Chapter 2

REVIEW OF OVERWASH PROCESSES IN BARRIER ISLANDS

2.1. DEFINITION OF OVERWASH PROCESSES AND MORPHOLOGIES

Overwash was defined as the continuation of the swash uprush or wave runup over the crest of the most landward (storm) berm (Shepard, 1973). Overwash was defined for this work, as a seawater intrusion over the frontal dune or, when absent, over the washover seaward limit. The resulting deposit is not subjected to reworking during fair weather (non-storm) conditions (Leatherman, 1976).

Types of coastal landform associated with overwash have been extensively described (e.g. Hayes, 1967; Andrews, 1970; Schwartz, 1975; Leatherman, 1976; Orford and Carter, 1982; Ritchie and Penland, 1988; Davidson-Arnott and Fisher, 1992) and diversely named in the literature. Two main morphologic types can occur: (a) a wide low-lying denuded area where overwash processes are relatively frequent, and (b) laterally confined conspicuous features that cut the dune field in specific places (Figure 2.1). Morphology (a) has been named, for example, as washover ramp (Fisher and Simpson, 1979), washover sheet (e.g. Ritchie and Penland, 1988), washover flat (e.g. Holland *et al.*, 1991), washover terrace (e.g. Bray and Carter, 1992), and washover plain (e.g. Vila-Concejo *et al.*, *in press a*). Morphology (b) has been named as hurricane channel (e.g. Hayes, 1967), washover breach (e.g. Hosier and Cleary, 1977), overwash features (e.g. Armon and McCann, 1979), washovers (e.g. Fisher and Simpson, 1979), dune terrace morphologies (e.g. Ritchie and Penland, 1988), washover fan (e.g. Kochel and Wampfler, 1989), individual lobe washovers (Andrade, 1990), individual washovers (e.g. Bray and Carter, 1992), and perched fans (e.g. Morton and Sallenger, 2003). In this work the term washover designates any type of overwash-induced morphology, regardless of their specific genetic process or subsequent sedimentary dynamics. Morphology (a) is named washover plain (Figure 2.1) because it corresponds well to a “plain” due to its semi-flat surface and its occurrence at a level related to the seawater elevation (spring tides, storm surge, storm-wave runup). Morphology (b) is designated as washover lobe (Figure 2.1), because it describes well the shape of the feature without being a term used to describe specific parts of the washover (the channel or the fan).

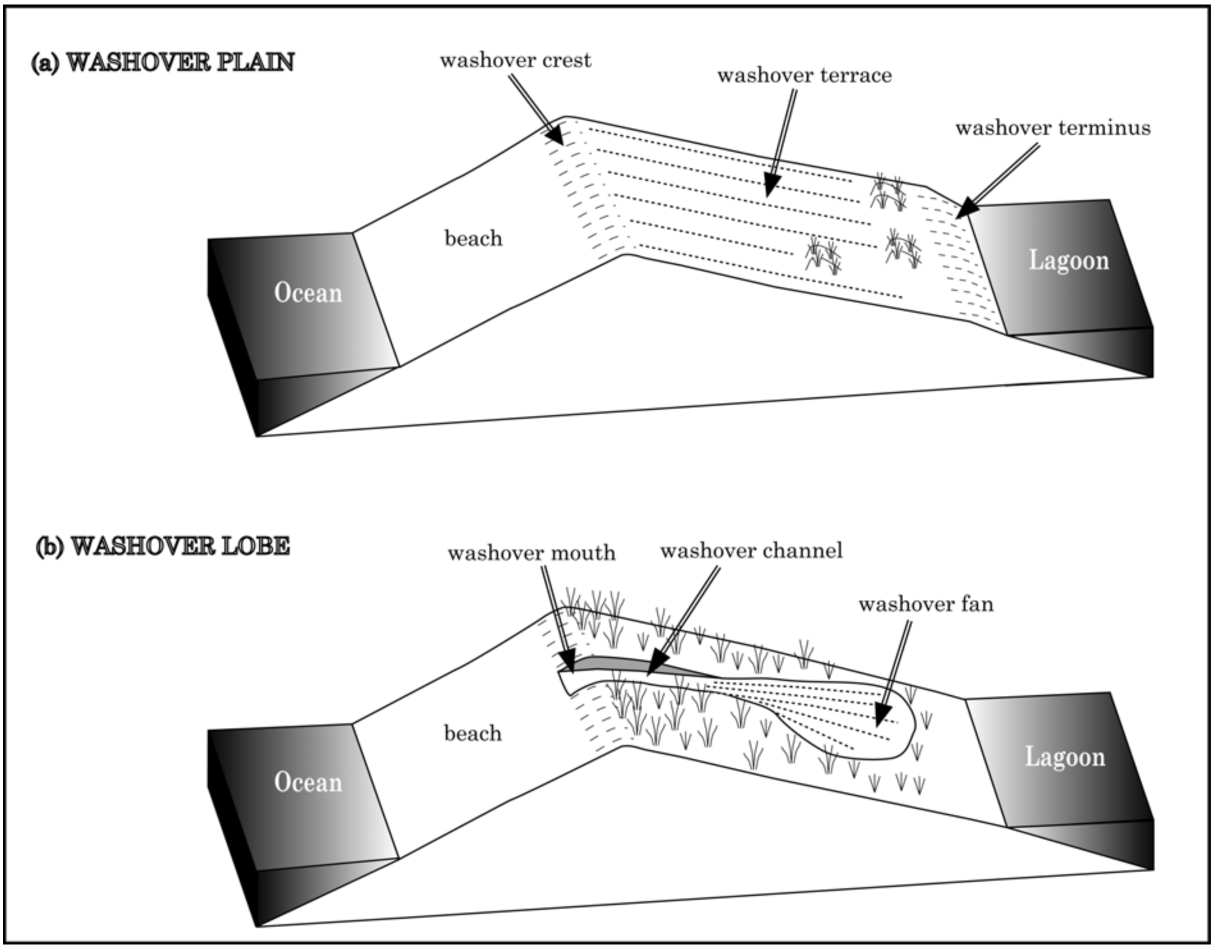

Figure 2.1. Washover morphologies terminology for (a) washover plain, and (b) washover lobe.

