LECTURE NOTES ON BEACH CHANGES
AND THEIR MEASUREMENT
# LECTURE NOTES ON BEACH CHANGES AND THEIR MEASUREMENT

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1. ABSTRACT

A brief theoretical background is given of the long and short term changes in beaches and the causes of these changes. A brief treatment of wave and tidal regimes is included as they relate to beaches in the Eastern Caribbean islands. The future impacts of sea level rise are outlined. The uses of beaches are listed together with the reasons why it is necessary to measure them accurately. The relevance of beach measurements to the planning process and coastal zone management is also discussed. It is suggested that beach erosion is likely to increase in the future as a response to increased natural and man-made stresses. Different measurement techniques are described, these include aerial photograph comparison, map comparison, beach surveying and the use of visual indicators, the use and application of each method is discussed. Finally the steps involved in setting up coastal monitoring programmes are outlined.
2. INTRODUCTION

Beaches are one of the most dynamic and fast changing environments existing in nature, they can change significantly in a matter of hours, such changes may be reversible or they may be one-way changes. In the islands of the Eastern Caribbean the coastal zone, of which the beach is a subsystem, is a very important area where much of the islands' infrastructure and industry is concentrated. In most islands, the beaches form an important part of the tourism product. For these reasons there is a need to understand and predict how the beach is likely to change in both the long and the short term.

This manual sets out to explain ways in which beaches may be measured so as to achieve these goals. Both qualitative and quantitative methods will be described. Qualitative indicators are especially important in the absence of long term data and can often be used to determine the direction of beach changes.

Firstly it is necessary to outline the natural processes that cause beaches to change over different temporal and spatial scales. The reasons for measuring beach changes will also be described, and how the data is directly relevant to many aspects of planning in the islands. Finally the actual methodology will be described, this will include the field and data analysis and their direct application to day to day planning problems. The setting up and continual modification of a beach monitoring program will be outlined.

It should be stressed that this is a working manual, it is not designed as a textbook. Further information on many of the theoretical aspects can be derived from standard texts. This document is essentially a working document for use in the field and the office.
3. BEACHES - FORM AND PROCESS

3.1 BEACH FORM

In the islands of the Eastern Caribbean, there are many different forms of shorelines, these include sand beaches, stone beaches, cliffed coasts, mangrove shorelines, etc. In this manual we are concentrating specifically on beaches and primarily sand beaches. There are two major types of beaches: sand beaches and stone beaches. Sand beaches may be composed of coral sand which may be derived from offshore reefs or the erosion of coral rocks, or they may be composed of sand derived from terrestrial material - many of the Eastern Caribbean Islands are volcanic in origin, so these beaches are composed of volcanic sand. (However, there are islands where the terrestrial material is not volcanic, such as Barbados, here the terrestrial sand is composed of silica). There is a third category whereby beaches consist of a mixture of coral and terrestrial material. Stone beaches usually consist of coral fragments or volcanic stones/boulders, the material varies in size.

The beach material may change after a particular wave energy event, e.g. after a storm a sand beach may be replaced by a stone beach, and similarly after a period of constructive wave activity the sand may be returned to the beach.

Figure 1 shows a typical beach profile or cross section. The major features to note are the fore-
shore, this is the area between high and low tide mark, above the high water mark there is usually a small crest, this is called a berm. It is not always present. Above the berm is the back beach area and the vegetation line. Below the low water mark there is a feature known as the offshore step which often coincides with the wave breakpoint.

Many of the Islands in the Eastern Caribbean are orientated north-south, and there are characteristic differences between the beaches on the east and west coasts. The east coasts are the windward coasts and experience high wave energy, this will be dealt with in more detail in Section 3.2.2, these east coast beaches often have very wide beaches in contrast to the narrow beaches of the west or leeward coasts. The reasons for these differences in form are predominantly a result of differences in beach material and wave characteristics. As a general statement, the coarser the material, the steeper the beach, for instance a stone beach will generally have a steeper gradient than a sand beach.

The form of the beach is also dependent on the wave parameters. One of the most important wave parameters is wave steepness (wave steepness is the wave height divided by the wave-length). For a given sediment size, as wave steepness increases, beach gradient decreases. So the narrow, steep beaches are often found on the west coasts where the wave steepness is lower.

