International Hydrographic Review, Monaco, LX (2), July 1983

DREDGING CONTROL BY HYDROGRAPHIC SOUNDINGS

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Where dredging work is to be undertaken, measurement "in situ" by hydrographic sounding may constitute an excellent basis for payment to the contractor, if the natural sediment movement is negligible compared with the volume to be dredged, and if the thickness of the material to be dredged is too dense to allow for the uncertainty concerning soundings.

As a general rule, requirements such as least and maximum depths to be attained, channel model, tolerance, are imposed for dredging areas, and hydrographic soundings are the only available means to assess that these requirements are being met; hence the importance of sounding accuracy.

The purpose of this note is to make some comments on this type of measurement by hydrographic sounding and on precautions to be taken in order to ensure its reliability; these comments appear under three headings :

- measurement of water-depth
- position of the survey launch
- data processing.

1. – MEASUREMENT OF WATER DEPTH

Inaccuracies due to wrong use of the sounder are becoming more and more uncommon, due to the great reliability of these devices. However, there are various

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points other than equipment quality which cause significant inaccuracies and these are :

(1) oscillator position linked with the movements of the vessel
- depth of oscillator
- squat due to speed
- roll, pitch
- heave

(2) echosounder calibration

(3) echo trace interpretation (bottom definition)

(4) tidal reduction

1.1.1. Depth of oscillators

Before sounding, the depth of oscillators, generally located on the hull of the vessel, has to be checked, as it can differ according to the loading of the vessel and the water density, which can vary widely in an estuary. (See Fig. 1).

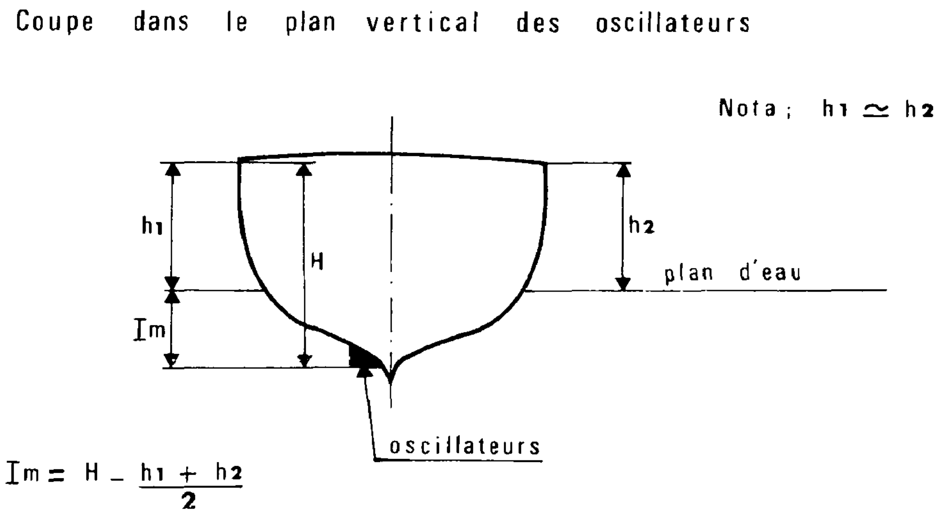
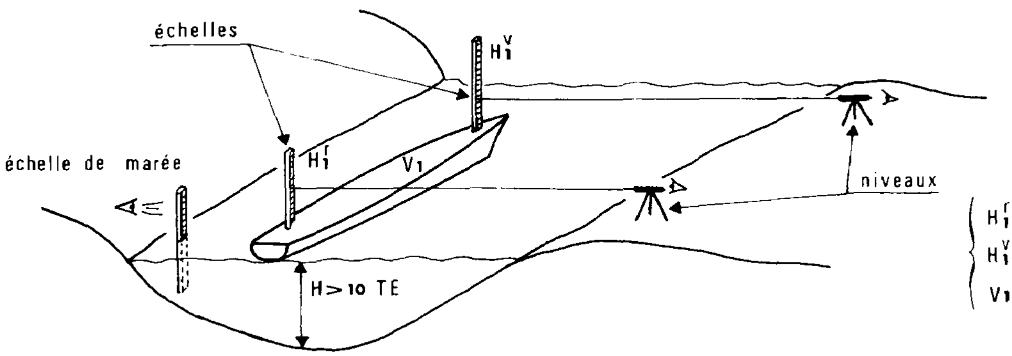


FIG. 1. – Read from top to bottom : Section in the vertical plane of oscillators. Water surface. Oscillators.

1.1.2. Speed of the launch

Speed is an important factor. Whatever the size of the vessel, it creates a squat with a consequent change of draft of the ship; therefore, we recommend calculating for each sounding device its squat curve (may be over 0.20 m when the speed is higher than 10 knots).

