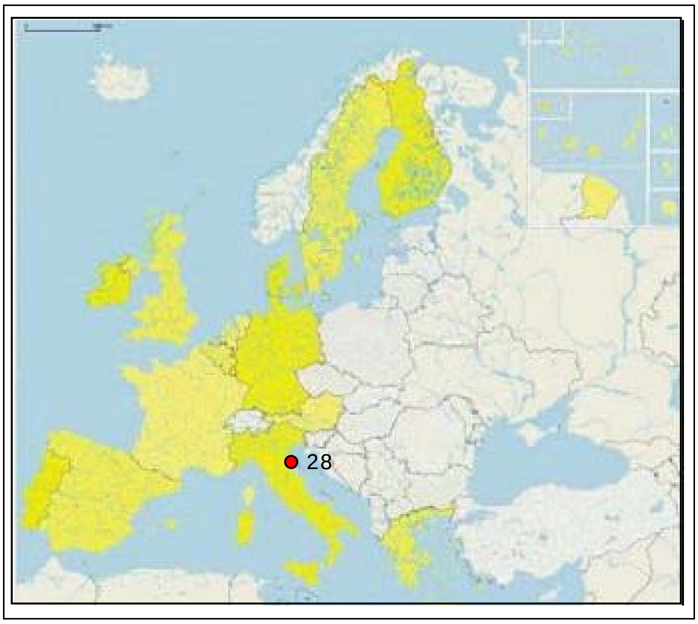
MARINA DI RAVENNA
LIDO ADRIANO
(ITALY)



Contact:

Giovanni GABIANELLI

Interdepartmental Centre for Environmental Sciences Bologna University

Via degli Ariani, 1
48100 Ravenna,
(Italy)

e-mail: gabgio@ambra.unibo.it

1. GENERAL DESCRIPTION OF THE AREA

The area considered in this report (about 10.5 km long) corresponds to the coastal area of Ravenna between the Fiumi Uniti river mouth and the southern jetty of the Ravenna Port (Fig.1). During the last century, the entire coastline has been strongly influenced by two main factors:

1) the building and progressive extending of Ravenna Port jetties (whose present length is about 2800 m) and the lack of sediment supply, formerly coming from the river and from the up drift beaches (South of the river mouth).
2) it is important to consider all the negative effects caused by subsidence and the high anthropic impact due to beach-tourism management.