Beach form changes as a result of tides and waves. Waves are predominantly a function of wind speed, wind direction and fetch, or area of open water over which the wind blows. Since waves are a function of winds and since winds change from day to day it can be expected that beach form will change as often as the weather or wind changes. The most important beach changes are the seasonal changes and the long term changes.

There are two main directions of beach change - erosion and accretion. It is useful to view these changes as directions, for often the beach form itself may not change drastically. To illustrate this point it is useful to refer to Figure 2. The first position shows the beach prior to the storm, the second drawing shows the beach after the storm, note that the beach has been eroded and the sand has moved offshore. The third drawing shows the beach a few weeks later when constructive waves have moved the sand back onto the beach. Although the beach looks the same as in the first drawing, the actual position of the beach has changed, it is further inland. Thus erosion may be defined as a movement of the beach form inland, similarly accretion may be defined as a movement of the beach form seaward. It is important to understand these definitions because the lay person will often try to convince one that the beach comes and the beach goes, and while this is correct as far as it goes, it is often not understood that the POSITION of the beach is changing.

Having discussed erosion and accretion, there is a third position to discuss and that is a beach in equilibrium. This is a beach that may erode or accrete, but the actual position of the beach remains static over time.

3.2 BEACH PROCESSES

The major processes influencing beaches in the Eastern Caribbean are waves and tides; tidal influences will be considered first.

3.2.1 Tidal Processes

Tides are generated by the gravitational attraction between the earth, moon and sun. The tides affecting the Eastern Caribbean islands are classified as mixed tides, there are two high tides and two low tides each day, however, there is a large difference in height between successive high tides or successive low tides. This is illustrated in Figure 3.

Average tidal ranges in the Eastern Caribbean are relatively low, 0.3 - 0.5 m (1 - 1.5 feet). The actual tidal range varies on a monthly and seasonal basis as a result of the phase of the moon and the distance between the earth and the
3. BEFORE THE STORM

2. DURING THE STORM: Note the waves reach higher up the beach and start eroding the back beach and dunes, depositing the sand offshore.

3. AFTER THE STORM: Note the beach has re-established its pre-storm profile. It looks the same as Position 1, but its position is further inland.

Figure 2: DIAGRAM OF BEACH CHANGES DURING AND AFTER A STORM
Moon. Each month there are spring and neap tides (high and low tidal ranges respectively), in addition tidal ranges are highest during the equinoxes, March and September.

Tidal state obviously affects the beach profile by determining the height the waves reach on the beach profile, obviously the waves reach further up the beach during spring tides than during neap tides. Thus a storm occurring during spring tides is likely to have more effect on the beach than one occurring during neap tides.

The passage of a major storm may influence the tidal range by causing a storm surge, e.g. a major storm may have an inverse barometric effect, that is the low atmospheric pressure centre results in a rise in the water level. A well developed hurricane may result in a storm surge of 1+ metres (3+ feet). Hurricane waves would be superimposed on top of this raised water level, thereby allowing the waves to reach much further inland.

3.2.1.1 High Tide Mark and Coastal Legislation

High tide mark, or high water mark is a very important parameter in coastal legislation because in Common Law it is used to define the limit of the foreshore. This is important because it delineates private property from public property. In most, but not all of the Eastern Caribbean Islands, the land below mean high water mark is publicly owned, whereas the land above this point is often in private hands. This law, which dates back to English Common Law, is fairly universal throughout the English speaking Caribbean islands, with perhaps one major exception, St. Lucia, where the Queens Chain extending 57 m (187 feet) inland from high water mark is in the public domain.

The problem arises how to measure the position of high tide mark since as we have seen it’s position varies with the moon and the weather. Where tide gauge data are available, high water mark can be defined as a specific vertical height. Usually tidal heights should be recorded over a full 12 hour period.
3. BEACHES - FORM AND PROCESS

A month period and it is advisable to continue the measurements for a period not less than three years in order to average out meteorological conditions. It is then possible to define mean high water mark as a vertical height. Unfortunately most of the Eastern Caribbean Islands do not have tide gauges and it is therefore necessary to try and define mean high water mark by other methods. These methods involve measuring high water mark relative to a fixed landmark such as a building or a tree. In practice three methods are used:

(1) Visit the beach at the predicted high tide on a particular date and measure the distance from the water line (the highest point the water reaches) to a fixed landmark. Basically all this gives is the position of high water mark on that particular date, the method can be refined by repeating the same measurement on a daily basis throughout a tidal cycle (28 days) and averaging the results, but in practice the time is rarely available to do this.

