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AUTOMATED SOUNDING SELECTION

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ABSTRACT

The problem of automating the current manual-visual methods of sounding selection is a very complex one. This paper describes the efforts being made at C.H.S. Headquarters to at least partially computerize the process of selection of soundings. Results of these efforts and the conclusions reached thus far are also given.

INTRODUCTION

In this paper I would like to describe current developments in automated sounding selection underway at C.H.S. Headquarters, Ottawa. While we have not yet achieved a working system which can be used for chart production, we have made enough progress to be worth reporting on.

What is sounding selection ? It is the process of selecting a small number of soundings from a much larger group of soundings in order to adequately represent the depth of the bottom without confusing the chart user. It is this word "adequately" which is hard to define. What does it mean ? What are the rules which compilers use now to obtain an adequate selection ?

The Canadian Hydrographic Service has done a fairly extensive study attempting to determine just how compilers select soundings at the present time. The initial study was performed by a group at Pacific Region and the work was continued at Headquarters in Ottawa. It ended in January 1972 with the publication of an internal report entitled "The Selection of

Soundings for Nautical Charts (Revised)". The report contains 83 pages. About 5 pages are devoted to what I shall call "background" selection; that is, a selection of soundings which follows a few basic rules. Most of the soundings on a chart fall into this category. The other 78 pages contain exceptions and special cases. The automatic method this paper will describe attemps to perform just the background selection.

MANUAL SELECTION

There are three major criteria involved in the selection of these background, or non critical, soundings. First, in any small area of the chart, the shoalest sounding must be chosen. Second, the density of soundings must be such as to draw attention to dangerous areas; that is, the spacing between soundings must decrease in shoal areas. This increase in density will tend to draw the navigator's eye to that area. Third, the sounding pattern must be "pretty". By pretty, I mean that the sounding pattern must have a relatively even spacing, the soundings must not lie on the shoreline or contours, and the soundings should tend to support the other features on a chart.

How does a compiler perform a selection ? Figure 1 shows a portion of an actual field sheet near Cape Freels, Newfoundland. This portion is

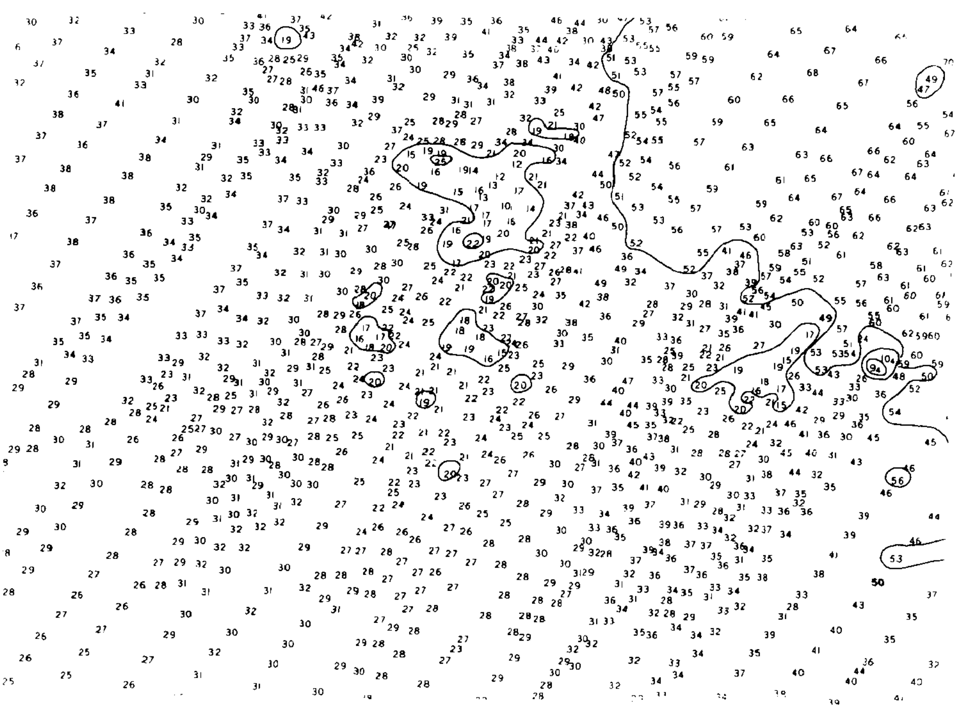

FIG. 1 — Portion of Field Sheet 2823.