A measurement method consists of levelling the bow and stern of the vessel when stopped and at various speeds (variations of water surface during measurements are to be taken into account). (See Fig. 2).



NOTE : The water depth where soundings are being taken must be greater than 10 times the draft, in order to eliminate the squat effect; this is another factor to be considered and will eventually be taken into account (generally, shallow water soundings will be carried out at reduced speed).

FIG. 2. – (Echelle de marée = tide pole; niveaux = levels).

1.1.3. Roll – Pitch – Importance of narrowness of beam

The results of rolling and pitching may in certain cases considerably affect the sounding accuracy. Such is the case, for instance, for soundings carried out on a slope or in its vicinity, which require considerable accuracy, and therefore call for the use of narrow-beam echosounders. (See Fig. 3).

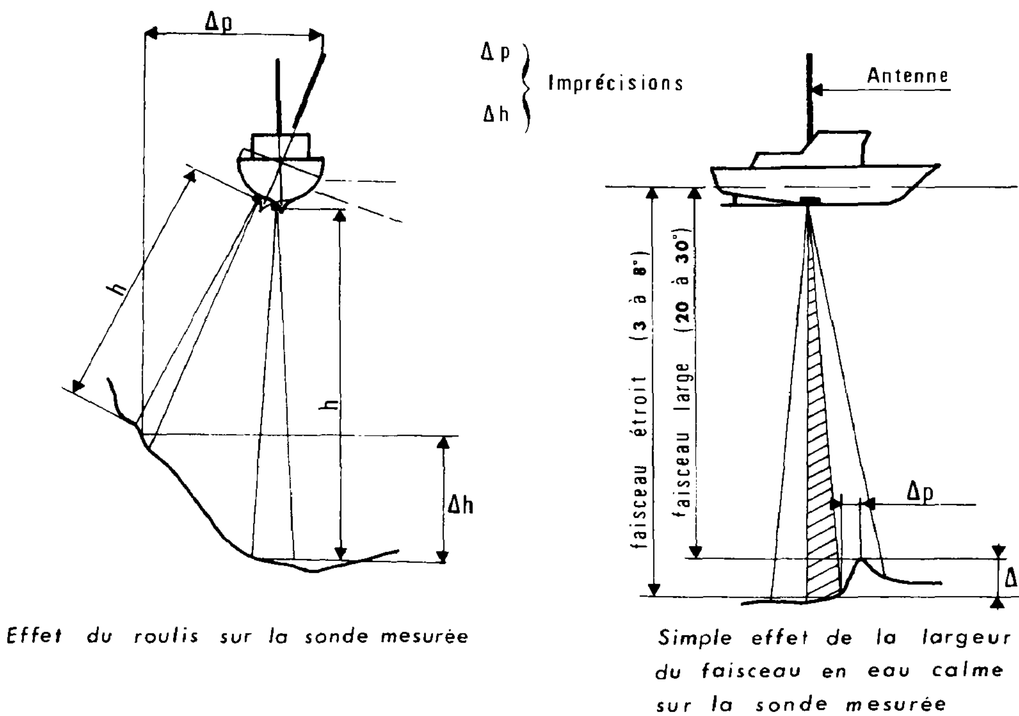


FIG. 3. – Read (left): Effect of rolling on the measured sounding; (right): Effect of the beamwidth on the measured sounding, in calm waters. Inaccuracies. Antenna. Narrow beam (3° to 8°). Wide beam (20° to 30°).

Correctors can be used to eliminate all soundings taken beyond a certain angle of rolling or pitching.

Fixed oscillators with electronic orientable beam, or mobile on a gyroscope platform also exist; such instruments are, however, for use aboard small hydrographic vessels.

Similarly, one should recall that, particularly at great depths, the beam will not penetrate into the furrows left, for instance, by the dredging pipe of an operating suction dredger. (See Fig. 4).

