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COASTAL EVOLUTION AT NHA TRANG BAY, VIETNAM

Kustutvecklingen vid Nha Trang-bukten, Vietnam

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Abstract

Over the past years the southern beach of Nha Trang, located in the south central of Vietnam, has started to indicate signs of erosion in the northern part. As the beach plays an important role for this touristic hotspot, the fear that the erosion will become severe has been raised. The limited knowledge and few previous performed studies of the general coastal processes affecting the shoreline evolution have motivated this study and abovementioned were investigated through field trips, data collection and simulations. Data and samples of sediment, beach profiles, shoreline position, wave and current properties and longshore sediment transport were collected. The wave transformation model EBED was used to simulate the nearshore wave climate from deep water wave data for the past 25 years. The resulting wave climate was further used as input data to the shoreline evolution model GENESIS, which calculated the net transport rate and the shoreline evolution for the coming 25 years. The field measurements and data analysis indicated a relatively stable shoreline, except for in the northern part where the retreat of the shoreline was visible. Beach nourishment would improve the condition of the northern part of the beach but required renourishment every second year. The wave climate in the bay is highly affected by the northeast monsoon, which generates a longshore sediment transport to the south, and the sheltering surroundings with the many islands and mountains.

Key words – Nha Trang, coastal evolution, longshore sediment transport, EBED, GENESIS, Vietnam

Sammanfattning

Under de senaste åren har den södra stranden i staden Nha Trang, som ligger i syd-centrala Vietnam, börjat påvisa tecken på erosion i den norra delen. Eftersom stranden spelar en viktig roll för denna turistort, så har rädslan väckts för att erosionen kan komma att bli allvarlig. De begränsade kunskaper och få tidigare utförda studier av de allmänna kustprocesser som påverkar strandlinjeutvecklingen har motiverat denna studie och det ovannämnda undersöktes genom fältstudier, datainsamling och simuleringar. Sedimentprover, strandprofiler, strandlinjeposition, egenskaper av vågor och strömmar och den kustparallella sedimenttransporten samlades in. Vågtransformeringsmodellen EBED användes för att simulera det kustnära vågklimatet baserat på djupvattendata för de senaste 25 åren. Det resulterande vågklimatet användes sedan som indata till modellen GENESIS, som beräknade nettotransport av den kustparallella sedimenttransporten och strandlinjens utveckling för de kommande 25 åren. Fältmätningarna och dataanalyserna indikerade en relativt stabil strandlinjeutveckling, förutom i den norra delen där en tillbakadragning av strandlinjen var synlig. Strandutfyllnad skulle förbättra tillståndet i den norra delen av stranden men krävde återfyllnad vartannat år. Vågklimatet i bukten är starkt påverkat av den nordöstra monsunen, som genererar en kustparallell sedimenttransport i södergående riktning, och den skyddande omgivningen med de många öarna och berg.

1 Introduction

In former years the income to the region of Nha Trang city in Vietnam was mostly made up from agriculture and fishing activities. Nowadays the city experiences new possibilities to earn capital as tourists are drawn to the area. Many come for the appealing weather, but the long and central located sandy beach is also making it an attractive place for leisure. Many constructions such as hotels and services are built in the direct precinct of the beach. The year following the hardening around Yersin Park and an adjacent restaurant, located south of the Cai river mouth, observations of beach changes were made. A sand spit at the river mouth disappeared and shoreline changes of the southern beach started to be more pronounced in the most northern part. As the beach located north of Cai river mouth eroded and left a less attractive area behind with only seawalls showing, concern about the evolution of the south beach was raised.

