MONITORING AND MANAGEMENT OF BEACHES IN THE ARCHIPELAGO OF LAS PERLAS, PANAMA

by

MARIE GOARIN
September 2006

Submitted as part assessment for the degree of

Master of Science
in
Marine Resource Development and Protection

School of Life Sciences

Heriot-Watt University, Edinburgh

TABLE OF CONTENTS

Acknowledgements i.

Abstract ii.

Aims 1

1. Introduction 2

1.1 Las Perlas and the Darwin Initiative 2

1.2 Beaches of Las Perlas 2

1.2.1 Tourism 6

1.2.2 Conservation and scientific research 11

1.2.3 Fishing 14

1.2.4 Sand Mining and Channel Dredging 15

1.2.6 Beaches and coastal protection 17

1.3 Beaches as monitoring and fundamental research tools 17

2. Materials and methods 20

2.1 Study area and general organisation 20

2.2 Beach profiles 21

2.3 Sediment analysis 25

2.4 Photos and GPS positions 26

3. Results **27**

3.1 General notes about profiles and sediment analysis 27

3.2 Site by site description and results 30

3.2.1 Saboga (beach 1 and 2) 30
3.2.2 Contadora (beach 3) 33
3.2.3 Chapera (beach 4 and 5) 35
3.2.4 Mogo Mogo (beach 6, 7 and 8) 36
3.2.5 Bolaňo (beach 9) 39
3.2.6 Gibraleón (beach 10) 39
3.2.7 Bayoneta (beach 11) 41
3.2.8 La Mina (beach 12) 42
3.2.9 Viveros (beach 13) 42
3.2.10 Rey Island (beach 14, 15 and 16) 44
3.2.11 San José (beach 17) 46
3.2.18 Bajo Boyarena (Sand bar 18) 49

4. Discussion and recommendations **50**

4.1 Future monitoring program 50

4.1.1 Methodology 50
4.1.2 Frequency of monitoring and site selection 52
4.1.4 Hydrodynamic and aerodynamic environment 54

4.2 SMZ management in relation to beaches and sedimentary processes 55

5. Conclusion **59**

References **60**

List of Appendices **65**

Acknowledgment

I would like to thank Hamish Mair and Hector Guzman for inspiring this dissertation and for their help and support throughout all aspects of the development of this study.

Thanks to Hugh Barras for helping with the use of the equipment and devising the methodology.

Field work would not have been possible without the precious assistance of Hamish Mair, Tom McGowan, Julio Aguretas, Hector Guzman and Carlos Guevara as well as Alexis Lam and Toribio.

Financial and technical support was provided by Heriot-Watt University, the Smithsonian Tropical Research Institute and the Watt Club.

Some of those without whom this dissertation would not have been possible. *From left to right:* Hector Guzman, Hamish Mair, Carlos Guevara, Tow McGowan and Alexis Lam.

Abstract

The 255 islands of the archipelago of Las Perlas in Panama, have been isolated from modern development until recently and about 10% of the population still relies on non-commercial artisanal fishing for a living. They are host too abundant and diverse wildlife with many species, communities and habitats of special interest.

In most recent times, there has been growing pressure on the archipelago's environment. In particular, global warming, tourism development and a sand mining project could have serious impacts on coastal stability and sedimentary processes.

This study proposes to develop a beach profile and sediment monitoring programme to better understand natural processes in order to better plan coastal use and development and create a tool to monitor man's impact on sediment transport.

During two field trips in May and June 2006, forty eight profiles were surveyed and marked for future reference and data collection, while fifty sediment samples were collected.

Recommendations are made for the improvement of the methodology to allow collecting larger amounts of data quickly while improving the data quality. This would consist in measuring the width of the intertidal area regularly while surveying in detail less often. Five beached were recognised as under particular threat or having features of special interest and should be prioritized in future monitoring. It is also recommended that more information is gathered about the hydrodynamic environment of the archipelago.

Finally, some suggestions are made regarding the management of a proposed Special Management Zone.

Aims

The principal aim of this study is to investigate beach environments in Las Perlas, in order to aid future development planning. Since very little information is available at present about the physical and ecological processes in the archipelago, this study is designed as an 'exploratory' investigation which will also provide baseline data to monitor change in the future. It was therefore important to develop a methodology which would be easily replicated in the future.

This study also aims at identifying the various groups of users which would potentially use beaches or whom activities could have an impact on beaches. The variety of users could result in conflict of interest and it is desirable to identify and take these into account in the management of the SMZ.

1. Introduction

1.1 Las Perlas and the Darwin Initiative

The archipelago of Las Perlas is located off the south (Pacific) coast of Panama (*figure 1.1*), in the Bay of Panama, and comprises around 255 islands. There are 59km between Panama City and the North of the Archipelago which approximately fits in a 55 by 46 by 39km triangle.

A large number of these islands are uninhabited while a few are scarcely populated and do not support large scale infrastructures, except for a few islands with bitumen roads, marinas and airstrips. The economy is mainly centred on agriculture and fishing (Campbell, 2005), with tourism becoming more and more important.

The islands are part of the remnants from an ancient coastal mountain range (Cordillera Costera) along with Coiba Island and several peninsulas from the mainland coast (Rubio, 1949). The petrology of the archipelago is dominated by basaltic rocks with some sedimentary features.

Most of the islands are densely vegetated in their centre and fringed by rocky shores, beaches or mangrove forests. The vegetation consists mainly of mature tropical forest. Patchy coral reefs are scattered around the islands.

The islands are accessible from the mainland by boat or plane; barges travel daily. Travelling around the islands is by boat or car for a few of the largest islands. Most boats are motorised

