

Cancun Beach Nourishment Environmental Effects

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1 Background

Cancun beach is located in the state of Quintana Roo, México. It is a littoral barrier beach with 12 kilometer beachface, semi confined to the North by Punta Cancun and to the South by Punta Nizuc. Limited by the coordinates $21^{\circ},07',08''\text{N}$, $86^{\circ},44',25''\text{W}$, to the North, and $21^{\circ},02',07''\text{N}$, $86^{\circ},46',38''\text{W}$, to the South, to the West by the Nichupté Lagoon System.

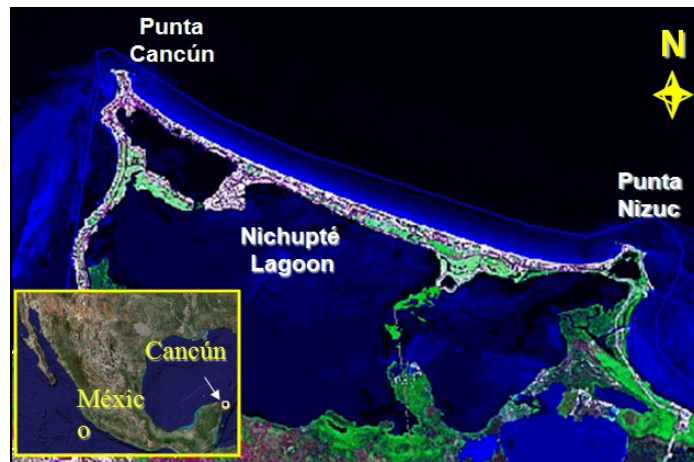


Figure 1 Cancun Beach location (Study area)

In 1970, Cancun beaches were in a natural equilibrium condition. Beach widths varied between 50 and 60 m. Sand volume on the beach was estimated on 11 million cubic meters. During 1972 hotel infrastructure construction started with the modifications and impacts to the environment as a result. This great investment on majestic hotels turned Cancun into the most important, attractive and beautiful resort area of Mexico.

Along 16 years, Cancun beaches behaved as a natural and equilibrium coastal system. In 1988, with the combination of Hurricane Gilbert (category 5, according to Saffir-Simpson scale) and the anthropogenic activities such as hotel construction on the beach dune, the first erosion problems started to be observed. The erosion process continued along the 12 kilometer beach front of Cancun, due to the combination of effects: hurricane occurrence and anthropogenic activities. In 2000, the first efforts to try to understand the highly complex hydrodynamic processes that caused the beach erosion were carried out. Bathymetric surveys, wave and current climate systematic measurements lead CFE engineers to estimate a 4 million cubic meters loss of sand.

In 2005, the beach widths fluctuated between 30 and 35 m. At the end of this year, a powerful and highly destructive hurricane impacted Cancun Beach: Hurricane Wilma. Its classification was 4, according to Saffir-Simpson scale and it stopped for almost 3 days between Cozumel Island and Cancun. It provoked many important urban damages including the loss of 6.6 million cubic meters of sand along Cancun 12 km beach front. Beach widths varied between 5 and 7 m, particularly Punta Cancun area lost completely its beach, consequently the waves attacked hotel foundations, provoking the collapse of some buildings.

After Hurricane Wilma impact, Federal Government implemented the "Cancun Beach Rehabilitation Emergency Project", performed by CFE coastal engineers. The available budget for this action was US\$20 million. Beach nourishment sand volume was only 2.7 million cubic meters, and final beach widths between 22 and 28 m as a result. So after finishing the nourishment

process, Cancun beach had 3.6 million cubic meters of sand approximately, which implied a 7.4 million cubic meters of sand deficit.

This “Cancun Beach Rehabilitation Emergency Project” helped have a continuous resort area along the 12 km beach front and at the same time to protect the wealthy hotel infrastructure. Nevertheless, through systematic bathymetric surveys and wave and current climate measurements it was clear that this coastal system needed more sand to reach 1970 primeval conditions. This situation set the stage for the Federal Government starting in 2008 the “Cancun Beach Rehabilitation Integral Project” and the placement of sand began on September 2009 finishing on February 2010.