Few former studies regarding the coastal evolution and hydrodynamic processes in the area of Nha Trang bay has been performed. Therefore, the study was performed to achieve a greater understanding of the governing processes of the shoreline evolution at Nha Trang bay. The main objectives of this study were to investigate and quantify the nearshore processes governing sediment transport and coastal evolution of the southern beach in Nha Trang bay. To study the evolution of the shoreline, the model GENESIS was used to calculate the longshore sediment transport. The present article is a brief presentation of the master thesis *Coastal Evolution of Nha Trang Bay, Vietnam*, and only a minor part of the studies and analysis are included. More information can be found in the master thesis (Böös and Dahlström, 2015).

2 Nha Trang

The coastal city Nha Trang is situated in the south central of Vietnam with a population of 304,200 people (Mårtensson, 2015). The city is located in a bay surrounded by mountains and stretches along a 16 km long beach, which is separated by Cai river mouth into a north and south beach (Figure 1, Figure 2). The bay covers 507 km^2 and contains 19 islands, which shelter the bay and create a complex bathymetry. The year is divided into two seasons, the dry season and the wet season, and has two monsoon periods, the northeast monsoon and the southwest monsoon. The large amounts of rainfall coincide well with the time of year when the northeast monsoon is taking place, i.e. in the months of October to March, while the southwest monsoon is most dominant in the month of April to September (Lefebre et al., 2014). Nha Trang bay experiences a mix of the diurnal tide and the semi-diurnal tide (Mau, 2014). Many constructions, such as seawalls, harbours, hotel complex and dams, have been built along the shoreline of Nha Trang city and upstream the river Cai over the last two decades (Figure 3). These constructions affect the wave climate and the sediment transport into and within the bay.

3 Methodology

Data of present shoreline and beach profile positioning, wave and current speed and direction, sediment samples and sediment transport rates were gathered during the stay in Nha Trang in the spring of 2015. In this report the focus will be on the shoreline evolution investigated through field measurements and simulations with the models EBED and GENESIS.

To get a historical evolution of the shoreline, GPS measurements and Google Earth images were used to digitalise the shoreline. On the fieldtrip the shoreline was measured by walking along the shoreline in the swash zone with a GPS connected to the levelling instrument Ashtech's ProMark 2. Shoreline coordinates from the years 2007, 2008 and 2009 were measured with a GPS by Tran Van Binh and Le Quang Thanh at the De-

Figure 1. *Satellite image over Nha Trang bay with the city of Nha Trang marked (Google Maps, 2014).*

Figure 2. *The sandy beach south of Cai river mouth in Nha Trang.*

Figure 3. *Concrete construction around Yersin Park at the river mouth of Cai river.*

partment of Marine Geology, Institute of Oceanography in Nha Trang. Google Earth images between the years of 2003 and 2014 were available over the bay of Nha Trang. To see changes in the shoreline, satellite images from August 2003, August 2006, May 2009 and March 2014 were selected and digitalised using the software Grapher 10. All historical shorelines were plotted together in a graph for comparison and investigation of the evolution.

4 Results and Discussion

The digitalisation of the whole south beach stretch with a distance of 7 km showed no greater deviation except for the northern part. Due to this, a more close-up plan view for the several shorelines is presented in Figure 4.

As can be seen in Figure 4, the early years show a sand spit in the most northern part, that in recent years been absent. The retreat came to a halt when constructions around the spit were built to protect the park. Seawalls were erected and the withdrawal of the shoreline at the spit was hindered. The area below the sand spit is also showing changes of the shoreline position during the investigated years. One theory is that by building the seawall around the park the sediment flow have been hindered and since no sediment could be provided from the sand spit, sediment is taken from the area south of the spit instead.

