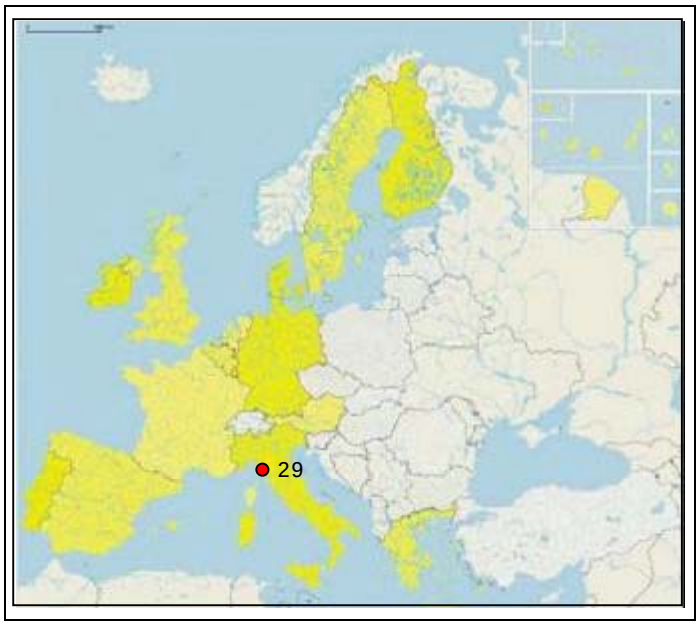
MARINELLA DI SARZANA (ITALY)



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1. GENERAL DESCRIPTION OF THE AREA

Marinella di Sarzana is located in south-eastern Liguria, in the Province of La Spezia (SP) under the Municipality of Sarzana. For a better understanding of the current morphological and sedimentary dynamics, it will be necessary to consider the physiographic sub-unit between the Magra River mouth and the Marina di Carrara harbour, located in the Municipality of Carrara in the Province of Massa Carrara (MS) (Regione Toscana). Thus, the study area administratively belongs to two different Provinces and Regions.

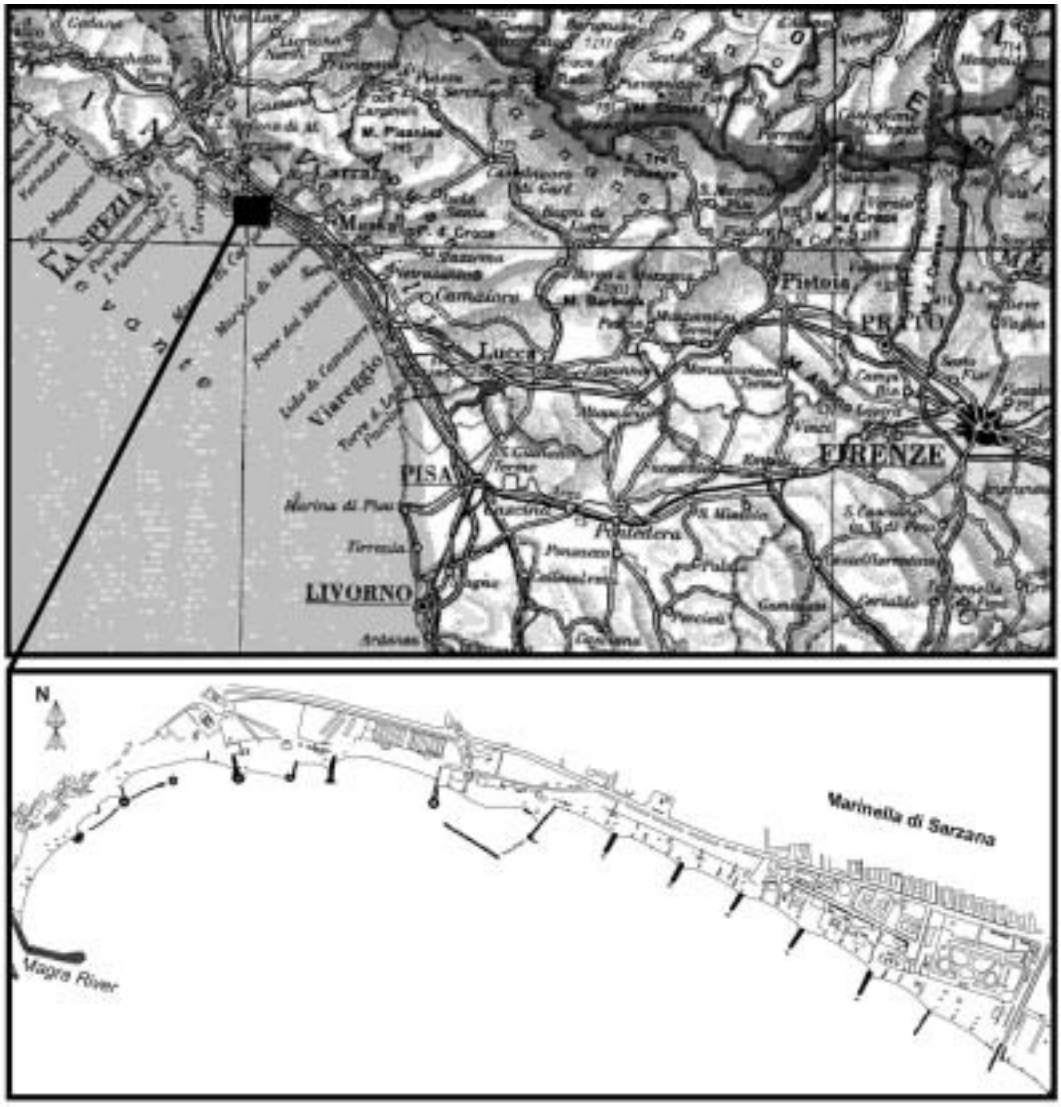

Fig. 1: Location map.

The total length of the sandy beach that stretches from the Magra River mouth to the Marina di Carrara harbour is 4,2 km.

