Draft Report

Investigations and Recommendations for Solutions to the Beach Erosion Problems in the City of Herzliya, Israel

Site Inspection Performed 30 April to 6 May 2007

Prepared for:

City of Herzliya
Office of the Mayor
Herzliya, Israel

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1 Introduction

Many papers, reports and studies document the beach erosion problems in the City of Herzliya following the construction of the Herzliya marina (completed in 1992) and the three breakwaters immediately to the north of the marina. In the years following the construction of those coastal works, the beaches to the north have experienced erosion. The City of Herzliya has been investigating solutions to the beach erosion problems, and the purpose of this study was to investigate the beach erosion problems, and to recommend possible solutions.

This report presents the results of field investigations, meetings, and information gathered prior to and during site visits to the Herzliya coast performed 30 April to 5 May 2007. Field investigations included walking and driving the length of the Herzliya coast, travel by boat from the marina to Apollonia, and SCUBA diving offshore of the northern beach area with Dr. Yehuda Benayahu. Materials gathered during these site visits included prior reports and studies, notes from meetings and interviews with local groups and individuals (government, scientific, environmental, etc.), published papers, maps, and charts.

In particular, investigations were performed to determine the feasibility of utilizing submerged offshore breakwaters at the north end of the Herzliya beaches, as has been recommended in previous studies.

2 Project Location and Conditions

Herzliya is located on the west coast of Israel in the Mediterranean Sea, as shown in Figure 1. Due to the large fetch to the west, the area is subject to large waves from the NW, W, and SW directions. Predominant alongshore current and littoral sand transport is from south to north, with sand sources reported as from far away as the Nile River Delta. Numerous coastal structures have been constructed along the Israeli coast, including port and harbor facilities, marinas, and emergent (subaerial) segmented breakwaters. Many examples of these coastal structures are located in Tel Aviv, south of Herzliya, as shown in Figure 2.

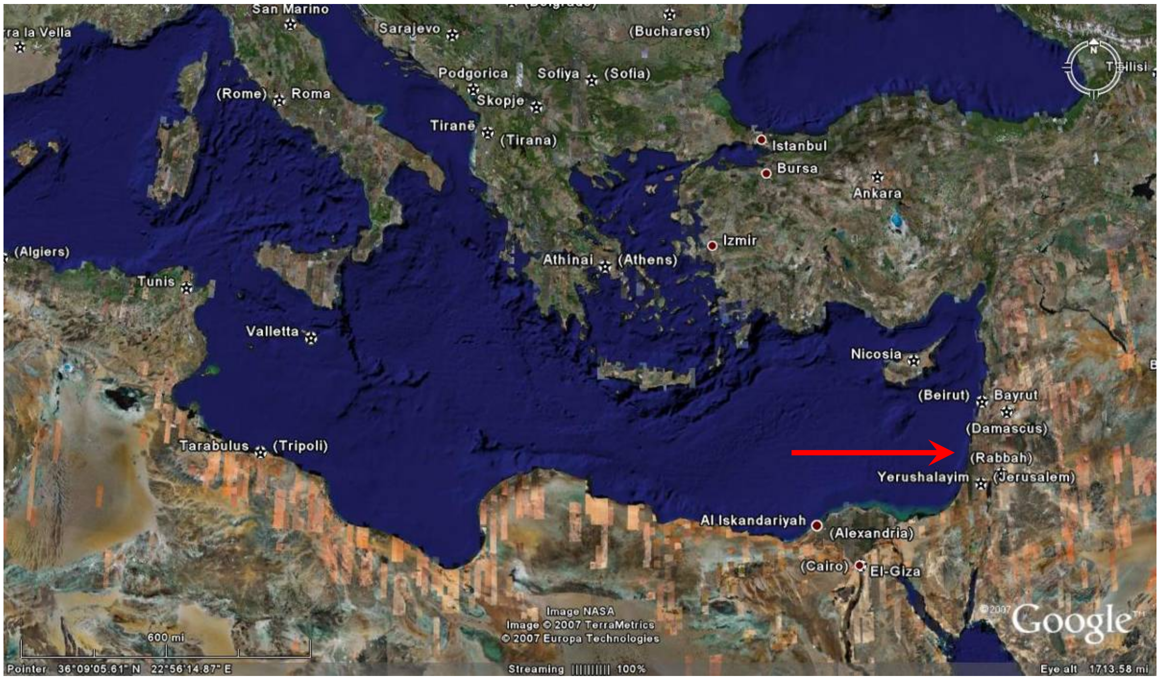

Figure 1. Project Study Area at West end of the Mediterranean Sea

Figure 2. Coastline from Tel Aviv to Herzliya
Predominant littoral sand transport is from S to N (left to right).

Figure 3 shows an aerial photograph of the City of Herzliya coastline, where the dominant features are the marina and segmented breakwaters immediately to the north (also evident in Figure 2). The three breakwaters were constructed to prevent the anticipated erosion downdrift of the marina, with natural sand accretion in their lee (they were not pre-filled with sand after construction). The widest beaches are found in the lee of the breakwaters, and south (updrfit) of the marina.

Figure 3. Project Study Area showing the zones North and South of the Marina

The beach is very narrow north of the breakwaters, due to the blockage of longshore sand transport by the marina, and the trapping of sand by the breakwaters. However, there are two salients with wider beaches, indicated in Figure 3, and in the photograph shown in Figure 4. These salients are formed due to the naturally occurring offshore reefs, visible in the photograph, that act as submerged breakwaters.

