ARTICLE REVIEW

NATURAL OSCILLATIONS OF THE BAY OF FUNDY

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An article thus entitled was published in *The Journal of the Fisheries Research Board of Canada*, 1968, Volume 25, pages 1097-1114. A summary of this paper is given below.

There has always been a tendency to explain the enormous tidal ranges in the Bay of Fundy on the basis of a resonance mechanism. According to this, the Bay of Fundy is supposed to have a free period in the vicinity of the M_2 tidal period of 12.42 hours and the proximity of the natural period to that of the forcing period excites the large tidal amplitudes. The past estimates of the free period were all made using the simple Merian formula for a bay $4\,L/\sqrt{gh}$ and all of these estimates place the period around 11.6 hours, which is close enough to the 12.42 hour period of M_2 for the resonance hypothesis to become credible. However, as remarked by SVERDRUP *et al.* in their book "The Oceans", no attempt has been made, rather surprisingly, to determine the natural period of the bay by a more accurate method.

The problem of determining the free periods of a one-dimensional basin with arbitrary variations of depth and breadth is a rather straightforward one. The dynamics of such a basin are governed by the well known channel equations. These consist of two partial differential equations, one of which expresses the momentum conservation and the other mass conservation; the momentum and mass being functions of the space (x) and time (t). The dependent variables that appear explicitly in the channel equations are the volume transport Q and the fluctuation of the water level ζ above the mean level. The coefficients that occur in the equations are the breadth b and the cross-sectional area S of the bay. In these channel equations, the time variation is expressed through exp $(i\sigma t)$ where σ is the oscillation frequency ($2\pi/\sigma$ is the period). This assumption for the time-variation reduces the channel equations to a pair of coupled ordinary differential equations with space coordinate x as the independent variable. These are then subject to the boundary conditions that the height of the water level is zero at the mouth and the volume transport is zero a the head of the bay to determine the frequency values σ.

For the purpose of this study the mouth of the Bay of Fundy was taken along a line joining Machias (Maine) to Chebogue Point (Nova Scotia). As one proceeds northward, the bay splits into two separate channels at Cape Chignecto — Chignecto Bay and Minas Channel. Chignecto Bay was closed off at approximately Grindstone Island and Minas Basin was closed off at Noel. Then the Bay was divided into a number of equally spaced points $X_i = (i - 1)\,\Delta x/2$. Taking a

$\Delta x = 6.3$ miles, we obtain 39 sections between the mouth of the bay and Cape Chignecto, 9 sections in Chignecto Bay and 19 in Minas Channel — Minas Basin. Then the differential equations are replaced by central-difference equations such that the ζ's are calculated at all odd-numbered points and Q's at all even-numbered points. The cross-sectional areas are needed at even-numbered points and the breadths at odd-numbered points. The data for this are obtained from the Canadian Hydrographic Survey Charts 4010 and 4011 of the Bay of Fundy.

The integration starts by prescribing a guess value for σ, assigning $\zeta = 0$ at the mouth (boundary condition) and an arbitrary value for Q. Then step by step we proceed along the length of the bay until we reach the head of the bay in Minas Channel where the boundary condition demands that Q be zero. This would be so if our guess value for σ were correct. If not, we modify the guess for σ and repeat the integration procedure until two successive iterates of σ converge in a prescribed manner or until Q at the head is zero. The oscillation in Chignecto Bay is exactly solved during each iteration by treating it as a co-oscillation with an imposed frequency σ and an elevation corresponding to the ζ-value at Cape Chignecto.

The above integration procedure was carried out to determine the periods of the lowest three modes of the Bay of Fundy. The numerical values of these periods are 9.047, 5.383 and 3.475 hours. In obtaining these periods, the effects of earth's rotation and bottom friction were omitted. An approximate analysis of these effects shows that rotation *decreases* the period by about three percent and friction *increases* it by at most one percent. Hence, the net result is that the period of the lowest mode is not significantly changed from its value of 9.047 hours. This period estimate is too far removed from the M_2 period of 12.42 hours to produce any significant resonance effects. A calculation of M_2 co-oscillation in the bay showed that the tide is only amplified by a factor of 2.5, a value that is realized in several other basins also. Hence, the enormous tides at the head of the bay, as REDFIELD pointed out, are due to the rather large input of the tide at the mounth itself and not due to any superiority of the bay as a resonating system. Finally, the spacial distributions of the ζ and Q fields in the free modes are also presented in the paper.

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