Chapter 1

INTRODUCTION

1.1. MOTIVATION TO STUDY OVERWASH

Overwash is a natural process that results from a singular combination of oceanographic and coastal geomorphologic conditions. Overwash processes occur in a variety of coastal and lacustrine environments around the world, but their occurrence in barrier islands are the most commonly described in the literature. Documentation of overwash was found on the coasts of Australia, Canada, Denmark, Ireland, Portugal, Spain, the U.K., U.S.A., on the Baltic Sea, on the Black Sea and on the Great Lakes of Canada and U.S.A. (Donnelly *et al., in press a*).

The occurrence of overwash in developed areas often represents a hazard. The socio-economic impacts of overwash includes loss of human life, damage of coastal property and infrastructure, intrusion of salt and sand in agriculture soils, and interference with channel navigation. The varied impacts of overwash are particularly well documented when they result from a major storm or a hurricane (e.g. FitzGerald *et al.*, 1994, Nordstrom and Jackson, 1995; Webb *et al.*, 1997; Bureau of Beaches and Coastal Systems, 2004). Overwash associated to major storms may appear to be catastrophic as the barrier environments are severely modified by this natural event. However, from a longer term point of viewed (hundreds of years), overwash can be considered as a nearly continuous process, shaping and reshaping the barriers (Leatherman, 1988). Where overwash is allowed to occur, the net volume of sand is often maintained, but the environments translate shoreward (Dolan and Godfrey, 1973).

Several papers, thesis, and technical reports have been written about overwash processes and washover dynamics. However, there are still gaps in the knowledge which this thesis aims to address. One of the main gaps in overwash studies are the limited number of *in situ* measurements. Therefore, there is a lack of data that is still being pointed out at present (Donnelly *et al., in press b*). The wave energy often associated with overwash events and its

unpredictable nature makes fieldwork planning and execution very difficult. Data sets regarding overwash sedimentation have often been obtained through indirect measurements, in cases some time after the event, and sometimes without recording the associated forcing mechanisms. Moreover, techniques like fluorescent tracers that have been widely used for sediment transport studies (e.g. Komar and Inman, 1970; Ciavola *et al.*, 1997; Vila-Concejo *et al.*, 2004), have never been tested for overwash.

Portuguese research on overwash processes at present is very limited, despite the identification of its importance in several places: Costa Nova to Cabo Mondego, in the northern coast (Ferreira and Dias, 1993; Vidinha and Andrade, 1995), coastal lagoons in the southwest coast (Freitas, 1996; Ferreira *et al.*, 2005), and Ria Formosa Barrier System in the south coast (e.g. Pilkey *et al.*, 1989; Andrade *et al.*, 1998). The focus of the Portuguese studies that include overwash processes have been mainly related with coastal vulnerability (Vidinha and Andrade, 1995; Andrade *et al.*, 1998). Data sets of overwash sediment dynamics are almost inexistent.

1.2. QUESTIONS AND OBJECTIVES

The main objective of this thesis is to study the overwash sedimentary dynamics at different time scales. The study area is the Ria Formosa barrier island system. The knowledge of overwash sedimentary dynamics encompasses several issues that raised the following questions:

1. *What are the mechanisms responsible for washover formation and disappearance?*

   In the case that hurricanes and major storms are frequent, their frequency and intensity strongly control the overwash occurrence and post-storm dune recovery. However, overwash may also occur under lower energy conditions where it is related to other coastal processes such as structural erosion or inlet dynamics amongst others. The first objective of this thesis is **to define which natural coastal processes or human interventions are associated to overwash occurrence, and which are responsible for overwash cessation**.

2. *What is the importance of non-storm versus storm overwash?*

   Existing literature mostly focuses on overwash driven by major storms, due to their capacity to transport sediments inland. However, non-storm overwash may be important because of the cumulative effect of repeated overwash. The second objective of this thesis is **to clarify the role of non-storm overwash in low-lying portions of barrier islands**.

3. *What are the factors governing the overwash sedimentation?*

   Washover deposits generally have dimensions related with storms intensity and coastal morphology. Overwash may occur under non-storm conditions in low lying barriers and/or when coincident with spring high tides. The third objective of this thesis is **to**

determine how waves, tides and geomorphology control overwash sedimentation at low-lying barriers.