(2) Measure from the berm crest to a fixed landmark, the berm is the small crest at the top of the beach, see Figure 1. The berm represents the position of spring high tide mark, the high tide mark reached during spring tides, which as described in Section 3.2.1 occur once a month.

(3) Measure from the edge of the permanent vegetation to a fixed landmark, this represents the upper limit of storm high water mark, such as during winter swells - but probably not hurricanes.

From a planning viewpoint methods (2) and (3) are to be recommended. Method (2) is perhaps the quickest and most practical method. The aim of all good environmental planning is to leave the beach room to fluctuate, to move in a landwards or seawards direction.

3.2.1.2 Sea Level Rise

Due to global warming and the Greenhouse Effect, it has been predicted that sea level will rise significantly in the coming decades. While the amount of sea level rise is debated by scientists, it is generally accepted that the mean sea level will rise. Figure 4 shows the predicted rise over the
next century with various scenarios ranging from low to high. It is predicted that by the year 2025 the low range rise is 13 cm and the high range rise is 55 cm. (Existing rates of sea level rise are estimated at 1 foot (30 cm) per century).

This predicted sea level rise is likely to have several impacts on low lying coastal areas:

1. Inundation of low lying areas;
2. Erosion of beaches;
3. Increased flooding and storm damage;
4. Increased salinity of surface and ground water;
5. Higher water tables.

Under 'normal' conditions, storms and hurricanes erode the beach and deposit the sand offshore and during calmer periods waves return the sand to the beach. Sea level rise results in a net erosion of the beach by allowing storm waves to reach further inland and decreasing the ability of calm waves to rebuild the beach. Figure 5 illustrates the upward and landward shift of the beach profile that accompanies sea level rise, this is known as the Bruun rule. Along most North American beaches it is estimated that a 30 cm rise in sea level would cause approx. 30 metres of erosion. The actual amount depends on the wave climate and the beach profile, these estimates could certainly be applied to the east coast beaches of the Caribbean Islands. Thus sea level rise, which is undoubtedly occurring is already influencing our beaches and is likely to have an increased impact in the future.

![Figure 5: The Bruun Rule: A Rise in Sea Level Causes Beach Erosion. If the sea rises one foot, so will the offshore bottom. The sand necessary to raise the bottom (area b') can be supplied by artificial beach nourishment or by waves eroding the upper part of the beach (area b).](image-url)


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3. BEACHES - FORM AND PROCESS

3.2.2 Wave Processes

Beaches respond directly to changes in incoming wave energy. The Eastern Caribbean Islands lie within the Northeasterly Trade Wind Zone, these winds approach with great constancy from directions between northeast and east. The greatest wind frequency is from the east, secondly from the northeast and thirdly from the southeast. Highest wind speeds are experienced during the period December through March, since waves are a function of wind speed, this is also the period of highest wave energy. There is a second high period of wind speed during June and July.

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It is usually found that on east coast or windward beaches, highest wave energy is experienced during the winter months, December to March. This is the period when these beaches commonly exhibit seasonal erosion. The period August to November is when these beaches experience lower wave energy and show seasonal accretion.

The leeward coasts, or west coasts show a different seasonal pattern. These coasts are sheltered from the Northeasterly Trade Winds waves, however, they do receive some wave energy as the wave fronts are 'bent' around the tips of the Islands. This process is called refraction, and as a result the leeward coasts receive small, low waves, often less than 15cm high (6 inches).

However, during the winter months, October to March, these leeward coasts sometimes experience high waves (swells) as a result of extra-regional storms. Very intense low pressure systems in the North Atlantic Ocean, off the east coast of North America, generate storm waves which travel south and affect the Islands of the Eastern Caribbean, these waves are known as swells. Such swell waves can travel thousands of kilometres. These waves approach from a northerly direction, and are therefore felt on north, west and east coasts, their effects are usually most severe on the west coasts, since these coasts experience only low wave energy for most of the year. Ten to twelve swell events can be expected on average each winter season, with each event lasting between 2 and 7 days. The intensity of the swell events may also vary. These swell waves often cause severe beach erosion on the beaches on the leeward coasts, and sometimes too on the windward coasts. Photographs 1,2 show such swell waves and the resulting beach erosion. Such wave phenomena are called by different names in the various Islands, eg. groundseas, northers, spring tides.