one that was digitized by us and plotted on our Gerber 32 plotter. The first thing the compiler does is to go over the sheet and select critical soundings. Figure 2 shows one compiler's version of the critical soundings here. What are critical soundings ? The compilers themselves have difficulty telling you. In general, though, these soundings will represent the shoalest ones in a small area. All contour intervals must have at least one sounding within them. Also if a contour line shows a shoal area jutting into a deeper area, a sounding will be selected to support this. Some soundings may be critical because they show the existence of a navigable channel. There are a number of other possible reasons for calling a sounding critical, but they will vary from compiler to compiler.

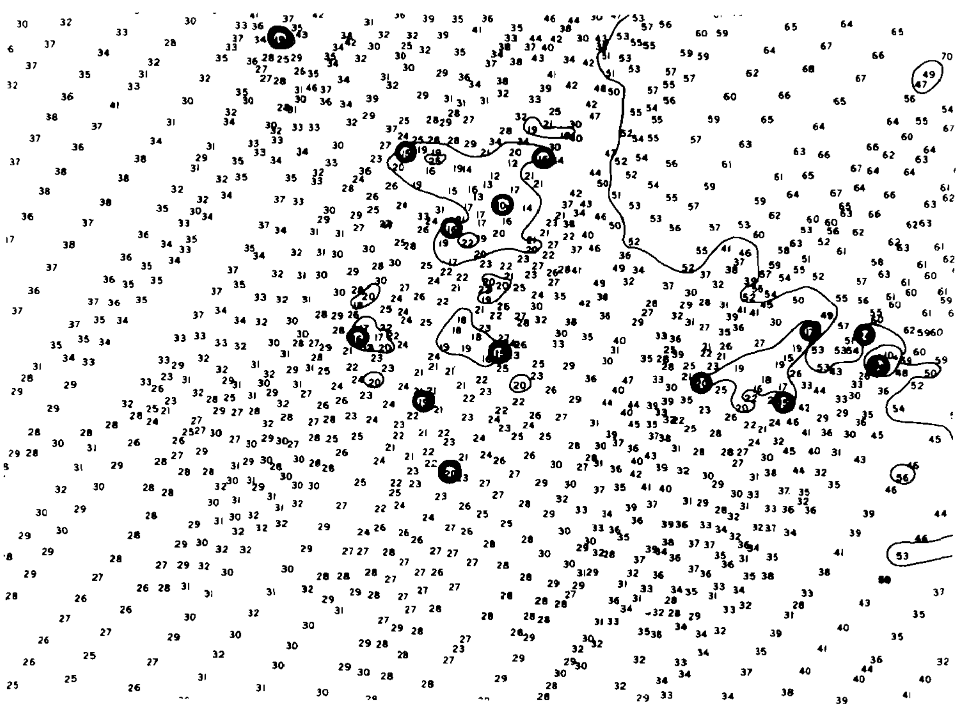

FIG. 2. — Manual selection. Critical soundings only.

The compiler now begins to fill in around these critical soundings and to expand outward from them. During this process he will keep two things in mind. The first is that the density of soundings (or the spacing between them) must vary in such a way as to draw the navigator's eye to dangerous areas on the chart. The second thing is that the soundings should be evenly spaced and should form a triangular pattern on the chart. Hence, when filling in this background area, the compiler will be mentally generating triangles and finding appropriate soundings near the vertices of them. The size and orientation of the triangles will be continuously varying. The final result for this area might be something like figure 3.