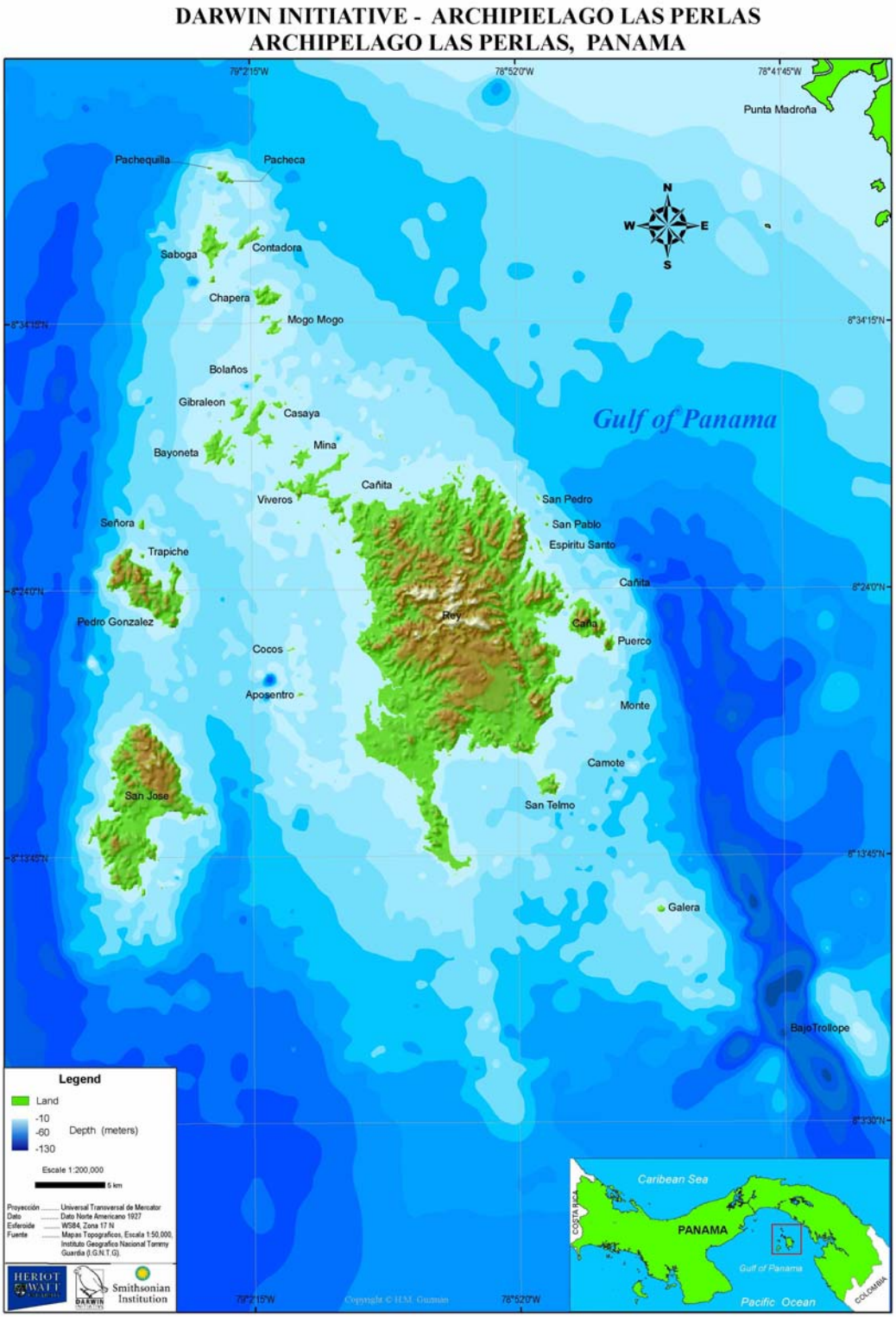


Figure 1.1: map of the study area. *Source: The Darwin Initiative*.

but a few wind sailing boats were also observed. Many internet searches on Las Perlas resulted in sail cruising related pages.

Due to their remoteness, and the lack of interest of developers and the scientific community in the past, the archipelago has been little studied and the literature about it is scarce.

The relative isolation of the islands as well as the small size of most of them, which renders them inappropriate for colonisation have so far prevented much development. However, isolation is becoming insignificant thanks to modern transport (planes and fast boats) which makes resources more accessible and attractive. People come from the mainland of Panama and neighbouring countries, mainly to exploit the fisheries and marine resources or to work for the developing tourism industry.

Pressure on several fisheries has already led to significant stock declines with some populations unlikely to recover. Fishing is the main activity of 64% of the population of Las Perlas and the impact of stock collapse is tremendous on the local economy and livelihoods.

This dissertation study is a contribution to the Darwin Initiative for the Las Perlas Archipelago (DILPA) which was initiated three years ago with the collaboration of Heriot-Watt University, Edinburgh and the Smithsonian Tropical Research Institute (STRI), Panama. DILPA is part of the Darwin Project, a fund created by the British Department for the Environment, Food and Rural Affairs (Defra) to promote sustainable development around the world and help developing countries meet their commitments to the United Nations Convention on Biological Diversity.

In light of the recent interest of developers to the area, in particular the tourism industry, and negative impact of over-fishing, DILPA's aims are to study the natural environment of the archipelago and propose managerial solutions for its future.

In just three years, DILPA has already contributed significant material to the understanding of the natural environment of Las Perlas. This has included mapping with remote sensors and GIS, the description of marine and coastal communities and habitats, as well as socio-economical studies on fisheries and involvement of the local population to the sustainable management of their islands.

Campbell (2005) found that 92.5% of the local population believes that a Marine Protected Area (MPA) would be beneficial to the management of the archipelago. The same survey showed that a large proportion of the population had noticed declines in fish catches and would be willing to participate in many aspects of an MPA's management.

Scientific evidence of the benefits and necessity of the introduction of management tools in Las Perlas gathered by DILPA and STRI has contributed to the government's awareness of local issues. In October 2005, a law to create a Special Management Zone (SMZ) was submitted to the National Assembly of Panama. The SMZ and associated regulation are being finalised by the Panamanian government and should become effective over the next few months. The proposed SMZ will include more than 99% of the total area of the archipelago (Comisión de población, ambiente y desarollo, 2005a).

With many islands less than a few kilometres across, and in the context of sea level rising, there is particular concern over shore stability and sedimentary processes in general. Beaches are among the most labile features of coastlines and the next section describes their value to a number of users and why they can serve as good indicators of change on the islands.

1.2 Beaches of Las Perlas

The best estimate of the number of beaches in Las Perlas was achieved by counting beaches appearing on available maps for 13 islands. The average number of beaches per island was 12.6 and when this number is multiplied by the number of islands the estimated total is 3,188. This, offcourse, is a very poor estimate as it should take into account lengths of considered coastline rather than number of islands and due to the fact that island number is also uncertain (due to different definitions of what an island is, estimates range between 53 and 300, in the proposed SMZ law the value of 255 is used). However, it reflects the abundance of beaches in the archipelago.

They are mostly undeveloped with the exception of a resort and a few hotels on Contadora Island and some villages.

Due to the absence of important freshwater systems on the islands and the distance from the mainland, the main source of sediment in Las Perlas are assumed to be from offshore sources, including biogenic material, and erosion of the islands themselves.

Following is a description of the main user groups which are related to beaches because they either use beach resources, are likely to have an impact on beaches or are likely to be affected by beach and sedimentary processes.

1.2.1 Tourism

At present, tourism in Las Perlas is concentrated on Contadora Island in the North but is likely to spread to other islands in the near future as tourism in the archipelago is being promoted by the Panamanian government (Gardelis, 2004) and as more development proposals have already been made on other islands (Jackson, 2006; Bamrud 2006). In particular, an

ecotourism resort on San José Island is being further developed while a large project is under development on Viveros Island (Jackson, 2006; Bamrud 2006).

The Panamanian government's push forward for tourism development takes into account the environment and in addition to the project law for an SMZ, it worked in partnership with the United Nation Development Programme (UNDP) on a 'Master Plan for Sustainable Tourism Development of the Las Perlas Archipelago and Isla del Rey' (Gálvez, 2005). This project involved the private sector and led to the mobilization of important foreign investment.

The programme included the development of new land use regulations prohibiting unsustainable tourism development projects. A waste management plant is also planned which will provide renewable energy to hotels and resorts (Gálvez, 2005).

Some of the most important assets of Las Perlas as a tourism destination include i.) the aesthetic value of the natural environment, in particular beaches, coral reefs and the abundance of small uninhabited islands, ii.) the balance between a relatively easily accessed location and feeling of remoteness, iii.) the abundance of marine, terrestrial and avian wildlife (more detail in *subsection 1.2.2*) for observation and recreational fishing.

The suitability of beaches to tourism depends on a number of factors. Micallef and Williams (2002) list 'physical aspects (local geology and geomorphology), biological attributes (flora and fauna) and a number of socio-economic criteria represented by recreational amenities, access, safety, landscape (aesthetics), archaeology, commercial interests and environmental quality criteria (cleanliness, hygiene and toilets facilities)'.

There are many beaches at Las Perlas which offer appropriate physical settings and possess biological attributes which would make them appropriate recreational sites. However, at present, there are few facilities designed for tourism. Facilities related to tourism can be

divided into the following categories: access, light facilities, accommodation/restauration and recreational facilities.

- **Access:** this includes transport to the islands from the mainland which can be by sea or air. There already exist a number of facilities such as airstrips and jetties or marinas. However, if traffic was to increase, these facilities might need to be upgraded or new ones added. In addition, the facilities may need to be improved for travellers with special needs (ramps and carriers for wheelchairs, etc…).

This type of infrastructures is large and needs to be developed in areas which are relatively protected from wind and surf/swell.

Maritime infrastructures are the most likely to affect sedimentary processes as they might be designed to include hard structures such as break walls and may require dredging. The impact of dredging is discussed in more details in subsection 1.2.4 Sand Mining and Channel Dredging.

Within the islands, distances are short, with the largest island, Rey Island, not exceeding 28kms in length. Transport can therefore mainly be handled by foot or light vehicles. Furthermore, transport can be by boat where access from the land is difficult.

Small dirt roads and tracks would therefore be suitable in most cases even though, again, some visitors might need hard surfaces if they are unable to or have difficulties walking.