Hurricanes are the most severe type of storms to affect the islands, these occur during the period June to November, with August and September being the most common months. Hurricane damage usually results from high winds, high waves, storm surge and flooding. As noted in Section 3.2.1 a fully developed hurricane may result in a raised water level (storm surge) of more than 1 m. Hurricane waves are the most damaging waves to affect the beaches. A fully developed hurricane could develop significant deepwater wave heights of 8 m (this represents the highest third of the waves), with a maximum wave height of 16 m. Such waves cause great damage and beach erosion, often the effects last for many years. Sand may be washed offshore into water so deep that the following constructive waves can never return it to the beach system. Coral reefs may also receive catastrophic damage, thereby influencing beach changes. Reefs provide natural breakwater protection and sand to the beach. Often after a hurricane there may be new offshore islands formed of mounds of dead coral rubble, these have been observed in Jamaica after Hurricane Allen in 1980 and in the British Virgin Islands after Hurricane Hugo in 1989. Hurricanes often result in long term coastal changes.

Wave direction is also an important parameter. Waves result in sand being moved along the beach as well as in an onshore/offshore direction. This longshore transport is termed longshore drift and is primarily a response to wave direction. Figure 6 shows the theory behind longshore drift. Photograph 3 shows an example of longshore drift, a river mouth is diverted to the left of the picture by
Photograph 1: SWELL WAVES ON THE WEST COAST OF BARBADOS, MARCH 1987. Normal conditions show small waves, less than 0.15 m high, these swells were approximately 2 m high at breakpoint.

Photograph 2: THE RESULTS OF SWELL WAVES ON THE WEST COAST OF BARBADOS. Note the fallen trees and exposed tree roots.
3. BEACHES - FORM AND PROCESS

Figure 6: DIAGRAM SHOWING LONGSHORE TRANSPORT. Longshore currents are generated by waves striking the shoreline at an angle. When the wave breaks at a slight angle to the beach, the water receives an impulse, part of which is in the longshore direction. Thus, the sand grains are moved up the beach face at an angle, only to return down the beach face perpendicular to the beach slope, then with the next wave the sand grains will be moved up the beach face at an angle again. So the sand grains follow a zigzag path along the beach and the direction of longshore sand movement will be dependent on the wave direction.

a spit of sand which has formed as a result of longshore transport moving sand from right to left across the photograph. Longshore drift is often confused with tidal currents, however, it should be realised that the two currents are different and may often flow in opposing directions. When a structure such as a solid jetty is built across a beach, this may interrupt the longshore drift processes causing accretion on one side and erosion on the other side, this is basically the theory behind groynes, i.e., to slow down longshore transport, however, it should be realised that one beach's gain is another beach's loss, see Figure 7.

Offshore structures such as coral reefs, breakwaters, may change the wave direction, causing the wave fronts to bend and approach from a different direction.

3.3 BEACH FORM AND PROCESS

The processes outlined above shape the beach form. There may also be other man-made impacts that shape the beach form such as beach sand mining. Seasonal changes are usually quite obvious to the observer, long-term changes are smaller in magnitude and harder to observe. Often they can only be detected by careful measurement. However, in most cases beaches are
Photograph 3  DIVERSION OF A RIVER MOUTH BY A SANDSPIT FORMED BY LONGSHORE DRIFT PROCESSES.
Example from the White River, North coast of Jamaica (Photo by J.S. Tyndale-Biscoe).
1. Wave direction

Direction of Longshore Drift

The solid groyne rein the build-up of sand on one side and sand starvation on the other side.

2. This example from Nevis shows two solid groynes each showing sand accretion on one side and sand starvation on the other side.