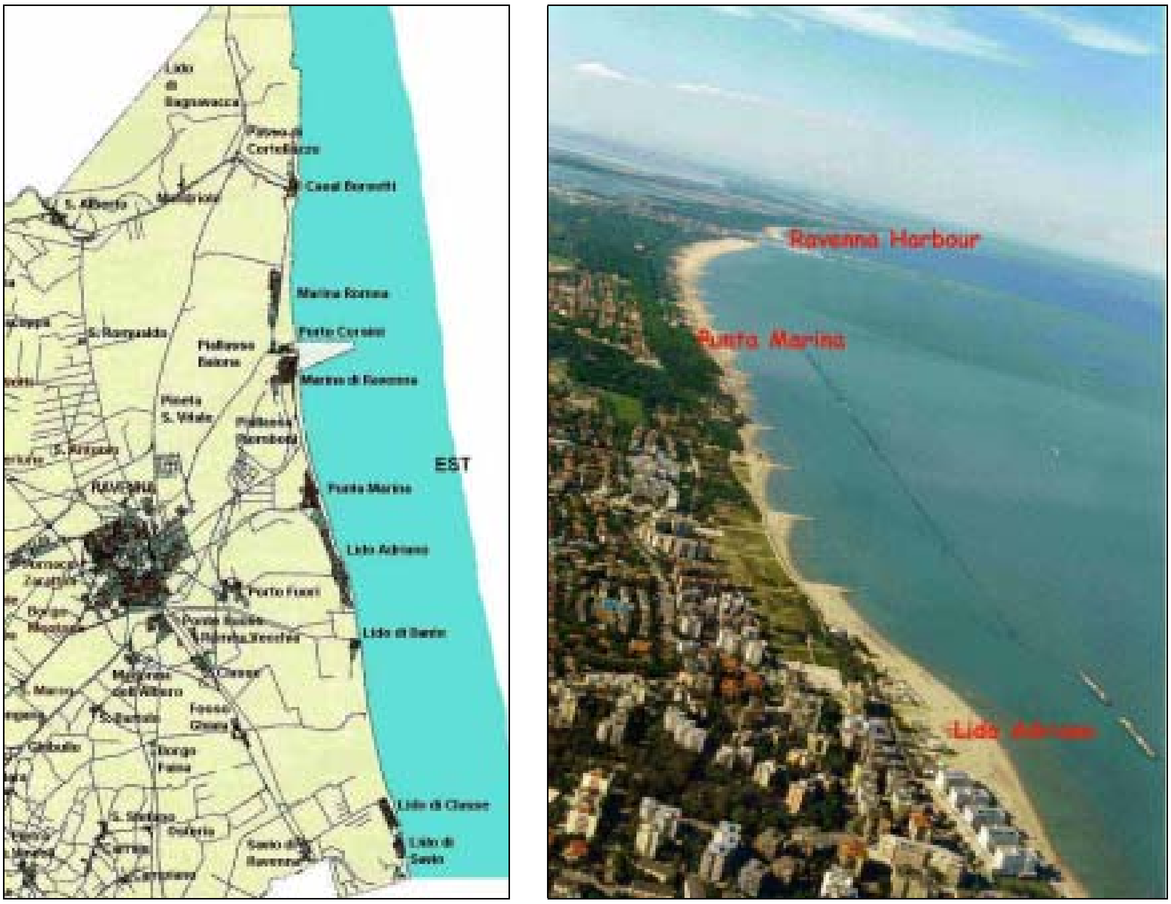


Fig. 1: Studied area (Marina di Ravenna- Lido Adriano area/ Ravenna's coast).

1.1 Physical process level

1.1.1 Classification

- General: continuous sand coast
- CORINE: beaches
- Coastal Guide: coastal plain

The examined area is formed by the interaction between river-delta and marine coastal processes. From the late Holocene until the beginning of the '900, the coastline has undergone a progressive accretion. This trend was possible through the development of a system of breakerbars which acts as a natural boundary for the marshlands and the backwater areas (Fig.2).

Fig. 2: Details of the beach - dune bars - lagoon system in the area. The pinewood has been artificially planted on ancient dune bars.

1.1.2 Geology

Detailed stratigraphical information available for the area (Emilia Romagna Region, 1999) shows that the coast is characterized by sand-beaches covering muddy-clayey materials derived from more ancient swampy and alluvial deposits (Fig. 3). Generally, the thickness of the modern sands does not exceed 4-6 m. This sediment, displaying a classic cuneiform geometry, completely disappear at a water depth of about 4-6 m. Type of surface sediments: approximately fine sands (an average of Mz 2.06 φ in the shoreline; 3.43 φ at 2.5 m depth)

The coast have experienced a subsidence greater than 1 m in the last 40-50 years; natural rates of 2-3 mm/y of magnitude have been in fact greatly accelerated in the last half century by fluidextractions (water and gas) from the underground. At present, along the coastal areas, the subsiding rates are, on average, 5- 6 mm/y, with peaks of 9- 10 mm/y. Land subsidence has contributed to heavy beach regression in some places, more than 200 m in about 20 years).

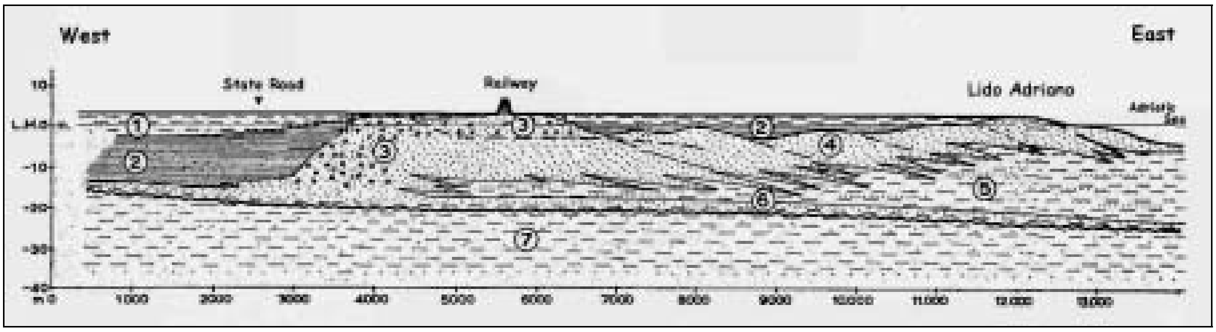


Fig. 3: Schematic stratigraphic section across Marina di Ravenna- Lido Adriano area. Legend: (1) yellow clay of modern land reclamation; (2) clay with peat, sandy and clayey mud of lagoon environment (3) Sands and beach gravel; (4) Beach and marine coastal environment sands; (5) Mud with sandy levels of marine coastal environment; (6) Sands and mud of Holocene transgression; (7) Clays, mud and sands of continental environment (Angeli et al., 1970; modified.).

