overwhelming control, causing the depths to decrease inspite of sea level rise, and thereby pushing the mouth seaward.

While, in general, increased water depth would increase the estuarine tidal range, the opposite effect could occur, for example, in cases where tidal resonance is a significant factor. This can be illustrated in a simple way by considering the case of a tidal wave entering a frictionless channel closed at the upstream end. In this case, considering complete wave reflection at the closed end, the incident and reflected progressive waves combine to form a standing wave, as shown in Fig. 4.1. The estuary is of length ℓ, with the closed end at x=0 and the mouth at $x=-\ell$. If the range of the progressive wave is H, the range of the standing wave at the closed end will be 2H. The standing wave envelope is thus defined by an antinode at the closed end and a node in the sea. It can be shown (Ippen and Harleman, 1966) that the ratio, R, of the amplitude, η_{om}, at the closed end to the amplitude, $\eta_{-\ell m}$, at the mouth will be (ignoring bottom friction)

$$R = \frac{\eta_{om}}{\eta_{-\ell m}} = \frac{1}{\left|\cos\left(\frac{2\pi\ell}{L}\right)\right|} \tag{4.2}$$

Since $|\cos(2\pi\ell/L)| \leq 1$, in general, the tide at the closed end will be higher than that at the mouth. This type of a resonance effect is well known, and occurs in such estuaries at the Bay of Fundy, Canada, and at Cambay in India. Given such a behavior, a situation can arise whereby an increase in water depth would in fact decrease the difference between the tide at the closed end and that at the mouth.

Consider first the case of an estuary of mean water depth, h = 15 m. Given an estuary length, ℓ = 108 km, from Eq. 4.2 R = 3.7, for a semi-diurnal tide. Now if h is increased, for example, by 2 m, R is reduced to 2.60 (assuming no change in the estuary length). Further suppose that as a result of the 2 m sea level rise, the tidal range at the mouth increases by 10%, say from 1 m to 1.10 m. Then, by virtue of Eq. 4.2, the range at the closed end will <u>decrease</u>, from 3.2 m to 2.9 m.

A bay-like water body connected to the sea via an entrance will experience range amplification as the frequency of tidal forcing approaches the natural period of oscillation of the water body. The situation is analogous to the response of a damped harmonic oscillation (Mehta and Özsoy,