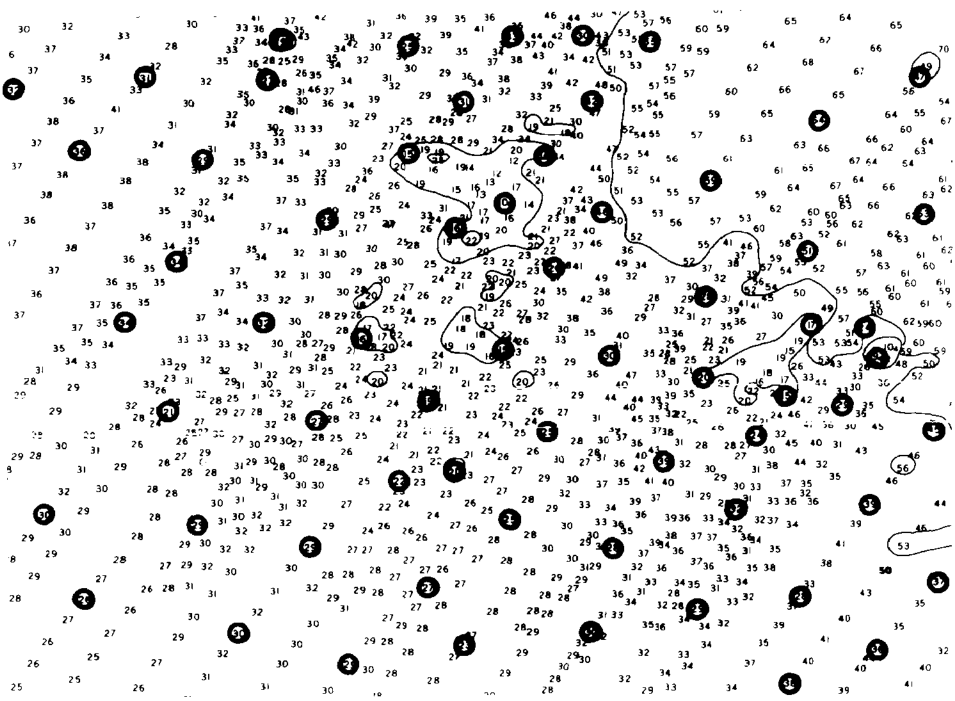

Fig. 3. — Manual selection complete.

AUTOMATION

The problem of producing a computerized sounding selection which perfectly imitates the present manual procedure is a very difficult one, in fact one could even say impossible with present technology. The magnitude of the problem is not generally appreciated by hydrographers, compilers, and others who are not computer-oriented. The reason for this is that the human eye is extremely good at discerning spatial relationships from a picture, so good in fact that determining these relationships involves no apparent effort. Unfortunately, the computer does not have a picture to work from, but only a table of numbers. Imagine yourself doing a sounding selection given a list of 50 000 soundings or so, a calculator, and a pencil and paper (with the condition that you cannot draw a picture on the paper). This is how a computer works. It is simply a giant calculator with an ability to store and recall numbers at will.

Anyway if one decided, as we did, to tackle automatic sounding selection, the first problem that must be solved is that of producing some kind of background fill. In other words, we must be able to select soundings in noncritical areas in such a way that in general the shoalest sounding in any area is selected, a regularly spaced pattern is produced, and the spacing of the soundings varies according to the depth. The exceptions and special cases mentioned previously must be ignored for the moment.

because until we have found a good background fill algorithm and thoroughly investigated it, we will not know how many of the exceptions will be handled by the algorithm.

A number of possible techniques for solving the problem can be thought of. The most obvious method is an imitation of the compiler's method. In other words, we first select a number of critical soundings and then use these as starting points to mathematically generate a pattern of triangles, and find appropriate soundings near the vertices of these triangles. The selection of the critical soundings can be made fairly simply. Unfortunately, the problem of filling in a triangular pattern of soundings around this, a problem which is trivial to a man, is exceedingly difficult on a computer. While a triangular pattern can be easily generated, it is difficult to continuously adjust the pattern to suit the soundings.

Another possible method is that of gridding the data to obtain a more manageable data set, and then mathematically modelling the bottom using these points. Once the model is set up, you have a very powerful tool for determining critical points, but the problem of obtaining a pretty pattern is still not overcome. A selection using this method could be done, but it would probably yield a selection where the spacing varied considerably from the ideal. A further problem is that sounding data does not readily lend itself to gridding, and if one does force the data into a grid, the data set will change somewhat. Until now we have been scrupulously avoiding the idea of changing a sounding, either its position or its depth.

The method we used to approach the problem was an extremely simple one. It was suggested to me by Peter CARRILLO, an electrical engineer who used to be with our group. It runs as follows :

1. Sort the whole data set by depth, the shoalest sounding first.
2. The first sounding in this list (the shoalest one) is selected and placed in the selected sounding list).
3. From the depth of this sounding, we can do a table look-up to find approximately how far away the next sounding should be. This table is found in our internal report mentioned previously, and is based on measurements taken on existing charts. This distance we shall call a radius of influence, and it defines a small circle on the chart centered on the selected soundings, and inside which no other soundings can be selected.
4. Examine the next sounding in the raw sounding list. Compare it to all the soundings which have been selected thus far. If it lies within the radius of influence of any previously selected sounding, reject it. Otherwise select it, add it to the list of selected soundings, and compute a radius of influence for it.
5. Repeat step 4 for all soundings in the raw sounding list.