4. *What are the main differences between the sediment transport under confined and unconfined overwash flows?*

   Overwash flow is often confined by the dune gap margins so that sedimentation occurs landward, at the washover fan, where lateral spreading and deceleration of the flows occurs. In the case of unconfined overwash flows the loss of flow capacity may start as soon as it overcomes the crest. The fourth objective of the thesis is **to define the sediment transport stages and patterns under confined and unconfined overwash flows and the conditioning factors**.

5. *Is there a washover textural signature?*

   Longshore sediment transport is the main source of sediments for the overwash deposits, dunes and tidal inlets. Different authors have obtained opposite findings about the possibility of the distinction of textural characteristics from the sediments of these coastal environments. The fifth objective of this thesis is **to identify the textural signature of the washovers in comparison with other barrier environments, and to relate each texture with the associated deposition conditions**.

6. *What is the role of overwash in the Ria Formosa barrier islands?*

   Overwash occurrence is sporadic, however it is relevant to the barrier islands dynamics because it promotes rapid and significant barrier changes. The sixth objective of this thesis is **to determine the relative importance of overwash in relation to other processes affecting the barrier dynamics**.

7. *What was the evolution of overwash in the Ria Formosa?*

   In the present context of rising sea-level and increasing coastal erosion, an increase in the frequency of overwash occurrence could be expected. Nevertheless, this trend may

be altered or even inverted by other ongoing coastal processes. The seventh objective of this thesis is **to understand the evolutionary trends of overwash processes, based on the recent past of the Ria Formosa barrier islands**.

1.3. OUTLINE OF THE THESIS

This thesis consists of general chapters (chapters 1, 2, 3, and 8) and specific chapters (chapters 4, 5, 6 and 7) that deal with one or more of the questions from the objectives. The existing knowledgement on overwash processes and the study area are presented in the first chapters. The several questions on overwash processes addressed in this thesis were organised from the shorter (hours to days) to the longer time scales (decades). Each specific chapter is organised as introduction, methods, results, discussion and partial conclusions. The introduction provides information about the questions and objectives that are addressed in each chapter. The methods relevant to each chapter are explained after the introduction because they widely differ between chapters. The results are described, the discussion is made with emphasis to the objectives of the thesis, and the partial conclusions are at the end of each chapter.

The outline of the thesis is as follows:

- A review of overwash processes is given in Chapter 2. The processes and morphologies that are used through the thesis are defined in the first section. The following three sections include a literature review on overwash processes. The last section describes the results of overwash studies made in the Ria Formosa.
- Background information about the study area is given in Chapter 3. Both the main forcing mechanisms (first section) and the geology and geomorphology (second section) regarding the Ria Formosa area are described based on the available literature. Especial emphasis is given to the Barreta Island because it is the site that was used for the monitoring and intensive campaigns.
- Detailed studies in overwash sediment transport are included in Chapter 4. Data were collected during intensive fieldwork campaigns for measuring overwash events. The

analysis of the results allowed a better understanding of the washover short-term dynamics. The main differences between unconfined flow over washover plains and confined flow over washover lobes is addressed (question #4). The oceanographic conditions registered during the fieldwork campaigns provide an answer to question #2.

- The factors governing overwash sedimentation and its role in barrier island dynamics are addressed in Chapter 5. Morphologic data was obtained during a three year monitoring program of a frequently overwashed low-lying barrier. Wave data from an offshore buoy and tide predictions for the study period were also analysed. The barrier profiling allowed the understanding of the relative role of overwash processes in the barrier island sediment dynamics (question #6). This was accomplished by dividing the profile in sections that are associated to the several coastal processes occurring at the barrier. The association of the results of Chapters 4 and 5 addresses question #3. Additionally, the thresholds of the governing factors were quantified for the study area.
- A textural analysis of sediments from washover, beach, dune and inlet environments was made in Chapter 6. The textural signature of washover (question #5), beach and dune were defined, and related with the associated sedimentary dynamics and dominant physical processes.
- A classification of washover dynamics is given in Chapter 7. The classification is based on the aerial photographs analysis and it integrates the formation and disappearance mechanisms of washover (question #1) and the overwash evolutionary trends (question #7).
- The general conclusions regarding all the analyses made for this thesis are summarised in Chapter 8.