Shoreline Dynamics And Preventive Measures At Southern Part Of Durrësi Bay

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ABSTRACT

One of the most important aspects of coastal management and planning programs that needs to be investigated is shoreline dynamics. Long-term coastal analysis uses historical data to identify the sectors along the coast where the shoreline position has changed.

At the southern part of Durrësi Bay, the sandy beach has suffered strong erosions for the last 20 years. In particular, in different segments situated at Karpen - Qerret lowland, during the last year the annual erosion rates reach values up to 30-37 m. The analysis of the coastal dynamics and spatiotemporal changes in the coastal morphology for the period between 1944 and 2010 is an important tool to identify the principal factor of these changes and consequently to recommend the appropriate engineering interventions necessary to protect and recover the interested area.

The present study takes advantage of geographical information system (GIS) tools to contribute to the knowledge of the shoreline dynamics of the southern part of Durrësi Bay. Shoreline changes were analyzed using the ArcGIS extension ‘‘Digital Shoreline Analysis System’’ (DSAS). The length of the shoreline analyzed is about 3 km.

Five shoreline positionscorresponding to four time intervalswereanalyzed. These analyses are based on bathymetric studies, sediments and sediment transport analyses, and the mapping of the shoreline positionsfor theperiods1944-1980, 1980-2007, 2007-2009and2009-2010.

Annualratesoferosion, grain size distribution and the alongshore transport rate of sediments are the basic data used forthe designofprotectivestructures.

INTRODUCTION

Thisstudywasundertakenin November – December 2010. The final objective was the identification of themainfactorsinfluencing the augmentation of the erosionratesin lasts years, in order to protectthearea, situated at Karpen Lowland.

A “Site” situated at the southern part of Durrësi bay was chosen. This site is included between X = 373846.349 at west and X = 374103.033 at east, while the latitude is between Y=4562714.686 at south and Y = 4563035.413 at north.

The site has an area of 39691.175 m^2 and an exposure length to the coastal processes of about 160 m.

To analyze the coastal processes and the impact to the site of interest a coast line of 3100 m is chosen which include the study area. The point X = 373193.509, Y = 4561957.490 to the SW of the site is denoted as “INITIAL POINT”. The coastal area under study is divided into three main zones (considering the mapping scale): Zone “A”, Zone “B” and Zone “C” as shown in the Figure 1. The study scales are respectively 1 : 10000, 1 : 1500 and 1 : 1000.

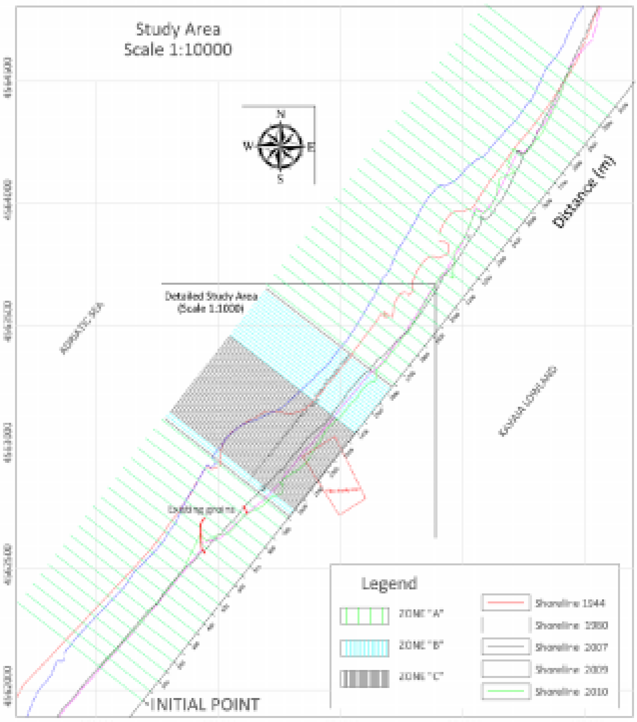

Figure 1Geographic location of the study area

The historical data used in this study was obtained from the different sources. The topographic maps at 1:10000 scale for the years 1944 and 1980 are issued from the Military Geographic Institute of Albania. The shoreline of year 2007 is digitized from the ortho photos produced by "ALUZNI" (Legalization, Urbanization and Integration Agency for Informal Area/Buildings). The shoreline of 2009 is obtained from the GSA (Geological Survey of Albania), while the 2010 shoreline for the study area is obtained from direct field measurement for the purposes of this study.