1.1.3 Morphology of the coast

In the last decades, as a result of the combined effects of subsidence, jetty construction, urbanisation, lack of sediment supply from rivers, etc., the coastline experienced a huge erosion rate in the southern part (from the Fiumi Uniti river mouth to about Punta Marina) and a significant accretion in the northern part (close to the jetty; Fig. 4).

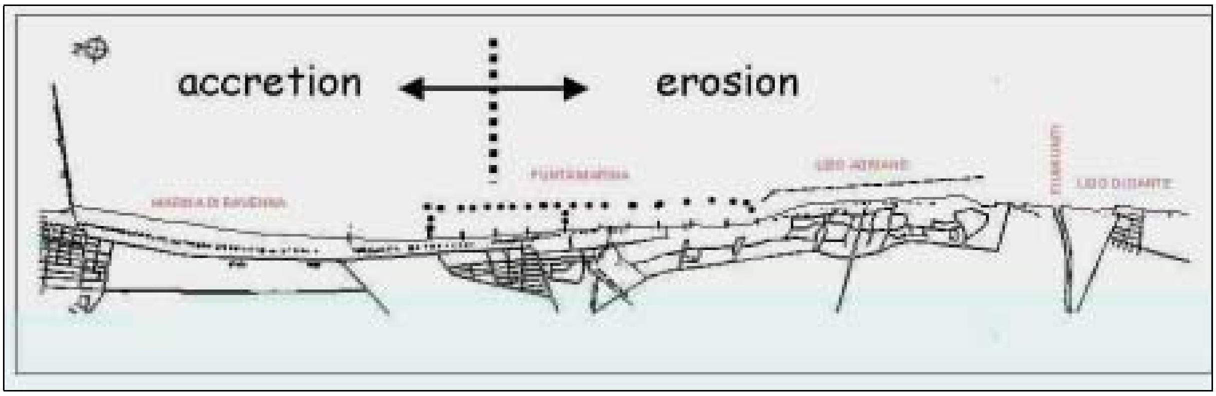


Fig. 4: Littoral area between the Fiumi Uniti river mouth and the southern jetty with a schematic map of the erosion-accretion zones

After an extreme storm event, which occurred in 1966, the majority of the Northern Adriatic coastal areas was flooded. Since then, many coastal protection structures have been built along the coastline. Protection structures can be found offshore Lido Adriano (Fig. 4), with a serie of detached breakwaters and a seawall (in the late sixties), offshore Punta Marina with a serie of rock groynes and a beach nourishment (in the late eighties) protected by a submerged breakwater and submerged groynes all of them made with sand bags.

In this area, the shoreline displays the following features:

- Orientation: about 330°
- A sedimentary cell about 10.5 Km long consisting of:

  - About 4.5 km of unprotected and accreting coast in the northern sector.
  - About 6.0 km of coastline characterised by erosional patterns in the central-southern sector. It corresponds to the area protected by artificial reefs (about 3.0 Km of submerged parallel breakwaters and about 3.0 km of emerged parallel breakwaters; where annual partial nourishment is performed).

- The beach width ranges from few meters in the southern sector to more than 150 m in northern part.

- Beach slope: from less than 1° (emerged) to 2.5° (submerged).

1.1.4 Physical processes

Based on its features, this coast can be assigned to a "dissipative" type. The shoreline is characterized by a slight topographical gradient. The "up rush" of waves on the shore is delimited by the external surf-line. The tidal regime is that of a micro tidal type with the diurnal mean range of 80 cm for the spring tide and 30 cm for the neap tide.

High waterlevels in the North Adriatic Sea can be caused by storms coming from the south-east, the Sirocco wind, associates to depressional fields, which move towards the East. These events can determine oscillations with periods of 22 hours and maximum amplitudes often exceeding 1 meter. The data recorded by the tidegauge of Porto Corsini showed that, during 1999, the maximum value of the sea level rise recorded was 1.67m, caused by both the astronomical and the meteorological effects.

The prevailing wind and waves, which determine the main components of the solid coastal transport in the area (Fig. 5) are those from the North-east (locally called "Bora") and the South-east ("Scirocco").

The typical characteristics can be summarised as follows:

- Waves range: main orientation of the waves is 30-45° and 120-145°.
- Max Hs: 4m, with a wave period of 8-9 sec.
- Mean Hs: 1.5-2 m, with a wave period of 5-6 sec.

Fig. 5: A schematic map of the main direction of the total solid transport recorded in the area (Idroser, 1996).

