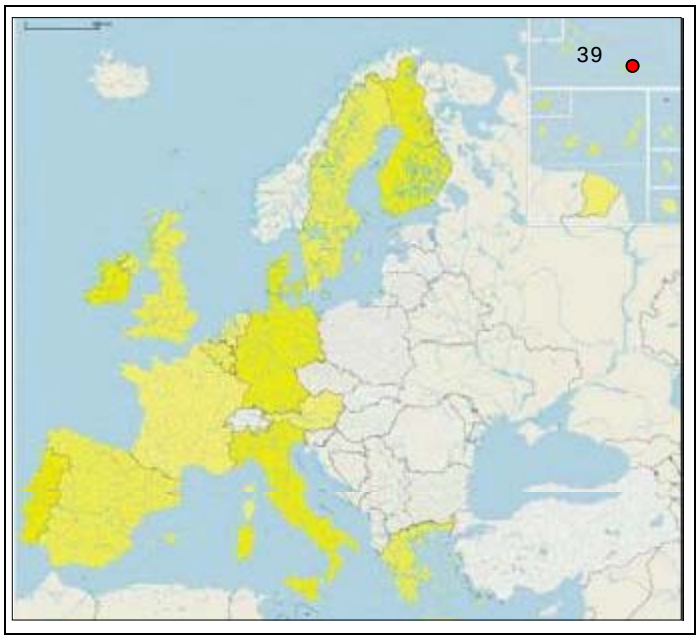
AZORES ISLANDS
(PORTUGAL)



Contact:

Fernando VELOSO GOMES
Francisco TAVEIRA PINTO

Instituto de Hidráulica e Recursos Hídricos - IHRH

Rua Dr. Roberto Frias, s/n
4200-465 Porto

e-mails:
vgomes@fe.up.pt

fpinto@fe.up.pt

1. GENERAL DESCRIPTION OF THE AREA

The Azores archipelago is located between the latitude 37º to 40º N and the longitude 25º to 31º W, extending for 480 kilometres in northeast-southeast direction. This group is formed by nine islands, and their origin it is directly related with the tectonic movements of three plates, the African, the American and the Euroasia. The Azores is located in the microplate of Azores and demarks the frontier of these three plates (Morton, B., *et al*., 1998).

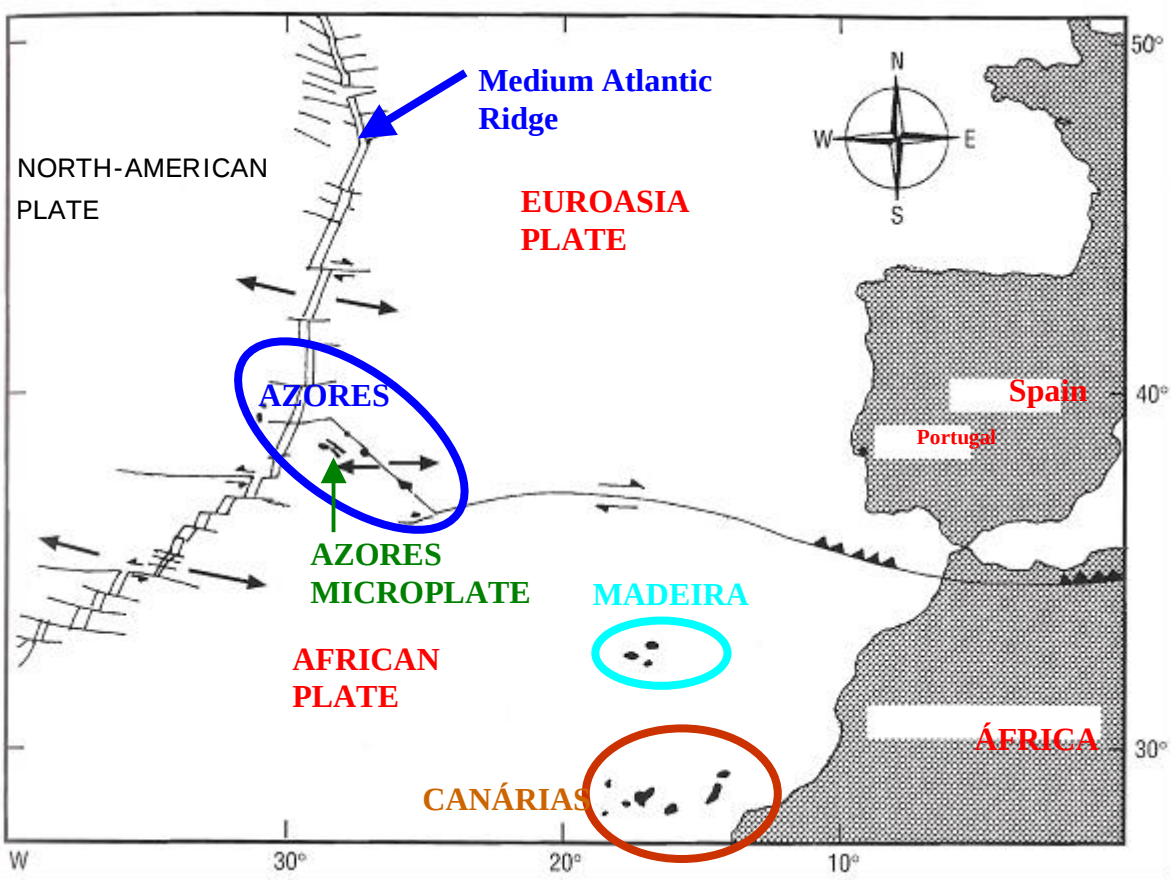


Fig. 1: Location of the Azores archipelago (Morton, B., et. al., 1998).

