Modeling of sediment transport of Capo Negro bay

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Abstract. The coastline is a curve/line representing the intersection between land and sea. The interaction between the atmosphere, the sea and the continent give the coastal fringe a multiphasic character that is very complex and difficult to manage. The concentration of human activity in coastal areas requires looking at problems that may endanger beach stability, coastal development, and consequently loss of human heritage. The most widespread problem on a global scale is erosion, especially with the current trend of rising sea levels. And given the complexity of this process and for better management of coastal areas, mathematical modeling is an indispensable tool.

In this work, we study the evolution of the Cabo Negro coastline and present a methodology based on two complementary approaches: first, an oceanographic, granulometric and sedimentological study of the site. Secondly, numerical modeling to analyze the evolution of the coastline and the prediction of its long-term position by using a mathematical model: the GENESIS calculation model.

Keywords: Numerical modeling, sediment transport, GENESIS, coastline.

1. Introduction
The coast (or littoral) defines the strip of land between a maritime area and the mainland. Depending on the scales selected, this area can range from a few hundred to several meters. These limited, coveted and attractive spaces, favorable to the various flows (trade, travel, tourism, etc.) receive a large part of the world's population. This coactualization is an ancient process but has taken on an important and global dimension. According to Bird [1985] [1] more than 70% of the world's sandy or gravel beaches are eroded. These beaches play an important role in human development and may show a retreat of several meters per year. Thus, all the cities and activities located near these coasts are directly threatened.

The retreat of the coasts can be explained by the accumulation of different natural and anthropogenic effects [Paskoff, 1998a] [2]. Schematically, the position of the coastline can be seen as a balance between the maritime and land sedimentary contributions, on the one hand under the action of waves and tides and on the other hand transported by rivers and wind.

Many researchers work on the development of modeling of the coastal sediment and changes in beach morphology. Margvellashi et al. (2008) [3] developed one-dimensional vertical and three-dimensional
The object of this study, which focuses on the coastline near Cabo Negro (Martil Bay) about 15 km
north of Tetouan in northern Morocco, is to correctly model and predict the evolution of the coasts in
order to better manage and protect them. To answer this question, our study concerns the observation
of the natural bay and the modeling of these beaches by mathematical model by using the coastline
evolution calculation code: GENESIS.

2. Theoretical formula
The bay of Martil extends about 9 km from the groin of Cabo Negro in the north to sidi Abdessalam in
the south.

The hydrographic network of the bay is composed by the two wadis:
- The Wadi Martil, whose sea mouth position was moved northward in the late 1970s with
  the construction of a left-handed groin;
- Wadi Mellah which flows into the sea, the mouth of this wadi is not fixed.
Since the beginning of the 80s and even before, this bay has been under a severe sand mining
(2 100 000 m³ since 1981) in various points: Sidi Abdessalam, Oued Martil mouth, oued Mellah
mouth. In 1992, 107 000 m³ of sand was removed from the south of the bay.
After the construction of the waterfront protecting the residential area in 1992, the width of the beach
at the right of developments has dropped sharply, a phenomenon that, if continued, may endanger the
sustainability of the urbanized area.

2.1. Winds
The tide is of semi-diurnal type (period 12h30). The tide characteristics are given in the following
table:
Table 1. The tide in the Cabo Negro area

|        | Low tide level (m NGM) | High tide level (m NGM) |
|--------|------------------------|-------------------------|
| MVE    | -0.60                  | +0.47                   |
| MVEE   | -0.88                  | +0.70                   |

2.2. Swell

The swell regime was established on the basis of an analysis of vessel observations made between 1960 and 1980 in the maritime area at the site.
- The main points emerging from the analysis of these observations are:
- Calm accounts for 60% of observations (219 days/year),
- Swells greater than or equal to 3 m have a frequency of 2% (7 days/year)
- The eastern sector is predominant in frequency of occurrence and it is also from this sector that swells with higher heights come.

2.3. Granulometry of the Study Area

The beach and the seabed of this zone are constituted by sands. The spatial distribution of the particle sizes along 4 profiles between Cabo Negro and the Wadi Martil is given in the following figure:

These curves show:
A refinement of D50 of the foreshore sands from south to north which indicates a resulting transit in this direction.
A granulometric sorting in the profile, the D50 passing from 0.25-0.35 on the foreshore to 0.15 mm in bottoms of -6 to -8 m, such sorting is characteristic of the action of the waves.
2.4. Sediment transit generated waves

Swell (waves) is the essential driver of sediment movements. The movements in the profile (cross-shore) have a virtually zero result. These movements decrease rapidly with depth. It can be considered that from the bottoms of -5 m the sedimentary movements are very weak.

The longshore transit which is the transport generated by the waves when they reach the coast with a certain incidence has been evaluated on the basis of the swell regimes by the use of the GENESIS coastline evolution software.

