penetration. This can be easily shown via Eq. 9.2, for example. A possible secondary effect in the event of a sea level rise could be higher tides at the mouth. In this case a_o would increase, thereby reinforcing the penetration effect produced by increasing h_o.

The aforementioned simple, demonstrative theory of course has major limitations by virtue of the assumptions under which the stated equations were derived. In general, however, many of the restrictions can be relaxed via solution of the fully three-dimensional transport equations numerically. Furthermore, by following a hybrid approach involving a combination of field data, physical model-based data and numerical simulation, it is presently feasible to arrive at realistic descriptions of salinity distributions in the estuary, and such effects as those due to sea level rise can be simulated with a reasonable degree of confidence, particularly in the tide-dominated (as opposed to waves) environment. It should, however, be noted that the costs involved in "full blown" studies remains high, with the result that salinity intrusion effects have been investigated so far, in detail, mainly in highly urbanized estuaries.

9.4 EXAMPLES

It suffices to examine the effects of channel deepening and runoff on salinity intrusion as paradigms (qualitative in the case of runoff) for what would occur in the case of a sea level rise.

A major salinity intrusion problem developed in the Maracaibo estuary, Venezuela, in the sixties (Partheniades, 1966). The problem was traced to the construction, during the previous years, of a deep, 60 km long, navigation channel connecting Lake Maracaibo to the Gulf of Venezuela. A representative salinity (chlorinity) record within the lake during the 1937-63 period is shown in Fig. 9.4. A significant fluctuation of salinity first occurred during the 1947-52 period. This rise in salinity, from typical values of 500-700 ppm during the previous and the subsequent years, to a peak of about 1,400 ppm, is believed to have been due to the occurrence of a dry period with low runoff. However, following the completion of the deeper (from 6 m to 11 m) channel in 1956, the salinity increased relatively rapidly and almost continuously to a peak of 1,500 ppm in 1959. At this time, to accommodate yet larger oil tankers, the channel was further deepened to 13.5 m. This caused a