CHAPTER 260

INTERVENTIONS ON THE COAST SOUTH OF BRINDISI

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Abstract

The coast between Torre Mattarelle and Torre San Gennaro (Italy) is deeply eroded. The recent construction of a thermal-electric power plant changed the natural morphodynamic characteristics and the erosion rate. Interventions on the coast were needed. This paper refers about the phases of design and construction of the maritime defence works and tries to call attention about the need of an extensive study before the construction of a power station along the coast.

Introduction

The coast between Torre Mattarelle and Torre San Gennaro, a few kilometers South of Brindisi (Puglia-Italy), consists of a cliff with an overhanging slope subjected to continuous erosion due to the combination of geotechnical instability phenomena, run-off from rain water and the action of the sea waves. ENEL (the Italian national board for electricity) in 1982 started the construction of a thermal power plant (4 units, 440 MW each) in this area. The plant required a system to discharge the cooling water formed by two groynes extending to -7.0 m water depth. The part of coast in front and north of the power plant was protected by a 1.8 Km long seawall system. The maritime works started in 1985.

These interventions effected the natural morphodynamic evolution of the coast; the area to the south no longer received material from the north, therefore, retreat of the coastline and cliff instability increased. A visible effect was the relatively fast disappearence of the swimming beach south of the power plant.

ENEL is involved in the protection works for the portion of coast to the south of the power plant.

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The coastline

The planform configuration of the coast represents an indipendent physiographical unit extending from the prominence at Torre Mattarelle to the headland at Torre San Gennaro, a distance of 6.5 Km. The shoreline developes as a spiral arc from Torre Mattarelle to the swimming beach south of the power plant (fig.1 & 2). After this part an almost straight beach is observed. Afterwards, the coast has a curvilinear trend till Torre San Gennaro (with an orientation from 40^0 to 30^0 North).
Before any maritime work was started, the sandy emerged beach had an average width of about 5 m for all the coast north and for 1 Km south of the system to discharge the cooling water. Further south, the beach width increased to approximately 15 m.
The cliff has an average height of 13 m above the still water level; next to Torre San Gennaro, the cliff height decreases to about 4 m and then disappears. Only 25 % of the cliff material is sand ($D_{50} = 0.3$ mm), the rest is clay and silt.
Analysis of several samples shown that the submerged beach is composed of material with $D_{50} = 0.3$ mm till water depth -1 m and $D_{50} = 0.075$ mm beyond this limit. The material from the cliff erosion, due to the absence of river estuaries along the coastline, is the only supply for sediment.
To avoid the retreat of the coastline in front of the power plant, a seawall system was built during 1989; the work phases were:

1) cliff face adjustment with a slope of 2/3;
2) driving of sheet piles in sea bottom along the line representing the external structure of the reef base;
3) excavation close to the sheet piles;
4) laying on the shore and on the sea bottom of a geotextile cover weighing 300 g/m^2;
5) laying of a "tout venant" bed;
6) armour construction consisting of natural rock weighing $500 \div 2000$ Kg;
7) extraction of the sheet piles.

After the construction of the two big groynes to discharge the cooling water and the seawall protecting the coast in front of the power plant, the width of the beach to the south reduced to $1 \div 2$ m.

Wave climate and currents

The area is exposed to waves from directions ranging between 330^0 and 120^0 N. To estimate the offshore wave climate the following informations were used:

- data from KNMI (Royal Dutch Metheorological Institute) for the period 1961-1987 (more than 30000 visual observations of the sea state);
- data for 1983 from the ENEL wave recording system placed out of Brindisi harbour.