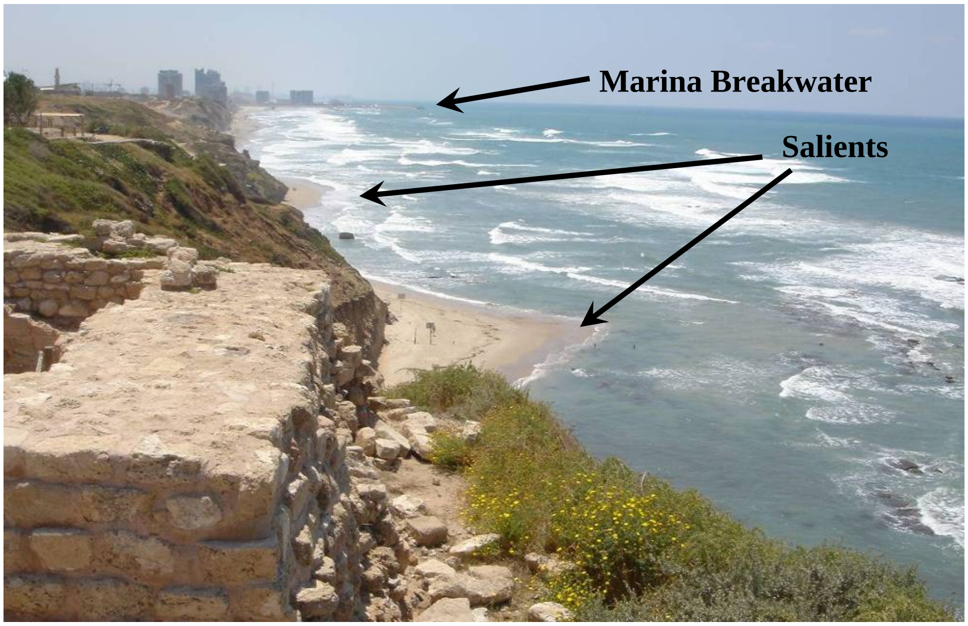

Figure 4. View to the South from Apollonia – 30 April 2007 Photograph
Note the wider beach areas North of the Herzliya Marina labeled as the two salients.

Previous papers, reports and studies document the effects of the marina and breakwaters on the beaches to their north (downdrift). Erosion of those beaches has led to increased erosion of the cliffs, and several areas where this has occurred are visible along the Herzliya coast, with one example shown in Figure 5.

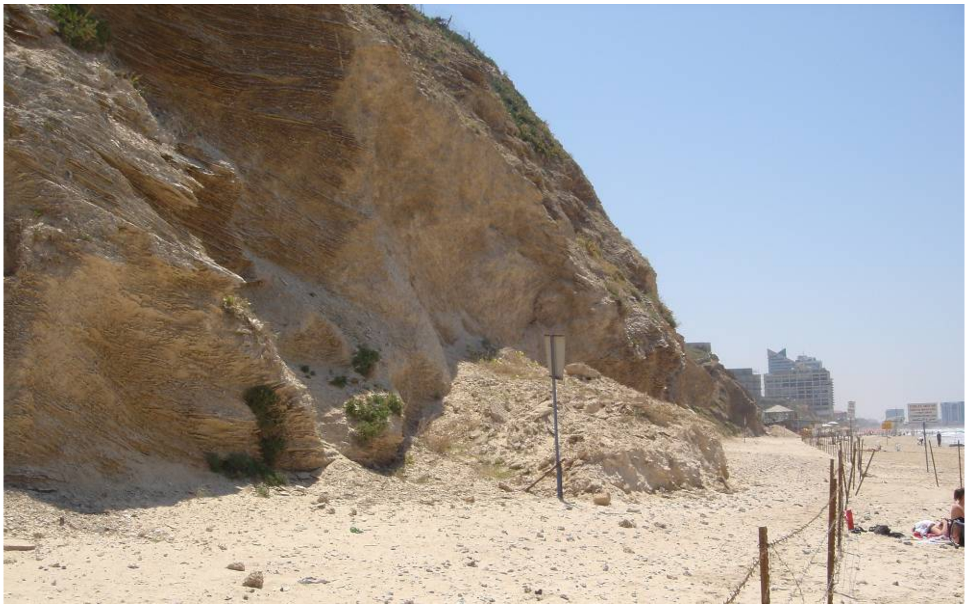

Figure 5. View of cliff erosion North of the Marina – 1 May 2007 Photograph

Recent reports on the Herzliya beach erosion have divided the region into 9 different zones, as shown in Figure 6. Zone 3 consists of the marina and Zone 4 contains the three breakwaters. These reports compare changes in the offshore bathymetry from available bathymetric surveys, and document and discuss the sand changes in each of the zones. It is estimated that the breakwaters have trapped approximately 300,000 cubic meters of sand from the littoral system.