The shoreline data sets used in this study provide sufficient information to calculate the primary direction of change, and the rate of either accretion or erosion at every point, from the time of a data set to the next. But since data sets are separated by relatively long lapses of time (1944-1980 and 1980-2007), it is not possible to establish which episodes happened in between, nor their duration. Especially important would be to identify the beginning of shifts in drift direction or the time of trend reversals, and to measure the duration of each period of accretion or erosion, in order to better understand their eventual causes.

BATHYMETRY OF THE STUDY AREA

Bathymetric mapping performed at a scale 1:1000 reveals shallow water and very gentle slope. The dip of 5 m is attempt only 2000 m far from the shoreline. The average inclination is 0.25%. The presence of the "battles" (elevated area), at the south of the site of interest, induced by the presence of conglomeratic formation of "Suita Rrogozhina" and expressed by the curveting of isobaths leads to the modification of waving climate (height, length and period).

The detailed bathymetric map shows that the depth of 1 m is achieved in 20-35 m distance from shoreline; the depth of 2 m at 120 to 160 m from the shore and depth of 3 m is situated about 320 m from the shore. In terms of sea bottom slope the depth interval between 0 and 1 m represents an average slope of 0.02; average slope of 0.008 m between 2 and 3 m, and 0.005 for the highest depths.

SEDIMENT ANALYSES (GRAIN SIZE DISTRIBUTION)

The grain size distribution analyses are based on the field observations by visual assessments (sand, silt or clay) and in laboratory tests. A total of 34 samples were analyzed, of which 20 are situated at sea bottom and 14 on the beach. The Particle-Size Analyses are made in accordance with ASTM D 422-63 (2002) standard which include the sieve analysis and the hydrometer test. For each of tested samples D_{50} is calculated.

The test results show that 50% of the soil constituting the beach has a particle diameter varying from 0.18 to 0.34 mm.

For the sea bottom a reduction of the particle size is observed with increasing depth and consequently for higher distances from the shoreline. So for depths from 0 to 1 m D_{50} varies from 0.6 to 0.13 mm; for depths between 2 and 3.5 m D_{50} range from 0.078 to 0.012 mm. For higher depths, the particle sizes are small and range from 0.012 to 0.053 mm. The particle size distribution will used in follow for the calculation of the beach equilibrium profile.

GIS-BASED ANALYSIS OF SHORELINE DYNAMICS

The study of shoreline dynamics has been based on the analysis of sets of individual transects drawn perpendicularly to a baseline. This has been the dominant technique in the field (Fig. 7).

Its assumptions are simple: at every point, the shoreline progresses or recedes along a major direction, which is perpendicular to the main orientation of the coastline.

Currently, the most user-friendly and powerful tool available is the digital shoreline analysis system (DSAS), created by Thieler and Danforth (1994).

The study of historical shoreline data is used to identify the predominant coastal processes operating in specific coastal locations using "**Annual Change Rates"** as an indicator of shoreline dynamics. The "Annual Rates of Change" for the time intervals 1944-1980, 1980-2007, 2007-2009 and 2009-2010 are calculated and given in the Figure 2.

RESULTS AND DISCUSSION

A) Annual shoreline change rates

For this study five data sets available (1944, 1980, 2007, 2009, and 2010), and four intermediary periods were analyzed.

It is evident that, excluding the time interval between 1944 and 1980, in this sector erosive processes are dominant. For each shoreline extracted, the total area lost by erosion is larger than the area gained to accretion.