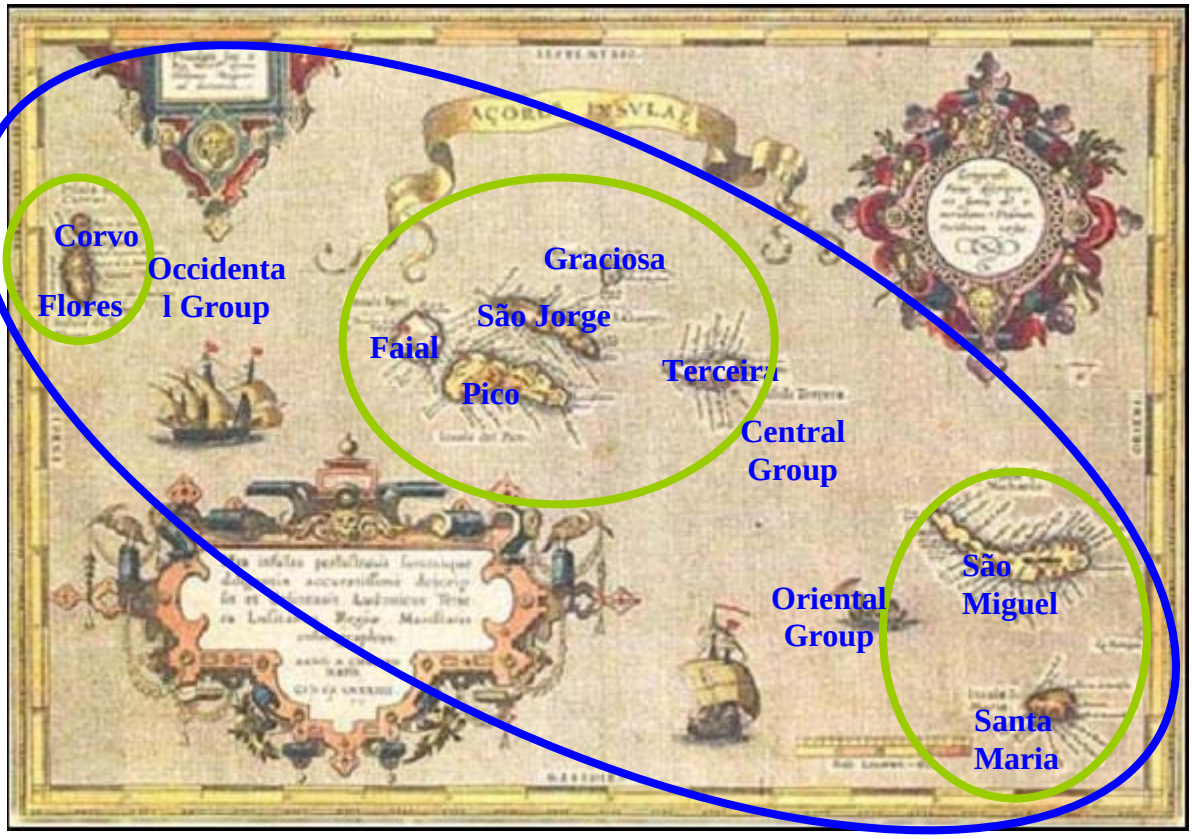


Fig. 2: Location and Distribution of the nine islands by the three groups.

1.1 Physical processes

1.1.1 Classification

These nine islands are divided in three groups – the Oriental group, with Santa Maria and São Miguel; the Central group, with Terceira, Graciosa, São Jorge, Pico e Faial; and the Ocidental group with Flores and Corvo (figure 2). According with Morton et al., 1998, the first two groups are located mainly in Azores microplate and the last group in American plate. These islands have a volcanic origin, composed mostly by basalts, pillow and stone pumice. The volcanic episodes are recorded in all the islands, with the last big episode to happen in 1957-1958 in Faial, where the island increased 1 km lenght. More recently, in 2000, occurred a submarine volcanic episode at Terceira island west side.

1.1.2 Geology and coastal classification

The geology of Azores is complex not only because involves volcanic phenomenon, but also due to the movement of the oceanic plates. This archipelago is a new one in a geological scale, with a different distribution in the Atlantic Media Ridge. The islands of Flores and Corvo are located in the American Plate that is moving to west. The rest of the islands are located on the east side of the Ridge.

None of this existed around 225 million years ago, when the movements that would produce the Atlantic Ocean, the Atlantic Media Ridge and the Azores Archipelago started (Morton, B., *et al*., 1998). The Azores islands are composed mainly by volcanic rocks, predominantly basaltics lavas and trachytics deposit of stone pumice. According to Morton, B., *et al*., 1998, the oldest island is Santa Maria, with 97 km^2 of area, and is more stable in tectonic terms. This island is dominated, on the north side, by high cliffs reaching 350 m above the sea level (figure 3). On south coast, there sandy beaches, reflecting the protect nature of this side of the island (figure 4).

Fig. 3: North coastal aerial view (Filipe Jorge, 2000).

Fig. 4: Formosa beach aerial view (Filipe Jorge, 2000).

São Miguel is the biggest island of the Azorean archipelago with an area of 750 km^2. The coastal zone varies between basaltic platforms, sandy beaches and high cliffs (figure 5). This island is essentially dominated by five calderas with volcanos. Two of them are already extinct, Pico da Cara and Povoação, and the other three are considered active but at sleepy, form the mainly highlands of islands. These three volcanos are – Água de Pau, 947 m height, Sete Cidades with two lagoons inside, Green and Blue lagoon, and Furnas with hydrothermal waters. These two islands form the oriental group of Azores archipelago.

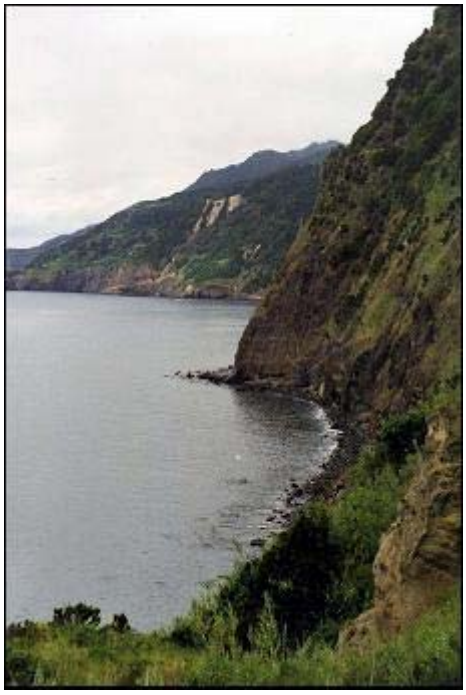


Fig. 5: Eroding cliffs on the São Miguel coast zone (F. Taveira Pinto, 2002).

The Graciosa, is one of the newest islands of archipelago, located more to the north of the Central group with the lowest average elevation in the Azores and the second smaller in size (62 km^2). The coastal zone is characterized by small cliffs through the north coast with 10 m high, by local outbreaks that reach 100 m high on the northeast and southeast areas. However, in the southwest part the cliffs could exceed the 300 m high. This island has also a sandy beach named Praia, located in east-centre (figure 6).

Fig. 6: Praia Sandy beach aerial view (Filipe Jorge, 2000).

Terceira island has an elliptical form with 29 kilometres length and 17 kilometres width, located 150 kilometres northeast of São Miguel. The coast line of this island is characterized by cliffs that varies from small to moderate heighs interrupted by small bays, above all through east and south sides (figure 7).

Fig. 7: Terceira south coast view (J. Pais Barbosa, 2002).

