International Hydrographic Review, Monaco, LXVIII(2), July 1991

ASSESSING THE PRECISION OF DEPTH DATA

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Abstract

The Hydrographic Department of the United Kingdom has traditionally gathered high quality depth data but, until recent years, without specifying a formal accuracy Standard. In 1986, an accuracy Standard, based on the IHO recommendation, was set. The experience of monitoring and maintaining the Standard, and much thought and discussion of the deeper theory of the subject have led to a revision of the Standard effective from January 1991.

INTRODUCTION

'No day too long or task too arduous' has summed up an attitude of mind of Royal Naval Surveyors of the past and, to this day, is as true as ever. It has allowed the Hydrographers of the Navy to be confident that any depth data gathered by their ships would be as accurate as a diligent surveyor could obtain with the equipment of the day. Commercial pressures to minimise costs and do only what was strictly required by a contract did not exist and putting a price on a time consuming and labour intensive task, that, at best, may result in a solitary symbol or sounding on the published chart, was never undertaken seriously. In the last decade, a number of surveys sponsored and overseen by the Hydrographer of the Navy have been completed by contractors and the requirement to balance the costs of running the Royal Navy's own ships with their productive output has grown. With these changes came a need to define a required accuracy Standard to ensure that surveys were adequate for the needs of the ultimate user of the data and gave the surveyor guidance on the precision to be maintained. In 1986, a Standard for the measurement of depths within the 200-metre line was defined and surveyors were required to show that the Standard was achieved by reporting an assessment of the contributions made by nine components of the

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measurement process. For surveys from January 1991 the Standard has been revised in the light of experience of the last five years. This article intends to describe the development of the Standard.

THE DEVELOPMENT OF THE STANDARD

In 1986, the IHO Standard was that errors should not exceed:

±0.3m for depths between 0 and 30 metres
±1.0m for depths between 30 and 100 metres
±1% of depths greater than 100 metres

Two points caused concern:

a. 'Should not exceed' was deemed to be too vague and it was considered that the probability level should be defined.

b. There seemed to be no justification for a depth of 30.1 metres being allowed to contain errors more than three times the size of those in a depth two decimetres shallower. Depths deeper than 31 metres are depicted on fair sheets and published charts in integer metres alone but the rounding is carried out to a policy that requires measurement with decimetre precision for its correct implementation.

To overcome these points the Standard for Royal Navy surveys specified that:

At the 2σ level (95.4%), the errors in the measurement of depths should not exceed:

±0.3m for depths less than 31 metres
±1% for depths greater than 31 metres

The following components of the total error were to be assessed:

Draught Setting
Variations in Draught
Velocity of Sound
Heave
Squat
Tide Readings
Co-tidal Adjustments
Application of Tidal Corrections
Trace Reading/Digitisation

The introduction of the policy sparked a lively debate among those with a taste for theory. The primary controversial point was to consider the various components to be independent random errors. Many are strictly systematic and a few can be shown to be correlated. The problem is that while criticising the use of random error theory is easy, producing a more appropriate treatment has been unsuccessful. The continuation of the policy of treating the errors as random has been justified by the assumption that, if care is taken to minimise systematic errors, it is likely that the characteristics of random errors will apply to the remainder. The errors will be small and have an equal probability of being positive or negative. It has to be accepted that the theory may not be perfect for assessing the precision of soundings but it is the best available.

It would be as well to mention at this point the way in which a range of component random errors are combined. It would be an unfortunate sounding if each potential error component had the same sign and combined to increase the total error. It is more likely that some components would have opposite signs and be partially self cancelling. Therefore the total Standard error of a sounding is not calculated by simply summing the Standard errors of the error components but by taking the square root of the sum of the squares of the component errors. One of the practical effects of this method is that the size of the combined error is dominated by the larger error components. A surveyor seeking to improve the quality of his soundings need only look at the sources of the larger errors as the minor components have very little effect on the total.

The second controversial point was the simplified means of defining allowable errors with two straight lines meeting at 30 or 31 metres. The lines are an approximation of the way errors may be expected to grow with constant errors dominating in shallow water but giving way to errors proportional to depth in deeper water. The use of straight lines has merits of simplicity and enables the mental calculation of the requirement at a particular depth to be completed without difficulty. The purists, however, favoured a more academically correct definition which would remove the discontinuity and replace it with a gradual change in gradient.

