Protecting the Coral Reef at Khalifa Port, UAE

(Site Selection and Environmental Breakwater Construction)

Summary

The Khalifa Port, Abu Dhabi, constructed between 2009 and 2012 is one of the Worlds' largest Ports, based on an offshore island. The development is located adjacent to the Ras Ghanada reef in the United Arab Emirates, (UAE) and Gulf's largest coral reef, around 35 sq. km in size and a home to approximately 8 million corals. This article mainly highlights the considerations that were taken into account to contain and limit any adverse effects from the construction of Khalifa Ports, especially the construction of Environmental Breakwater which costed approx. USD 240 million. This submission highlights the complex environmental impact assessment (EIA), marine infrastructure impact assessment (MIIA), ecological monitoring & preservation program implemented at Khalifa Ports.

Introduction

In 2006 Abu Dhabi Ports (AD Ports) prepared a Master Plan for the development of a new port as part of the 'Khalifa Port and Industrial Zone' (KPIZ) development at 'Al Taweelah' in Abu Dhabi. The function of the new port facilities is to accommodate the current and future marine traffic served by Zayed Port and to create a gateway for the import and export of raw materials and finished products, which are associated with the adjacent Industrial Zone. The general location of the KPIZ development is illustrated in Figure 1. The objective of the Port Master Plan was to provide direction and guidance regarding the development priorities of the new port facilities.

The detailed studies needed to develop a master plan, including a marine infrastructure impact assessment report, site investigations and an environmental impact assessment; the master plan for Khalifa Port was completed in July 2007.

The master plan highlighted the importance of several features of the area in terms of environmental considerations, as well as the potential effects on the sea water intakes of local infrastructure. One of the driving factors that placed the Port Island 3 km offshore was the presence of the Ras Ghanada reef and sea grasses. Covering nearly 20 km2 Ras Ghanada coral reef boasts the only cactus coral along Abu Dhabi's mainland coast, and is recognized for its biodiversity and reef development.

The reef is integral to the Gulf's marine ecosystem. The **8km-long environmental breakwater,** was built at a cost of $240 million US has two main sections – an inner breakwater to protect the sensitive coral reef from contamination, turbidity and unwanted temperature fluctuation caused by port operations; and an outer breakwater to reduce the wave action within the port area.

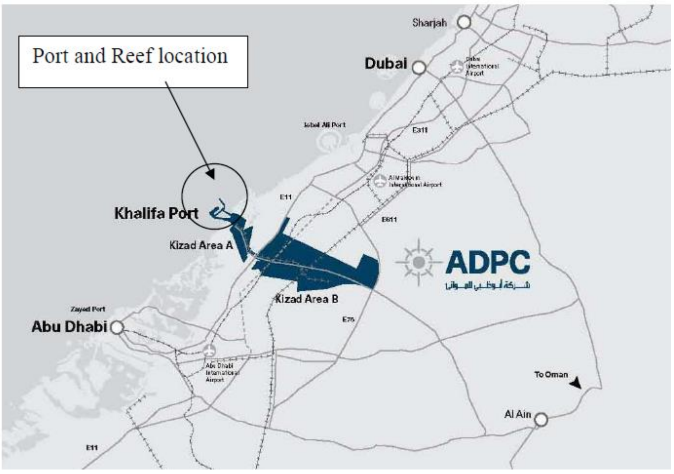

Figure 1 – Location of Khalifa Port

Port Layout and Design

Built over 3km offshore, the port is being developed in five planned stages over 20 years (Figure 2). Phase one, completed in September 2012, has an initial capacity of 2.5 million TEUs (twenty-foot equivalent units) of container traffic and 12 million tons of general cargo annually. By 2033, as subsequent phases come on-stream, it is expected that it will be able to handle 15 million TEUs and 35 million tons of general cargo per year. With a semi-automated container and general cargo facility handling bulk liquids, dry bulk, roll on and roll-off cargo, Khalifa Port is one of the most modern facilities of its kind in the region.

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Figure 2 – Full Port Build plan in year 2030

Choice of Location

During a Pre-Master Plan study, four general alternative locations for the port were considered. They ranged from an offshore location to an inshore location, with two intermediate locations. For each of the four alternative locations, an initial layout was prepared, along with a final layout illustrating how the initial layout would be expanded to accommodate future traffic.

