THE PONTINO NOURISHMENT WORK ALONG REGION LATIUM'S BEACHES

Paolo Lupino, Gestione Aree Marine Protette, Regione Lazio (Italy), paololupino@beachmed.it
Piergiorgio Scaloni, Dir. Ambiente e Coop. tra i Popoli, Regione Lazio (Italy), pscaloni@regione.lazio.it

Abstract

The Region Latium (Italy) has a coast of about 300 Km of which about 70% constituted of beaches very appreciated and strategic for the regional economy. The erosion phenomena strikes its littoral along about 70 Km where the yearly loss of beach surface is about 200.000 m^2, only partially compensated with some stretches in advancement. Since 1999 the Region Latium tackled the erosion problems by using massive nourishment techniques, with sand dredged from the bottom of the sea. After several experiences carried out for a total amount of about 4 million of m^3 of sand, the region designed the project PONTINO for the protection of about 13 km of beaches with groynes and 3 million of m^3 of sand dredged from very deep quarries (-100 m.s.l.). Started in 2005, the work ended in 2007 and has been fund with 30 million of euro. New technologies have been used for different aspects of the work: new criterion for the project of hard structures (groynes) in relation to the nourishment, original cost analysis, model for the profile settlement, systems for a continuous granulometry survey, environmental monitoring, techniques for granulometry correction, etc.. A series of interesting elements for setting up projects like the PONTINO will be furnished and the results of the work will be illustrated with reference as well to a series of web-cam installations currently running over the nourished beaches.

1 Description of works

The works of defence and reconstruction of PONTINO littoral (Region Latium) are started on September 2005 and are finished on June 2007. Region Latium contracted out the works to the Company "S.I.D.R.A. spa". Region Latium Administration (ing. Paolo Lupino) has been the Work Supervision (WS). The executive Project has been developed by the planning group "Observatory of Lazio's littoral" (November 2004). 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.

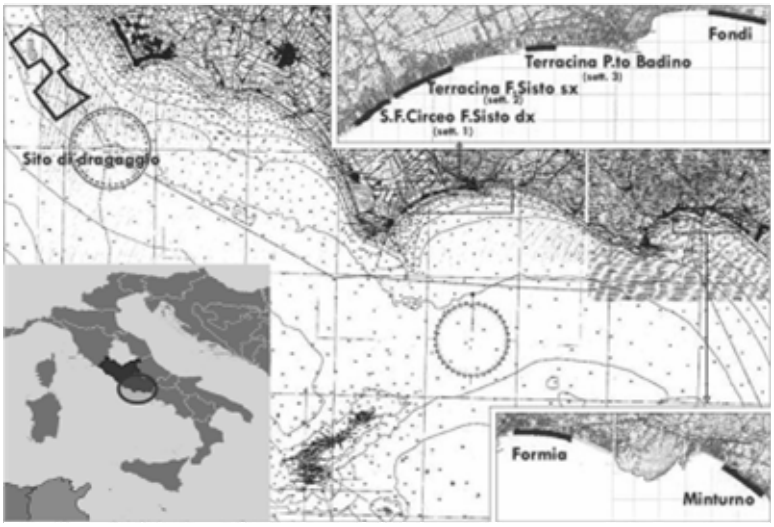

Fig.1 – Area of nourishment works and borrow quarry (ICZM Monitoring Center)

The data Project are reported on the following table (Fig. 2):

Nourishment work	**Length [m]**	**New beach area [m^2]**	**Settled mean advancement [m]**	**Nourishment volume [m^3]**	**Number of Groynes**
1st sector Terracina	1.650	52.400	33	435.000	-
2nd sector Terracina	2.600	76.000	30	613.100	-
3rd 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

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 (one-line analysis) study and the analysis of realization and maintenance costs has been fundamental for the choice of the intervention typology. On the following chapter is reported a synthesis of the initiatives carried out by the WS during dredging and nourishment activities, made unusual by the characteristic of borrow quarry, with a dept of 100 m, and the bimodal quality of sediment grain size (about 70 % sand and 30% gravel).