The introduction of the policy identified two dominant sources of error in most surveys, heave and the co-tidal correction. Heave compensators can remove virtually all of the effects of heave and have now been fitted in most of the Royal Naval surveying ships operating on the continental shelf but unfortunately not their boats. In the meantime, ships have had to compensate for heave, as in the past, by estimating a mean level through the oscillations displayed on the echo sounder trace. The difference has been that the surveyor has had to put a figure on the precision of his smoothing.

The co-tidal problem is not so easily rectified. The UK continental shelf is extensive and experiences a wide range of tidal regimes: Mean Spring Ranges of up to 12 metres in the Bristol Channel, an amphidromic point and pocket of diurnal tides off the West Coast of Scotland, a difference of four hours between the times of high water along 50 miles of the coast of East Anglia, and complex shapes to the tidal curves along the central part of the South Coast of England. For most surveys, tidal reduction of soundings has been achieved by correcting data obtained from shore based gauges using the published co-tidal charts. This method is adopted because it is economical and allows soundings to be reduced shortly after they are measured. It, in turn, provides the surveyor with a progressively growing record of his efforts to assist him in the management of further work.

The density of data used to construct the co-tidal charts varies widely, some of the larger bays are surrounded by so many tide gauge sites that the co-tidal contours have been plotted with confidence, other areas are so remote from any data that the contours can be only an inspired artist's impression. Anglo-

German and Anglo-Dutch trials in the southern North Sea have found differences of less than 0.5 metre between different methods of reducing the tide and in many other areas cross line comparisons have been surprisingly good. For a number of surveys, however, the co-tidal reduction has limited the precision that can be achieved and the requirement has not been met. The way ahead may be to use sea bed tide gauges around the survey area and a trial is in progress but there are fears that a treasured principle will have to be given up. The inability to obtain the tidal reduction until, perhaps, several months after the data was gathered, may require the surveyor in the field to abdicate responsibility for a fundamental stage of the data processing, namely, the application of the tidal reduction. It is intended that soundings will be initially reduced using predicted tides to provide the surveyor with a working record on which to base decisions on further work. When the sea bed tide gauge data becomes available a major reprocessing task will have to be accommodated. It may have to be fitted around (in terms of both staff and computer time) work on the current survey if it is undertaken by the ship or it could become a new task for a shore support facility.

In shallow water, the Standard was found to be particularly demanding and was only achieved in a minority of surveys. The majority of error components could not be kept below 0.1 metre under practical conditions and if larger errors were present in just a few categories the combined total soon exceeded 0.3 metre.

Interestingly, the data gathered have shown that the depth dependent components are easily kept within the requirement. Sound Velocity is the primary element, the instrumentation available and the ability of modern echo sounders to maintain a constant speed have made it relatively easy to keep errors below 1% of the depth in depths of more than 100 metres. Also, in shallow water quite marked variations in Sound Velocity can be tolerated before the errors become significant. For the manual systems trace resolution can be a problem if the echo sounder is not run on the largest scale able to detect the depth. The problem does not affect the digital systems in service in the Royal Navy as all depths are recorded with such high precision that the errors are rarely significant.

When the original Royal Naval Standard was set it did not take into account that, in the IHO Standard, the tidal reduction was treated as a separate observation with the same allowance for errors as for depth measurement. In 1987, the IHO published a revised Standard. The step change at 30 metres was removed and a standard similar to the Royal Navy definition adopted by using the 90% probability level or 1.64σ. The split between depth measurement and tidal reduction was retained. If the two parts of the IHO Standard are combined, using the technique applicable to independent random errors, and the total is expressed at the 2σ level the IHO Standard becomes:

0.52 metre from 0 to 30 metres
1.72% of depths greater than 30 metres

From January 1991, the Royal Navy has adopted a standard at the 2σ level of:

± 0.5 metre $\pm 0.9\%$ of depth

The two parts are combined as independent random errors so that the error at any depth is calculated using the formula:

$$\text{error at depth } d = \sqrt{0.5^2 + (0.009d)^2}$$

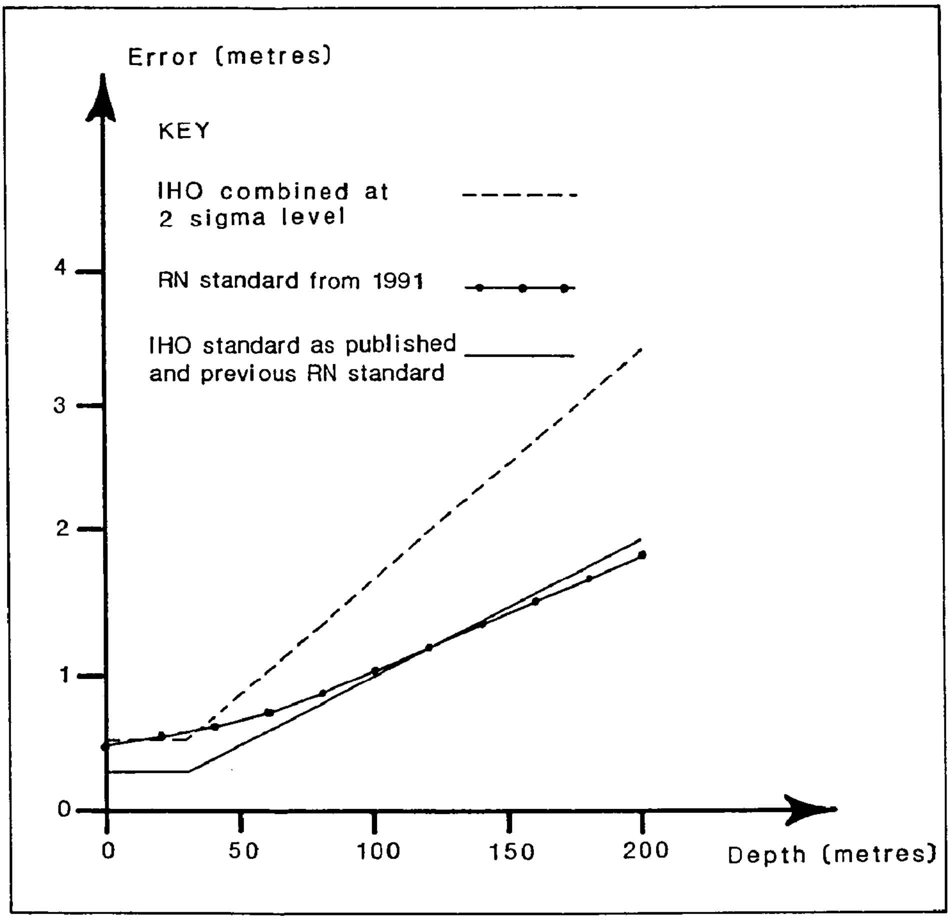

FIG. 1.— Comparison of IHO and RN Standards.

The IHO and Royal Navy Standards are illustrated in Figure 1. It can be seen that the new Royal Navy Standard is very slightly more demanding below 16 metres and is significantly so in depths of over 34 metres. Between 16 and 34 metres, the IHO Standard is the more demanding with a widest gap of 5cm at 30 metres.

The list of components to be assessed was extended to 15 but some are applicable only to digital or only to manual systems. The main increase has been brought about by splitting the previously single topic of Sound Velocity (SV) into:

SV measurement
Spatial Variation in SV
Temporal Variation in SV
Application of measured SV

This division has taken some of the guess work out of the assessment of the error component and should encourage surveyors to look critically at the way Sound Velocity data is used to adjust their echo sounders.

It is anticipated that the new Standard can be maintained for all surveys on the UK continental shelf within 50 miles of the tide gauge used to reduce soundings. If the trial of the offshore tide gauges proves successful it is hoped that it will become possible for even the more distant surveys to meet the requirement. The tidal data gathered will be used to improve the co-tidal charts but it will take many years to reach the point where they will provide sufficiently precise data in offshore survey areas for the sea bed tide gauges to be made redundant.

CONCLUSION

The requirement to assess the precision of soundings has bred a healthy awareness of the quality of work being carried out and has drawn attention to the weak areas. The initial Standard set was undoubtedly too tight to be applicable to all surveys and unnecessarily more demanding than the IHO recommendation. The Standard was met in a few cases where good fortune and favourable conditions prevailed. Those that did not meet the standard generally fell short by a very slim margin. They still provided valuable data and deserve their place in the history of the United Kingdom Hydrographic Service as modern examples of the traditionally high quality data.

References

[1] *IHO Special Publication No. 44* (3rd Edition, 1987). IHO Standards for Hydrographic Surveys.

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NOTE

This subject is greatly expanded upon in the UK Hydrographic Office's Professional Paper No. 25 (The Assessment of Precision Soundings).