Figure 7 EFFECT OF A SOLID STRUCTURE ON THE ACTIVE BEACH ZONE.
changing their position in the long term, either by erosion or accretion. Given the stresses being placed on the beaches by man, e.g. increased development, sand mining and by a combination of nature and man e.g. global warming and sea level rise; it is likely that the magnitude of long term change will increase. In addition, given these stresses, it is also likely that the direction of these increased long term changes will be towards more erosion. For this and other reasons, the physical aspects of beach change need careful monitoring and need to be included in all aspects of a country's coastal development planning.
4. BEACH CHANGES AND PLANNING

Beaches are important in the Eastern Caribbean islands for many reasons, they can be listed as follows:

1. They provide a buffer between the land and the sea, protecting the land behind the beach from wave action;
2. They are an aesthetically pleasing part of the natural environment of the Eastern Caribbean islands;
3. They provide an important recreation resource for local people and for visitors;
4. They are an important part of the tourism product in most Islands;
5. They are an important source of fine aggregate for the construction industry;
6. They provide sites for the beaching of boats and the landing of catch for the fishing industry;
7. They provide a habitat to many animals and nesting sites for turtles.

Thus beaches provide many uses, some of these uses are not compatible e.g. sand mining and nesting turtles. As development proceeds, the beaches come under increasing pressure especially from the tourism development sector. Tourism development along the beachfront need not be in conflict with other uses, but because of poor coastal management in many of the islands, conflicts result.

The foregoing sections have shown how beaches change naturally. If many of these concepts were incorporated into development planning then many of the existing beach problems such as beach erosion, lack of public access to the beach, etc. might not be major problems.

To take an example, beach erosion is not a problem provided there is no development behind the beach. The best action is to let the beach erode, or re-position itself further inland. However, as soon as the land immediately behind the beach is developed with houses or hotels, the beach cannot re-position itself further inland, and then erosion becomes an expensive problem often necessitating sea defence works such as groynes or seawalls. So the best course of planning action is to position the buildings well back from the beach so that the beach can move naturally, then everyone is satisfied - the private owner does not have to build expensive sea defences and he conserves the beach, and the general public is satisfied because their access along the beach and use of the beach is also conserved.

But the question arises, how far back from the beach is a safe distance. In order to answer this, it is necessary to know how that particular beach is changing, is it eroding or accreting? This is where it is necessary to regularly measure the beach so that an answer can be given, for obviously a stable or accreting beach would require a lesser setback from the high water mark than an eroding beach.

As mentioned earlier, environmental concerns should enter into the early conceptual development planning stage, yet it is rare that this ever occurs in the Eastern Caribbean Islands. Instead environmental planning may come in at the final stage of a particular project. It is often very difficult to convince a developer that he should spend more money on a project or site it in a different position further back from the high water mark. This is one of the many reasons why it is necessary to have good data to prove, or at least emphasise, the arguments being advanced.

Similarly with other uses, e.g. beach sand mining or turtle nesting, it is essential that the beach changes are monitored and known in order to manage those uses. Extensive sand mining from an already eroding beach will only worsen that problem. Development on beaches used for
turtle nesting should be specially sited so that the two uses can continue in harmony, simple measures such as not placing strong lights near the beach which might cause the turtles to become disorientated, can be included.

Other aspects of beach use are also dependant upon regular monitoring and measurement, e.g. placing a public access by an eroding beach may be self defeating. The examples can go on and on, the final conclusion is that the beaches of the Eastern Caribbean Islands are already heavily utilised by various different users, and this is likely to increase in the future. As previously discussed, natural changes especially erosion, are also likely to increase in the future, the need for regular and accurate measurement of the valuable beach resource cannot be overstressed.
There are several different ways to measure beach changes, the method selected depends on the resources available and the time scale over which the change is to be measured. Long term changes (10+ years) can best be measured using aerial photographs and maps. Short to mid term changes (1-10 years) can best be measured using surveying techniques.

5.1 AERIAL PHOTOGRAPH COMPARISON

The main method used to determine long term coastal change in the Eastern Caribbean islands is to compare aerial photographs of different dates. Most islands have aerial photographs at approximately ten year intervals, dating back to the 1940’s or 1950’s, comparison of these photographs can establish the direction and extent of beach change.

The position of the beach or high water mark as determined on an aerial photograph is plotted onto a base map of the same scale. (It may first be necessary to use equipment such as an opaque projector to reduce the base map to the required scale). The exercise is then repeated with a later photograph. Figure 8 shows the results of such an exercise which was carried out for the west and south coasts of Barbados. Once the coastline positions have been plotted on a base map, it is possible to determine the amount of change over the time period by measuring the area between the two coastline positions with a planimeter and dividing by the number of years between the sets of photographs. Thus the end product is a rate of change per year, if the coastline has moved seawards this will be an accretion rate, if it has moved landwards this will be an erosion rate.

