



The Pontino nourishment work along Region Latium's beaches

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Direzione Regionale Ambiente e Cooperazione tra i Popoli



Venice - November 25-28, 2008

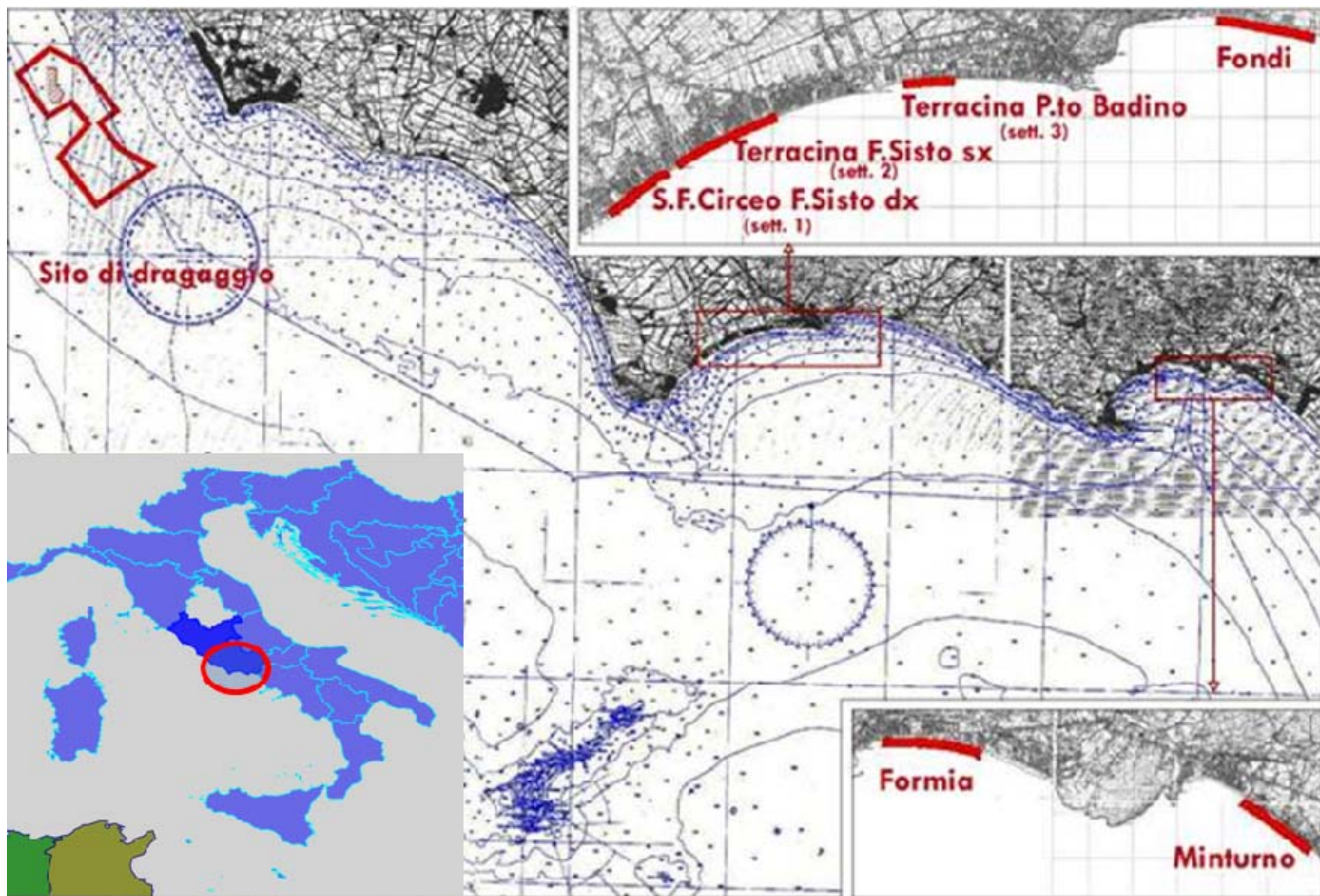


Fig. 1 – Area of nourishment works and borrow quarry (ICZM Monitoring Center)

