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Sustainable beach design for Raf Raf, Tunisia

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Abstract:
The beach at Raf Raf, Tunisia, has a high recreational use. Continuous erosion due to gradients in the littoral drift combined with urban developments placed close to the beach has reduced the beach width. In order to re-establish the wide beach, an extensive modelling study has been conducted by DHI by use of the new MIKE21 Shoreline Morphology FM model. The numerical study was used to investigate possible mitigation scenarios, which included beach nourishment and different types of stabilising structures. Finally an optimisation of the sand placement was undertaken in order to reduce costs of nourishment. The criteria for selecting the final mitigation scenario were largely based on longevity of the solution thus reducing the need for continuous maintenance.
The new shoreline model proved to be a valuable tool for comparing different mitigation scenarios in a systematic manner. Based on the model results it was possible to select a mitigation scenario which best satisfies the Client's needs.
The implementation of the new beach design is expected to be finished in 2016.
Keywords: MIKE21, Hybrid model, Shoreline model, Beach design, Morphology, Submerged breakwater, Groyne.

1. Introduction

Raf Raf beach is located approximately 40 km N from the capital Tunis of Tunisia and is characterised by the presence of a headland in the West and a beach which follows the shape of a logarithmic spiral. In the eastern end of the beach rocky outcrops appear as a result of continuous erosion. The beach has a high recreational value for tourists and locals. The beach is typically wide in the eastern end, while urban development

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along the western end of the bay has resulted in construction of a rubble mound revetment with little or no beach in front of it.

The beach is under continuous erosion because the net littoral drift is towards east and little or no sediment is supplied to the bay from west. A coastal study and beach design has been carried out in order to mitigate the effects of the ongoing erosion and sustain the recreational value of the beach. The focus of the study is to secure a wide beach along the eastern half of the bay through a combination of hard and soft solutions.

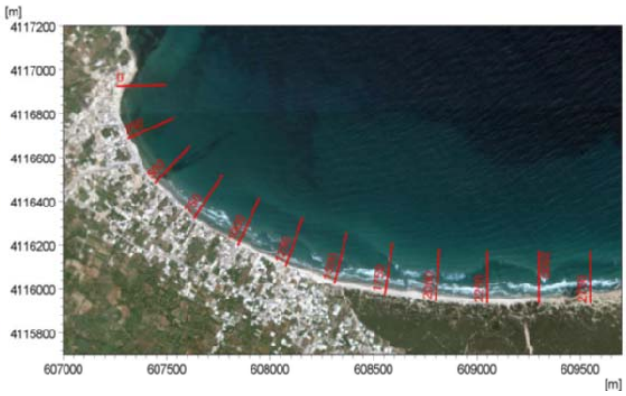

Figure 1. General setting of the study area in Tunisia (left) and zoom of Raf Raf site with indication of applied baseline (right). Background pictures from Google Earth.

2. Methodology

The beach design is supported by 11 year simulations with morphological evolution using DHIs new 2D shoreline evolution model, MIKE21 Shoreline Morphology FM. The model builds on the area model with a dynamic coupling of a hydrodynamics module, a spectral wave module and a sand transport is module (non-cohesive sediment). Morphological evolution is however constrained by forcing the bed update in the model in terms of seaward or landward movement of the shoreline in response to accretion or erosion as described in (KAERGAARD & FREDSOE 2013; KRISTENSEN *et al.*, 2010). Previous application of the model includes determination of shoreline response to breakwaters, (DRØNEN *et al.*, 2011; KAERGAARD *et al.*, 2014) and development due to mega nourishment, (KAERGAARD & DRØNEN, 2015).

The morphological model is first setup to reproduce the overall sediment budget obtained by analysis of the bathymetric surveys carried out in 2000 and 2014. Successful setup included: High flow resistance over the reef in the western end of the bay and a sediment availability map to mimic the reduced supply of sand from west.

