Journal of Coastal Research	SI	71	86–92	Coconut Creek, Florida	2014

Beach Restoration at Grand Velas Hotel, Riviera Maya, Mexico

Raul Lopez[†]

[†]Tecnoceano
Cancún, México
raul_minutti@hotmail.com

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Lopez, R., 2014. Beach restoration at Grand Velas Hotel, Riviera Maya, Mexico. *In:* Silva, R., and Strusińska-Correia, A. (eds.), *Coastal Erosion and Management along Developing Coasts: Selected Cases*. Journal of Coastal Research, Special Issue, No. 71, pp. 86–92. Coconut Creek (Florida), ISSN 0749-0208.

Shore erosion is a serious problem that is present in many countries with coastal regions. Mexico is no exception; coasts on the Pacific Ocean, the Gulf of Mexico and the Caribbean Sea suffer from erosion. The pass of seasonal storms and hurricanes and anthropogenic actions on the coasts have played an important role in this matter. These coasts need to be protected to avoid beach retreat and property damage. Knowing how to design suitable coastal protection structures is important to help recover and stabilize a beach. The objective of this study case is to evaluate the performance of a 2008 project designed and built to stabilized and protect 500 m of beach in front of the Grand Velas Hotel Riviera Maya in the state of Quintana Roo. From the observation of what happened on this coast it may be possible to understand erosion protection projects more fully and so, to improve designs in the future.

ADDITIONAL INDEX WORDS: *Beach restoration, nearshore structures, erosion reduction, wave energy control.*

INTRODUCTION

The coasts of Quintana Roo, in Mexico have been experiencing increasing erosion, especially in the last ten years, and one of the causes of this phenomenon is the pass of strong seasonal storms and hurricanes. It seems to be that hurricanes are stronger than they used to be due to the global warming but there is not enough evidence yet to be sure of this and the discussion and analysis continues (www.climate.gov/news-features/features/will-hurricanes-change-world-warms). Another cause is anthropogenic, man has constructed hotels along the coast of the State of Quintana Roo and the dunes have been invaded by hotels. The last cause is sand budget, the coast of Quintana Roo is a flat area without overground rivers, all the water that exists inland is in underground rivers that arrive at the sea without bringing important amounts of sand. Actually, what the water brings is a fine sediment very different from beach sand. The nice white sand characteristic of the Mexican Caribbean beaches is biogenic so it is produced in the sea and moved along the beach by the waves and currents, the movement is in both directions but the dominant movement is from south to north. This is notorious along the coast where structures are to be found. The sand accumulates at the south side (because it comes from south), and only in winter when cold fronts are present, does sand accumulate at the north sides. One problem with the budget of sand is that when a strong storm hits the beach, sand is dragged toward the sea and is deposited over the bottom, too deep to be moved by the mean regime waves. At this point, as the sand is not moved by waves, there is no way it for it to return to the shore in a natural way. In October 2005 hurricane Wilma (Category 5 on the Saffir-Simpson Hurricane Scale) passed over the northern part of the state, affecting the beaches of Cozumel, Playa del Carmen and Cancun.

All the beaches were severely damaged and eroded; many hotels were affected by damage to their structure, installations and furniture. This study is about a property where there was a hotel called Capitan Laffite, at coordinates 20°40’30.7935” N, 087°01’17.9711” W (Figure 1). This hotel lost around 20 m of beach and its foundations were submerged in the sea. As recovery would be too expensive, the land was sold to a developer, who built a new hotel: the Grand Velas, Riviera Maya. This developer invested in hydrographic studies for a project to recover and stabilize the beach in front of the property, which is important for the following reasons:

