could subsequently be processed by computer. The Port of London Authority (PLA) had a well established computer department with a newly installed ICL 4-50 computer, and at first sight it seemed obvious that this should be employed to process any data logged on board.

Our first thoughts were thus to data-log position, depth and time on board the survey launch, pass the tapes ashore, process them on the big computer and return the resultant plot of reduced soundings to the surveyor for checking before publishing. Further thought, however, ruled this policy out on several counts. First, and perhaps most important, was loss of "surveyor control" : we felt that he needed to know how much work he had done and where he had done it so that he could assess what work still remained. Secondly, the logging of all raw data would result in unwieldy data tapes, whilst sampling the data would mean that the best use was not being made of all the data available; in other words some form of onboard on-line editing was highly desirable. Thirdly, there was the practical difficulty, not to say expense, of physically getting the data tapes and results to and from launch and computer centre. The next idea was to put a small processor on-line with the data-logger to edit and possibly reduce part of the raw data. But then if one has a mini-computer to edit the data, why not make use of its undoubted capacity and capability to do the whole process ? This, then, is what we decided to do; and a specification was drawn up on the basis that the equipment on board

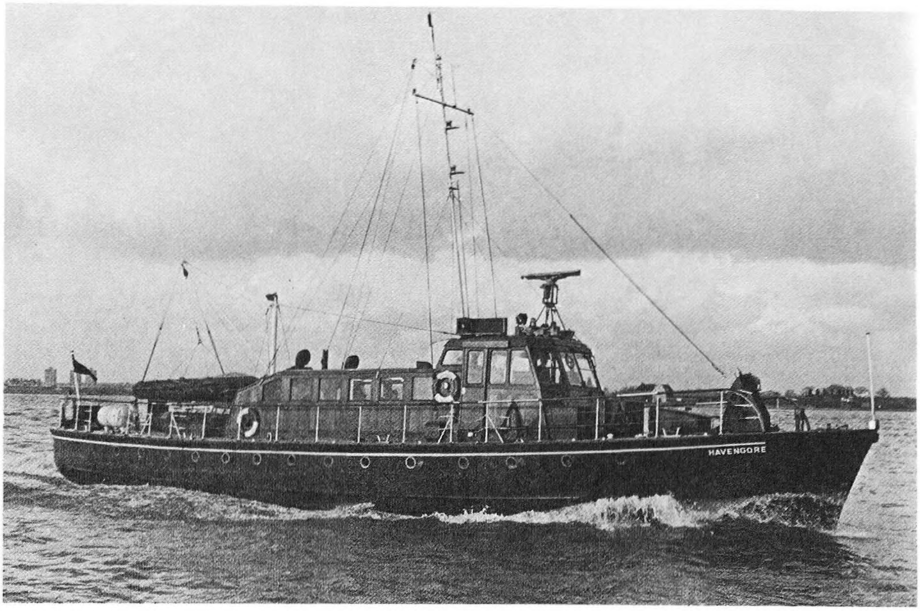

FIG. 1. — M/L *Havengore* : Twin screw survey launch, 85 ft overall, in which POLAPLOT is fitted.

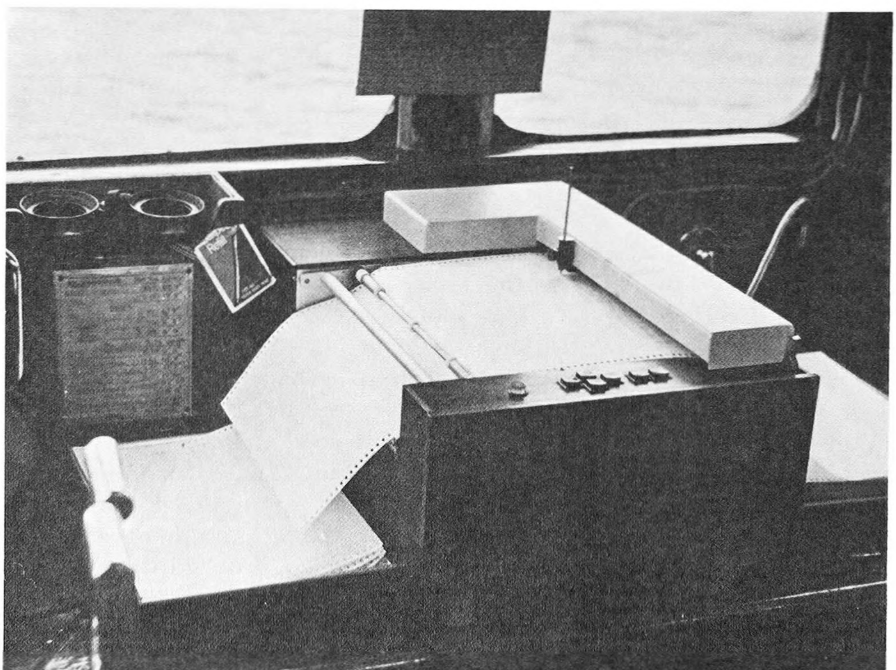

FIG. 2. — Incremental Plotter.