Once this exercise has been conducted, there is no need to repeat it. Although very time consuming and tedious, it provides very useful information concerning historical trends. However, although rate of change per year can be calculated, there is no way of knowing whether all of that change took place in one year, or spread over several years. For instance a beach may have accreted for seven years, then a hurricane occurred and the resultant erosion masked the accretion, so that the net change over the ten years was erosion and no evidence of the accretion would be apparent.

Another problem is to actually define the high water mark on an aerial photograph. It is sometimes difficult to determine this in the field and on a photograph it is even harder. If the section of coast is undeveloped, then the vegetation line can be plotted instead, but if the coastline is anchored with buildings, plotting the building line is not going to establish coastal change.

Also this method is in essence measuring the position of two high tide marks at two different times, as previously seen the position of high tide mark varies naturally on a daily, monthly and seasonal basis.

Despite these problems and inaccuracies, aerial photograph comparison provides a quantitative evaluation of long term coastal change and as such is an invaluable tool.

5.2 MAP AND FIELD COMPARISON

The comparison of maps of different dates does not tell much more than the previous method, since most recent survey maps are based on aerial photography. However, the comparison of old maps dating from the nineteenth and early twentieth centuries can tell much about historical coastal changes, although this is only semi-quantitative. Similarly old photographs and local knowledge can help to build a picture of historical coastal change.
Coastal Changes at Bridgetown, Barbados

1954 offshore sand step
--- 1964 offshore sand step
------------- 1982 offshore sand step

Esplanade

Figure 8: MEASUREMENT OF LONGTERM COASTAL CHANGE IN BARBADOS USING AERIAL PHOTOGRAPHS. In this case the coastline has accreted between 1954 and 1982 or in other words, the high water mark has moved seawards.
5. BEACH MEASUREMENT TECHNIQUES

Another quick method that can be used to give some quantitative idea of coastal change, is to use a large scale survey map to measure the distance from fixed landmarks such as a road end or a building to the high water mark, and then repeat this measurement in the field. This will give a quick point assessment of the amount of coastal change over a given time period. It is quicker than the previous method, 5.1, but less accurate since it is only a point measurement and not an areal measurement. Nevertheless in the absence of any other data, it provides a quantitative assessment of the net change over a certain time period.

5.3 BEACH SURVEYING

Regular beach surveying from fixed reference points is undoubtably the most accurate way of measuring beach changes. In the developed countries such records may extend back for decades, but the Eastern Caribbean islands are just in the process of setting up regular beach surveying programmes. Basically the technique consists of having a landmark at the back of the beach, such as a building or a tree, this is the starting point of the measurement, it can be marked with spray paint for ease of identification. Then the beach profile or section is measured, both the distance and the slope. The profile is plotted graphically and the area under the profile is calculated. (A step by step methodology is given in OECS-NRMU/GTZ REPORT 2a - OECS)

This is the basics of the method, the instruments and the method of calculation may vary depending on the available resources. The starting point may be a properly anchored surveyors mark sunk in concrete. However, a painted mark on a tree is also adequate, the most important point about the reference mark and starting point is that it should survive hurricanes and storms and man's action, thus it should be well back from the beach. If the mark is on a tree it should be at least the second or third line of trees inland from the beach. To survey the profile it is necessary to measure the slope and the distance, this can be done with an engineers level, a theodolite or a simple hand held Abney level. Obviously the level of accuracy will vary depending on the instrument, but any of these levels will provide a quantitative measurement. Engineers levels and theodolites usually need a surveying team of 2 or 3 persons, whereas an Abney level can be used with just one person.

Measurements can be taken at incremental distances, say every 5 metres, or alternatively measurements can be taken at each break of slope. Profiles should always be measured along fixed bearings. Figure 9 shows a typical beach cross section or profile. Ideally the reference point or starting point should be tied in to island datum, so that an exact height can be assigned to the starting point. Then the profile area above a fixed vertical height can always be calculated, such as the area above 0 datum or above -0.5 metres. However, this requires a considerable amount of detailed and accurate surveying work, and the time is not always available for this work. Instead a temporary height value can be assigned to the reference mark, and the profile area above a fixed vertical height calculated.