1. The hotels in the Riviera Maya and Quintana Roo coasts live from tourism and need nice, white and wide beaches for the people from all over the world who come to see and enjoy them.
2. Seasonal storms develop medium to high waves with enough energy to make sand move and erode beaches. In winter, cold fronts generate waves from the North East that may last up to a week. In summer, winds from South East and East generate high waves that may last for weeks. All this movement displaces the sand in front of the hotels, making the beaches narrower and exposing the hotel facilities, especially public areas such as pools, restaurants and bars. Protecting the beaches from erosion helps the hotels to maintain their facilities in good condition.
3. Mexican law states that the “Maritime Federal Zone” is 20 m from the High Sea Level, measured inland. Therefore, if the beach is eroded, the Maritime Federal Zone moves and the hotel property becomes part of the Federal Zone, at which point the property limit needs to be adjusted and part of the land is lost. It is important for developers to keep a wide beach in front of their property with a minimum buffer of 20 m before reaching the sea.

In the case of the Grand Velas Hotel, bathymetric and topographic surveys were performed, current measures were

DOI: 10.2112/SI71-010.1 received 12 February 2014; accepted in revision 21 September 2014.

also taken, and a project was initiated to protect, recover and stabilize the shore line of 500 m of beach front.

Figure 1. Location of the study site.

The project planned five 70 m breakwaters, parallel to the shoreline, with 30 m gaps between four of them and the last one separated by 131 m. In addition, 30 m geotubes were located close to the property line to catch as much sand as possible and eventually be buried. Then, finally, an artificial dune made with massive 1.8 m geotubes filled with sand, was set parallel to the property limit. The geotubes were buried with sand and vegetation was planted on the top, the objective being to catch sand moved by the wind and fix it in the dune with the roots of the plants.

The project was finished in 2008 and it has been working well; the beach has been widened. However, no salients have been clearly formed, so the question is now: was this arrangement the best option?

The beach has been widened and it narrows a little with the different local wave conditions, so it has reached equilibrium. The sea bottom is rocky and no sand banks are found close to the study zone, sand moves only alongshore in both directions predominantly from south to north as it is possible to observe in Figure 2, which shows the coastal line in front of another hotel at the same zone about 2.8 km north from Grand Velas Hotel. That hotel has a jetty where the south part of the beach is wider to the south and narrow to the north because sand is coming from the south. Neighboring beaches are still being eroded every year nevertheless the Grand Velas Hotel beach is wide and pleasant Figure 3.

CHARACTERISTICS OF THE STUDY AREA

The study area is vulnerable to hurricanes and it is necessary to take into consideration that year after year tropical storms hit the area. The Grand Velas Hotel location has the typical characteristics of Quintana Roo coasts, *i.e.* flat and low; the average elevation at the dune is about 2 m above sea level, rising slowly inland.

Figure 2. Coast line over the same area about 2.8 km north from Grand Velas Hotel, the jetty keeps the sand at the south part of the beach, his proves that sand moves from south to north primarily, even though there is movement in both directions.

Figure 3. From this satellite photo, it is possible to observe that southern neighboring and northern neighboring beaches are narrow while the protected beach is wide.

CHARACTERISTICS OF THE STUDY AREA

The study area is vulnerable to hurricanes and it is necessary to take into consideration that year after year tropical storms hit the area. The Grand Velas Hotel location has the typical characteristics of Quintana Roo coasts, *i.e.* flat and low; the average elevation at the dune is about 2 m above sea level, rising slowly inland. The beach slope is about 20:1 and the sea bottom is a rocky continental platform with sandy areas of between 5 cm and 2 m, the orientation of the beach is 39 degrees with respect to the geographic north. Small reef heads may be present on the sea floor. The sea bottom gets deeper slowly up to about 50 m to 55 m off the beach, where a ledge appears and the bottom drops to a depth of 400 m. The average tidal range between the Mean High Water and Mean Low Water is only 30 cm.

Predominant waves and winds are from the southeast and east, with winds from the northeast in winter due to cold fronts.

Several field studies were carried out such as a topographic survey, a bathymetric survey, current measurements and exploration dives with SCUBA equipment to look for marine sand banks. Figure 4 shows some of the field work being done.