The **washover plain** (Figure 2.1a) is composed by a *crest*, which makes the transition to the beach environment; a *terrace*, that has a gently landward-dipping slope; and a *terminus*, which is the most landward and steepest part of the washover plain. The **washover lobe** (Figure 2.1b) is composed by a *mouth* that corresponds to a disruption on the dune front; a *channel* that has laterally confined margins and that crosses the dune field to a variable extent; and a *fan* that can be located inside the dune field, on a bay beach, on marshes, lagoon channels, etc.

Washover lobes are invariably dune related features; however the washover plains can occur as a result of a variety of barrier situations, for example, they can develop from coalescence of washover lobes, correspond to transitional stages of newly formed spits, or represent relict structures of ephemeral tidal inlet channels. Both washover lobes and washover plains can be developed and reworked under variable overwash situations. The **overwash intrusion**, i.e., the distance along the overwash flow main direction between the mouth/crest and maximum overwash water excursion, may vary from only a few meters up to the total width of the barrier, which were named **complete overwash**.

The term overwash has been used to designate diverse situations. The following concepts are defined for the purposes of this work: the **overwash flow** corresponds to a single passage of seawater; an **overwash event** is a set of overwash flows that occur consecutively during a particular combination of oceanographic and morphologic conditions. Under non-storm conditions, overwash events can have the frequency of the spring high tides.

2.2. DRIVING MECHANISMS AND OCCURRENCE CONDITIONS

Overwash is a global phenomenon that is usually associated with storms; therefore, the accepted geological definitions and descriptions of washovers specifically state that it is a storm related phenomenon (Morton *et al.*, 2000). Overwash is geologically important since catastrophic storms play a very important role in nearshore sedimentary processes, and they leave an indelible record in the sediments (Hayes, 1967).

Factors controlling the frequency and intensity of overwash, and the resulting morphologies, include marine conditions (e.g. Fisher *et al.*, 1974), relative orientation of a coast to the storms (e.g. Fletcher *et al.*, 1995), beach topography (e.g. Leatherman, 1976), backbeach elevations (e.g. Morton and Sallenger, 2003), nearshore bathymetry (e.g. Ritchie and Penland, 1988), and engineering structures (e.g. Hayden and Dolan, 1977).

Measured overwash flow velocities were generally of the same order of magnitude (around 2 m/s) regardless of the different methods used and the diverse geographical and oceanographic conditions. Leatherman (1977) obtained a mean overwash flow velocity of 1.95 m/s in Assateague Island (U.S.A.); Leatherman and Zaremba (1987) measured 0.5 m/s to 2.0 m /s overwash flow velocities at Nauset Spit-Eastham (U.S.A.); a maximum of 1.5 m/s was the overwash flow through the Trabucador Bar (Spain, Guillén *et al.*, 1994); mean velocities of 2.0 m/s were obtained by Holland *et al.* (1991) at the Isles Dernieres (U.S.A.); and Bray and Carter (1992) measured overwash flow velocities between 1-3 m/s at a barrier in Lake Erie (U.S.A.).

Sallenger *et al.*, (1999), Sallenger (2000) and Sallenger *et al.* (2003) developed a storm impact scale with four regimes including overwash. The scale is based on four parameters: R_{LOW}, R_{HIGH}, D_{LOW}, D_{HIGH} (Figure 2.2a). R_{HIGH} and R_{LOW} are the high and low elevations of the landward margin of swash relative to a fixed vertical datum. R_{LOW} represents the elevation below which the beach is continuously subaqueous. D_{HIGH} is the elevation of the highest part of the “first line of defence” of the barrier beach, i.e. the elevation of the foredune ridge or crest of the beach berm. On beaches where there is a foredune ridge, D_{LOW} is the elevation of the base of the dune. In the absence of a foredune ridge $D_{LOW}=D_{HIGH}$.

The Storm Impact Scale has four regimes: swash regime, collision regime, overwash regime and inundation regime (Figure 2.2b).

The **swash regime** is the condition, during a storm, where swash is confined to the foreshore of the beach seaward of the dune and R_{HIGH}/D_{HIGH} is less than the critical threshold defined by

$$R_{HIGH}/D_{HIGH} = D_{LOW}/D_{HIGH} \qquad \text{(equation 2.1)}$$

Under these storm conditions, the beach foreshore erodes and sand is transported offshore where it is deposited, only to be returned to the beach following the storm under fair weather conditions.

The **collision regime** occurs when the critical threshold of equation 2.1 is exceeded. The eroded sand is transported offshore (or longshore) and, in contrast to the swash regime, does not typically return to re-establish the dune.

The **overwash regime** occurs when $R_{HIGH}>D_{HIGH}$, hence the critical threshold

$$R_{HIGH}/D_{HIGH} = 1 \qquad \text{(equation 2.2)}$$

defines the difference between the collision regime ($R_{HIGH}/D_{HIGH}<1$) and the overwash regime ($R_{HIGH}/D_{HIGH}>1$). In the overwash regime, as runup overtops the dune (or berm crest) water can flow landward decelerating with distance. This gradient in flow leads to erosion of the dune and deposition further landward.

The **inundation regime** is defined by the threshold

$$R_{LOW}/D_{HIGH} = 1 \qquad \text{(equation 2.3)}$$

This regime occurs when the storm-induced sea level rise is sufficient to completely submerge a barrier island, and the flows over the barrier are no longer simple overwash.

Rather, the once subaerial part of the barrier island becomes impacted directly by surf-zone processes.