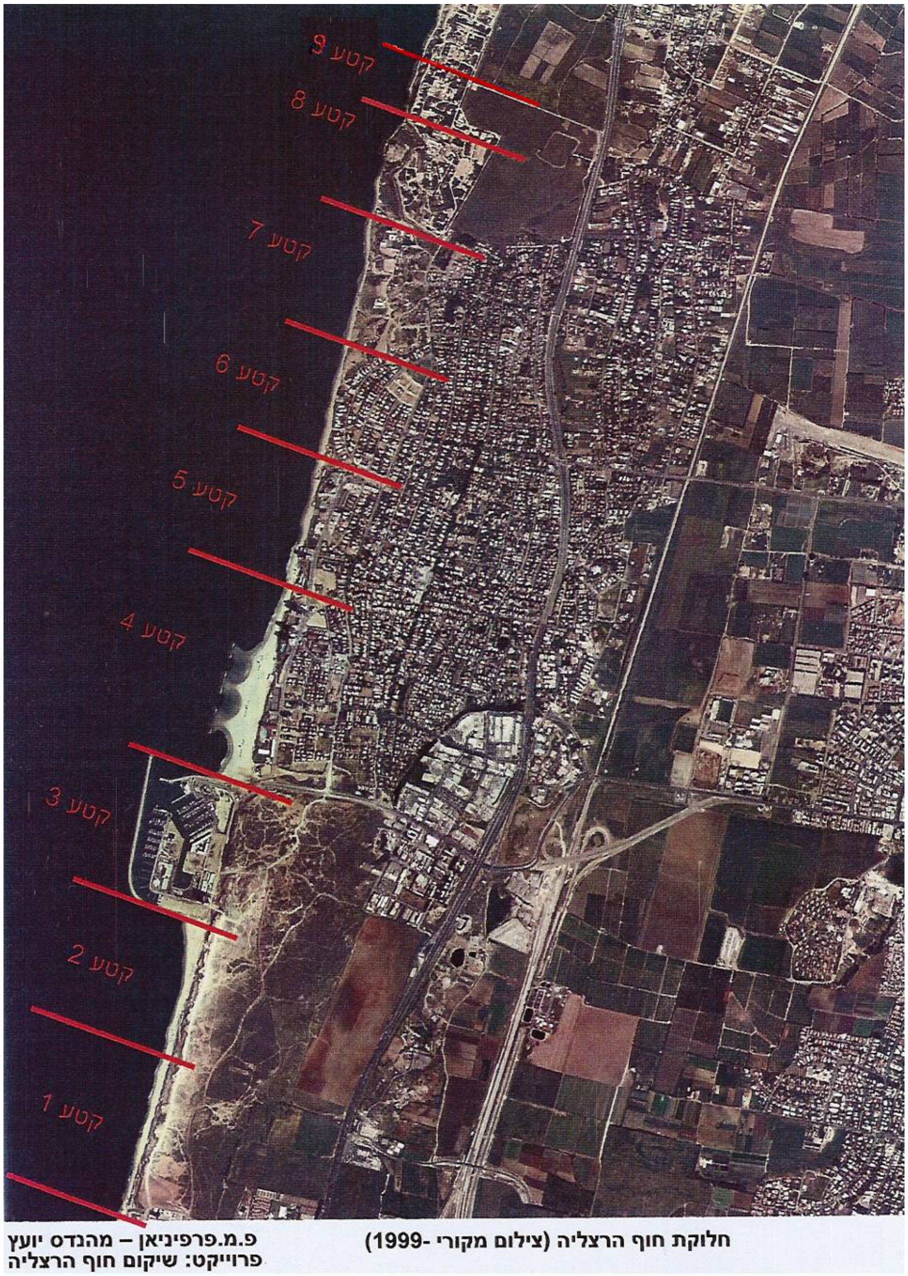

Figure 6. Project Study Area with 9 Regions

3 Tide and Wave Data

The tides for the Herzliya coast are relatively small, with astronomical tide ranges ranging from 20 to 40 centimeters. Larger water levels (storm surges) do occur due to onshore winds and wave setup. Tide data for the project area during the time period that the site visit was performed are shown in Figure 7. Onshore winds and wave setup were observed to create higher water levels during the site visit.