should consist of digital outputs for Hi-Fix (position) and Echo-sounder (depth), a mini-computer, paper tape punch and read station, teleprinter and small incremental plotter: all except the teleprinter and plotter to be housed in a standard 19″ rack together with the power supply and interface units.

In outline the equipment was to operate in the following manner. Whilst surveying, the computer should edit the soundings and depths, correlate them with time, and output the resulting edited data onto punch tape; at the same time the vessel's positions should be plotted on the incremental plotter, whilst any messages regarding the survey (generally speaking "error" messages) would appear on the teleprinter — through which the surveyor would communicate with the computer system.

Having completed the work, on the way back to base the surveyor would read the "on-line" tape back into the machine together with tidal heights, echo-sounder and Hi-Fix corrections. The computer would then process this data and produce as a first development stage a plot of corrected position and a list, on the teleprinter, of corrected and selected soundings; at a later stage in development we hoped to print the corrected selected soundings direct on to the plotter. In fact, the first stage never became necessary and we went direct to the second stage; we also felt it necessary to have some visual proof that the system was doing its job satisfactorily, so a program was written to plot the corrected selected soundings to the same scale as the echo-sounder trace; the former could then be laid over the latter and inspection would reveal if the soundings reflected the true state of affairs.

Having decided the road which we wished to follow, financial approval to go ahead was obtained in 1971, the equipment was delivered and fitted on board the Authority's survey launch *Havengore* in mid 1972. Not unexpectedly some difficulties were encountered — in almost all fields : hardware, software, environment, power supplies; two surveyors were sent on a computer programming course and they, together with the expertise of our own computer Department, wrote the programs, tested them, rewrote them, tested them again, until in early 1974 we started getting reliable usable results.

Apart from its prime task of sounding data reduction, the system (which has been named POLAPLOT), is capable of carrying out a number of other hydrographic tasks — e.g. the plotting of float-tracks — and the programming for such tasks is a relatively simple matter as FORTRAN can be used.

TECHNICAL DESCRIPTION

The hardware consists of :
- — Kelvin Hughes MS 36 echo-sounder with Automatic Digital Output;
- — Decca Hi-Fix receiver with Data Acquisition Module;
- — Creed Envoy teleprinter;
- — 12 inch incremental plotter (EAL 130);

— General Automation SPC16 mini-computer with 16K store;
— Trend Data Systems paper tape station (high speed punch and read).