Let us look at an example of this. Going back to figure 1, the first sounding we consider (the shoalest) is the 9_4. We select it. The radius of influence for this depth is 0.26 inches, and thus we have the situation shown in figure 4, where no sounding lying inside the circle can be selected. (Note that the figure is not drawn to scale). The next shoalest sounding is the 10_1. This is clearly not within any radii of influence, and

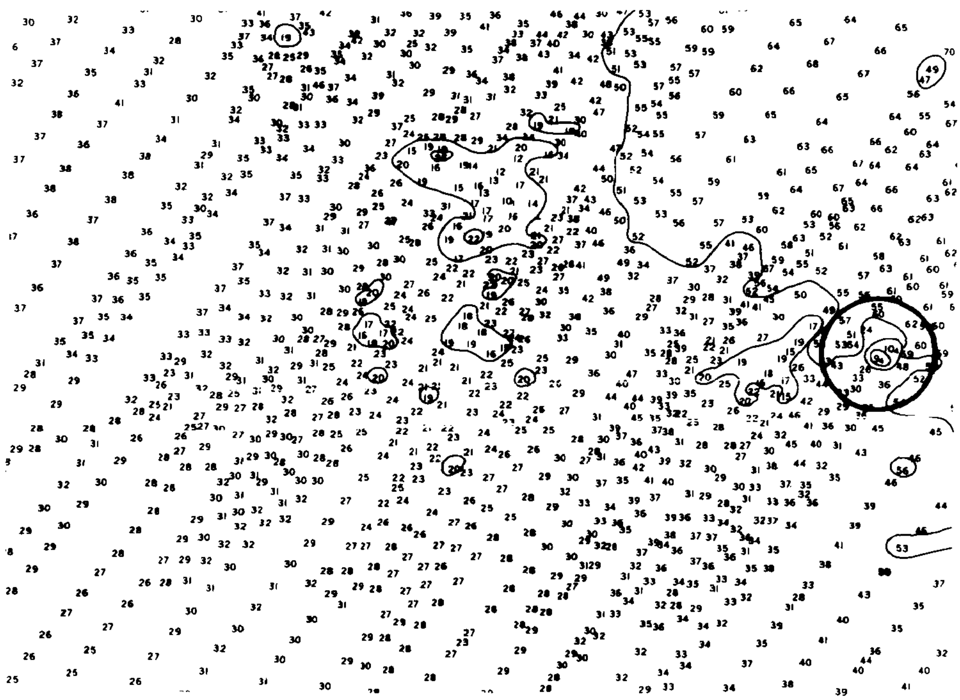

FIG. 4. — Automatic selection showing radius of influence.