2 Monitoring of dredging and nourishment activities during works

The activities of dredging and nourishment of PONTINO littoral are been realized on two following times, characterised by two different borrow quarries. The first phase between May 5th 2006 and July 3rd 2006 with 59 cycles of dredging concerned the C2 quarry, 11 Km far from the coast and with a

depth of 100 m. The second phase between February 23rd 2007 and June 9th 2007 with 178 cycles of dredging concerned the A2 quarry, 7 Km far from the Anzio harbour with a depth of 45 and 54 m. On this report we are going to describe the first phase of dredging for reasons of interests linked to the singular problems of quarry depth and sediment typology, as better described in the following text.

The presence of a geologist (doct. Alfredo Pazzini of "Dipartimento di Biologia Animale e dell'Uomo" of "La Sapienza" University of Rome) onboard of dredge "PEARL RIVER" property of S.I.D.R.A. spa, it was necessary for the compilation of onboard journal, describing all the activities concerning the dredging cycle. Synthetic information of onboard journal are reported below.

"PEARL RIVER" is a trailing suction hopper dredger (Fig. 2) built on 1994 with a length of 144 m and a capacity of 17.000 m^3 On 2000 with a following transformation, it became 188 m length with 24.000 m^3 of capacity.

After ten cycles of dumping, the first pelite layer was removed for volumes of 109.000 m^3 of pelite with 170.000 tons of weight, between 0,5 and 2 m depth of layer.

The loading phase was carried out with a mean time of 5,6 hours and mean volume of 13.500 m^3 and a total of 802.500 m^3 of dredged sediment on an area of 665.000 m^2.

The dredge route during the transport phase was variable with maximum gap of 1.500 m one from another. The velocity of the dredge at full load was of 14,5 knots. With the purpose to decrease the suspension of the sediments in phase of approach to the shore, the WS has arranged a plan of approach that foresaw the arrest of the dredge propeller 500 metres before the point of connection to the pipelines. The assistance of a pontoon was necessary for the operation of link to the pipelines, especially in case of big waves.

Several kind of spoils during the dredge cycles, caused delays of 290 hours (12 days) that is about 20% of total time of permanence of the dredge.

3 Examination of innovative aspects

Innovative aspects characterise the PONTINO littoral works, during the phases of planning, realization and after the end of the works.

3.1 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 fruition of tourists (Fig 3)

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

3.2 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 actualisation 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.

Description of intervention	**AV [millions euro]**
Only Nourishment	5,0
Longitudinal barrier protected nourishment	16,7
Longitudinal barrier and groynes protected nourishment	17,4
Groynes protected nourishment	7,1

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

3.3 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 as reported on the following paragraph. On figure 5 are reported the granulometric curves of "ideal" sand (native sand) and borrow sand.