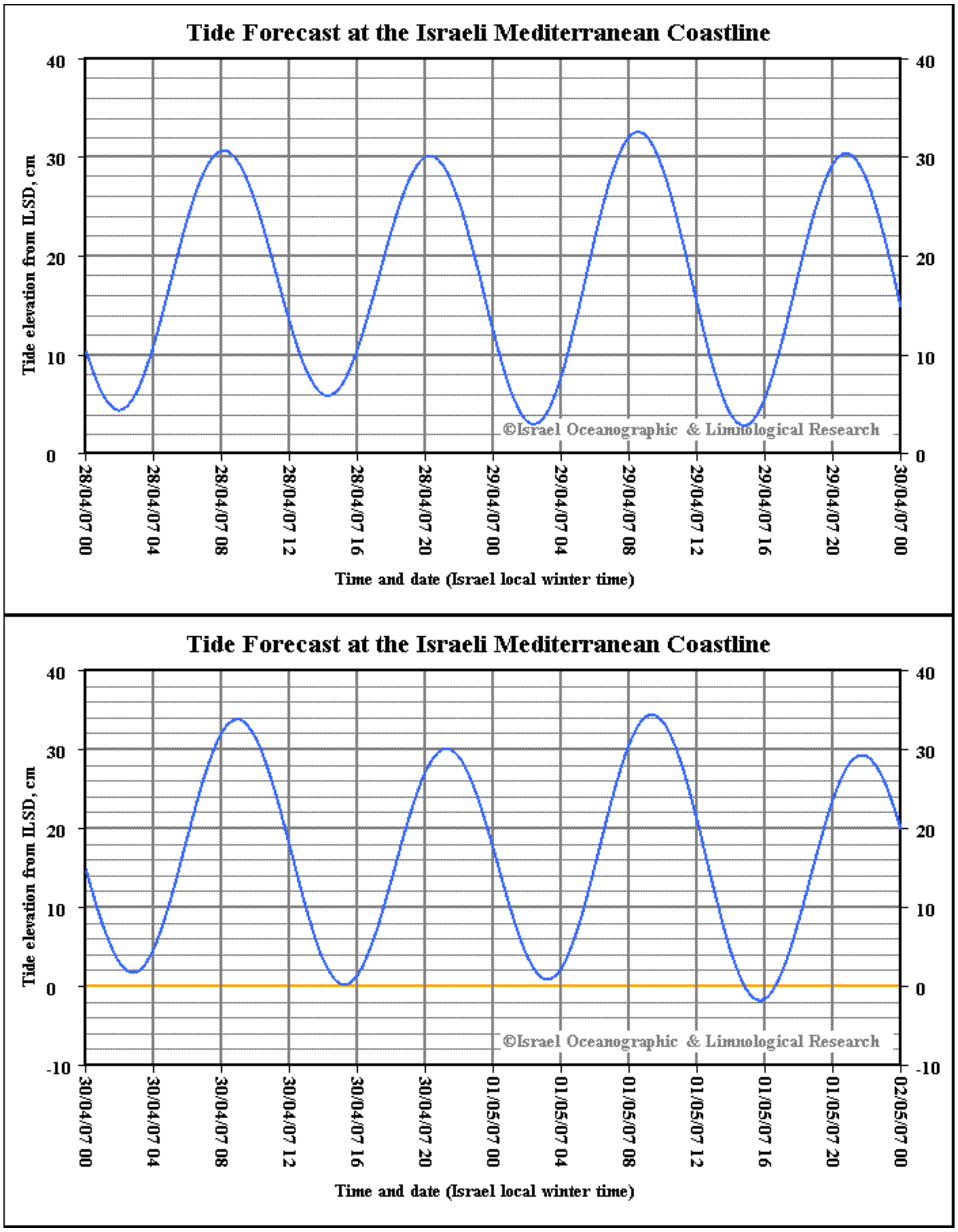

Figure 7. Predicted tides during the Site Visit

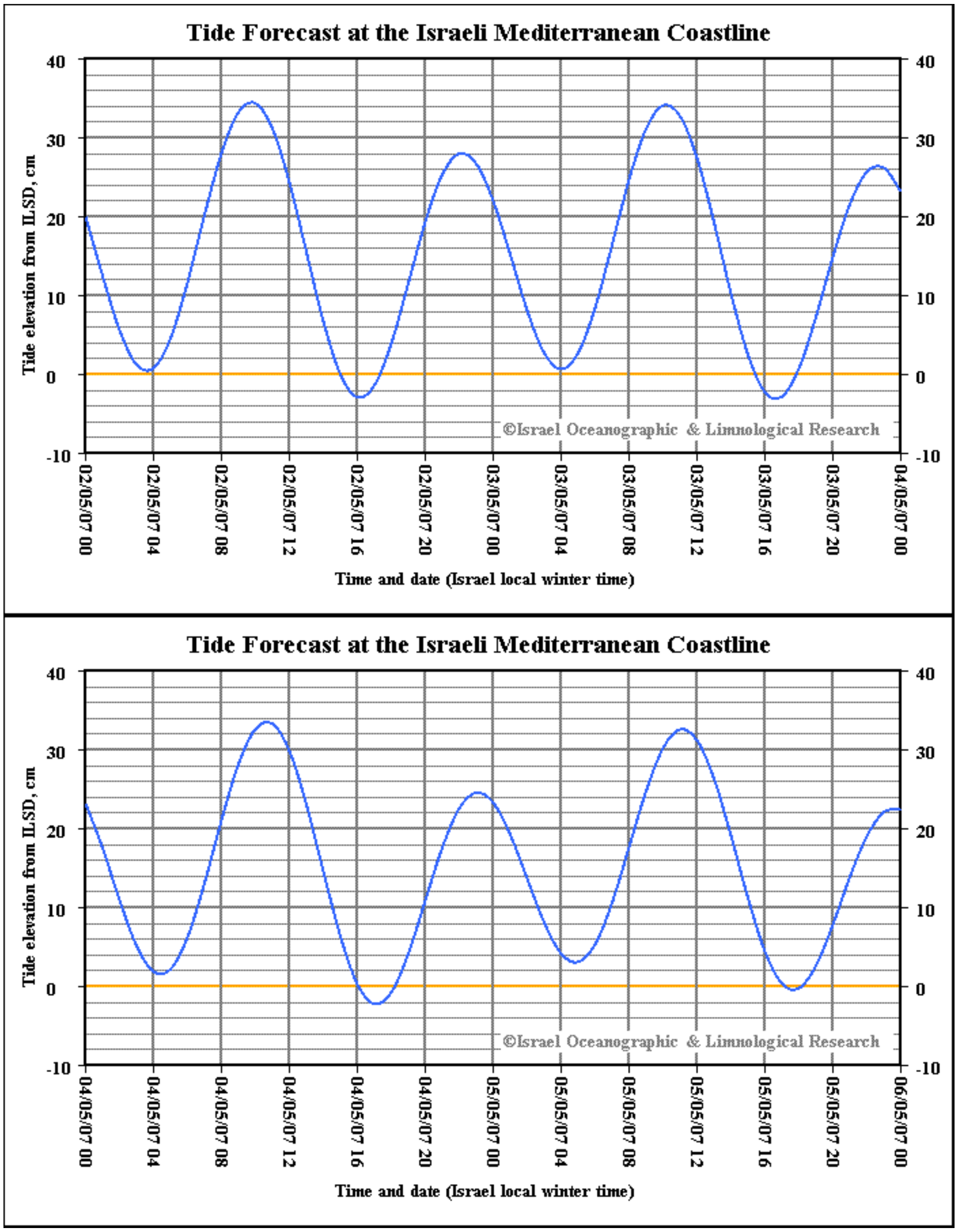

Figure 7. Predicted Tides during the Site Visit (continued)

Offshore wave gages are located at Haifa, Hadera, and Ashdod, and it has been reported that wave heights of up to 9m during storms have been observed offshore of the Israeli coast (with 5m wave heights typical). Nearshore waves will be depth-limited with the design wave being the largest breaking wave possible for the design water depth. During storms, the existing low and narrow beach north of the marina and breakwaters is underwater, with waves reaching and eroding the base of the cliffs.

4 Beach Erosion Problems

As previously discussed, there are many papers, reports and studies that document and discuss the shoreline changes that have occurred subsequent to the construction of the Herzliya Marina and adjacent breakwaters. The shore parallel length of the marina and breakwater is approximately 800m, and the outer breakwater of the marina protrudes 500m out from the coast. The three breakwaters were each constructed approximately 200m offshore, with shorter lengths for each breakwater from south to north. Some of the major factors affecting the beach erosion along the Herzliya coast are listed below:

1. sand traveling from south to north (the dominant longshore sand transport direction) is blocked by the marina breakwater, which can trap sand adjacent to the southern end of the marina and deflect the sand offshore, which prevents the natural longshore transport of sand to the northern Herzliya beaches
2. sand can be trapped within the marina and its entrance, and if it is dredged and dumped offshore, that sand is removed from the littoral system
3. the breakwaters have trapped an estimated 300,000 cubic meters from the littoral system. To prevent that from occurring, the beach in the lee of the breakwaters should have been pre-filled with sand to prevent that loss of sand from the littoral system.
4. there are outfalls for storm water that empty directly onto the beach, with examples of these in Figure 8. The largest of these is the outfall immediately north of the marina, which is at the end of a drainage canal (top photograph in figure 8). All of these outfalls have the potential to wash sand from the beach, especially during large rainfalls. There is also a discharge for a water-cooled air conditioning system shown in Figure 8 (last photograph), and although minor, shows water flowing out, washing sand offshore and eroding a channel in the beach.

The largest factors contributing to the erosion of the northern Herzliya beaches are the existing marina and adjacent breakwaters, which block the flow of sand along the coast, deflect sand into deeper water, and trap sand within their boundaries.

Figure 8. Various Outfalls along the Herzliya coast

5 Beach Erosion Solutions

Several alternatives for alleviating the beach erosion problems for the northern Herzliya beaches have been proposed. At present, sand scraping of the beach within the lee of the breakwaters is performed every year prior to the summer beach season, with 10 to 15,000 cubic meters of sand removed and placed on the northern Herzliya beaches. This and other alternatives which can be considered alone or in combinations are discussed as follows.

5.1 Modification of Existing Structures

The only modification of the existing coastal structures that could reduce the amount of sand being trapped and prevented from reaching the northern Herzliya beaches would be the modification of the three detached breakwaters. In the last 15 years considerable sand has been trapped within the lee of the three detached breakwaters (estimated at 300,000 cubic meters). This could include shortening the breakwater lengths, reducing their heights, moving them closer to shore, or removing one or more of the breakwaters.

However, had the three detached breakwaters not been constructed, severe erosion in this area would have occurred due to the marina construction, and the breakwaters have prevented that from occurring, although contributing to the erosion of the northern Herzliya beaches (which could have been minimized by pre-filling the breakwaters by adding 300,000 cubic meters of sand in the lee of the breakwaters as part of the breakwater construction).