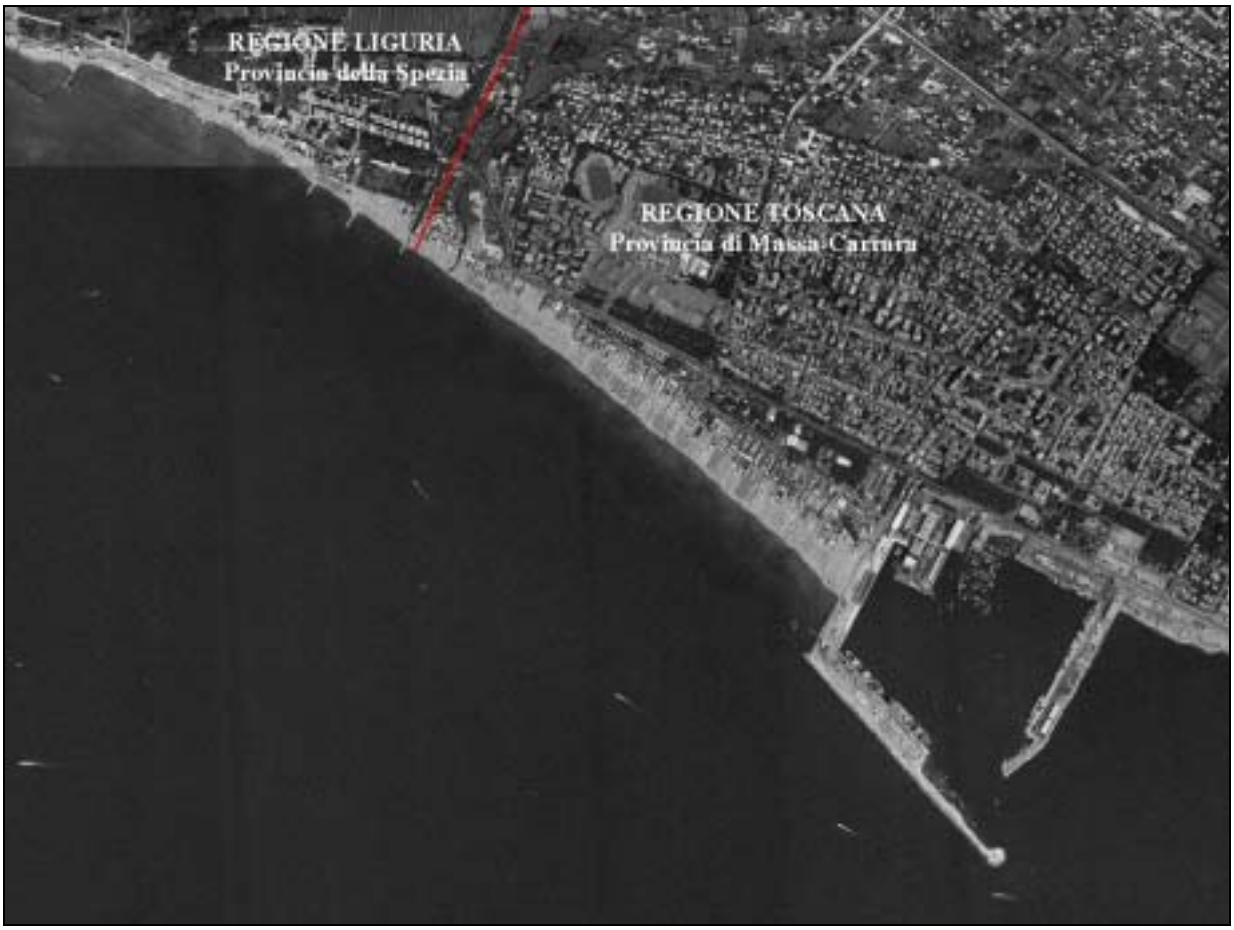

Fig.2: Sub physiographic unit with administrative limits.

1.1 Physical processes

1.1.1 Classification

- General: sandy beach, river delta.
- CORINE: beaches.
- Coastal guide: coastal plain.

1.1.2 Geology

The study area is located in south-eastern Liguria and northern Tuscany and it is part of a larger physiographic unit that extends between Magra River mouth and Livorno for about 63 km. This lowland plain facing the Ligurian Sea to the NE, is bounded by the Apuan Alps which are part of the Appennines chain, the major orographic feature of the Italian peninsula. The maximum altitude of the Apuan Alps is approximately 2000 m.

Apart from a few seasonal streams coming from the Apuan Alps, the largest river crossing this lowland is the Magra River which originates in the Appenines chain to the N-NE some 40 km from the coast and runs for 62 km with a catchment basin of approximately 1655 km^2. Until the XIX Century the lowland was largely a swamp area and after human intervention most of it has been reclaimed by artificial drainage systems.

From a geological point of view the Appenines chain consists of a series of Nappes which override each other from West to East. These Nappes are either sedimentary and ophiolitic (Ligurian Nappe) or exclusively made up of sedimentary formations (Tuscan Nappe) while the Apuan Alps, together with Monti Pisani, constitute the low grade metamorphic basement over which, at place, the Nappes have been tectonically emplaced.

The Magra River develops through the sedimentary formations of the Tuscan Nappe and, in particular, in its upper and middle courses before meandering in the alluvial plain, it flows within a widespread and thick (in general many hundred meters and, at some places, even more than one thousand meters) Oligocene sand stone formation known as “Macigno”, which represents the top of the Tuscan Nappe. As a matter of fact the sand which constitutes the beaches of the area under consideration is almost entirely the result of the “Macigno” erosion, transport and sedimentation by the Magra River (Rosi and Di Paola, 2001).

The mean grain size (Mz) distribution of beach sediments in the study area is shown in figure 3.

