# CASE STUDY

## *Esposende – Ofir stretch*

**LOCATION:**

*Esposende/Ofir, Portugal*

**TOPIC:**

*Development Pressures*

**KEYWORDS:**

*Coastal erosion*

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## EXECUTIVE SUMMARY

The coastal stretch between *Esposende/Ofir* is located in Minho littoral, northwestern coast of Portugal, but can be integrated in a wider geographic unit that extends from river Neiva mouth, in the north, to Apúlia, in the south, following a general orientation N-S and having a linear extension of ca. 13.5 km.

This coastal stretch is undergoing severe erosion and there are several areas at high risk due to erosion. Significant beach retreat and dune overtopping and breaching, frequently occur during winter. One direct consequence of the decreased width of beaches and dunes is the raise of the built-up areas vulnerability to erosion impacts; another is the flooding of good arable areas with salt water, and their consequent lost.

Some of those areas at risk were already submitted to coastal engineering interventions. The majority of these mitigation solutions is connected with the need to protect human development along the coast, which in most cases have wrongly developed since decades – many times to close to the shoreline.

The information gathered in this case study provides a good insight into the development pressures, coastal defences, and vulnerability at the coastal stretch of *Esposende/Ofir*. More comprehensive information can be found at Mota Oliveira *et al.* (2002).


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## 1. GENERAL DESCRIPTION OF THE AREA

### 1.1. Introduction

The coastal stretch between Esposende/Ofir is located in *Minho* littoral, northwestern coast of Portugal, but can be integrated in a wider geographic unit that extends from river *Neiva* mouth, in the north, to *Apúlia*, in the south, following a general orientation N-S and having a linear extension of ca. 13.5 km (Figure 1). In great extent, the former unit coincides with the boundaries of the Protected Area of the Littoral Park of Esposende (APPLE). It is mostly a coastal plain with sandy beaches and dunes.

The wider sector of *Caminha-Espinho*, where the stretch in analysis is located, is characterized by the presence of estuaries with sand-spits set in the southern banks, by dunes and by the absence of active coastal lagoons except for the residual *Apúlia* Lagoon.

From the morphological point of view this coastal zone is homogeneous, suffering only significant modifications when going further inland. Here there is an evident contrast between the rock formations of the *Maciço Hespérico* (with over 350 millions years), constituting a scarped granite fossil cliff parallel to the coast, and the littoral plains of schist formations.

In the marine side, the stretch is characterized by rock formations that may emerge during low-tide. Occasionally they also emerge close to the shoreline, especially where the erosion is more accentuated.

### 1.2. Physical Processes

The major storms reaching the northwestern coast of Portugal come from the North Atlantic, mainly between October and March. The wave climate is characterized by average significant wave heights ranging from 2 to 3m, with periods ranging from 8 to 12s and storm significant wave heights exceeding 8m, with periods reaching 16 to 18s. Almost all waves come from the N-W quadrant and the dominant wave direction is NW (~50%). Very occasionally there are waves from the SW.

The local wave conditions differ from those offshore due to the effect of the bathymetry and local phenomena, especially refraction, diffraction and shoaling. These local phenomena mainly affect the direction and height of the waves.

Tides on the Portuguese northwestern coast are of the semidiurnal type, reaching a medium range of 2m and a maximum of 4m. The characteristic values of tides in *Esposende* are (Consulmar, 1999):

- Average level: + 2.00m (HZ);
- Spring tides:
  - Maximum high tide: + 4.07m (HZ);
  - Minimum low tide: + 0.58m (HZ);


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- Mean high tide: + 3.42m (HZ);
- Mean low tide: + 1.02m (HZ);

¬ Neap tides:

- High tide: + 2.71m (HZ);
- Low tide: + 1.58m (HZ);

The tide and wave values indicate that this is a macro-mesotidal tide dominated coast. Meteorological tides are not significant outside enclosed waterbodies, but they can contribute to increased onshore consequences when occurring simultaneously with spring astronomical tides or severe storms.