The northern coast is constantly submitted to the wave action, and on the other hand, the eastern part is protected from these actions. This way it was possible to appear a wetland, Paúl da Praia da Vitória, that attract many kind of sea birds exclusive from this place, and form a long beach with 3 kilometres length; unique in Azores, and with a dune field of 13 metres width. In our days this wetland does not exist, it was drained and the habitat disappeared some decades ago as well as the beach, only remaining a small strip of sand (figure 8).

Fig. 8:Praia da Vitória aerial view (Filipe Jorge, 2000).

The longest (56 kilometres) and narrow (8 kilometres) island of São Jorge is located south of Graciosa and at southeast of Terceira. This island has two small islands, in each extremity, named Topo and Rosais, located on east and west extremities respectively (figure 9 and 10).

Fig. 9: Aerial view of Topo small island (Filipe Jorge, 2000).

Fig. 10: Aerial view of Rosais small island (Filipe Jorge, 2000).

The north coastal zone is characterized by great slopes, cliffy, and the inexistence of protected bays, making this coastal side of São Jorge inaccessible with the exception of small number of *fajãs*. An example of these *fajãs* is the *fajã* of Cubres and Santo Cristo (figure 11), that are local slope field above a basaltic platform, produced by land slide of adjacent cliffs when earthquakes occured. The south coast of this island, although also constituted by cliffs, has lower heights with numerous re-entrances and bays (figure 12).

Fig. 11: São Jorge north side - Fajã de Santo Cristo (J. Pais Barbosa, 2002).

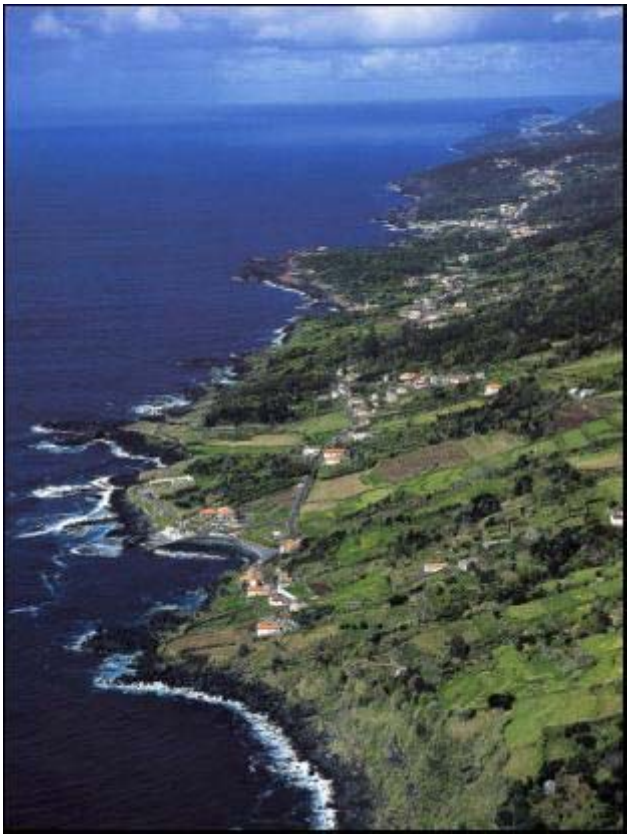


Fig. 12: São Jorge South side aerial view (Filipe Jorge, 2000).

The Pico island is located southwest of São Jorge, and separated by a deep and narrow channel. This island is the second one in area with 436 km^2, dominated by the volcano that reach 2351 m of height (figure 13). The coastal areas almost don't have high cliffs, characterized by the low lava areas (figure 14).

Fig. 13: View of Pico volcano (J. Pais Barbosa, 2002).

Fig. 14: Pico island north side view (J. Pais Barbosa, 2002)

This island was joined formerly to Faial, however is now separated by a channel, not too deep, with five kilometres width. Faial has an area of 173 km^2, with a central “caldera” that reach 1043 m height. In this island in 1957 and 1958 occurred important eruptions on “Capelinhos” volcano that increase one kilometre to the length of the island (figure 15).

Fig. 15: Capelinhos volcano aerial view (Filipe Jorge, 2000)

The last two islands belong to the occidental group that, named Flores, with 143 km^2, and Corvo, the smallest one with only 17 km^2 of area. These islands are relatively distant from the others, for example 234 kilometres of Faial and they are the most occidental territory of Portugal and Europe. The coastal zone of Flores are occupied by abrupt cliffs (figure 16) and water falls and the Corvo island, most difficult to have access, with high cliffs with exception on the south side (figure 17).

Fig. 16: Flores abrupt cliffs view (Filipe Jorge, 2000).

Fig. 17: Corvo aerial view (Filipe Jorge, 2000).

1.1.3 Morphology

Topography and bathymetry

The topography of these islands, as referred before, is made of high balsaltic cliffs, in some cases very abrupt and in others alternating with a lower coast and bays. These lower coasts generally are located in areas more protected from the sea actions and in many cases forming sandy beaches. The sea bathymetry is dominated by a very irregular submarine volcanic relief with abrupt slopes. These islands grown directly form the bottom of the ocean implanted in small plate. These islands don't have continental platform that made the bottom of the ocean to vary quickly at a small distance from the coast line, from small depths to hundreds of metres (figure 18).

1.1.4 Physical processes

Wave Climate

There are any buoys to obtain records on the oceanic waters of the Azores Archipelago. In the Atlantic North, at North of Azores, the significant heights (mean of the higher 1/3) distribution is dominant in the range of 1 to 6 m. The percentage of occurrence of waves higher than 6 m indicate a very energetic wave climate and the most probable existence of significant waves higher than 12 m. The maximum wave heights can reach 1.8 times the significant wave heights. The medium wave periods occurs in the range of 6 to 12 seconds. As it is physically predictable, to higher significant waves correspond higher annual medium periods. This way, periods higher than 12 s correspond significant wave heights higher than 9 m. In the North Atlantic, at North of Azores, the wave direction sector between S and NW is the one with the higher percentage of occurrences.

This distribution is locally changed by shoaling, refraction, diffraction and reflection phenomena thus serving just as indication. There are areas partially sheltered, at least when considering some quadrants due to the existence of natural formations (the "pontas") or artificial structures (e.g. breakwaters).