Traffic between islands can be handled by boat and watercrafts such as jet skis. At present, these usually launch directly from the beaches and few jetties are available. However, tourists may have different needs in terms of the type of vessels they use and larger, more comfortable boats might be preferred which may not be suitable for beaching. This might lead to the

construction of more jetties or even larger structures. Such infrastructures are likely to be small and if they have an impact, this is likely to be localised.

- **Light facilities** include toilets, bins, carparks, sitting, shades, showers, barbeques… They provide comfort to the visitors and are management tools which can help reducing environmental impact. Toilets and bins in particular can help reduce waste inputs while carparks, sitting facilities, shade and barbeques can be used to canalise traffic and some activities in specific areas. Barbeques also reduce fire hazards as visitors are less likely to build fires which present a danger to the visitors themselves and the surrounding environment. Light facilities usually have a low impact on the environment however to be efficient they need to be maintained appropriately which can be demanding in resources and manpower.

- **Accommodation/ restauration:** The range of possible accommodation and restauration services is very wide and will depend mainly on developers and the customers they target.

These facilities are likely to be developed near shores and in particular beaches, as the scenery and recreational features of such settings are highly attractive. The proximity to shores can however present risks linked to erosion and flooding and appropriate siting is therefore very important, in particular for large structure which can enhance erosional processes.

The construction of building in the proximity on the littoral may also have other negative effects on the landscape and through the destruction of habitats.

For people travelling and staying on their own boat, facilities may include moorings or more equipped marinas with access to power and water supplies and showers.

- **Recreation**: these facilities might be found within resorts and hotels or can be independent. At Las Perlas, most recreational activities would be expected to be centred on

water activities and wildlife. This might create some conflict where different activity groups want to use the same area, for example the traffic of watercrafts can make swimming or snorkelling unsafe and the noise from powered craft may disturb beach goers or wildlife.

The archipelago has been used by filming crews on several occasions, for the shooting of movies as well as reality television shows. This is treated with tourism, as in many ways, the arrival of a filming crew to the archipelago resemble that of tourists, even though in some ways it is on a much larger scale.

Episodes of the TV show 'Survivor' were being shot during some of the time spent for field work for this study. As a result, the resort, hotels and rented accommodation on Contadora and Saboga were full and there was a noticeable increase in boat traffic.

The attraction of the industry is based on similar assets (landscape, relative remoteness, wildlife…). Like tourists, the crews require accommodation and restauration. However, their needs for transport are probably higher than that of most tourists.

In addition, if movie and television crews might expect or wish for facilities to enjoy during their leisure time, they also require wild settings with no facilities at all for shooting. They also expect no other users on the beach during filming. (Note the co-operation of the producers when surveying was carried out on Gibraleón Island during a show which is based on the participants being completely isolated from the rest of the world).

Only 8.1% of a survey population viewed tourism as an important resource (Campbell, 2005). This might be associated with the fact that the majority of employment generated through tourism goes to people who are not originally from the archipelago but from the mainland or other countries (Campbell, 2005).

Tourism development can lead to increased erosion where constructions are too close to the shore or where large areas of wooded land (in particular mangroves) are cleared. Furthermore, the abundance of visitors can lead to habitat destruction (and possibly erosion) through trampling. This is also true for marine habitats where fin kicking, anchors and propellers in particular, can lead to severe damage to benthic and coral communities.

Note that tourism development goes beyond the construction of facilities for tourism as workers who move to the islands also need housing, services, etc. There is also a risk of relocation of the existing population to less attractive areas as richer outsiders buy land. On the Bragança coast in Brazil, Krause and Glaser (2003) showed that local population relocation led to mangrove clearing and severe erosion and shoreline retreat.

1.2.2 Conservation and scientific research

Due to low human impact on the environment and a rich biodiversity, Las Perlas offer a great setting for conservation and research in the natural sciences. STRI has engaged in several research projects mainly on ecological systems. There is no known research station and visiting scientist utilise facilities usually catering for tourists.

In addition to fundamental research, species richness offers great study material in technological and industrial application, in particular the pharmaceutical industry with species of corals and sponges with known potential (Comisión de población, ambiante y desarollo, 2005a).

There are 15 known pre-Columbian archaeological sites and large numbers of sub-marine relicts dating from the Spanish colonial era from the beginning of the XVIth century (Comisión de población, ambiante y desarollo, 2005a).

Usually the impact of research on the environment is low, but there can be some conflict with other users of the area as their impact might be seen negatively by the researchers. Some projects may require living marks or measurement and recording devices which can be seen as visual pollution and/or may be tempered with.

Conservation is being recognised as an important aspect of the management of the islands as evidenced by the creation of the SMZ. The project law describes the conservation value of Las Perlas and the following section is drawn from this (Comisión de población, ambiante y desarollo, 2005a). Habitats and species are recognised for their intrinsic value and their service value, in particular as important fish habitats contributing to the health of fish stocks. The proposed law recognizes, in particular, mangrove habitats and coral reefs and communities. Coral reefs and communities are rare in the Tropical Eastern Pacific and Las Perlas is a hotspot of abundance and diversity in Panama (Autoridad Nacional del Ambiante, 1998 p38; Berman, 2004). Terrestrial habitats are mainly composed of mature and secondary tropical forest.

Beaches are used as nesting sites by 5 species of marine turtles, all protected internationally, and two of which the Leatherback (*Dermochelys coriacea*) and Hawksbill (*Eretmochelys imbricata*) turtles are critically endangered. There are at least 8 beaches which are used by the different species in Las Perlas (Guzman, pers. comm.).

A sanctuary for the Humpback whale (*Megaptera novaengliae*) to which Las Perlas constitute the preferred area for reproduction in the Tropical Eastern Pacific has been implemented by law in 2005 (Comisión de población, ambiante y desarollo, 2005b). Other cetacean species are known to use the waters for reproduction or feeding.

Las Perlas hosts over 150 avian species, with 16 endemic subspecies, 5 threatened or vulnerable species and nationally important colonies of Brown pelicans (*Pelecanus*

occidentalis) (*figure 1.2*), Neotropic cormorants (*Phalacrocorax brasilianus*), Blue-footed boobies (*Sula nebouxii*), Magnificient frigatebirds (*Fregata magnificens*) and Brown boobies (*Sula leucogaster*).

Figure 1.2: Nesting site of the Brown pelican: adults and fledging juveniles.

The archipelago contributes to the status of the Pacific coast of Panama as the richest in fish species with the highest rate of endemism. This is explained by the great number of islands and their closeness to the mainland which create a system of typical and atypical habitats. Notably, the largest of all, the whale shark (*Rhinchodon typus*), listed on the IUCN Red List of Threatened Animals with indeterminate status (ecoocean.org) is a regular host of Las Perlas.

In addition, there are 10 species of mammals and 7 listed reptiles.

Conservation is normally carried out with the aim of preserving landscapes and biodiversity and in the case of Las Perlas, it will insure the value of the environment to a range of users (fishermen, agriculture, tourism, film and TV industries) which rely on ecosystem functions and/or attractive natural features such as pristine areas and wildlife abundance.

However, there is often conflict arising because conservation may require these users to qualitatively and/or quantitatively revise their activities. The benefits are not always understood, which can and should be prevented through education, and the time scale of conservation aims may be in disagreement with immediate needs.

Erosion could lead to the loss of important habitats such as mangroves or bird and turtle nesting sites. Increased sediment transport may disturb benthic systems through benthos instability and increased turbidity, leading to the smothering and reduced photoproduction.

1.2.3 Fishing

Fishing is the main activity in Las Perlas with approximately 65% of a survey population dedicated to it (Campbell, 2005). Nearly a third of these people do not sell their catch which is used for personal consumption. Fishing is mainly artisanal but some industrial vessels do come from the mainland (Anderson, 2005; *figure 1.2*). Small-scale artisanal fishing is mainly by 'hook and line' or skin-diving on bongos (Anderson, 2005; *figure 2.1*).

