THE HYDROGRAPHIC DEPARTMENT OF THE ADMIRALTY : THE TIDAL BRANCH

by Commander W. I. FARQUHARSON, R. N.

From the *Journal of the Royal Naval Scientific Service*, Vol. 10, No. 5, 1955.
Published by permission of the Admiralty.

This branch is primarily responsible for providing information which is in any way related to the tides and tidal streams.

It is commonly assumed that our knowledge of the tides should, by the present day, be nearly complete and, because there is unlikely to be any material change in the tides, a statement made 50 to 100 years ago about the tides at a particular place must still be true. In those days, however, tidal theory was so imperfect that inferences drawn from occurrences recorded under specified conditions are not necessarily correct in the light of present knowledge. It is therefore continuously necessary to investigate the sources upon which such statements as to tidal conditions are based. Unfortunately until comparatively modern days there were no standard methods of time keeping, and only too frequently there is a doubt as to the times in which the observations were recorded. Furthermore these old observations were taken in the light of the comparatively modest requirements of the day. Sailing ships were so much at the mercy of the wind that the delays involved in waiting for a favourable tidal stream, or for high water, were comparatively unimportant. It was the introduction of steam ships running to regular schedules, the construction of artificial harbours all over the world, the dredging of approach channels, and the various activities associated with modern warfare which have led to demands for ever increasing accuracy in tidal and tidal stream data. Accurate long period tidal observations are easily obtained from the more important naval and commercial ports where automatic tide-gauges are maintained. Along the less developed coasts the only observations available are usually those obtained during the course of hydrographic surveys, and such coasts are only surveyed at rare intervals. Nevertheless in wartime it frequently happens that it is just those undeveloped coasts, or islands, which become of great strategic importance. It is therefore essential that the best possible use should be made of old observations at the many places for which they are the only data available.

The chart is the principal aid to navigation and, in so far as it is feasible, provides all the essential information. The tides and tidal streams being subject to periodical variations, the chart can only give information about them under certain average conditions. The additional information about the tides is given in *Admiralty Tide Tables*. The tidal streams in constricted waters differ very markedly from place to place and information cannot be given on the chart in sufficient detail

without the sacrifice of other important information. The additional details are given in *Admiralty Sailing Directions*, and in areas of particular importance in special *Tidal Stream Atlases*.

Admiralty Tide Tables.

The three volumes of *Tide Tables*, which are issued annually, cover every ocean and tidal sea, and each volume consists of two parts. The first part contains daily predictions of the times and heights of high and low water for most of the important naval and commercial ports of the world. It is in fact mainly a compilation of the official tide tables predicted by or for the authorities controlling the various ports. It has been agreed internationally that all countries shall use the same predictions for any one port and to that end there is an exchange of predictions sufficiently far in advance to enable them to be printed in the various official tide tables. The object is to prevent the confusion which might arise if different versions for the same port were published in different tide tables. With the same object in view the material in private almanacs and tide tables is controlled through copyright laws.

The tides are predicted harmonically by the Liverpool Observatory and Tidal Institute for the governments or harbour authorities of Australia, Belgium, Canada, Denmar, Eire, Iceland, New Zealand, Pakistan, South Africa, United Kingdom and for a number of Colonial Authorities. The tides for a few British Ports, are, however, predicted by non-harmonic methods in the Tidal Branch. Predictions are also received for inclusion in the *Admiralty Tide Tables* from the appropriate authorities in Argentina, Brazil, France, Germany, India, Japan, Netherlands, Norway, Philippines, Portugal, Thailand and U.S.A. Thus, for this part of the tide tables, the work of the Tidal Branch largely consists of converting foreign predictions to the units of height and the zone times used in the *Admiralty Tide Tables*, preparing the material for the reproduction by photolithography and in compiling the *Tide Tables*. Official tide tables for New Zealand, the Federation of Malaya, Singapore and Hong Kong are also compiled in the Tidal Branch. The number of ports for which daily predictions are given in the various volumes of *Tide Tables*, compiled in the Branch, is about 200. The actual ports vary to a small extent each year, with the rise in strategic or commercial importance of new ports; and, from time to time, ports for which only old data are available are replaced by alternatives where modern long period observations have been obtained.