More detailed analyses of the distribution of total solid transport perpendicular to the coastline show that for different intensities, frequencies and waves steepness, the prevailing sea are from the SE (influenced by Sirocco wind) close to the shoreline, and from the NE (influenced by Bora wind) where water depth is higher than 3 m.

1.1.5 Erosion

The shoreline shows erosion and accretion in different places. These erosion and sedimentation patterns change over time. The development of the coastline, based on the analysis of available aerial imagery taken from 1954 to 2000 is schematised in Fig. 6. Bottom altimetric evolutions, obtained by 1968-2000 bathymetric surveys, are summarised in Fig. 7-8.

In Marina di Ravenna the emerged beach shows a marked accretion (about 140-150 m in the last 50 years) while, where water depth exceeds 3-4m, a slight negative altimetric budget can be observed. It was caused by a loss of about 1.7 million m^3 of sediment, in the period between 1968 and 2000 (Fig. 7).

Obviously, during the same period, higher volumetric values have been recorded in Punta Marina and Lido Adriano where erosion takes place. In this areas the loss of sediment ranges from about 13 million m^3 between Punta Marina and Lido Adriano (Fig. 8a) to more than 27,5 million m^3 in the area between Lido Adriano and the Fiumi Uniti river mouth (Fig. 8b).

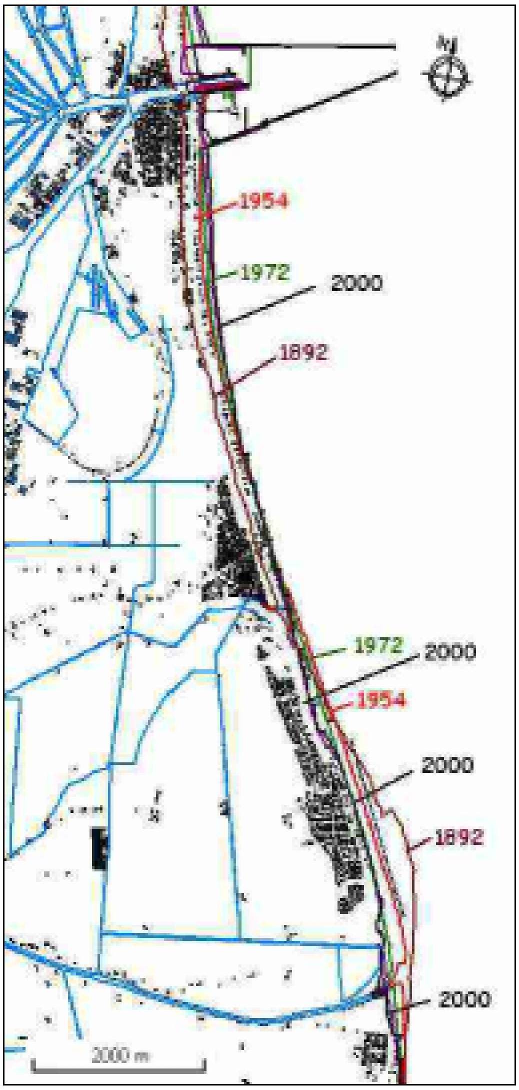


Fig.6: A schematic map of the modern coastline evolution of the area.

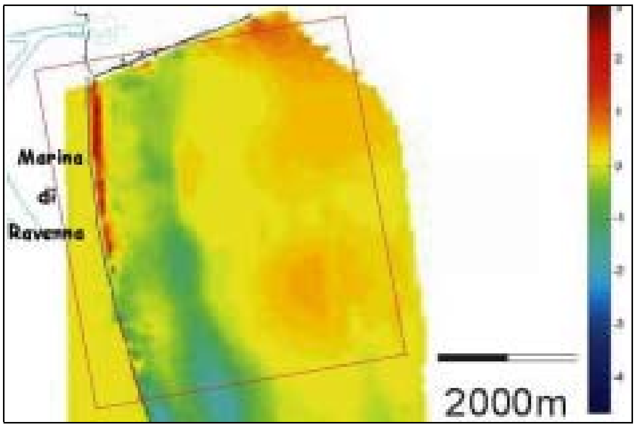


Fig. 7: Schematic map of altimetric variation (m) of the seafloor from 1968 to 2000 in the Marina di Ravenna zone.