Both the GPS and Google Earth measurements are from different seasons and thus making the results less comparable as the shoreline is changing with season. During the northeast monsoon the wind blows stronger and thus creating higher waves, that when breaking contains higher energy and will generate stronger cross-shore and longshore currents. The strong current will

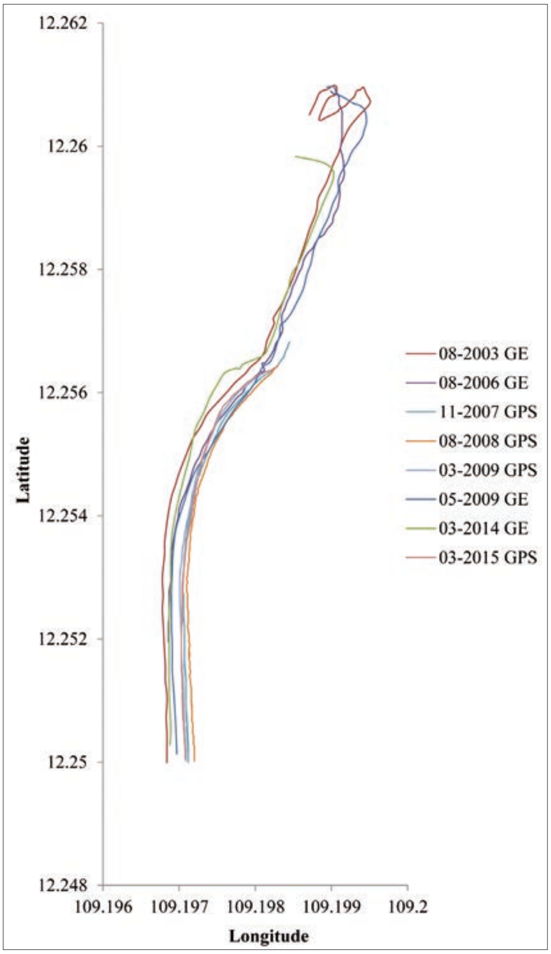

Figure 4. *A close-up view of the shoreline positions at the northern part of the beach estimated from Google Earth images (GE) and measured with GPS (GPS).*

then transport a larger quantity of sediment, which might make the beach retreat. When the southwest monsoon is occurring the waves are smaller and less sediment is transported in the longshore direction. During this time the beach is accreting due to the cross-shore transport of sediment by the waves. Shorelines from the same months would be preferable to get a more precise evolution as well as collected shorelines from the same tide level. Also the results from the two techniques being used, GPS and satellite images, can deviate due to different definitions of the shoreline. With the arguments mentioned above, the shoreline measurements are regarded as unsure with many uncertainties. But even though, they give a hint of the evolution of the beach and one might suspect and fear that the retreat of the northern part of the beach will continue in a southward direction.

5 Wave Transformation Model EBED

A modified version of the multi-directional random wave transformation model EBED by Nam et al. (2009), originally formulated by Mase (2001), was used for transforming offshore wave data into nearshore wave data. The model is based on the energy balance equation and can with the model inputs significant wave height, H_S, significant wave period, T_S, and mean wave direction, $\bar{\theta}$, for offshore waves calculate the same parameters as output values for a nearshore climate.

5.1 Input Data and Model Implementation

Offshore hindcasted wave data was extracted every third hour for 25 years (1990–2014) from the model SWAN (Simulating WAves Nearshore) (Courtesy of Duong Cong Dien, Institute of Mechanics, Hanoi), which is developed at Delft University of Technology. The wind data origin from The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) (Saha, 2010, 2011). The detailed bathymetry data of the bay used for the wave modelling was developed from Vietnam Navy maps of the East sea and neighbouring seas combined with the nearshore bathymetry data measured with a sonar instrument in the project by Nguyen (2013).

The grid placed in the study area needed to be fine enough to mirror the changes in bathymetry, but the downside of a fine grid was the long processing time for the software EBED as a small grid means more cells to process. A grid with cell sizes of 100 m x 100 m gave a satisfying result in relation to the simulation time after running EBED for a test wave series and was decided to use for the simulation. The grid consisted of 209 columns and 275 rows, which covers an area in the bay of 20,900 m x 27,500 m.