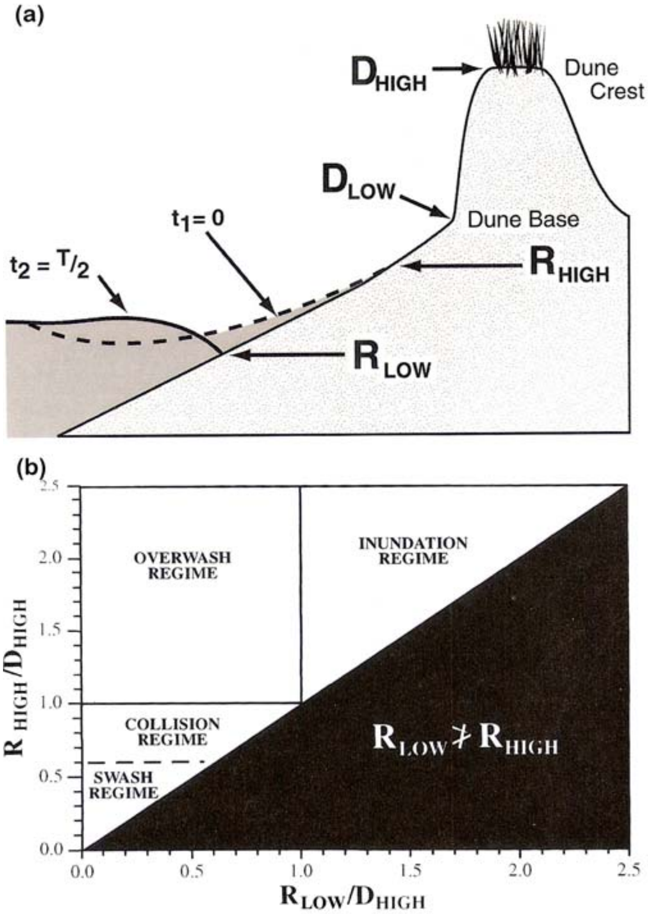

Figure 2.2. (a) Definition sketch describing variables used in scaling the impact of storms on barrier islands; (b) Delineation of four different regimes important to categorizing storm impacts on barrier islands. From Sallenger (2000).

Orford and Carter (1982) defined the relations between overtopping and overwashing with the increase of water volume over the barrier crest. The complementary processes of overtopping and overwashing form part of a continuum of wave/swash-related actions, whereby water and entrained sediment move landward over the barrier crest. According to Orford and Carter (1982) **Overtopping** (in natural systems) may be considered a process in which swash excursions just carry over the crest, causing vertical accretion at the swash-limit in the presence of rapid crestal percolation (Figure 2.3A); **Overwashing** can be considered an extension of overtopping since it requires an increased volume of swash capable of generating a competent, unidirectional flow largely unaffected by percolation (Figure 2.3B and 2.3C). Overtop and overwash processes may occur at the same place on the barrier crest under conditions of increasing or decreasing wave height, rising or falling tidal stage, and waxing or waning meteorological surge (Orford and Carter, 1982).

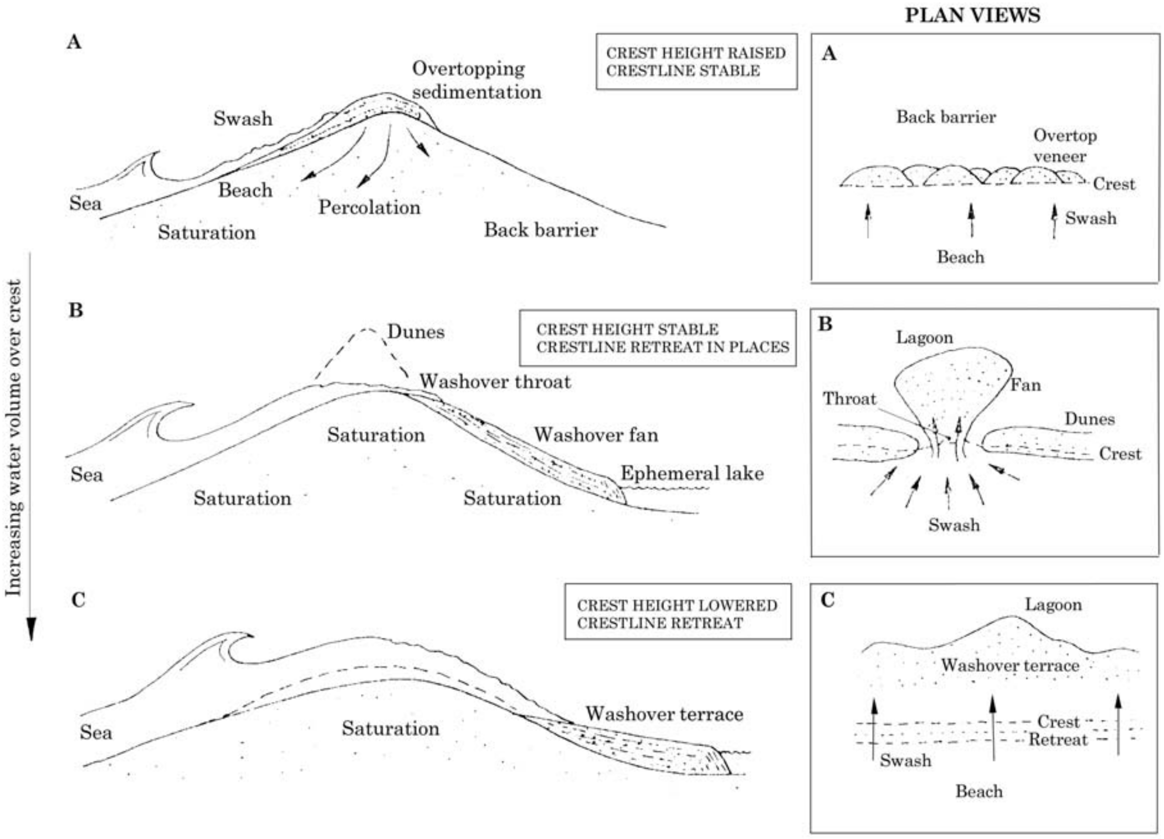

Figure 2.3. The continuum of overtop-washover sedimentation as a function of the increasing water volume passing landward over a barrier crest during a severe storm. With an increasing volume of swash or surge water passing over the crest, net vertical aggradation associated with beach crest overtopping (A) is superseded by distinctive washover fans emanating from throats (B). With major surge volumes the crest is often relocated landwards by overwash, and near continuous washover lobes merge laterally into a washover terrace (C). From Orford and Carter (1982), with the nomenclature of washover morphologies adapted to the definitions of section 2.1.