Figure 1.2: Francisco, a seine net fishing vessel from the mainland

Several fisheries have collapsed in the past with no recovery observed several decades later. The most famous examples are that of the pearl oysters from which stems the name of the

archipelago (Las Perlas means The Pearls), and of the scallops. Recent surveying of other invertebrates indicate dramatic decline of several species (Guzman, pers.comm.). Several finfish species are also under significant fishing pressure (Anderson, 2005).

Some of this has been associated with the presence of Kuna Indians from the North of Panama who are known to skin-dive for these species (Campbell, 2005). From conversations with local residents, it was gathered that there is a conflict with Kuna Indians who are not welcome. A similar attitude exists towards larger, industrial vessels from the mainland.

The Panamanian government and about 82% of the local population of Las Perlas recognize a decline in fin- and shell-fish in the area (Campbell, 2005; Comisión de población, ambiante y desarollo, 2005a).

Over-catch is often the main reason for stock decline, however, habitat destruction is also an important contributor. Many fish species utilise different types of habitats throughout their life-cycle and it is important that these are adequately protected.

Even though there is little fishing from beaches or in their vicinity, fish production could decline severely if sedimentary processes were disturbed. For example, if sediment in suspension increases, reduced primary production and disturbance of sessile organisms could lead to the collapse of entire food-chains, including fished species. Increased erosion could also lead to the loss of nursery habitats like mangroves.

1.2.4 Sand Mining and Channel Dredging

A license for sand mining offshore Las Perlas is under negotiation (Guzman, pers. comm..) between a private company and the Panamanian government. The extent of the project is yet unknown but a site has been proposed to the North-East of Viveros Island. The exact location of the site is unknown.

As mentioned earlier, dredging for waterways is also likely to take place and as the environmental impacts of these two activities share similarities, they are treated here together.

The most direct impact of removing material from the seafloor is to mechanically destroy benthos communities. Adjacent pelagic and benthic communities are subjected to increased sediment in suspension, in particular with fine particles, toxins and nutrients with the effect of smothering and clogging organisms, reducing photosynthesis and increasing toxicity (Carter, 1988; Morton, 1977). Dissolved oxygen tends to decrease in the water column above dredging sites (Morton, 1977). The recovery of these habitats and possible re-colonisation depends on the intensity of dredging.

Less direct effects of dredging are related to changes in the morphology of the seabed and their impact on sediment transport. The spatial and temporal scales of such processes can be up to several kilometres and years (Morton, 1977; Price et al., 1978).

Modifications to the morphology of the seabed can act to reduce the dissipation, breaking and reflection of wave energy (Price et al., 1978). This is translated at the shore by changes in wave energy and attack angle thus leading to changes in littoral drift and shoreline stability (Price et al., 1978). The gap in the seabed left behind, after material removal, can act as a sediment trap, leading to a deficit in beach sediment budgets and shoreline erosion (Price et al., 1978).

Borrow zones close to shores tend to get filled with silt size material which is undesirable in recreational beach areas and can be detrimental to marine organisms.

It would be expected that a defined area around the mining site would be closed to fishing and other vessel traffic and this can lead to conflict if this area is presently frequently used.

1.2.6 Beaches and coastal protection

With global warming and relative sea level (RSL) rising expected to continue over the next decades, there is concern over land loss and this is particularly true for small islands (IPCC, 2001). Beaches act as buffers of wave energy and it has been shown that they act to maintain coastline stability (Carter, 1988; Byrnes et al. 2004). Beach nourishment is practiced throughout the world for recreational but also coastline protection purposes.

1.3 Beaches as monitoring and fundamental research tools

Coastal environments are very dynamic and their management is more successful if this is understood and integrated into planning strategies. Monitoring allows the detection of change in the environment, may it be natural or human induced and is therefore an indispensable tool in coastal management.

Beaches offer many advantages as indicators of change in coastal sedimentary processes: they are easily accessible at low tide and very labile, responding promptly to changes in the physical forces which shape them.

There is constant sediment exchange between beachfaces and adjacent features (surf zone, berm, dune…) (Masselink and Puleo, 2006). This leads to changes in the morphology of beaches which can be easily monitored by regular surveying of beach transects and the analysis of corresponding profiles. Careful analysis of beach morphodynamics and sediments provides information not only on the processes occurring on the beach themselves but can also give an indication of sediment movement direction and intensity on a wider scale and can help in the identification of the source and target of any detrimental impact.

The driving forces behind the movement of sediment are waves/swells, currents, tides and wind while the type of sediment and beach morphology affect the extent of transport (Carter, 1988; Komar 1998; Short, 1999; Klein and Menezes, 2001 Woodroffe, 2002; Masselink and Puleo, 2006). The effect of wind is usually insignificant in comparison to hydrodynamic forces and has very localised impact so that it is often left out of beach dynamic studies (Carter, 1988).

The theoretical concept of beach equilibrium assumes that under any set of hydrodynamic conditions, beach slope will be shaped overtime into a stable slope sometimes referred to as 'equilibrium gradient' (Masselink and Puleo, 2006). If the beach is flatter than the equilibrium gradient, sediment will be moved onshore, eroding sediment from the bottom of the beach and moving it to its top and resulting in a steeper gradient. If the beach is steeper than the equilibrium gradient, sediment transport will be offshore, reducing slope (Carter, 1988; Woodroffe, 2002; Masselink and Puleo, 2006).

Because hydrodynamic conditions are ever changing, so is beach slope. However, it can be assumed that overtime, under natural conditions, these conditions will only change within a certain range and a beach will assume a limited range of slopes revolving around its 'median gradient' (Carter, 1988).

The aim of beach profile monitoring is to identify this range of slopes and how it responds to varying hydrodynamic conditions. This information can then be used in

a) forecasting events such as flooding, erosion or silting
b) siting development projects where the range of conditions is the most adequate
c) isolate unnatural deviations from the expected range of slope.

Changes in beach morphology indicate changes in 'sediment economy' which affects not only the beaches themselves but a range of habitats.

In particular, sedimentation affects coastal habitats, benthic systems and water turbidity. Where sedimentary processes are highly dynamic, colonisation by benthic communities can be physically limited and high turbidity may reduce primary production. Ecological processes being intrinsically complex and inter-linked, any modification in sediment movements could have tremendous impacts on a variety of organisms and habitats.

Over the long term, the information collected through monitoring can be used to better adapt to the environment. For example where waterways are concerned it is interesting to know where shoaling is the least likely to occur or for coastal development where the risks of erosion or flooding are highest.

Monitoring beaches in Las Perlas offers more perspective than serving as a management tool. Beach morphodynamics and sediment transport are yet little understood processes (Klein and Menezes, 2001; Masselink and Puleo, 2006) and beachfaces have been described as 'one of the most scientifically challenging oceanic environments for describing sediment transport' (Masselink and Puleo, 2006). From an academic point of view, Las Perlas offers a close to ideal setting for studying these processes.

With certainly thousands of beaches in pristine condition, in a relatively small area, one could expect to find a range of beach types and environmental conditions which would allow gathering invaluable data. Different degrees of beach embayment, sediment types and exposure to swells and currents are found in the archipelago and are relatively close to each other and easily accessible.

2. Materials and methods

2.1 Study area and general organisation

For this study, 10 islands (17 beaches) and 1 sand 'bar' were visited. On most islands, one beach was visited with exception of Chapera, Mogo Mogo, Rey and Saboga islands where several beaches were explored. The 18 sites were numbered roughly from North to South and are shown in *appendix 1*. The length of beaches was measured on maps.

Field work was carried out during two successive trips to the archipelago. The first trip took place between the 11th and 19th of May 2006 while the second trip was between the 11th and 16th of June of the same year. The work was carried out by teams of two or three people on the sites and a person in charge of the transport and boat.

Transport to the beaches was by boat and accessibility was condition dependent (e.g. safe landings on low surf/wave areas).

On the first trip, the embarkation was shared with another team from the Darwin Initiative and was a large boat with a cabin and a capacity of 10 people. The vessel could not reach the shore and had to remain in at least 1 meter of water depending on sea conditions.