2 Cancun Beach Rehabilitation Integral Project Description

This relevant project is based on the placement of 5.2 million cubic meters of sand along a 10.5 km beach front. Construction beach widths varied from 80 to 110 m, and the final beach widths are expected to reach 30 and 40 m. A closure structure on Punta Cancun was included in order to trap the sediment transported from South to North, and at the same time to dissipate wave energy coming from North-Northeast sector.

Due to the big amount of sand needed for this rehabilitation, two borrow sand areas were used: La Ollita 2 borrow sand located 15 km Northeast of Isla Mujeres, and Punta Norte borrow sand located 4 km Northwest of Cozumel island. La Ollita 2 borrow sand had a 5 km² surface and 2 million sand volume. Punta Norte borrow sand covers 17 km² and contains a 40 million sand volume. The sand in both sites was completely compatible with the native sand.

2.1 Project Stages

The project includes 2 studied areas; the rehabilitated area and the sand borrow area. It was divided into 3 main stages:

- During the first stage the activities focused on site characterization from physical and environmental point of view for the placement site as well as borrow sand sites.

Physical characterization was carried out through all the available technical information analysis on the project, and included beach state definition, erosion process analysis, bathymetric surveys, wave and current climate measurements, sand samples analysis (specific gravity and granulometric curve determination) on the beach (sand placement site) as well as on the borrow sand sites. Particularly, borrow sand sites were explored systematically in order to estimate a feasible dredged sand volume. This exploration was executed through geophysical surveys (indirect method) and scuba diving (direct method).

Environmental characterization was carried out on the beach (sand placement site) as well as on the borrow sand sites, and included water samples to determine water quality parameters such as temperature, dissolved oxygen, salinity, pH, transparency, total suspended solids along the water column. On the other hand, the identification and quantification of biota individuals per species per square meter through direct inspection (diving) and sediment removal. All this information was the basis for determining a feasible impacts matrix before dredging operations. A quite careful and detailed inspection was accomplished to coral reef colonies “Chitales” located North of Cancun and the first and second coral reef barriers, South of Punta Nizuc. The measurements focused on the sediment accumulation rate before and after the beach nourishment process.

- The second stage is the beach nourishment process and it started on September 2009 and finished on February 2010. On this period of time 5.2 million cubic meters of sand were placed along a 10.6 km beach front. Construction widths fluctuated between 80 and 110 m. Beach berm level was 3 m above mean sea level. Closure structure on Punta Cancun was 305 m long and it was formed by 2 articulated arcs joined by the small Islet “Las Golondrinas”.

At this stage, the environmental activities were performed quite heavily in order to avoid any kind of impact on the ambience, through the next actions:

- Dredging area monitoring on borrow sand sites, in order to guarantee the authorized extraction zone is being respected by the contractor. Dredger navigation routes are within the authorized by Mexican Port Authority.
- Biota monitoring on borrow sand sites, by means of test channels
- Fine sediment dispersion cloud control during the sand placement on the beach
- Sessile fauna rescue and relocation on borrow sand sites
- Coastal fauna monitoring on the placement site (beach) focusing on the protected species named by NOM-059-SEMARNAT-2001
- Follow-up and support to sea turtles rescue program
- Coral reef colonies tracking using the suggested technique on the “Manual para el monitoreo de arrecifes de coral en el Caribe y Atlántico Occidental”. This activity was effected in order to avoid the settlement of sediment transport on the coral reef colonies during and after the nourishment process.
- Physical and physicochemical water quality systematic measurements along the 10.6 km water front, during and after the nourishment process.
- Physical and physicochemical water quality systematic measurements on both borrow sand areas during and after the nourishment process



(a)



(b)

Figure 2 (a) Sessile fauna rescue and relocation on borrow areas, (b) Coral reef monitoring.

- Third stage is the permanent monitoring program implementation. This monitoring program will last 10 years after finishing the nourishment works process and it started on February 11th, 2010. It consists of monthly bathymetric surveys, wave and current climate, sand samples along the recently rehabilitated 10.6 km beach front systematic measurements. All this information will be used to implement a beach maintenance policy. Regarding the environmental conditions, CFE technical team continued this extremely relevant monitoring program, as it has been described above.