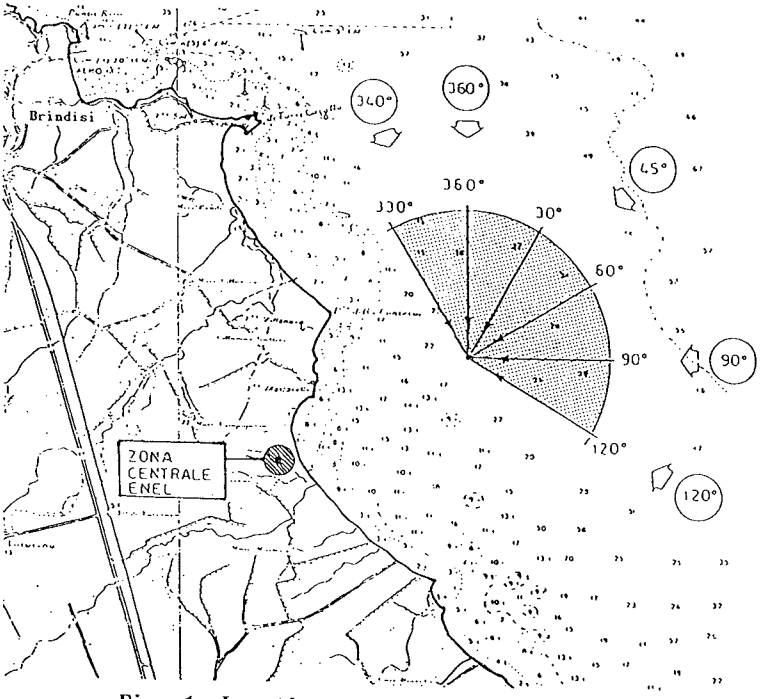


Fig. 1. Location of the power station

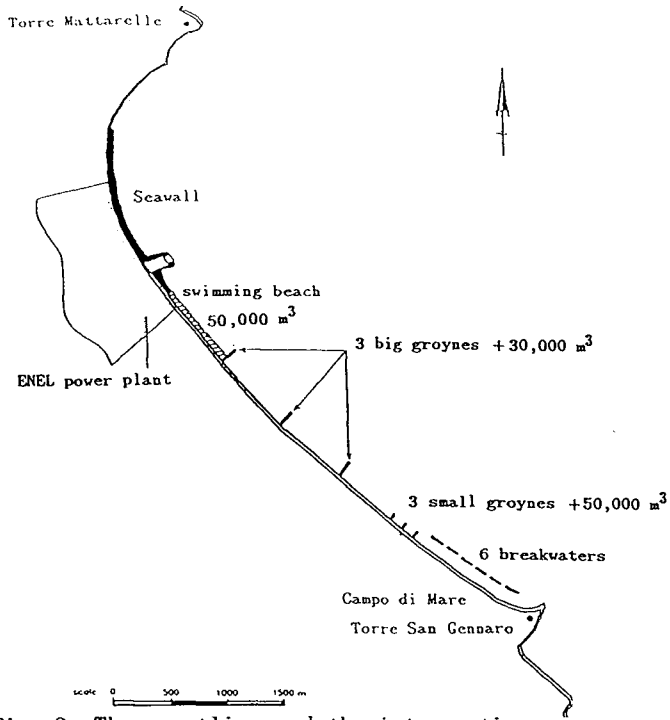


Fig. 2. The coastline and the interventions

years 1961÷1980
All directions ($330^0 - 120^0$ N)
T = 1 year $H_s = 4.5$ m
T = 10 years $H_s = 6.2$ m
T = 50 years $H_s = 7.5$ m

Direction (^{0})	H_s for T = 1 year	H_s for T = 10years
330	3.50 m	5.30 m
0	3.75 m	5.75 m
30	3.50 m	5.30 m
60	3.50 m	5.75 m
90	2.50 m	3.60 m
120	3.00 m	4.30 m

Table 1. Wave climate based on visual observations for different return period T

It was observed (table 1) that the most frequent wave conditions are from the directions 30^0 and 150^0 N; the last direction is practically out of the sector of exposure of the coast. These characteristics of the wave climate are typical for all the seasons; only during autumn and winter the frequency of waves coming from 30^0 and 60^0 N is increased.