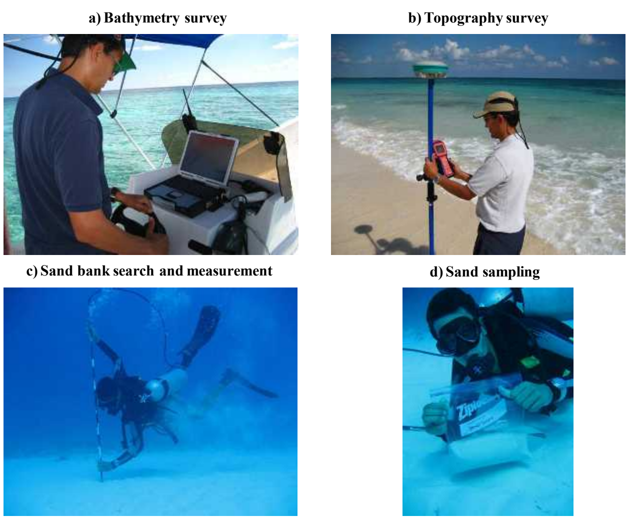

Figure 4. Field work images.

Work was carried out using computer programs to determine wave patterns. The surveys provided: topography and bathymetry, currents mainly travel from south-west to north-east, no nearby sand bank of importance for beach nourishment was found and good movement of sand parallel to the beach from south to north for most of the year with some episodes in the opposite direction in winter due to the cold fronts that last between 2 and 7 days.

From the mathematical model Wave Watch III, information based on 9 years of measurements made by NOAA at a deep water point North of Cozumel Island with coordinates 21° N, 86.5° W, and using program STWAVE (Figure 5), Table 1 was obtained (http://polar.ncep.noaa.gov/waves/index2.shtml).

Table 1. *Characteristics of waves in deep water.*

Deep water characteristics	
Mean height wave (*H*)	1.4 m
Mean period (*T*)	5.5 s
Mean direction	106.9°
Highest wave (HS, hurricane Wilma)	11.7 m
Highest wave period	13.4 s
Direction of highest wave	135.0°

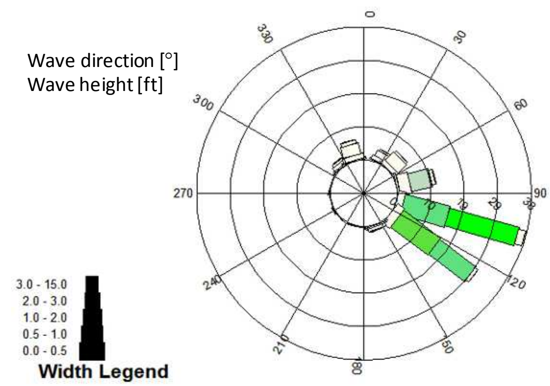

Figure 5. Deep water wave characteristics.

Wave propagation from the numerical simulation provided wave heights and periods in front of the property at a distance of 100 m offshore according to Table 2 and Figure 6.

Table 2. *Wave characteristics at a water depth of 100 m offshore.*

Shallow water wave characteristics	
Mean height wave (*H*)	0.5 to 2.0 m
Mean period (*T*)	5 to 6 s
Mean direction	East-South

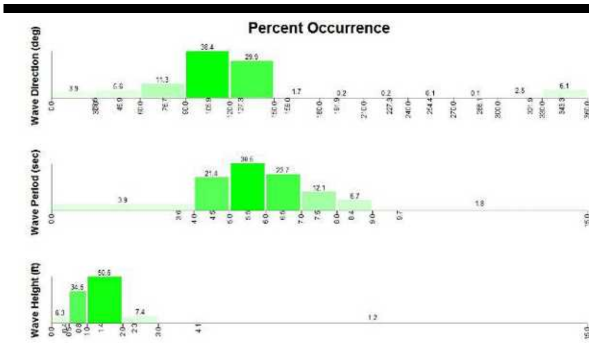

Figure 6. Wave direction, wave period and wave height.