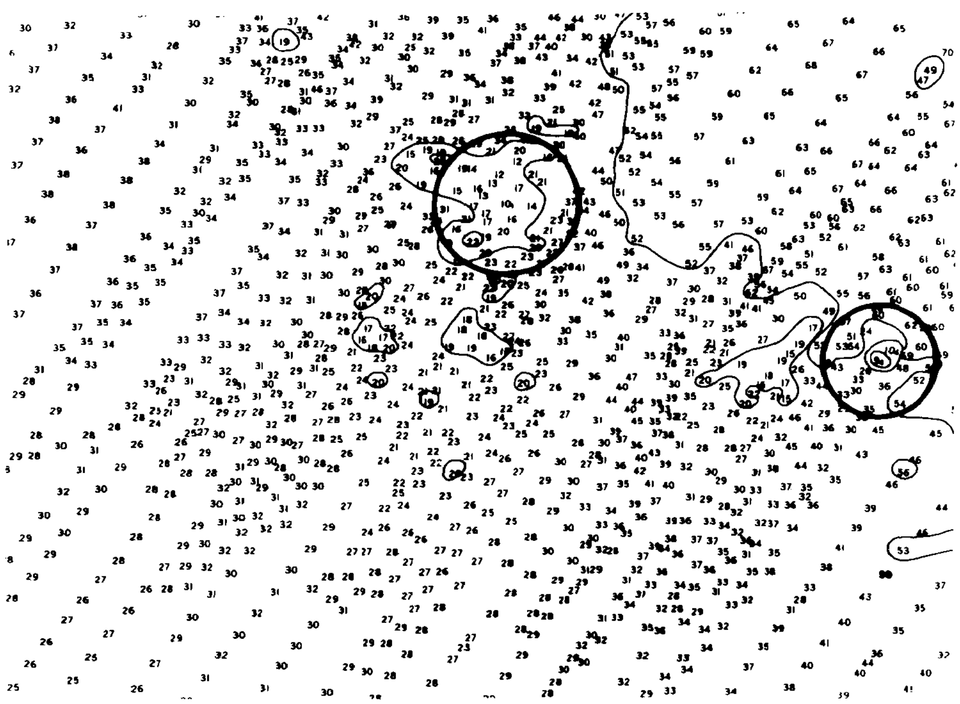

FIG. 5. — Automatic selection showing radii of influence.

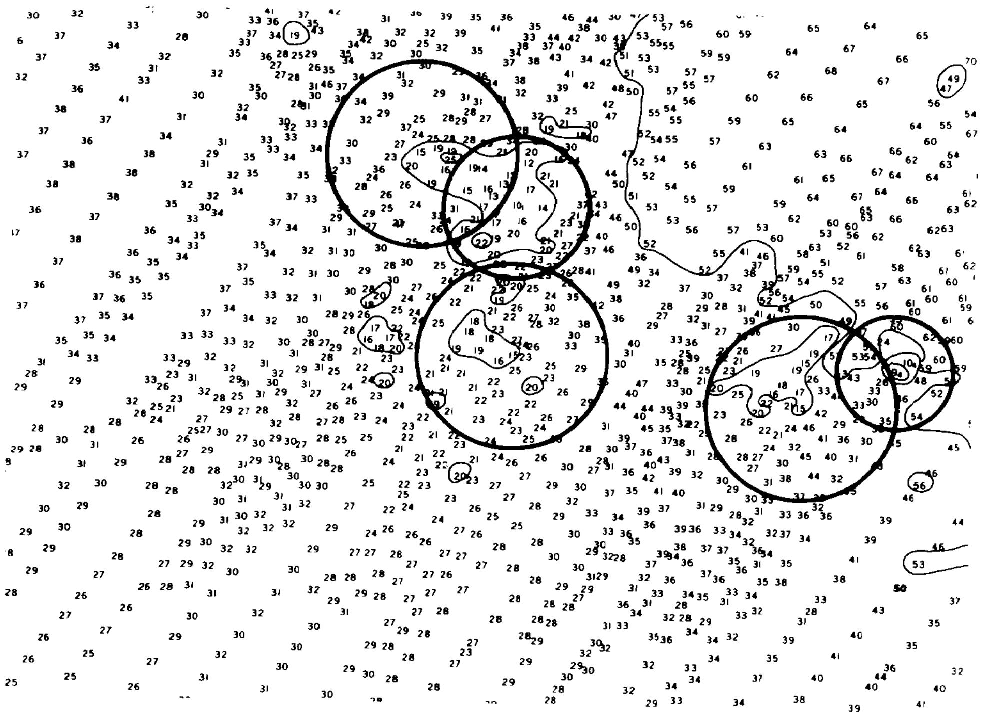

FIG. 6. — Automatic selection showing radii of influence.