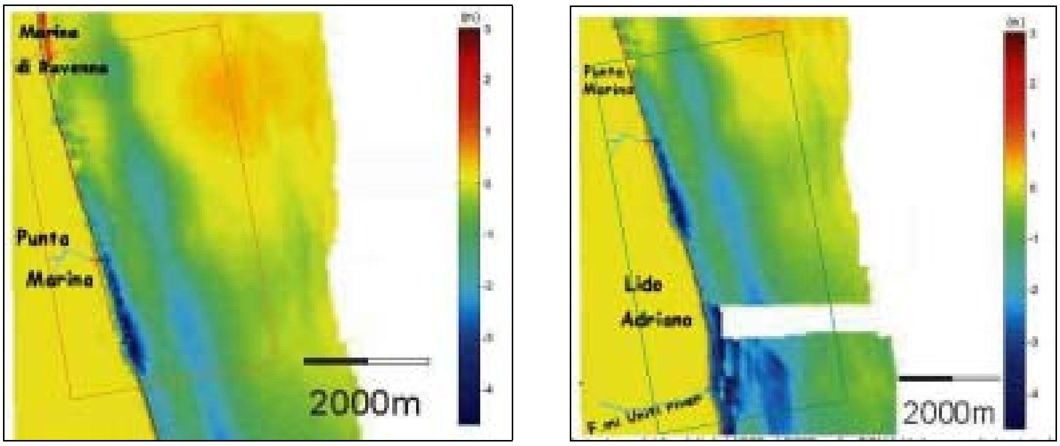


Fig. 8a & 8b: Schematic altimetric variation (m) of the seafloor from 1968 to 2000 in the Marina di Ravenna zone (on the right) and Lido Adriano- Foce F.mi Uniti (on the left).

Erosion Type

Figure 6, 7 and 8 show both erosion and sedimentation in the area. The main erosive phenomena are recorded in the zones surrounding the Fiumi Uniti mouth, which has been dismantled and withdrawn of about 450 m in the last century mainly because of the decreased fluvial solid contributions (consequent negative total sediment budget). During this century the entire region has suffered from the modifications of the human activity, which has almost completely destroyed the original environmental setting.

Acute erosion can also occur in case of severe storms. Than the sand on the shore will first be transported to the beach where it might stay or will be transported in a longshore direction.

Erosion Cause

The cause of erosion is mainly due to the lack of fluvial sediment input. Extractive activity exercised until 1978 along fluvial river beds, the embankment interventions, the lack of cleaning activity in river beds, etc., have concurred to produce a strong reduction of the sediment supply to the coast, determining a sensitive deficit in the sedimentary budget (Idroser, 1984).

In addition, in the last 30-40 years, an intensively increased anthropic activity, mainly connected to the development of tourism, has led to a complete alteration of the coastal morphology (for example, substantial dismantling of the sand bars and urbanisation in proximity of the beach; Fig. 9) and of the coastal dynamics with an associate increasing subsidence.

The subsidence produces a big impact on the erosional process. For instance, at Lido Adriano, approximately 45 cm of land lowering, recorded in the period 1957- 1977, has caused a regression of the shoreline of about 126 m (Carbognin et al., 1982). Further, the subsidence phenomenon does not only cause an accentuation of the erosional processes. Being an irreversible phenomenon subsidence in a low coastal plain produces a definitive decrease of the land elevation in respect to the sea level rise and therefore an increasing risk of marine ingressione (Cenas, 1997).

The highest crisis level along the entire north-Adriatic coast has been reached at the end of the 70s, when the anthropic activities on the shoreline had reached the maximum uncontrolled expansion.

This expansion has been partly decreased from the beginning of the '80 as a consequence of the adoption of a specific regional Law (n. 35 of 1984) which has resulted, in more restrictive terms and a national law for the protection of the territory (Galasso Law, n. 431, 1985).

The protection structures built up in the '70s nearby Lido Adriano influence the erosion. In such a limited sedimentary cell, an action of this kind caused constant underflow erosion, which induced an accentuation of the erosional phenomena, northwards.

Fig. 9: Clear example of uncontrolled coastal urbanisation in Lido Adriano area.

1.2 Socio-economic aspects

The major function of the coastal area is tourism and recreation. Industrial buildings are located only in the area of the harbour. More than 100 bathhouses are located on the 10.5 km of beaches. Some of them are big in size because they include bars, restaurants, various entertainment infrastructures, etc. These structures damaged and destroyed the dune bar (Fig. 10) and, because of an uncontrolled use of the beach, they caused heavy and continuous impacts on the existing residual dune bars and on the pinewood. Some sectors of the pine forest, together with the "Piombone lagoon" in the back (Fig. 2) are included in the protected areas of the Regional Park of Po Delta and classified as SIC/ZPS (Sites of Community Importance/ Special Protection Zones) on the base of the UE - Habitat directive.

Fig. 10: Example of bathhouse built in Punta Marina impacting the residual dune bars and pinewood.