The wave output data gained from the model EBED was the wave input data used in the shoreline evolution model GENESIS (GENEralized model for SImulating Shoreline change). Therefore, the grid used in EBED was studied to locate appropriate cells to extract the nearshore wave climate data. In total five cells at a water depth of 10 m located along the shoreline were selected as output data cells.

5.2 Model Validation

To validate the model, the nearshore wave heights simulated with EBED were compared with measured data collected during a project performed by Nguyen (2013) (Figure 5). The simulated results and measured data represented the same location and were gathered from the same dates.

The validation indicates that the model underestimates the real value of the nearshore wave heights, though, the trend of the simulated wave heights follows

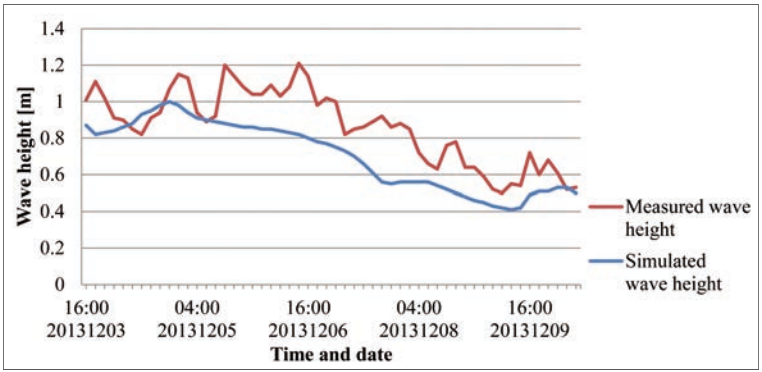

Figure 5. *A validation of the model results performed by comparing wave heights achieved from the EBED model with measured data from December 2013.*

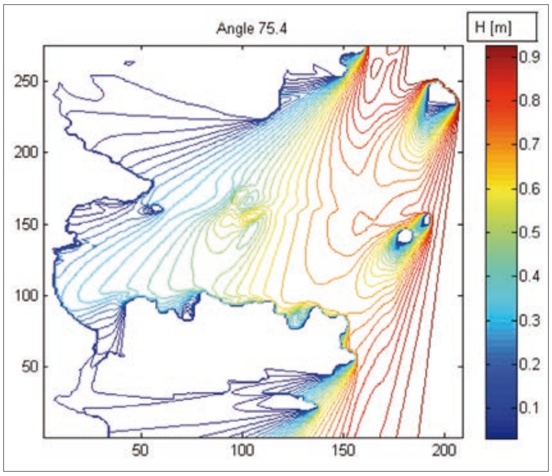

Figure 6. *Simulated wave climate in the bay generated by incoming waves from approximately 0 degrees to true north.*

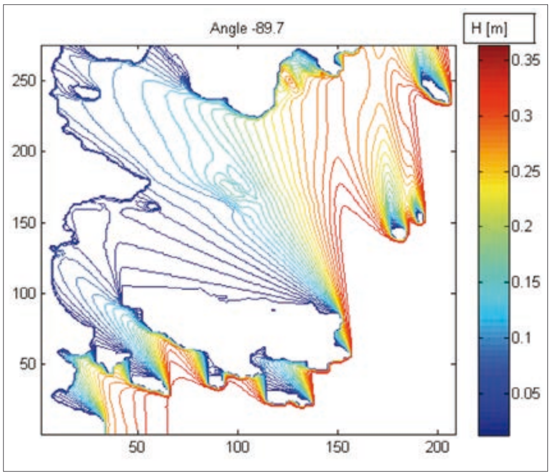

Figure 7. *Simulated wave climate in the bay generated by incoming waves from approximately 180 degrees to true north.*

the measured wave heights well. One explanation for the underestimated results is that the model does not include the effects of local wind. The force of winds blowing over the sea surface has a great impact on the propagating waves as they transfer their energy to the waves and hence the results will not coincide completely with reality. The distance from the offshore to the nearshore data station is approximately 32 km and the wave height will increase during the propagation over the long fetch length.