Perhaps of greater importance than the cost and expansion of the Port, was the potential negative impact of the new port on the adjacent marine ecosystem and infrastructure. In this regard, the offshore location was assessed as having the least impact, and the Inland location the next least impact. The project was also involved dredging of some 46,000,000 m3 of sand and caprock, and the offshore port option gave a suitable location for the disposal of this dredged material. This was also an important factor in the choice of the offshore port island location. One of the key considerations of the offshore port was the requirement for a breakwater to separate the sediment plumes from the reefs.

Ras Ghanada Coral Reefs

As mentioned above, one of the driving factors that placed the Port Island 3km offshore was the presence of the Ras Ghanada reef and sea grasses. Figure 3 below shows the breakwater, reefs and offshore port island.

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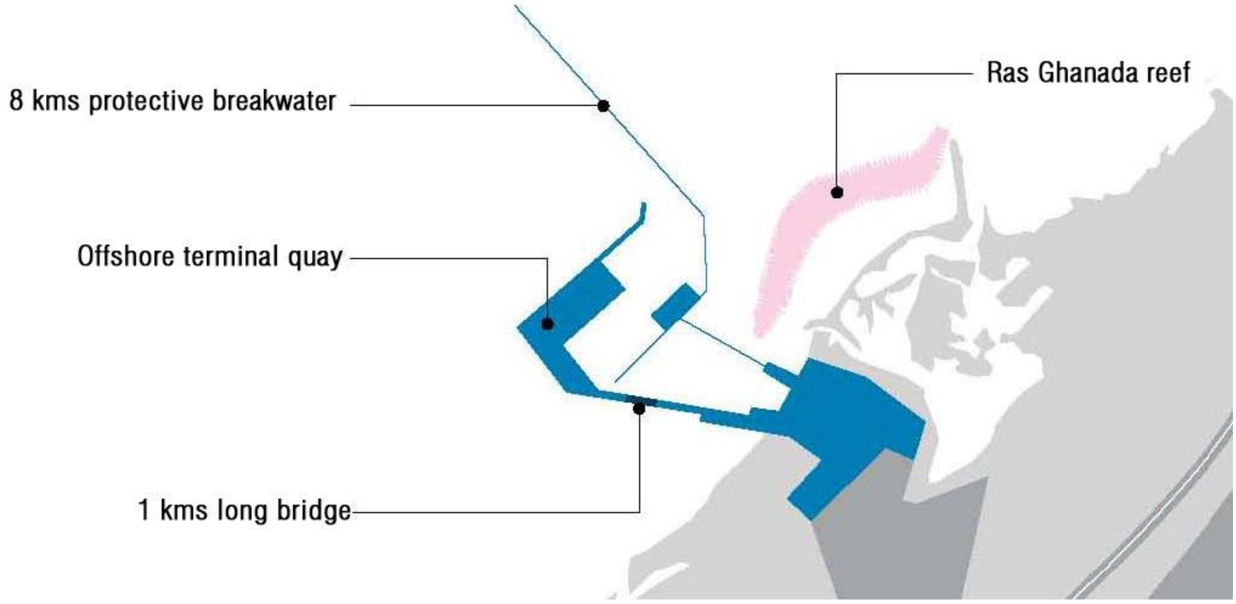

Figure 3 – location of Ras Ghanada reef and breakwater

During the EIA undertaken at Master Plan stage, the dredging operations and notably the spreading of the spilled material was investigated using a numerical model of cohesive sediment transport. Simulations were performed at various key stages of the Khalifa Port expansion, using sediment spill sources, over a long-term historical combination of tide, wind, waves, and residual currents.

The concerns over sediment plumes' smothering the reef, another concern was the potential for sea water temperatures to rise due to port operations. Prior to any works, surveys showed that the corals in the area were living in water with a temperature near the upper limit for survival.

Thus, an increase in summer water temperature caused by the project could raise coral mortality and prove fatal for the coral in front of Ras Ghanadah. Recommendations for monitoring this during construction, based on modelling were also given.

Monitoring Regime during Construction

Following the findings and recommendation of the EIA undertaken at Master Plan stage, in order to minimize the impact of the construction works on water quality and to protect the precious Ras Ghanada coral reef, the project team has employed an extensive monitoring programme based on the recommendations given.