Description of works

The works of defence and reconstruction of PONTINO littoral are started on September 2005 and are finished on June 2007. The total budget of the works has been 32,4 millions of euro for the reconstruction of 5 Municipalities of PONTINO's littoral for a total amount of 12,4 Km of coast: a) S. Felice Circeo, on the hydraulic right of "Sisto" river; b) Terracina, on the hydraulic left of "Sisto" river and hydraulic left of "Badino" harbour; c) Fondi, on the area between "Foce Canneto" and "Foce Canale S. Anastasia"; d) Formia, on the area between "Torre Mola" and "Fosso dell'Acquafredda"; e) Minturno, between "il Porticciolo" and "Monte d'Argento".

The Project consist of a beach nourishment with borrow sand coming from marine quarry, protected by perpendicular structures (groynes). A nourishment without groynes was provided for the "Formia" Municipality because of the existence of emerged barriers before this intervention.

During the Project development phase, important deepening studies were carried out. A study of **Environmental Impact Assessment** with an Incidence Assessment is provided from the Project with a Specific study of Environmental Impact for the borrow quarry exploitation. The **Analysis of grain size compatibility** between native sand and borrow sand has been adopted for a comparison between original and settled beach profile. A **morphodynamique study** (one-line analysis) and the **analysis of realization and maintenance costs** has been fundamental for the choice of the intervention typology.

An intense activity of monitoring carried out by the WS during dredging and nourishment works, through the presence of a geologist on board of the dredge, it was necessary due to the unusual characteristics of borrow quarry, with a dept of 100 m, and the bimodal quality of sediment grain size (about 70 % sand and 30% gravel).

Nourishment work	Length [m]	New beach area [m ²]	Settled mean advancement [m]	Nourishment volume [m ³]	Number of Groynes
1 st sector Terracina	1.650	52.400	33	435.000	-
2 nd sector Terracina	2.600	76.000	30	613.100	-
3 rd sector Terracina	1.650	36.800	23	322.600	-
Total Terracina	5.900	165.200	86	1.370.700	16
Fondi	2.200	65.000	29	580.000	7
Formia	2.200	30.400	15	100.000	-
Minturno	2.500	57.700	23	516.000	5
Total	12.800	318.300	38	2.566.700	28

Fig. 2 – The data of the Project

New Project measures for the choice of the structures typologies for protect nourishments

The groynes made on natural rocks are designed considering aspects linked to wave height, action of sand retaining, and touristic fruition. Classic criterions were utilized for the first aspect (Gerding, Van der Meer). Innovative designs are adopted for the second aspect: part of groyne is submerged, to guarantee the passing of longitudinal transport of sand, the final part of groynes have an Y plan to reduce the erosive effect to the bottom of the structure, finally the progressive reduction of the length of groynes in direction of the last groyne underflow. This approach is a consequence of the hypothesis that groynes have the role of retaining of new sediment coming from nourishment, and their function is to release gradually the sediments on the direction of prevalent currents. Third aspect is respected through the realization of a walk on concrete on the top of groynes, to guarantee the tourists fruition.



Fig. 3 – Two images of groynes realized on PONTINO littoral

Model of simulation of equilibrium beach profile in function of the characteristics of borrow sand grain size

The characteristic of "ideal" borrow sand for this nourishment was calculated considering the grain size of native sand and the equilibrium profile of the beach before the intervention. This model adopt the hypothesis that the post-operam beach profile, in a dynamic equilibrium condition, maintain the same granulometric characteristic of ante-operam equilibrium profile. More the borrow sand is similar to native sand, more high is the probability that the natural equilibrium profile will be reached. The results for this study is the design of an "ideal" characteristic of borrow sand. Activities of monitoring and comparison have been followed during the dredging of borrow sand. A second phase of this study concerned the assessment of sand volumes and their distribution on the settled beach profile, considering some coefficients linked to the granulometry of borrow sand. An estimated settled profile is compared with the ante-operam profile on figure 5. In this case the characteristic of borrow sand would have guaranteed more volumes of sand in correspondence of emerged beach on respect of submerged beach.