On the second trip, a 'bongo' (*figure 2.1*) was used to get to the sites. This type of embarkation is typical of the local artisanal fisheries and is an approximately 20 feet long, narrow fibreglass boat with outboard engine.

Loading and unloading the equipment was easier with the bongo, however in rough conditions (which were not experienced with this embarkation) it might have been impossible to approach beaches. On one occasion, with the larger boat, the surveying equipment could not be carried to shore safely due to extreme weather conditions.

Figure 2: photo of the 'bongo' used for transport during the second field trip.

Islands and beaches were selected to represent a variety of sizes and nearby population densities. Some beaches were chosen for being known to be used for a variety of reasons. This included tourism, an airstrip and tourist accommodation construction site as well as turtle nesting sites. A number of beaches were chosen for their location and orientation in relation to the proposed mining site and their potential susceptibility to change as a result of sand extraction. Saboga Island was found to be used for illegal 'artisanal' sand mining and other islands were used by reality TV filming crews.

2.2 Beach profiles

At every beach, except on San José Island, three transects, running perpendicular to the shore line were surveyed. Transects were numbered from 1 to 3 with number 1 always corresponding to the transect on the left of the beach when viewed from the sea.

At the top of each transect a homemade 1-meter long, 3cm in diameter PVC tube was staked as a benchmark, leaving at least 20cm of the tube visible. Benchmarks were located above the highest visible high water mark (strandline). The location of the benchmark was recorded using a handheld GPS and a photo was taken to allow future surveyors to return to the exact location. On beach 3 (Contadora Island), human made, hard structures were used as

benchmark as PVC tubes might have been tampered with on this highly frequented beach and as the hard structure would be easier to locate in the future. The compass bearing of transects was also recorded.

Transects were approximately equidistant, with transect 2 (central transect) located about half way down the beach length and the 2 other transects about a quarter up or down the length. However, this was not always feasible for a number of reasons:

a) The beach was too long, and there was not enough time to cover the ideal distance as transects ought to be surveyed at low tide.
b) The top of a profile would have been on rocks, making it impossible to stake a benchmark. On one occasion, due to the prevalence of rocks at the top of the beach, the benchmark was signalled with marker pen on the rock itself.

Furthermore, the location was determined by expected ease of finding the benchmark in future surveys (e.g. proximity of obvious feature, absence of dense vegetation) and/or the presence of beach forms which would be expected to change over time (e.g. freshwater stream, berm…).

At each transect, measuring tape was attached to the benchmark and laid across the beach. Height and distance were recorded before and after any change in steepness and/or change in sediment or rock type. When there was no obvious change, records were taken at regular intervals (±15m). This was done using an auto level TOPCON AT-F7 on a tripod and a 5-meter extendible graduated pole.

At low tide, wood sticks found on the beach or PVC tubes were used to mark the water edge of each transect and the corresponding height, length and GPS coordinates were recorded.

During the second field trip, the methodology was modified to allow surveying two beaches per day. Since it was physically impossible to mark low tide at both beaches, 'a' water mark, as low as possible, was surveyed at each transect and corresponding time recorded.

Since no information on tidal fluctuation was available for the archipelago, tide tables for Balboa (the port at the Pacific end of the Panama Canal, approximately 70km from the North of the Archipelago) were used to determine the semi-diurnal macro-tidal range. The tables for the year 2006 indicated that the highest tide was 5.67m above chart datum (CD) while the lowest tide was 0.55m below CD.

Using these tidal predictions, the height relative to CD was found for recorded low tide marks. Where 'a' water mark had been recorded, height relative to CD was calculated based on the time of recording. A spread sheet was devised to calculate the rate of water level change by inputting the duration of the half-cycle (between low and high tide) and the change in water height for this duration. It was assumed that during the first half of the half cycle, the rate of change of water level increased by a twelfth every sixth of the duration while this trend was reversed during the second half.

The spread sheet outputs were rates of change for every sixth of the duration of the half cycle (approximately one hour) in centimetres by minutes. These were used to calculate the height of the recorded low water mark in relation to CD (based on the time of recording).

Recorded heights were adjusted in relation to CD based on the new low water marks heights and were plotted against distance to produce a profile for each transect. The distance corresponding to the lowest water mark (0.55m below CD) was extrapolated based on the slope of the lowest section of the profile. The distance corresponding to the highest water

mark (5.67m above CD) was either determined graphically or extrapolated when it was above the highest recorded height.

For each transects two slopes were calculated and expressed in percentages.

a) Extrapolated slope: this was equal to the tidal range (5.67 + 0.55 = 6.22m) divided by the distance between the extrapolated lowest and highest water marks (extrapolated intertidal width).

b) Observed slope: this was calculated using the largest distance actually surveyed within the intertidal zone (first survey point below 5.67m and last survey point above -0.55m) and the corresponding change in height.

Figure 2.2 shows corresponding intertidal widths and slopes within the range of observed values.

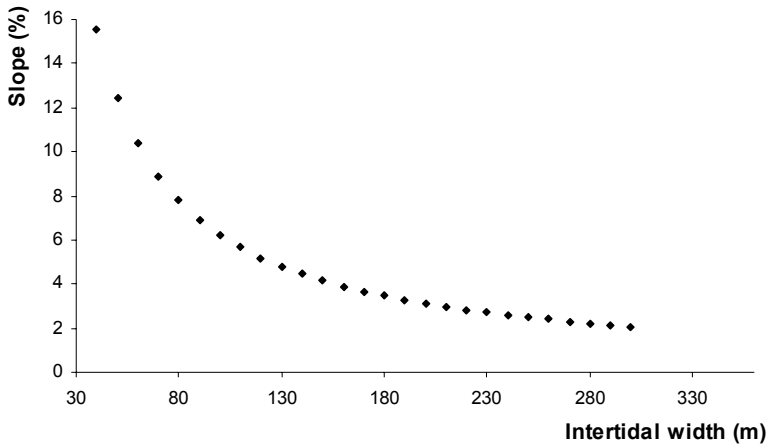


Figure 2.2: relationship between intertidal width and slope for a 6.22m tidal range.

2.3 Sediment analysis

At each site (17 beaches and 1 sand bar), surface sediment samples were collected for analysis. At all beaches where profiles were surveyed, samples were collected at the bottom, halfway up and the top of the transect 2 (middle transect).

At Bajo Boyarena, the sand bar, one sample was collected at mid-tide level on the west side of the exposed sand and GPS coordinates were recorded. At San José, where it was not possible to unload the surveying equipment due to rough sea conditions, sediment samples were collected along an imaginary transect near the southern end of the beach and GPS coordinates positions were also recorded.

The samples consisted of approximately 50g of sediment, collected from the top 15 cm layer of sediment with an extemporary soil tube and were stored and frozen in zip-lock bags. These were analysed by Heidi Collazos in Panama City for organic carbon and carbonate contents as well as grain size distribution.

For each sample, cumulative grain size frequency distribution was plotted and Φ_{50} (median grain size), Φ_5, Φ_{16}, Φ_{84} and Φ_{95} (grain sizes corresponding to the respective percentage frequencies) were read off the graph and used to calculate σ_1 (sorting) using:

$$\sigma_1 = (\Phi_{84} - \Phi_{16})/4 + (\Phi_{95} - \Phi_5)/6.6$$

In addition sediment samples for metal analysis were collected at 5 beaches, using the same procedure. These have not been analysed yet but have been washed with deionized water and dried overnight in a slow oven and are stored at STRI.

It had been intended to collect sediment for infaunal analysis as well. These were to be sieved in the field and preserved in alcohol to be sent to the laboratory for analysis. However, due to the coarseness of the sediment, volumes remaining after sieving were too large for storage and transport.

2.4 Photos and GPS positions

At each site, and in particular at San José, where no transect were surveyed, interesting features were recorded and photographed. The GPS position of these features was also recorded. The amount of information recorded for each site was mainly dependent on the time available which varied at each location. On the second trip, it was decided that it would be useful to survey twice as many beaches as on the first trip but to reduce data collection since it was not possible to spend as much time recording this 'extra' information.