On average, the total annual use of the beach, recorded in this part of the coast, is described in the table below (from Comune di Ravenna, 1996, 2000):

Table 1: Tourist statistics from Ravenna community.

Site	Resident population year 2000	Tourists attendance in hotels	Tourists attendance in other structures
MARINA DI RAVENNA	4126	93225	206266
PUNTA MARINA	3280	65587	514724
LIDO ADRIANO	5120	47246	169078
TOT.	**12526**	**206058**	**1529822**

2. SOLUTIONS / MEASURES

The actual beach management strategy, according to the present knowledge, began in 1997, with the design of a new coastal semi- submerged protection structures (Fig. 11, 12), required because the previous submerged breakwater and groynes made of sand bags resulted ineffective. The former works, in fact, did not give any kind of protection to the beach, which kept eroding very quickly.

Starting from 1997 a series of successive projects has been developed to protect the urban area and to maintain a reasonable beach width in order to permit the tourism development, which is the most important economic income for the area.

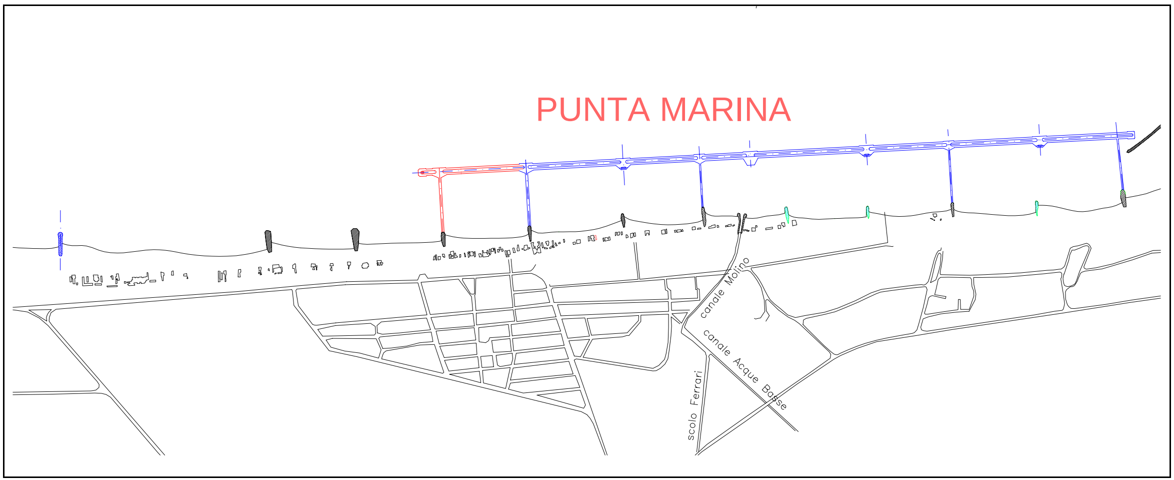


Fig. 11: Coastal area of Punta Marina with existing coastal protection structures (in blue 1999-2000 protection structures, in red breakwater prolongation).