Other factors contributing to the error sources of the validation are the used input wave data and grid size. The wave data used as input for the model EBED origin from the model SWAN and hence the risk of errors and uncertainties of the result are increased. The grid with a cell size of 100 m x 100 m might be too coarse and the simulation result can be too rough and imprecise estimated.

The data were never re-simulated with modified model parameters for a better validation result due to the restricted time schedule for the project. Also, the conclusion that there still would be uncertainties of the simulated data even if the parameters were modified, since the offshore wave data used as input data for EBED also origin from a simulation, were drawn.

5.3 Analysis of Model Results

To get a general understanding of the wave climate in the bay, the simulated wave heights for different incoming wave angles were plotted in the software Matlab (Figure 6–7). The result shows that the wave heights are highly affected by the direction of the incoming wave, due to the surrounding islands. The islands create shadow zones, in which the wave height decreases, when the waves are diffracted around the islands. Waves with an incoming angle of approximately 0 degrees to true north will create a shadow zone, with lower wave heights, south of the island Hon Tre, while waves with an incoming of approximately 180 degrees to true north will create a shadow zone north of the island. In the centre of the bay there is a shallow, which also affects propagating waves by creating an area with an increased wave height climate, which can be noticed in Figure 7. Worth noting is that the model EBED do not include the effects of the wave transformation process reflection, so the real wave climate in the bay would most likely evolve differently. Also the graphs lack a background with land contours, which might give a false illusion of for example size and shape of the island Hon Tre.

6 Shoreline Evolution Model GENESIS

The numerical model GENESIS, developed by Hans Hanson, Faculty of Engineering (LTH), Lund University, is a well working model for computing long-term change of shoreline position. Based on the one-linear theory, the model assumes that the bottom profile will remain unchanged over the time of the simulation. Only the longshore sediment transport is taken into account in the model and the beach profile is assumed to be in equilibrium (Hanson, 1989).

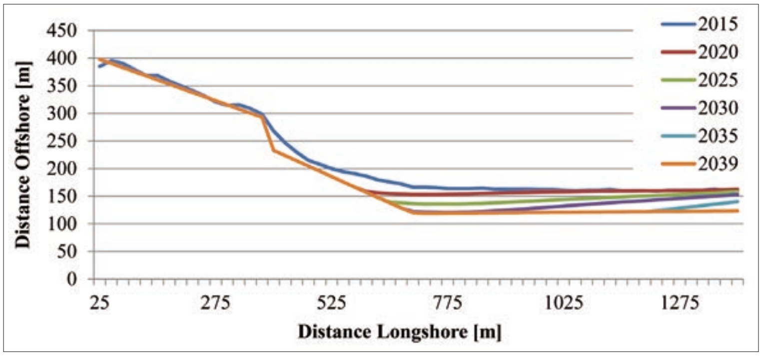

Figure 8. *A close-up of the shoreline evolution in the north part of Nha Trang beach for the 25-years simulation period.*

6.1 Model Implementation

The studied beach stretch for the future coastal evolution used for the GENESIS simulation was 4,925 m. The present, or initial, shoreline orientation was extracted from a Google Earth image photographed in July 2014 with the help of the software Grapher 10. It was divided into 197 cells of 25 m width each. The wave climate used as input in GENESIS was the five locations that were the output from the EBED model. GENESIS interpolates the wave heights in the cells between the locations to get the wave climate in all the cells for the entire model.

The setup of the model and its parameters were done to imitate the historical evolution of the shoreline. As indication from the review of the GPS measurement and Google Earth images, the beach is not changing to a great extent. The wanted result from the simulation was therefore a stable shoreline with not too much changes occurring. Different parameters and boundary conditions were used to get satisfying results of the situation at Nha Trang beach, with a relative stable shoreline evolution. The left hand boundary was set to "gated", meaning that there is a structure prohibiting transport beneath its location. The boundary at the right hand side was set to "pinned", which allows transport possibilities past it. The stretches where seawalls were built were also included in the model. Simplifications were made when short jetties of tetrapods and a small ferry terminal were excluded in the model.