Fifteen fixed monitoring stations were used to provide real-time data on turbidity, waves, currents, water levels and weather conditions. Specialists using a dedicated monitoring

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vessel worked to ensure that water quality was maintained and undertook regular dive inspections of the coral reef.

Computer modelling was used to predict the turbidity and suspended sediment concentrations around the work areas. The monitors relayed water quality to a central manned location every 15 minutes.

The monitoring station immediately raised the alarm should agreed levels of quality be exceeded and works would be ceased in that particular area of the project until levels returned to the accepted limits.

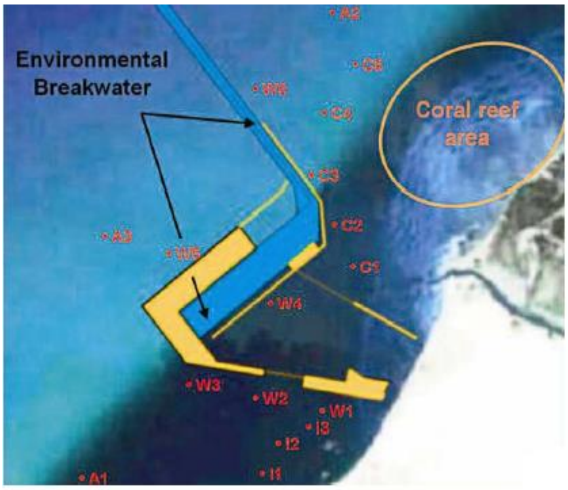

Figure 5 - location of monitoring equipment and one of the permanent stations installed.

This approach was successfully used to minimize the environmental impact of the dredging operations. Surveys conducted throughout the project indicated the impact of construction on the sea grass and the coral reef was minimal. Figure 6 shows typical marine life on the reef during the construction works.

The monitoring was also used to ensure that water quality around Abu Dhabi Water and Electricity Authority's intake to the south of the port was maintained.

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Figure 6 – Marine life on the Reef during construction works

Key Facts of Phase 1

Some of the key facts about of phase 1 are:

• Total length of Breakwaters - 17 km in all

• Total length of Revetments and causeways – 10 km in all

• Total length of Blockwork quay walls – 3.2 km in length and height of up to 24 m

• Total amount of Dredging 46,000,000 m3 used to reclaim the Port islands

• 2 number Bridges leading out to the offshore island some 1.5 km long each

Design and Construction of the Breakwaters

During the design development, several types of concrete armour units were discussed with the Contractors who had previous experience with manufacturing and placing Accropode™ units. A single layer Accropode™ system was selected for the design and typical units can be seen in Figure 7.

The main breakwaters on the project, Environmental breakwater and the Wave attenuation breakwater are identified in Figure 8 below showing their development under construction. With wave heights up to 6m and periods of up to 8 seconds, the general principles in terms of design for breakwaters were;

1. The design life of the breakwaters and revetments is 50 years.

2. The allowable damage level for rock structures designed for the 100-year event is 5%, considered over the full height of the armour for each 100 m of armouring.

3. The allowable damage level for Accropode™ 0%

4. In no case will the secondary armour (filter layer) be displaced

5. Oblique wave effects will be considered in stability calculations for structures where the design wave conditions approach from extremely oblique directions

6. Sizing of concrete armour units for both breakwaters was carried out using both Hudson's and Van de Meer's methods.

7. A stability coefficient (KD) value of 15 for Accropode™ units on a trunk section and 11.5 for units on roundheads and bends with flat foreshore was used in line with recommendations from the manufacturer.

These, along with other governing criteria such as wave agitation limits at various berths, navigation restrictions and vessel characteristics were used in the design process

Figure 7 - Accropode™units stored ready for transport to the breakwaters.

Approximately 130,000 Accopode™ were used across the project site, varying in size from 0.8m3 to 2.5 m3.