The existing breakwater system appears to be in relative equilibrium, and instead of modifying those structures, which could be difficult and expensive, continued and increased volumes of sand removed from the lee of the breakwaters and used to renourish the northern Herzliya beaches could be performed, as discussed in the Backpassing alternative below.

5.2 Sand Backpassing

This alternative consists of going to where sand is being trapped, and passing it back to where it is eroding from. This method is already being practiced by the City of Herzliya, with a sand volume of 10 to 15,000 cubic meters transferred from within the lee of the breakwaters to the northern Herzliya beaches each spring. Due to the tremendous volume of sand trapped within the lee of the existing three breakwaters that have formed tombolos (sand accreting all the way from shore out to the breakwaters), the volume of sand removed from the lee of the breakwaters could be greatly increased without reducing the necessary recreational beach area in that location. However, the sand volume trapped within the lee of the breakwaters is probably in equilibrium, so that any volume of sand removed from that area may be expected to be trapped there again. This makes this alternative one that is sustainable, and could assist with trapping sand that may otherwise form shoals within the marina and entrance, but one that could contribute to the trapping of sand that may otherwise naturally nourish adjacent beaches.

5.3 Sand Bypassing

This alternative consists of bypassing sand around the existing marina and breakwaters, to restore the natural sand flow to the northern Herzliya beaches. As previously discussed, sand is being trapped south of the marina, offshore of the marina, in the marina and marina entrance, and within the lee of the three breakwaters. To restore the natural flow of sand to the northern Herzliya beaches, a permanent or periodic sand transfer operation could be established south of the marina, with the transfer of sand from that area to the northern Herzliya beaches.

An impoundment basin could be dredged just offshore and south of the marina, with the dredged sand placed on the northern Herzliya beaches. As sand moves from south to north and accumulates in that impoundment basin, it can be transferred either hydraulically through pipelines or trucked to the northern beaches. This would trap the sand that is accumulating south of and offshore of the marina breakwater before it reaches those areas, and restore it into the longshore sand transport.

Successful sand bypassing operations require a consistent and substantial volume of sand flowing in one direction. Although the predominant flow of sand is from south to north, there are times when waves, wind and currents from the north or northwest can create a reversal of sand transport from north to south. The longshore sand transport rate would need to be well documented in order to properly utilize sand bypassing.

5.4 Beach Nourishment

There are approximately 300,000 cubic meters of sand stockpiled from the dredging of the marina construction project, which can be used to nourish the beaches. This sand can be placed along the northern Herzliya beaches, but the longevity of this beach nourishment is not certain. Beach nourishment adds sand to the beach, but does not stop or slow down the beach erosion problem. Typically beach nourishment projects are performed as an initial nourishment, with periodic renourishment of the beaches as the sand is eroded. Typically 3 to 10-year periodic renourishment is required, with additional or more frequent renourishment following storm events. A source of sand for future periodic renourishments of the beach should be determined if beach nourishment is selected as the only beach construction. The sand trapped within the lee of the three segmented breakwaters is one possible source, but any sand removed from that area will

5.5 Emergent Segmented Breakwaters

Additional emergent (subaerial) offshore detached breakwaters could be constructed to the north of the existing breakwaters, adding a continuous system of additional breakwaters as far north as Apollonia. This would be an expensive solution, but could be used to assist in stabilizing any sand that is added to the beaches in that area.

Another alternative would be to add one or more breakwaters to the north end of the Herzliya area, as shown in Figure 9. The salients or tombolos formed in the lee of those northern breakwaters could assist in stabilizing the beaches to their south. Pre-filling of the breakwaters is recommended, so that initial accretion in the lee of the breakwaters with the formation of the salients or tombolos does not rob sand from surrounding beach areas. However, if tombolos form in the lee of the breakwaters, then longshore sand transport will be blocked and sand can be deflected further offshore, thereby adversely affecting the downdrift beaches to the north.

Any emergent breakwater greatly alters the aesthetics as well as the coastal processes. To avoid the potential unsightliness and to maintain but reduce the amount of sand that is trapped in the lee of the structure, the alternative of using submerged breakwaters are discussed in the following section.

Figure 9. Proposed Breakwaters at the North end of Herzliya

5.6 Submerged Breakwaters

There has been an increased interest and utilization of submerged breakwaters for shoreline stabilization in recent years. As compared to emergent breakwaters that stop all wave action from passing over them, submerged breakwaters allow the smaller waves to pass over them, only attenuating the larger waves. This allows the continued flow of sand along the coast in the lee of those structures, preventing the formation of tombolos, and with smaller salients than expected with emergent breakwaters.

The left aerial photograph in Figure 10 shows the existing northern Herzliya coastal area, with naturally occurring offshore submerged reefs and salients that form naturally in their lee. The right photograph in Figure 10 is the same area, with a conceptual layout of two proposed submerged breakwaters and the formation of two additional salients in their lee. These breakwaters could be designed and constructed as submerged artificial reefs, to enhance the marine habitat provided by the natural reefs in this area, as well as to assist with shoreline stabilization.

Figure 10. North End of Herzliya Beach (Apollonia at the top)
The left photograph shows the existing offshore submerged reefs with salients that have formed naturally along the coast The right photograph shows a conceptual layout of two offshore submerged artificial reefs, and the salients that would form in their lee.

In addition to using submerged and segmented breakwaters, permeable breakwaters can be used to ensure that ponding will not occur in the lee of the breakwaters, and that a limited salient will form. One alternative is the use of Reef Ball^{TM} artificial reef units to construct the submerged artificial reef breakwaters, as discussed in the following section.

6 Reef Ball^{TM} Submerged Artificial reef Breakwaters

6.1 Reef Ball^{TM} Reef Units

One of the designed reef units that have been used to construct submerged breakwaters is the Reef Ball^{TM} reef unit, shown in Figure 11, with data on available sizes and weights shown in Table 1. Variations of this reef unit include the "Layer Cake" reef unit, also shown in Figure 11.

Figure 11. Traditional Reef Ball^{TM} Unit (L) and "Layer Cake" Reef Ball Unit (R)

Originally designed as reef units for habitat enhancement in deeper water depths, Reef Ball units have several advantages over traditional breakwater materials, including:

1. easy and economical on-site fabrication using a patented mold system, as shown in Figure 12,
2. easy and economical deployment of the units by floating them using lift bags (not requiring barges and cranes, see Figure 13),
3. ability to anchor the units to the bottom (covered later), and
4. units can be custom designed as habitat for selected benthic and pelagic species, including aquaculture applications and transplanting and propagation of corals.