3 Main Results

3.1 Beach Rehabilitation Project

Beach rehabilitation assessment is based on monthly bathymetric surveys, wave and current climate, sand samples along the recently rehabilitated 10.6 km beach front. It starts from August 2008 and finishes on January 2011. The analysis of all this information is used to establish a beach maintenance policy.

Figure 4 shows clearly these project most representative beach widths. On 2008 beach widths fluctuated between 40 and 50 m along only 600 m, which represent 5% of 12 km total beach front. On 2011, one year after finishing rehabilitation works, beach widths vary between 70 and 100 m and represent 94% of 12 km total beach front. A very special case is 160 m beach width created by the closure structure on Punta Cancun.

On the other hand, on 2008 beach widths less than 30 m were 74% meanwhile on 2011, beach widths between 30 and 40 m represent only 6% of 12 km total beach front.



Figure 3 Cancun Beach before and after the nourishment Project (Punta Cancun zone)

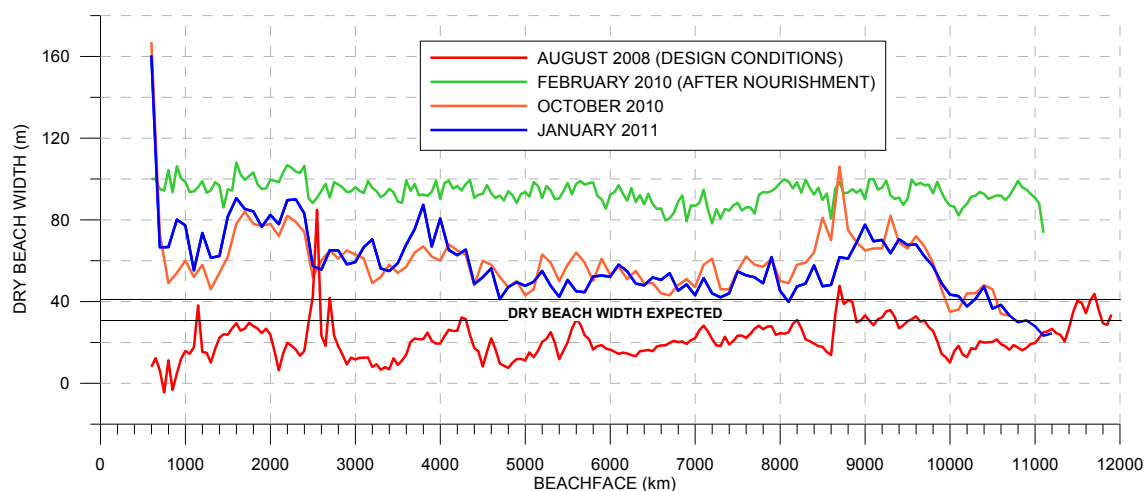


Figure 4 Coastline Evolution

3.2 Feasible Environmental Effects

One year after construction, suitable studies were carried out in the placement area, borrow sand sites and neighboring areas like coral reefs, in order to identify, predict and assess all relevant environmental impacts provoked by the Cancun Beach Nourishment. As expected the most significant environmental impacts were registered on the borrow sand sites, as described next:

3.2.1 Borrow Sand Sites

In both cases the whole area is on optimum conditions for marine biota restock. Water temperature and transparency are quite good for the biota that lived on these areas before dredging process.

After nourishment, 9 species were found on the dredged zone of La Ollita 2, furthermore the dredged zone is being restocked by minor size organisms. The dominant species on La Ollita 2 borrow sand is the Encope (aberrans species), best known as sand dollar. Generally speaking this borrow sand area shows excellent environmental conditions, after one year of finishing dredging works.

In Punta Norte Borrow Sand 1,704 organisms which belong to 8 species were found on this area showing a 90% biota recovery. Some pink shell groupings were found on this area, therefore this is a dominant species. White shell groupings were also found but in minor quantity. In brief, Water temperature, transparency, salinity and all the physicochemical parameters reveal this area is on optimum environmental conditions for marine biota restock.