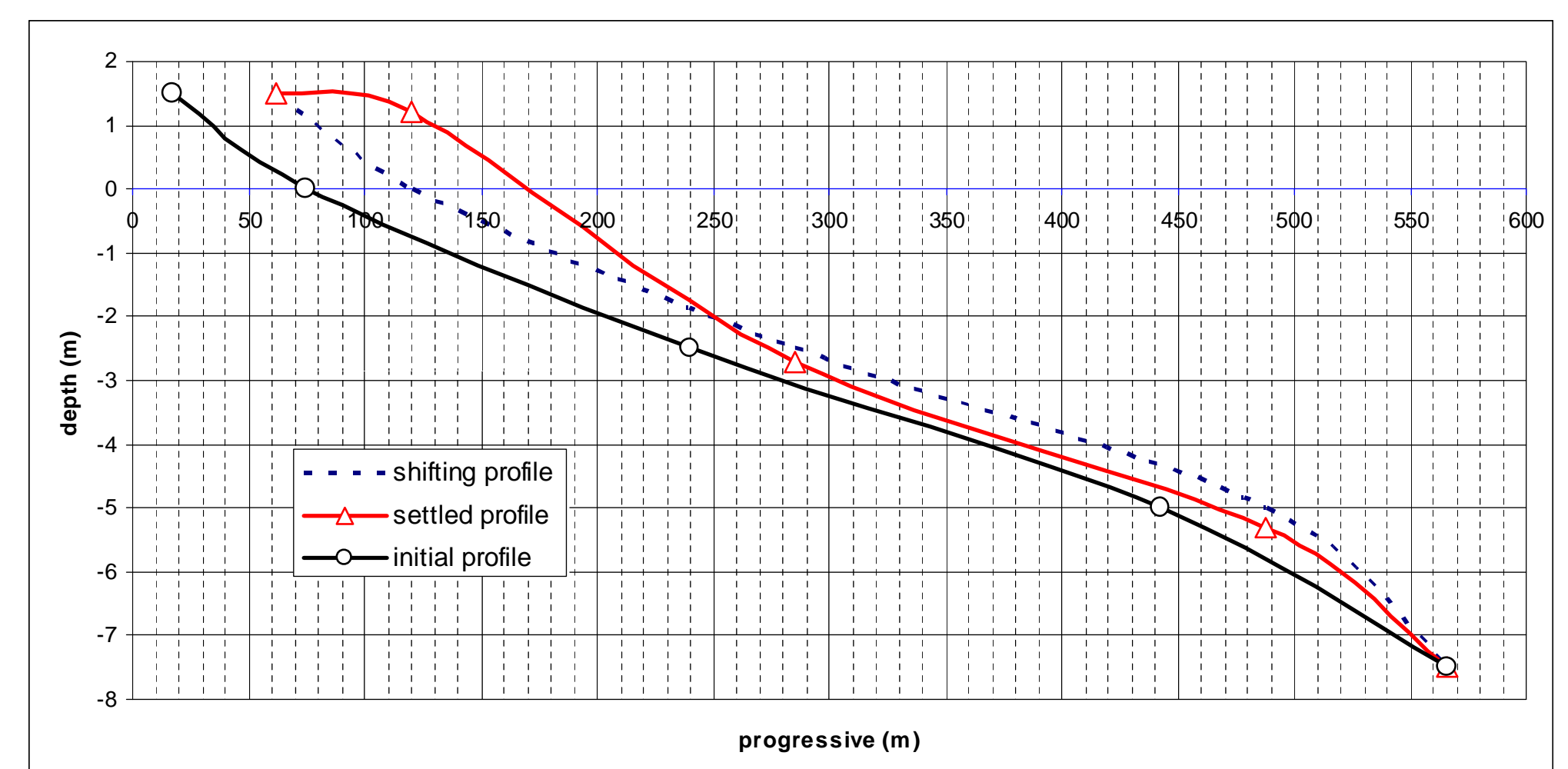