For the 1944-1980 time interval an accretion is observed. The annual rate of accumulation varies from 1.5 to 3.5 m/year leading to a land accretion of 17.5 ha. During this period the annual erosion rates are about 0.5 to 0.7 m/year. The erosion is located in SW part of the site from the "Initial Point" to a distance of 750 m (fig 1&2). The site of interest is in part subject to erosion and in part subject to accretion. The eroded area is 0.12 ha while the gain is about 0.6 ha.

In this period, an imbalance between areas of erosion and accretion is observed. The eroded areas were always lower than accretion areas (Fig.2). This situation (erosion in SW part and accretion in the NE part) may be a first indication of predominant movement of sediments from southwest to northeast along the coast of Durrësi Bay.

After this, during the period from 1980 to 2010, in this tract there is a dominance of erosion along the whole length of the shoreline (3.1 km). The annual erosion rates vary from 2.64 m/year at a distance of 2700 m to 10.26 m/year at the distance of 1000 m from the "INITIAL POINT".

Dividing this time interval in shorter periods such as 1980-2007, 2007-2009 and 2009-2010 changes in the annual rates of shoreline changes are observed.

The annual rates of changes for the period 1980-2007 vary from 3.0 to 9.36 m/year respectively at 3100 m and 950 m from the INITIAL POINT for the entire length of the coast under study (Zone A). During this period only erosion is observed. The highest rates correspond to the coast in front of the interest site. More accurate analysis (Zone C) shows that the rates of erosion vary from 5.75 to 9.36 m/year.

From 2007 to 2009, erosion ranging from 2 to 4.6 m/year is observed at the coast from “Initial point” to 500 m to the north, whereas in the area between 500 to 670 m from the “Initial Point” is observed an accretion ratio of 3.5-6 m/year. Following this direction, in 1km of shoreline (including the interest site) an alternation of zones with erosion 3-17.15m/year) and accretion (3-18m/year) is observed. At the end of the area only erosion is observed and the erosion rate varies from 0.5 to 5 m/year. Alternation of erosion and accretion zones follows a sinusoidal pattern with lower frequency going to the northeast. Unfortunately, the entire coast at the site of interest is involved in erosion phenomena of a ratio which varies from 5.6 to 16.8 m/year with an average ratio of 12 m/year. Some, even small, accumulation phenomena are induced by the construction of some protection works in the neighboring areas. This kind of protection measures (groins) constructed at the south-west, have an important impact to the site of interest.

During the period 2009-2010, the pattern of the graph is similar to the precedent period but with more frequent alternations. This phenomenon is due directly to the progressive increasing number of the groins at the north and to the south of the site of interest.

The accumulation rates are visibly increased and attempt very important values (20-30 m/year) downward the protective constructions (groins). Their protective impact is largely expressed to the south (upward) of the constructions, while to the north of them the erosion rates are increasing.