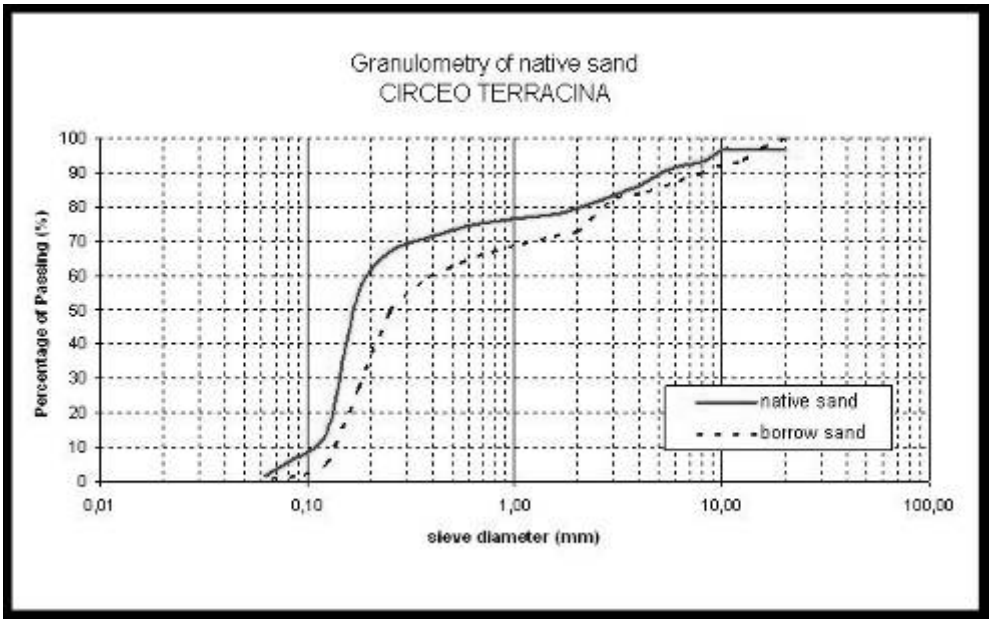

Fig. 5 – Comparison between Project granulometric curve (borrow sand coming from C2 quarry site 1) and ideal granulometric curve (native sand) for Circeo-Terracina area (data processing "Osservatorio dei litorali laziali")

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 6. 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.

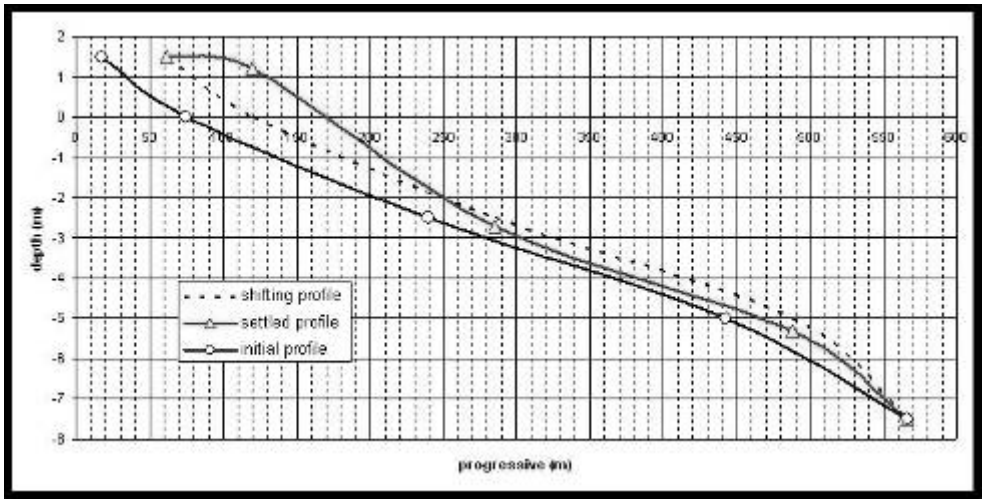

Fig. 6 – Settled beach profile result of granulometric simulation model adopted for Terracina-Circeo nourishment (Data processing "Osservatorio dei litorali laziali")

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

Thanks to the presence of a geologist on board of the dredge, this activity have guaranteed an optimal monitoring of the quality of borrow sand during the operations of dredging.

This activity, coordinated by the WS, 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 onboard sampling design has been performed through a material remixing thin to get representative tests through also visual observations that have kept in mind the distribution of different granulometric components inside the dredge wells.

Granulometric curves give a matrix of sand mixed to a portion of gravel. 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.

The comparison has been performed between project data and nourishment data. In figure 7 the comparison among the granulometric curves confirm the respect of the project parameters.