Tidal change is about 30 cm in average with maximums of 70 cm, the tides were taken from the EasyTide model from the United Kingdom Hidrography Office (UKHO, www.ukho.gov.uk/easytide/EasyTide).

SHORELINE PROTECTION ALTERNATIVES

The following possible solutions for shoreline protection were taken into consideration when developing the mitigation strategy for the beach at the Grand Velas Hotel:

Beach nourishment. This option represents a solution with a low-impact on the coastal ecosystem and tourism aspects. However it requires a sediment supply source (*e.g.*, a big sand bank close to the beach). It is obvious that it would be necessary to continue this nourishment, since sand will continue to be mobilized under storm wave conditions and go downdrift or move out to sea. For this reason, a structure retaining the sand would be preferable.

Jetty. The local ecological authority does not allow the building of jetties or any other structure that stops the long shore sediment transport. Therefore, this alternative was not considered further.

Breakwaters parallel to shore. Breakwaters parallel to the shoreline were the only option that could be authorized, so this was the solution adopted.

Artificial dune. Additionally, an artificial dune made of geotubes filled with sand and aligned in front of the hotel is perfect for vegetation, protecting the sand from erosion caused by wind and providing a barrier in case of extraordinary storm waves. This geotube line should be heavy enough to withstand wave impact and should have an antiscouring carpet to prevent the geotubes from moving. These geotubes are intended to work only in case of a hurricane and if all the sand is taken away, and for a short period of time to protect the pool, bar and other hotel facilities, they were not designed to be breakwaters for a long time.

The solution selected is the construction of several breakwaters parallel to the shoreline. This system would help dissipate wave energy; and capture sand. No side effects would impact on neighboring areas; no interruption of sediment transport would be caused. The quantity, size and gaps between the breakwaters would be determined by formulas to get the best results.

MODELING OF WAVE CONDITIONS IN FRONT OF PROTECTED COAST

Modeling of different wave conditions was performed using Genesis software (Gravens *et al.*, 1991) with four of the structures because the model was not stable with five breakwaters at that point and there was not another software to make a better simulation. The conditions used were: a) H=0.7 m, T=6.6 s and Dir=259°, b) H=0.7 m, T=6.6 s and Dir=281°, c) H=0.7 m, T=6.6 s and Dir=238°, c) H=6.93 m, T= 8.3 s and Dir=220° and d) H=2.45 m, T=6.6 s and Dir=333°, tide was considered zero at all times. The software showed basically two different responses. Figure 7 shows the salients expected to form under normal wave conditions and Figure 8 shows the salient formation under storm wave conditions.

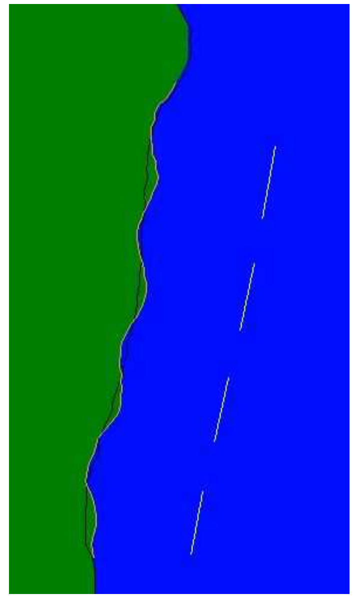

Figure 7. Beach response under normal wave conditions, the black line corresponds to the original coastal line and the green salient corresponds to the shape generated by the presence of breakwaters.

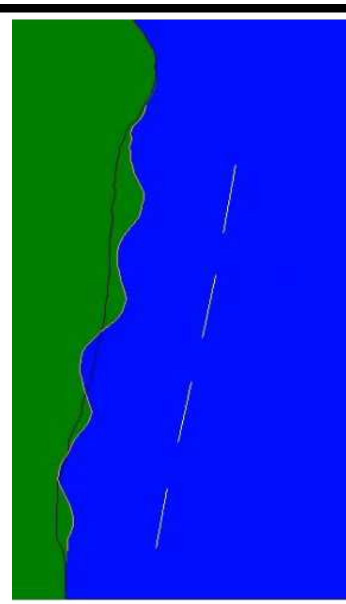

Figure 8. Beach response under storm wave conditions.