The type of features of interest consisted in changes in sediment type, the presence of exposed rocks, the edge of rock platforms, etc. These were chosen for their potential for change over time which would make it possible to detect change easily using the record of photographs and positions.

At the sand bar , Bajo Boyarena, GPS coordinates of the edges of exposed sand were recorded and will allow future assessment of any movement of the bar.

GPS coordinates are not presented in the result section but are in *appendix 5*.

3. Results

If not specified otherwise, results are expressed as mean ± S.E.

3.1 General notes about profiles and sediment analysis

Studied beaches had lengths between 100m (beach 1 on Saboga Island) and 3,220m (beach 15 on Rey Island). In total, 45 transects were surveyed and extrapolated and observed slopes ranged between 0.8% (beach 3 on Contadora Island; 0.46°; tanβ =0.008) and 15.7% (beach 16 on Rey Island; 8.92°; tanβ = 0.156). However the low value of 0.8% is likely to be biased (*see subsection 3.2.3*) and a better estimate might be 1.8% (1.03°; tanβ = 0.018) which is still the lowest value. Using this value, the corresponding intertidal width range is 39.6 to 345.6m.

All 50 sediment samples had high levels of carbonates and little organic carbon content. Mean carbonate content for all samples was 84.4±1.6% and was independent of location on the shore ($F = 1.73, p = 0.19$) but varied significantly between beaches ($F = 4.27, p = 0.0003$). The lowest values were at beach 2 on Saboga Island (61.8±4.7%) and beach 17 on San José (64.5±4.6%) while the highest values were at site 11 on Bayoneta Island (96.7±4.6%) and 13 on Viveros Island (94.0±4.5%).

Organic carbon content (OC) averaged 0.3±0.03% and was independent of distribution up and down beaches or between beaches ($F = 1.78, p = 0.18$ and $F = 0.64, p = 0.83$ respectively). Out of the 50 samples, 48 had OC contents lower than 0.4%, the highest value was for the high station sample on beach 4 on Chapera Island which had 1.3% OC. This was the only value above 1%.

There did not appear to be a relationship between OC and carbonate content but even though the differences were not significant, it appeared that samples from the high stations had lower carbonate and higher organic carbon contents than the other two station locations (*figure 3.1*).

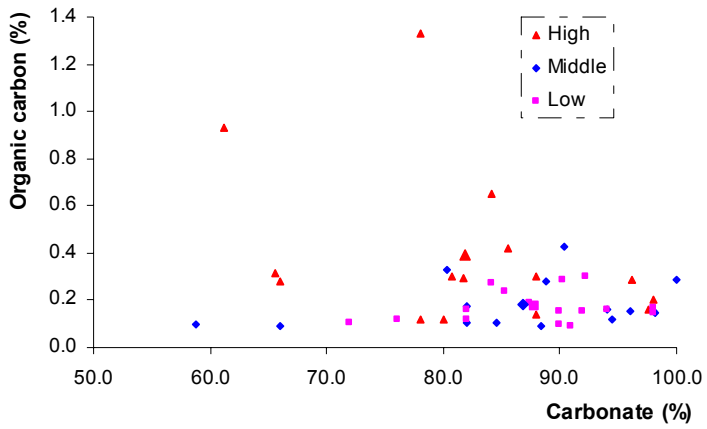


Figure 3.1: organic carbon and carbonate content arranged by position on beach. The *larger data points* are average values for the respective position.

Median grain size (Φ_{50}) was between -1.75 and 3.95 on the Wentworth scale, corresponding to granule/pebble and coarse silt, respectively. Mean Φ_{50} was 0.35±0.17 (corresponding to coarse sand) and was significantly related to beach ($F = 3.73, p = 0.0006$) but not to location on the beach ($\chi^2 = 2.81, p = 0.25$) even though samples from low stations were, on average, coarser and not as well sorted (*figure 3.2*).

Mean Φ_{50} indicated granule/pebble rank at beaches 16 and 17 on Rey Island while the finest sediments were found on beach 7 at Mogo Mogo, Boya Arena and beach 10 on Gibraleón, with mean Φ_{50} corresponding to medium sand.

Sorting (σ_1) ranged from 0.32 and 1.92 which corresponds to very well and poorly sorted sediment, respectively. There appeared to be a trend for finer grain sediments to be better sorted (*figure 3.2*).

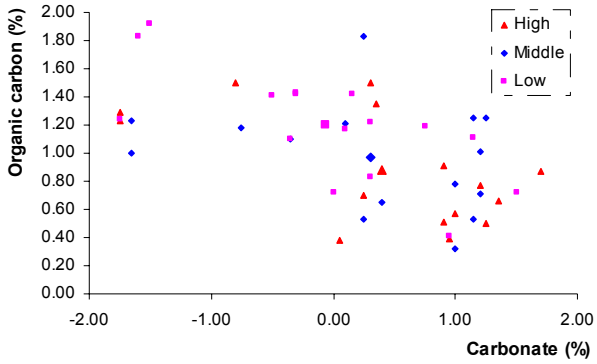


Figure 3.2: Median grain size (Φ_{50}) and sorting (σ_1) arranged by position on beach. The *larger data points* are average values for the respective positions.

There was no straight relationship between OC or carbonate content and grain size or sorting, however sediment samples with high OC or low carbonate levels appeared to be finer (*figure 3.3* and *figure 3.4*).

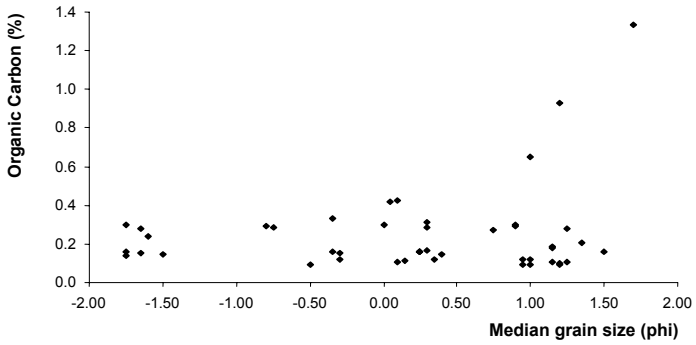


Figure 3.3: Median grain size (Φ_{50}) and organic carbon content.

Similarly there did not appear to be any relationship between slope and sediment characteristics but high levels of OC seemed to be associated with low slopes (*figures in appendix 4*).

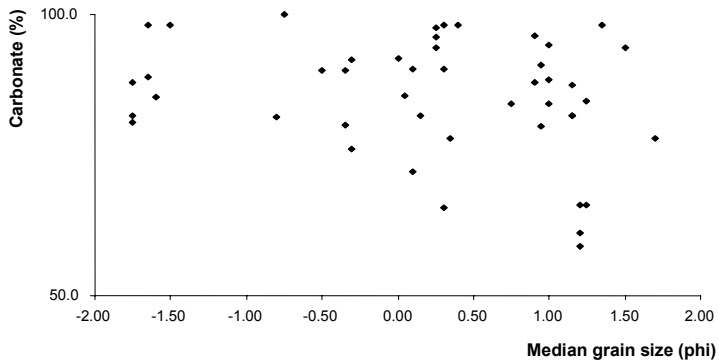


Figure 3.4: median grain size (Φ_{50}) and carbonate content.

3.2 Site by site description and results

Survey data and profiles in appendix 2. Sediment analysis results in appendix 3.

3.2.1 Saboga (beach 1 and 2)

Saboga Island along with Contadora Islands is one of the most northerly of all visited islands. Saboga is to the west of Contadora and is one of the populated islands, with a population of about 380 (Campbell, 2005).

Beach 1 is about 100m long, and the observed and extrapolated slopes for this beach were between 2.1 and 3.9% which was the lowest range of slopes overall. Sediment characteristics are shown in *table 3.1*.