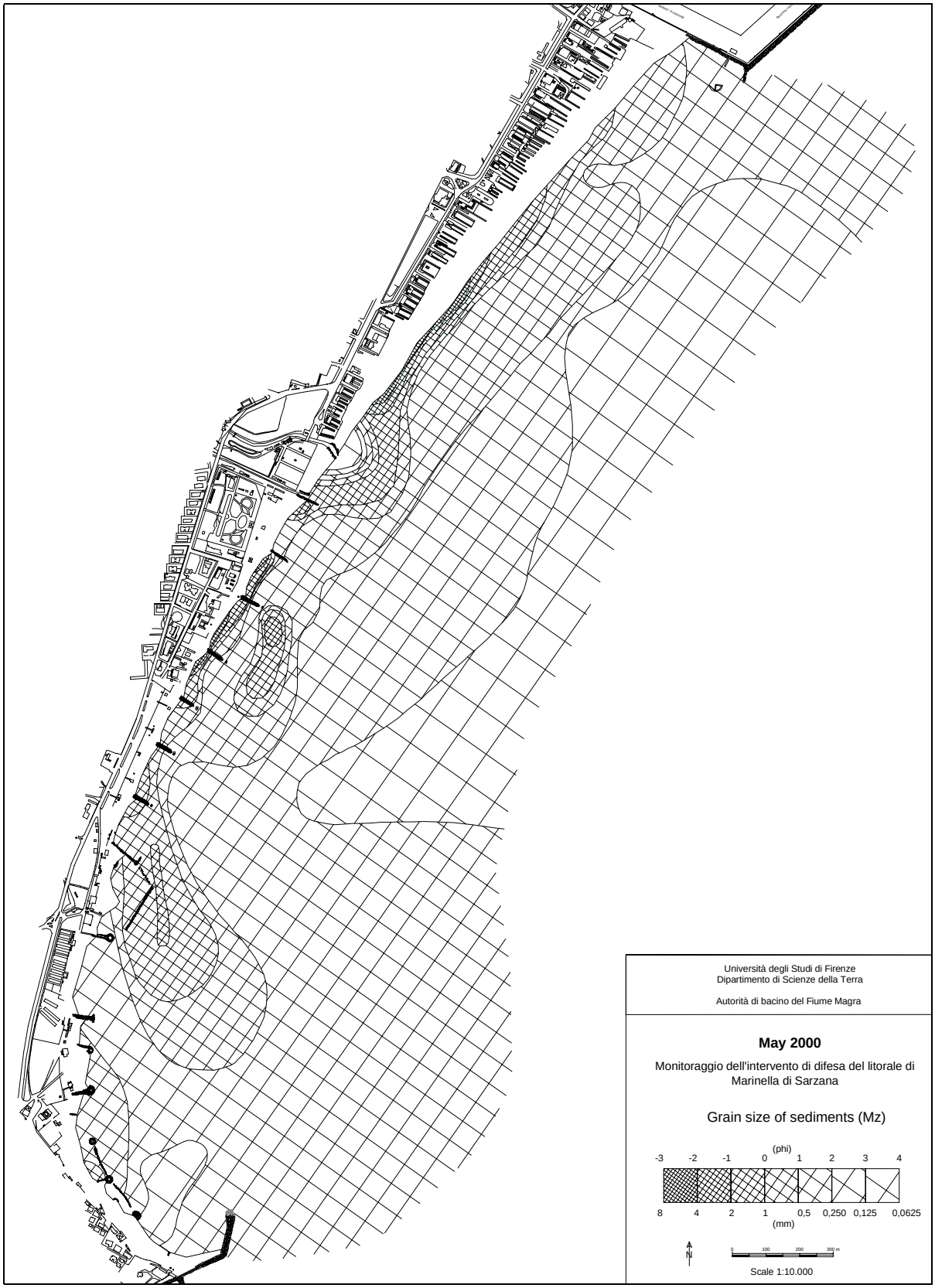

Fig. 3: Beach sediments mean grain size (Mz) distribution map.

1.1.3 Morphology of the coast

The Marina di Sarzana coastal area is currently being intensively protected by hard defence structures placed in proximity to the Magra River mouth. The internal parts of the coastal area are constituted by plains, mostly used for agricultural purposes, and which are often interested by flood phenomena due to the overflowing of the Magra River. The beaches of Marinella di Sarzana therefore represent the current junction between the sea and the coastal plain which extends for about 7 km landwards up to the Apuan Alps (Figure 4).

Fig. 4: The Sarzana coastal plain.

1.1.4 Physical processes

In this area the potential net longshore sediment transport was estimated to be directed southwards for approximately 150.000 m^3/yr (Aminti *et al.*, 1999).

The Magra River, with a length of approximately 62 km and with a catchment basin of approximately 1693 $km^{2,}$ is the third stream of the whole physiographic unit going from Magra River mouth to Livorno, after the Arno and the Serchio Rivers. The Magra River

sediments represent the main natural nourishment for the beaches going from the Magra River mouth to Forte dei Marmi, as demonstrated by beach sediment petrography (Gandolfi and Paganelli, 1975). The Magra River mean sediment load was estimated to be of approximately 50.000 m^3/yr (Gonella 2002 personal communication).

All of the studies performed so far ascribe the NW-SE direction to the distal drift, while the proximal drifts -which are the cause for the re-distribution of the sediments along the coast- show variable directions which are linked to the presence of different types of defence structures which determine local inversions of the longshore sediments transport direction (Figure 5).

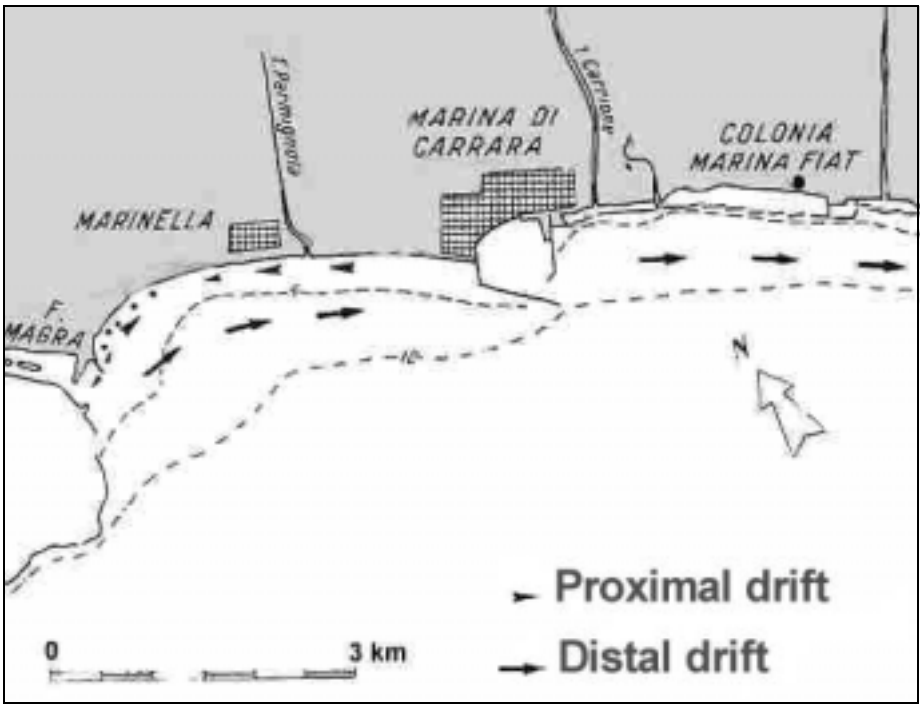

Fig. 5: Longshore sediment transport.

1.1.5 Erosion

The beaches of Marinella di Sarzana have been experiencing severe erosion since the XIX Century. The sectors near the Magra River mouth suffered the strongest damage in terms of loss of beach surface (Figure 3). As the erosion processes were taking place around the Magra River mouth, the beach of Marina di Carrara experienced accretion due to the presence of the Marina di Carrara harbour which intercepts the longshore sediment transport directed southwards.

From the shoreline evolution map it is possible to see that the mouth of the Parmignola Creek is the only area next to which evident erosional-depositional phenomena have not been recorded, therefore representing the point around which the entire physiographic sub-unit shoreline rotated clockwise (Figure 6).

