STATUS REPORT FOR THE SUBMERGED REEF BALL™ ARTIFICIAL REEF SUBMERGED BREAKWATER BEACH STABILIZATION PROJECT FOR THE GRAND CAYMAN MARRIOTT HOTEL

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August 2003

Introduction

This report presents an update on the submerged Reef Ball™ artificial reef breakwater that was installed during the summer and fall of 2002. The purpose of this system is to assist with beach and shoreline stabilization, and the project also provides the additional benefits of environmental enhancement and snorkeling reef attraction for resort guests. Photographs of the beach in October 2002 (prior to completion of the Reef Ball breakwater) and February 2003 (3 months after the completion of the Reef Ball breakwater) are shown in Figures 1 and 2.

Figure 1. Before and After Breakwater Installation Photographs – View South

October 2002 (left) and February 2003 (right)

Figure 2. Before and After Breakwater Installation Photographs – View North

October 2002 (left) and February 2003 (right)

Initial field inspections at the Grand Cayman Marriott Resort were first performed in February 2002 to investigate the beach erosion problem at the Marriott Hotel at the southern end of Seven Mile Beach on Grand Cayman Island, and to determine alternatives for restoring and stabilizing the beach at this site. An array of alternatives was considered, and a submerged breakwater constructed of 200 Reef Ball™ artificial reef units was chosen. Design and permitting of the project was performed during the winter and spring of 2002, with fabrication of the units and deployment offshore completed in November 2002. Figures 1 and 2 show the accretion of the beach following installation of the Reef Ball breakwater.

This report provides an update of the status of the beach and submerged Reef Ball artificial reef breakwater. The beach erosion problem at the Marriott is discussed, and the performance of the Reef Ball breakwater to date is evaluated. Additional Reef Balls are proposed to extend the existing breakwater further south to increase protection from SW waves. The Cayman Islands are also considering adding sand to the beaches in the Seven Mile Beach area.

Beach Erosion Problem

The Marriott Hotel lies near the southern end of Seven Mile Beach. The aerial photograph in Figure 3 shows a view north from the Port, with the locations of Seven Mile Beach and the Marriott Resort indicated. The beaches in the Seven Mile Beach area generally become wider as one travels north from the Marriott Hotel to the central Seven Mile Beach area, while to the south there is only a short stretch of sand beach that is followed by a rocky shoreline as you approach the Treasure Island Resort. There also are some rock groins that were constructed in this area, as shown in Figure 4, and the shoreline here curves around to the east into the Port area. This rocky shoreline to the south of the Marriott, the reorientation of the shoreline, and the rock shoreline with no sediment source to the south prevents any potential natural transport of sand from the south to the Marriott's beaches.

These factors have resulted in the beaches in the southern Seven Mile Beach region to be particularly susceptible to erosion from waves coming from the southwest, due to the lack of sand along the coast to the south. Waves from the southwest, especially during storm events, transport sand from the southern end of the Seven Mile Beach area to the north. Waves from the northwest tend to transport sand to the south along the Seven Mile Beach area, which nourishes

the beaches at the south end (including the Marriott), but this occurs at a much slower rate than the erosion of sand accompanying southwest wave activity. An increase in the frequency and magnitude of southwest waves over the past few years has prevented the beach from accreting out to the beach width that the Marriott had prior to 1996.

Figure 3. Aerial View North from the Port towards Seven Mile Beach

Due to the erosion of the beaches along the southern reach of the Seven Mile Beach area, natural sand accretion and return of the beach width to that in the mid 1990's could take several years, if at all, and any future southwest wave events will further erode the beaches in this area, and slow this natural recovery. The beaches in the Seven Mile Beach area have been continuing to narrow in recent years. Waves from tropical storms and hurricanes, such as Hurricane Michelle in November 2001, and again during storm events in 2002 and 2003, have resulted in increased transport of sand to the north.

Figure 4. View SW towards the Port showing the existing Groins south of the Marriott (left); and view N towards Seven Mile Beach showing the rocky coast south of the Marriott

Figure 5 shows the previous beach width at the Marriott Resort prior to 1994 (source, Marriott Brochure), compared to the much narrower beach widths in recent years. Beach width measurements are presented in the following section.