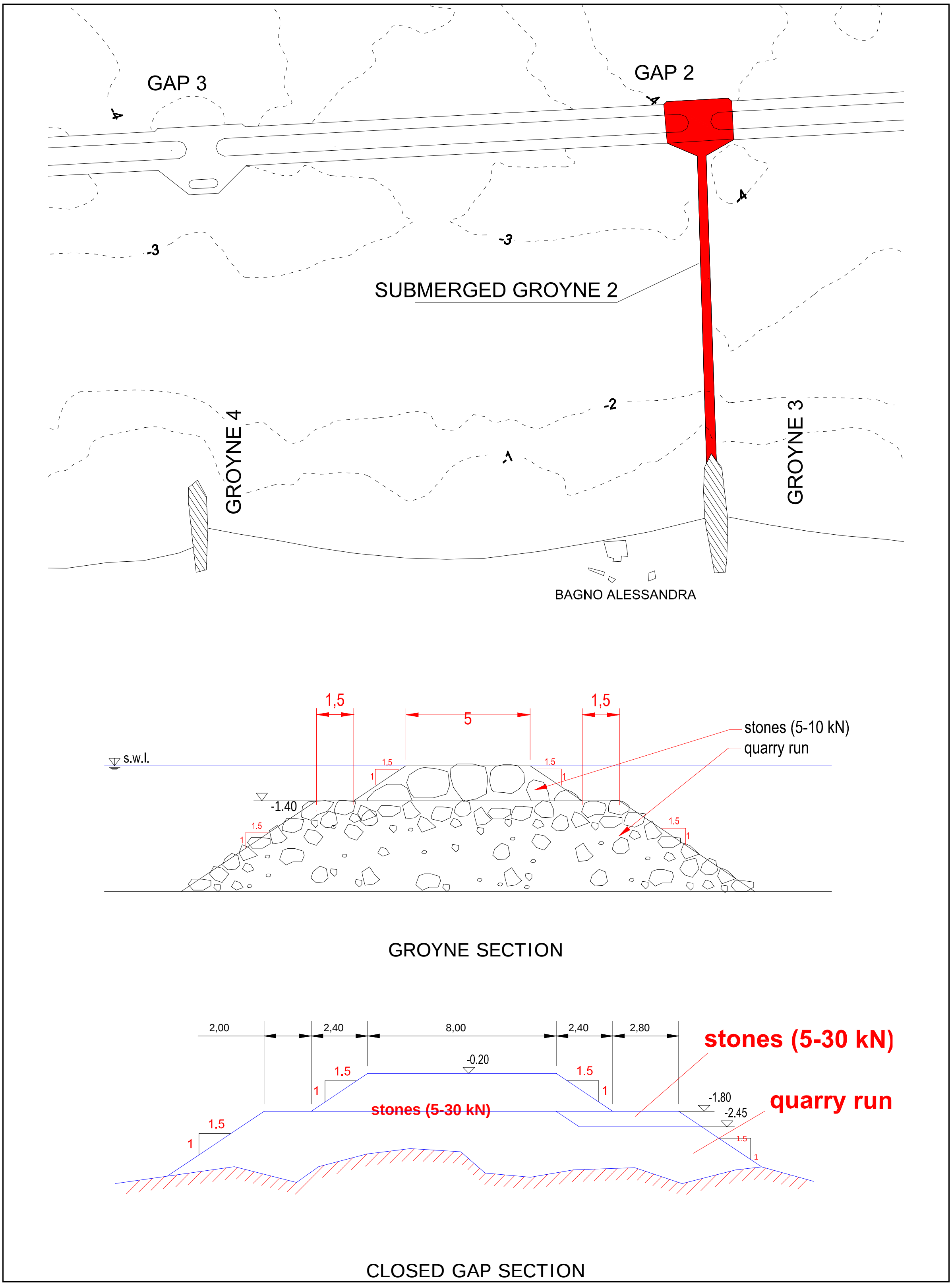


Fig. 12: Designed maintenance and improvement of new semi- submerged structures in front of Punta Marina.

Coastal protection works began in the late 1999; in the following table performed and planned works are summarised.

Table 2: Planning of works.

Date	Type	Description	Cost (ML €)
1999-2000	Protected nourishment	Construction of a submerged breakwater (2450 m long, about 250 m offshore the coastline, 0.20 m below s.w.l.), with a series of gaps to enhance inner water quality, and 4 submerged groynes. Construction of a groyne (partly submerged) North of the breakwater to allow for compensation of downdrift effects. All structures were made of random placed rock elements. Beach fill along the beach protected by the breakwater (D_{50} = 0.20÷0.26 mm, 125.000 m^3).	5.79
2000	Structures	Prolongation of the submerged breakwater (420 m North) and construction of a new submerged groyne. All structures were made of random placed rock elements.	0.89
2001	Protected nourishment	Beach fill along the beach protected by the breakwater (D_{50} = 0.20÷0.26 mm, 25.000 m^3).	0.38
2002	Maintenance nourishment	Beach fill in critical areas shoreward of the breakwater (D_{50} = 0.20 mm, 17.000 m^3) and downdrift of the breakwater (D_{50} = 0.20 mm, 40.000 m^3).	0.83
2003 (constructio n ongoing)	Maintenance and improvement of structures	Closing of a gap in the breakwater and reshaping of the wide gap in front of Molino channel. Reshaping of an existing submerged groyne and construction of a new one south of Canale Molino.	0.52
2003 (constructio n ongoing)	Maintenance and improvement of structures	Closing of a gap in the breakwater and reshaping of an existing submerged groyne.	0.21
2003 (design ongoing)	Maintenance nourishment	Beach fill in critical areas shoreward of the breakwater.	-

NOTE: all costs are V.A.T. and tender mark-down excluded.

Further step in coastal management will consist of the design of beach maintenance (behind the breakwater and downstream of the protected beach) and the analysis of costs and benefits in case of breakwater prolongation towards the North.

The local beach managers and the tourists have appreciated the type of intervention: in effect the beach stabilisation created a high increase in the tourist attendance in the last summer seasons. The problem of the partial closure of the coastal waters, due to the structures, did not create any big problems on the water quality, also during the warm summer period. The tourists tend to appreciate the quality and the extension of the sandy beach more than the water characteristics.