The differentiation between overwash and inlet formation is by its nature gradational. Overwash represents a minimum value for normal landward transport to the barrier island (Leatherman, 1976). Tidal inlets generally account for the maximum landward transport of sediment in a barrier island system. Inlets permit the exchange of water and sediment between ocean and bay for a longer time interval than that during which the area is influenced by a storm (i.e. overwash). The overwash is ephemeral and generally ends with the storm waning or with the tidal drop. Conversely, the water exchange at inlets is permanent through the entire tidal cycle, and under storm and non-storm conditions. **Barrier island beaching** is an intermediate state between overwash and inlet formation. A breach is a new opening in a narrow landmass such as a barrier spit or barrier island that allows water to flow between the water bodies on each side (Kraus *et al.*, 2002). A breach can lead to the formation of a new inlet or may close naturally by littoral processes with subsequent barrier recovery.

2.3. OVERWASH SEDIMENTARY DYNAMICS

The sediment transport induced by overwash constitutes a major issue in geologic coastal processes because it predominantly moves sand from the beach face to the washovers and backbarrier environments (e.g. Hayes, 1967, Andrews, 1970, Schwartz, 1975, Leatherman, 1976, Figure 2.4 as an example). Overwash sedimentation is episodic, occurring during discrete events of varying magnitude and frequency (Kochel and Wampfler, 1989).

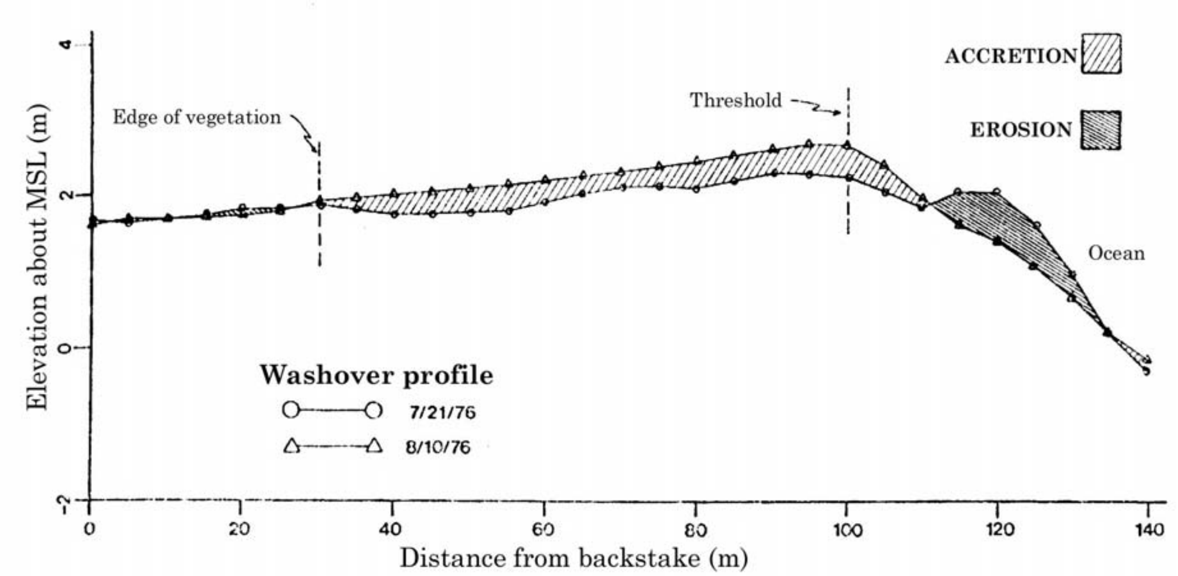

Figure 2.4. Example of a cross-shore profile before and after overwash. Profile on the centre of a washover on Assateague Island, Maryland (U.S.A.), before and after Hurricane Belle, August 9, 1976. From Fisher and Stauble (1977).

Sediment transport during overwash events has been measured through surveys performed before and after a storm (Fisher *et al.*, 1974, Leatherman, 1976, Leatherman and Zaremba, 1987, Guillén *et al.*, 1994, Ramsey *et al.*, 1998, Stone *et al.*, 2004), and also by measuring the washover dimensions and deposit thickness (Schwartz, 1975, FitzGerald *et al.*, 1994, Stumpf *et al.*, 1996, Morton and Sallenger, 2003). Overwash sediment transport on the coast has also been semi-quantitatively evaluated with ground photographs and aerial vertical or oblique photographs by measurements of overwash intrusion, normally identified by the contact between fresh sand and marsh/dune vegetation (e.g. Hayes, 1967, Cleary *et al.*, 2001, Morton and Sallenger, 2003), or by the existence of a debris-line, particularly noticeable in developed coasts (e.g. Rodríguez *et al.*, 1994, Nordstrom and Jackson, 1995; Fletcher *et al.*, 1995, Webb *et al.*, 1997).