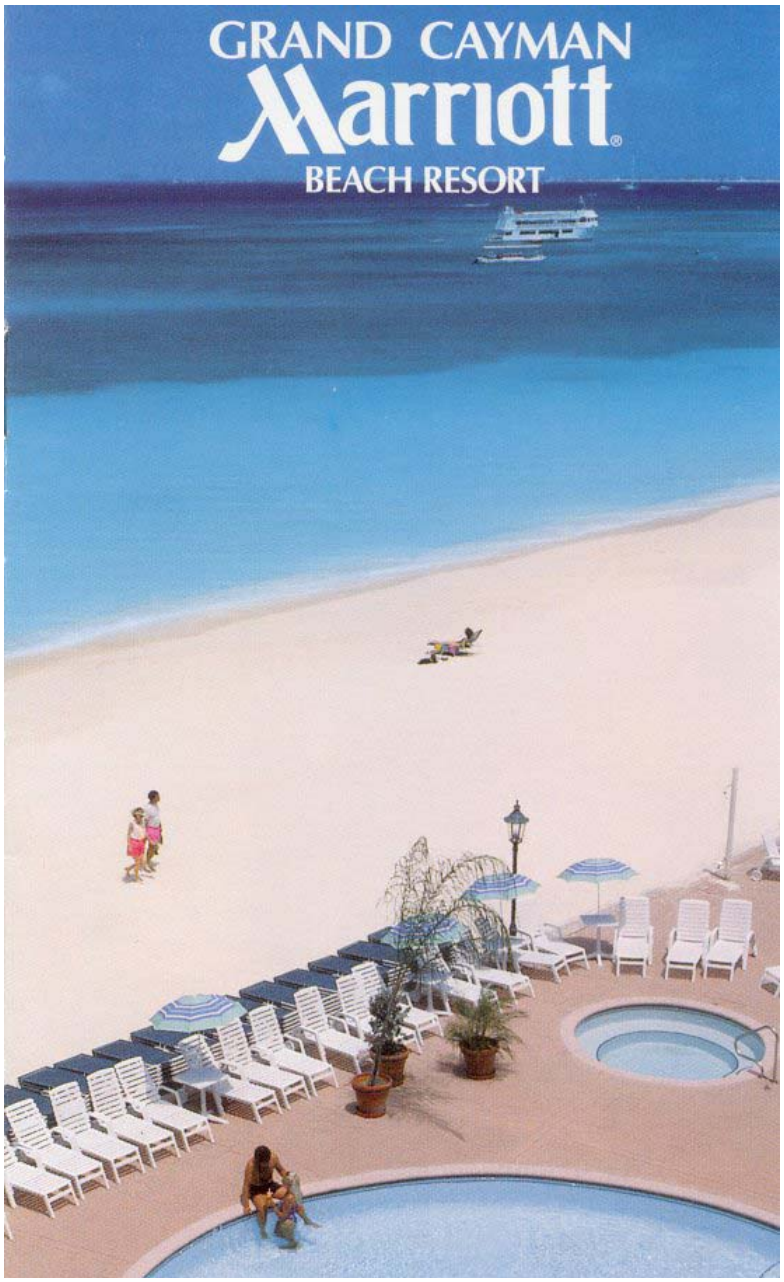


Figure 5. Photograph of the Beach Width at the Marriott Resort prior to 1994

(from Marriott Brochure)

Beach Width Measurements

The Grand Cayman Marriott Resort has experienced beach erosion. The existing beach width varies seasonally and with storm events, and although it does begin to recover by sand transport into the area from the north during the winter months, the beach continues to be eroded away by waves coming from the southwest during the fall (August to October). The staff at the Marriott measures the beach width from the seawall at the north, center and south end of the property every day. This information provides a good record of beach changes, and should be continued

to be collected. These data are shown in the graphs in Figure 6 for the variation in the average beach width in front of the Marriott over time. Gaps in the data occur due to inconsistencies in making the daily measurements during the earlier years, and due to storms and wave action preventing the taking of measurements.