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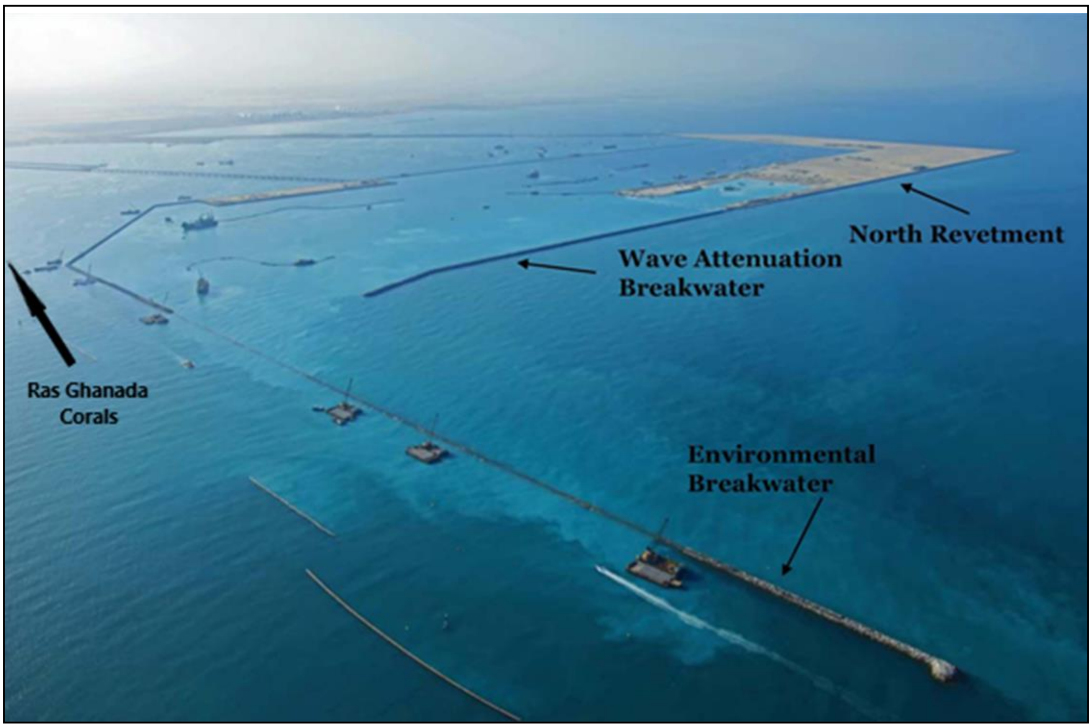

Figure 8 – Phase 1 under construction showing various breakwaters looking south

Wave Attenuation Breakwater (WAB)

The purpose of this breakwater is to reduce wave penetration into the port basin such that downtime due to wave agitation would be to acceptable limits as identified in the master plan. Wave transformation modelling was carried out to transform the offshore wave conditions determined from the joint probability analysis and the corresponding average water level at the port. These in turn were used to design the structures around the port. For the WAB, transmission through the crest was also a consideration in the design process as well as rear face armour design. Using approaches in the CIRIA 683 rock manual (2007) the design calculated both the front and rear face armour requirements.

To ensure a cost effective yet workable solution the designs were tested in physical modelling laboratories in South Africa and Europe to ensure that the performance criteria were met. The core of the structure was Quarry run, with 1.5m3 Accropode™ on the front face at a slope of 4:3 (in accordance with published design guidance for such units), crest width of 6 Accropode™ units, with the rear face consisting of 1.5m3 Accropode™ with rock armour at a slightly flatter slope than the front face, of 1 in 1.5.

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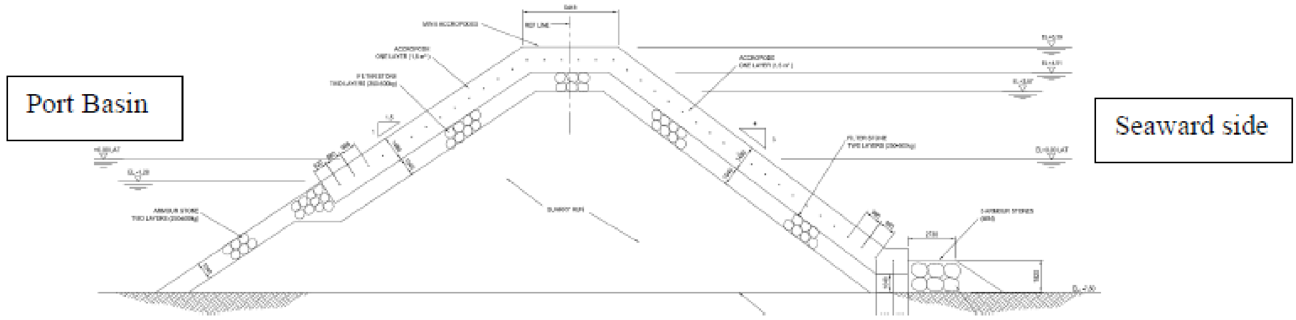