Table 3.1: sediment characteristics for beach 1 on Saboga Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	65.5	Coarse sand	Poorly sorted
Middle	0.3	80.4	Very coarse sand	Poorly sorted
Low	0.2	90	Very coarse sand	Poorly sorted

A freshwater stream meandered through the northern section of the beach creating a small ridge near the benchmark of transect 3. This is visible on the corresponding profile of which the higher section is lower than that of the two other profiles as a result of the stream weathering this portion of the beach.

Figure 3.5: men illegally loading bags of sand from beach 1 on Saboga Island.

This beach was visited on two consecutive days and each time illegal sand mining was observed (*figure 3.5*). Sand was extracted near the stream, where the sand appeared finer and with less pebbles and cobbles which were abundant on the rest of the beach. Several patches of pebbles and cobbles occurred throughout the beach, with the northern end being dominated by these (*figure 3.6*).

Figure 3.6: the northern end of beach 1 on Saboga Island. This part of the beach is dominated by cobbles and pebbles.

Beach 2, adjacent to beach 1 to its south is about 260m long and slopes ranged between 3.8 and 8.1%. However, the value of 3.1% for transect 2 was extrapolated and is likely to be underestimated due to the extrapolated lowest water level being further away than in reality. The observed slope, for the surveyed portion of intertidal zone was 7.5%. When the low value is removed, the range of slopes is 6.8 to 8.1%.

The vegetation consisted of large trees and shrubs at the two extremities of the beach. In the centre, a relatively well developed berm was cover with ground vegetation (*figure 3.7*). It appears on profiles 1 and 2.

Sediment characteristics are shown on *table 3.2*.

Figure 3.7: the berm on beach 2 on Saboga Island.

Table 3.2: sediment characteristics for beach 2 on Saboga Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.9	61.1	Medium sand	Moderately sorted
Middle	0.1	58.8	Medium sand	Poorly sorted
Low	0.1	82	Coarse sand	Poorly sorted

3.2.2 Contadora (beach 3)

The island is about 1.9 by 0.5km while the beach is 530m in length and there is a large coral reef adjacent to its northern headland.

This is the island with the most tourist facilities and the beach surveyed is adjacent to a resort with construction encroaching on the intertidal zone (*figure 3.8*), retaining walls have been built along most of the beach. In addition, a barge, which travels to the mainland several times a week, uses the beach as its loading/unloading and launching platform (*figure 3.9*).

None of the profiles included the highest part of the intertidal section due to the constructions blocking access. The highest surveyed point at profiles 2 and 3 were close to the highest expected water levels, so this was extrapolated (i.e. where the highest water mark would be if there was no construction).

Figure 3.8: photos of the tourist infrastructures on beach 3, Contadora Island.

The benchmark for transect 1 was under a small bridge which goes across a freshwater stream. This was much lower than the expected high water mark and the profile shape was very irregular due to the action of the stream. It was therefore not possible to extrapolate the highest water mark.

The slopes of the highest sections of profile 2 and 3 were very similar (*see profiles in appendix 2*), however the lower portion of transect 3 was much flatter and this resulted in large differences in the observed and extrapolated slopes for the two profiles. Profile 2 had both slopes as 6.9% while the extrapolated and observed slopes of profile 3 were 2.6 and 4.8% respectively. For profile 1, the slopes were much flatter than the other two, with 1.8 (observed) and 0.8% (extrapolated).

Figure 3.9: barge on beach 3 on Contadora Island.

The flat portion of beach near profile 1 can be explained by both the freshwater stream at work on this section of the beach and possibly the effect of the barge.

Table 3.3 shows the results of the sediment analysis for beach 3.

Table 3.3: sediment characteristics for beach 3 on Contadora Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.1	80.0	Coarse sand	Well sorted
Middle	0.4	90.4	Coarse sand	Poorly sorted
Low	0.1	72	Coarse sand	Poorly sorted

3.2.3 Chapera (beach 4 and 5)

The island is rather small, 2.01 x 1.44 km approximately and from an aerial photo from this year, there is only one house on the island. However, due to its closeness to Contadora and tourism developments, it is likely to be affected by high numbers of visitors. Two beaches were surveyed, one on the west of the island (beach 4) and one on the south (beach 5). Reality TV crew members informed us that filming was to take place on this island. Beach 5 faces the proposed mining site.

Beach 4 is about 550m long and its steepness was between 3.2 and 6.5%. The profiles at this beach were very regular with no berm except for a very poorly developed section in the middle (appearing on profile 2). There were extensive patches of cobbles and pebbles throughout this beach.

Table 3.4 shows its sediment characteristics. The top station sample had the highest OC of all 50 samples.

Table 3.4: sediment characteristics for beach 4 on Chapera Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	1.3	78.0	Medium sand	Moderately sorted
Middle	0.1	76.0	Granule	Moderately sorted
Low	0.3	88.9	Very coarse sand	Poorly sorted

Beach 5 is about 410m in length and was rather steep with slopes ranging between 6.8 and 10.8%. Its planform is peculiar as its southern end follows the corner of the island.

Table 3.5 shows sediment characteristics for this beach.

Table 3.5: sediment characteristics for beach 5 on Chapera Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.4	85.6	Coarse sand	Well sorted
Middle	0.2	94.0	Coarse sand	Moderately well sorted
Low	0.3	90.3	Coarse sand	Poorly sorted

The vegetation was similar on both beaches with thick trees and shrubs and little undergrowth.

3.2.4 Mogo Mogo (beach 6, 7 and 8)

This island has a very particular shape with two main sections separated by a sandy 'bottle-neck' section. Beaches were surveyed on each side of the bottle neck (beach 6 on the east and beach 7 on the west) as well as one beach on the largest of the main island sections (beach 8). There is one building on the island, which was not accessible but resembles a large house or possibly a hotel from afar. Both beaches adjacent to the bottle-neck, as well as a third one which was not surveyed, have been used by reality TV filming crews for several years.

Beach 6 is 770m long. The three profiles were very similar, but steepness was highly variable between observed and extrapolated calculations, ranging between 5.3 and 7% and 2.3 and 2.7% respectively.

This can be explained by the fact that the lower section of the beach was much flatter than the top and that the steepness of this lower section was used to extrapolate the lowest water mark. It is interesting to note on the profile (*appendix 2*), that the deviation of transect 3 from the

two other transects corresponds to a rock outcrop. However, it does not affect the rest of the profile which remains aligned with the other two.

Most of the beach was sandy with some pebbles and exposed rocks towards the southern section.

Table 3.6 shows results from the sediment analysis for this beach.

Table 3.6: sediment characteristics for beach 6 on Mogo Mogo Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.6	84.1	Medium sand	Moderately well sorted
Middle	0.1	88.4	Medium sand	Very well sorted
Low	0.1	90.1	Coarse sand	Well sorted

Beach 7 is 400m in length and had slopes between 3.6 and 9.8% with the most southerly transect being very flat at the top so that the highest water mark, if extrapolated would have been further than the eastern limit of the island (i.e. in the sea).

Sediment characteristics are shown in *table 3.7*.

Table 3.7: sediment characteristics for beach 7 on Mogo Mogo Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.2	98.0	Medium sand	Moderately well sorted
Middle	0.2	82.0	Medium sand	Poorly sorted
Low	0.2	87.5	Medium sand	Poorly sorted

The vegetation between the two beaches was made up of large trees and dense bushes towards the south and some mangrove trees in the north. There was a clearing in the central section between the two beaches, which is believed to have been cleared for reality TV shooting purposes and was being recolonised by ground vegetation, in particular graminae.

Beach 8 is 310m in length and its steepness ranged between 5.3 and 8.5%. However, because transect 1 ended on rocks, it was difficult to extrapolate the low water mark for this profile which appeared flatter than the other two.

This beach had many exposed rocks throughout its length and an abundant cobble patch at its western end (*figure 3.10*).

Figure 3.10: photo of cobble patch on beach 8 on Mogo Mogo Island.