DESIGN OF PROTECTIVE STRUCTURES

The Dally and Pope (1986) formula from the Coastal Engineering Manual (2006) was used to find a mathematical relation between offshore distance and the structure longitude (see Table 3).

Table 3. *Conditions for the formation of salients. Ls represents the length of structure, Y the distance from shore to the breakwater and b the minimum beach width at MHW after nourishment (Ward, 2006).*

Geometry	Tombolo/salient formulation Reference
Ls/Y < 1.0	No tombolo
Ls/Y < 0.4 to 0.5	Salient
Ls/y = 0.5 to 0.67	Salient
Ls/Y < 1.0	No tombolo (single breakwater)
Ls/Y < 2b/Ls	No tombolo (multiple breakwater)
Ls/Y < 1.5	Well-developed salient
Ls/Y < 0.8 to 1.5	Subdued salient

According to the length of the breakwater and its distance offshore, based on Figure 9, the structures create salients, which is the desired response of the beach.

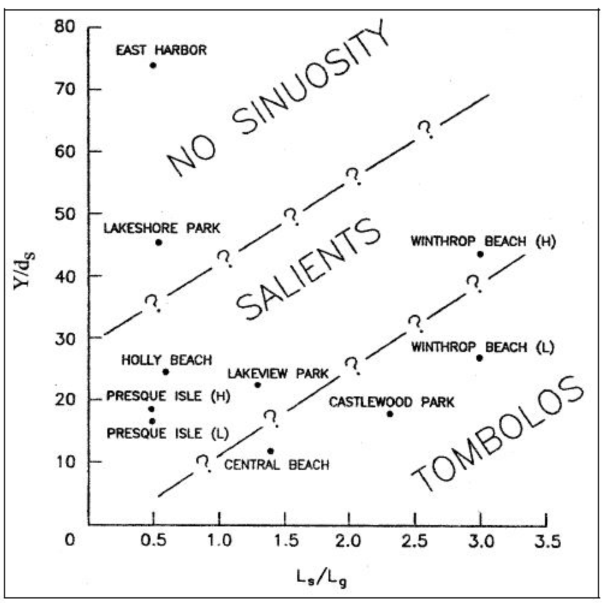

Figure 9. Conditions for formation of salients and tombolos (Coastal Engineering Manual, 2006), Ls represents the structure length, Lg the length of gap, Y is the distance from shore and ds is the depth at which the structure is located.

Five 70 m long breakwaters were designed to be built in front of the property, four of them parallel to the shoreline and on the same axis, with 30 m wide gaps and the fifth with an angle of 131 degrees from the rest, and a gap of 131 m, as shown in Figure 10. The crown width is 2 m, the base width is about 5 m and the slope is 1:1.

The material used for the construction of the breakwaters was "bolsacreto" which is an impermeable bag that is extended on the seafloor and filled with cement. Several bags are set to form a pyramid with an angle of 45°. The bags of "bolsacreto" are 2 m wide, 0.5 m high and 3 m long. Figure 11 shows the cross section of the breakwater, the crown of the structure is at Mean High Water so it provides protection most of the time but it is not very visible from the shore, as it is not desirable that the landscape is affected by the presence of high structures.