Figure 9 - Cross section through WAB

Environmental Breakwater (EBW)

As mentioned in earlier sections, the 8km-long environmental breakwater, built at a cost of US$240 million serves two purposes. The protection afforded to the Ras Ghanada reef to protect the sensitive coral from contamination, turbidity and unwanted temperature fluctuation caused by port operations; and an outer breakwater to reduce the wave action within the port area.

Wave transformation modelling was carried out to transform the offshore wave conditions determined from the joint probability analysis and the corresponding average water level at the port. These in turn were used to design the structure. To ensure a cost effective yet workable solution, as with the WAB, the designs were tested in physical modelling laboratories in South Africa and Europe to ensure that the performance criteria were met.

It was the contractual requirement that the underside of the primary armour on the EBW has a minimum elevation of Mean High Water in order to minimize the passage of fines and pollutants through the structure. The crest level of the EBW was set at a minimum of +3.35 m LAT. Transmission and overtopping of the structure under different return period conditions was assessed in accordance with the guidance given in the CIRIA Rock Manual, C683 (2007) and EurOtop (2007). Careful consideration during the design process meant that these restrictions could be met, whilst at the same time deriving the most cost efficient cross section. The cross section of the breakwater changes as water depth and wave exposure increases as the structure moves seaward.

<u>Inner Basin Area</u>

The inner section of the breakwater, located within the port basin, has relatively flat slopes at 1 in 3, using 70 to 300 kg rock. With little wave action on this area the design

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could accommodate the use of the 70 to 300kg rock with dredged material as the core as shown below. The dredging quantities produced by the port basin and navigation channel produced 46,000,000 m3 of sand and caprock and this material was used as core material in areas of the project such as the inner basin area and causeways elsewhere on the project.

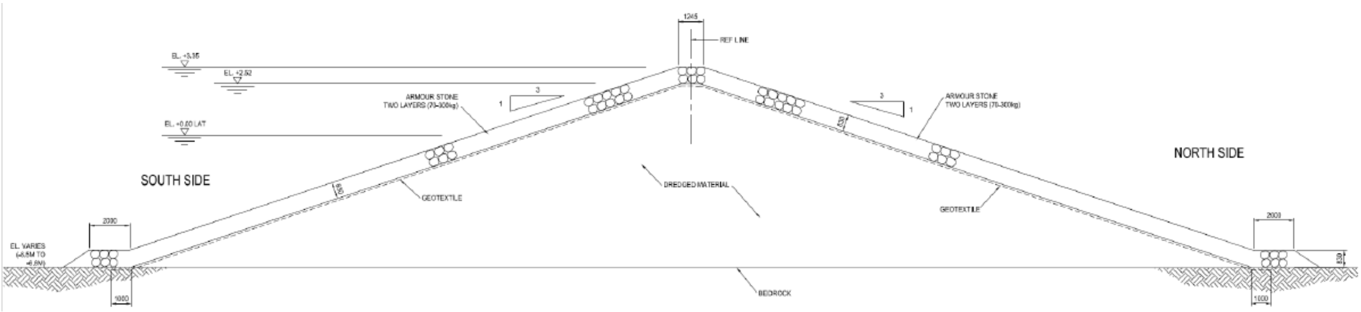

Figure 10 – Cross Section through breakwater inner basin area

Middle Section

Moving seawards to areas where larger waves could attack the structures the armour size increased to 1 to 3 tonnes overlying a filter layer of 70 to 300 kg rock, with slope of 1 in 2.5 with a quarry run core as shown below.