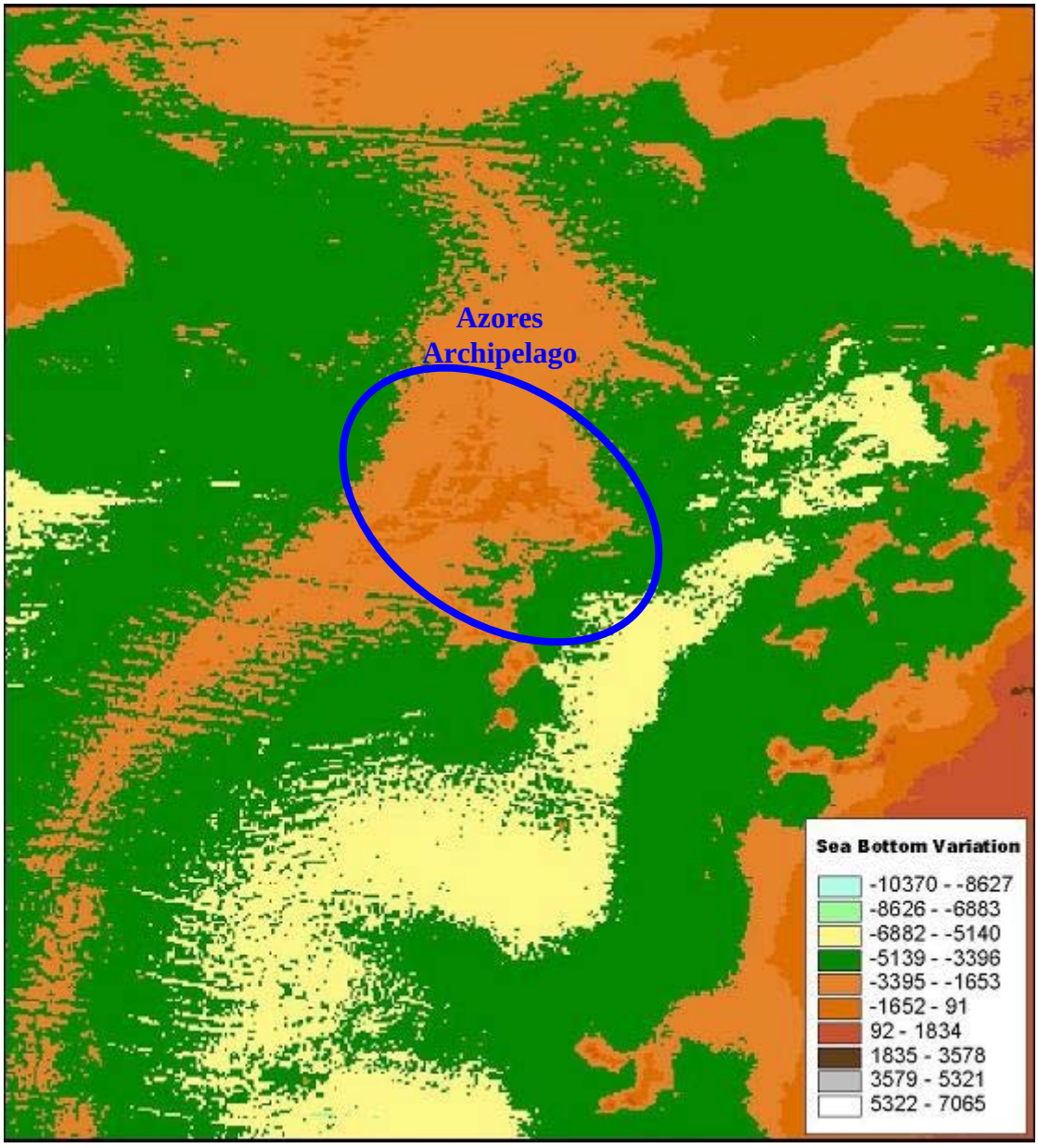


Fig. 18: Study area bathymetry (based on Large Marine Ecosystem).

The shoaling and refraction phenomena occurs due to the interaction between the waves and the bottom, locally aggravating or disaggravating the wave heights. The diffraction occurs around obstacles during wave progression (in an island, a cape, a “ponta”, a rock). The obstacle offers some shelter. Reflections are most stressed in vertical or very steep walls (rock cliffs, docks, retaining walls). Only through the elaboration of wave plans, using numerical models and having available detailed topo-hydrographic information, is possible to determine which local values of the directions, heights and wave length should be used along the island perimeter. This modelling has been made at least for the locals where the two commercial harbours are located. The bays and inlets offer some natural shelter against the waves coming from certain directions.

The significant wave heights vary according to the season. This way, the significant wave heights are higher from October to March when comparing to the values occurring between April and September. Other wave data in the Region can be found in the *Ocean Atlas of the North Atlantic Ocean*, in General Directorate of Harbours reports on the wave observations on Vitória beach (the older are dated from 1970, 1971, 1972 and 1973), in the *Water Wave Report* and in the *Technical Magazin nº 340* (IST, author Reis de Carvalho). This last reference titled *Vitória Beach Harbour, Damages in the Breakwater caused by the 26th-27th December 1962 Storm*, demonstrates that the history of damages and destructions in Azores, particularly in the Vitória beach, is not at all recent.

Actually, the two breakwaters of Vitória beach are deeply damaged which suggest problems with their conception, design and construction due to the high energetic level that they are submitted. In the beginning of the 80's, the *General Plan for the Vitória Beach Bay exploitation and valuation* (Hidrotécnica Portuguesa) selectet the value of 7.5 m, as the significant wave height with most probability to happen on a return period of once in fifty years, for the design of the exposed layers of the breakwater. The simulated local directions were between NNE and SSE and the wave periods in the range of 7 to 14 sec. However, is very likely that these values wave underestimated.

Tidal Regime

The astronomic tide is regular of the semidiurnal type. The Hydrographic Institute provides a daily prediction for the Angra do Heroísmo harbour and for the Vitória beach (considered secondary in relation to the first).

The harbour works have been designed considering:

- Maximum high spring tide: + 1.80 m (HZ)
- Maximum low spring tide: + 0.20 m (HZ)

The meteorological tide (over elevation due to wind and wave persistence or significant atmospheric pressure variations) assumes values that vary slightly along the coast. It is on the inserted coastal waters (bays) that the meteorological tides can assume oscillations with more significance. Nevertheless, there is no information regarding the meteorological tide. The overlapping of the astronomic tide with the meteorological tide should increase the previous mentioned tide values at least for + 2.00 m (HZ) and HZ.

Wind Regime

The winds are associated with the wave generation (surges), the oceanic and coastal currents generation as well as the aeolian currents over the shoreline. The wind velocities have a seasonal character similar to the waves. The available statistical elements concerning the wind regime on the North Atlantic at North of Azores show that the probability of exceeding wind velocities higher than 10 and 16 m/s is 48% and 9.4% respectively. The wind rose sector with most probability of occurrence is between SE and NW, which is practically the same as for the waves. This distribution is locally influenced by the orography, that can produce vorticity, ascending currents and on shelter areas. Winds with higher velocities (more than 18 m/s) occur with higher frequency coming from the W quadrant. Higher wind velocities are associated with higher wave heights.