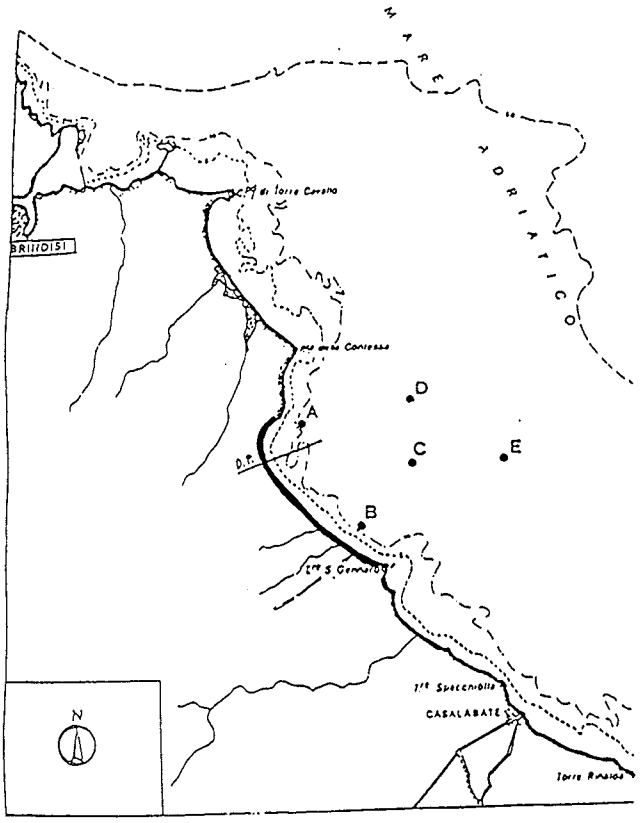
Five fixed current meters, installed in water $10 \div 30$ m deep (fig.3), were used to measure currents. The charts from current meter data that ENEL prepared show a large frequency of the currents to S-SE; the currents distribution indicates a net littoral transport to the south. The velocity of the longshore current is rather high (more than 30 cm/s).
The observed astronomical tide is small (about 30 cm), consequently the tidal currents are weak.

Erosion rates and sediment transport calculation

The recent evolution of the shoreline has been assessed using:
- topographical charts by ENEL from years $1982 \div 1985$;
- aerial photographs series from years 1974, 1981 and 1987.

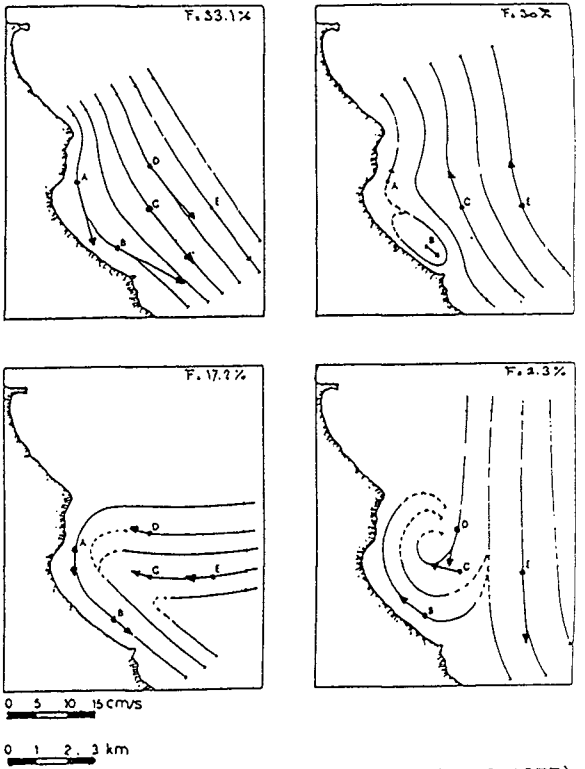
The approximate scale of the photographs was known. The surveys were not perfectly comparable. In the ENEL area the 1987 series were already disturbed because of the works for the sea-water adduction consisting of under water concrete pipe-lines having intake structure about 400 m from the shoreline.
The mean slope of the foreshore along the coast is approximately 1:45.
The observed retreat rate of the cliff (fig.4) before any ENEL intervention was $1 \div 2$ m/yr for the mid section of the coast and $0.2 \div 0.5$ m/yr for the remaining part.

The effect of the two groynes forming the system to discharge the cooling water was to subtract for the entire coastline to the south a natural supply of about 20,000 m^3/yr (assuming that with 1 m coastline retreat a sand volume of 10 m^3/m is required). This influenced the sediment transport Q distribution, giving an increase in the retreat of the swimming beach coastline from about 1 m/yr of the natural condition to $4 \div 5$ m/yr (fig. 5).
For the part of coast to the south of the swimming beach, as an average yearly retreat of the coastline, a value of 0.5 m/yr was calculated. The observed yearly erosion of 0.5 m gives consequently a gradient in the longshore transport rate of 5 m^3/m per year. Basing on almost 4,000 m coastline (south of the power plant), a 20,000 m^3 yearly loss of sand was estimated. An estimated value of the eroded material of the cliff is 50,000 m^3/yr. Only 25 % of this material (about 13,000 m^3/yr) consists of sand with a size sufficient to remain stable under the action of the longshore current. Therefore, the erosion of the cliff is not sufficient to increase the dimension of the beach.