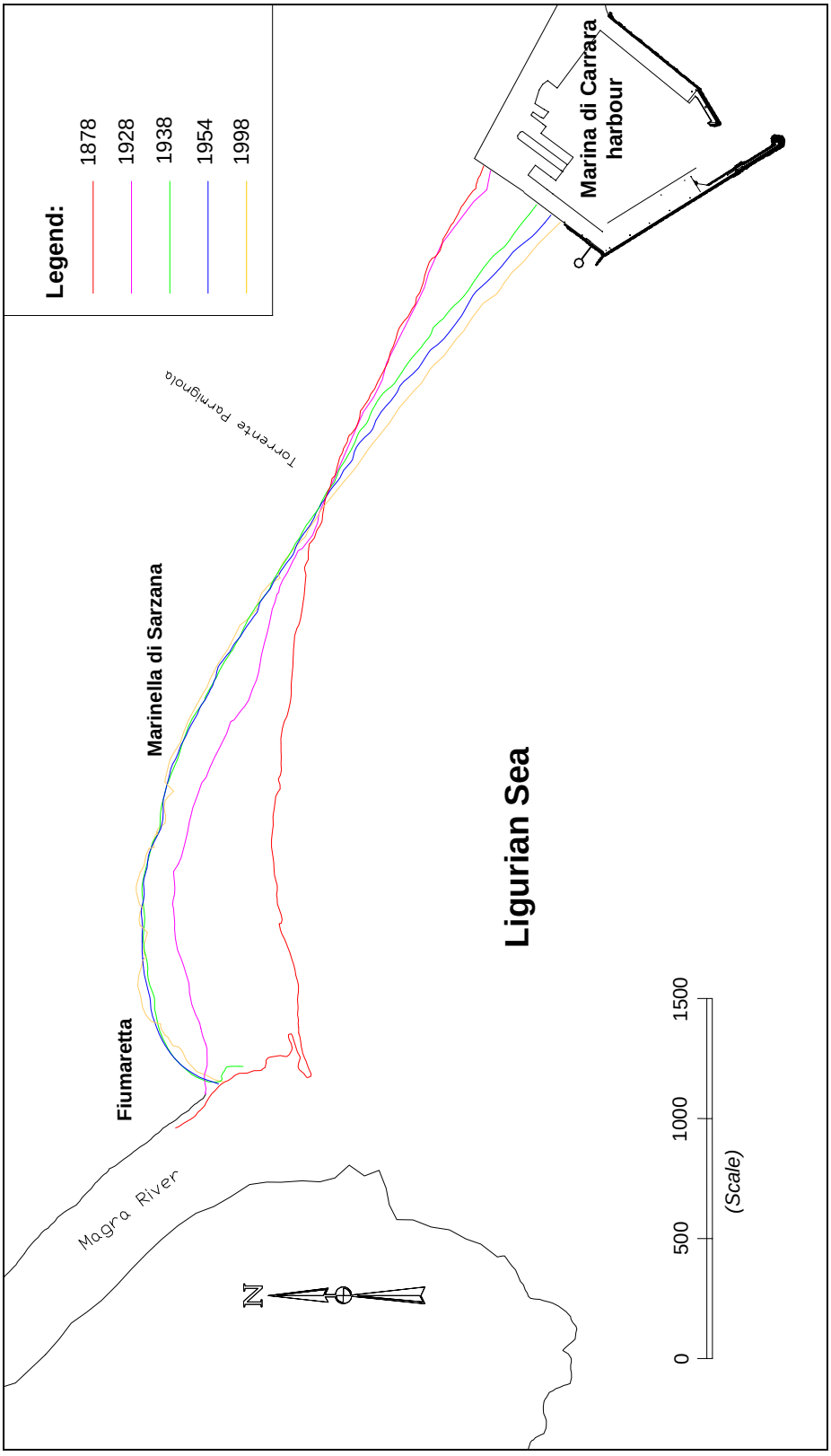

Fig. 6: Shoreline evolution from 1878 to 1998.

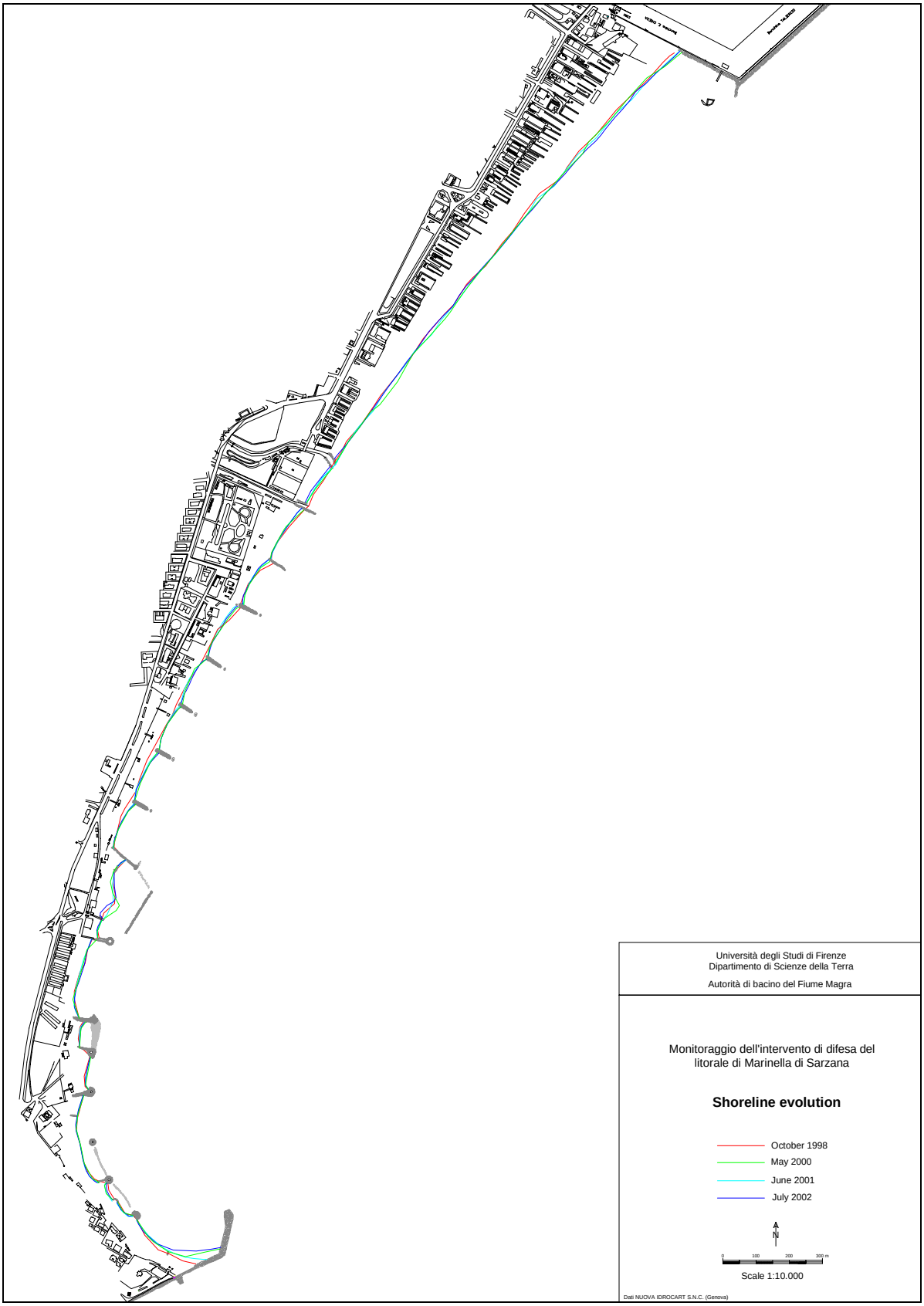

Fig. 7: Shoreline evolution from 1998 to 2002.

Type of erosion

On the basis of the subdivision of the coast into sectors (Figure 8), the mean shoreline retreat (m) and the annual erosion rate (m/yr) of the shoreline were calculated. In function of the available surveys it has been possible to calculate the shoreline variations between 1878 and 1927, between 1928 and 1938, between 1939 and 1954 and between 1955 and 1998; the erosion rates for the entire period (1878 and 1998) have also been calculated (Tables 1, 2).