Sea Level Rise

There are no records related with sea level rise in the Azores archipelago.

Sediment transport

The inexistence of significant sandy beaches, dunes, sand spits and estuaries in Terceira island, means that its geological formation and geographic configuration do not promote great sand movements along the shoreline. However, there are significant mass movements, rock falls and the torrential regimes of small riverbanks. There are not though available data on these phenomena.

For its specificity it's important to refer the case of Vitória beach bay. The phisiography of the Vitória beach bay has suffered some changes due to the implantation of the harbour structures. With the construction of a 600 m length breakwater in the beginning of the 60's, associated to a small-refined products terminal and complementary facilities, have occurred some significant changes in the beach that till that moment occupied the entire perimeter of the bay. With the breakwater implemented at North, there have been some changes on the local wave patterns due to refraction and diffraction phenomena, causing a beach thinning in the central bay beach and sand accretion on the sheltered harbour area. Due to harbour exploitation reasons the dredged sand was placed outside the breakwater.

The erosion on the central and south areas of the beach has progressed forcing the construction of a groyne field (with 5 groynes in total) and a adherent sea defence. With the *General Plan for the Vitória Beach Bay exploitation and valuation* from 1990, is constructed a new breakwater implanted at South thus remaining the bay with ocean connexion through the water plan between the two breakwaters head. There are several hydrographic and geotechnical surveys related to the harbour infrastructures of the bay.

Actually sand dredging is being carried out in the shoreline strip outside the Vitória beach harbour breakwaters. According to information from the Regional Secretariat for Environment, dredging activities are executed bellow - 24 m (HZ) and has reached 30 000 m^3 per year between 1996 and 2000 and 80 000 m^3 in 2001, and in 2002 the licensed volume was 50 000 m^3. The accretion in the recently built yachting dock is also known.

1.1.2 Erosion

Erosion Rates and Trends

The coast line is stable as reflex of its constitution. The totality of the coast line is basaltic type that only after some thousands of years of permanent sea action could erode significantly. Analysing this process in a human scale, the effect of erosion occurs in this islands by natural actions, don't happens in a way that can be easily observed and to provoke important damages, as happens on the Portuguese Continental coastal line. The most important issues are related with some cliff erosion.

1.2 Socio-economic aspects

As happens in the Portuguese coast, in Azores there is high concentration of population in relation to the rest of the territory. In these islands, the population is located almost in coastal villages. This could be related with the facility of access or with the rigorous climate of the highlands in the centre of the islands. The urbanistic pressure, especially for touristy reason, lead to a certain difficulty on the area management. Despite the need for studies on these types of impacts and on assessment of capital at risk, in Portugal special attention has not yet been taken into account on this important subject.

1.2.1 Population rate

In Portugal, there is an uneven distribution of population between the littoral area and the rest of the country. In Azores, the population is distributed on littoral areas due to the fact that towns, villages and small villages are located in or near to the coastal zone in all the islands (Table 1). According to the table 1, between 1991 and 2001, the Azores population has maintained stable with a small increase. It is important to refer that the population has decreased in all islands with exception of São Miguel island, the biggest island and Corvo the smallest one.

Table 1: Recent evolution, density and rate of change, for Azorean archipelago islands.

Municipality	Total Area (km^2)	Resident Population (Inhab)		Density (Inhab/km^2)	Rate of Change 1991/2001 (%)
		1991[1]	2001[1]		
Santa Maria[1]	97.07	5 922	5 524	56.91	
São Miguel[1]	746.79	125 915	129 512	173.42	
Terceira[1]	399.81	55 706	54 924	137.38	
Graciosa[1]	60.94	5 189	4 713	77.34	
São Jorge[1]	245.59	10 219	9 528	38.80	
Pico[1]	450.74	15 202	14 557	32.30	
Faial[1]	169.94	14 920	14 772	86.92	
Flores[1]	141.7	4 329	3 941	27.81	
Corvo[1]	17.12	393	414	24.18	
Azores[1]	2 329.70	237 795	237 885	102.11	
Portugal[2]	92151.8	9867147	10355824	112.4	4.7

Sources: [1] Regional Directorate of Statistic, 2001.

[2] National Statistic Institute (INE), preliminary results of the 2001 Census.

In the Azorean archipelago employment structure, the 1st sector has an important reduction when compared with the data of 1990 and with country average, table 2 and figure 19. Nevertheless, the population belongs mostly to the 3rd sector exceeding the values of Portugal.

Table 2: Population per sector.

Region	Population (%)		
	1st Sector	2nd Sector	3rd Sector
Azores (1990)[2]	23.1	25.2	51.5
Azores (2000)[2]	16.2	26.6	57.2
Portugal [1]	13.0	35.3	51.7

Sources: [1] National Statistic Institute (INE), final results of the 2001Census
[2] Regional Directorate of Statistic, 2001

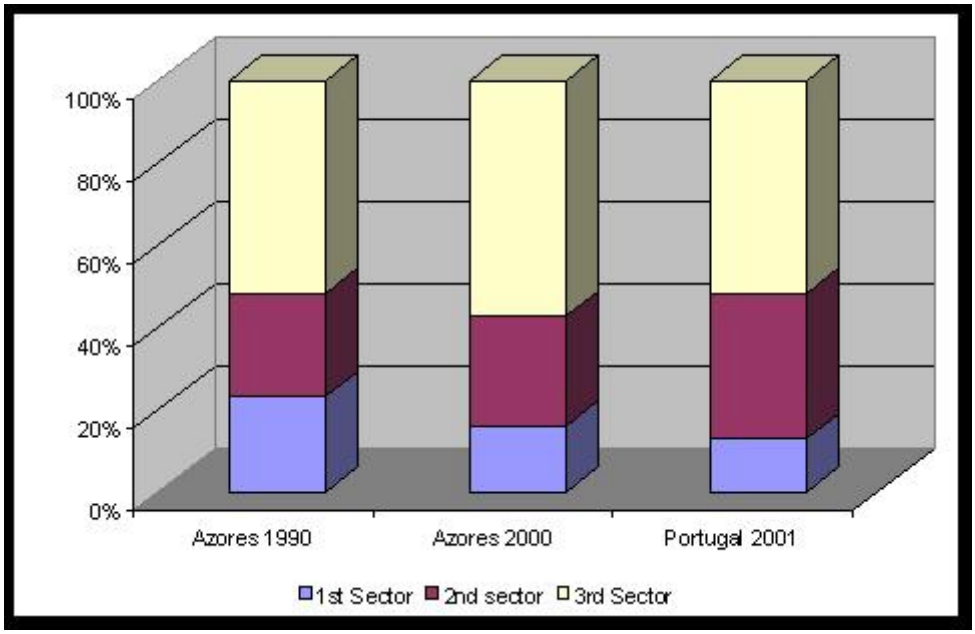


Fig. 19: Population percentage per sector.