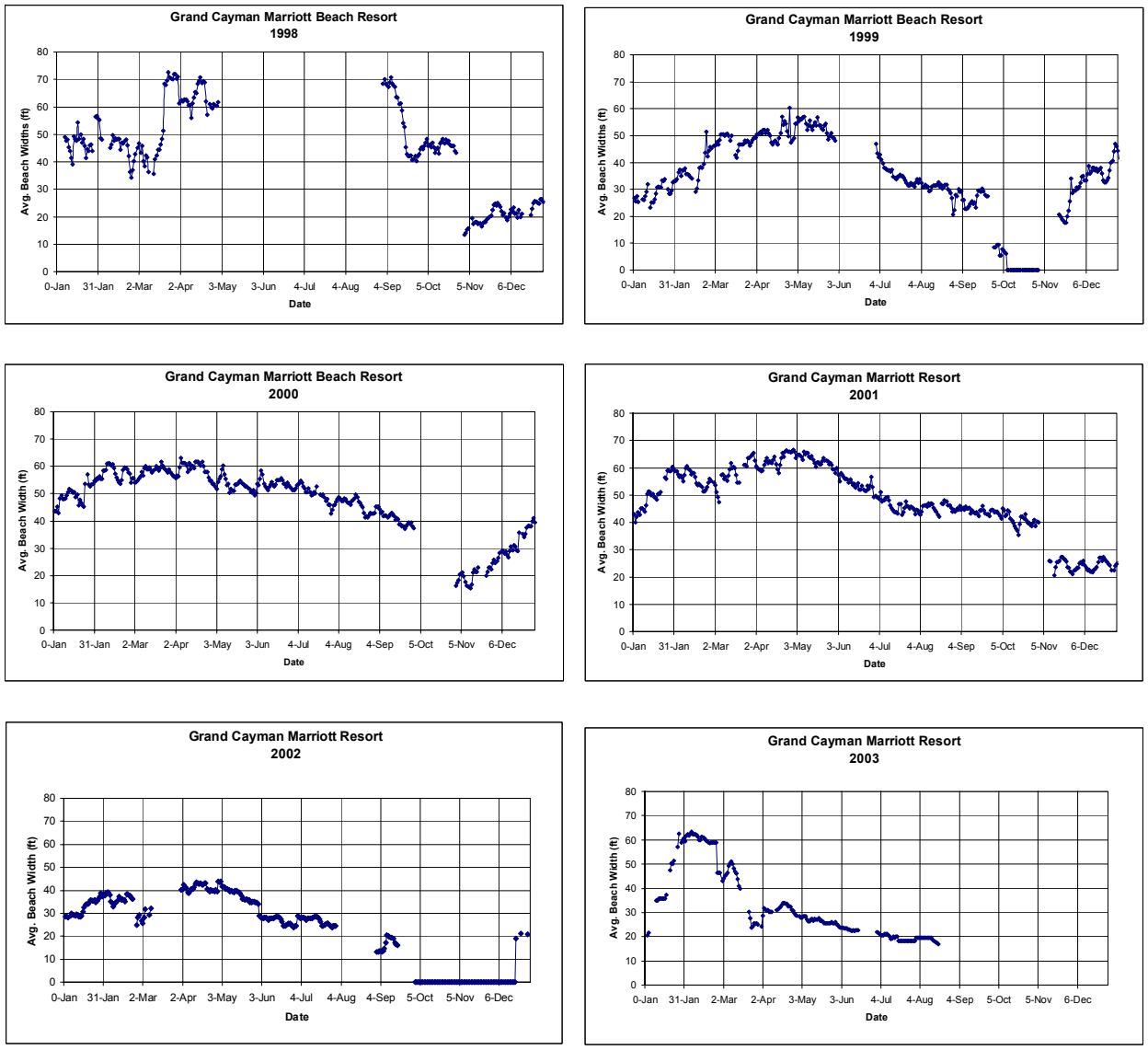


Figure 6. Beach Width Measurements taken by Marriott Staff

Note that these graphs show that there are seasonal changes in the beach width, but the beach width is continuing to decrease each year. In 2002 the maximum beach width was only 45 feet and the minimum width was zero, and the zero beach width occurred over a much greater time period than in prior years. Following the installation of the Reef Ball breakwater (completed at the end of 2002) the beach width increased to a width in excess of 60 feet, which was wider than the beach had been since June 2001 (last 2 years). Storms during the Spring 2003 reduced the beach width to 25 feet at the Marriott (and to zero on adjacent beaches to both the north and south). Further erosion of the beach has reduced the beach width at the Marriott to 19 feet in August 2003. The fall tropical storm and hurricane season has the narrowest beach widths, which

could reduce the existing beach width further, depending on the tropical storm and hurricane activity near Grand Cayman.

The graph in Figure 7 shows the beach width measurements for the past 6 years all on one graph, to show the variations from year to year. This graph shows the seasonal changes in beach widths and the variations from year to year depending on the variation in oceanographic conditions. For example, waves impacting the Seven Mile Beach area from Hurricane Michelle in November 2001 reduced the beach width at the Marriott from an average of 40 feet to 20 feet, with some recovery after the storm with beach widths varying from 20 to 28 feet. In September 2002 waves reduced the beach width from 20 feet to zero, and the beach width did not recover until after the Reef Ball breakwater was completed in November 2002.

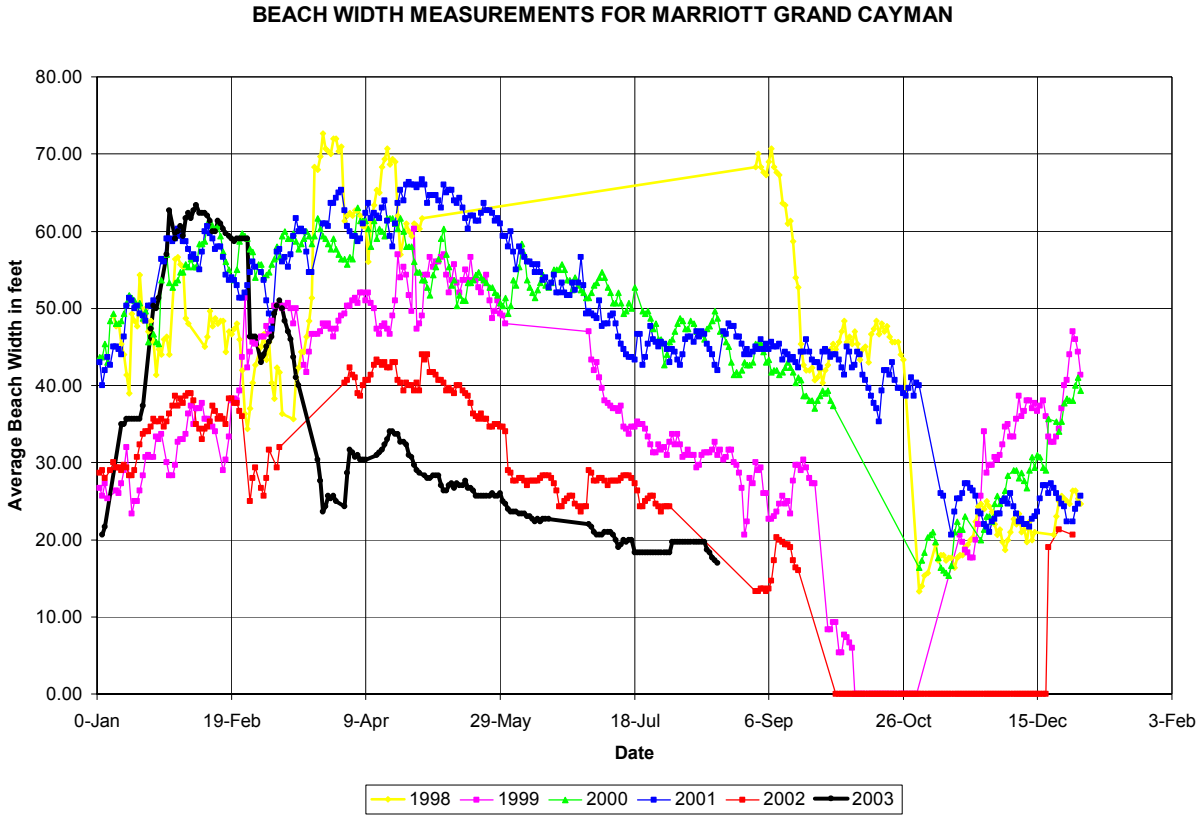


Figure 7. Beach Width Measurements showing Seasonal and Annual Variations

Artificial Reef Submerged Breakwater Project Design

To stabilize and enhance the beach at the Grand Cayman Marriott Resort, an artificial reef submerged breakwater was installed in Fall 2002 to reduce the wave action reaching the beach. A submerged breakwater reduces the wave action that reaches the beach, thereby assisting to stabilize the shoreline. Unlike traditional breakwaters that project above the water surface and stop all wave action, submerged breakwaters allow the smaller waves to pass over the structure so that sand transport along the coast is maintained during normal conditions. During large wave events, the larger waves are forced to break on the submerged breakwater, thereby reducing the wave energy reaching the beach from large waves and reducing the associated beach erosion. The disadvantage of submerged breakwaters is that they become less effective as their depth of submergence increases, so that they are less effective at reducing wave action during elevated

water levels due to storm surge. The use of artificial reef units for a submerged breakwater also provides underwater habitat, enhancing the environment.