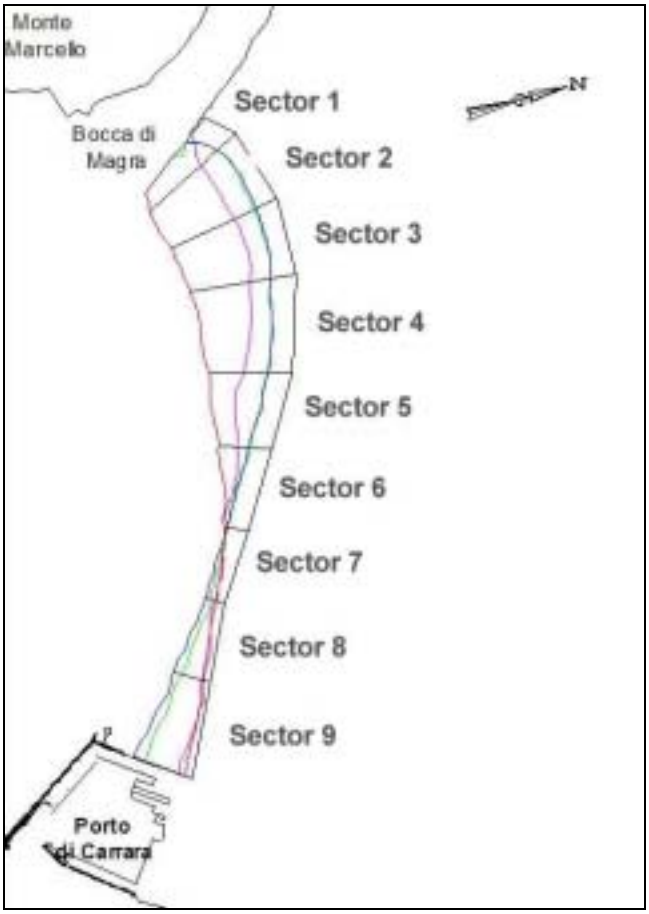

Fig. 8: Subdivision of the Marinella di Sarzana coastal zone into sectors, with the aim of evaluating the shoreline evolution between 1878 and 1998.

Table 1: Shoreline accretion/retreat (m) from 1878 to 1998 .

Period:		1878 - 1927	1928 - 1938	1939 - 1954	1955 - 1998	1878 - 1998
Pilot site	Sector 1	-284	-33	-9	18	-308
	Sector 2	-303	-133	-10	-4	-450
	Sector 3	-312	-113	-3	-8	-436
	Sector 4	-276	-128	1	-4	-407
	Sector 5	-142	-128	0	-16	-286
	Sector 6	-62	-37	7	-3	-95
Marina di Carrara	Sector 7	6	11	18	31	66
	Sector 8	9	77	44	49	179
	Sector 9	20	188	50	48	306
Pilot Site		-230	-95	-2	-3	-330
Marina di Carrara		12	92	37	43	184

Table 2: Erosion/accretion rates from 1878 to 1998 (m/yr).

Period:		1878 - 1927	1928 - 1938	1939 - 1954	1955 - 1998	1878 - 1998
Pilot site	Sector 1	-5,8	-3,3	-0,6	0,4	-2,6
	Sector 2	-6,2	-13,3	-0,7	-0,1	-3,8
	Sector 3	-6,4	-11,3	-0,2	-0,2	-3,6
	Sector 4	-5,6	-12,8	0,1	-0,1	-3,4
	Sector 5	-2,9	-12,8	0,0	-0,4	-2,4
	Sector 6	-1,3	-3,7	0,5	-0,1	-0,8
Marina di Carrara	Sector 7	0,1	1,1	1,2	0,7	0,6
	Sector 8	0,2	7,7	2,9	1,1	1,5
	Sector 9	0,4	18,8	3,3	1,1	2,6
Pilot Site		-4,7	-9,5	-0,1	-0,1	-2,8
Marina di Carrara		0,2	9,2	2,5	1,0	1,5

As can be observed from tables 1 and 2, the net decrease in solid transport of the Magra River has determined, starting in the XIX Century, a relevant erosional process, which strongly mitigated since 1938 due to the construction of the river jetty. A further attenuation of the erosion rates has been recorded in the period 1955-1998, which is when most of the breakwaters that still protect this coastal stretch were built.

With the aim of evaluating the efficiency and effectiveness of the interventions carried out between 1998 and 1999, the *Magra River Basin Authority* commissioned a research to the Earth Sciences Department of the University of Florence, with the aim of monitoring the evolution of the stretch of coastline comprised between Magra River mouth and Marina di Carrara harbour following the above mentioned interventions.

The elaboration of the gathered data within this monitoring process has been performed by subdividing the coast between the Magra River mouth and the Carrara Harbour into 22 sectors (Figure 9).

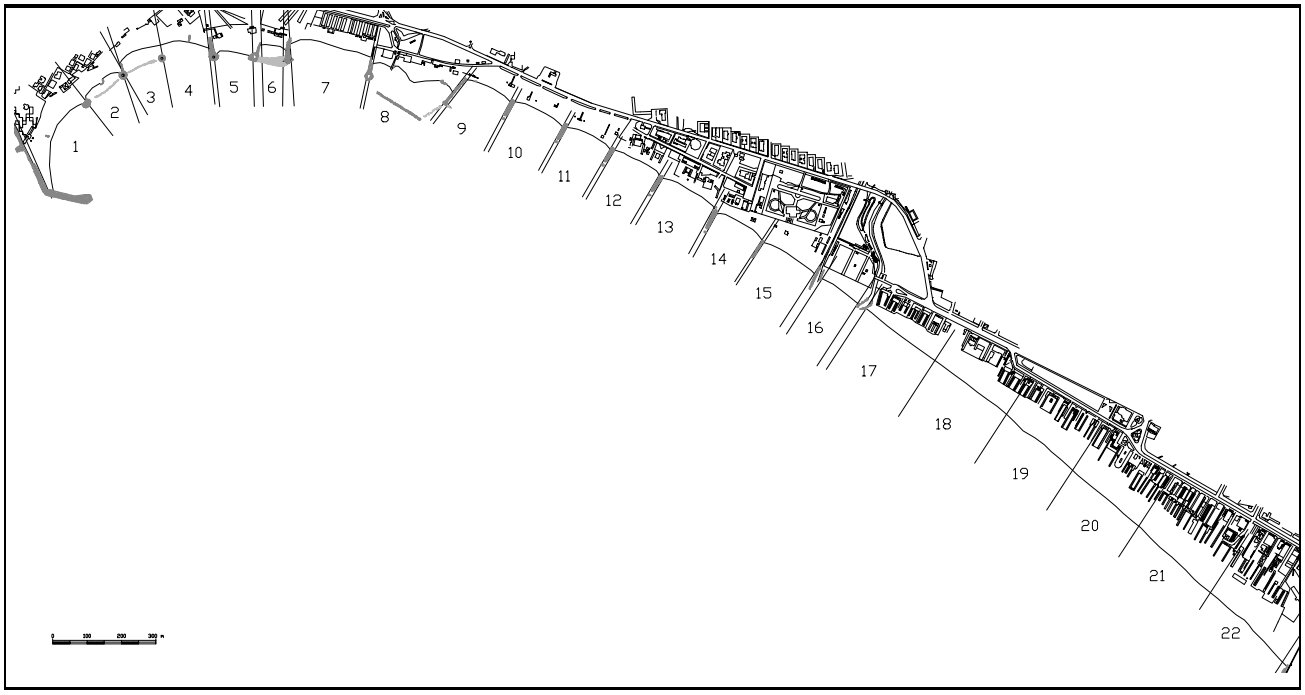

Fig. 9: Subdivision into sectors aimed at evaluating the evolution of the shoreline between October 1998 and July 2002.