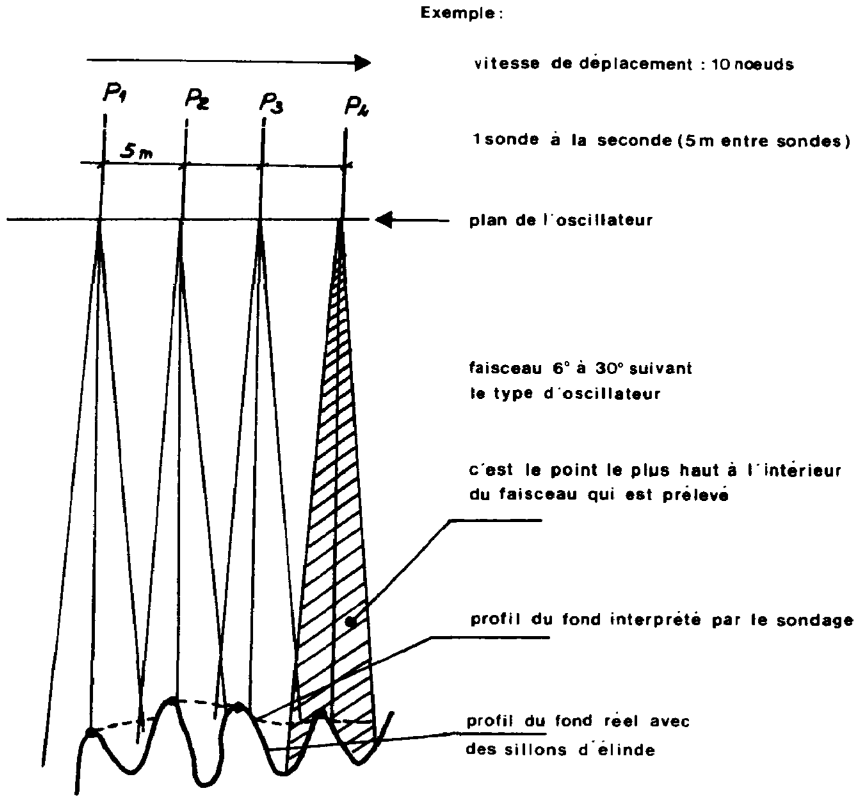


FIG. 4. – Read from top to bottom : Example : surveying speed : 10 knots; 1 sounding per second (5 m-interval between soundings); oscillator plane; 6° to 30° beam according to type of oscillator; highest point within beamwidth being plotted; bottom profile interpreted by soundings; profile of real bottom within dredged furrows.

1.1.4. Heave

The heave of the sounding instrument may have significant effect on the accuracy of surveys in areas exposed to swell, which is frequently the case in the outer approach channels to large ports.

Apart from awaiting calm sea conditions, at least 4 methods for eliminating heave exist :
– by manual smoothing

- by simple computerized smoothing
- by mathematical correction (DALI programme)
- by heave corrector.

Manual smoothing, well known to hydrographers, consists of plotting on the bottom profile (trace) an average line of the waves generated by the heave and by an uneven bottom. It is therefore impossible to have an exact picture of the bottom since the bottom itself will be equally smoothed.

Simple computerized smoothing is utilized when data acquisition is done automatically on board. It consists of calculating a mobile mean on an odd number of n points, the median point having the greatest weight, the others having symmetrically equal weights of decreasing value when going away from the median point.

Mathematical DALI smoothing (Lighthouse Authority/Service des Phares et Balises), based on spectral analysis, is of value when the swell spectrum is different from the bottom spectrum.

But such methods, like manual smoothing, have their limitations. As a matter of fact, if the bottom contains irregularities of a similar magnitude to the wave length of the relative swell encountered by the launch, these operations will give an incorrect picture of the bottom.

The *heave corrector* is composed of an accelerometer fixed on a gyroscope. The vertical acceleration is first measured and then twice integrated in order to obtain the vertical displacement.

At each turn of the vessel (change in profile) adequate time should be allowed until the gyroscope becomes stabilized (a few minutes). Except for this constraint, this instrument gives a perfect representation of the bottom on a rectilinear profile as long as the heave duration remains shorter than 25 seconds.

1.2. Calibration of sounder

The wrong calibration very often entails inaccuracies which are not negligible when sounding. It is an operation the periodicity of which essentially depends on the site.

In the case of an estuary, it should systematically occur before each sounding. Since the water salinity and temperature may vary considerably between low water and high water, calibration should systematically be carried out at least once during the course of sounding. The problem is different in ocean areas.

Bar calibration is the most precise system; it is, however, difficult to apply it in estuaries or coastal areas where strong currents prevail. Therefore, it is also possible to utilize a measurement instrument which consists of an oscillator connected to the sounder and a reflecting plate lying at different depths. (See Fig. 5).

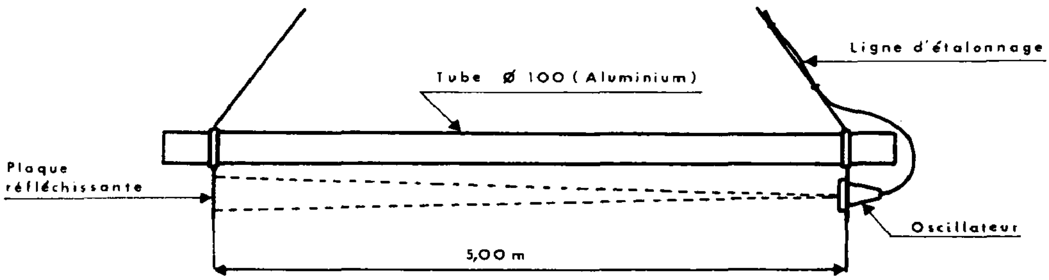


FIG. 5. – Read from left to right : Reflecting plate. Pipe ∅ 100 (aluminium). Calibration line. Oscillator.