The wave height and the surge level that promotes overwash and volume of sediments deposited by overwash can vary significantly (Table 2.1). Existing studies relate storm-induced overwash changes with wave heights from less than 4 m to more than 9 m and surge levels from 0.3 m to 1.6 m (Table 2.1). Volumetric calculations show that under storm overwash conditions the washover has a general positive balance between less than 5 m^3/m and 150 m^3/m (Table 2.1).

The washover intrusions studied by Morton and Sallenger (2003) for 717 washover structures generated mostly by hurricanes in the Atlantic Coast and Gulf of Mexico Coast of U.S.A., varied between 3 m and 927 m. The authors concluded that a washover intrusion of at least 100 m has a probability of occurrence of 67%, whereas a washover intrusion greater than 400 m has a probability of less than 10% (Figure 2.5).

There has been considerable controversy in recent years concerning the relative importance of overwash *versus* aeolian processes in the vertical accretion of barrier islands. Some models were developed with the interaction of overwash and aeolian processes in barrier evolution. Cleary and Hosier (1979) proposed two models of overwash and recovery: “Fine-grained washover model” and “Coarse-grained washover model”. The “Fine-grained washover model” was described as follows:

- Recession of foredunes allows overwash of the ridge with subsequent washover fan formation;
- Herbaceous and arborescent vegetation is removed during overwash events;
- Sediment remobilization on the washover surface and foreshore areas
- Creation of a dune field and re-establish foredune ridge.

Table 2.1. Storm parameters and estimated average overwash-induced deposition.

Storm dates	Ho* (m)	Storm surge/tide (m)	Overwash deposition (m^3/m)	Location	Source
February 9-11, 1973	6.9	0.6/1.7	10.8 – 13.5	Caffey Inlet to Buxton, NC, U.S.A.	Schwartz, 1975
February 9-11, 1973	6.9	0.6/1.7	44.3	Buxton, NC, U.S.A.	Schwartz, 1975
March 22, 1973	5.3	0.5/1.3	4.6	Assateague Island, MD, U.S.A.	Fisher *et al.*, 1974
October 26, 1973	4.3	0.4/1.3	5.4	Assateague Island, MD, U.S.A.	Leatherman, 1976
December 1, 1974	5.1	0.8/1.5	20.2	Assateague Island, MD, U.S.A.	Leatherman, 1976
March 19-20, 1975	3.5	0.3/1.0	2.7	Assateague Island, MD, U.S.A.	Leatherman, 1976
February 6-7, 1978	5.0	1.2/ -	150	Nauset Spit-Eastham, MA, U.S.A.	Leatherman and Zaremba, 1987
October 8, 1990	4.4	0.4/ -	75	Trabucador Bar, Catalunya, Spain	Guillén *et al.*, 1994, Sánchez-Arcilla and Jiménez, 1994
October 29-31, 1991	9.1	1.6/3.1	10	Good Harbour Beach, MA, U.S.A.	FitzGerald *et al.*, 1994
October 29-31, 1991	9.1	1.6/3.1	4.5	Devereaux Beach, MA, U.S.A.	FitzGerald *et al.*, 1994
October 4, 1995	8	- / -	56	Santa Rosa Island, FL, U.S.A.	Stone *et al.*, 2004
September 28, 1998	10	- / -	29	Santa Rosa Island, FL, U.S.A.	Stone *et al.*, 2004

* offshore wave height.

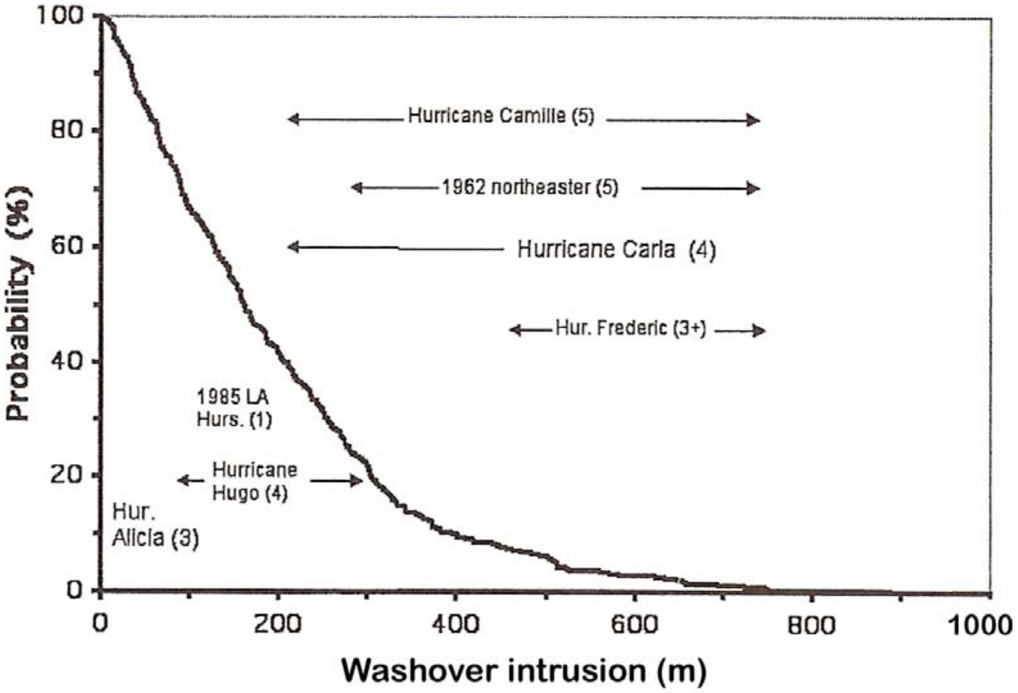

Figure 2.5. Probability curve fitted to the washover intrusion measurements (n = 717) including Hurricanes Hugo (n = 131), Camille (n = 30), Carla (n = 167), Alicia (n = 74), Frederic (n = 31), the 1985 Louisiana hurricanes (n = 84), and the 1962 northeaster (n = 200). Numbers in parentheses represent storm intensity. From Morton and Sallenger (2003), modified with the definitions of section 2.1.

