CHART DATUM

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It gives me great pleasure to speak to you about chart datums, a subject which has been discussed at almost every International Hydrographic Conference. It was in 1919 that the suggestion was made that an international low water as the datum for soundings should be adopted and, after fifty years of discussions, it seems that it is almost impossible to reach an agreement on all the implications which have to be considered before adopting this datum. We all know that the International Hydrographic Bureau recommends that chart datum should be a plane so low that the tide will seldom, if ever, fall below it.

1) It is recognized that the datum should be sufficiently low so that under normal weather conditions there will always be at least the charted depth of water;
2) The datum should not be so low that it gives an unduly pessimistic impression of the least depth of water likely to be found;
3) The datum should be in close agreement with those of neighbouring surveys.

Having some of the most interesting and pecular tides, possessing great bodies of inland waters, many navigable rivers and a vast extent of coastline, we in Canada insist that every hydrographer must obtain accurate and reliable tide and water level records.

The suitability of the datum selected by the hydrographic party must always await the analysis of the tide or water level observations, since the analysis may show that on the days when the water level fell below datum the cause was unfavourable weather conditions (such as strong winds and high barometric pressure), and where the tide did not fall anywhere near the datum the reason may have been that the astronomical conditions during that period did not produce a large range of tide. The datum established by a Canadian hydrographer is called a sounding datum and is the plane to which he reduces his soundings during the course of a hydrographic survey. It need not be the same as the chart datum.

How do we go about establishing a chart datum for Canadian waters ?

With the use of electronic computers it is now relatively easy to analyse any given tidal recordings. We are in a position to supply to field parties, within a day or so, a datum which conforms to our definition of " lower low water large tides " for the sounding reductions, or to " higher high water large tides " for the establishment of elevations.

To compute datums along our Pacific, Arctic and Atlantic coasts, where the character of the tide passes from semi-diurnal to diurnal, the following data are required :

1) The diurnal component of the tide
   a) average amplitude DL
   b) constituents K_1 and O_1;
2) The semi-diurnal component of the tide
   a) average amplitude SD
   b) constituents M_2, S_2 and N_2;
3) The mean water level for the period of observation;
4) The seasonal changes as obtained from long periods of data.

Instructions on how to compute lunitidal intervals and average heights with the aid of constituents can be found in the *Admiralty Manual of Tides*.

Before electronic computers were employed to carry out datum computations we used the following formula to predict " large tides " (HHW', LLW')

$$(1)\quad \left.\begin{aligned} HHW' &= HHW + 0.2\,(HHW - LHW) + 1.3\,HS_2 + HN_2 \\ LLW' &= LLW - 0.2\,(HLW - LLW) - 1.3\,HS_2 - HN_2 \end{aligned}\right\}\ \text{if } DL/SD < 0.4$$

$$(2)\quad \left.\begin{aligned} HHW' &= HHW + 0.5\,(HHW - LHW) + 1.3\,HS_2 \\ LLW' &= LLW - 0.5\,(HLW - LLW) - 1.3\,HS_2 \end{aligned}\right\}\ \text{if } DL/SD \geqslant 0.4$$

The large tides obtained by this forecast were compared with the average of the three highest tides predicted and the average of the three lowest tides predicted for 1964 for all Canadian ports. The agreement was generally satisfactory if DL/SD was between 0.1 and 1, but was much poorer when this fell outside this range. Therefore a series of linear regressions were made and the best fit for the Canadian ports gave the following formulae :

$$\begin{aligned} HHW' = {} & (1.01 + 0.20D)HHW + (1.16 - 0.77D)\,(HHW - LHW) + \\ & + (0.02 + 1.3D)HS_2 + (1.8 - 5.0D)HN_2 + 0.02\ \text{ft} \end{aligned}$$

$$\begin{aligned} LLW' = {} & (0.82 + 0.07D)LLW - (0.14 + 0.23D)\,(HLW - LLW) - \\ & - (0.42 + 1.9D)HS_2 - (0.77 - 1.8D)HN_2 - 0.29\ \text{ft} \end{aligned}$$

where $D = (DL/SD)^{1/2}$.

Moreover, by having all our data in a computer usable format, we were now able to obtain the appropriate high and low water heights for several years for testing the new formula.