1.3. Echosounder frequency (interpretation of echo trace)

Modern echosounders can work at ultrasonic frequencies from 5 to 700 kHz; and often at two frequencies simultaneously. Penetration into muddy areas will not be the same (this depends on the transmitting frequency, site, type of bottom, density gradient).

Given a certain experience of the equipment used, a good knowledge of the site and particularly of the density measurements "in situ" for calibration, such echo traces can be interpreted (liquid mud, mud in the process of consolidation, density, etc.).

Contrary to a still widespread belief, the fact that there can be several echoes, and that their interpretation may be difficult, does not mean that the echosounder method is less precise than the sounding lead method; although the sounding lead has the advantage of giving only one sounding at one given point, a single "z" spot sounding which cannot be interpreted, one will not know its real significance from the point of view of mud density, navigability... (it depends on the type of sounding lead, its weight and, above all, the experience of the operator).

The fact that there may be several echoes does not necessarily preclude automatic processing of data. It is possible to select automatically a certain number of echoes, according to previously established criteria, and to eliminate the others by the computerized techniques of a conversational graph on the computer screen utilized by the Port Autonome de Bordeaux.

1.4. Tidal correction

The water depth, as measured by the launch, should of course be reduced to chart datum by a correction corresponding to the water level when sounding above this datum (tidal correction).

The evaluation of this tidal correction at a given point x, y, is certainly the most frequent source of sounding errors.

It is important to have the use of a tide gauge or a tide pole appropriately set to local chart datum in the vicinity of the sounding area, or even better, of several tide gauges placed on either side of the survey area.

In an estuary like the Gironde, for instance, which is sounded regularly along its whole length, there are 8 transmitting tide gauges plus one remote-controlled tide-gauge buoy offshore. The position of each of these stations has been determined in order that the tidal curve at any instant may be accurately reproduced and that only a minimum of local irregularities of the tide will escape notice : at each point x, y, sounded at time t, the computer calculates the tidal correction applicable at this point x, y, at the given time t, according to the records of the closest tide gauges.

Measuring the tide offshore is a difficult task, if no sophisticated instruments, such as a tide-gauge buoy, are available; significant errors may be introduced into the survey, particularly when a tide gauge located on shore, and therefore subject to the local irregularities of the sea surface, due to the wind, is used in the absence of suitable instruments.

It should be noted, particularly in case of dredging control, that the tidal correction does not necessarily need to be exact in absolute terms; it is sufficient for the sounding method used to have reliable repeatability (in the sense of quality of the measuring instrument which must give the same indication if placed in the same conditions). In order to compare the characteristics of 2 different bottom types, it is advisable to carry out the two sounding operations under the same conditions (notably, the same tidal conditions).

For offshore sounding, it is advisable, whenever possible, to check on a bottom known to be perfectly stable, of known depth and in the vicinity of the area to be surveyed, that the measurements obtained are correct (*Note* : If they are not, the error may come from sources other than the tidal correction; see preceding paragraphs).

2. – LAUNCH POSITION

2.1. Position errors – Radio-positioning

2.1.1. Selection of a positioning system

All optical positioning systems are dependent on the visibility of landmarks which can be at a distance of several miles. However, at least at sea, when visibility is good, it often happens that the water surface is too rough to allow a sounding vessel to work. On the other hand, the water surface is generally calm when visibility is reduced. This explains why the optical positioning systems have now been replaced by radioelectrical methods :

- these entail a satisfactory degree of accuracy, even when visibility is poor. The sounding vessel positioning error is between 1 and 10 metres.
- they enable instant digital recording of the position of the mobile unit, even at high speed.