Coastal area and position of the current meters

Fig. 3



Charts from the current meters (1976-1977)

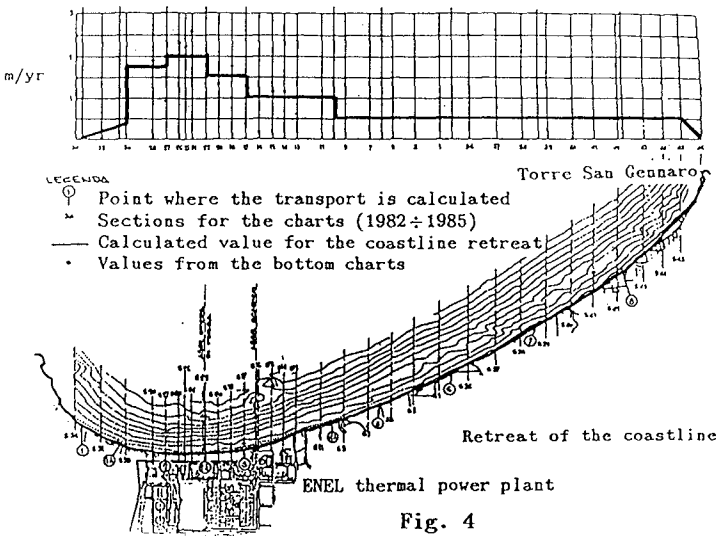
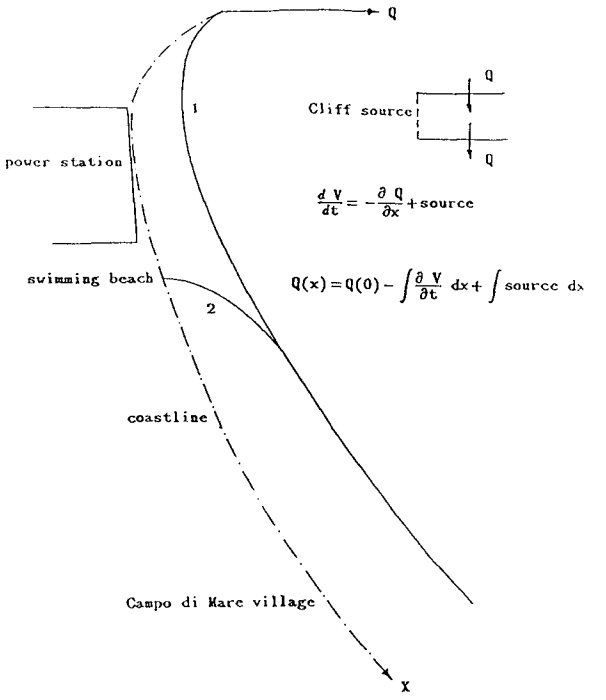


Fig. 4



1 – before discharge system and seawall construction
2 – after discharge system and seawall construction

Fig. 5. Q distribution along the coast

In order to evaluate the direction and the entity of the longshore sediment transport, a study concerning the transformation of the waves from offshore to the limit of the surf zone was carried out. Three refraction models were used for the entire coast taking into account five directions for wave incidence. The longshore transport was evaluated in some positions along the coast.
Calculations were performed using the CERC formula, the Bijker formula and the Engelund-Hansen formula. The results have a range of approximately 3 times the smaller value. The results of the computations (Delft Hydraulics, 1990) with the CERC formula are between the results of the Engelund and the Bijker formulae (giving the smallest value).

Conditions				Total Transport in m^3/day		
Run	H_{osig}	T	θ_0	Engelund	CERC	Bijker
	(m)	(s)	(°)			
1	1.0	4.5	10	1350	1000	450
2	2.0	6.0	10	11400	5650	3500
3	1.0	4.5	20	2500	1950	800

Conditions: - beach profile slope m = 1:45
- particle size $D_{50} = 200\mu m$
- fall velocity $w = 0.025$ m/s
- bottom roughness $r = 0.05$ m

H_{0sig} : significant wave height (deep water)
T : wave period
θ_0 : angle of approach (deep water)

Table 2. Comparison sediment transports various formulae

The CERC formula is:

$$S = 0.040 \cdot H_b^2 \cdot n_b \cdot c_b \cdot \sin(\beta_b) \cdot \cos(\beta_b) \qquad [m^3/s]$$

where:
H_b = signinificant wave height;
n_b = ratio group velocity to wave propagation speed;
c_b = wave propagation speed;
β_b = angle of approach of waves with respect to the coastline orientation;
b = index indicating the waves at breaking point.