In Azores, the 3rd sector is the most important one in the two records, as it happens in Portugal.

1.2.2 Major functions of the area

- **Tourism:** is an important sector of the Azores economy. Actually in Azores the industry of tourism is growing in a great rhythm, with construction of new hotels namely in Terceira and São Miguel islands, construction of yacht marinas (figure 20) and the amplification of Pico airport. In table 3, there are included some values related to the tourism sector in the year of 2001 in the area and in Portugal.

Table 3: Tourism indicators

Municipality	Capacity of Hotel Facilities (No. of places)	Nights Lodging (No.)	Guests in Hotel Facilities (No.)	Average Stay (nights)
Santa Maria [1]		...	...	
São Miguel[1]		360 667	101 764	
Terceira[1]		67 475	31 458	
Graciosa[1]		9 309	3 504	
São Jorge[1]		...	...	
Pico[1]		42 696	14 454	
Faial[1]		64 990	26 634	
Flores[1]				
Corvo[1]				
Azores[1]				
Portugal[1]	222 958	33 795 123	9 515 615	3,6

Sources: [1] Regional Directorate of Statistic, 2001.

Fig. 20: New Angra do Heroísmo yacht marina (J. Pais Barbosa, 2002).

1.2.3 Land use

The land use in the area is mainly related with concentrated urban areas especially in the coastal zone but with some exception like the village of Furnas and Sete Cidades in São Miguel. These islands are also characterized by extended areas of forests and agriculture. In Terceira, in the north part of the island, Biscoitos Village, a great area of the costal zone was occupied by vineyards has well as in some littoral areas of Pico islands. It is important to refer the existence of many coastal ecosystems unique in the world (fajã de Santo Cristo e dos Cubres in São Jorge island, Wetland in Pico island), which in some places have already disappeared (Praia da Vitória Wetland in Terceira).

1.2.2 Assessment of capital at risk

Has happens in the other cases of wp 4, in Azores special attention has not yet been taken into account on this important subject. The uncertainties and the low scientific capability to forecast extreme coastal forcing events (storms, sea level, tsunamis), the “intangible” and the cumulative environmental evolutions and impacts and the lack of quantification of the needs, values and aspirations of coastal communities are some of the actual limitations to assess capital at risk. Management plans should be based on an adequate understanding of the coastal dynamics. In Azores, the Coastal Management Plans only now starting and correspond to the first steps of the process.

Action and risk associated to coast dynamics

The Shoreline of Azorean islands is vulnerable to several natural and anthropogenic actions, presenting risks to the populations, ecosystems and edificated patrimony. The most relevant natural actions are:

- Volcanic eruptions
- Earthquakes
- Tsunamis (long period waves)
- Slope sliding
- Blocks fall
- Storms (sea action)
- Torrential floods (small river watersheds)

Due to the continuous action of the wave climate and storms some problems of coastline evolution (erosions), are associated of natural or artificial barriers, floods, disaggregation of cliff basis, scarps and slopes, destruction of support walls and other structures, blocks projection and sediment deposition. The wave climate can contribute for the occurrence of slope sliding, blocks fall and for the worsening of the torrential flood consequences in the mouth of small rivers.

The identified anthropogenic actions, with most relevance are:

- Accidents with ships transporting pollutants or explosive cargo
- Spills, from ships, of pollutant substances
- Sliding caused by movements, impermeabilization and soil cover alteration

The risks of exposing people, ecosystems and edificated patrimony to these actions, depend on the nature, intensity and frequency of these actions and from the degree of exposure of people and patrimony.

The construction of tracks, roads and parking-places as well as the construction of houses, in areas vulnerable to the sea dynamic action increases the risk of patrimonial loss and in some extreme cases, results in the loss of human life.

The frequency associated to a certain occurrence probability, is crucial. Although there is a scientific incapacity to present entrusted values for the intensity and occurrence probability of actions like earthquakes, tsunamis and volcanic eruptions, but also to the other actions referred.

The existence of databases about actions and consequences that occurred in the past, does not allow by is own the extrapolation for the future due to:

- The short extension and quality of that database
- The strong possibility of occurring climatic alterations induced by man
- The raise of human presence, notorious in terms of edifications (buildings, street layouts)

As examples of problems and situations documented that have been, in the last years, identified in the Terceira Island shoreline, quoting (source: Regional Environment Secretary, Regional Direction of Territory and Hydrology Resources):

- Instability in the cliff next to the road, near the “Biscoitos” seaside place, (Biscoitos, June 2001)
- Damages caused by the waves in the road between “Canada da Salga” and “Canada das Vinhas”, southwest of “Biscoitos” port (storms of October 1999, July 2000)
- The collapse of the cliff, destruction of the fort, overtopping of adjacent lands next to “Mós” bay, near “Contendas” (storms of December 2001)

This list its not exhaustive. The intention is only the tipify of situations associated with the coastal dynamics that has been causing some worries to the populations and authorities, inducing the intervention of local and regional entities.

There are no delimitated areas on the Maritime Public Domain (*Source: Regional Environment Secretary*), being the instruction of the processes been realized on the basis of the Law-decree 468/71, from 5 of November.

A special analysis must be done to cases where the construction of marginal roads or buildings brings an additional vulnerability or risk. Quoting some of those cases in which will be necessary to go further:

- Inline buildings, in construction, between the “Silveira” Quay and “Monte Brasil” (figure 21)
- Hotel near “Silveira” Quay (figure 21)
- Football Field West of the “Silveira” Quay
- Marginal road in the “S. Mateus” new social neighbourhood
- Marginal road near the “S. Mateus” Youth Hostel
- Parking-place with retaining wall between “S. Mateus” and “Pesqueiro”
- Marginal road extended in “Porto Martins”/ “Ponta de S. Fernando”