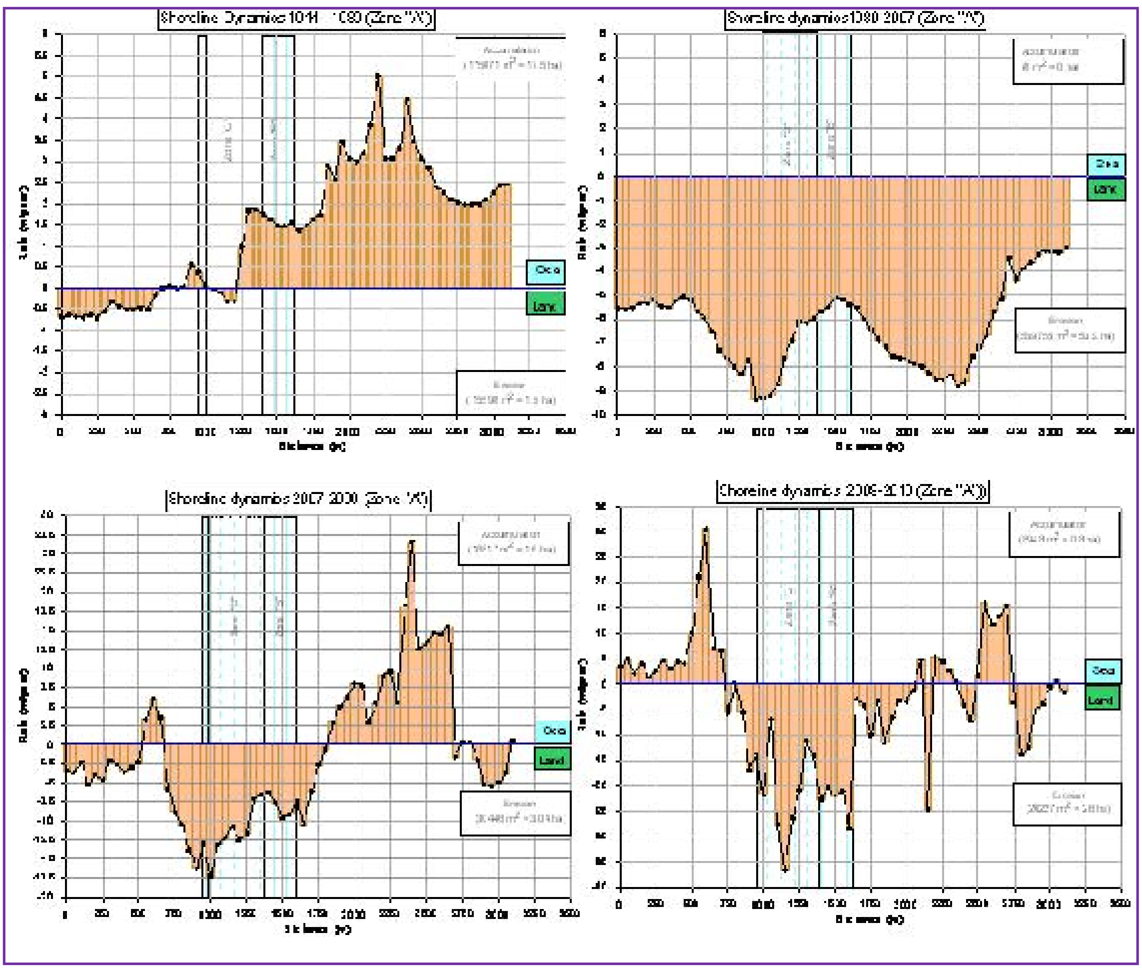

Figure 2Annual rates of shoreline changes for the selected time intervals

During this period, in the site of interests the erosion rates vary from 6 to 37 m/year (highest values are observed to the southern part). These rates are 1.5 to twice the average rate of the period 1980-2010 and 2.5 to triple of the rate of erosion during the precedent period. That indicates the construction of protective measures at the south led to a negative impact at the site of interest. The particular increasing of the erosion ration corresponds to the elongation of the curved groin which was initially of 125 m long and in 2010 attempt 158 m, trapping more sediment. The sediment deficit is to the origin of the accelerated erosion rates.

b) Area Variation Analysis

The area variation analysis is done separately for three segments according to the level of the study scale respectively A, B and C zone.

For the entire period of the analyses the total lost area is 61.2 hectares in the entire length of the shoreline of 3.1. Km. In the detailed area with a shoreline length of 380 m, the eroded area is about 10 hectares that make 16.2% of the total lost area, while his shoreline length is only 12%. For a better understanding and interpretation the annually eroded surfaces for unit length of the shoreline are calculated.

The chart presented in the Figure 11 shows that the rates of loss surfaces per unit length in front of the interested site (Zone B and Zone C) start to become significantly higher than the average rate of the entire shoreline length after the year 2007. That corresponds to the construction of protective works (groins) in different parts of the coast line. While in the period 1980-2007 the rates are comparable along the whole length of the shoreline, after this they are 2.5 times higher in Zone B and Zone C.