Here also, a number of prejudices should be discounted concerning the accuracy of soundings carried out according to traditional methods : a launch

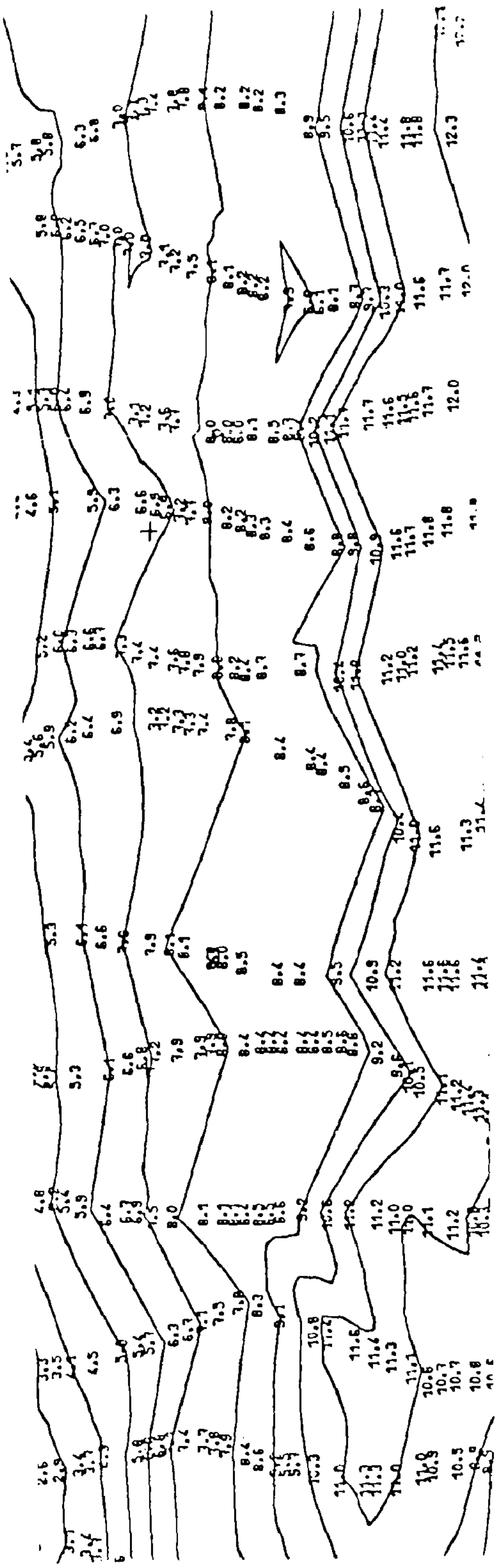


FIG. 6. – 1st example : bad positioning of antenna.

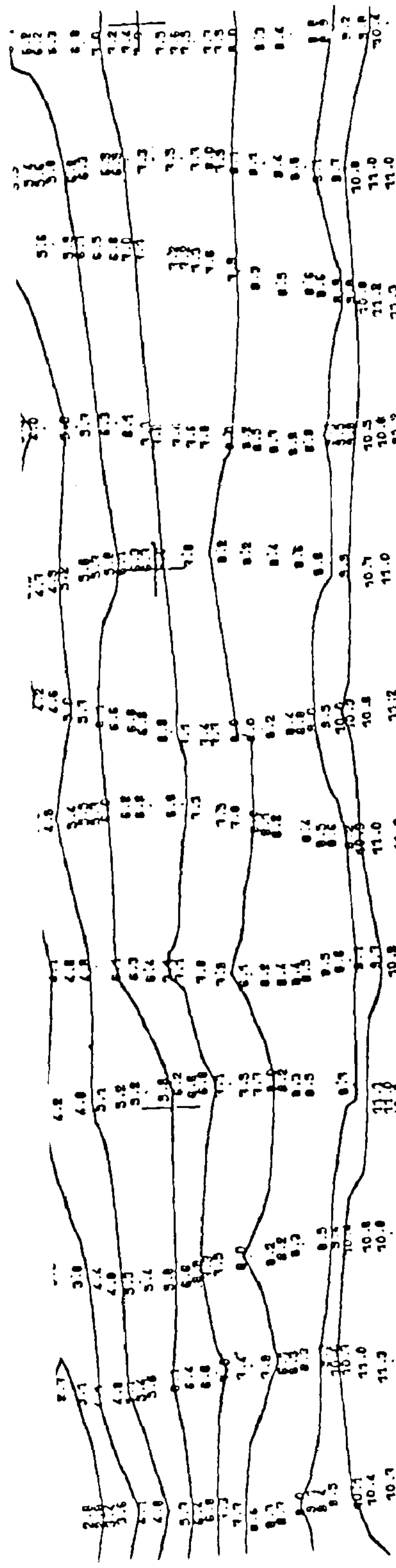


FIG. 7. – 2nd example : correct functioning of antenna.

cannot strictly follow (better than to the nearest 10 metres) a line or a given arc with a cross current or swell. With radio-positioning systems, the logging of the mobile position will give the position of the launch, taking account of yawing or of human errors.

The selection of the radio-positioning system obviously depends on the site and requires an in-depth study; the system the most widely used for sounding operations in France is SYLEDIS (Bayonne, Bordeaux, Nantes, Sète, among others).