Custom designed reef units such as the Reef Ball^{TM} have been designed to attract and provide habitat for fish, lobster, and other marine life. A special concrete mix using special additives was developed that allows the Reef Ball modules to be deployed within

24 to 48 hours of being fabricated, and with special formulations that reduce the concrete pH to match that of natural seawater. The pH balancing and unique textured surface of the Reef Ball modules ensures that coral larvae and other marine life can easily attach to the modules to develop into a natural biological reef.

Table 1. Available Reef Ball Unit Sizes (smaller sizes are also available)

Style	*Width*	*Height*	*Weight*	*Concrete Volume*	*# Holes*
Goliath Ball	6 feet (1.83m)	5 feet (1.52m)	4,000-6,000 lbs (1800-2700 kg)	1.3 yard (1.0 m3)	25-40
Super Ball	6 feet (1.83m)	4.5 feet (1.37m)	4,000-6,000 lbs (1800-2700 kg)	1.3 yard (1.0 m3)	22-34
Ultra Ball	5.5 feet (1.83m)	4.3 feet (1.31m)	3,500-4,500 lbs (1600-2000 kg)	0.9 yard (0.7m3)	22-34
Reef Ball	6 feet (1.83m)	3.8 feet (1.22m)	3000-4200 lbs (1350-1900 kg)	0.75 yard (0.6m3)	22-34
Pallet Ball	4 feet (1.22m)	2.9 feet (0.9m)	1500-2200 lbs (700-1000 kg)	0.33 yard (0.25m3)	17-24
Bay Ball	3 feet (0.9m)	2 feet (0.61m)	375-750 lbs (170-340 kg)	0.10 yard (0.08m3)	11-16
Mini-Bay Ball	2.5 feet (0.76m)	1.75 feet (0.53m)	150-200 lbs (70-90 kg)	less than four 50 lb bags	8-12
Lo-Pro Ball	2 feet (0.61m)	1.5 feet (0.46m)	80-130 lbs (35-60 kg)	less than two 50 lb bags	6-10
Oyster Ball	1.5 feet (0.46m)	1 foot (0.30m)	30-45 lbs (15-20 kg)	less than one 50 lb bag	6-8

Reef Ball unit fabrication is shown in Figure 12. Concrete is poured into the top of the assembled mold, as shown on the left, with an inflated buoy located in the center to form the hollow interior, and smaller balls fastened to the mold pieces for external holes. After hardening, the buoy is deflated and removed, and the mold is removed, leaving the completed Reef Ball as shown in the photograph on the right. Figure 13 shows a Reef Ball unit being deployed by floating from the beach to construct an offshore submerged breakwater. Trestles from shore or barges and cranes can also be used to construct Reef Ball breakwaters.

Figure 12. Traditional Reef Ball Unit Mold Fabrication

Figure 13. Deployment by Floating Reef Ball Units from Beach
Small boats or jet-skis can also be used to tow the units out to the breakwater installation site. Fabricated units awaiting deployment can be seen in the background.

6.2 Reef Ball Submerged Breakwaters

A new application for Reef Balls was developed for shoreline stabilization, using Reef Ball reef units to construct submerged breakwaters. Physical model tests have been performed to evaluate the stability of the individual units, and to test the wave attenuation of various configurations and numbers of rows of units deployed as submerged breakwaters.

The first submerged breakwater project constructed using Reef Ball^{TM} reef units was along the southern Caribbean shore of the Dominican Republic during the summer 1998. Figure 4 shows the three-row Reef Ball submerged breakwater. Approximately 450 Reef Ball^{TM} reef units were installed to form a submerged breakwater for shoreline stabilization, environmental enhancement and eco-tourism. The individual units used for the breakwater were 1.2m high Reef Ball units and 1.3m high Ultra Ball units, with base diameters of 1.5 and 1.6 meters, respectively, and masses of 1600 to 2000 kilograms. The breakwater was installed in water depths of 1.6m to 2.0m, so that the units were 0.3m to 0.8m below the mean water level (the tide range in the project area is approximately 0.4m).

Figure 14. Gran Dominicus 3-Row Reef Ball Submerged Breakwater (Harris, 2003)

In the fall of 1998 shortly after the installation of the breakwater system, a direct hit by Hurricane Georges (Category 3) and large waves from Hurricane Mitch (Category 5) impacted the project area, but not a single Reef Ball^{TM} unit was displaced or damaged. The beach profile shown in Figure 15 shows that the Reef Ball^{TM} breakwater has been very effective in stabilizing the beach, with a significant increase in beach width and elevation along the project shoreline.

Shoreline and sand volume calculations are shown in Table 2. As shown in Figure 16, the beach and shoreline in the lee of the submerged breakwater system has been stabilized and has accreted sand, and there have been no adverse impacts on adjacent beaches. In addition, the use of designed reef units for the breakwater provides habitat enhancement for the marine life, which can be enjoyed by divers and snorkelers.

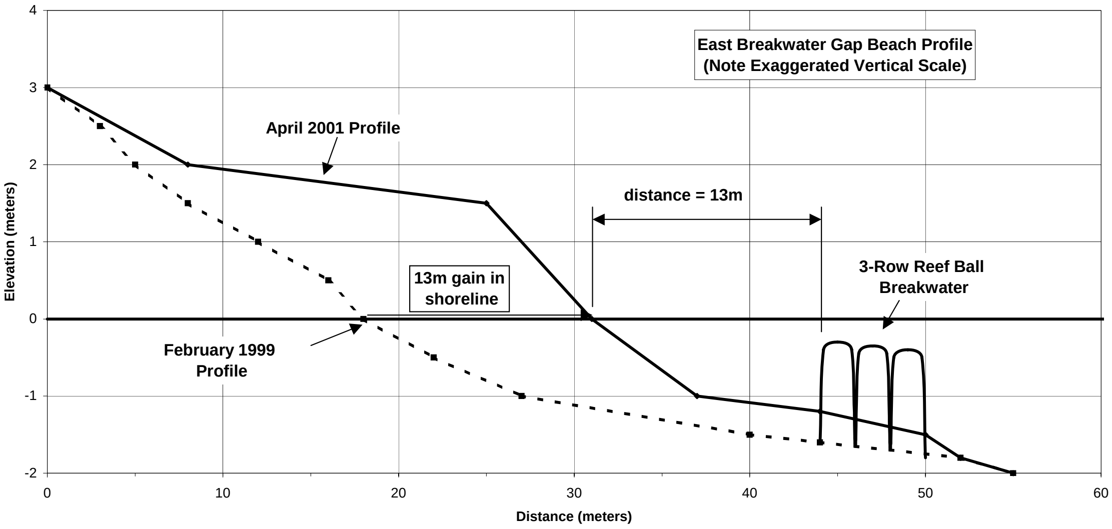

Figure 15. Beach Profile across Breakwater at Gran Dominicus (Harris, 2003)