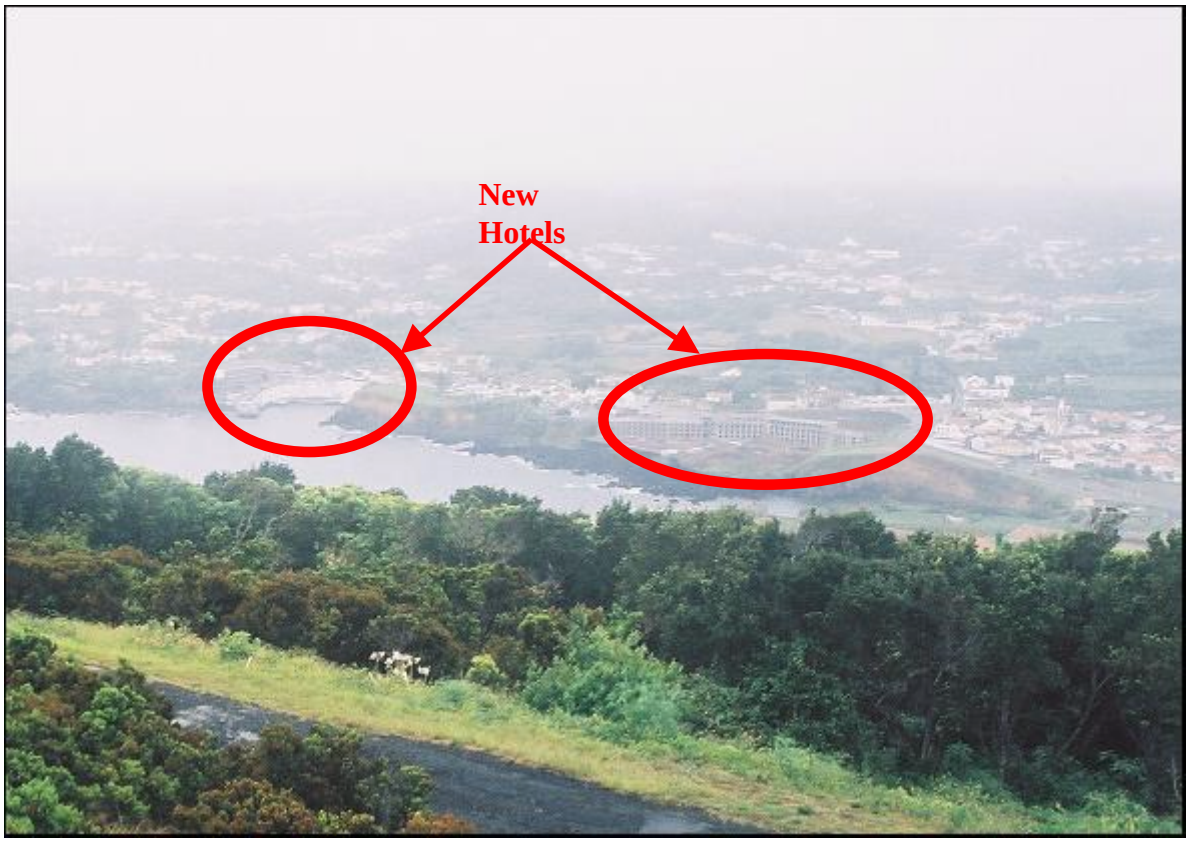


Fig. 21: Construction of two new hotels near the coastal zone (J. Pais Barbosa, 2002).

An example of the wave actions and their power, was what happens to the “Praia da Vitória” Harbour during a storm on the Winter of 2001. The “Praia da Vitória” Harbour is located at 38º 43’ N 27º 03’ W, in the Vitória beach bay, in the Terceira island. This harbour as commercial functions, fishing, military navy support and is endowed with a Yacht Marina.

The General Plan (*brochure of the Autonomic Region of Azores, Hidrotécnica Portuguesa, 1991*), foresees that after its own concretion, the harbour will be endowed with the following infrastructures:

Shelter workmanships:

- North pier, constructed in the sixties, with 600 m long and North/South alignment. Increasing of its extension that is predicted to be around 600 m

- South pier, constructed in 1984/86, with a length of 1300 m, breakwater type, with a wall curtain in concrete and exposed rubble mound with tetrapods and antifer blocks (in the head) and with North/South alignment

North Sector:

- Terminal for refined products POL (American authorities) reception
- Nucleus of Naval support (War Navy)
- Yacht nucleus

South Sector:

- Commercial nucleus, with two infrastructures
- General Cargo Terminal with vocation for container handling and fuel reception, docks in cellular caisson (coffin) made of concrete with 500 m long (350 m of quay with a depth of - 12 ZH, 150 m of quay with a depth of –10 ZH), 8 ha of platform and a rotation basin at –12 ZH, support facilities
- Cement Terminal, with two berthing "duques de Alba" in cellular caisson of concrete, with a depth of –7 ZH, for vessels until 4000 dwt and two silos with 7000 ton of capacity
- Support buildings (warehouses, workshops, administrative services, lodge)

Fishing Nucleus:

- Complementary shelter work (piers A and B)
- With 27 hectares, being 9 of liquid area
- 345 m of pile quay at –6 ZH, and platform at +3,5 ZH
- 230 m of quay at –4 ZH, and platform at 3,5 ZH
- Inland parking for 8 boats with a maximum of 40 m long each
- 18 hectares of platform
- access for hand-made boats
- cold-storage warehouse

The support services buildings, lodge of the harbour authority, customs, Autonomous Board, Guarda Fiscal and social services are located on the approaches of Santa Catarina Fort.

In the neighbourhood of the harbour enclosure and directly related with the harbour activities, with own road network, the plan foresees:

- Containers park Zone (7 hectares)
- Industrial Zone (7 hectares)
- Fuel Store Zone (projected)

The Harbour Infrastructures imply the canalisation/piping of the "Santa Catarina" and "Barreiro" streams.

Nowadays the breakwaters of Vitória Beach Harbour are very damaged, being visible the destruction almost generalized of the wall curtain and the exposed protection rubble mound. The severe damages were evident after the December 2001 storm (figure 22) where high and persistent waves were registered with strong winds and gust of wind coming from the northeast quadrant. The damage level is one of biggest, registered in Portugal after the port "Sines" accident in the ends of the seventies and beginning of the eighties.

Fig. 22: "Praia da Vitória" harbour entrance, after the destruction provoked by the storm of December 2001.

According to information gathered, a report about the causes of the accident is being elaborated and studies for the reconstruction are being prepared. Due to the magnitude of the accident and the costs that predictably will be involved in the reconstruction (around 25 millions of euros), becomes necessary the organization of an extended technical meeting, to discuss the problem, like happened with the Sines situation.

The Vitória beach marina, in an advanced state of construction, has a capacity for 207 boats, with a deep load-draught of 3 m and maximum length of 20 m. As a support infrastructure to the Yachting, will be included a building for supporting the navigators, a ramp, inland boat parking, nautical club, restaurants and bars. The Vitória beach Town Hall confirms that the place where the marina will be implemented, "needs to be dredged regularly". The knowledge of the sedimentary dynamic evolution in the marina implementation spot, as referred in the proper chapter, predicted the occurrence of sedimentation problems.