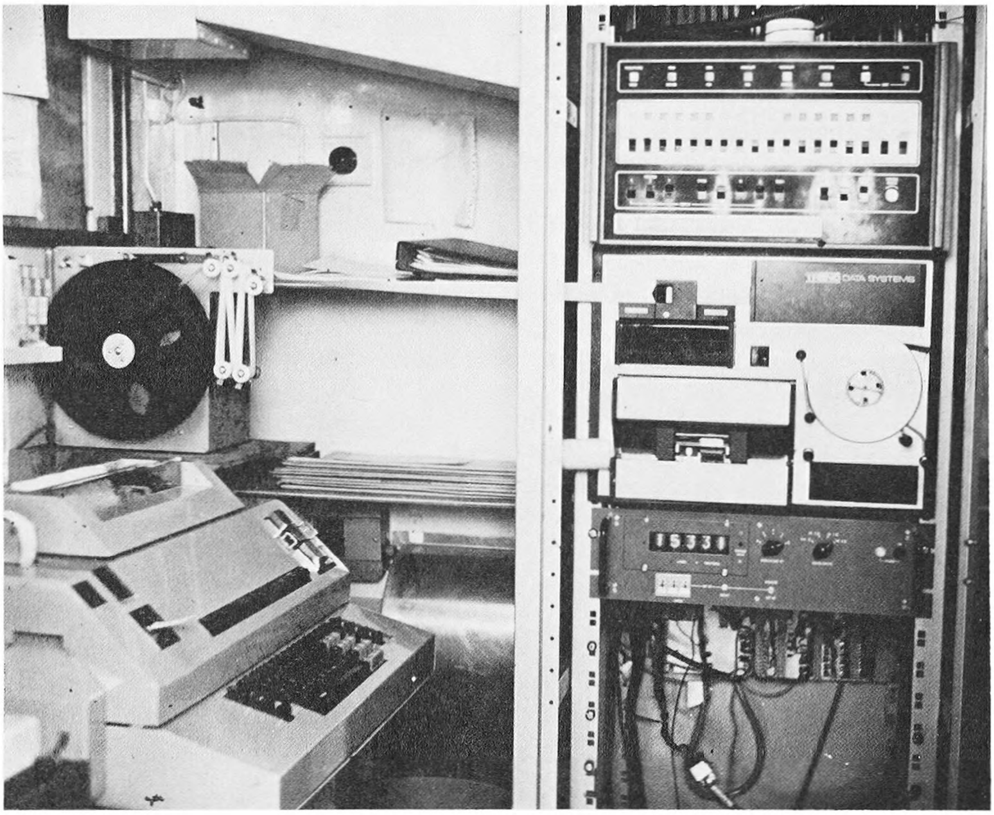

FIG. 3. — Teleprinter and rack containing mini-computer, high speed paper tape punch and read station, Decca Data Acquisition Module, interface and power units.

The last 2 items are housed in a single 19″ rack together with a power supply unit and an interfacing unit. Suitable ventilation must be supplied, and a reasonable quality alternating current 240 volts 50 cycles supply is required.

PROGRAMS

The software for the sounding system consists of six programs, described below. All of these programs run under a standard operating system. Most of the equipment is controlled by FORTRAN coding via standard software routines but the Decca and Kelvin Hughes equipment is controlled by a special driver module which has been written in CAP-16 ASSEMBLER. All of these programs are written in a modular form. All of the modules, except the special module mentioned above, are written in FORTRAN. This high-level language should be readable to most people, the modular approach ensuring that each logical section is an entity in its own right and can be understood as such. This approach has ensured a high degree of flexibility. For example, should a different hardware configuration be used, such as an alternative automatic position fixing system; then, apart from amending the special driver module and replacing the Hi-Fix to National Grid conversion module with an alternative, the system would be unaffected. This approach has also fitted in well with the architecture of the computer — especially the real time PLAT program. Within this program the concept of priority interrupts is utilised to access data concurrently with processing data already accessed. It works as follows.

The processing being performed is interrupted about 700 times a second by the execution of a "clock" routine. By an incremental count this routine keeps accurate time. The "clock" routine calls the driver module to initiate Hi-Fix and Kelvin Hughes echosounder readings at a rate of one and eight times a second respectively. The driver module outputs an update pulse to the relevant digitiser. Upon receipt of an update pulse the relevant digitiser obtains the data required and sends a data-ready pulse back to the computer. This data-ready pulse is interpreted as an interrupt, and the processing being performed is interrupted by the execution of the relevant routine to read the data.

The bulk of the program is processing data read approximately 2-3 seconds earlier while being interrupted by the routines collecting current data. In unusual circumstances this time lag may stretch from 2-3 seconds up to about a minute; however the data collection routines always keep to "real" time. Further interrupts are utilised to provide ad hoc surveyor access to the system. For instance one interrupt causes a routine to be entered which enables a variety of interrogation requests via the teletype (everything from time of day to passing survey messages out on to the output tape). Another interrupt routine causes an "event mark" to be output to the echo-sounder trace in addition to computer instigated fix marks. These routines are of course interrupted by the data acquisition routines.

The processing side of the program fully checks the data and keeps an accurate position on the plotter. The data is, however, only output on to paper tape if the position is within the survey area. The PLAT program will run continuously for as long as it is required — the surveyor has to tell it to stop.

The remainder of the suite consists of conventional "batch processing" type programs that read data, process it and output results. These programs may be re-run as many times as required; this applies particularly to the PLAN program as different parts of an area may be required at different scales. Providing the data is retained in a library it will be possible to do this over a considerable period of time. The recorded and corrected data tapes should be stored in separate localities for security purposes.