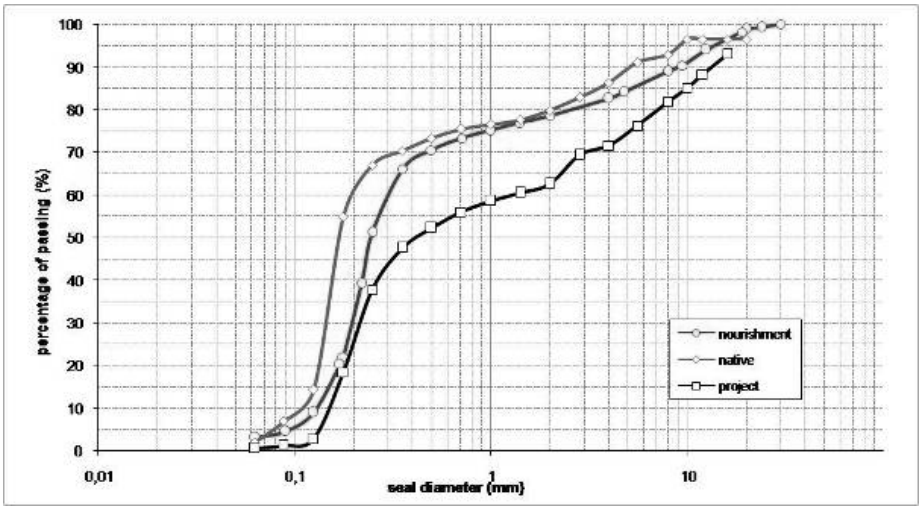

Fig. 7 – Granulometric curves. Comparison between native sand (ante-operam), project sand (dredging corridor) and nourishment sand (from dredge wells) (Data processing Osservatorio dei litorali laziali)

3.5 Environmental monitoring in progress of work

The environmental monitoring in progress of work has concerned two aspects 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, performed thanks to the use of a boat, equipped with Acoustic Doppler Current Profiler (ADCP) and a CTD feeler (Conductivity, Temperatures, Depth), coupled to turbidity tools, 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 cms^{-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. The objective for the future, in the circle of some European projects already developed (INTERREGIIIC BEACHMED-e) or in proposition phase (SPACE MED COASTANCE), it is to define a methodology of investigation for the produced plumes and a map of the natural turbidity in the zones of interest, to be able to operate comparisons, therefore evaluations of real impact.

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 by 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.

3.6 Techniques of grain size correction on site (mechanical reduction of gravel on the beach)

With the purpose to bring back the grain size of the nourishment sand to the optimal values of project, especially in the more sensitive superficial part of the beach in the Terracina area, a mechanical reduction of gravel has been made, realized through the sifting and vibration of coarse material with diameters of granules greater than 4 mm. The intervention has been realized with the aid of Tractors endowed with sieve and towing able to separate the component of coarse material from thinner present on the shore. The material has been selected for a mean depth of 30 cm. The intervention has interested by the nourishment of Terracina Center area (1.600 m x 60 m). Anymore a variation has interested a further field of beach of 150 m on south of “La Stiva” lido (150 m x 60 m) for a total of 108.500 m^2 of beach to be sieved.

This service, performed by the “POSEIDON” Company of Latina, started on April 5th 2007 and finished on June 5th 2007 for a total of 60 days more 7 days of variation for a total of 67 days. The cost of the operations was of 1,79 euro/m^2 of sieved beach, for a total of 194.215 euro.

The gravelly material, coming from the operation of sifting, has been transported and deposited in borrowed hole 2 m high, obtained inside the intervention area. A series of sand tests of sediment after these operations and grain size analysis have been made to appraise the real percentage of demolition of the present coarse material on the beach. A reduction in coarse gravel content (d > 4 mm) is calculated about 72%. Before these operations the composite test of the emerged beach had a 23,6% content, while after the operations is passed to 6,4%. Nevertheless this result, cannot be considered representative of the whole nourishment material, because the operations of gravel reduction the following sample, are been performed on a superficial layer of the beach of some dozen of centimetres. However that was the objective because the necessity to do not modify the gravel

content of nourishment body with the purpose to guarantee a greater stability of it (Project objective). The realized one is therefore an innovative technique of differentiation of nourishment grain size to reach a bimodal characteristic of the material that at times are even anticipated during project phase (gravel on bottom and sand on top). Obviously It's difficult to obtain this bimodal characteristic during the nourishment realization, therefore the post-sifting represents, both from the economic point of view and of the results, a valid procedure for a bimodal nourishment.

4 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 by Geom. Alessandro Bratti 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 m^2/m during 6 months in 1.600 m length beach around Badino harbour.