The question of the dominance in the Vitória beach bay should be re-considered. The entire bay is artificialized. Concerning the wave climate, there are two extended harbour breakwaters, vital for the harbour commercial, fishing and recreation activities. The bottom was dredged to compatible levels with the different sectors of nautical activities but more maintenance operations will be needed. There are groynes and adherent coastal work in the non-harbour sea road. There are sections of sea road very vulnerable to the direct action of waves as well as slope instability (where the sea road was recently extended, without licensing).

The area under jurisdiction is limited to the harbour commercial sector. Although there are some harbour activities associated to the navy activities and yachting. An important urban front and a balneary area with sandy beaches is located in the bay.

Other harbours and small harbours in Terceira Island

According to the classification adopted in the Regional Legislative Decree nº 17/94/A from 18 of May, the class D Harbours ("those exclusively dedicated to Fishery") in the island of Terceira are the following::

"S. Mateus"	"Biscoitos"
"Porto Judeu"	"Vila Nova"
"Porto Martins"	"Cinco Ribeiras"

The Azores Autonomic Region classifies those who don't have a "specific function" as small harbours (table 4). "In cases where the historical value and the operational conditions allow, the small harbours can be used by the local autarchy or other entities that pretend to use it for recreation or pleasure through the celebration of concession contracts with The Regional Government". In Terceira island the following Harbours are classified as small.

Table 4: Harbours of terceira island.

Municipality	**Small Harbours**
Angra do Heroísmo Municipality:	"Silveira" "Negrito" "Serreta" "Salgueiros" "Salga" "Cais da Figueirinha" "Cais da Alfândega"
Vitória Beach Municipality:	"Quatro Ribeiras"

Some recovery and beneficiation works were adjudicated in "Biscoitos" Harbour, with a total cost of 225 thousand euros.

Another example of these problems and situations documented that have been, in the last years, identified in the S. Jorge island shoreline, (source: Regional Environment Secretary) are the following:

- Velas village, "Conceição" avenue: instability of the slope by direct waves action, overtopping of the sea road for waves bigger than 5 m, hitting urban agglomeration.
- "Calheta" harbour bay: damage in the sea road wall, near edifications. Overtopping in "Caminho de Baixio", hitting some houses.
- "Porto Novo", "Ribeira Seca": partial collapse of the slope, with obstruction of access road.
- "Topo" small harbour: boats and stores inundated and destruction of sea road wall by the slope collapse with the 1980 earthquake.

- "*Fajã* da Penedia": overtopping of the coast line, with about 300 m extension, for waves bigger than 4-5 m, hitting some buildings. Protection barrier, made of roled rock, affected.
- "*Fajã* das Pontas": about 200 m of sea road sidewalk destroyed by the sea action.
- "Fajã de S. João": damage in the road´s retaining wall of the "*Fajã*" small harbour access. Collapse of the access road to "*Fajã* da Gaivota" by the erosion action of the sea in the slope basis.
- "*Fajã* dos Vimes": damage in the retaining wall. Destruction of a small quay for cabotage boats. Retreat of shoreline in result of erosion due to the wave action. Overtopping due to the wave climate.
- "*Fajã* Grande": Obstruction of the sea road, with rocks and waste material, brought by the sea. Partial destruction of the sea road by the sea action.
- "*Fajã* João Dias": erosion problems that might affect the existent buildings.
- "*Fajã* da Gaivota": road slope affected. Strong erosion.
- "*Fajã* da Saramanqueira": erosion problems that might affect the existing buildings.

This list its not exhaustive. The intention is only to tipify the situations associated with coastal dynamics that has been causing some worries to the populations and authorities and the intervention of local and regional entities. There are no delimited areas on the Maritime Public Domain (*Source: Regional Environment Secretary*), being the instruction of the processes realized on the basis of the Law-Decree 468/71, from 5th of November.

There are some documented cases where the construction of sea roads, in the Maritime Public Domain, was not object of any licensing. These initiatives appear with the objective of improving the mobility conditions of populations but they don't take into consideration the appearance of new vulnerability and risk situations.

The "*Fajãs"* (formed by big mass movements), are associated with the collapse of big cliffs, and in some situations with contributes of solid material brought by the stream of the small rivers, and are exposed to erosion induced by the continuous and intense action of wave climate and overtopping phenomena.

The intensity of wave action varies along shore due to local wave deformation phenomena and the existence of some natural protection. The consequences of such actions also vary along the shore according to the geologic/geothecnical terrestrial interface.

2. SOLUTIONS / MEASURES

As was described the Azores Archipelago don't have important problems of erosion, as happens in Portugal continental so the policy options to this area must be different from the ones applied there.

In these islands, the problems are different because almost all the perimeter of the islands is constituted by very high hard basaltic cliffs that protect land against the sea action. However, now is possible to observe some constructions in areas near the coast line, and in some cases in lower areas that can be reached by storms and probably will provoke damage in the buildings or in the infrastructures. Until now the Azores don't have any Coastal Management Plan approved to rule and forbid some human actions. However they are under elaboration.

In this plans the land management and use are the most important aspects to take into account. It must be verified (for example) the areas with bigger possibility of landslides provoked by earthquakes, volcano's and deforestation and areas that can be reach by storms forbidding the construction of any kind of infrastructures. This way in the future, the Azores archipelago maybe clouds not have destruction problems in the costal zones and this way could save important amounts of money on the infrastructures damage repair. Anyway the general policy will be to hold the line.

3. REFERENCES

Jorge, F., Valdemar, A., (2000) – "Açores visto do céu". Argumentum edições lda, Lisboa. ISBN:972-96025-8-9.

Martins, J. A., Santos, R. S., (1988) – "Breves considerações sobre a implantaçãode reservas marinhas nos Açores". 1ª Jornadas Atlânticas de Protecção do Meio Ambiente, Secretaria Regional do Turismo e Ambiente, Direcção Regional do Ambiente, Camâra Municipal de Angra do Heroísmo.

Morton, B., Britton, J.C., Frias Martins, A. M, (1998). "Ecologia Costeira dos Açores". Sociedade Afonso Chaves, São Miguel, Açores, Portugal. ISBN: 972-97774-1-1.

Rodrigues, F. C., (2002) – "Hidrogeologia da Ilha Terceira". Dissertação apresentada à Universidade dos Açores para o efeito da obtenção do grau de doutor no ramo de engenharia do ambiente.