It is the second part of the Tide Tables with which the Tidal Branch is more exclusively concerned. This contains data whereby the mariner may predict the tides at some 6,000 additional ports and harbours in every ocean and tidal sea. The observations on which these data are based vary widely in their adequacy. At some of them modern observations over long periods of time are available; at others continual hourly observations have been obtained during the course of hydrographic surveys for periods of from a fortnight to several months. At many of them, however, the observations are old and inadequate by modern standards. A steady trickle of new and reliable observations flow in every year from H.M. Surveying Ships, Commonwealth and Foreign sources. Those received for any particular port will in most cases lead to the reassessment of the available data, if of an unsatisfactory standard, at other places in the vicinity. Thus the second part of *Admiralty Tide Tables* is under continual revision from year to year.

Prediction Data in the Tide Tables.

The ports for which daily predictions are given in the tide tables are known as Standard Ports, while those for which only prediction data are given are known as Secondary Ports. These prediction data are given for either or both of two methods of prediction, the data given depending upon the observations available and upon characteristics of the tide at the Secondary Port.

The less laborious of these methods is to predict the times of high and low water at the Secondary Port by the application of differences to the times at a Standard Port, and to predict the heights of high and low water by the application either of differences to the heights, or of a factor to the range of the tide, at the Standard Port.

In order to obtain accurate predictions by this method it is essential that the responses of the water to any particular astronomical conditions should be similar at the Secondary and Standard Ports, and that changes in those astronomical conditions should have similar effects upon the responses of the water at the two ports. There is usually a fair degree of similarity in the tides on a long stretch of the shore of an ocean, but in partially enclosed seas, in gulfs and in straits the tides undergo marked changes within quite short distances. The characteristics are clearly discerned from the relative magnitudes and phase relationships of the principal harmonic constituents of the tide. The phase lag and amplitude of each constituent change progressively from place to place, but in any area where one or more of the constituents have amphidromic points there will be continual changes in the relative magnitudes and phase relationships of the various constituents. In many cases these relative magnitudes and phase relationships are peculiar to particular areas and are quite different from those which exist at any Standard Port. This method of prediction is therefore limited in its application and is really accurate only in those areas where the tides are of a very uniform type. Elsewhere it can only be used subject to cautions with regard to its lack of accuracy under some astronomical conditions. It is a method which was used widely and without discrimination in the past and it has been noted that the tide tables of certain countries have undergone drastic revisions as a result of its inaccuracies, when employed indiscriminately, becoming apparent during war-time operations.

The other method of prediction, known as the Admiralty method, is rather more laborious but it has the great advantage that, no matter how unusual the relative magnitudes and phase relationships of the constituents may be, the tide can be predicted at almost any place with equal accuracy, and without reference to the predictions at a Standard Port. By this method the tide is predicted from the constants of the two principal semidiurnal harmonic constituents and those of the two principal harmonic constituents, in conjunction with astronomical arguments which introduce the effects of a number of other harmonic constituents. This method was devised for the Admiralty by Dr. Doodson, F. R. S., of the Liverpool Observatory and Tidal Institute, and was originally introduced as a purely arithmetical one. Since then it has been modified in the Tidal Branch to a semigraphic form, and the labour involved has been reduced by the calculation, in advance, of the daily values of the astronomical arguments and by their inclusion in the *Admiralty Tide Tables.*

For the selection of the most suitable Standard Ports, in prediction by the first method, the constants of the four principal harmonic constituents of the tide are of considerable value, while for prediction by the Admiralty method they are essential. The harmonic analysis of the tide was originally introduced by Lord

Kelvin more than eighty years ago for the purpose of predicting mechanically the tides at Standard Ports. For predictions of that order of accuracy it is really essential to analyse automatic tide gauge records for the continuous period of a year or more. Such records are available for only very few ports, and an essential preliminary to the introduction of the Admiralty method of prediction was an accurate means of determining the constants of the principal harmonic constituents from much shorter periods of observations Dr. Doodson devised a method whereby these could be obtained from hourly heights for a minimum period of fifteen days, but preferably from hourly heights for a period of twenty-nine days. When sufficient of these data have become available for any area, then the construction of co-tidal charts reveals inaccuracies in any of the individual constants.

This method of analysis has been recently modified in the Tidal Branch to a semigraphic form, which reduces the arithmetical processes involved and also allows of some flexibility in the frequency and period of the observations.