The submerged Reef Ball artificial reef breakwater has assisted in stabilizing the shoreline by reducing the wave action that impacts and erodes the beach, especially when the waves strike and reflect from the vertical seawall. The existing natural reef offshore of the hotel is only sufficiently wide and high enough to assist with wave attenuation in one spot, which is where the gap between the two breakwaters was designed.

The recommended design shown in Figure 8 uses 5 rows of Reef Ball™ artificial reef units to provide a 30-foot wide submerged breakwater. The 3.7 to 4.5 feet high artificial breakwater units were installed in low tide water depths of 4 to 5.5 feet, so that the top of the units are slightly below the lowest normal water level (0.3 to 1.8 feet).

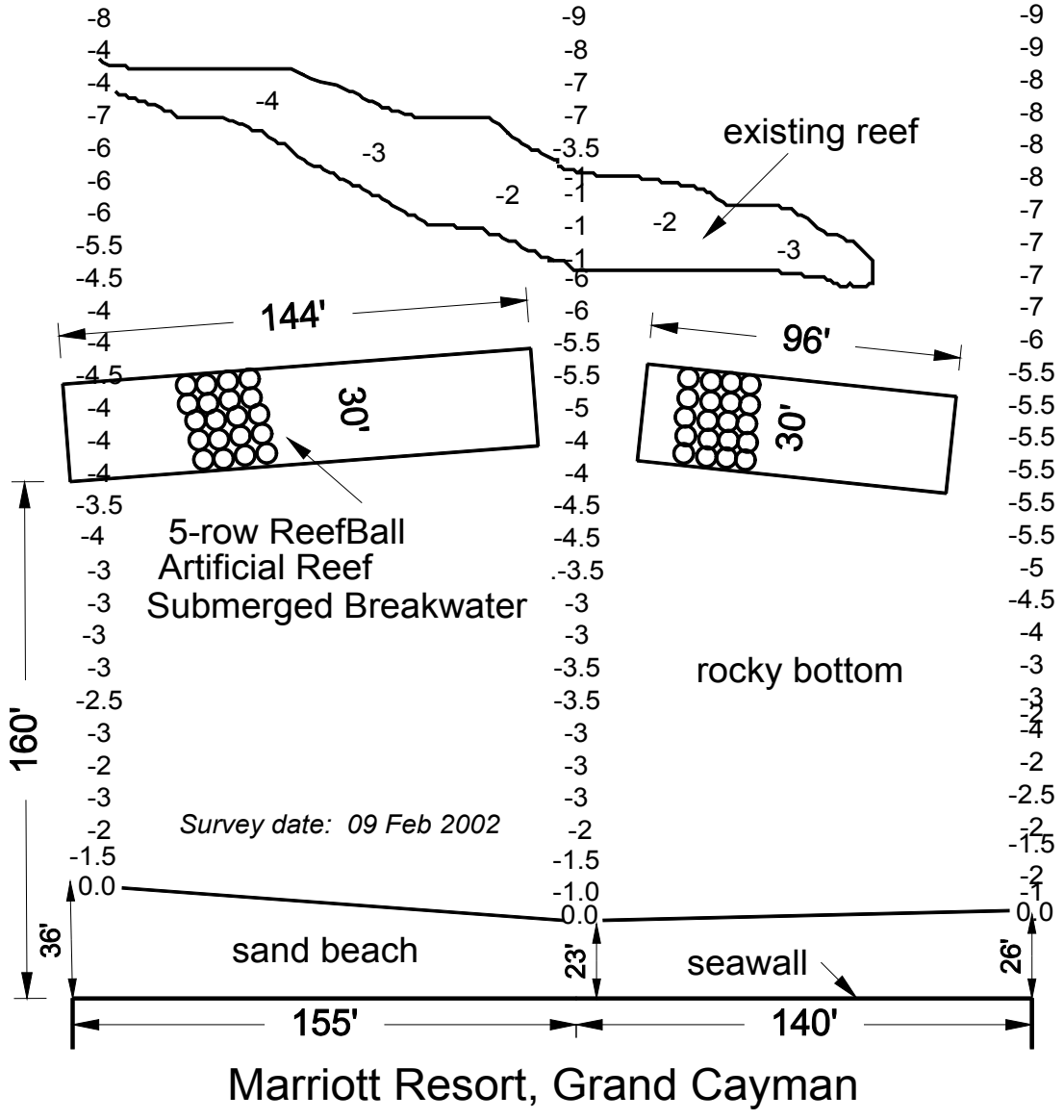


Figure 8. Original Reef Ball™ Artificial Reef Submerged Breakwater Design

As presented in Table 1, various sizes and weights of Reef Ball™ artificial reef units are available. To obtain the proper heights and largest individual unit weights possible, the larger Reef Ball™ units (Ultra Balls) were used, resulting in each individual Reef Ball™ unit weighing approximately 4,000 pounds (2 tons). Microsilica and other additives were used in the concrete to increase the strength and workability, as well as to decrease the pH of the concrete to that of the surrounding marine environment.