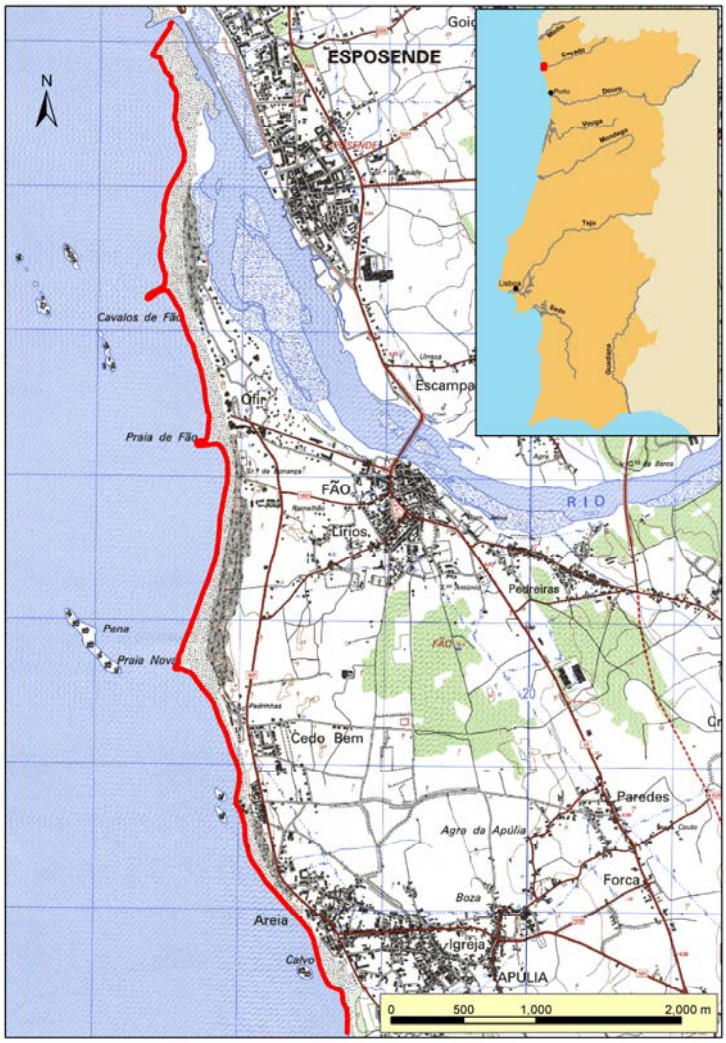


Figure 1. Location of the coastal stretch of Esposende/Ofir.


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Longshore transport is dominant along the shoreline and is mainly wave induced. The dominant direction is mainly from north to south. The sedimentary cell is of ca. 20km from the river *Cávado* mouth to *Póvoa do Varzim* harbour and the main source of sediment is the river *Cávado*. Beaches in the process of erosion provide another possible source of sediments.

### 1.3. Development Pressures

The natural dynamics of the shoreline has greatly constraint human settlement along the coastal stretch of *Esposende*/*Ofir*. The most ancient signs of human presence here date from the Paleolithic period.

The river *Cávado* has been always strategically used as a mean of transportation, and therefore human development along its banks has occurred in different periods of the history. This is particularly true for *Esposende* and *Fão* where important commercial and fishery ports are settled, since the XVI century. With the objective of improving the navigational conditions of the river mouth, several measures were implemented and structures were built. For instance, around 1800, a wall was built in the last stretch of the river; this wall was re-built several times during the XIX and XX centuries.

Despite the adversities posed by the environment, this coastal zone provides interesting resources, which justify the search for implementing the necessary conditions to attract investment to areas that were traditionally occupied by fishermen communities (e.g. *Apúlia*, *Cedobém* and *Pedrinhas*).

Over the last decades, tourism has grown in relation to the other economic sectors. It represents a significant share of local income therefore imposing changes to the coastal zone with relevant impacts; for instance, facilities were created close to the shoreline not always following the best territorial planning strategies.

Most of the built-up areas along this coastal stretch are either illegal, some of these corresponding to former fishermen-agriculture communities, or recent house constructions, the majority of which for seasonal or secondary use.

This development pressures have generated significant impacts upon the environmental and landscape equilibriums of the coastal area described in this case study (e.g. the number of constructions built-up over the dunes, being these houses, tourism facilities or roads).

On the other hand, the natural dynamics of the coast, and especially erosion, is jeopardizing human development along the coastal stretch of *Esposende*/*Ofir*.

### 1.4. Coastal Defence Structures

The coastal stretch described in this case study is undergoing severe erosion and there are several areas at high risk of erosion. Some of those areas were already submitted to coastal engineering interventions. The majority of these mitigation solutions is connected with the need to protect human development along the coast, which in most cases have wrongly developed since decades – many times too close to the shoreline.