TABLE 1

	Tide Station readings		Predicted values		Mean of three highest & three lowest predicted values		Mean of three largest predicted ranges
	HH	LL	HH	LL	HH	LL	
142, POINTE-AU-PERE, Quebec	15.7	-0.3	15.8	-0.2	15.9	0.4	15.5
143, HARRINGTON, Quebec	7.3	-1.0	7.4	-0.3	7.2	0.2	7.0
147, PICTOU Nova Scotia	7.3	-0.5	6.5	0.1	6.1	0.0	6.2
151, St. JOHN'S Newfoundland	5.6	-0.1	5.1	0.0	4.9	-0.2	4.8
152, PORT AUX BASQUES, Newfoundland	6.8	0.0	6.3	0.5	5.6	0.2	5.3
153, CHARLOTTETOWN, Prince Edward Island	10.3	-0.9	9.3	-0.1	9.3	0.1	9.2
154, HALIFAX Nova Scotia	8.4	0.2	7.4	0.4	7.3	0.2	7.0
155, SAINT JOHN, New Brunswick	28.4	0.0	28.8	0.5	28.5	0.3	28.4
161, CHURCHILL, Manitoba	16.3	-0.6	15.2	-0.2	15.4	-0.1	15.5
168, VICTORIA, British Columbia	10.6	-0.7	10.2	-0.3	10.3	-0.4	10.7
169, FULFORD HARBOUR, British Columbia	12.8	-0.8	12.6	-0.2	12.5	-0.5	12.8
170, VANCOUVER, British Columbia	14.7	-2.0	14.9	-1.8	14.2	-1.7	15.8
171, POINT ATKINSON, British Columbia	15.4	-1.5	15.5	-1.3	15.1	-1.3	16.1
172, TOFINO, British Columbia	13.6	-0.3	13.7	0.1	13.6	0.0	13.5
173, ALERT BAY, British Columbia	17.6	-0.1	18.2	-0.2	17.5	-0.1	17.3
174, BELLA BELLA, British Columbia	17.7	0.0	18.0	-0.1	18.0	-0.2	17.8
175, PRINCE RUPERT, British Columbia	23.8	0.0	24.6	-0.1	24.0	0.0	23.9

In column 1 of table I are shown higher high water large tides and lower low water large tides obtained for a complete year at all Canadian reference stations. These values when compared with the predicted data given in column 2, and obtained from the five constituents M_2, S_2, N_2, K_1 and O_1, show that the differences between observed and predicted values for lower low water large tides are less than one foot. Column 3 contains the mean of the three highest and the three lowest predicted values obtained with over thirty constituents, and column 4 gives the mean of the three largest ranges for predicted tides for the years 1964, 1965, 1966 and 1967. The DL/SD ratio of these seventeen tidal stations varies from 0.05

at St. John (New Brunswick) to 1.71 at Victoria (British Columbia), and the ranges are from about thirty feet to less than five feet.

We have rigorously adopted this method for chart datum computations, and we shall change all sounding datums computed by hydrographic field parties if their value differs by more than ± 1 foot from the value obtained by the aforementioned method.

The reasons for having chosen this somewhat large margin are several:

a) We realize that predictions made from all available constituents (say sixty) may easily differ from the observed value by one foot;

b) We know that along our Atlantic coast mean sea level changes by over one foot per century;

c) Until such time as the metric system is adopted in North America and since soundings are obtained to the nearest foot the accuracy obtained by these computations is quite sufficient.

The past fifty years have shown that it is not possible to have chart datum accepted on an international basis. However, this is not quite true as far as the Great Lakes — St. Lawrence System is concerned. The seaway now extends some 2 000 miles into the North American Continent, and water level gauges have been in operation on this waterway for many decades, but they were not based on a common reference datum until 1960. The United States authorities and the Canadian Hydrographic Service agreed in 1960 to adopt a new level system within the Great Lakes — St. Lawrence River region, and to establish from that system common chart datums for both nations from the international boundary at Cornwall to all the Great Lakes and the rivers connecting them.

Before establishing this new datum several requirements had to be met. The datum had to be acceptable to both governments so that most of the existing datums could be abandoned. It had to compensate for changes in elevations due to the movement of the earth's crust prior to its introduction, and it had to be suitable for hydraulic and hydrographic purposes. After careful consideration it was decided to use dynamic elevations for the levelling network. These elevations take into account not only the measured linear height above the reference zero but also the *force of gravity at each particular locality*. Father Point was chosen as the reference zero for the levelling network, for the Canadian Hydrographic Service maintains a tide gauge there and has been obtaining tide levels for several decades. The chart datum and the elevation of chart datum for each of the lakes are the same at both the United States and the Canadian side.

Since the St. Lawrence River — Great Lakes system is merely an extension of the coastal area into the heart of the continent we feel that the levels to which inland water charts are referred should be similar to the ones we are using in tidal waters. For higher high water on lakes and rivers we shall adopt the highest instantaneous recording for the period of observation. As for high water, we think that the average of all the highest daily mean values, as computed for each year within the period of observation, can be used as the datum for elevation. Low water or chart datum could be the average of all the lowest daily mean values as computed for each year within the period of observation.

No doubt you will realize that, since Canada possesses tides showing all possible tidal characteristics, the method for computation of datums as outlined above could be employed for almost anywhere in the world. Computer programs and further information on these matters can be obtained from our office.