The choice of paper tape as the storage media was a simple one. It provides a cheap, practical and permanent way of storing data as opposed to the magnetic media which are far more prone to failure caused by bad conditions or handling. (Some four years after drawing up the specification, we would probably say that magnetic tape cassettes were preferable. However, few difficulties — no major ones — have been found with the paper tape).

PROGRAM DESCRIPTION

A summary of the six programs provides an overall specification of the suite (see Flow Chart).

PLASMA Accepts information defining the survey. National Grid coordinates of the corners of the area, Hi-Fix chain to be used, scale of the survey, etc. are input, and a parameter paper tape is output together with a plotting sheet of the area to be surveyed.

PLAT Accepts the paper tape and uses the plotting sheet produced by PLASMA. This is the "Data Logging" program. It produces a paper tape containing position, depth and time data as well as an on-line plot of the vessel's position.

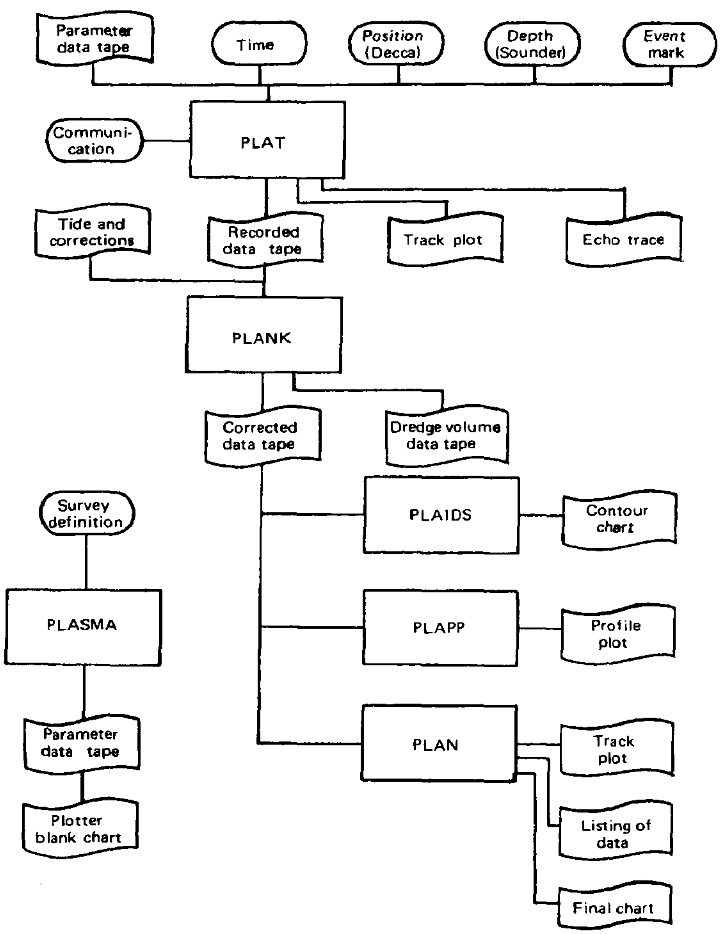

FIG. 4. — POLAPLOT. System Flowchart.

PLANK	Accepts the "recorded data" from PLAT, applies the corrections, and outputs the "corrected data" tape.
PLAN	Accepts the "corrected data" tape and produces the depth, position, and time print, the vessel track plot or the final chart.
PLAIDS	Accepts either the "recorded data" tape or "corrected data" tape, and produces a dredging contour map — in Hi-Fix terms similar to a Decca track plotter chart.
PLAPP	Accepts either "recorded data" or "corrected data", and produces a profile of the sea bed.

Note : PLANK also acts as an interface to a "Dredging Volumes" suite based on the PLA's Main Computer.

The following describes more fully the function and operation of the programs.

PLASMA

This program is run before reaching the survey area. It provides a parameter tape to be used by both the PLAT and PLAN programs. It also prepares the plotting sheet by drawing the grid and outlining the survey area. There is a facility to modify existing parameter tapes and to redraw the plotting sheet. The scale of the survey may be chosen by the surveyor but the survey area must fit the plotter. If it does not, the surveyor has the option to change the scale or the area. The concept of producing a parameter tape before reaching the survey area has several advantages:

(a) For routine surveys parameter tapes may be taken "off the shelf" and easily modified to meet current requirements.

(b) Tapes may be prepared well in advance, thus saving time on the survey ground.

(c) The parameter information had to be stated only once but is used by more than one program. This enables both a time saving and a reduction in the possibility of a discrepancy caused by a parameter error.