Our still very limited knowledge of the tides, by modern standards of accuracy, can be appreciated in light of the fact that, whereas the length of the coastline of the British Isles alone is over 5,000 nautical miles, in all the oceans and seas of the world there are not more than 2,000 places at which the tides have been harmonically analysed. During the war tidal predictions, of an accuracy compatible with the risks involved, could not be prepared for the landings in the Bay of the Seine because there were no adequate analyses of the tides in that area. Because of the still general deficiency of systematic tidal observations in so many parts of the world and the improbability of such observations being obtained in the near future, it is essential to make the best use of all available data. One advantage of the semigraphic method of analysis is that it facilitates interpolation from broken series of observations.

Tidal Stream Information.

Whereas the tides are the vertical response, the tidal streams are the horizontal response of the sea to the tractive forces of the Moon and Sun. In consequence the preceding remarks with regard to the analysis and prediction of tides are equally applicable to tidal streams. It is, however, more difficult to predict tidal streams with the same accuracy as the tides, because of the practical and economical difficulties in obtaining tidal stream observations over long periods of time. The problem is also rendered more complex by the fact that tidal streams vary in both direction and rate, and whereas the vertical movements do not differ very materially at places close together, the rates and directions of the tidal streams can be completely different in different parts of the same channel. In the open sea the movements of the tidal streams are of course much more uniform and reliable inferences may be made from observations at comparatively few points. It can generally be assumed that the tidal streams have the same characteristics as the tide in the same locality and in such cases they may be predicted be reference to the times of high or low water and the range of the tide at a Standard Port. In certain localities the tides and tidal streams have quite different characteristics, and for a number of these places where tidal stream observations have been taken for periods sufficiently long to permit of their harmonic analysis, daily predictions of the times of maximum rate, the maximum rates and the times at which the streams turn are given in *Admiralty Tide Tables*. These are predicted in the Tidal Branch with a small tide-predicting machine.

Where the tidal streams can be predicted by reference to the tide at a Standard Port, the necessary information is given in tidal stream atlases, on the charts and in *Admiralty Sailing Directions*. The atlases show the general movements of the tidal streams at hourly intervals, over, as a rule, fairly wide areas of open water. Tables of the hourly rates and directions of the tidal streams relative to tidal conditions at a Standard Port are given for specific points on the larger scale charts, on which the existence of eddies is also indicated. The *Sailing Directions* give more detailed information about the tidal streams, eddies, cross sets, etc., than can be shown on the chart.

There is an accumulation of short period, or intermittent, observations taken in the past by H. M. Surveying Ships in waters where the diurnal constituents of the tidal streams are relatively large. At present no reliable deductions can be made from them until suitable methods of analysis are developed.

Flood Warning Service.

Ever since the disastrous floods of 31st January-1st February 1953, the Tidal Branch has played an important part in the operation of a Flood-Warning Service. In conformity with the recommendations of the Waverley Committee, the service is now operated from the Central Forecasting Office at Dunstable and involves the co-operation of the Admiralty, Air Ministry, Ministry of Transport, General Post Office, Home Office and Ministry of Agriculture and Fisheries. The warnings are based on meteorological forecasts and on tidal readings received from a number of ports on the East Coast. These warnings are issued whenever there is a probability that the sea will rise to or above a dangerous level at specified points on the coast. The storm surges, which, when adversely combined with the tide, are the cause of disastrous floods, are now the subject of much research.

Other Aspects of Tidal Branch Work.

The routine work of the Branch is largely concerned with the publication of tidal and tidal stream information for naval operations and general navigation together with the associated analyses, predictions and research into methods of observing, analysing and predicting the tides and tidal streams. So many other activities are affected by tides and tidal streams that there is a continual demand for additional of more detailed information on such subjects as:

Engineering: Construction of docks, wharves, slips, sea defences, barrages, coast erosion, reclamation, dredging, disposal of sewage and other materials in the sea.

Scientific: Oceanography, marine biology, geology, investigation of secular changes in sea level etc.

Law: Legal aspects of groundings, collisions, and foreshore rights.

International: Exchange of tidal predictions and other information with Dominion, Colonial and Foreign Hydrographic Authorities. Supply of Information to the International Hydrographic Bureau.

General Information: Inquiries from Press, B.B.C. and private individuals ranging from questions of theory to the practical ones, such as the best time and place to view the Severn Bore, or the most favourable tidal conditions for swimming the Channel. Other questions have related to the association between the tides and certain historical events, such as the landing of Julius Caesar on the shores of Britain, or the escape of the Pilgrim Fathers from Boston, Lincs.

As in other branches of Hydrography, much of the interest of tidal work lies in the contact with so many different aspects of daily life and in the contacts with those engaged in similar work in so many different parts of the world.