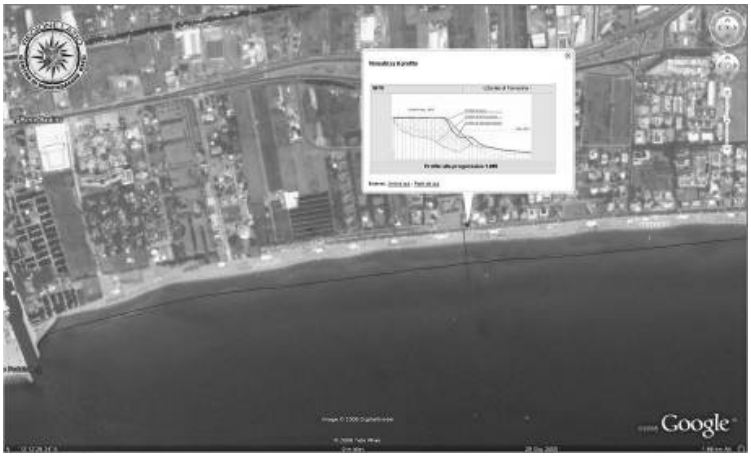

Fig. 8 – Terracina (Latina). Shoreline overlap obtained on October 2007 (blue) and March 2008. (cartography web service available on www.beachmed.eu)

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.

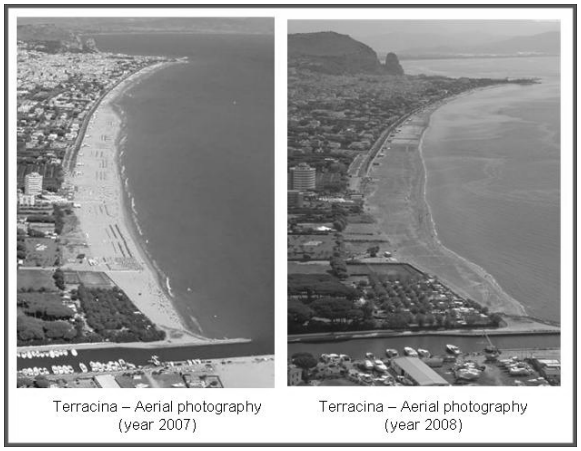

Fig. 9 – Terracina (Latina). Aerial photography one and two years after the end of nourishment realization

Conclusions

This paper, result of an intense activity of monitoring in progress of work made by the Works Supervision during the works realization, it has a double objective: to underline the importance of monitoring activities for the correct realization of works and to divulge all those information that could be useful for the carrying out of future activities on this field, above all for this typology of intervention, innovative both in phase of planning, and in phase of monitoring in progress of work.

This paper is a tool destined to all the operators of the sector that have a primary role in the realization of the interventions: Public administrations, planners and analysts, private Company, consultants.

One year after the conclusion of the works, the Lazio Region can concludes to have met numerous difficulties tied to the typology of the intervention and the extension of the same work, and thanks to the intense work of control and monitoring it has been possible to daily face with full awareness of the actions to undertake for the result of this work that is distinguished for ambition and executive efficiency.

Information to public opinion has been one of the most greater problems that Lazio Region has had to face. Both planners and Administration have had difficulty to spread and to make understand the results of this kind of project to the beach users and the media. It is therefore recommended a particular attention for the future in the preventive care of this aspect, without nevertheless to fall in the temptation to surrender to some external interferences that would go versus some project choice dictated instead by studies of close examination, essential for the result of the intervention.

For obvious reasons of synthesis, it has not been possible in this paper to bring big part of the information that are picked up during the jobs, it is therefore recommended to contact the authors of this article for further close examinations.

References

A. Pazzini, 2006. “Attività di controllo su mezzo dragante”.

G. Ardizzone et al., 2007. “Cartografia e monitoraggio delle praterie di *Posidonia oceanica* comprese tra il promontorio del Circeo e Sperlonga. Relazione finale di Fase C”.

L. Nicoletti, M. Gabellini, 2007. “Studio per l’impatto ambientale connesso allo sfruttamento di depositi sabbiosi sommersi ai fini di ripascimento lungo la piattaforma continentale laziale: CAVA C2 – Torvaianica (RM). Fase C2 – Controllo in corso d’opera.

P. Lupino, 2004. Relazione Tecnica Generale “Lavori di ricostruzione del litorale Pontino – Progetto Esecutivo All. A-1”.

P. Lupino, P. Scaloni, 2004. Studio di Compatibilità Granulometrica “Lavori di ricostruzione del litorale Pontino – Progetto Esecutivo All. A-1_1”.

P. Lupino, P. Scaloni, 2006. Monitoraggio delle attività di dragaggio “PRIMA FASE” - Litorali di Terracina e Fondi.