The "Coarse-grained washover model" was described as follows:

- Scarped foredune ridge continually recedes with impingement of storms in area;
- An overwash may occur in a section of narrowed dunes and resultant washover sediments are carried through the dune field onto back-barrier environments, elevating tidal and subtidal environments;
- Continued overwash across the low dune ridge gradually eliminates intervening dunes resulting in washover plain features with low relief;
- Following a period of fair weather conditions, redevelopment and coalescence of foredune ridge occurs.

Godfrey *et al.* (1979) proposed two models of overwash response and retreat for the U.S.A., the "Northeast model" and "Southeast model", based on a geobotanical approach.

- On the Northeast barriers of the U.S.A., an occasional massive overwash will create an extensive surface on which new dunes can form. Rapid growth of *Ammophila* leads to the development of substantial, stable dune lines, that can resist most overwashes.
- On the Southeast barriers of the U.S.A., rapid revegetation of washover fans by *Spartina patens*, and little deflation of overwash deposits, results in more open, flat topography than found in the Northeast. Flat topography leads to an increased likelihood of overwashing.

The work of Inman and Dolan (1989) on the Outer Banks (North Carolina, U.S.A.), Kochel and Dolan (1986) and Kochel and Wampfler (1989) on Assateague Island (Maryland, U.S.A.), Héquette and Ruz (1991) on southeastern Beaufort Sea (Canada), suggested that overwash sedimentation was the primary process responsible for vertical accretion and landward movement of sand on barrier islands. On the contrary, Leatherman (1976) concluded that on Assateague Island the aeolian processes were slightly more dominant than overwash. Kochel and Wampfler (1989) became aware of the importance of the data acquisition interval in the interpretation of the sediment budget. These authors stated that the factors that controlled the relative role of aeolian *versus* overwash sedimentation during survey periods included: (1) the frequency of overwash events; (2) single-event and annual thickness of overwash sedimentation; (3) amount of precipitation; (4) the frequency of precipitation events; and (5) the nature of the wind climate.

The geological significance of overwash, i.e. the importance of overwash in barrier islands formation and evolution over long time scales, is more important to barriers that have narrowed to a critical width (Leatherman, 1979). The onshore migration or **rollover model** is applied to barrier coasts where overwash becomes an important process (Swift, 1975). The rollover is a process where the barrier island migrates landward while maintaining its general shape. Overwash may be the means by which barrier coastlines are preserved through a natural process under the action of storms and relative sea-level rise. However, some authors state that inlet breaching and subsequent flood tidal delta formation is the dominant process for landward migration (e.g. Pierce, 1969; Leatherman and Williams, 1978; Armon and McCann, 1979).

2.4. WASHOVER SEDIMENTS CHARACTERISTICS

As an overwash flow moves through the washover throat or washover terrace, material in suspension is continuously being interchanged with that on the bed. The amount of material in suspension and the rate of exchange is directly related to the turbulence of the flow (Leatherman and Williams, 1977).

The presence of overwash deposits has been described both in modern and ancient sedimentary environments. However, the sedimentary characteristics attributed to these deposits can be variable. One of the structures most commonly referred is the presence of a basal gravel layer (e.g. Davidson-Arnott and Fisher, 1992; Nichol and Boyd, 1993; Anthony *et al.*, 1996). A set of well laminated, sub-horizontal to landward dipping beds is the main sedimentary structure found on overwash stratigraphic sequences (Hobday and Jackson, 1979; Schwartz, 1982; Leatherman and Williams, 1983; Nichol and Boyd, 1993; Davidson-Arnott and Reid, 1994; Anthony *et al.*, 1996, see Figure 2.6). Authors frequently observed coarsening upward sequences attributed to overwash deposits (e.g. Andrews, 1970; Orford and Carter, 1982; Nichol and Boyd, 1993; Ward *et al.*, 1998). However, Leatherman *et al.* (1977) and Masselink and Lessa (1995) described coarsening down sequences that Leatherman *et al.* (1977) associated with the washover throat since high velocity overwash surges resulted in hydraulic stripping of material from the bed. The association with lagoon muds (Andrews, 1970; Schwartz, 1982; Anthony *et al.*, 1996; Ward *et al.*, 1998) or aeolian deposits (Schwartz, 1982; Jelgersma *et al.*, 1995) is another frequently mentioned characteristic.

In siliciclastic dominated sediments the presence of other grains was noticed, sometimes as placers of shells and shell fragments (Andrews, 1970; Morton, 1978; Jelgersma *et al.*, 1995; Anthony *et al.*, 1996) and also of heavy minerals (Hobday and Jackson, 1979; Leatherman *et al.*, 1977).