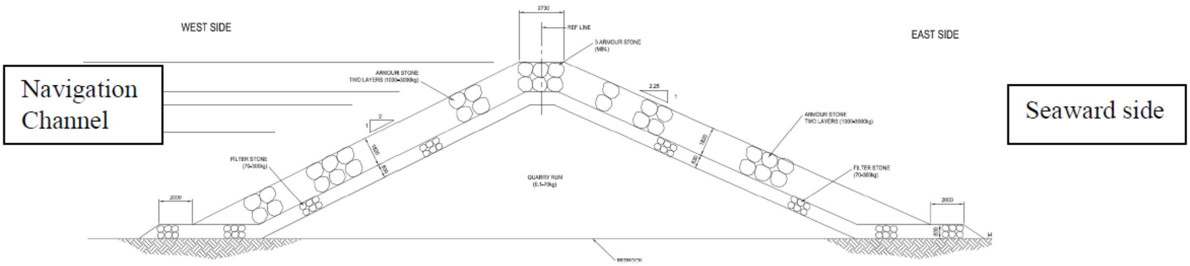

Figure 11 – Cross Section through breakwater at approximate mid-point

Outer Section and Roundhead

The outer section of the EBW and the roundhead were armoured with Accropode™ and has a quarry run core as shown. Both sides are at 4 in 3 slopes, with 1.5m3 Accropode™ on the exposed seaward side, with 0.8 m3 units on the more sheltered Navigation channel side. This section of the breakwater was tested at length in the physical models to ensure that a robust, yet cost efficient cross section was derived.

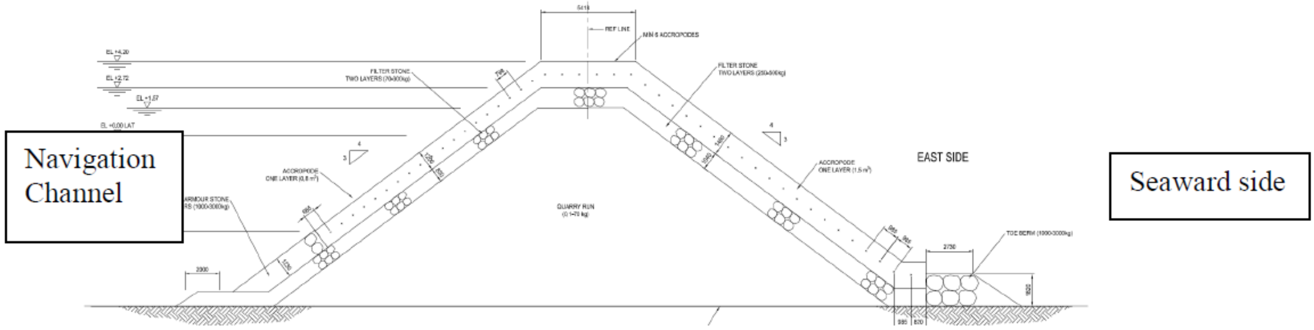

Figure 12 – Cross section at seaward end of EBW

Ecological Monitoring Program

To ensure the marine ecosystem including coral reef and other habitats are not impacted due to the ports construction as well as and future operational activities, or from any other natural impacts, a marine ecological monitoring program was designed and implemented to evaluate the anthropogenic impacts, if any, resulting. This monitoring program includes the detailed baseline survey carried out in 2008, followed by regular 3 surveys every year in the month of January, May and September.

The Chosen habitats for monitoring were: Dense and sparse coral, and dense sea grass. The monitoring consists of quarterly visits to 85 stations at which short, geo-referenced video-clips are taken. These stations were installed in the January 2008 base-line survey, and subsequently visited three times every year from 2008 to date (2018).

Also a total of 40 photo-transects were placed randomly in four permanent stations that were originally installed during the January 2008 base-line. Later in the year 2013 -2014 the photo quadrates monitoring stations were increased to 9 stations representing 3 for each habitats i.e. Dense & Spares corals and sea grass.

From both the 85 video points and the 225 photo-transect stations, 4 levels of degradation of environment and coral assemblage are measured:

GREEN: comparable to baseline, no visible degradation

BLUE: slight degradation; impact <10%

ORANGE: moderate degradation; impact <25%

RED: heavy degradation; impact > 25%

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The monitoring is carried out by consultants from the **National Coral Reef Institute (NCRI), Florida, USA** which includes Baseline Monitoring in the year 2008 and 3 times yearly monitoring from (2008 to 2018).