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Legend:

(a) river *Cávado* mouth;
(b) northern part of the sand-spit;
(c) northern dique;
(d) longitudinal dique (right bank);
(e) *Esposende*;
(f) Marina and fisherman harbour;

Figure 2. Mouth of Cávado and southern coastal stretch
(Orto-photograph: INAG, September 17, 2001).


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Legend:

(h) curved groyne;
(i) wetland;
(j) houses of *Ofir*;
(k) *Ofir* towers;
(l) *Ofir* hotel;
(m) *Ofir* groyne;

Figure 3. Southern segment of the sand-spit
(Orto-photograph: INAG, September 17, 2001).


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Legend:

(o) *Pedrinhas* village;
(p) *Pedrinhas* groyne;

Figure 4. *Pedrinhas* segment
(Orto-photograph: INAG, September 17, 2001).

From the river *Cávado* mouth downdrift the existent defences are as follows:

- ¬ Northern dique of the river *Cávado* mouth (right bank), Figure 2;
- ¬ Curved groyne between the *Cávado* sand-spit and *Ofir*, Figure 3;
- ¬ *Ofir* groyne (southwards the hotel), Figure 3;


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¬ *Pedrinhas* groyne, Figure 4;

¬ *Apúlia* groyne (regularization of the small stream), Figure 5;


Legend:

(q) *Cedobem* village;
(r) *Wind mills*;
(s) *Apúlia*;
(t) *Apúlia groyne and small stream.*

Figure 5. *Cedobem/Apúlia* segment
(Orto-photograph: INAG, September 17, 2001).


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Mota Oliveira *et al.* (2002) includes the houses over the *Cávado* sand-spit, the built-up areas of *Ofir* and the *Pedrinhas* village in the former set of coastal defences. These built-up areas are established too close to the shoreline constituting indeed the first line of defence for several of inland areas.

## 2. VULNERABILITY AT THE *ESPOSENDE*/*OFIR* COASTAL STRETCH

### 2.1. Introduction

The coastal stretch of *Esposende*/*Ofir* is undergoing erosion. Significant beach retreat and dune overtopping and breaching, frequently occur during winter. One direct consequence of the decreased width of beaches and dunes is the raise of the built-up areas vulnerability to erosion impacts; another is the flooding of good arable areas with salt water, and their consequent lost.

As in many other locations worldwide, conflicts are only raised where there are populations, economical assets or natural habitats at risk and/or areas prone to coastal flooding. Hence, erosion peaks are mostly considered important when posing threats to populations. This was the case of 1992, when the *Cávado* southern sand-spit breach, and for a while the estuary had two inlets. Also by this time, deep morphological changes have occurred in the sand-spit, and sand banks have formed affecting significantly the navigational conditions of the access channel.

Generally speaking, the stretch in study is changing since several decades. So far, three studies about this segment of the coast have been performed. More recently, in October 2001, the Water Institute (INAG) has asked a group of specialists to elaborate a technical/scientific report characterizing and typifying the vulnerability/safety of the built-up areas in *Ofir*, with basis on the risk associated to coastal dynamics. This report is included in Mota Oliveira *et al.* (2002).

The first of the above mentioned studies was performed by Hidrotécnica Portuguese in the late 80s. This study has evidence that *Esposende* beach is in a stable condition and has even grown after the construction of the north groyne of *Cávado* mouth. Unlikely the beach of *Ofir* where it was observed the following:

- ¬ from the 70s onwards erosion has significantly progressed southwards the *Cávado* mouth. According to this study, the average erosion rate was 0.4m/year between 1923 and 1950, and 2m/year between 1950 and 1980. Contrary to what was expected, the erosion phenomena was intensified with the construction of the groyne of the sand-spit of *Cávado*, about 4m/year were lost between 1983 and 1987 corresponding to a lost of about 36,500 $m^3$/(km year) of the ca. 46,500 $m^3$/(km year) volume of sediments accumulated in the period between 1980 and 1983.
- ¬ between the north groyne of *Cávado* and southwards the hotel of *Ofir* (Figures 3 & 6), contrary to the erosion rates of 0.2m/year between 1923 and 1950, a lost of ca. 1m/year has occurred in three decades, between 1950-1980; a new accretion period, related with the construction of a groyne southwards the hotel of *Ofir* was initiated in 1983; by this time, the shoreline growth was about 5m/year however today the shoreline is again experiencing erosion estimated at a lost of ca. 0.8 m/year.