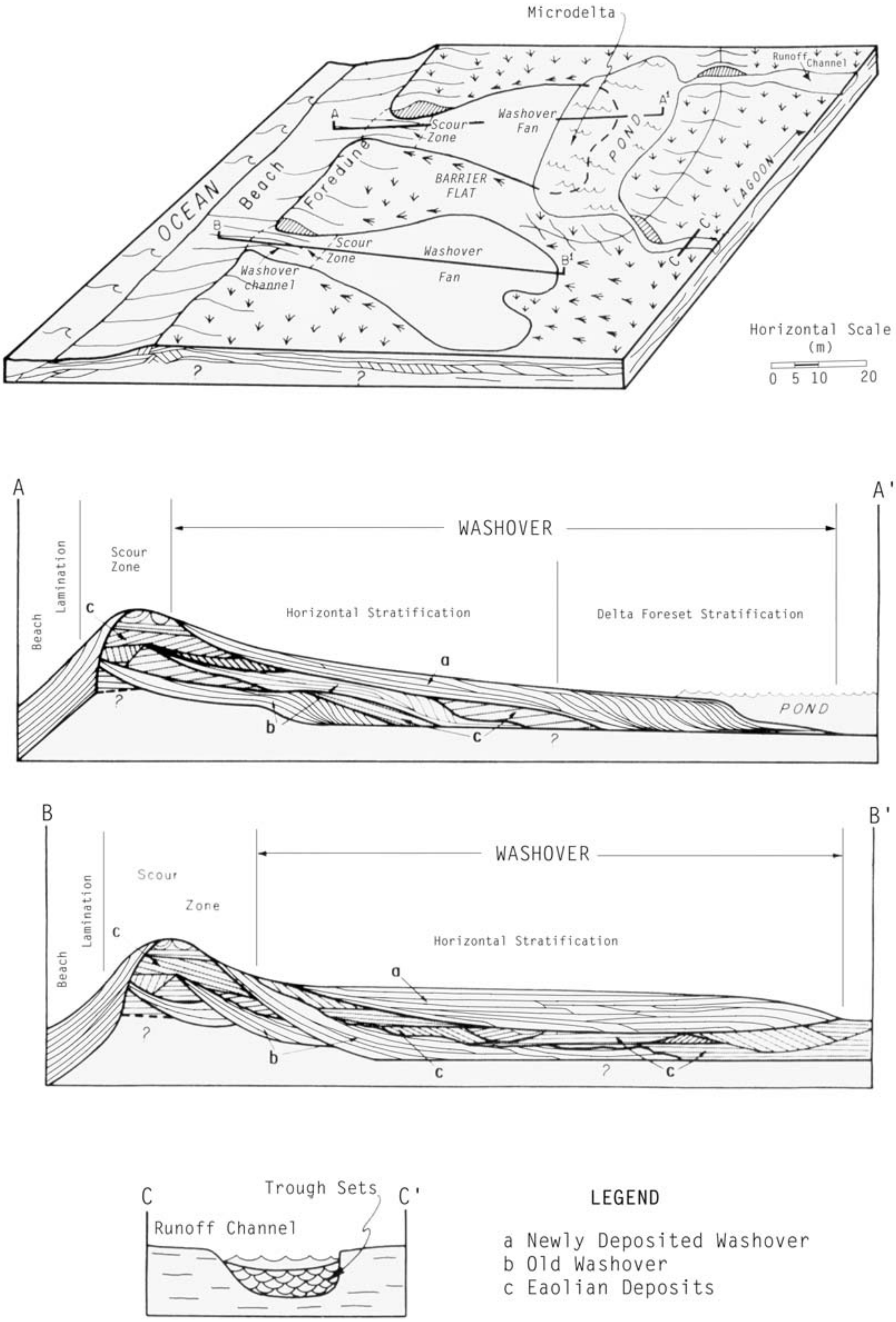

Figure 2.6. Schematic diagram of small-scale washover lobe and their internal sedimentary structures. The sectional views represent the upper meter of the sand-body complex, from Schwartz (1982) that based the scheme in studies made on Outer Banks, North Carolina; Presque Isle Peninsula, Pennsylvania; Arnold Road Beach, California, U.S.A..

In terms of the dominant textural characteristics, coarse sand with large quantities of cobble-size material has been mentioned (Davidson-Arnott and Fisher, 1992; Anthony *et al.*, 1996), however, medium sands have also been attributed to overwash deposits (Kochel and Wampfler, 1989; Nichol and Boyd, 1993; Ward *et al.*, 1998) as well as fine sands (Morton, 1978; Masselink and Lessa, 1995). Both well sorted (Hobday and Jackson, 1979) and poorly sorted (Masselink and Lessa, 1995; Anthony *et al.*, 1996; Ward *et al.*, 1998) sands have been observed. Due to this variety of sedimentary characteristics, the distinct nature of overwash sediments has been a topic of discussion. Schwartz (1982) stated that overwash processes result in a limited, but distinctive set of sedimentary structures. Leatherman and Williams (1983) and Delaney and Devoy (1995) distinguished washover sediments from aeolian sediments on the basis of grain composition and sedimentary structures. Andrews (1970), Masselink and Lessa (1995), and Anthony *et al.* (1996) described distinct textures and structures for several sedimentary environments adjacent or close to overwash deposits. However, Hobday and Jackson (1979) observed that aeolian sands are texturally almost indistinguishable from the barrier washover deposits. Hennessy and Zarillo (1987) stated that the grain-size characteristics of washover deposits are very similar to those of flood-tidal deltas, and Schwartz (1975) concluded that the texture and composition of washover sediments are nearly identical to that of the adjacent storm beach.

2.5. OVERWASH PROCESSES IN THE RIA FORMOSA

Washover dynamics and sediment characteristics were never analysed in depth in the Ria Formosa (Algarve, Portugal), although the importance of overwash processes has been recognised for the sedimentary budget of this barrier system (Dias, 1988; Pilkey *et al.*, 1989; Andrade, 1990). Andrade (1990) calculated that the washovers occupy 25% of the barriers ocean shoreline, and 20% of the lagoonside using field observations and aerial photographs. According to Pilkey *et al.* (1989), overwash processes are dominant in between 0% (Tavira) and 100% (e.g. Cacela) of the ocean shoreline, and between 0% (e.g. Culatra) and 100% (e.g. Cabanas) of the lagoonside.

Three types of washover structures were identified and described by Andrade (1990): *washover lobes*, *washover plains*, and *accreted structures* (when appropriate the nomenclature was changed to the definitions of section 2.1). Single *washover lobes* are elongated and have a shore-normal, sometimes clockwise rotated orientation. The associated intrusions are generally smaller than 100 m, with average mouth width between 15 and 20 m. *Washover plains* are generally associated to the barriers extremes, and occasionally to the coalescence of single lobes. They indicate early development stages and are frequently reworked by waves. *Accreted structures* develop where ephemeral inlets or complete overwash has occurred. Therefore, they are more likely to occur in narrow islands or in islands where the lagoonside is indented by the occurrence of tidal channels.