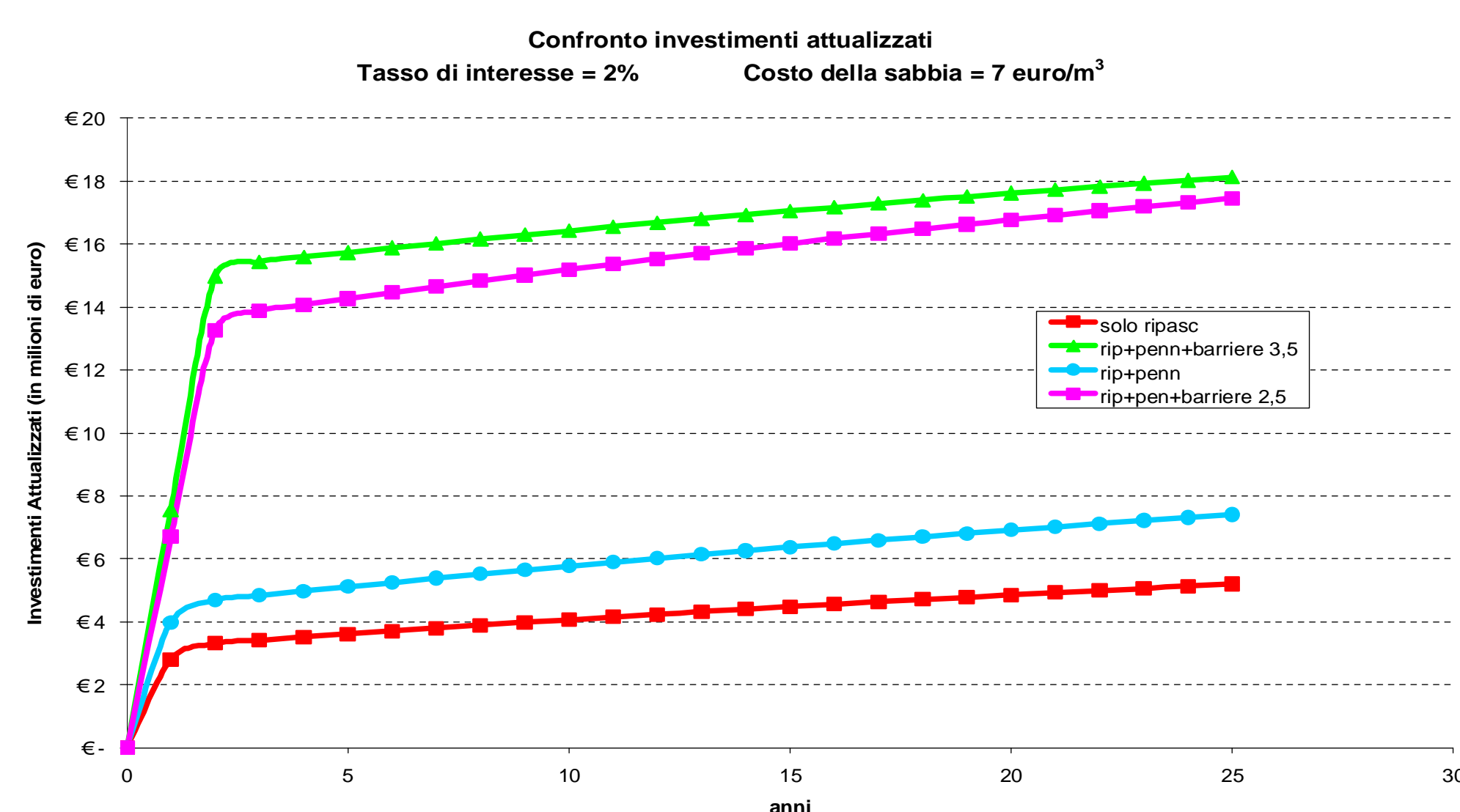