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¬ according to Hidrotécnica (1988), the coastal stretch between the groyne of Ofir and the Pedrinhas one suffered significant retreat in 1976/77 and 1987 and less significant between 1980 and 1983; southwards the groyne of Ofir the ongoing erosion is more intense than in the rest of the stretch.

Figure 6. *Ofir* towers and hotel
(photo: Francisco Piqueiro, November 15, 2000).

Another study was performed by the Hydraulics and Water Resources Institute (IHRH) of the Faculty of Engineering of the University of Porto (FEUP) with basis on a comparison of topographic surveys from the years 1987 and 1994. Main results of this study are as follows (IHRH, 1994):

¬ in a stretch of 400m length, north and south the *Pedrinhas* groyne (Figure 4), the bathymetric 0m has retreat, in a range of 22 to 44m; the bathymetric +2m has retreat, in a range of 16 to 50m southwards the groyne and progressed in the northern segment; finally, the bathymetric +5m has retreat, in a range of 7 to 42m.

¬ in a stretch of 700m length, close to the *Ofir* towers (Figures 3 & 6) and southwards the groyne close to Hotel of *Ofir*, there was a generalized retreat of the -5, -2, 0, 2 and +5m bathymetries, with the exception of the +5m which progressed north and immediately south the groyne. Table 1 gives values of bathymetries variation between 1987 and 1994.


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Table 1. Bathymetries variation between 1987 and 1994 [m].

| Parallel | Bat -5 | Bat -2 | Bat 0 | Bat +2 | Bat +5 |
|---|---|---|---|---|---|
| **205 700 (N tower)** | -55 | -10 | -15 | -18 | -10 |
| **205 600 (S tower)** | 0 | 0 | -48 | -26 | +8 |
| **205 500 (N groyne)** | 0 | -10 | -56 | -15 | +18 |
| **205 400 (S groyne)** | -95 | 0 | -35 | -19 | +14 |
| **205 300** | -5 | 0 | -15 | -18 | -8 |
| **205 200** | -48 | -17 | -21 | -19 | -17 |
| **205 100** | -76 | -38 | -33 | -25 | -28 |
| **205 000** | -76 | -26 | -54 | -35 | -30 |

¬ in a stretch of 300m length, in south Apúlia (about 2 km south the groyne of Pedrinhas), from 1986 (when the groyne at the mouth of the small stream of Apúlia was built) to 1994 it can be observed that the bathymetric +2m has in average maintained its position and the bathymetric +5m has moved seaward (maximum 128m). On the contrary, between 1990 and 1994 a generalized retreat of those bathymetries was observed, indicating that "*the accretion caused by the groyne has decreased in consequence of the drastic reduction of the volume of sediment transported by the littoral drift currents*".

The third study, which has given basis to Mota Oliveira *et al.* (2002) report, was made upon a comparative analysis and interpretation of aerial photography (at approximate scale of 1:8,000), from 1996 and 2001 (aerophotogrametric of the area performed by INAG). The former comparison permits to verify that within this period of five years the coast was actively eroding, fact which was reflected in deep changes in beach and dunes morphology. The significant retreats southwards the groynes of Ofir and Pedrinhas, gives particular evidence of this erosion; from distance measurements of the dune crests the average is between 3 and 5m/year.

Dune overtopping is also a frequent phenomena and a widely visible one, in the low-lying areas (e.g., at the soccer field located in the south of Hotel *Ofir*), in the mouth of small streams and/or wind or pathway breaching through the dunes. Generally speaking, the importance of dune systems in the wider context of the hinterland areas is considerable, as it constitutes a buffer zone between lowlands and the sea, avoiding low lying coastal plains flooding. From the observation of vertical aerial photography of September 1996 and September 2001, as well as other historic data, is possible to delineate some areas prone to coastal flooding, namely in the north of *Cávado* mouth, in the sand-spit, and southwards the groyne of *Ofir*.

## 2.2. Vulnerability Assessment

### *2.2.1. Introduction*

The sand-spit of *Cávado* is 1800m-long, measured from the Ofir groyne to the river mouth of Cávado. On its northern part, closer to the groyne, the beach is maintaining its width or enlarging, which has lead the dune to move seaward. On the contrary, closer to the mouth of river Cávado mouth, the sand-spit is showing some instability, which will furthermore aggravate due to the actual conditions of poor sediment availability.