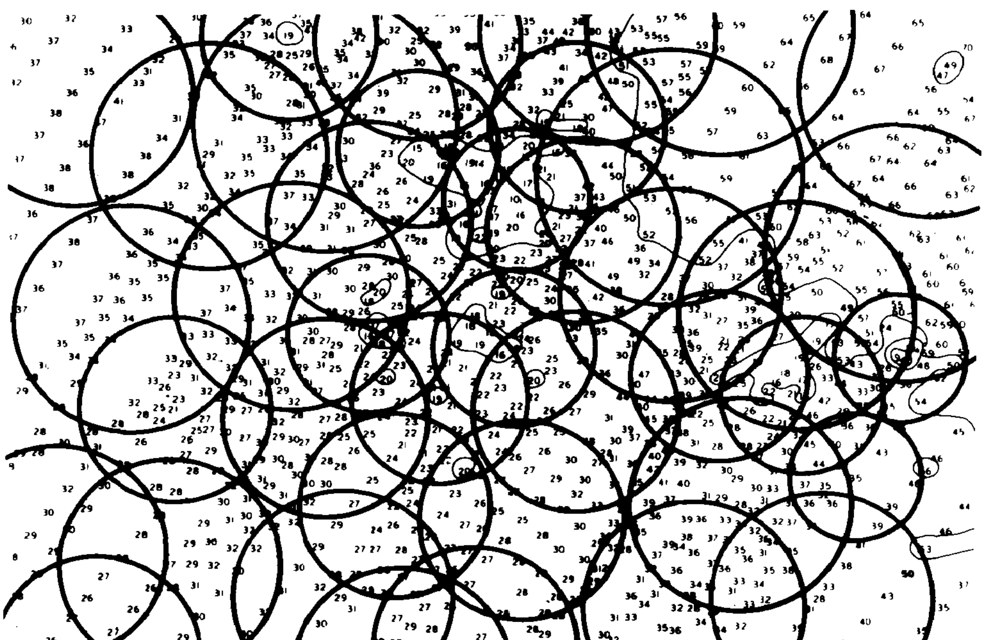

FIG. 7. — Automatic selection showing all radii of influence.

so we select it. Its radius is 0.29 inches, giving figure 5. The next shoalest sounding is the 10_4. It is inside a circle; hence it is rejected. Similarly the two 13's and the 14 are rejected. The next soundings to be selected are three 15's, giving figure 6. Finally we get figure 7. Figure 8 shows the chart scale version of a more interesting area of the same field sheet, showing raw soundings in small digits and selected soundings in large digits. Due to size limitations, the full data set used for the selection cannot be shown. It contains 27 500 soundings, from which about 1300 were selected.

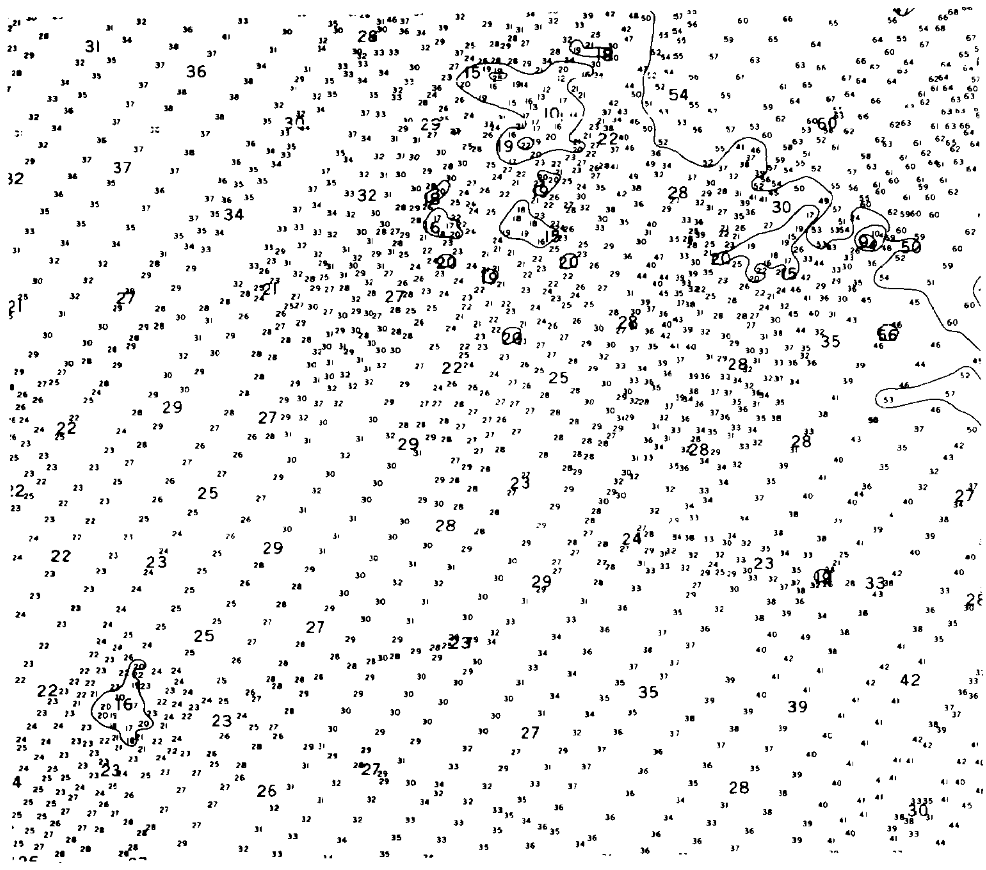

FIG. 8. — Automatic selection complete (chart scale).