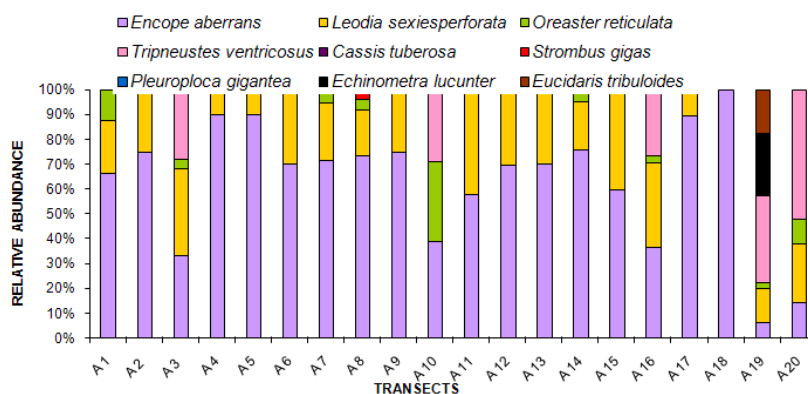


Figure 5 Fauna monitoring on La Ollita 2, after nourishment.

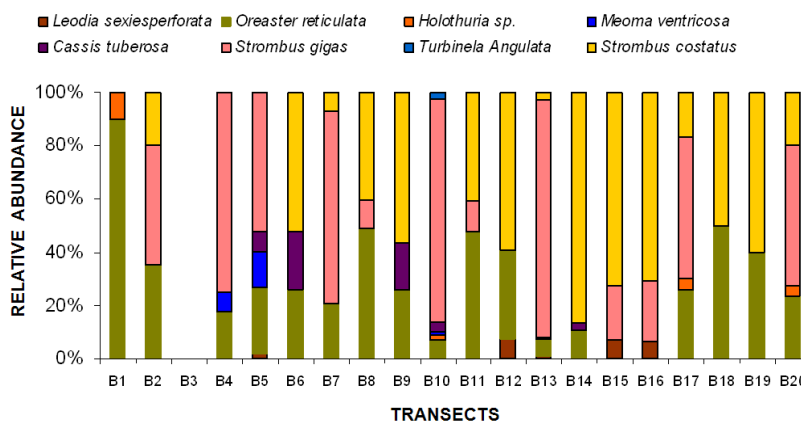


Figure 6 Fauna monitoring on Punta Norte, after nourishment.

The environmental effects were evaluated in terms of the modification degree taking into consideration the next impact attributes:

- ❖ **MAGNITUDE.** Due to the sand borrow area belonging to the Caribbean Sea and being compared in length to it (showing the same bottom characteristics), the affected area is comparatively small.
- ❖ **INTENSITY.** As the sand borrow area was not fully dredged, the sediment that nowadays remains in the area is being distributed along the whole area where the impact has been considered as medium.
- ❖ **ENVIRONMENTAL RECOVERY.** The Benthos alteration could be considered as reversible by its own mechanisms of self depuration. In terms of volume of sediment dredged, the impact is high by the time scale to be recovered (2 to 4 years).

4 Main Conclusions

After one year of completing Cancun Beach rehabilitation works and taking into consideration the monitoring program results it can be concluded that this beach is highly satisfactory due to the fact that 90% of it shows beach widths bigger than the expected ones (30 to 40 m). Therefore after a year of beach nourishment process it is not necessary do any kind of maintenance work immediately, however it is essential to continue monitoring.

From the environmental point of view, it has been shown that the final environmental variation is considered low, with an altered temporal persistence between 1 and 3 years to achieve homogeneous benthic settlement.

Regarding the sand-volume-dredged recovery, the environmental impact has been considered as of permanent persistence because the sand volume would be recovered in a high time scale (2-4 years).

Therefore, it is not necessary to implement corrective or protective actions, but it is of the utmost importance to continue with the environmental and physical monitoring.

Cancun beach rehabilitation works did not cause an important impact on biota in the placement site. On the Coral reef colony "Chitales" located North of Cancun and the first and second coral reef barriers, South of Punta Nizuc are completely out of danger due to the dredging process

Generally speaking the main conclusion of this paper is that **Cancun Beach Rehabilitation Integral Project is a successful project from the coastal engineering and environmental point of view.** It respected all the environmental conditionings demanded by Mexican Authorities (SEMARNAT, SEMAR, SCT).