Andrade *et al.* (1998) analysed the overwash vulnerability in the Ria Formosa Barrier System using a multi-attribute rating technique (SMART). The vulnerability to overwash was described as the product of interaction between erosivity and susceptibility. Erosivity was defined as an attribute of ocean waves and it is related with their ability to surge and overtop a pre-established surface (e.g. the back-beach or a foredune). Susceptibility represented the morphological properties that offer resistance or inhibit the waves to overtop and spill over the back-barrier area or the foredune. Andrade (1990) draw overwash susceptibility maps for all barrier islands of the Ria Formosa based on the foredune height, the horizontal distance between the dune crest and the level -2 m in respect to mean sea level (MSL), the island width in respect to the -4 m MSL, and the type of foredune (Figure 2.7).

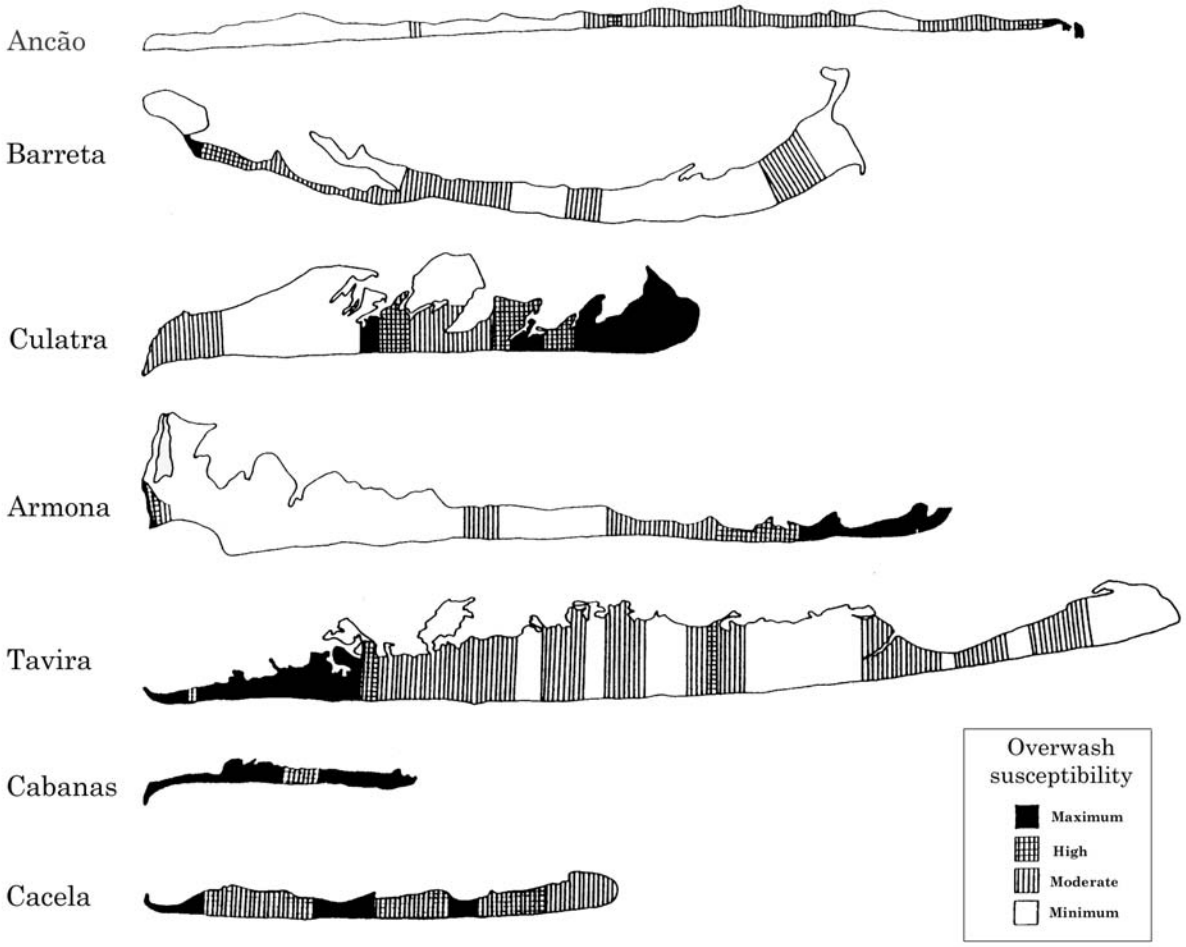

Figure 2.7. Overwash susceptibility maps of the Ria Formosa barrier islands. From Andrade (1990).

Andrade *et al.* (1998) acknowledge that the vulnerability to overwash of the Ria Formosa barrier system was governed by the recent morphodynamics of the coastal barriers, with special relevance for the processes and patterns of barrier accretion, foredune growth and anthropic action. Washovers are often caused by the existence of access paths (footpaths/tractor) to the beach that have been in continuous use by fishermen and tourists for many years (Pilkey *et al.*, 1989).

Andrade (1990) analysed sediment samples collected on recovering washovers, and found that they are mostly composed of coarse sands but also medium sands, poorly sorted, approximately symmetrical, and mesokurtic. They are generally coarser and slightly poorer sorted than dune and berm sediments (Andrade, 1990).

Pilkey *et al.* (1989) stated that overwash was the dominant process bringing sediments to the lagoon shoreline of the narrow barriers. Andrade (1990) concluded that overwash was not relevant for the transference of oceanic sand to the lagoon, however it was important for: (1) the vertical accretion of newly formed island portions, (2) generation of backshore sandy surfaces for embryonic dune development, (3) periodic and intermittent fresh sand supply for aeolian mobilization, (4) generation of deflation corridors with beach sand supply under onshore winds.