2.1.2. Relative position of antenna and oscillator

The position of the radio-positioning receiver antenna should, in principle, stand vertically above the sounder oscillator; the sounding and its position should be recorded at the same time. In practical use, this synchronization requirement is not always respected by manufacturers; it should therefore be taken into account in order to correct this error. (See figures 6 and 7).

2.2. Selection of profiles

The automatic sounding systems offer the possibility of logging data (x, y, z) at a very high rate along the track of the launch (profile) (for example, 1 point per second at a speed of 10 knots, i.e. one sounding every 5 metres). The distance between profiles will be, in practice, between 20 and 100 m, depending on the site and the desired accuracy. The density of the measured points will therefore be much higher along the profiles than in the direction perpendicular to these. This has a significant effect on the plotting of levees and slopes : the profiles should preferably be orientated according to the slope (see figures 8 and 9), but the two sounding methods, by cross-section or longitudinal profiles, are complementary to one another.

3. – DATA PROCESSING

3.1. Selection of soundings

In "manual" data handling, the selection of soundings to be plotted on the sounding sheet depends on the hydrographer who selects visually from the echosounder record the soundings considered to be of significance.

Automatic data processing requires a number of selection criteria to be established, such as :

- number of soundings for each profile,
- minimum and maximum distance between two soundings,
- the most critical sounding for navigation, for instance,
- elimination of abnormal soundings, etc.

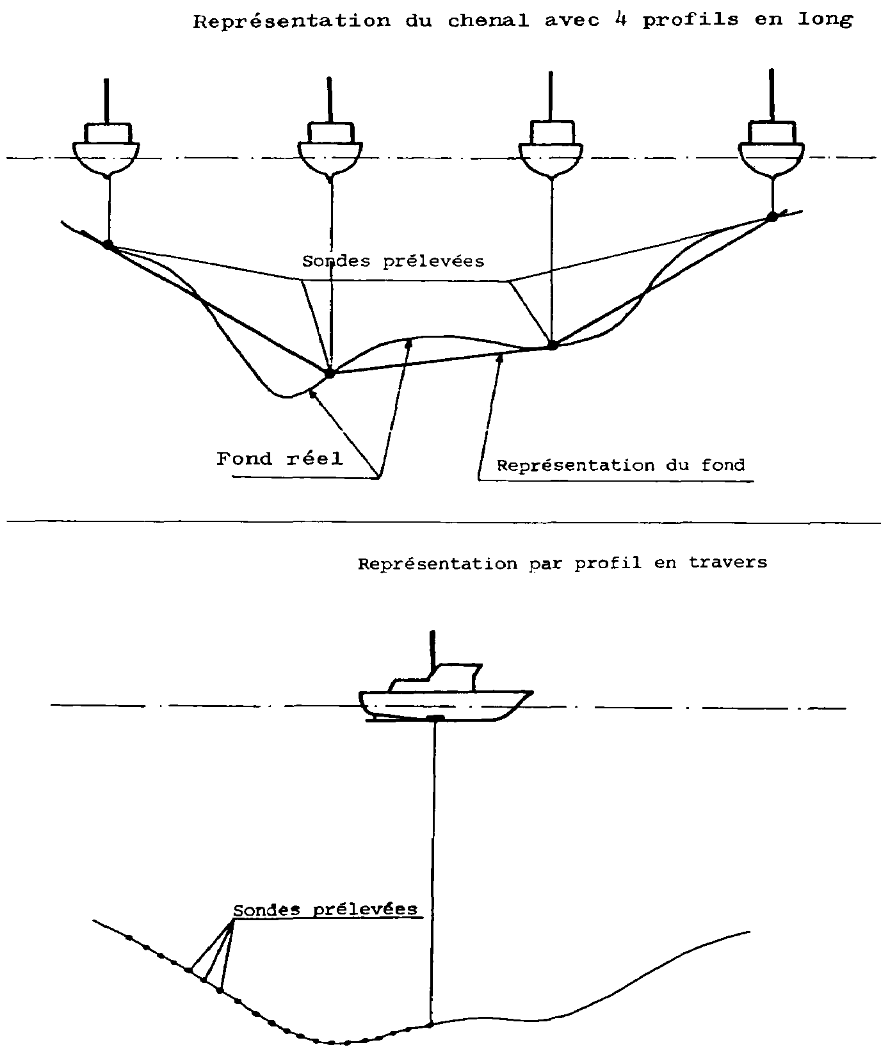


FIG. 8. – Read from top to bottom : Representation of channel with 4 longitudinal profiles. Plotted soundings. True bottom. Seabottom echo trace. Representation by cross-section profile. Plotted soundings.