The data shows that in the short period analysed it has been possible to record a strong accretion of the shoreline in the sectors 1 and 2, with a beach expansion of respectively 12,6 and 3,6 m (Table 3). From this data we can observe that the area which has mostly been affected by the erosion phenomena is sector no.16 which is bounded by the mouths of the Parmignola Creek and of the Fossa Maestra; it is thus evident that the erosion is moving towards the Carrara harbour; it is in fact possible to observe that in the last few years the erosive phenomenon has also affected the beaches placed 500 m north of the harbour (sector 19-Table 3).

Table 3: Mean shoreline evolution (m) between 1998 and 2002.

N° Sector	Length (m)	June 2001 - July 2002	May2000-June2001	May 2000-July 2002	October 1998-July 2002
1	233,14	12,63	-5,41	7,22	21,87
2	142,71	3,56	-3,23	0,33	-3,13
3	128,60	0,06	-2,46	-2,40	-2,68
4	137,37	-1,14	-0,71	-1,85	-2,26
5	114,64	-0,36	-1,90	-2,26	3,07
6	63,34	1,26	-2,61	-1,35	3,34
7	239,26	2,65	-2,20	0,45	0,85
8	251,38	-1,88	-2,28	-4,17	-2,60
9	141,62	-0,44	-1,17	-1,61	5,41
10	141,14	2,36	-3,83	-1,48	8,94
11	140,69	1,21	-1,23	-0,02	6,00
12	148,42	3,58	-1,80	1,78	4,68
13	172,25	3,20	-4,34	-1,14	-0,76
14	151,49	-1,15	-2,21	-3,36	-3,79
15	172,14	-0,25	-0,13	-0,38	-4,35
16	125,34	-5,11	-2,55	-7,66	-10,81
17	250,03	-1,53	-1,82	-3,35	1,71
18	213,84	-3,61	-6,02	-9,64	0,06
19	250,68	-3,27	-1,52	-4,79	0,16
20	193,69	1,90	-0,61	1,29	8,66
21	282,29	4,92	0,20	5,12	9,42
22	286,45	0,84	3,44	4,28	7,90

Erosion causes

The presence of such a strong erosional phenomenon can be ascribed to the drastic decrease of sediment transport by the Magra River which nourishes these beaches. The decrease of sediment transport in the Magra River is strictly connected to the abandonment of the agricultural areas located in its drainage basin, which has become progressively stronger starting from the mid 1800's. The uncontrolled dredging of sediments from the river bed, which characterized the period between the end of World War II and the end of 1970's and the construction of various types of dams along the stream have worsened the situation of the river which from the 1960's onwards had already experienced a reduction of the solid transport by about a third of what was recorded in the mid 1800's.

The beaches of Marinella and Sarzana, located at the northern end of the physiographic unit, have been the first to be affected by the erosive process as they are placed in continuity with the Magra river mouth.

1.2 Socio-economic aspects

1.2.1 Major functions of the coastal zone

Until the 1960's the area was exclusively agricultural, whereas in the last years a strong tourist industry has developed in Marinella di Sarzana, especially for the recreational use of the beach. This industry has more and more often been threatened by the presence of erosive phenomena which have endangered both the stability of the beach establishments as well as the coastal viability.

Another important activity in the area is shipbuilding and mooring points, which developed along the whole lower part of the Magra River: the various small docks are actually simple moorings managed by private individuals. The frequent flood events of the Magra River often have devastating effects on these activities for which it hasn't yet been possible to plan any solutions aimed at their protection during these extraordinary events.

1.2.2 Assessment of capital at risk

Although the area is not densely populated, the coastal road represents an important resource which is more and more often endangered by coastal erosion. During the strongest sea storms the waves often reached the coastal road, creating viability problems. In these occasions the beach resorts have suffered the strongest damages and many of them have been moved landwards in order to increase their distance from the seashore, thus diminishing the risks during sea storms. Although the damage suffered by the beach establishments is often most greatly emphasized on the local press, the loss of recreational beach surface and the damages caused by a storm to the defence structures have a much greater impact on the area's economy.

2. PROBLEM DESCRIPTION

2.1 Impacts

The main impacts determined by erosion on the coastal area can be listed as follows:

- Loss of recreational beach surface.
- Damages to the beach establishments and facilities.
- Viability problems due to the frequent flooding suffered by the coastal road.
- Construction of hard structures, which have a strong impact on the landscape.
- Damages to such hard structures during sea storms- this implies expenses for their maintenance.

3. SOLUTIONS / MEASURES

3.1 Policy options

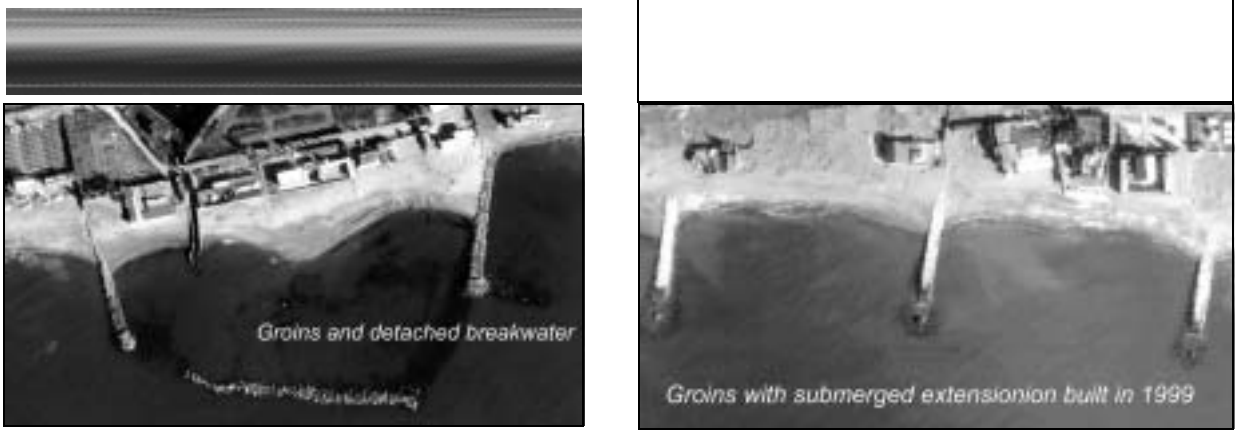

Fig. 10: Different kinds of defence structures built on the beach from the Magra River mouth to Parmignola Creek mouth.

Due to the presence of severe erosion that induced a shoreline retreat of approximately 95 m in only ten years (9,5 m/yr), several hard structures like groins, breakwaters and circular artificial islands made of rocky stones around a concrete ring have been built in the pilot site starting at the end of the 1930's.

The interventions carried out succeeded in **holding the line** reducing the erosion rates, though causing heavy impact on the coastline.

The last coastal defence intervention was performed between the winter 1998 and the spring 1999. The work consisted in the construction of four groins, placed in the sectors 4, 5 and 6 in Figure 8, corresponding to sectors 10, 11, 12, 13 and 14 in Figure 9.