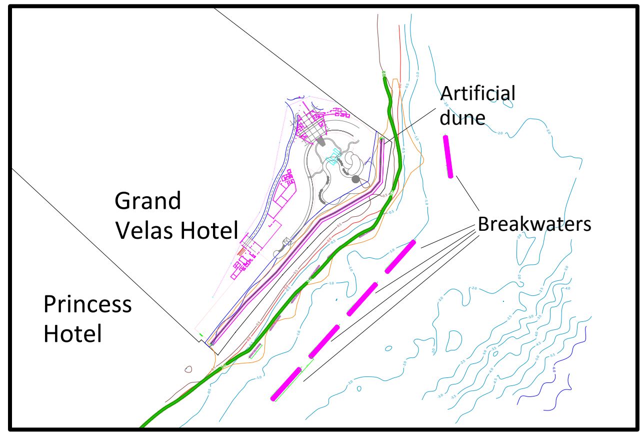

Figure 10. Coastal protection project with the five breakwaters and an artificial dune.

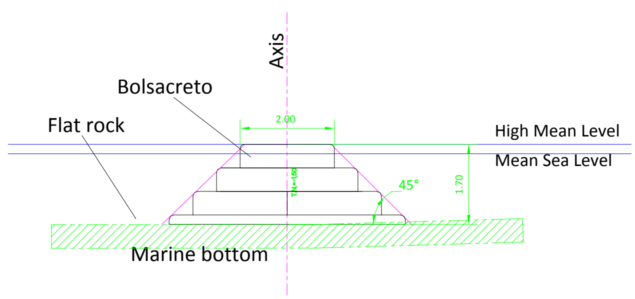

Figure 11. Breakwater cross section.

The height of the artificial dune was determined by copying the geometry of a natural dune and adding extra height, taking into consideration that water level rises by 1 m due to surge under storm wave conditions. Thus, the final height of the dune was 2.70 m over the Mean Sea Level. Figure 12 shows the cross section of the artificial dune. The total length of the dune was 502 m, made with geotubes of 20 m tied to each other. The geotubes were 1.4 m high and 2.7 m wide when full, and the antiscouring carpet was 5.5 m long. The plants selected to cover the dune were "Spermacoce laevis", a plant native to the area, which grows on beaches and places with high levels of salinity. Its roots tighten the sand under them and help keep the sand in place and capture more wind transported sand. The sand used to fill the geotubes and cover the artificial dune was taken from the beach.

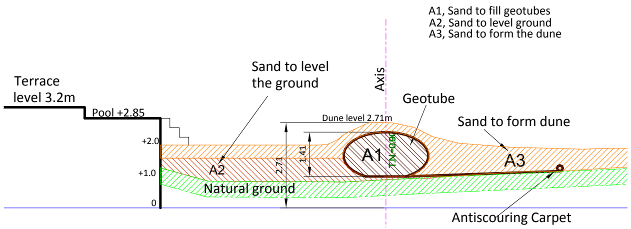

Figure 12. Cross section of constructed artificial dune.

CONSTRUCTION OF PROTECTIVE STRUCTURES

The artificial dune and the breakwaters were built in 2008. Figure13 and Figure 14 show the building stages and the final view of the dune.

a) Geotubes filled with sand and covered with beach sand b) Dune cover and slope formation

Figure 13. Construction of artificial dune.

Figure 14. View of artificial dune in front of the hotel.

It was expected that a prominent salient would be formed, but although the beach response was good, no well-defined salient has appeared.

In 5 years the shoreline has recovered 20 m in its best part located in the middle of the property, after which the beach recovery goes down to 14 m on average.

The north point did not widen much, apparently because the gap between the fourth and fifth breakwaters is too big (130 m).

The salients were not prominent, probably because the gaps are too small.

Comparing topography from 2008 (with the project finished) and 2013 (the only data available), the amount of sand captured by the structures was calculated and the result is 15,867.20 m^3 of sand over five years, Figure 15 shows the beach profile comparison, this volume seems to be stable most of the time just as it is observed in Figure 16.

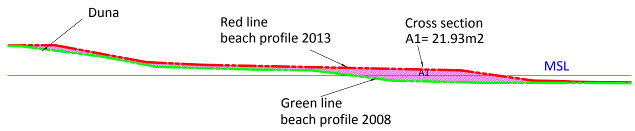

Figure 15. Comparison between beach profiles 2008 when dune was finished and 2013.