6.2 Analysis of Model Results

The model showed that the beach will retreat in the northern part (Figure 8) and accrete in the southern part, confirmed by the shoreline evolution and the mean net sediment transport rate for each cell (Figure 9). The net sediment transport showed a positive value from north to south along the shoreline, meaning a longshore sediment transport take place in the same direction. As the wind and waves are most dominant in this direction, the result correlates well with the transport pattern. But the retreat and accrete of the shoreline simulated by GENESIS is questionable. It is believed to show higher change of shoreline than what feels reasonable from looking at the historical evolution. As the model setup was quite simple, the beach complexibility was not able to be fully mapped and included in the model. For ex-

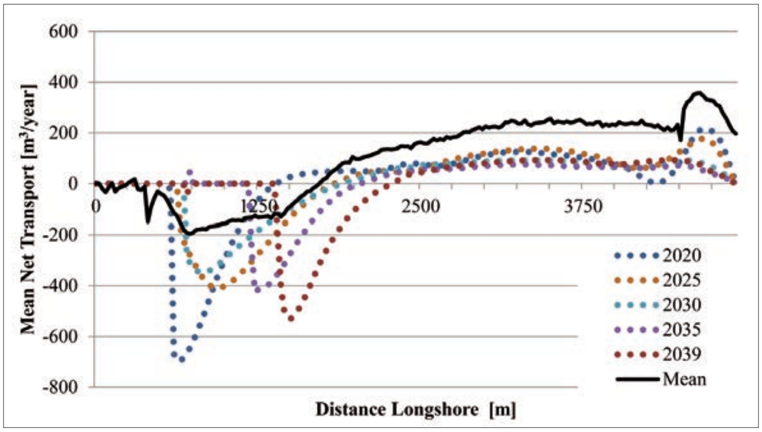

Figure 9. *The resulting mean net transport rate for each cell along the shoreline of Nha Trang beach for the 25-years simulation period.*

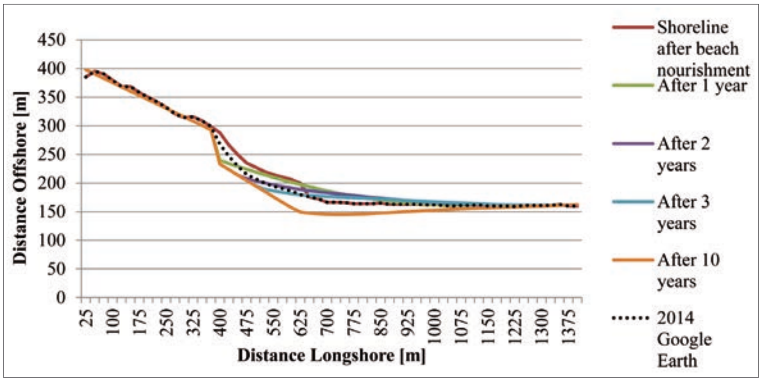

Figure 10. *Shoreline evolution for selected years after a beach nourishment of 20 m over a stretch of 250 m along the shoreline.*

ample, the sediment flow from the river is not included. The river flow transports sediments and contribute to the material of the beach and it would be interesting to investigate how the nowadays more regulated flow will affect the shoreline evolution. It is also well worth noting that the model results origin from simulated input data, which in turn also is simulated based on predictions of the global wind field. Hence, the uncertainties of the accuracy have been introduced already in the beginning of the modelling chain and the model should be used precisely as a model and not as a mirror of the reality. The model gives an indication of the evolution and is a tool used to be able to understand the processes acting in the bay.