These groins were developed for a length of about 90 m with a submerged extension and they were made with marble blocks (production rejects from the marble quarries in Carrara); in an analogous way a pre-existing shorter groin placed downdrift was extended to the same length as the new ones.

The intervention also included performing an artificial nourishment with 17.500 m^3 of materials with various lithologies, discharged on a coastal stretch of about 650 m of length (27 m^3/m). From a granulometric point of view the discharged materials range from pebbles (average diameter comprised between 40 and 70 mm) for about 8.000 m^3, to gravel (average diameter comprised between 3 and 7 mm) for about 8.000 m^3, down to very fine sand dredged at the Magra River mouth for the remaining 1.500 m^3. The gravel has been

placed in two overlapping homogeneous levels, with the coarsest material placed at the bottom; this has allowed to obtain a solid skeleton which provided the support for the subsequent discharge of fine sand (1.500 m^3 with an average diameter of 0,125 mm) dredged at the mouth of the Magra River.

In the spring 2002 a new artificial nourishment intervention was performed using materials dredged from the Magra River mouth and re-distributing them along the beach of Marinella di Sarzana. Approximately 45.000 m^3 of mixed sand and gravel was dredged to then be discharged on the beach before the tourist season. The intervention was sponsored and financed by the Municipality of Sarzana with a total cost of approximately 230.000 Euro.

3.2 Strategy

Given the heavy impact induced by the interventions performed by the Genio Civile Opere Marittime of the Ministry of Public Works during the XX Century, the Regione Liguria and the Regione Toscana have commissioned the management of a preliminary project for a coastal defence intervention aimed at re-balancing the coast stretching between the Magra River mouth and the Marina di Carrara harbour. The proposed solution should reduce the impact of the structures and re-use the sediments dredged from the Magra River in order to reduce overflows in the lower part of the river.

The preliminary project phase has in fact been coordinated by the Magra River Basin Authority which is the area's relevant Body for flood risk prevention politics and for all the river structures made to improve the hydraulic functions of the Magra River. For the first time in the physiographic unit comprised between Magra River mouth and Livorno a coordinated intervention in the drainage basin and on the coastal belt has been performed.

In this particular case the coordination of the Basin Authority has brought to an agreement between all the City and Province Administrations of the two Regions Liguria and Toscana which administer the studied territory, thus overcoming the typical obstacles usually caused by parochialism which in the past have always hindered profitable communication between Administrations. For the planning phase it has been necessary to use all the studies on fluvial and coastal dynamics written for the studied physiographic unit by the Regione Toscana and by the Magra River Basin Authority.

All this shows the final abandonment of those coastal defence politics which only act locally, not taking into account the natural dynamics of the physiographic unit and the impacts of the defence structures of the nearby beaches. This improvement in defence politics has been possible thanks to the contribution of the new national legal context on coastal defence, which recently was transferred to Regional Administrations in agreement with the national, inter-regional and regional River Basin Authorities.

In the past, the Municipal Administrations which did not have the financial resources needed for coastal defence would ask the State, through the office of the Genio Civile per le Opere Marittime of the Ministry of Public Works, to intervene in order to defend the towns, infrastructures and productive activities damaged by shoreline retreat. The State used to intervene in the case of an emergency, without planning or evaluating on the environmental impact of the works. The consequences can today be seen along the coast of the study area, which is characterized by a series of hard structures built at different times in order to defend the nearby coastal stretch.

The new project (Consorzio Pisa Ricerche, 2002) is aimed at re-establishing order and harmony in the defence structures of the coast comprised between Magra River mouth and

the Marina di Carrara harbour in order to favour the natural coastal dynamics. In particular, the project consists in constructing a ca. 2,6 km-long and 70 m wide artificial submerged bar made of fluvial sediment (boulder, cobble and pebble from the Magra River upper drainage basin) and placing it on the nearshore along the 4 m isobath and with a submergence of – 2 m (Figure 11).

The ideal size and the submergence of the artificial bar have been defined in detail on the basis of the results of a study on a numerical model (MIKE 21) financed by the Regione Toscana Administration. The project consists in modifying the existing defence structures, transforming part of the emerged ones (detached breakwaters, groins and artificial islands) into submerged structures, so as to favour the sediment transport induced by the wave motion and by the superficial water circulation, in order to improve the quality of bathing water.

The groins built during the 1999 intervention will be modified through a submerged extension down to the 5 m isobath, in order to reduce the longshore component of nearshore sediment dynamics. In the downdrift unprotected beach of Marina di Carrara two new submerged groins will be constructed in order to induce nearshore sediment deposition and the related decrease of the foreshore slope. At the end of the works, the beaches of the study area will be artificially re-nourished with medium coarse sand. In order to reduce the costs and the environmental impact of the restoration project it is crucial to use fluvial sediments coming from the Magra River bed, whose dredging is needed in order to maintain safe navigation in the lower part (medium and coarse sand) and to reduce the flood risks in the upper part (boulder, cobble and pebble).

A final draft of the project is presently being elaborated by the Provincial Administrations of La Spezia and Massa-Carrara, and will soon be evaluated by the Regione Toscana and Regione Liguria Administrations for the Environmental Impact Assessment procedure.