Fig. 5 – Settled beach profile result of granulometric simulation model adopted for Terracina-Circeo nourishment (Data processing "Osservatorio dei litorali laziali")



Analysis of realization and maintenance costs

Also economic aspects have been considered during the Project phase. A study of realization and maintenance costs comparison between different types of interventions were made (nourishment only, nourishment and groynes, nourishment and longitudinal barriers). An actualization costs analysis was made for three area of intervention, considering a 25 years of life of the opera. Results showed nourishment with groynes the lower cost kind of intervention with hard structures. On figure 4 are reported the results of Actual Value (AV) of intervention for the area of "Fondi" Municipality. Note that this study didn't consider the Benefits Analysis.

Fig. 4 – Actual Values (AV) for the intervention of "Terracina" Municipality

Monitoring System for the granulometric characteristic of sediment coming from borrow quarry

This activity, coordinated by the Work Supervision, thanks to the results of granulometric analysis of 59 sand tests (one for each trip) have guaranteed a steady control of dredged sand with project requirements. The differences among the various tests confirmed the heterogeneous characteristic of borrow quarry. Mean grain size goes from a minimum of $D_{50} = 0,18$ mm to a maximum of $D_{50} = 20,5$ mm. During the project phase, the heterogeneous nature of the quarry was already underlined both in horizontal and vertical sense. In figure 6 the comparison among the granulometric curves confirm the respect of the project parameters.