6.3 Simulation of Future Evolution

One scenario of beach nourishment was simulated, where 20 m of additional added shoreline was placed along the 250 m stretch at the northern part of the beach where the signs of retreat was most distinguished. The simulation was run to investigate possible benefits with beach nourishment and how long time it would take for the shoreline to retreat to its initial condition. The initial shoreline orientation, to which the beach nourishment was performed at, was based on a satellite plan view image photographed in June 2014 for the software Google Earth. Shorelines for the years following the beach nourishment were plotted until the shoreline had retreated past the initial shoreline (Figure 10) and the results show that the shoreline past the north part of the initial shoreline already at the first year after the beach nourishment (green shoreline). After three years have passed, almost the complete beach nourishment volume will have been transported southward (blue shoreline). Ten years after the beach nourishment, the shoreline has retreated back to the seawall (orange shoreline).

Another simulation was run to investigate the shoreline evolution if another beach nourishment event would be performed at the same stretch and with the same volume of sand after two years of the first event. The results show similar results as the previous simulation of the first beach nourishment occasion. Already two years after the sand filling the shoreline has retreated passed almost the whole stretch of the initial shoreline. Hence, to benefit from the beach nourishment it would be necessary to redo it every second year.

Beach nourishment can be a good alternative when wanting to recover a beach, but such a measure is not for free. With the estimated price of 130,000 VND/m^3, discussed with Pham Thanh Nam (2015) over mail correspondence, the needed amount of sand for a beach nourishment event as presented was estimate to cost 2,905,500,000 VND, i.e. around 134,000 USD.

One important thing to take into consideration when do a filling is where the material is coming from. The area from which the sand is removed should be able to withstand such a loss and the operation should be done without interfering with the sediment balance as well as the ecosystem. Even if the sand used for renourishment is a cost for the municipality, a more attractive beach could lead to greater income for the business in the area if more tourists come to Nha Trang.

At the present, a beach nourish event is not seen as an urgent measure, since the beach is mainly affected by the seasonal variations. If considering beach nourishment in the future, further investigations need to be performed.

7 Conclusion

Few previous studies have been done regarding the hydrodynamic processes in Nha Trang bay and this master thesis was performed as an attempt to understand and map the governing processes affecting the evolution of the south beach in Nha Trang. At the present the shoreline of the southern beach in Nha Trang is in a quite stable condition with mainly seasonal variations, which was confirmed by shoreline and beach profile measurements. The simulation program GENESIS predicted a quite rapid retreat of the shoreline for the next 25 years, leaving no beach left in front of the seawall structure at the northern part of the beach. The result was regarded as unsure as the simulation was done under simplifications and assumptions. However, the northern section of the beach has experienced erosion since the sand spit at the river mouth of Cai disappeared. With the knowledge of the severe erosion at the beach north of the river mouth one might suspect and fear that the retreat of the northern part of the southern beach will continue in the southward direction along the shoreline. Beach nourishment was suggested as a soft measure to improve the condition of the beach, but renourishment every second year would be necessary to maintain a continuous shoreline. This would imply investment for the municipality and would have to be weighed against the profits of having an extra stretch of beach. At the present this is not considered to be an urgent measure and further investigations are needed if planning a future beach nourishment event. The area of Nha Trang bay, sheltered by the many islands and mountains, experiences an unique wind climate which affects the wave climate of the bay. The strong northeast monsoons results in a longhsore current transporting sediment from the north to the south. From the simulation of the nearshore wave climate it was evident that the islands in the bay create shadow zones, where the wave heights become significant lower than in places more exposed to open sea. The wave climate, and consequently also the shoreline evolution, is also highly influence by the seasons and the monsoons taking place in Vietnam. The weather conditions and tidal variations create a complex system for the governing processes of the shoreline evolution. For complete understanding of the ongoing processes in the bay and better predictions of the future evolution, further studies are needed. The area has to be studied for a longer time period, more collection of samples would be preferable and the simulation models need to be modified and adapted for this specific case to achieve a greater understanding and more reliable results.

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