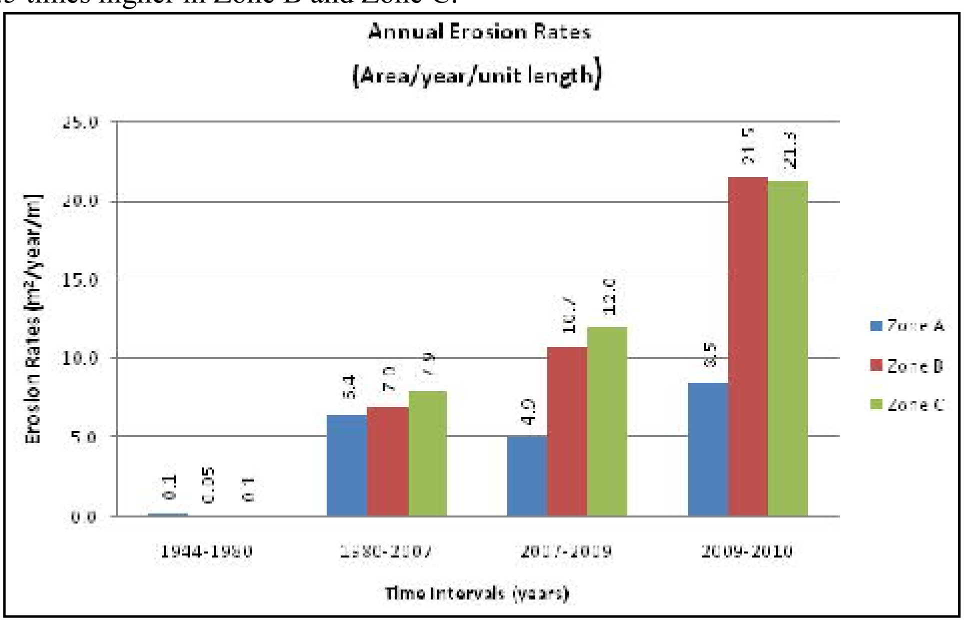

Figure 3 Annual eroded surfaces per unit of shoreline length

SEDIMENT BUDGET

For the estimation of the sediment budget the segment from Darci River (Point A) and northeastern extreme of the interested site (Figure 4) is selected. The incident waves (with an angle of 5-10 °) produce a potential net alongshore transport rate of 12000 m.^{3}/year (estimated by CERC formula; U.S. Army Coastal Engineering Research Center, 1984). The major contributors in sediment supply are the Darci River and the Erosion of beach segment between A and B. The total loss of sediments in this segment is about 3000 m^3/year (considering only the time interval 2009 – 2010). The contribution of the coast segment in front of the site is 1800 m^3/year.

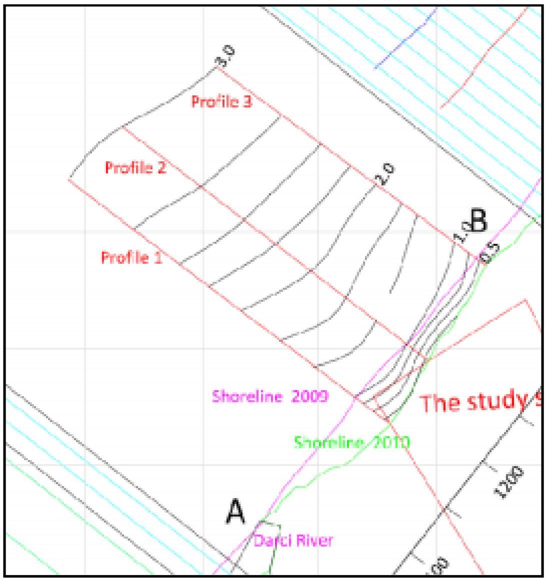

Figure 4 Location of observed bottom sea profiles

Calculating the volume of the fillet upward of the existing groin at SW of the site, during the 2009-2010 period only, results a total volume of 5300 cubic meter. In order to ensure the necessary quantity of sediment for the alongshore transport downward the groin we have the erosion of the beach from the river up to the site of interest with a volume of 3000 cubic meter year (2009-2010). The rest of sediment is provided by the solid discharge of Darci River. By this can calculate the solid discharge of Darci River which is about 2300 cubic meter per year.