(d) As many plotting sheets as required may be produced using just one parameter tape.

PLAT

PLAT, the "Data Logging" program, reads the data tape provided by PLASMA and is initialised by typing in date and time. The program will continue to run indefinitely but will only output data if within the survey area. The plotter will, after initialisation of the program, follow the vessel's track continuously. A safeguard is built in to prevent the plotter losing reference should the vessel go "off the plotter". It is therefore possible to start the program well in advance of arriving at the survey area. The following options are open to the surveyor in order to get maximum flexibility out of the plotter:

(a) Continous tracking but not plotting.
(b) Continous tracking with plotting inside the survey area.
(c) Continuous tracking with plotting.

Fixes are indicated by a cross. Start and end line fixes have a unique symbol and only these have their numbers plotted. Fixes are not generated when outside the survey area.

The main functions of PLAT are to collect fix, depth and time data, and validate this data, check the readings for invalid data, warn the surveyor in this event, and finally output the data on tape.

The arrangement of data collection and output is now broadly outlined. The computer contains a relative time clock which is driven by internal interrupts. This is used to update the "survey" clock which has been referenced at initialisation time. The computer interrogates the echo-sounder at a rate of 8 times per second. The Hi-Fix is sampled every second. An event is transmitted to the echo-sounder every 10th Hi-Fix position, i.e. every 10 seconds. These fixes are only generated within the survey area, and each start and end fix is indicated by a double line on the echo-sounder record. Each fix is numbered consecutively. Output on punch tape consists of a time group and fix number every 10 seconds, a Hi-Fix reading every 5 seconds and 24 soundings covering the period of 10 seconds. These soundings consist of 8 groups of maximum, minimum and mean soundings. Each group covers a time period of 1.25 seconds. For each maximum and minimum sounding an indicator pinpoints its position in time within 0.125 second. The mean sounding is the arithmetical mean of 10 successive soundings and is placed in the mean position.

As shown above, the data is output on a time basis, no regard being made to the vessel's speed, and it follows that the accuracy and density of the data is a function of this speed. Assuming a required plotting accuracy of the soundings to be 0.6 mm, the maximum speeds allowable for various scales are given by 0.0096 × scale. For a plotting distance between soundings of 4 mm, the maximum speed is given by 0.0064 × scale. It can be seen that if the plotting distance between soundings is satisfied then so is the accuracy. For a scale of 1/1250, any speed up to about 8 knots is satisfactory.

It is important that safeguards are built into this program to ensure that the quality of the data is consistent with predefined tolerance, and with this in mind the surveyor sets, and is able to update, certain tolerances and corrections. If these tolerances are exceeded the surveyor is warned.

Depth

Before sounding, the digitiser must be calibrated against the echo-sounder. Further checks should be made at the end of the survey. To ensure that faults in the digitiser and echo-sounder are detected, a check is made of the number of invalid soundings returned. If this exceeds a given tolerance, the surveyor is warned. Current soundings are checked for consistency and invalid depths ignored.

Hi-Fix

Hi-Fix error corrections may be applied. These may be modified at any time. A Hi-Fix smoothing routine may be employed. This replaces the current position with the mean of 7 readings. A "standard deviation" is calculated and compared with an error factor as decided by the surveyor. A failure will cause a warning to be output to the surveyor who may wish to increase the tolerance or suspend the survey. At the end of the survey the maximum and mean "standard deviation" are output and these will give some idea of the quality of the Hi-Fix. This option may be introduced or suspended at any time. Hi-Fix malfunctions will cause a warning to be generated.

The surveyor is able to control tolerances and corrections and to monitor data at all times.

Monitoring Facilities

Time :	The current time may be requested.
Hi-Fix :	Patterns 1 and 2 are printed. These should be checked against the digitiser.
Depth :	The current depth at the time of the request is printed.
Fix Number :	The next fix number is printed.

Operating Facilities

Suspend plotting :	Plotting is stopped but the pen continues to follow the vessel's track. Data continues to be output.
Resume plotting :	Re-introduce the plotting. This is the normal condition.
Permanent track plotting :	Vessel's track is continously plotted while within the plotter limits. Fixes are only plotted within the ,survey area.
In-area only track plotting :	Plotting ceases outside the survey area, but the pen continues to follow the vessel's position.
Hi-Fix error up-date :	The Hi-Fix corrections for Patterns I and II may be amended.
Hi-Fix error factor up-date :	The error factor against which the "standard deviation" of the Hi-Fix is compared may be altered at will.

