Estuaries: Dynamics, Mixing, Sedimentation and Morphology

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Source: Journal of Coastal Research, 2010(263) : 586-587

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/JCOASTRES-D-09-00121.1

Journal of Coastal Research	26	3	586–587	West Palm Beach, Florida	May 2010

BOOK REVIEWS

Estuaries: Dynamics, Mixing, Sedimentation and Morphology. 2009. David Prandle. Published by Cambridge University Press, New York. x + 236 pp., £65.00. Hardback. ISBN-13: 978-0521888868.

> "The river-water meets the sea diffused uniformly through a deep mass of water scarcely fresher than the sea itself, so that the two mix uniformly, the sea becomes slightly freshened throughout its whole depth for many miles from land."
> —*The Realm of Nature*, Hugh Robert Mill, 1897.

Estuary is from the Latin *aestuarium*, a place reached by *aestus*, the tide. Estuaries, as beautiful and ephemeral features on a geological timescale are fortunately offered to humankind and the world and are unusually rich in modern times. From a scientific perspective, the perception of the beauty and mystery of estuaries should be the best motive of the pursuit of science of estuaries. From an engineering perspective, estuaries should only be engineered as a kind of art that will benefit human beings. Estuaries are of great importance in physical oceanography, marine geology, marine ecology, marine biology, hydraulic engineering, shipping, and pollution monitoring and assessment and, thus, receive greatly increased attention by the scientific and engineering community all over the world. This timely book enhances and disseminates physical knowledge about estuaries.

Not surprisingly, given David Prandle's professional experience, from civil engineering to physical oceanography, the book is generally written from the theoretical perspective and takes the reader through estuarine physics and the derivations of many mathematical equations. Unlike previous books, *Estuaries* well-summarizes David Prandle's lifetime of work on estuaries: (i) dynamics, (ii) mixing, (iii) sedimentation, and (iv) morphology in eight chapters. Because some of the central problems are exceedingly difficult, the major approach used in the book is one based on dimensional-scaling analysis, supplemented by fairly reasonable assumptions.

In Chapter 1, Introduction, Prandle presents a brief introduction to objectives and scope, challenges, overall contents, modeling, and observations, together with a brief summary of formulae and theoretical frameworks, and ended by an appendix, which is useful for the reader to further study.

In Chapter 2, Tidal Dynamics, Prandle focuses on tidal dynamics of the estuarine system by examining the propagation of tides, generated in ocean basins, into estuaries, explaining how and why tidal elevations and currents may vary within estuaries. The bases of the shallow-water wave equations are described first. The variations in elevation and current responses are then illustrated. The controlling mechanisms are discussed in some depth. An explanation is given of how the associated nonlinearities result in the generation of significantly higher harmonic and residual components with pronounced spatial gradients. In Section 2.7, Prandle indicates some of the peculiarities of surge-tide interactions in the Thames Estuary. For several reasons, some early classic textbook literature can be added. The harmonic analysis of tide analysis was developed by Lord Kelvin and Sir George Darwin, starting in 1867, following an earlier suggestion by Laplace along similar lines. The energy equation derived from tidal dynamics was first given by Taylor (1919). It was Doodson (1921) who first performed an accurate representation of the Earth tide-generating potential by harmonic series. Dronkers (1964) wrote the first long book (518 pages) on tidal computation in estuaries.

In Chapter 3, Currents, Prandle addresses how tidal currents vary along (axially) and across estuaries and from surface to bed. To explain changes in current speed, direction, and phase, the tidal current ellipse is decomposed into clockwise- and counterclockwise-rotating components. The vertical structures of both tidal- and wind-driven currents are described as well. It would be more helpful for the reader if the author had briefly outlined the various approaches to solutions using the different numerical methods in the estuarine modeling of tidal propagation, namely, the finite difference method (FDM), the finite element methods (FEM), and the finite volume method (FVM). Generally, the FVM combines the simplicity of the FDM with the geometric flexibility of the FEM. Regarding the turbulence model in Appendix 3B, it would be surprising if Prandle's choices for estuaries did not give rise to some debate.