Table 1. Reef Ball™ Sizes, Weights, Volume & Number of Holes

Style	Width	Height	Weight	Concrete Volume	No. of Holes
Ultra Ball	5.5 feet (1.68m)	4.3 feet (1.31m)	3500-4500 lbs (1600-2000 kg)	0.9 yard ($0.7m^3$)	22-34
Reef Ball	6 feet (1.83m)	3.8 feet (1.16m)	3000-4200 lbs (1350-1900 kg)	0.75 yard ($0.6m^3$)	22-34
Pallet Ball	4 feet (1.22m)	3 feet (0.91m)	1500-2200 lbs (670-1000 kg)	0.33 yard ($0.25m^3$)	17-24
Bay Ball	3 feet (0.91m)	2 feet (0.61m)	375-750 lbs (170-340 kg)	0.10 yard ($0.08m^3$)	10-16

The sea bottom where the submerged breakwater is installed consists primarily of barren rock with some patches of sand, so that scour and settlement of the artificial reef units are not a problem. For increased stability of the structure, sleeves for fiberglass rebar were pre-cast into the Reef Ball™ units, with No. 5 fiberglass rebar driven or drilled into the bottom to provide additional resistance to sliding of the units. If desired, the central cavities of the Reef Ball™ units can be filled approximately one-third full with small rocks to provide additional weight and habitat.

Field Investigations

Inspections of the Reef Ball submerged breakwater constructed offshore the Marriott Resort on Grand Cayman were performed on February 6-8, 2003 and on May 26-28, 2003. This included above and underwater inspections, surveys, and photographs of the Reef Ball™ units and beach areas at the property, and the beach areas to the south and north along Grand Cayman's western Seven Mile Beach shoreline.

The photographs in Figure 9 taken in February 2003 show the condition of the beach, which increased in width from zero to over sixty feet wide, following the installation of the Reef Ball breakwater. Over 200 Reef Ball units were installed in the design template, with top elevations near but below the normal low tide elevation as designed and permitted, and shown in the photographs in Figure 10 and 11.

Figure 9. Views North (left) and South (right) of the Marriott Beach in February 2003

Figure 10. February 2003 Photographs showing the offshore Reef Ball Breakwater

Figure 11. Northern (left) and Southern (right) Reef Ball Artificial Reef Submerged Breakwater Segments at Extreme Low Tide.

The underwater photographs in Figure 12 show the condition of the Reef Ball units. After only 3 months, there was considerable marine growth on the Reef Ball units and several species of fish in and around the artificial reef units. Note that some of the Reef Ball units had to be fabricated shorter than the standard size, due to the shallower water depths at the south end of the breakwater.