For some of the selected positions along the coast and for some directions of wave approach the calculation was in good agreement with the field observations. The shadow effect of the headland where the town of Brindisi is located and of Torre Mattarelle gives a large effect that was considered using the transport formulae with weighed coefficients.

Design and its adjustments

The main purpose of the design was to stop the retreat of the coastline to the south of the power plant. This result had to be reached with a multipurpose series of works: in fact the swimming beach just south of the power plant had to assume again the bathing properties, further south the village Campo di Mare (which promenade was already interrupted) had to be protected from the sea action.

The local Authority, in order to protect effectively the coast, approved the design of six detached breakwaters which were constructed during 1991 in front of Campo di Mare village. They are situated in rather shallow water (about 3 m) and present a crest at + 2.5 m above s.w.l.. The six detached breakwaters were designed to take overtopping only during severe wave conditions. These protection works were chosen to give to inhabitants an impressive idea of safety. Moreover, the local Authority approved the design of three big groynes (which length is about 85 m) that were constructed just south of the swimming beach with an inter-distance between two groynes of about 700 m. The groynes reach −2.0 m water depth and present a crest at +2.5 m above s.w.l..

The design consideres a nourishing initial material supply:

- 50,000 m^3 just SE of the ENEL power plant (swimming beach);
- 30,000 m^3 together with the three big groynes south of the swimming beach;
- 50,000 m^3 together with the construction of three small groynes (reaching −1.0 m water depth) just N of Campo di Mare. The three small groynes should have the effect of a hinge between the six detached breakwaters and the big groynes.
- a maintenance sand supply of 20,000 m^3 as an average yearly volume.

Together with the construction of the two last detached breakwaters the nourishment of the swimming beach and the construction of the first one of the three big groynes were started. As nourishing material a mixture has been adopted:

- 40 % material with $D_{50} = 0.26$ mm;
- 60 % material with $D_{50} = 5.00$ mm.

The nourishing material is composed of 40 % material having a characteristic diameter even smaller than the natural one ($D_{50} = 0.3$ mm) from the cliff erosion. The net longshore transport brings a large part of the smaller part of the supplied material to the south together with the natural one.

Nowaday a total of 24,000 m^3 material has been placed to re-create the swimming beach; 6,000 m^3 material has been placed south of each of the 3 big groynes.

Monitoring programme

To assess how well the project performed the desired function and to optimize the nourishment time schedule, an extensive monitoring programme consisting of bathymetric records normal to the coast and tide level measurements has been initiated. The monitoring consists of 26 bathymetric sections extending to a water depth of 10 m, photographs taken from the sea towards the coast at certain months throughout every year. Informations from the monitoring suggested that a slow supply of sand should be arranged.

The three big groynes do not give a satisfactory defence; in fact, some parts of the coastline are still subjected to retreat. This, probably, is due to the too large interdistance between two groynes. Therefore, the construction of some smaller extra groynes is not excluded; the material for their construction could be get removing stones from the too high crest of the existing groynes.

A massive accumulation of sand behind the six detached breakwaters and an evident tendency toward a tombolo are observed (fig.6 & 7); as expected, the last offshore breakwater (measured from Torre San Gennaro) catches most of the longshore sediment transport. During last winter 6,000 m^3 of naturally stored sand were removed and placed close to the headland Torre San Gennaro. After a few weeks that large amount of sand was lost.

An extra intervention for Torre S. Gennaro headland was necessary in order to protect some private houses; the protection works consisted of a seawall with $1 \div 2$ t rock stones and were carried out during autumn 1992.

The first from the North of the three small groynes was built (completed in November 1992, 56 m long, fig. 8). The proposed construction of the two remaining small groynes (together with 50,000 m^3 material supply) is under discussion: these works will be probably obmitted. The common idea is to spend some more time observing the behaviour of the coastline.

Conclusions

This paper tries to emphasize that the design of a large plant along a sandy coastline requires a very attentive design phase for the maritime works. The design should be verified basing also on physical model tests. Sometime, attention during the design phase helps to save future efforts, which are needed to avoid not expected effects. Even if with large tolerance, nowaday, specialized coastal engineers can successfully foresee the coastline development with or without any human intervention. A monitoring programme assists the designer in defining a nourishing time schedule and in a better understanding of the error for the rates of erosion from the not perfect comparability of the surveys.

