1
Introduction

In the context of this book, tidal inlets are defined as the relatively short and narrow passages between barrier islands. They are sometimes referred to as passes or cuts. Tidal inlets are a common occurrence as barrier island coasts cover some 10 percent of the world's coasts (Glaeser, 1978). According to Hayes (1979), their presence is limited to coasts where the tidal range is less than 4 m.

The earliest interest in tidal inlets originates from their importance to commercial shipping. The relatively protected back-barrier lagoons were a favorite location for harbors. Later, with the increase in recreational boating, small boat basins and marinas were located in back-barrier lagoons. In addition to these commercial and recreational aspects, tidal inlets are ecologically important. Through the exchange of lagoon and ocean water, they contribute to the increase of water quality in the lagoon. Unfortunately, there is also a downside: tidal inlets interrupt the flow of sand along the coast. They not only interrupt but also capture part of the sand, causing erosion of the downdrift coast. For example, in Florida, with some eighty inlets, much of the beach erosion has been attributed to tidal inlets.

Most natural tidal inlets are less than ideal from a navigational point of view. The many shoals, the strong tidal current and the exposure to ocean waves make entering difficult. In addition, on timescales of years to decades, the morphology shows considerable variation, and maintaining sufficient depth and alignment of the channels requires substantial dredging. To minimize dredging and to improve navigation conditions, many inlets have been modified by adding jetties and breakwaters. As a result, tidal currents, waves and sand transport pathways differ from those at inlets without these structures. Nevertheless, in this book, emphasis is on tidal inlets that have not been modified. The reasoning is that understanding the physical processes governing the behavior of tidal inlets in a natural state is a prerequisite for the proper design of engineering measures. This includes the determination of undesirable side effects such as erosion of the adjacent beaches.

The main morphological features of a tidal inlet are the inlet, the ebb delta on the ocean side and the flood delta on the lagoon side. The morphology of the inlet and deltas is shaped by tide and waves. Depending on their relative importance, tidal inlets have been categorized as tide- or wave-dominant (Davis and Hayes, 1984; Hayes, 1994). Tides tend to keep inlets open. In this respect, the tidal prism – the volume of water entering the inlet on the flood and leaving during the ebb – is an important parameter; the larger the tidal prism, the larger the inlet. In turn, waves tend to close the inlet through the wave-driven longshore and cross-shore sand transport.

Scoured in sand, tidal inlets are dynamic features; inlet and channels move, ebb deltas change shape and volume. In discussing these morphological changes, emphasis is on processes with timescales of days (storm timescale), weeks and decades, as opposed to the geological timescale. This excludes the small-scale sand transport processes to which reference is made to Soulsby (1997) and van Rijn (1993). The morphology of the back-barrier lagoon comes into play only as it affects the water motion in the tidal inlet. For the water motion and morphology of the back-barrier lagoon, reference is made to Dronkers (2005).

Examples of barrier island coasts are the East Coast of the US, the Gulf Coast of the US, the Dutch, German and Danish Wadden Sea coast (Fig. 1.1a), the east coast of Vietnam, the northeast coast of the North Island of New Zealand, the Algarve coast of Portugal (Fig. 1.1b) and the Adriatic coast of Italy (Fig. 1.1c). Many inlets along these coasts have been studied extensively. For the origin and morphology of barrier island coasts reference is made to a series of articles in Davis (1994). Rather than one, most barrier island coasts consist of a chain of islands resulting in multiple inlets connected to the same back-barrier lagoon. In fact, it would be difficult to find a tidal inlet that is not affected by a companion inlet. In case of multiple inlets, each inlet competes for part of the tidal prism. This could lead to some inlets closing while others remain open.

Since the 1960s the main tool in studying tidal inlet processes has shifted from laboratory research, including scale models and flume studies, to mathematical models. A distinction is made between process-based models and empirical models (van de Kreeke, 1996). Following Murray (2003), process-based models are divided in exploratory and simulation models. Exploratory models only include the processes that are essential in reproducing the basic behavior. Process-based simulation models start with basic physics and are designed to reproduce the behavior of a natural system, or a schematization thereof, as accurately as possible. Process-based exploratory models are usually simplified to a level allowing analytical or semi-analytical solutions. Although not adequate for predictive purposes, they can be used in a diagnostic mode to help understand phenomena observed in the field