The area under the profile can be calculated using simple trigonometry or mathematically. This section of the work can be speeded up using a computer.

Beach profiles should be measured as regularly as possible, and at least every three months. This should enable seasonal changes to be established. The data can be averaged yearly to provide some idea of the net change for a particular profile. This is so important because it has been found in beach measurement programmes in both Grenada and Barbados, that while one year may show very significant change, this is often followed by several years with little or no change. This emphasises the need for regular and continuous measurements.
5.4 INTERMITTENT MEASUREMENTS AND INDICATORS OF CHANGE

If manpower resources are insufficient to conduct regular beach surveying, the setting up of baseline data measurements is all important. Once the baseline measurement has been set up, it is possible to return some years later and repeat the measurement and thus determine the net change over that period. This is not as accurate as regular measurements but still provides a quantitative measure of the net change over a specific time period.

It is also possible to use natural phenomena to show coastal change. For instance the exposure of beachrock provides strong evidence of beach erosion. Beachrock consists of grains of sand cemented together with calcite and aragonite, it forms within the body of the beach around the water table. Once exposed it becomes hard and the beds usually dip seawards. Photograph 4 shows an outcrop of beachrock from Grenada, bearing in mind that this rock was formed within the body of the beach, its exposure in the sea indicates the extent of beach erosion at this site. Thus the exposure of ledges of beachrock provides evidence for long term beach erosion. Other signs include undermined buildings, exposed tree roots. All these indicators help to put together the history of change at a particular beach. Photographs taken from the same point can also help record the changes at a particular beach. If no data are available, these indicators can show the direction of coastal change, either erosion or accretion. However, ideally they should be used to supplement regular beach surveys.
Photograph 4 BEACHROCK LEDGE AT BATHWAY BEACH, GRENADA, 1985. The arrow shows the beachrock ledge, this rock was formed within the body of the beach, thus it’s exposure indicates the extent to which the beach has retreated inland.
6. COASTAL MONITORING PROGRAMMES

When setting up a coastal monitoring programme, it is first necessary to determine the manpower and time available, and to design the programme accordingly. This will determine the number of sites that can be measured, the frequency of measurement and the level of measurement.

The design of the programme will determine the following aspects:

(1) Persons available for monitoring, level of expertise, number of hours available per week.

(2) Number of sites to be measured: include the sites where erosion is already taking place and causing problems, include at least one site as a control site, where perhaps there is no known change taking place or where there are no developments influencing natural beach changes.

(3) Frequency of measurement: for the first year it is advisable to measure each site at least every three months and more often if possible. After that it may be possible to reduce the frequency of measurement, perhaps to 2 or 3 times a year. However, 3 monthly intervals are to be recommended.

(4) Level of measurement: if the expertise and manpower are available it is better to go for a higher level of accuracy such as may be obtained with an engineers level. However, particularly if time and manpower are limited, a hand held Abney level can be utilised.

(5) Data computation: again this will depend on availability of equipment such as computers, if they are available they will greatly speed up data computation. However, if not, data can be computed graphically.

There are two very important aspects of any monitoring programme, these are continuity and assessment. The programme must be set up in such a way that it can be continued by other people with minimum handover. Thus once the sites are set up they should be accurately recorded and photographed, and the methodology described, so that a different person taking over the programme could locate the sites and continue the monitoring in a similar manner. This is essential for any long term monitoring programme.

Secondly the data should be computed as it is collected. This helps to determine any errors in measurement. In addition it is especially useful to assess the data after each 12 month period, and perhaps to produce a short technical report summarising the findings. The important thing to realise is that the monitoring is not being done for research or its own sake, it is being done to provide a direct input in planning decisions and other coastal management issues. Thus providing summary reports may be especially useful for other Government agencies, special interest groups, etc. In the Eastern Caribbean islands, coastal zone management is usually achieved through a number of different agencies working together, and the more inter agency communication, the more efficient the management process.

The importance of regular, accurate data collection in a programme such as described in this manual cannot be over-emphasised. It can provide the basic scientific foundation for well informed decision making in coastal zone management.