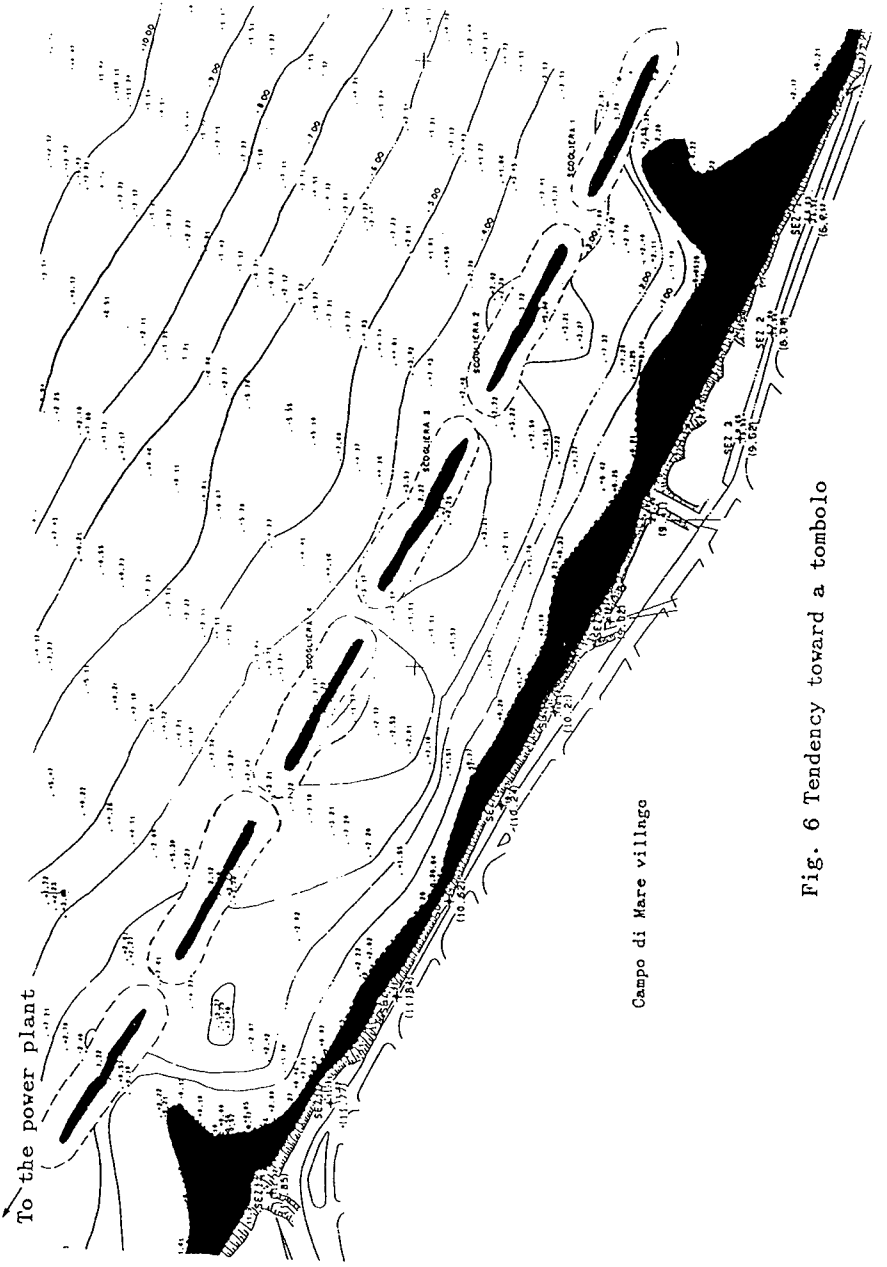


Fig. 6 Tendency toward a tombolo

Fig.7. The first from the south of detached breakwaters and the tombolo

Fig.8. The just built small groyne and the cliff from Campo di Mare village

Acknownledgements

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References

CERC, (1984). Shore protection manual.
Delft Hydraulics, (1990). Some morphodynamic considerations of the Brindisi Sud project. February 1990.
Polytecna-Harris S.p.A., (1986). Impianto termoelettrico di Brindisi sud, Opere di difesa della centrale ed interventi sul litorale, Progetto esecutivo. Marzo 1986.