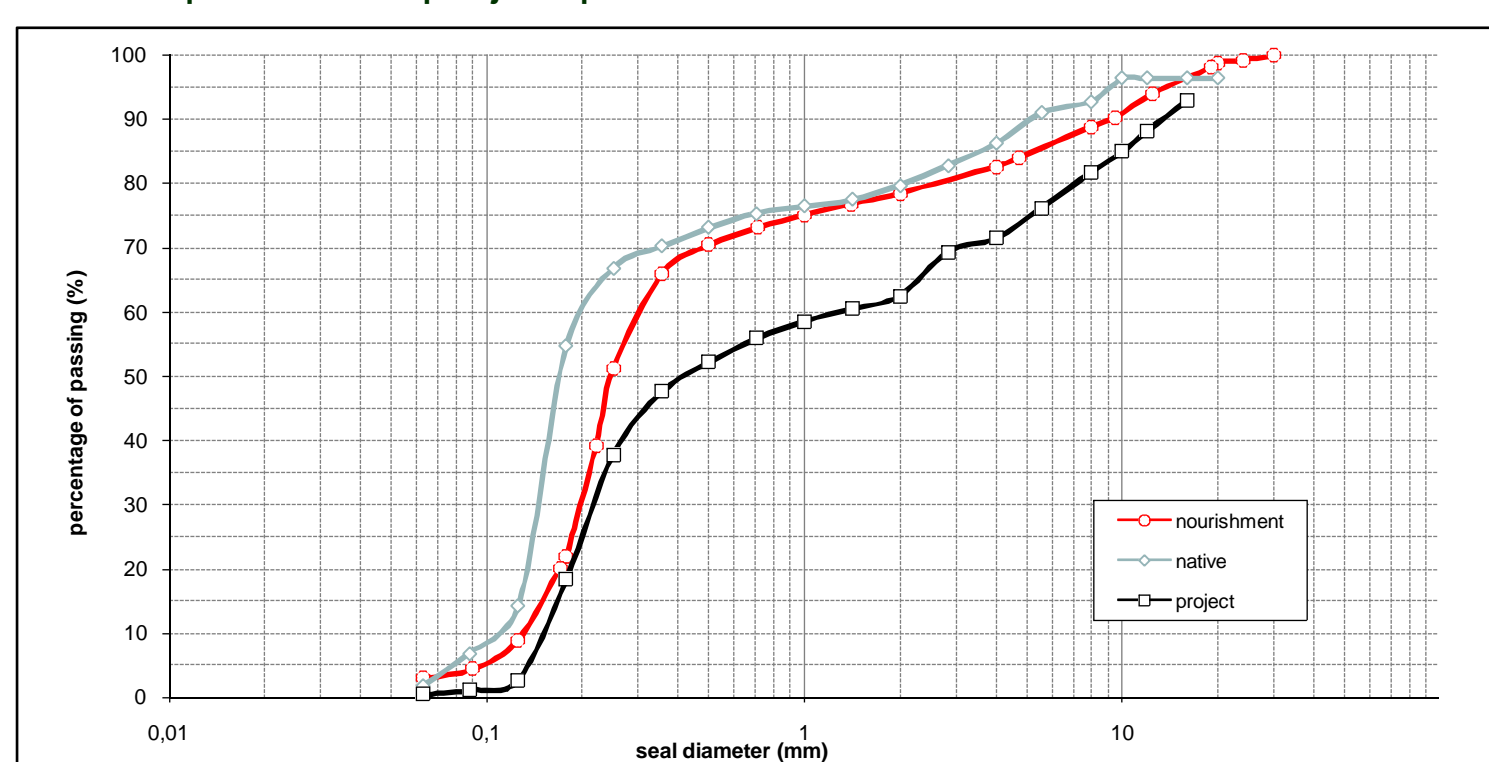


Fig. 6 – Granulometric curves. Comparison between native sand (ante-operam), project sand (dredging corridor) and nourishment sand (from dredge wells)

Environmental monitoring in progress of work

Two aspects have concerned this activity, both linked to sediments handing effects take from sea environment both during dredging phase and in deposit phase near the shore. ICRAM Rome (today ISPRA) has studied the effects induced by the sand suction on the column of water in the area and in the immediate proximities. "Dipartimento di Biologia Animale e dell'Uomo" of "La Sapienza" University has studied the effects of thin sand suspension on the *Posidonia oceanica* near the coast. Thanks to these two activities the WS has received all the information necessary to be able to operate in safety against the environmental risks in phase of dredging and nourishment. During first activity, are been observed different turbidity clouds following a principal axle induced by the tides. On surface waters, clouds have been separate, while in the depth waters they are united forming an only vast dimension area of turbidity with greater concentrations of thin sediment in comparison to surface waters. The sands of turbidity in surface, leaving quickly, while the slimy material that forms the turbidity on the fund, reaches more elevated concentrations and it is persistent in the time. It could go up again in suspension, with current greater of 100 cm s^{-1} , forming some secondary clouds of turbidity with transport of side sediment. A fundamental element is to valuate natural turbidity on the bottom of the sea, with the purpose to appraise how the produced turbidity can engrave the natural conditions. During second activity, a total of 19 bodies by the weight of 30 Kg (*balise*) have been positioned with as many pickets in steel one meter tall. For each station direct observations have been effected thanks to the work of two underwater biologists assisted by a raft equipped with differential GPS. For every stations, parameters of grassland coverage, substratum typologies, border typologies, *Posidonia* density have been monitored. The reliefs have shown different situations in the area of study: in proximity of hydraulic right of Sisto river, among 4 cm and 10 cm of sediments height variations have been recorded between 12,5 and 14,5 m of depth with woodpeckers of 40 cm on 10 m of depth. This phenomenon has been recorded before the start of the second phase of nourishment and it is absolutely improbable that a quantity of sand could have moved without a gradual raising along the intermediary run and without analogous intensity of variations on nourishment, before one year of its realization. The mobility of sediments at 14 m of depth is very meaningful, contrarily than generally affirmed. It is evident that this phenomenon is dynamic independently from nourishment new addition of sediments. Little remarkable changes are recorded in the other studied zones.