During the winter season some problems have been observed in relation to the stability of the protected nourishment close to the gaps. For that reason it has been chosen to close some gaps expecting an increase of the stability of the nourishment without an unacceptable effect on the internal water quality.

As forecasted, some erosion problem have been observed in the northern part of the beach, downstream of the protection system. The groyne placed in the northern area is a good solution to prevent extended erosion problems and it acts as fixed reference to perform the planned nourishment interventions on the beach and between the breakwater and the groyne.

3. EFFECTS AND LESSONS LEARNT

The last protection system adopted can be considered as a relative good and effective intervention: it is appreciated by the population and the beach users, without substantially negative effects to the environment and with a good cost/benefit ratio.

Nevertheless the experience shows that a continuous monitoring and management plan is necessary to maintain the level of anthropic impact that doesn't change the natural characteristics of the environment in the area, radically.

Unfortunately, the limited circulation of the sandy materials close to the coast, has forced to reduce the width of the gaps between the breakwaters in order to protect the beach extension, and many submerged breakwaters have been built between the gaps. Sometimes, also the height of the emerged breakwaters has been increased. These kinds of protections require, in any case, systematic nourishment in the most negatively effected areas.

In general, more frequent marine ingression and a worse seawater quality are a clear manifestation of the irreversible crisis through which the environment has undergone. This environment was once characterised by wide beaches, dune bars, pinewoods and brackish lagoon. During the past few decades, the environment has been heavily deteriorated as a consequence of immediate economic profit. Therefore, natural resources have been consumed at a rate untenable with a sustainable coastal management. This type of management will require high economic and social efforts especailly when the foreseen climate changes are taken in account.

3.1 Relation with ICZM

It is thus clear that the highest priority is to maintain a reasonable beach width, which prevents flooding. The coastal maintenance is carried out by the Municipality and by the Regional department of shore protection.

At present, Emilia-Romagna Region is preparing a Master Plan (possibly available starting from 2005) for an Integrated Coastal Management, which will indicate the guidelines for an adequate coastal protection plan. The preferred strategy will mainly focus on nourishment actions, sometimes coupled with submerged breakwaters, to help the sediment restraint. In some of the coastal areas, nourishment using relict sands (dredged from the seafloor at a depth of 30-40 m; Idroser, 1996) or sediments derived from the excavation of Ravenna's harbour is already taking place.

3.2 Conclusions

Effectiveness

- Submerged breakwaters have limited local erosion of the coastline, but constructions always need maintenance. Nourishment has shown to be effective mainly when coupled with hard breakwaters.
- Profound knowledge of the system is absolutely necessary to successfully apply hard constructions.

Possible undesirable effects

- Morphological variation of the beach and the seafloor.
- Increasing of fine sediments between breakwaters and coastline. The accumulation of muddy sediments could be connected to the increase of pollutant (i.e., heavy metals), which preferentially associate with fine sediments.
- Modification of the direction of solid transport.
- Variations in (phyto- and zoo-) benthic populations.

4. REFERENCES

Angeli, A.; Rizzini, A.; Veggiani, A. (1970). *I sedimenti recenti della costa adriatica romagnola. Mineralogia e Stratigrafia del Sottosuolo Ravennate.* Camera di Commercio, Industria, Artigianato e Agricoltura di Forlì (a cura di). Tipografia Moderna F.lli Zauli, Forlì.

Carbognin, L.; Gatto, P.; Marabini, F. (1984). *"Correlation between shoreline variation and subsidence in the Po River Delta, Italy"*. IAHS Publication N° 151.

CENAS Project (1997). *Study on the Coastline Evolution of the Eastern Po Plain Due to Sea level Change by Climate Variation and to Natural and Antropic Subsidence.* Commission of the European Communities Directorate-General XII, Science, Research and Development.

Comune Di Ravenna (1996). *Studio su valutazione e conseguenze delle variazioni del livello marino medio nella costa ravennate dovute a subsidenza ed effetti climatici*.

Idroser (1996). *Progetto di piano per la difesa del mare e la riqualificazione ambientale del litorale della regione Emilia-Romagna.* Relazione generale, Regione Emilia-Romagna, Bologna.

Regione Emilia-Romagna (1999). *Note illustrative Carta Geologica d'Italia scala 1: 50.000 - Ravenna*. A cura di A. Amorosi, pp 144, Ist. Poligrafico e Zecca dello Stato Ed., Roma.

Internet:

DMMMSA. Università degli studi di Padova. http://cenas.dmsa.unipd.it/cenas.