After having calibrated the model to the existing conditions, a number of scenarios have been investigated. The scenarios were composed of beach nourishment combined with stabilising structures such as submerged shore parallel breakwaters (SBW) and terminal groynes. Table 1 lists the characteristics of some of the scenarios.

Table 1. Characteristics of some of the tested scenarios.

Scenario	***Characteristics***
3 SBW	*250,000 m^3 beach nourishment, giving 30 m accretion* *3 SBW 175 m long located 350 m apart and 250 m from the coast*
Terminal groyne	*450,000 m^3 beach nourishment, giving up to 93 m accretion* *1 terminal groyne, 370 m long located at eastern end*

3. Synthesis of results from the study

Two of the investigated scenarios included a combination of a 250,000 m^3 nourishment and construction of submerged shore parallel breakwaters located inside the active profile. The nourishment gives a 30 m shoreline advance over approximately 2000 m. The shoreline model is combined with a 2D bed update over the submerged structures to allow bypass of sediment over the structure.

The calculated shoreline response for one of the scenarios (with three submerged breakwaters) is shown in Figure 2, in terms of "additional beach width" which is defined as the width of the beach compared to the existing beach position. The nourishment is therefore directly derived from the 2001 result. The figure shows that the model predicts formation of salients within the first year. However, because the breakwaters are submerged and located inside the active profile, they do not reduce the longshore transport completely thereby resulting in a continuous retreat of the shoreline. Similar results were also obtained for a scenario with 5 submerged breakwaters.

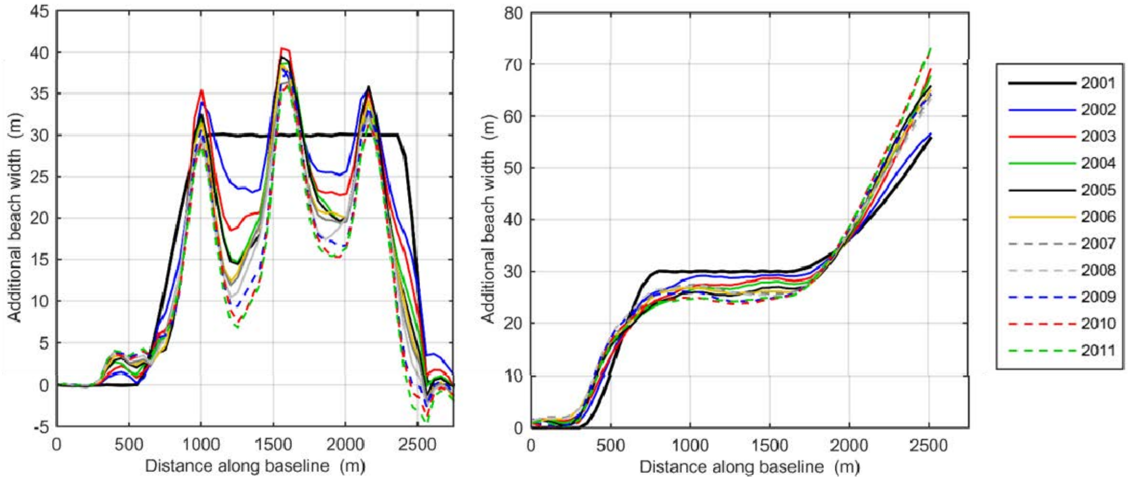

Figure 2. Results from 10 years of 2D shoreline modelling for the scenario with three submerged breakwaters (left) and a terminal groyne at the eastern end (right). The figure shows additional beach width.

A final scenario was investigated which included a larger nourishment of 450,000 m^3 and a terminal groyne. In the final scenario the beach is designed such that it will slowly turn towards the equilibrium orientation, thus resulting in erosion along the central part and accretion along the western and eastern end. The slowly turning beach will over the years reduce the littoral transport further towards zero thereby ensuring the longevity of the nourishment. The simulated shoreline response for the final scenario is shown in the previous Figure 2.

4. Acknowledgements

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