Table 2. Changes in Shoreline and Sand Volume Calculations 1998 to 2001

Profile Line	Shoreline Change (meters)	Sand Volume Change (m^3/m)
West	+10 m	+25.65 m^3/m
East	+13 m	+44.25 m^3/m
Control	0 m	+2.0 m^3/m

Figure 16. Increased Beach Width at Gran Dominicus 1998 to 2001

Other Reef Ball submerged breakwaters have been constructed in other parts of the Caribbean including the Cayman Islands. The 5-row submerged Reef Ball breakwater, shown in Figure 17 was constructed in 2002, and is located offshore of the Marriott Beach Resort at the south end of Seven Mile Beach on Grand Cayman Island. The before and after photographs shown in Figures 18 - 19 show the successful beach stabilization, even after Category 5 Hurricane Ivan impacted the area in 2005 and subsequent wave impacts from other more distant storms.

Figure 17. Above and Underwater Photographs of the Reef Ball Breakwater
Submerged Breakwater offshore of the Grand Cayman Marriott Beach Resort

Figure 18. Marriott Beach Before and After Reef Ball Breakwater Installation
Photo from Fall 2002 (L) and February 2003 (R) after the breakwater installation

Figure 19. Grand Cayman Marriott - November 2006 (L) and February 2007 (R)

The breakwater reef units have remained stable during waves from major hurricanes, including the direct hit by Category 5 Hurricane Ivan in 2005 (photograph on the left in Figure 20 shows the breakwater with no damages, but damages to an upland building which forced its demolition). Large waves from nearby Category 5 Hurricane Wilma (as shown in photograph on the right in Figure 20) reached the seawall landward of the breakwater, but did no breakage or movement of the anchored Reef ball units occurred. An overall comparison of before and after breakwater conditions is shown in Figure 21.

Figure 20. 2005 Photos of Grand Cayman Marriott
Hurricane Ivan damaged upland buildings but not the Reef Ball Breakwater (L);
Waves from Hurricane Wilma striking the Marriott Seawall (R)

Figure 21. Marriott Beach before and After Reef Ball Breakwater Installation
Fall 2002 photo on the left and February 2007 photo on the right.

6.3 Reef Stability, Scour and Settlement

Stability, scour and settlement are much greater design problems for reef units deployed as submerged breakwaters in shallow water, and many experimental projects have undergone substantial settlement due to scour (Stauble, 2003). Submerged breakwaters must be designed to withstand the large forces due to breaking waves, wave induced currents, and scour that occurs in the surf zone. Both settlement and burial by sedimentation are important design considerations.

For reef units placed on hard bottom where settlement and scour cannot occur, the concerns are the strength of the units and resistance to movement by sliding or overturning. The weights of the individual units contribute to their resistance to movement, and the units can be pinned to the bottom for additional stability. When placed on sand in shallow water, reef units are very susceptible to scour and settlement (Smith, Harris, and Tabar, 1998). Two methods have been developed to increase the reef unit stability and resistance to movement, as well as minimizing problems due to scour and settlement of reef units:

1. rods or pilings drilled, driven and/or jetted through the reef units into the bottom (Figure 22), with rods used for rock bottoms and pilings for sand bottoms, and
2. attaching the reef units to an articulated mat (Figure 23).

The pilings and rods go through the reef unit and into the bottom at an angle, so that the reef units will resist both movement and settlement.

Figure 22. Pilings (left) and Rods (right) into Sea Bottom through Reef Ball Units

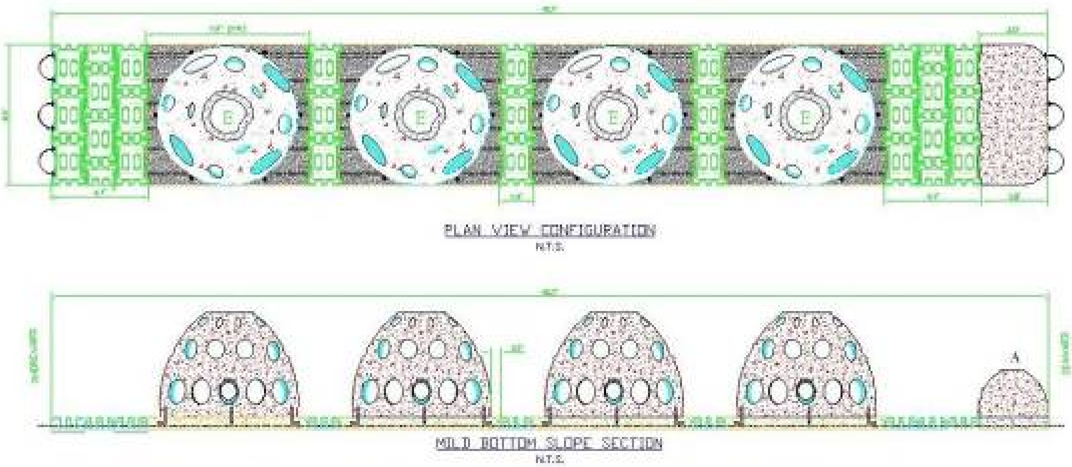

Figure 23. Reef Ball Units on Articulated Mat (Harris, Turk, & Mead, 2004)

Reef Ball units have been successfully used to construct submerged breakwaters for shoreline stabilization. These systems mimic natural reefs in reducing the wave energy that reaches the shore. Special design considerations are necessary to ensure that these man-made reefs will be stable, durable, and provide the intended purposes. Anchoring of reef units is required in shallow water due to forces by large waves and strong currents. In addition to the coastal erosion protection, environmental, and recreational amenities can be provided by these systems, including environmental mitigation and enhancement, increased habitat for marine life, and recreational benefits including swimming, snorkeling, diving, fishing and surfing.