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Several intervention scenarios for this coastal stretch were defined:

S1: coastal defences without repair or maintenance;

S2: coastal defences with maintenance after repair;

S3: removal of all existent defences;

S4: removal of all existent defences and artificial sand nourishment of beaches;

S5: change of the river Cávado mouth;

S6: use of dredged sands from the estuary in the artificial nourishment of beaches;

S7: reinforcement and repair of existent defences;

S8: new coastal defences;

S9: use of off-shore sand sources in the artificial nourishment of beaches;

S10: use of multiple interventions;

### *2.2.2. Urban area of Esposende*

The urban area of *Esposende*, especially the maritime promenade and the first line of houses, is not totally exempt of risks related with coastal flooding. This flooding can be caused in first instance by the *Cávado* sand-spit breaching, connected to abnormal conditions: sea storms, exceptional sea levels and eventually river floods. Obviously the risk to the urban area of *Esposende* raises as the breaching length grows.

### *2.2.3. Built-up areas of Ofir*

The built-up areas of *Ofir* are sparsely located along the spit. The most vulnerable zone, and the one which raises more concern in the *Ofir/Apúlia* coastal segment, is an area of about 850m length where a set of buildings is located. This set, constituted by some houses within some 500m length, three towers and the more advanced area of the Hotel *Ofir*, is currently in the limit of the beach. Two groynes, about 1km away from each other, of which the south one is implemented close to the Hotel, have been able to give some reasonable physiographic stability to this critical stretch.

The conditions of poor sediment availability jeopardize these first line built-up areas, especially in the scenario where no additional interventions are anticipated. Generally speaking, on average sea conditions, and in the near future, it is not expected security to be in threat; however, for abnormal ones it is prudent to admit that the existing defences may not be able to maintain a satisfactory level of security.

### *2.2.4. Pedrinhas and Cedobem Villages*

In several of the above-mentioned intervention scenarios, the *Pedrinhas* village can suffer significant losses and even disappear in some stretches. In the longer run, if defences are maintained the built-up areas can be safely protected but the frontal tendency is to disappear.


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On the contrary, the *Cedobem* village shoreline will continue to follow its natural dynamics in a slow regressive tendency. The final shoreline position will depend on the net value of sediments transported by the littoral drift current.

### *2.2.5. Built-up areas of Apúlia*

The best way to protect the built-up areas of *Apúlia* was to have an enlarged beach in front of it. This is highly depending upon what is done updrift, according to the different scenarios proposed. On the other hand, the graoyne at the mouth of the small stream of *Apúlia* have contributed to beach enlargement but the degradation it suffered in recent years justifies its less influence in beach accretion.

### *2.2.6. Northern area of river Cávado mouth*

Some years ago, there were several houses at risk in the northern area of river *Cávado* mouth but with the increasing of the north breakwater length, which facilitates the entrapment of sand in this area, the shoreline is now in a position that offers a higher level of safety to those houses.

### *2.2.7. Southern area of Apúlia*

The southern area of *Apúlia* is showing signs of a certain instability since several years due to erosion, which is more severe in the coastal stretch closer to the *Apúlia* small stream but still visible along the whole stretch up to *Aguçadoura*.

## 3. OUTLOOK

The coastal area described in this case study includes the former Area of Protected Landscape of the Littoral of Esposende (APPLE – *Área de Paisagem Protegida do Litoral de Esposende*). Created in 1987, this protected area has been enlarged and transformed in July 21, 2005 into the Natural Park of the North Littoral.

This new coastal management unit develops along 18km of coast from the river Neiva mouth to southern *Apúlia*, encompassing 8,836ha landward and 7,637ha seaward. In May 2006, a Ministry Council has approved the development of a plan for the spatial planning of the park. This plan will aim at the sustainable management of the natural park, by regulating uses and activities in the light of the safeguard of natural resources, and will have to deal with significant problems – mainly related to coastal erosion impacts and urban development along the coast.

One of the most important problems the plan will have to deal with is the potential breaching of *Cávado* sand-spit. Since late 2005, the dune ridge has lost ca. of 400m, which added to the several already lost in previous years' leads to conclude that the city of *Esposende* is increasingly more vulnerable to sea attacks.


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However, it is not only the spit that is undergoing severe erosion inside the coastal stretch in analysis. The shoreline regression and beach width decreasing can be observed practically along the entire stretch. This situation has motivated the construction of some coastal defences.

Indeed, the region has unique characteristics of landscape, natural resources, among others which attract the population settlement, not always in the safer places neither in the best conditions of implementation.

Hence, it is anticipated that the existing defences will undergo monitoring and maintenance despite the fact that the managed realignment is being put into thought in some of the areas.

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