One should keep in mind that the results obtained are not independent of these criteria and that the criteria themselves are not always clearly stated (data entered into the processing programme are sometimes forgotten). (See Fig. 10).

According to bottom configuration, the results on the plotting sheet may be substantially different.

A plotting sheet, if established for navigational safety purposes, should, of course, take into account every peak : the third criteria mentioned in our example should therefore be ignored; the first two should be considered as acceptable.

On the other hand, if one has to measure a volume dredged with a dredger which left furrows and holes behind, the first two criteria will hardly be applicable

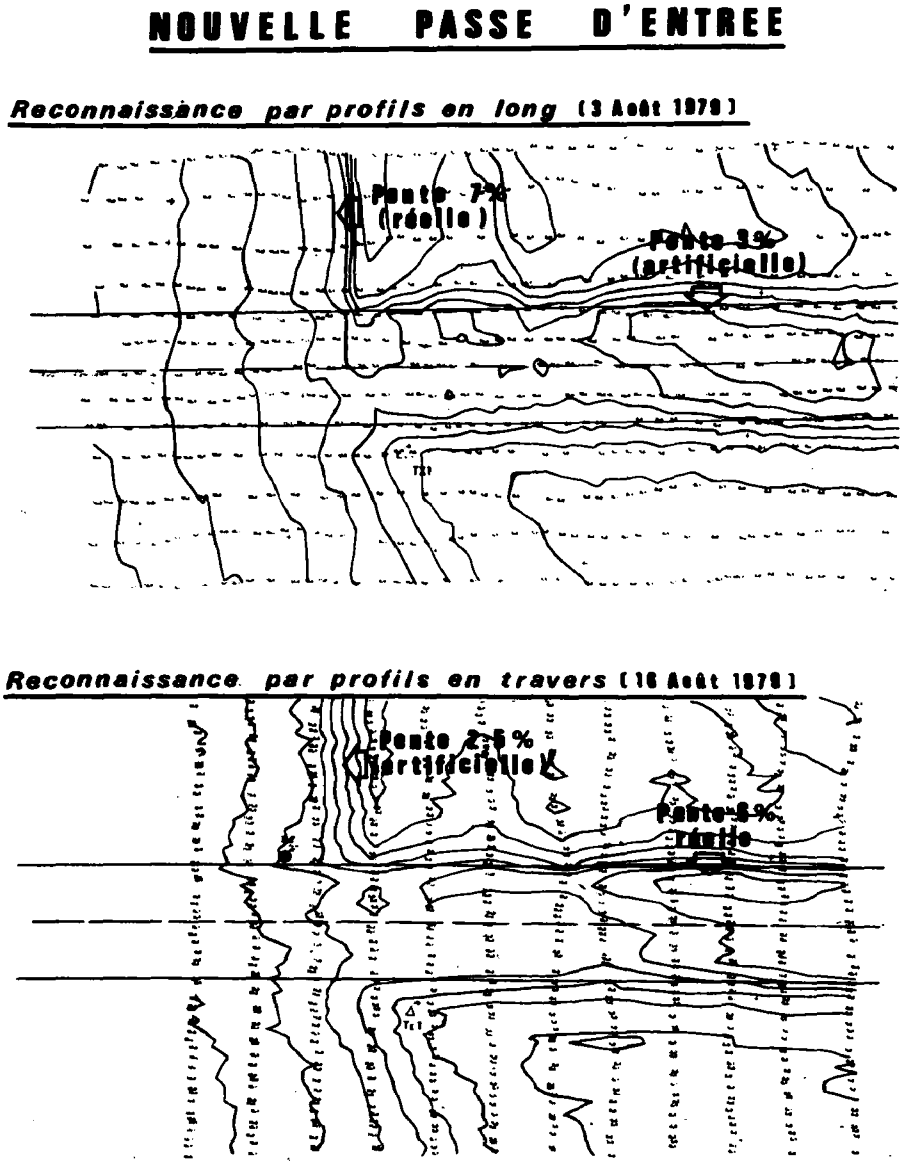


FIG. 9. – Read from top to bottom : New entrance channel. Reconnaissance by longitudinal profiles (3 August 1979). True slope 7 %. Artificial slope 3 %. Reconnaissance by cross-section profiles (16 August 1979). Artificial slope 2.5 %. True slope 6 %.

since it will not be possible to take into account the volume of the furrows. (See Fig. 11).

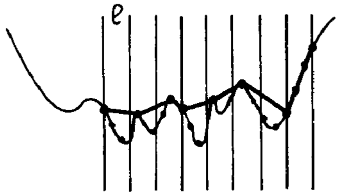
If the furrows caused by the dredger disappear due to currents, a deepening will occur (due to the crests falling into the holes) without any further dredging. (See Fig. 12).