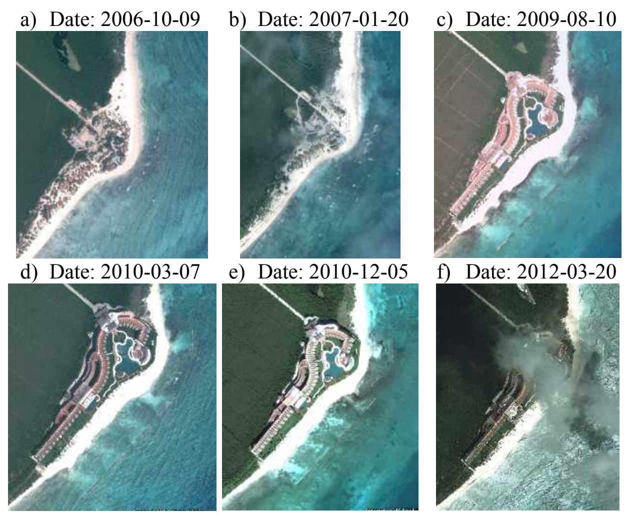

Figure 16. Images c, d, e and f show that the beach protected by the breakwaters is wider and remains wide over several years, this proves that this sand is very stable, and even though topography is not realized on a yearly basis, the satellite pictures from Google Earth show clearly the shape of the beach.

Figure 17 shows the shoreline evolution, the thick red line with numbers represents the old “zero” line 5 years ago, the green thick line represents the new “zero” line nowadays and the orange wavy thin line represents the prominent salient that was expected.

The beach at the Grand Velas Hotel in 2009 is shown in Figure 18a and in 2010 in Figure 18b. In 2009 better salients were formed, while in 2010 an even shoreline with small salients were observed.

Figure 17. The hold "zero line" is represented in red, the thick green line shows the shoreline after six years and the wavy orange line represents expected salients.

Figure 18. Aerial photos of the beach at the Grand Velas Hotel 2009 a) A wide beach with space enough to have chairs on the beach for guests, is visible. Note that the protected area is a lot wider than the unprotected beach to the south and to the North. Salients are visible and the North point looks wide but not as wide as the rest of the beach (November 2009). b) A wide beach with no salients, the north point is not so wide probably due to the big gap between breakwaters 4 and 5 (February 2010)

DISCUSSION AND CONCLUSIONS

From analysis of the performance of these structures we can say that the breakwaters have helped to recover the beach and keep it stable for six years.

The position of breakwater number five has been helpful in episodes of strong cold fronts which appear in winter. In order to evaluate whether this is the best position for this breakwater, or if any other position could protect the beach for a longer period of time during the year, it would be necessary to generate several models and to compare the results in order to get a conclusion.

The way the artificial dune was made and its natural appearance is excellent, this dune has been widening and it is a good barrier in case an extraordinary storm hits the coasts.

ACKNOWLEDGMENTS

This publication is one of the results of the Latin American Regional Network global collaborative project ''EXCEED – Excellence Center for Development Cooperation – Sustainable Water Management in Developing Countries'' consisting of 35 universities and research centres from 18 countries on 4 continents. The authors would like to acknowledge the support of the German Academic Exchange Service DAAD, the Centro de Tecnologia e Geociências da Universidade Federal de Pernambuco, the Fundação de Amparo a Ciência e Tecnologia do Estado de Pernambuco-FACEPE and the Instituto de Ingeniería of the Universidad Nacional Autónoma de México for their participation in this EXCEED project.

LITERATURE CITED

Gravens, M.B.; Kraus, N.C., and Hanson, H., 1991. *GENESIS: Generalized Model For Simulating Shoreline Change*. Technical Report CERC-89-19, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.

Model WaveWatch III NOAA: *http://polar.ncep.noaa.gov/waves/*

Ward D.L., 2006. *Shore protection projects*. Coastal Engineering Manual, V-3.