Suspend smoothing :	Stops Hi-Fix smoothing.
Resume smoothing :	Starts Hi-Fix smoothing.
Suspend output :	Suspends output from punch, stops event marks on the echo sounder and stops plotting.
Resume output :	Restarts the plotter event marks and punch.
Message :	Any message up to 22 characters may be typed. This message will be output on the punch.
End of survey :	This stops the program after certain operations have been performed. They are : Output special trailer on the tape; Reference the plotter; Work out and print overall Hi-Fix errors.

PLAT, although a powerful and flexible program, is straightforward in its operation. The "surveyor communication" especially has been carefully considered to combine a high degree of flexibility with simplicity of use.

PLANK

This program acts as an interface between PLAT and the remaining programs. It outputs the "corrected data" in one of two forms :

(a) In the same format as output by PLAT.

(b) In a format suitable for use by the dredging volume program which is run on the large computer installation ashore.

The following corrections are applied to the "recorded data" tape.

(a) Tidal information. Accepts tidal readings at 10 minute intervals up to 4 hours. Tidal corrections are applied by linear interpolation between these heights.

(b) Fixed constant tidal correction. This may combine transmission zero and datum correction.

(c) Echo-sounder speed error. A progressive correction is applied according to recorded depth.

(d) Separation error.

(e) Hi-Fix corrections. These will be in addition to those corrections applied by the PLAT program.

PLAN

PLAN, the chart producing program, accepts the corrected data tape from PLANK and the parameter tape from PLASMA. If plotting is required, PLASMA is also used to draw up the plotting sheet.

The data is checked and processed, to provide a succession of depths each with a National Grid position. This data is then output according to the method selected.

To provide flexibility of operation, a console interrupt system enables the surveyor to alter the output method, or change many of the parameters during the run.

Output options

For initial testing of the system and for close investigation of critical or suspect areas, the positions and depths may be listed on the teletype and vessel's track drawn on the plotter. Each fix is numbered and the start and end-line fixes have unique symbols similar to the on-line plot. The depths listed may be :

(a) "raw data" straight from the data tape;

(b) "plotted depths", i.e. those which have been further selected for plotting at the specified scale.

Further selection of soundings for plotting is done according to scale and the spacing of the depths on the plotting sheet. Depths are plotted provided they do not overlap. Those depths which cannot be fitted in are discarded provided they are not significant to the seabed profile. The depths are in metres and decimetres, the true position being marked by the decimal point.

Processing options

If the surveyor wishes to process only part of the data tape, he may confine the output to specified limits of area, time or fixes. Area checking operates in a similar way to the PLAT program, data outside the area being rejected. Checking by time or fix numbers inhibits output of data which fall outside the specified limits. Output method may be changed at any time. Any combination of listing and/or plotting option may be used. Various parameters may be changed during the run. The only exception to this is that scale cannot be changed whilst plotting is in progress. Other parameters which may be changed are :

(a) Depth checking factor, i.e. the software "gate" against which the rate of change of depth is checked.

(b) Spacing of depths on the plot.

(c) Size of depths on the plot.

Checking data for validity

If invalid Hi-Fix readings are detected by the sounding program PLAT, the data tape contains zeroes in place of the Hi-Fix readings. PLANK leaves these values intact whilst applying Hi-Fix corrections, and so program PLAN may receive some invalid readings from the corrected data tape. When this occurs these positions are filled with readings extrapolated from the two previous fixes. A second check is applied after the Hi-Fix readings have been converted to National Grid.