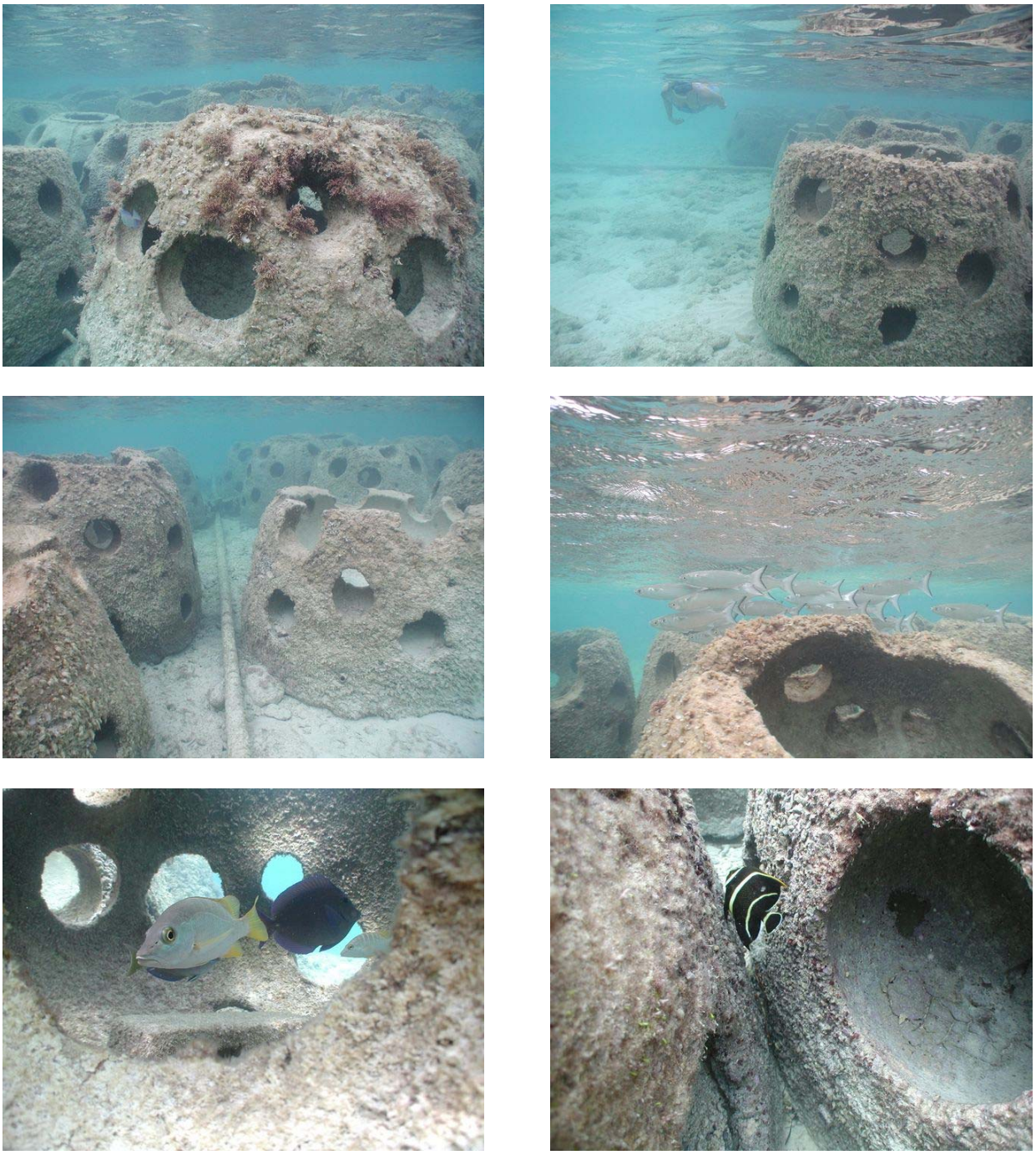
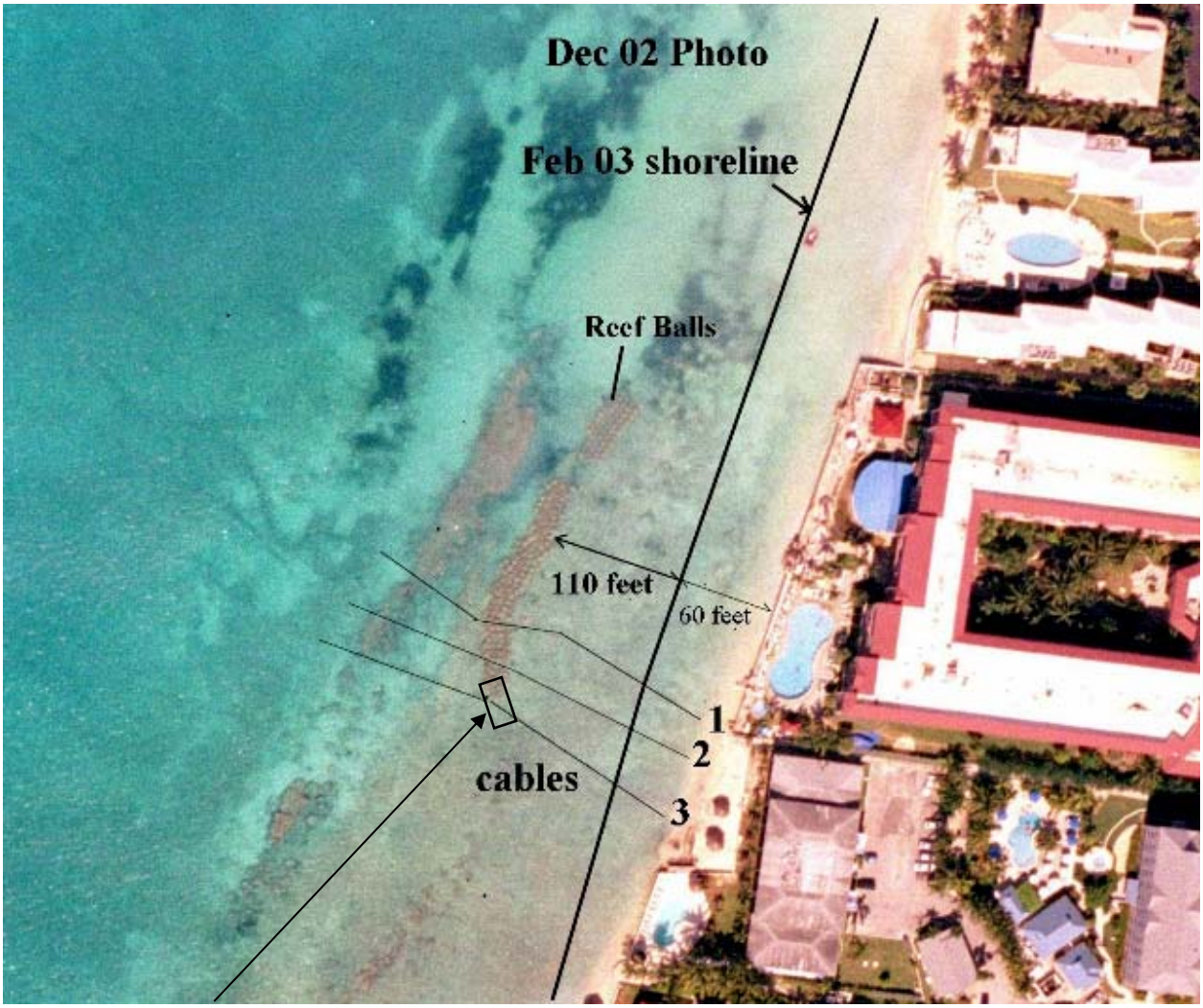


Figure 12. Underwater Photographs of Reef Ball Breakwater Units

Additional Reef Balls

A survey of the water depths in the vicinity of the south end of the breakwater was performed to investigate the proposed addition of 32 more Reef Ball units at the south end of the project to increase wave protection against sand transporting wave action from the SW. Special permission was required from the property owners to the south, as this extension will be located offshore of the north end of their property. The proposed extension is shown in the aerial photograph below, which would increase protection for the Marriott beach from waves from the southwest.



Area for Additional Reef Ball Units

Figure 13. December 2002 Aerial Photograph showing the Completed Reef Ball Breakwater and Area for the Proposed Additional Reef Ball Units

Recent Beach Profile Data

Surveys were performed in February 2003 which document the beach condition after 3 months, and are compared with the beach condition immediately following the completion of the Reef Ball breakwater in November 2002, as shown in Figures 14 through 16 for the 3 profile lines at the south end of the Marriott.

These graphs show the additional sand that accreted seaward of the Marriott seawall following the installation of the Reef Ball breakwater. The beach width increased from zero to 40 to 55 feet in width from November 2002 to February 2003, whereas the widest beach width in all of 2002 was 45 feet. Recent summer seasonal wave action has reduced the beach widths to an average of 19 feet at the Marriott (but even less at adjacent beaches in the area), and the current tropical storm and hurricane season may further erode the beach. However, the completed Reef Ball breakwater (and extension if added) is designed and has served to minimize the beach erosion and assist with the stabilization of the beach at the Marriott.