The nonlinear coupling between the flow velocity fields and salinity is of crucial importance in the dynamics of estuaries. In Chapter 4, Saline Intrusion, Prandle examines the details of mixing in estuaries. This chapter starts with the vertical structure of residual currents associated with saline intrusion, river flow, and wind forcing. Both observational and theoretical approaches are described for predicting salt-water intrusion lengths. Emphasis is placed on the importance of incorporating the effects of tidal straining and the resultant convective overturning in rates of mixing in estuaries. It is shown that the ratio of currents, associated with river flow and tides, is the most direct determinant of stratification in estuaries. Notably absent in this chapter are discussions of (i) estuarine circulation (longitudinal and lateral), (ii) regions of

DOI: 10.2112/JCOASTRES-D-09-00121.1 received 29 August 2009; accepted 29 August 2009.

freshwater influence (ROFIs, for short), (iii) river plumes, and (iv) estuarine fronts.

In Chapter 5, Sediment Regimes, Prandle focuses on the character of sediment regimes in strongly tidal estuaries. A review discusses sediment processes and approaches in estuaries, which is followed by analytical expressions for erosion and deposition of suspended particulate matter in estuaries. Sections 5.4 and 5.5 provide further insight into mechanisms. Intercomparisons are made between results from observations and those from models. Results and guidelines for applications of models are summarized. In many muddy or turbid tidal estuaries around the world, high concentrations (>100 g L^{-1}) of suspended sediment occur near the bed, beneath the turbidity maximum (<10 g L^{-1}). Inglis and Allen (1957) first used the term *fluid mud* for describing this type of high-concentration sediment regime in the Thames Estuary. Chapter 5 does not include fluid mud, which seems an unexpected omission from such an otherwise much useful chapter.

In Chapter 6, Synchronous Estuaries: Dynamics, Saline Intrusion and Bathymetry, Prandle uses those ideas, theories, and approaches discussed in previous chapters to address the more fundamental question of how estuarine morphology is determined and maintained by the combined actions of tidal dynamics and the mixing of fresh and salt waters. In Chapter 7, Synchronous Estuaries: Sediment Trapping and Sorting, Stable Morphology, Prandle further develops generic, quantitative expressions to represent the fundamental mechanisms that produce those high-sediment concentrations for strongly tidal estuaries. To that end, Prandle identifies the scaling parameters that determine the sensitivities to sediment type (noncohesive to cohesive), spring to neap tides, and dry to wet river flows, together with feedback processes that maintain the long-term stability of estuarine bathymetry. These two chapters are Prandle's own major significant contributions to estuarine research.

Finally, in Chapter 8, Strategies for Global Climate Change, by drawing on a case study of a partially mixed estuary—the Mersey Estuary in England—Prandle leads the reader to look at how estuaries might adapt to global climate change. This is an interesting and important chapter. In Section 8.2, a review and discussion are offered on developments in modeling, observational technologies, and theory in the Mersey Estuary. Prandle uses the explicit formulae and theoretical framework to make future predictions with respect to likely impacts from global climate change. Strategies for long-term management of estuaries are discussed with sections on modeling, observations, monitoring, and forecasting. In Appendix 8A, emphasis is placed on the necessity of international cooperation. Surprisingly, the author omits the McDowell and O'Connor (1977) book, *Hydraulic Behaviour of Estuaries*, in the discussion of studies on the Mersey Estuary system.

Estuaries is well presented and structured. The references are listed at the ends of each chapter. It would undoubtedly be useful for the novice entering this field if the author had indicated the pages number where each reference was cited in the text. The Index is helpful, but, like all published books, *Estuaries* is not without its disappointments. The same figure is repetitively reproduced in the different chapters. For example, Figure 1.5 (p. 8) is reproduced in Figure 4.2 (p. 81), in Figure 1.6 (p. 9), in the lower part of Figure 5.8 (p. 140), in Figure 1.7 (p. 10), in Figure 6.12 (p. 169), in Figure 1.8 (p. 11), and in Figure 7.8 (p. 194). These pitfalls could have been easily avoided by adding a full list of figures for the author's own checking. The same references are repetitively presented in the References at the ends of different chapters. Similarly, that could have been avoided by adding a full list of all references at the end of the whole book. The subject "Turbidity Maximum" is indexed twice. Tense choices in that citations have not been used consistently throughout the book.

Overall, *Estuaries* is an excellent book, full of state-of-the-art knowledge, practical formulae, and new hypotheses for the dynamics, mixing, sediment regimes, and morphological evolution in estuaries. The book does achieve the objectives of explaining the underlying governing processes and has synthesized them into descriptive formulae that can be used to guide the future development of any estuary around the world. The book is useful for students and researchers in physical oceanography, geological oceanography, biological oceanography, and hydraulic and coastal engineering, and should be able to serve as a valuable reference and source of ideas for professional research for engineering and management communities concerned with estuaries.

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