This phenomenon should not be ignored : if payment to the contractor is

Exemple : prenons un même profil

Cas 1

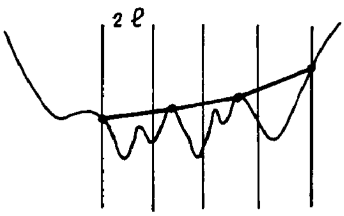
Sonde sélectionnée : point le plus haut sur un intervalle ℓ



Profil n° 1

Cas 2

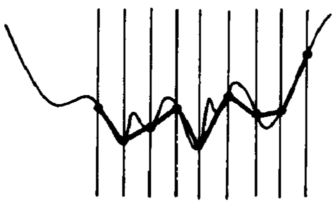
Sonde sélectionnée : point le plus haut sur un intervalle 2 ℓ



Profil n° 1

Cas 3

Sonde sélectionnée : prélèvement à intervalle régulier



Profil n° 1

Cas 4

Sonde sélectionnée : moyenne des sondes de l'intervalle 2 ℓ centrée au milieu de l'intervalle

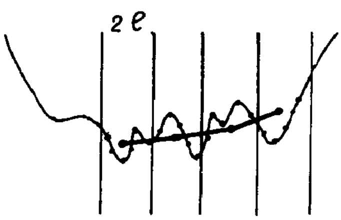


FIG. 10. – Read from top to bottom : Example : Taking the same profile. Case 1 : Selected sounding : highest point in interval l. Case 2 : Selected sounding : highest point in interval 2 l. Case 3 : Selected sounding : plotting at regular intervals. Case 4 : Selected sounding : average of soundings at interval 2 l, centered in middle of spacing.

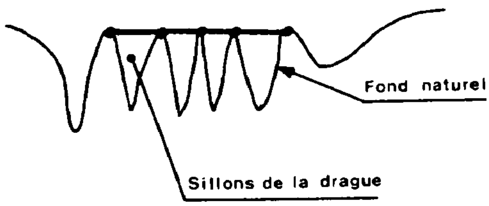


FIG. 11. – Natural bottom. Furrows due to dredging.

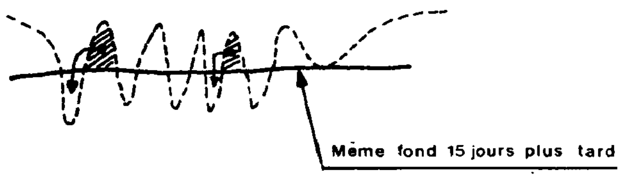


FIG. 12. – Same bottom fifteen days later.

based on this type of sounding, different results may occur, according to the date of sounding.

Such conditions account for the principle of dredging "tolerances".

3.2. Volume calculation

In order to check "in situ" the volumes removed by the dredger, one should adopt criteria for the selection of soundings which represent the "average bottom" (the selected sounding is, for instance, the average of recorded soundings during a given interval; see case No. 4, fig. 10).

In such a case, it is possible to compare the dredged volume, as measured "in situ", and the corresponding volume as measured in a dredging pipe or the volume dumped. It should moreover be noted that the logged soundings do not represent the deepest points in the furrows or holes; following the ultrasonic beamwidth, the measured depth is that of the highest point within the beamwidth (see fig. 4).

Nevertheless, comparison between two plotting sheets and dredged volumes calculated, as can easily be done with a programme such as DALI, gives extremely useful checking information for the conduct of the dredging operations.

4. – CONCLUSIONS

We have gone through a number of sources of errors which can occur in hydrographic surveys; most of these can easily be overcome if some precautions are taken, as explained in this note.

Some are more difficult to eliminate than others (accuracy of the echo sounder, tidal error...); it should, however, be emphasized that the absolute accuracy of a survey is less important than its repeatability (quality of a measurement providing the same indication in the same situation). The soundings carried out in the Gironde show that the repeatability of soundings is better than 0.10 m, even as far as 20 km offshore or where depth is greater than 15 m, also when operating under different conditions of swell, tide, or profiles. It is however advisable, if the site does not have such reliable control as the Gironde, to carry out the sounding strictly in the same way and under identical conditions, in order to achieve the desired repeatability.

The advantages of automatic sounding systems should also be emphasized :

- they improve the accuracy of the soundings (precise digital plotting of the sounding position x, y – non-subjective selection criteria for soundings);
- they allow for a greater operating speed, and consequently increase the frequency of sounding;
- they allow better handling of the collected data through computer processing (representation of sea bottom, calculation of volumes), this being too long and tedious to be done by hand.