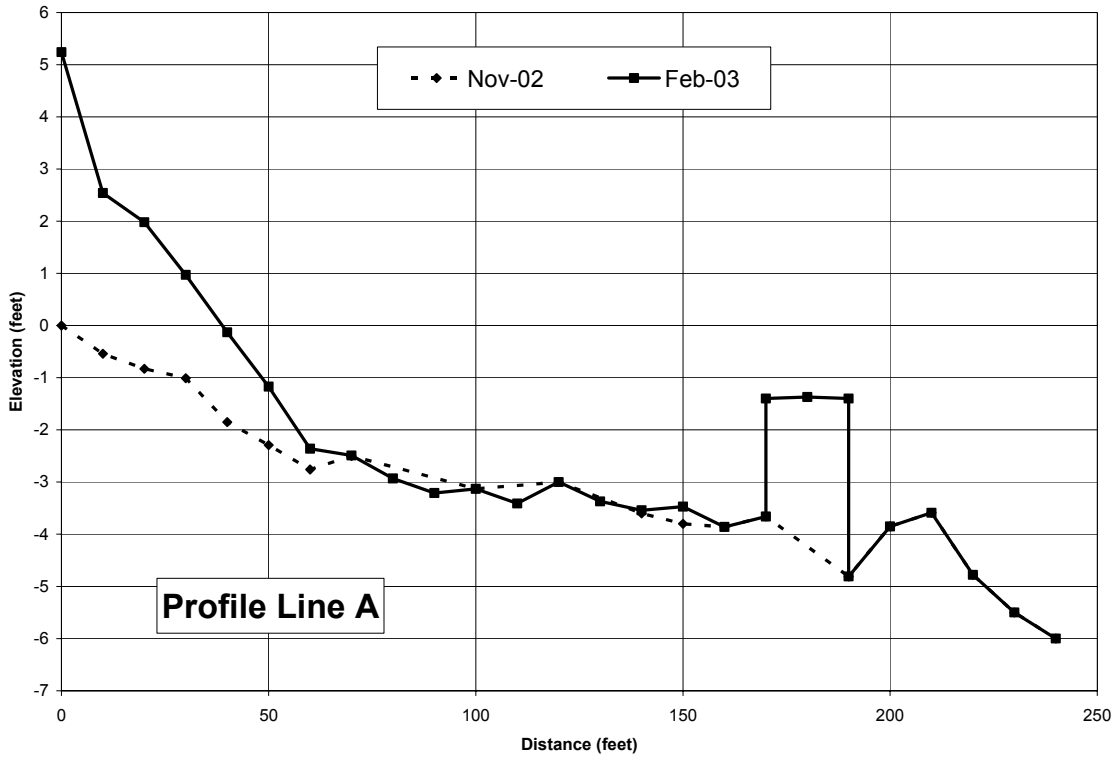


Figure 14. Profile Line A – Across South End of Reef Ball Breakwater

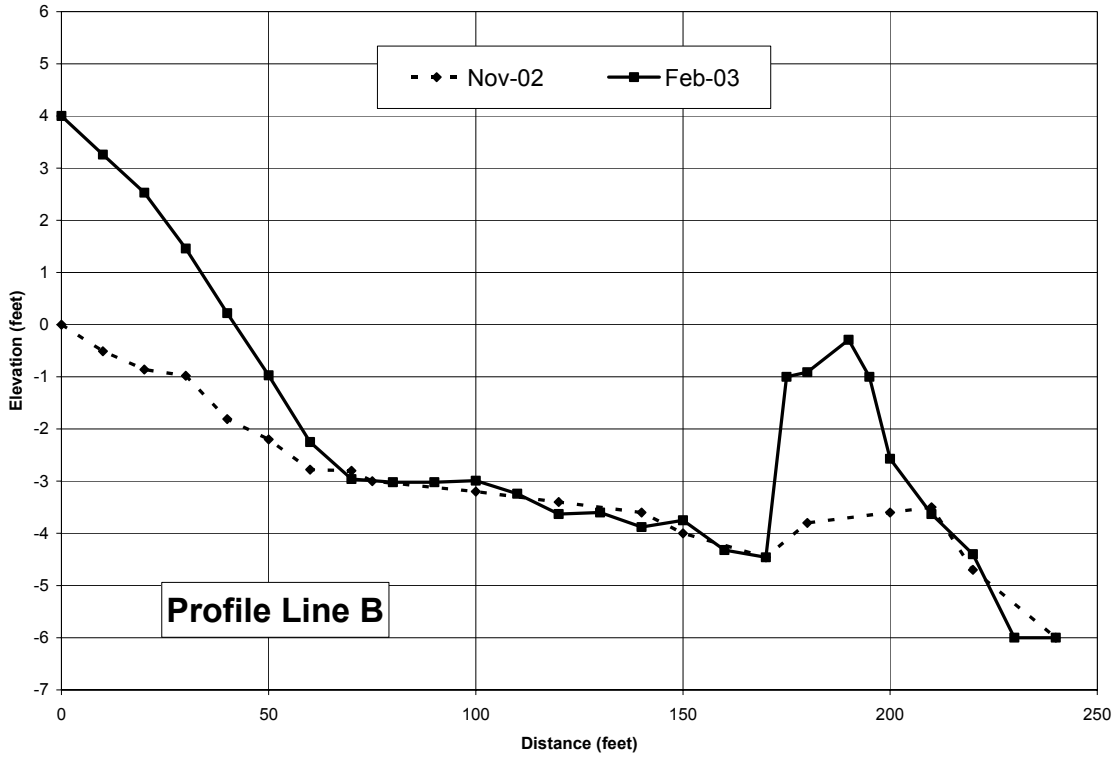


Figure 15. Profile Line B – 30 feet North of Southern End of Reef Ball Breakwater