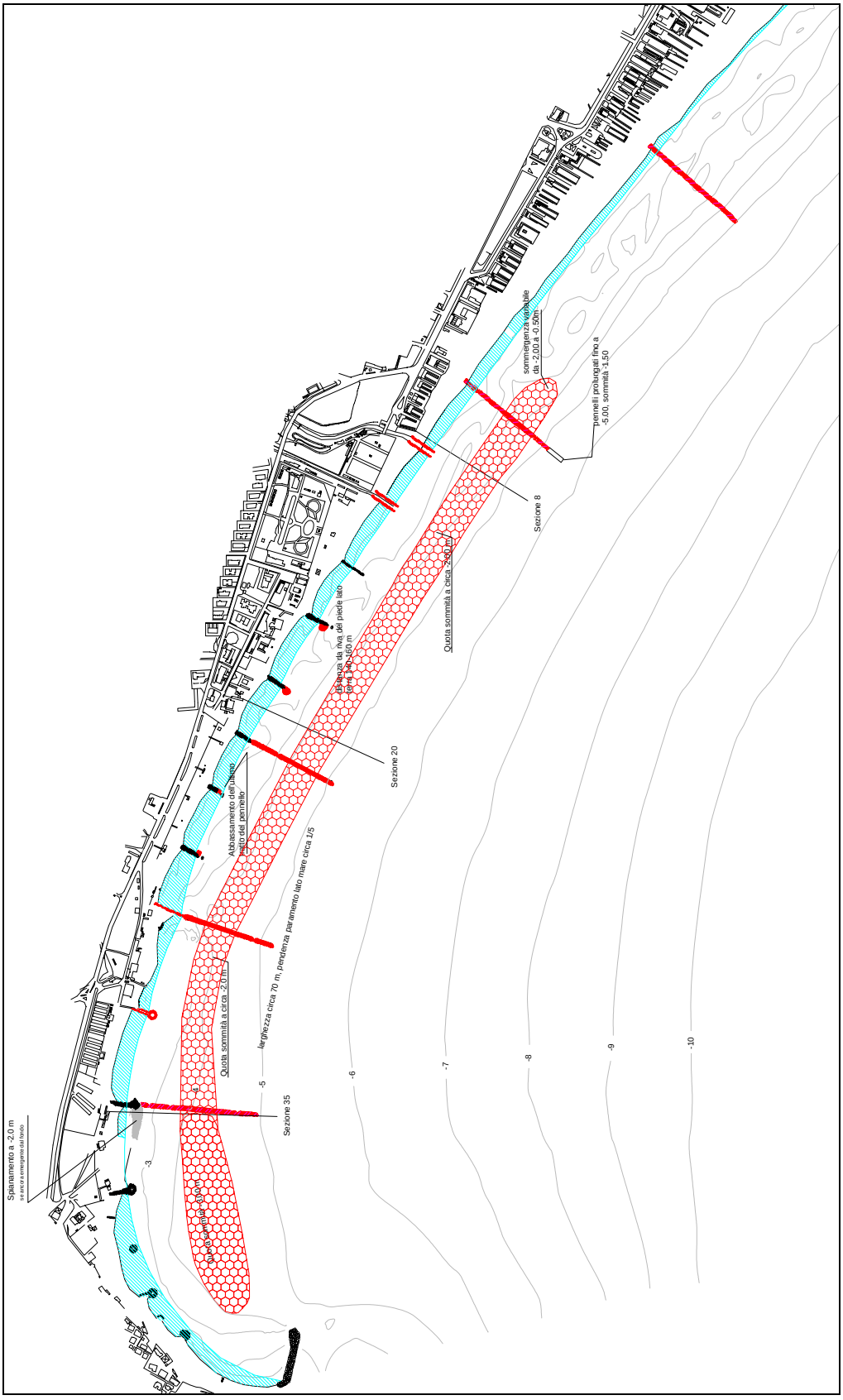

Fig. 11: Proposal for intervention.

3.3 Costs

The cost of the spring 1999 project was of approximately 250.000 Euro for the construction of groins made of rocky stones and of ca. 240.000 Euro for the artificial nourishment (gravel and sand).

For the new intervention (Figure 11) the two Regions (Liguria and Toscana) estimated a cost of 5.000.000 Euro each.

4. EFFECTS AND LESSON LEARNT

4.1 Effects related to erosion

Chronic shoreline retreat along the study area as shown in Figure 4 has been contrasted since the early XX Century by the construction of hard defenses like groins, detached breakwaters and artificial islands, only looking at the local scale and never considering the effects of the works on the physiographic sub-unit induced by the construction of Marina di Carrara harbor. In fact the harbor northern jetty intercepts the south-eastward longshore sediment transport inducing shoreline accretion along the Tuscan part of the study area. Following the construction of hard defenses along the Ligurian part of the study area, close to Magra River mouth, shoreline retreat rates decreased rapidly, and consequently the south-eastward longshore sediment transport. Thus shoreline accretion at Marina di Carrara decreased gradually to the point that now at the regional border (Parmignola creek) shoreline retreat was surveyed in recent years (figure 7).

Hard engineering constructed with the emergency to defend the seaside resort or the coastal road without both a preliminary study of coastal morphodynamics of the area and the environmental impact study, resulted to be effective at local scale only, exporting beach erosion downdrift. In the meantime along the beach at Marina di Carrara which experienced shoreline accretion, the newly gained beach has been rapidly used to build sun-bathing establishments and facilities like bars, restaurants and so on, so that now in the case of shoreline retreat the new structures will experience serious damages.

The lesson learnt is that structural erosion cannot be stopped with hard structures. Since the main cause of erosion is a sediment starvation due to a strong decrease in Magra River sediment load, artificial beach nourishment proved to be more effective and more environmentally friendly. Hard structures resulted to be effective in order to hold the line at local scale. Their actual cost (construction and maintenance) and impact on the environment is very high; in addition, they move the problem downdrift.

4.2 Effects related to socio-economic aspects

Local economy converted to tourism in recent years. Shoreline retreat and the related loss in beach surface, in addition to the serious damages caused by storms to the sun-bathing facilities, induced the Municipality of Sarzana to ask the Ministry of Public Works the construction of hard defences. Groins, breakwaters and artificial islands have temporarily stabilized the shoreline and the sun bathing facilities were moved inland in order to have more beach space for tourist recreation. However, beach and sea water quality decreased rapidly after the construction of hard defenses, provoking a remarkable economic damage to the area. Frequent damages to the defense structures and the coastal road flooding during storms, induced local population supported by the Municipality of Sarzana to ask the two Regions Liguria and Tuscany to elaborate and to realize a more homogenous coastal restoration project in order to re-establish the natural function of coastal defense to the new beach, beyond to favor the tourist economy tied to the bathing activities. The population and the local press have given importance strongly to the new plan and above all to the aspect related to the collaboration either in the phase of study and planning and then realization of the new project by the two Regions with the coordination of the Magra River Basin Authority.

4.3 Relation with ICZM

Both Regione Toscana and Liguria have included the new restoration project in their ICZM Regional Plans. Funding for Regione Liguria comes from the EU, while the Regione Toscana will use its regional sources. The new project will be evaluated through the Environmental Impact Assessment procedures where all the aspects related to biological, chemical, physical impacts on the environment and on locals (related to the construction period and afterwards) will be analysed.

This is the first case in Italy in which a coastal restoration project is planned and performed by two different Regional Administrations. Safety for the local population is one of the main goals of this project, for both the risks of river and sea flooding of low elevation areas. A set of new regulations on the future use of the beach and adjacent areas will be produced by both Regional Administrations in order to avoid new constructions on the beach.

4.4 Conclusions

Hard engineering (groins, detached breakwaters, artificial islands) showed to be effective in order to decrease shoreline retreat rates at local scale only. Beach nourishment projects were undertaken only on a local scale in order to stabilize the shoreline before the summer tourist season.

A global project for the restoration of the entire physiographic sub-unit, together with the evaluation of the environmental impact of defense structures along adjacent beaches has never been performed before. The opportunity to acknowledge the in-depth study of the coastal morphodynamics of the entire physiographic unit made by Regione Toscana between 1997 and 2000 (Regione Toscana 2000), in addition to the monitoring of the evolution of the coastal zone of the study area by the University of Florence (Dipartimento di Scienze della Terra 2002) under the supervision of the Magra River Basin Authority, made it possible to plan the restoration of the coastal zone in order to decrease the anthropic impact and to enhance the natural defense function of the beach and of its recreational use.

The preliminary restoration project funded by both Regione Liguria and Toscana will be evaluated through the Environmental Impact Assessment procedures, especially for the possible impact on ecological functions of the gravel nourishment along the nearshore of the study area. Local stakeholders and public in general will have the possibility to participate in the discussion and approval procedure inside the EIA process.

The preliminary objective to allow full cooperation among the different Administrations (Regional, Provincial and Municipal) was achieved. The Regional ICZM Plans by Liguria and Toscana allowed to find the financial support for the design project and for the future realization of the restoration works.

5. REFERENCES

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