These calculations are affected by an uncertainty related to changes in the size of the existing groin which was extended by about 35-40 m recently. For the moment we cannot calculate the effect of this extension in the alongshore transport of sediments. This evaluation will be part of the monitoring to be performed after protective intervention.

All estimations are made based on the data concerning the 2009-2010 time period using 3 sea bottom profiles and the equilibrium beach profile (Fig. 12, 13)

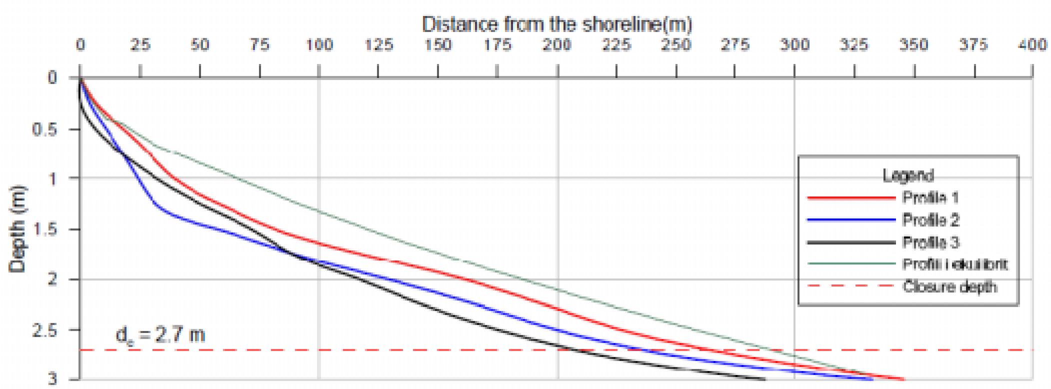

Figure 5 Observed and equilibrium beach profiles

PREVENTIVE MEASURES

Based on above evaluations in order to block the erosion of the site three engineering solutions are proposed as follows:

Solution 1 Consists in the construction of a groin placed in the north-eastern part of the site with a total length of 70 m. The exact position, orientation and all its characteristics are given in figure 6-a. Since thealongshoretransport of sediments takes placefromsouthwesttonortheastin theupward side of the groin the creation of a sediment fillet is expected. If theperformancedoesnotcomplywiththe previsions, one of the following options must be chosen.

Solution 2 To improve the performance of the groin 1, two breakwaters should be constructed. Their position, orientationanddimensions are given in the Figure 6-b.

Thissolutionis recommendedif duringthemonitoringprocessafter theconstructionofthegroin 1 an offshore sedimenttransport is observed.

Solution 3 This solution consistsin the construction of a second groin at the south-western partof site. The orientationanddimensionsare givenin the Figure 6-c.

This solutionis recommendedif duringthemonitoringprocessafter theconstructionofthegroin 1 the erosion continue in the south-eastern part of the site.

Takinginto account the bathymetry, and the volume of sediments supplied by Darci River the shoreline evolution after the groin construction(solution 1) is predicted and is givenin the figure6-d.