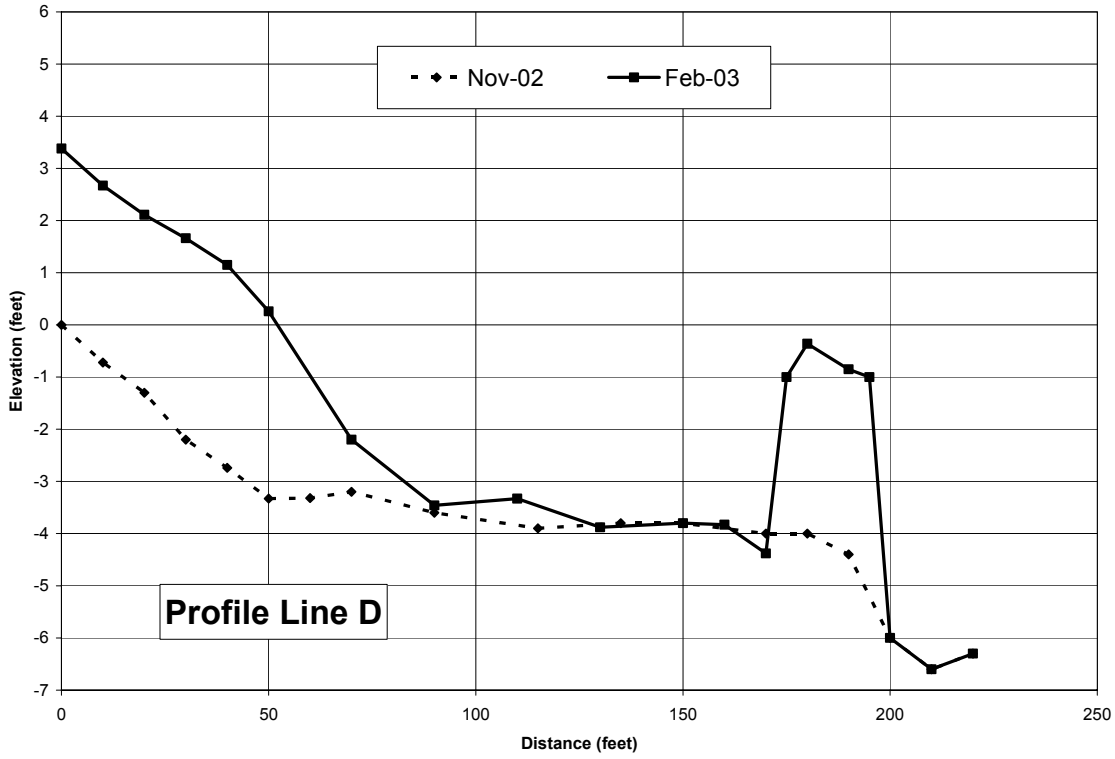


Figure 16. Profile Line D – 130 feet North of Southern End of Reef Ball Breakwater

Cayman Islands Government Plans

The government of the Cayman Islands has established a Beach Review and Assessment Committee (BRAC), which has released a May 2003 report with recommendations for beach management. This includes major recommendations and priority groupings into:

- High priority, short term solution – to be performed within 2 to 6 months
- High priority, long term solution – to be performed within 2 to 12 months
- Intermediate priority, long term solution – to be performed 12 months

The recommendations for the High priority, short term solution to be performed within 2 to 6 months are summarized below:

1. removal of derelict rock and rubble coastal structures that are inappropriately sited and form obstructions along Seven Mile Beach
2. conduct an immediate Government initiated trial of spot nourishment of heavily eroded sections of Seven Mile Beach utilizing sand sources stockpiled from previous construction projects
3. conduct an "Engineering Feasibility Study" in preparation for a beach nourishment program during the next major erosion event and as a major part of the Strategic Beach Management Plan

These recommendations for the short term as well as the long term solutions greatly affect the Marriott Resort area, and the government has appropriated funds to provide additional sand to the beach system in the eroding areas of Seven Mile Beach in November2003. Furthermore, the recommendations to the Cayman Island Government by BRAC set the stage for long-term beach management and maintenance of the beaches in the Seven Mile Beach area. This is expected to include beach nourishment to replace the sand that has been lost from the beaches (lost to the offshore). The Reef Ball breakwater at the Marriott will work well with the recommendations of the BRAC, and the Reef Balls will contribute to the stability of any additional sand that may be placed on the beaches in this area.

Conclusions and Recommendations

The completed Reef Ball breakwater offshore of the Grand Cayman Marriott has served to minimize the beach erosion and has assisted with the stabilization of the beach. Additional Reef ball units have been budgeted and the Marriott is awaiting final permit approval for the 32 additional Reef Ball units to be added at the south end of the project to increase the protection from SW waves (this now can be done as the necessary permission from the neighboring property to the south has been obtained). An additional benefit of the Reef Ball breakwater is the environmental enhancement of the area, providing increased marine habitat for benthic and pelagic species, and serving as an attraction for snorkeling.

Based on the Interim Report dated May 2003 by the Cayman Islands Beach Review and Assessment Committee (BRAC), it is anticipated that sand will be added to the southern end of the Seven Mile Beach area in November 2003. This will help to restore the sand to the beach system, and the existing Reef Ball breakwater will maximize this benefit by assisting with stabilizing the placed sand. Additional sand can be added to the beach by the Marriott if desired, but it is recommended to await the actions by the Cayman Island government.