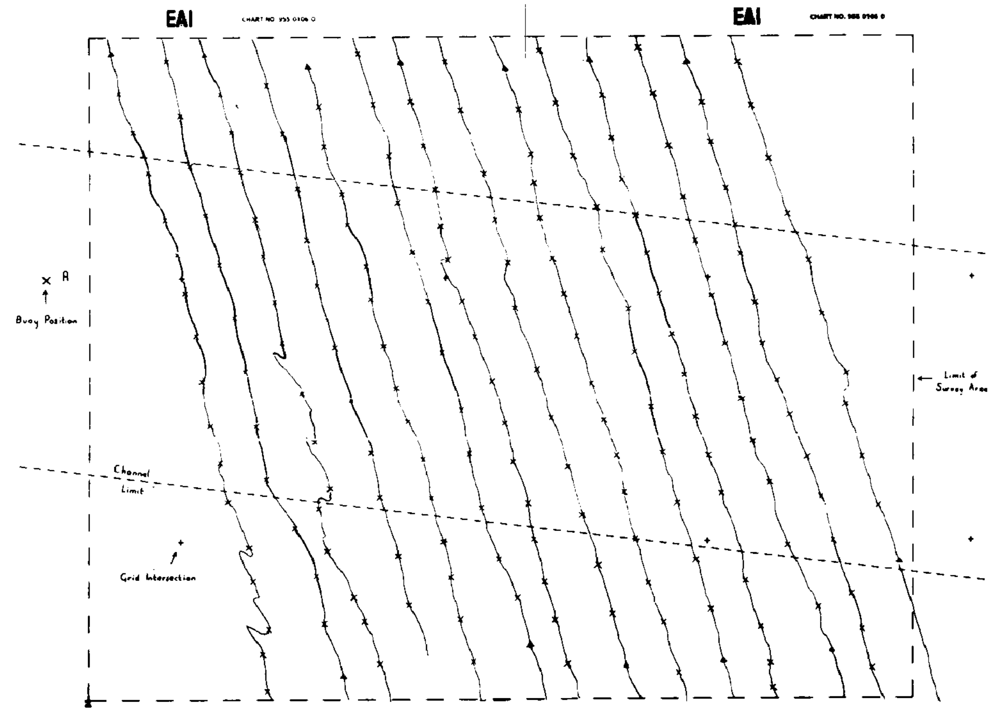

FIG. 5. — On-line track print-out.
Original scale : 1/2500.

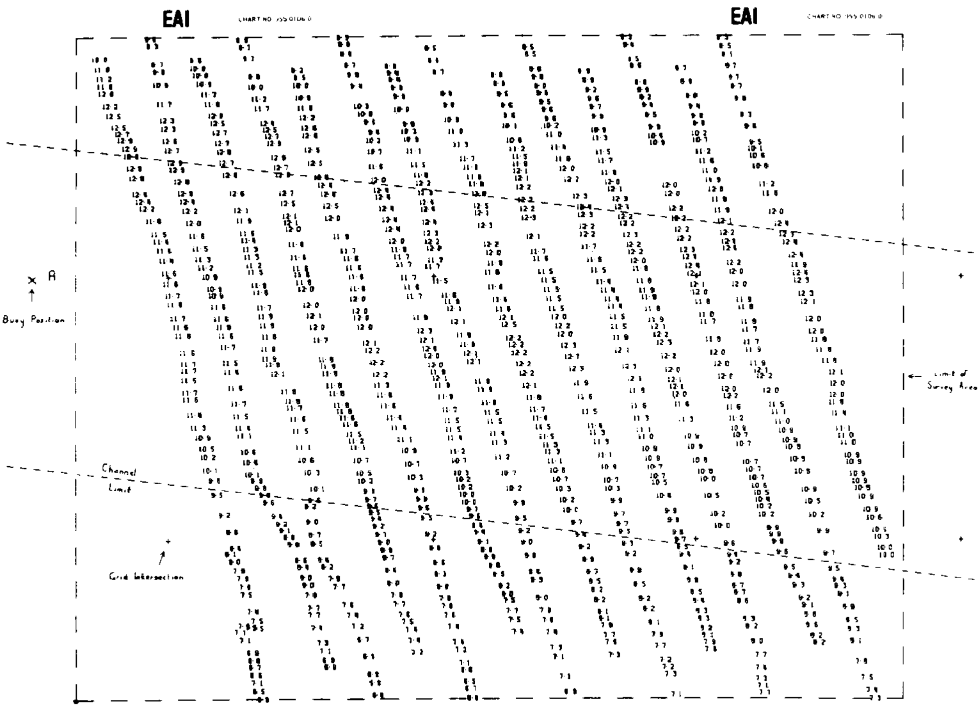

FIG. 6. — Off-line sounding print-out.
Original scale : 1/2500.

Similarly there may be invalid depths on the data tape. These are ignored during the processing, and gaps are left on the plotting sheet. Depths which are apparently valid are checked against a maximum change of 2 metres from a mean of the previous 5 depths. This gate may be changed during the run.