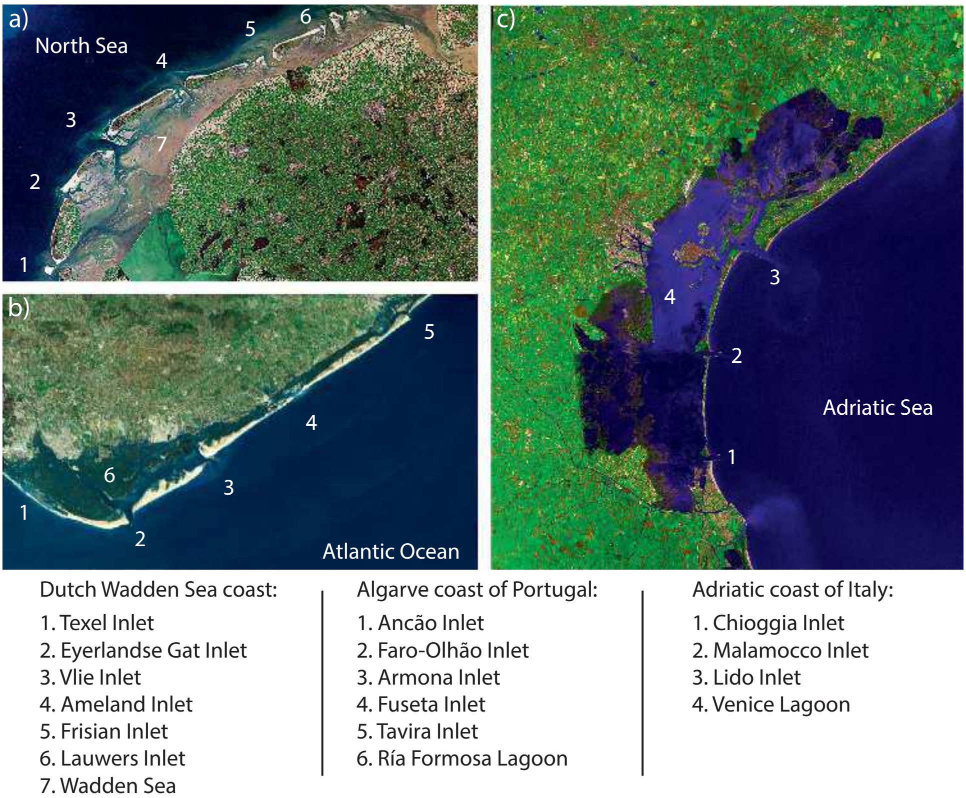

Figure 1.1 a) the Dutch Wadden Sea coast (USGS and ESA, 2011), b) the Algarve coast of Portugal (Esri et al., 2016) and c) the Adriatic coast of Italy (NASA et al., 2003).

and to check the validity of the results of the more complicated simulation models. Solving the equations underlying the process-based simulation models requires a numerical approach. The models provide a far more realistic representation of the physical processes than the exploratory models; however, a drawback is that it is often difficult to pinpoint the interactions that determine the overall behavior.

Empirical models are based on the assumption that after a perturbation the morphology tends towards an equilibrium state. The equilibrium state is defined by empirical relationships between the size or volume of the morphological units and the tidal prism. The return to equilibrium is described by empirical equations. Empirical models are a useful substitute when knowledge of the basic processes is insufficient, as is often the case.

The book summarizes and synthesizes the advances in tidal inlet research over the past 40 years. Emphasis is on natural inlets in a sandy environment with tide and waves as the dominant forcing. The book is organized as follows.

In Chapters 2–4 a description of the morphology and morphological changes of tidal inlets is presented. Chapter 2 describes the origin and major elements: inlet, ebb delta, flood delta and back-barrier lagoon. Chapter 3 focuses on sand transport pathways and sand bypassing. Attention is given to location stability, modes of bypassing and their relationship to the ratio of tidal prism and longshore sand transport (P/M ratio). Furthermore, the effect of inlets on the adjacent shores is discussed. In Chapter 4, selected inlets are reviewed with emphasis on sand bypassing and location stability.

Chapter 5 deals with the empirical relationships. The empirical relationship between inlet cross-sectional area and tidal prism (A–P relationship) is discussed and a physical explanation for this relationship is given. Additionally, the concept of equilibrium velocity is introduced. An empirical relationship between delta volume, tidal prism and wave energy is also presented.

Chapters 6 and 7 introduce process-based exploratory models that are used to explore the hydrodynamics of tidal inlets. In Chapter 6 a lumped parameter model and the Keulegan and Öszoy–Mehta Solutions are described. The internal generation of the third harmonic is discussed. Solutions are applied to a representative inlet and results are compared to those of a numerical solution. In Chapter 7 the hydrodynamic equations are expanded to include depth variations with tidal stage. The analytical solution to the expanded equations shows the generation of even overtides and the resulting tidal asymmetry, mean inlet velocity and mean basin level.

Chapters 8–10 deal with cross-sectional stability. Cross-sectional stability is determined using the Escoffier Stability Model. The Escoffier Stability Model, including the Escoffier Diagram, is described in Chapter 8. As examples, the model is applied to two single-inlet systems, Pass Cavallo (TX) and a representative inlet. An expression for the adaptation timescale of the inlet cross-sectional area after a storm is presented. Chapters 9 and 10 deal with the cross-sectional stability of double inlet systems, i.e., rather than one inlet the back-barrier lagoon is connected to the ocean by two inlets. In Chapter 9 the water motion in the inlets is described by the lumped parameter model. This model includes the one-dimensional hydrodynamic equations for the inlet and the assumption of a uniformly fluctuating basin water level. To investigate the effect of this assumption on cross-sectional stability, variations in basin water level are introduced by dividing the basin into two sub-basins connected by an opening, representing a topographic high. As part of the stability analysis a flow diagram is introduced. The flow diagram is the two-dimensional counterpart of the Escoffier Diagram. In Chapter 10, the spatial variations in basin water level are introduced by describing the hydrodynamics of inlets and basin by the shallow water wave equations. A semi-analytical solution is used to solve the governing equations.

Chapters 11 and 12 present applications of a process-based simulation model and an empirical model, respectively. In Chapter 11 a process-based simulation model is used to determine the morphology of a newly opened tidal inlet with emphasis on the inlet and the ebb delta. Using different inlet dimensions, ocean tidal amplitudes and basin surface areas, a series of numerical experiments is carried out to verify the A–P relationship. Chapter 12 describes the use of empirical models to explain the ebb delta development at a newly opened inlet (Ocean City Inlet, MD) and the adaptation of an inlet and ebb delta after basin reduction (Frisian Inlet, NL).

Chapter 13 focuses on the effect of river flow on the entrance stability of tidal inlets. The effect of river flow on the basin tide and the mean basin level is shown by expanding the Öszoy–Mehta Solution to include river flow. The effect of river flow on cross-sectional stability is discussed for a permanently open inlet, a seasonally open inlet and an intermittently open inlet. An exploratory morphodynamic model for the evolution of the depth of an inlet subject to river flow is presented.

Chapter 14 reviews measures to improve navigation and sand bypassing at tidal inlets.