6.4 Reef Ball Breakwater Application for Herzliya

Field investigations showed that the northern Herzliya beaches are suitable for Reef Ball submerged artificial reef breakwater construction, due to the water depths, tide range, bottom type, and wave climate. The effectiveness of any submerged breakwater depends on the degree of submergence and width of the breakwater. Existing nearshore reefs that have formed salients in the northern Herzliya beach areas are located in water depths of 1m to 3m, which are suitable depths for the largest Reef Ball units. With the small tide range at Herzliya (the same as that in the Caribbean projects discussed), if the crest of the breakwater is constructed near the water surface at low tide, it will only be submerged 30 to 40 centimeters at high tide. This will allow the submerged breakwater to be effective at all astronomical tide levels. Decreased effectiveness can occur during storm surge events, but this can be countered by increased breakwater width. .

Due to the potential for large waves in this area, the Reef Ball units must be anchored securely to the bottom. This can be done by using rods drilled into the existing hardbottom, or by pilings jetted into the sand bottom, depending on the bottom type and sand thickness in the area in which the breakwaters are constructed. The use of an articulated mat can also be considered, for areas in which natural rock reefs are absent.

A very detailed beach and bathymetric survey would be required for detailed design of a Reef Ball breakwater system. A closely spaced survey grid would be required in the area of the proposed breakwaters, and jet probes would be required to determine bottom type and sand thickness for anchoring and foundation design.

For preliminary cost comparison, submerged breakwaters in the Caribbean have been constructed at a cost of around US$1,000 per Reef Ball unit installed. At that price, for example, one 10m wide 100m long breakwater which would require approximately 250 units would cost about US$250,000 for a cost of US500,000 for two 100m long 30m wide breakwater segments. However, the actual costs are very site specific, and depend on many factors including the following:

1. local cost and availability of concrete, labor and heavy equipment for fabrication of the units and deployment,
2. shipping costs for the molds, and any specialized supplies and equipment not available locally,
3. import duties, taxes, insurance and other required costs,
4. water depths (governs unit sizes and breakwater width),
5. bottom type and sand thickness (governs anchoring and foundation design),
6. location for fabrication of Reef Ball units (governs transportation costs),
7. deployment method (floating from the beach or using barges and cranes).

7 Recommendations for Herzliya

Based on the field investigations, meetings, discussions, and review of all available papers, reports and studies, the following are recommended as actions to be taken into consideration for improving the scientific understanding, available engineering design data, and best methods for beach improvements to the City of Herzliya beaches:

1. Establish and maintain a system of survey benchmarks along the Herzliya shoreline, so that periodic beach profile surveys from those markers can be performed (see Figure 15 for an example beach profile survey).

There are a few limited beach profile surveys of the Herzliya coastal area, with reports showing nine beach profiles surveyed in 1980, 1995, 1998, and 2000 (but not all profile lines included in each survey date, and profile lines absent for the northernmost beach areas). Unlike detailed offshore bathymetric surveys using boats, beach profile surveys to wading depths (out to 2m depth) using differential leveling or other surveying techniques are not expensive, and can be performed at regular intervals and following storm events to document short-term, seasonal and long-term changes. Beach profile data provide the information necessary for studies of beach changes, and for engineering designs and construction of coastal structures and beach nourishment projects.

The State of Florida established a series of such markers at 300m intervals along all of its sandy shorelines in the early 1970’s, and these form the basis for scientific studies and engineering data used to understand and document shoreline and sand volume changes in the beach, and are used for engineering designs and analyses, including monitoring the performance of beach nourishment projects and coastal structures. In specific project areas, spacing of beach profile survey lines are often at closer intervals. For Herzliya, beach profile line locations and spacing should be done in association with the existing profile lines, existing coastal structures, and the nine beach zones identified in previous studies, from permanent markers set landward of the sandy beach on concrete walls, or at the base of the cliff.

In Florida, this beach profile survey program was first set up and performed by the University, and the periodic surveys required to monitor the beaches and determine shoreline and sand volume changes are an excellent project for university students. At present, the Florida Department of Environmental Protection (FDEP) maintains an on-line database of all of the beach profile surveys performed by the FDEP and other government and private surveyors. These form the basis of all studies of beach changes and all engineering designs and permits of coastal structures and beach nourishment projects. The horizontal coordinates and vertical elevation of each of the survey monuments are available on the FDEP web site, and are used for locating the markers and establishing the survey elevations.

Although there are bathymetric surveys available for the area offshore Herzliya, there are limited surveys of the beach, shoreline, and nearshore areas. Beach widths and elevations change considerably seasonally and due to storm events, and knowledge of those changes and variations are essential for a thorough understanding of the coastal processes, and design of beach nourishment and coastal structures. The design and implementation of all of the alternatives for beach stabilization discussed in this report would benefit from this type of data for optimizing designs and monitoring performance.

2. Consider increasing the volume and frequency of sand backpassing.

The current practice of annually transferring sand trapped in the lee of the three detached breakwaters to the northern Herzliya beaches can be continued, and may be expanded to transfer greater volumes of sand to the northern Herzliya beaches. Beach profile surveys performed in conjunction with this work would document the sand volume quantities, movement and longevity of the placed sand, and recovery of the sand that was taken from the lee of the breakwaters. Increased sand backpassing may reduce the shoaling in the marina and entrance, as sand moving from north to south that is able to bypass the filled breakwater tombolos and reach the marina may be trapped in the area from which the sand is removed for the backpassing.

3. Consider sand bypassing around the marina and breakwaters.

As discussed in this alternative, an impoundment basin could be dredged just offshore and south of the marina, with sand placement on the northern Herzliya beaches by hydraulic sand pumping or by truck hauling. Initial and periodic dredging of that area would provide a "sink" into which sand traveling along the coast would be trapped, prior to being deflected offshore and depositing along the outer marina breakwater or within the marina and entrance channel. Dredging operations should occur as sufficient qua

4. Perform additional surveys so that detailed designs of emergent and submerged breakwaters can be developed.

A detailed beach, shoreline and nearshore bathymetric survey using a close spaced grid is required in order to design emergent or submerged breakwaters. Detailed water depths, offshore distances, and jet probes to determine sand cover and bottom type are required for detailed design of any breakwater alternatives. This data is especially critical for submerged artificial reef breakwaters using units such as Reef Balls, so that the sizes of the units and foundation design can be determined.