PLAIDS

Vessels carrying out dredging operations within PLA limits normally use Hi-Fix in conjunction with a Decca Track Plotter for positional control. Charts for this purpose are provided which show the areas to be dredged. These charts need updating as the work progresses, and PLAIDS has been designed specifically for these interim dredging surveys. It accepts either the "recorded data" or "corrected data" tapes and produces a facsimile of the track plotter chart with symbols indicating depth relative to the dredging contour. The symbols have been selected so that the overall impression is a shaded plot with shoal areas immediately apparent. These are then traced through onto a fresh track plotter chart. Normally the "recorded data" tape is used, position and depth corrections are applied and depths reduced to chart datum. This by-passes the PLANK program and therefore saves time; a new chart can be ready for the dredger within minutes of completing the sounding.

PLAPP

The surveyor must have complete confidence that the soundings plotted by the PLAN program do in fact represent the sea bed and that no significant soundings are lost, either by the hardware or software gates, or by the selection processes. With this in mind the PLAPP program was written and its purpose is to draw a profile of the bed from the data obtained, to the same scale as the echo-sounder trace. Fixes are marked by short vertical lines and the start and end line fixes numbered. This allows easy lining up with its echo-sounder trace. All the surveyor has to do is to lay the profile over the echo-sounder trace and any discrepancy becomes immediately apparent.

The PLAPP program contains the same logic to process the data as the PLAN program. In addition to a profile of the bed, selected soundings for a particular scale are plotted. These soundings then represent the soundings plotted by the PLAN program, before tidal reductions have been applied. The surveyor therefore has a profile of the bed against which data from the PLAT program may be checked. In addition he has selected soundings against which actual plotted data may be checked.

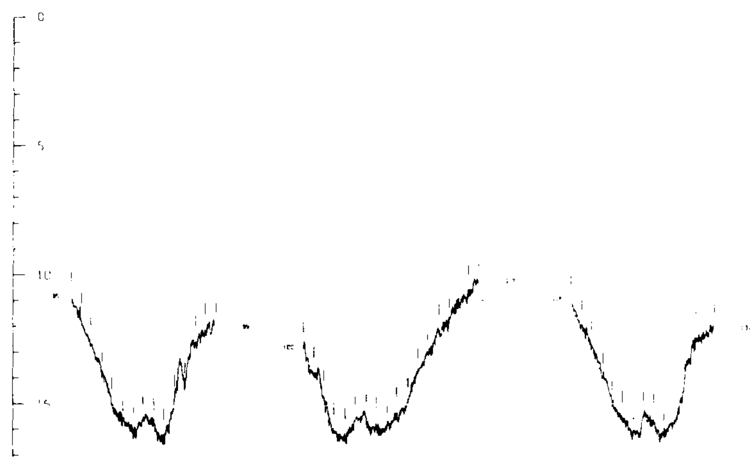

FIG. 7. — Profile of selected, corrected soundings plotted to echo-sounder recorder scale.

An extension of the PLAPP program is to feed in the corrected data as output by the PLANK program, which has already had tidal reductions applied to it. A profile of the bed may now be drawn at any horizontal and vertical scales, normally a very time-consuming process when done by traditional methods. The PLAPP program is a very powerful checking facility as the accuracy of the soundings can be validated by eye with relative ease.

CONCLUSION

Summarising the system from the point of view of the surveyor who must use it, three principal benefits to be expected are :

1. An increase in productivity;
2. An increase in accuracy;
3. An ability to make thorough and critical studies of data collected, including comparative studies between successive surveys.

The increase in productivity arises in the PLA's case because the surveyors who make the survey are also responsible for reducing the data; thus if part of this task can be done automatically, their output must be increased. There are other by-products: results can be available more quickly and the surveyors are relieved of the more tedious aspects of their work.

The increase in accuracy must result — in position at any rate — both because more positional data is being utilised and because correlation between sounding, position and time is virtually continuous rather than at set intervals as in conventional hydrographic practice. Error corrections can be applied at any stage of the work. This aspect also implies that the surveyor has the ability to check and monitor what the computer has done, and to override it in certain circumstances.

The ability to make thorough and critical studies is really a facet of data logging. Once on tape the data can be used in a large computer in practically any way one could wish — or had the time to program for. Computations of volumes, or comparison between successive surveys, are good examples. Even on board the launch, using the mini-computer to give a different form of output for different purposes can be very useful; the program PLAIDS which outputs soundings in symbols in Decca Track Plotter format rather than in geographical terms is a very practical presentation for the dredger.

All in all we think we have a useful tool for the surveyor, flexible enough and simple enough to enable the surveyor to use it in the way in which he wants.