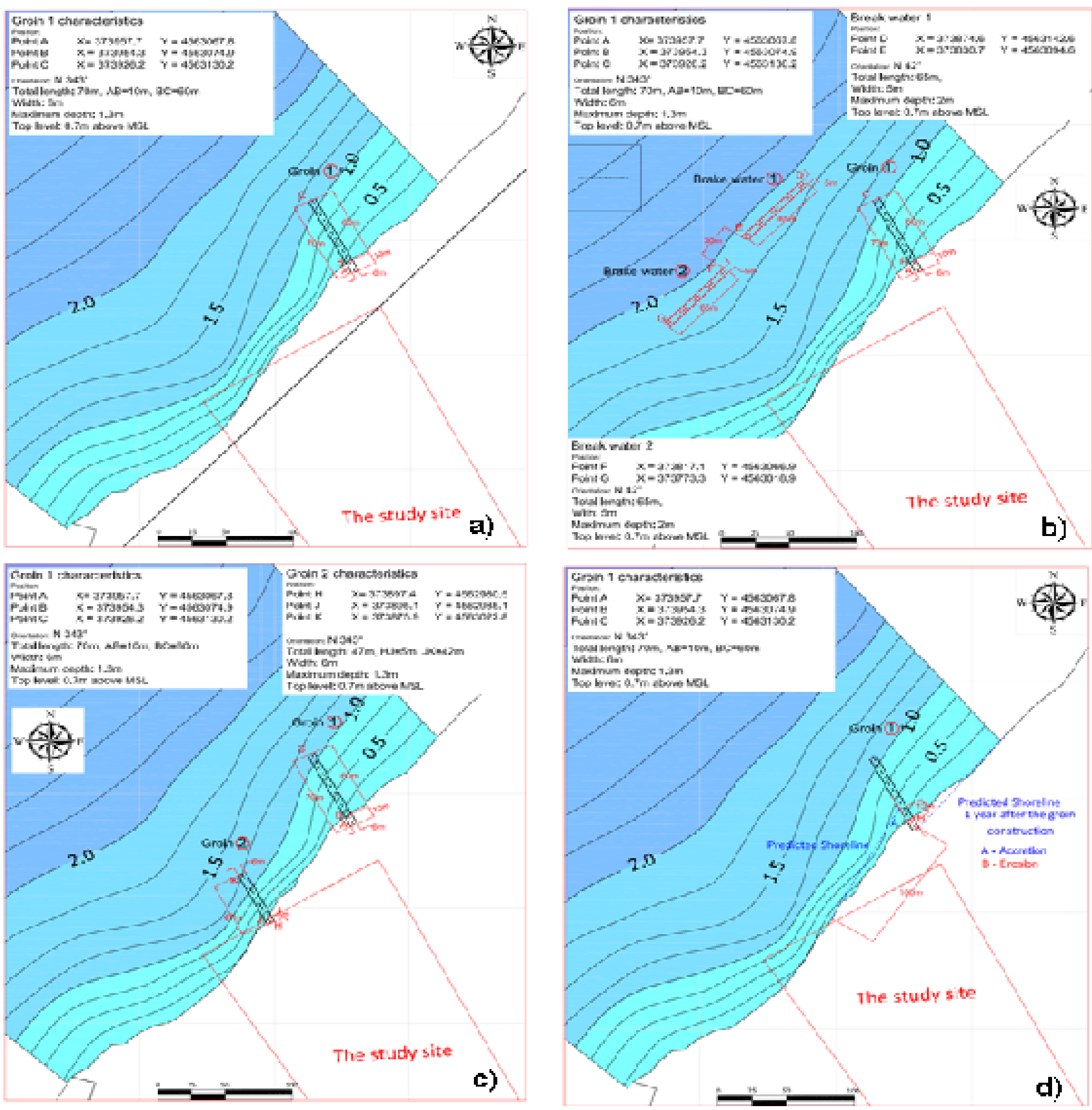

Figure 6 Proposed preventive measures (a, b and c) and shoreline prediction for the first year.

CONCLUSION

The use of the GIS environment and software tools used for this analysis increased the accuracy of the measurements.

The Topologically Constrained Transect Method offers a new and more flexible way to analyze coastal systems using more than a pair of shoreline positions.

The shoreline dynamic analysis shows that the main factor that influences the coastal processes, without neglecting the regional factors, is the alongshore transport of sediments.

In the Durresi Bay the dominant direction of the alongshore sediment transport is from south-west to north-east direction.

The diminution of the soliddischarge of the riversconstitutesthe main factortoincreasederosion ratesin general. In thestudy area this is due to the diminution of Darci River solid discharge.

Another important factor causing high erosion rates in the area is the inappropriate human intervention by the construction of groins, giving morphology a “ZIG-ZAG” to the shoreline.

The designofprotectivestructuresmustbebased onawiderstudythat includesalltheDurresiBay shoreline.

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