The orders of magnitude of the coastal transit that emerge from this estimate are as follows:

| Transit (m³/y)                      |
|-----------------------------------|
| Southward                         |
| Northward                         |
| Total                             |
| Resulting (from South to North)   |

|                |    |
|----------------|----|
| Southward      | 40 100 |
| Northward      | (-) 55 800 |
| Total          | 95 900 |
| Resulting      | (-) 15 700 |

Martil Bay receives sand inputs from the Martil Wadi which are less than 10 000 m³/year, before the construction of the two groins (Martil and Cabo Negro) and sand mining, the resulting transit from the south to the north was 15,000 to 25,000 m³/year.

Thus, in total, the bay was in dynamic equilibrium and the long-term evolutions had to be very weak. There could, however, be seasonal advances and retreats.

Human interventions have chronologically consisted of:
- The construction of Cabo Negro groin at the beginning of the sixties, which resulted in an advance of the coastline to the south of groin,
- The construction of the Martil groin in the late 1970s with the aim of fixing a new mouth of the wadi Martil,

Sand extraction the south of Wadi Martil (1,250,000 m³ since 1981), at Wadi Mellah (900,000 m³ between 1986 and 1992).

The study on a mathematical model of the coastline evolution in the area between the Wadi Martil groin and that of Cabo Negro will allow to specify the evolution if on the one hand no development is carried out And on the other hand for the construction of a new groin at the mouth of the Oued mellah.

3. Modeling of the coastline

The longshore sediment transport along Martil bay has been modeled considering the existent coastal structures with the use of GENESIS numerical model (Hanson and Craus, 1991) [5]. GENESIS model was developed by US Army Corps of Engineers and it is one of the most common used sediment models in the literature. It is applied for the sediment transport due to wave effects. Several numbers and combinations of groins, breakwaters, and seawalls can be examined by GENESIS model. The effects of combined T and Y type groins can be investigated and the sand erosion and deposition around groins are taken into account for different wave heights, wave periods and incident wave angles. But GENESIS model has some limitations such as neglecting wave reflection on the structures, tides.

The model covers a coastal zone of 7300 m extending from the Cabo Negro groin in the north to the Wadi Martil groin in the south. The model was built in local landmark Oxy.

The calibration of the model consisted of reproducing the evolution of the bay between 1981 and 1993. At the Wadi Mellah level, 793 000 m³ of sand were extracted between 1986 and the end of 1991 and 107 000 m³ between April and May 1992.

After performing the calibration. This model can be used to predict future developments for various management scenarios. To this end, two scenarios have been established, each one consisting of
reproducing the evolution of the coastline for 10 annual cycles (10 years), starting from the current state of the coastline. The two tests are carried out as follows:

- Scenario 1: Evolution in 10 years if no development is carried out and if there is no sand removal at the Wadi Mellah.
- Scenario 2: construction of a sand-stop groin to depths of -5m with a beach nourishment of 250 000 m³ to the north of the jetty.

4. Result and discussions

![coastline evolution](image)

**Fig 3.** coastline evolution for Scenario 1

This test gives the expected evolution within 10 years if no other development is carried out (maintenance of the structures in their present situation) and if the sand excavation is totally stopped. The results of this trial show that the coastline will tend to realign with:

- Progress (advance) located on the 500 m north of the wadi Martil groin with a peak that exceeds 15 m to disappear 1000 m north of the cob.
- A coastline retreat of more than 20 m in a zone 700 m south of Wadi Mellah, this decline decreases in directions, north and south.
- Progress of the coastline in the zone ranging from 200 m to the north of the wadi Mellah up to 700 m in the south of the wadi Mellah. This advance can reach 45 m at the level of Wadi Mellah.
- Slight tendency to retreat in the immediate south of Cabo Negro ear, less than 5 m over 10 years.

Thus, if nothing is done (no development, no input and no excavation), the zone between the coordinates 2000 and 4500 would progress at the expense of the zone that is further south (figure 3).
For the scenario 2, we observe the following changes:
- A 40 m erosion south of Wadi Mellah, this retreat decreases on both sides of the peak point located at 2000 m south of the southern jetty.
- An advance to the south of the groin due to the effect of swells diffraction.
- Sand deposits allow advancing of the coastline more than 60 m at the north of the groin, this advance decrease going north to the Cabo Negro groin.

5. Conclusion
The evolution and morphology of beaches change under the effects of coastal structures, wind, current and waves. Coastal structures and human interventions significantly affect the natural balance of sediment transport in coastal areas. To study sediment transport and shoreline changes, it is necessary to fully understand the coastal hydrodynamics, waves and the current system in the region. The coastal circulations and long-term shoreline changes of Capo Negro Beach located at north of morocco, have been modeled by numerical models. The GENESIS model was applied after calibration to the coastal zone. Numerical simulations were able to provide reliable representations of the coastline trend. These representations show that if no remedial intervention (stopping sand mining, breakwaters construction, beach nourishment…) has been carried out, the Bay of Capo Negro Beach risks undergoing severe changes in its morphology especially with the growth of its urbanization.

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