The method, although extremely simple, works surprisingly well. It does satisfy the three criteria we established previously for a good background fill algorithm. Considering that the program is only fifty cards long, these results are quite encouraging.

The method, however, has a number of deficiencies. One basic problem is that contours are not considered. There are a large number of small circular contours which do not have soundings inside them, and there are other places where the soundings do not properly support the contours. Other problems are that soundings are plotted on shoreline, navigational channels are not taken into account, and so on.

We decided our next step in the development of a sounding selection program should be to make certain that all small closed contours have a sounding selected within them. This decision was based on two factors — the number of soundings which might be corrected, and the complexity of the programming task. One of the great advantages of this background sounding selection algorithm is that soundings can be preselected, either manually or by computer, and placed in the selected sounding list with some appropriate radii of influence. The background routine will then fill in around these. Thus we wrote a program which located the small closed contours on the chart, selected appropriate soundings inside, and wrote these out onto a preselected soundings file. We then rewrote the background selector to read this file and place the soundings into the selected sounding list, and then to perform a normal selection around these.

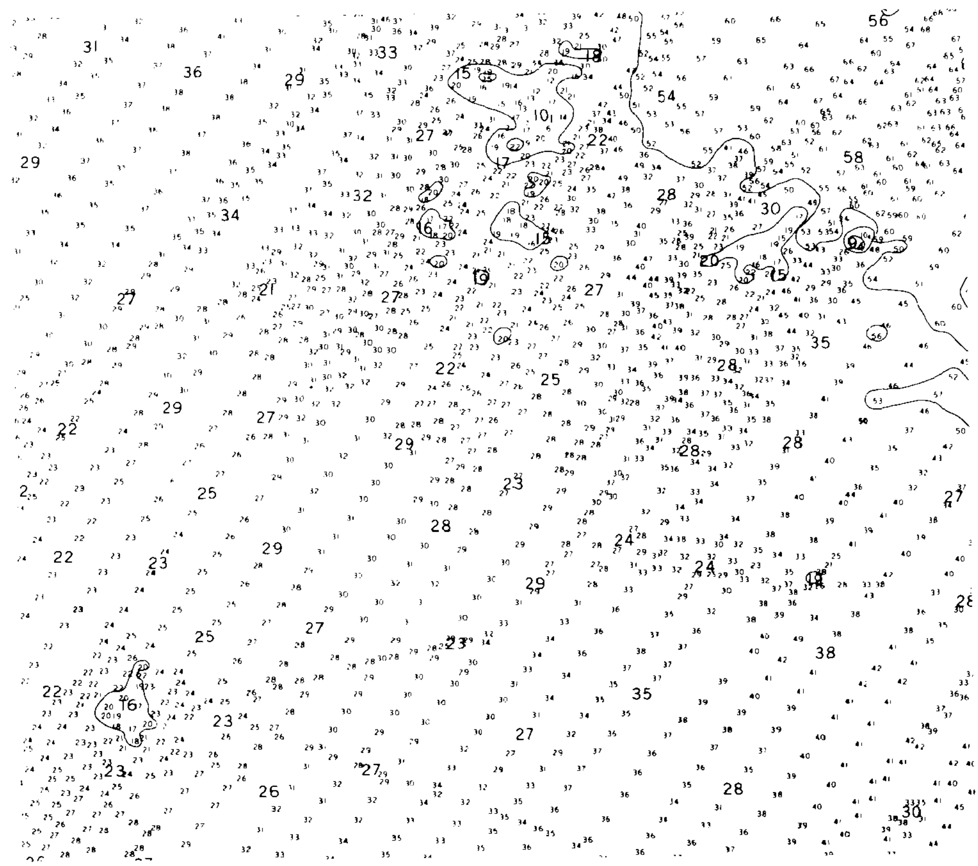

FIG. 9. — Automatic selection with preselection.