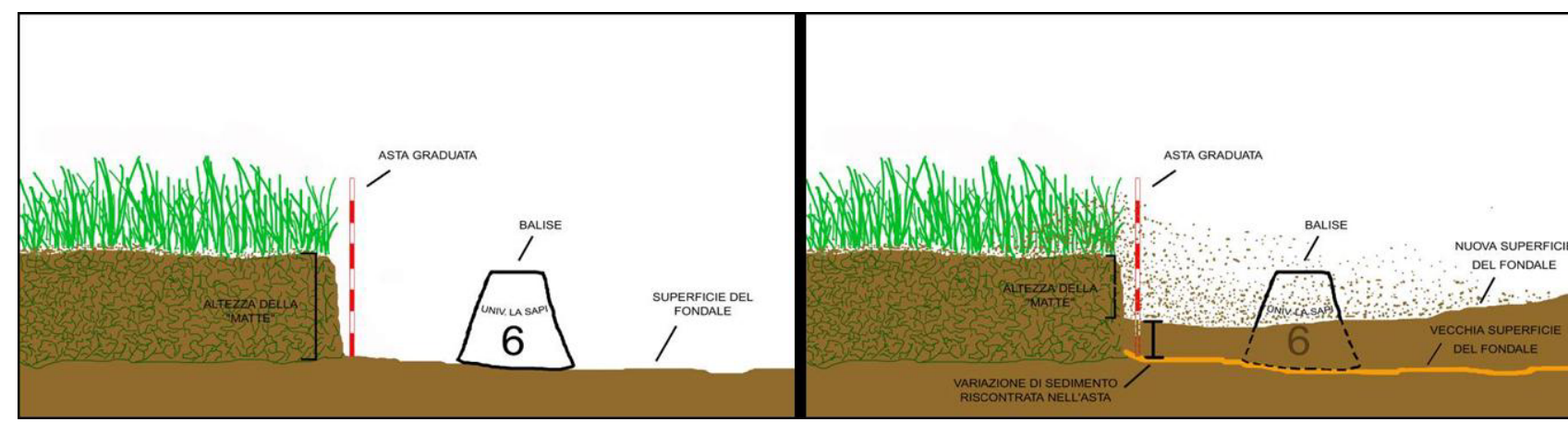


Fig. 7 – Technique of "Balisage", for the study of the effects of thin sand suspension on the *Posidonia oceanica* superior border. (G.D. Ardizzone et al., 2008. Monitoraggio delle praterie di *Posidonia oceanica* comprese tra il promontorio del Circeo e Sperlonga)

Results, one year after works

One year after the end of works, two reliefs of shoreline with GPS technology have been made. In figure 8, a representation of cartography web service developed on Google platform for the ICZM Monitoring Center of Lazio Region, show the overlap of two shorelines obtained on October 2007 and March 2008. The vector elaborations have obtained a mean withdrawal of $8 \text{ m}^2/\text{m}$ during 6 months in 1.600 m length beach around Badino harbour.

A continuous monitoring of shorelines interested by the nourishment has been submitted to a web-cam system, installed both in Terracina beach and Marina di Minturno beach. The images are available on www.beachmed.eu.

Fig. 8 – Terracina (Latina). Shoreline overlap obtained on October 2007 (blue) and March 2008 (red). (ICZM Monitoring Center - cartography web service available on www.beachmed.eu)



Fig. 9 – Terracina (Latina). Aerial photography one and two years after the end of nourishment realization

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