We ran this on the same set of data as before, a small portion of which is shown in figure 9. About 1400 soundings were selected, as compared to 1300 previously. The reason for this is that we assigned a much smaller radius of influence to each of the preselected soundings. We found this was necessary, because otherwise the preselection was having a harmful effect on the automatic selection.

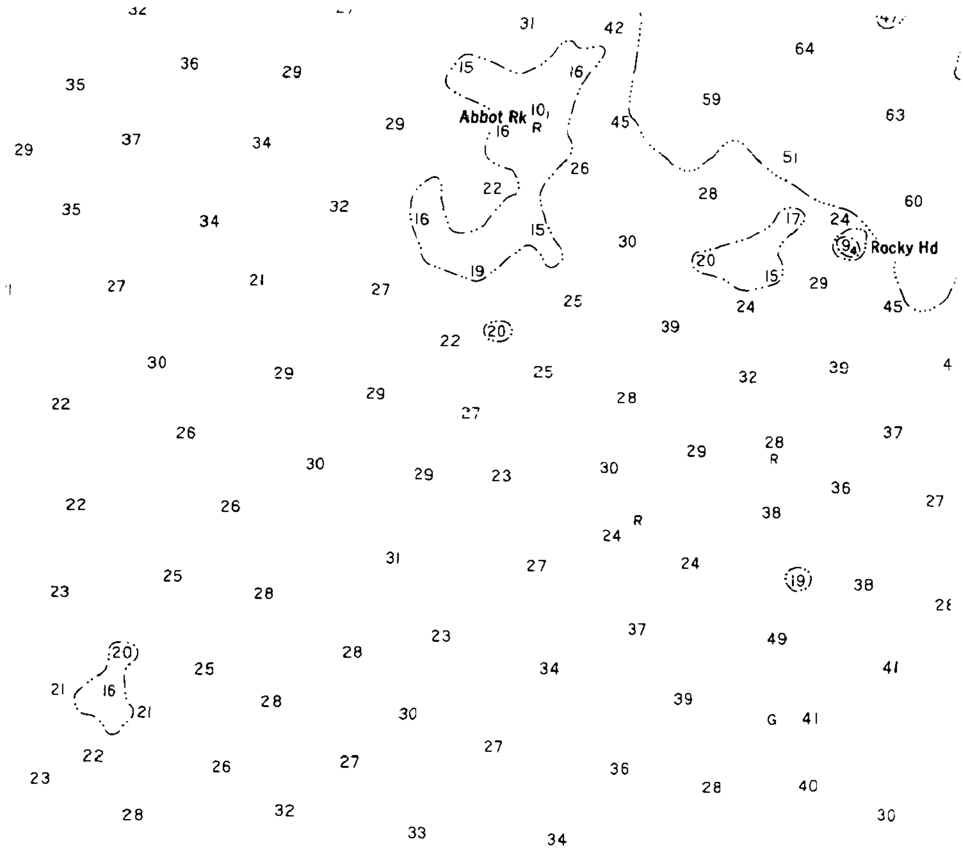

FIG. 10. — Manually compiled chart. (Canadian Chart L(D2)4560, November 1967). Soundings in fathoms, actual scale.

How can these selections be evaluated ? Since there is no set of rules we can check it against, the only final test is to ask a number of knowledgeable compilers to accept or reject it. We have not yet done this, as we know they would reject it. With a bit more work we feel we will be able to produce a product which we can submit to a test.

A very interesting comparison can be made with the hand compiled chart of the area, a portion of which is shown in figure 10. In one area, the chart had 340 soundings, our plot had 265 soundings, and 110 of them were the same as on the hand-compiled chart. In general, the more critical soundings tended to be the same.

CONCLUSIONS

In our opinion, it is probably impossible to computerize the selection of soundings if the goal is to perfectly imitate the present manual selection. If, instead, we aim for an "adequate" selection — and we must go back to the basics in order to decide what this is — then we will have more success. However a program which will produce an adequate selection over all areas of a chart and under all conditions is a long way in the future. The best solution is a man-machine interaction, where the man performs the selection in difficult areas and the computer takes over the tedious job of filling in the less critical areas.

(Manuscript submitted in English)