For unknown reason, the sediment sample collected at the high station went missing. *Table 3.8* shows the sediment analysis results for the other two stations.

Table 3.8: sediment characteristics for beach 8 on Mogo Mogo Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
Middle	0.1	66.0	Medium sand	Moderately well sorted
Low	0.1	90.0	Very coarse sand	Poorly sorted

The vegetation consisted of very thick bushes.

This beach faces the proposed mining site.

3.2.5 Bolaňo (beach 9)

This is one of the smallest surveyed islands being about 750m across. The survey beach facing west is relatively protected due to its position relative to other islands. However it faces the proposed mining site and is relatively close to it. Its length is about 390m and it is one of the steepest with slopes between 6.9 and 12.1%.

The top of transect 1 consisted of small to large boulders and its lowest part was a rock platform while the middle section was sandy. Transect 3 started with cobbles and finished on pebbles with a sandy area in between. These transects had a marked ridge at their top due to the boulders and cobbles. Transect 2 was very regular, did not have any ridge or berm and was sandy with scattered pebbles all through. The sedimentary analysis results are shown in *table 3.9*.

The vegetation consisted of old growth tall and large trees.

Table 3.9: sediment characteristics for beach 9 on Bolaňo Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.1	78.0	Coarse sand	Poorly sorted
Middle	0.1	94.5	Medium sand	Moderately sorted
Low	0.2	91.9	Very coarse sand	Poorly sorted

3.2.6 Gibraleón (beach 10)

The island is about 1.8 by 0.8 kms and the surveyed beach was 800m long. The surveyed beach was being used by a reality TV show at the time of sampling, with contestants staying at a rudimentary camp site for several weeks.

The beach was rather steep with slopes between 9.4 and 13.4% and the beach appeared to drowning towards the south. There was a well marked ridge along the northern section (*figure 3.11*) which became less marked going south. This appears on the profiles (*appendix 2*) with profile 1 being the most northern one.

Results from the sediment analysis are shown on *table 3.10*.

The vegetation was very heterogenous with some mangrove species in the north, young trees and shrubs in the middle and old trees with important undergrowth in the south.

Figure 3.11: photo of the well formed berm on the northern section of beach 10 on Gibraleón Island

Table 3.10: sediment characteristics for beach 10 on Gibraleón Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	66.0	Medium sand	Well sorted
Middle	0.1	84.5	Medium sand	Poorly sorted
Low	0.3	84.2	Coarse sand	Poorly sorted

3.2.7 Bayoneta (beach 11)

The island is about 1.8 by 1.0 km and there is no known settlement except for the regular use of the surveyed beach as a nesting site by turtles. The beach limits are marked with granite headlands and there are a few apparent large and flat granitic outcrops toward the low water mark. The beach is relatively exposed being orientated west to the open ocean.

The total length of the beach is approximately 1040 meters with slopes between 10.9 and 7.1%. The profiles are steep and there is a berm which becomes wider due north and is best marked in the mid-section (*figure 3.12* and *appendix 2*).

Figure 3.12: photo of the well marked berm in the middle section of beach 11 on Bayoneta Island.

The vegetation behind the beach consisted of low shrubs with abundant ground cover.

The sediment analysis is shown in *table 3.11*.

Table 3.11: sediment characteristics for beach 11 on Bayoneta Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	88.0	Coarse sand	Moderately sorted
Middle	0.3	100.0	Coarse sand	Poorly sorted
Low	0.2	94.0	Medium sand	Moderately sorted

3.2.8 La Mina (beach 12)

The island of La Mina is about 1.1km by 0.7km and the surveyed beach is approximately 410m long. This beach is close to the proposed mining site but does not face it directly. This is one of the flattest surveyed beaches with slopes between 2.1 and 5.2% and the profiles were very irregular due to the presence of rocks.

The fringing vegetation consisted of trees and shrubs with abundant ground cover (mainly graminae). The northern end is also fringed by some mangrove trees however these are scarce.

Table 3.12 shows the sediment characteristics.

Table 3.12: sediment characteristics for beach 12 on La Mina Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.2	97.7	Coarse sand	Poorly sorted
Middle	0.3	100.0	Coarse sand	Poorly sorted
Low	0.1	98.2	Coarse sand	Poorly sorted

3.2.9 Viveros (beach 13)

The island has more or less the shape of a V with branches of approximately 6.2 and 5.7 km. Viveros is an inhabited island with existing tourism facilities. More tourism development is underway, as evidenced by an active construction site for an airstrip and probably more tourism development, as the first 5-10 meters of vegetation along the surveyed beach had also been removed (*figure 3.13*).

Furthermore, while carrying out work on the beach, students in tourism development and one of their professors also paid a visit to the beach. Following a brief conversation with them, it

was still not known what was the exact purpose of their visit however their presence indicates some interest of the tourism industry for this island and beach.

Figure 3.13: photo of worked area on the top section of beach 12 on Viveros Island.

Beach 13 is known locally as Playa de Viveros and is at the extremity of one of the V branches. It is exposed to the north-west open ocean facing the proposed mining site and is about 610m long.

Steepness was between 5.4 and 6.8%. Traces of recent work was mainly visible on the western end of the beach and it appears to have flatten this top section as illustrated by profile 3 which does not have a marked berm as do profile 1 and 2 (*appendix 2*).

Sediment characteristics are shown in *table 3.13*.

Table 3.13: sediment characteristics for beach 13 on Viveros Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	96.2	Coarse sand	Moderately well sorted
Middle	0.2	96.0	Coarse sand	Poorly sorted
Low	0.2	98.0	Coarse sand	Moderately sorted

3.2.10 Rey Island (beach 14, 15 and 16)

This is the largest and most southerly island of the archipelago, approximately 25 by 16 kms. It is the most populated and also has at least four beaches with turtle nesting sites. Three beaches were surveyed on this island.

Beach 14, known as Playa de Punta Coco, is on the southern peninsula (*appendix 1*) and is protected by a prominent headland and Bahia San Telmo. It is about 1,590m long. The southern headland consists of a basaltic platform backed by a clay mound (*figure 3.14*) which extends about halfway up the beach where it is replaced by small and medium boulders (*figure 3.14*) for about 30 meters. The northern headland consists of a rather flat basaltic outcrop. The vegetation behind the beach is dominated by mature trees and thick shrubs.

Figure 3.14: photos of clay mound and boulders on beach 14 on Rey Island.

Profiles 1 and 2 had steepness between 9.0 and 11.1% which is about twice as steep as transect 3 with 4.4 and 3.6% for the extrapolated and observed steepness respectively. This

transect was so flat that the extrapolated highest water mark was more than 70m behind the benchmark.

Table 3.14 shows the sediment analysis results. Because of a change in the surveying team members and misunderstanding about the sediment sampling protocol, samples were only collected at the low and high sections of the beach.

Table 3.14: sediment characteristics for beach 14 on Rey Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	81.8	Very coarse sand	Poorly sorted
Low	0.2	85.3	Granule	Poorly sorted

Beach 15 is just north of the peninsula, on the east side of the island. It is one of the largest beaches known to be used by turtles with a length greater of approximately 3,220m. Steepness ranged between 6.0 and 14.7% and there were well developed ridges and runnels along the length of the beach.

The vegetation consisted mainly of low shrubs and abundant ground cover and there was some mangrove towards the southern end of the beach.

Table 3.15 shows sediment analysis results.

Table 3.15: sediment characteristics for beach 15 on Rey Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.3	80.8	Granule	Poorly sorted
Middle	0.1	82.0	Medium sand	Moderately well sorted
Low	0.1	98.0	Granule	Poorly sorted

Beach 16 is just to the north of Rey Large and 710m in length. It had some of the steepest profiles, between 9.6 and 15.7% and some ridges and runnels.

The vegetation was dominated by low shrubs and abundant ground cover.

Table 3.16 shows the sediment characteristics for this beach.

Table 3.16: sediment characteristics for beach 16 on Rey Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.1	88.0	Granule	Poorly sorted
Middle	0.2	98.0	Granule	Poorly sorted
Low	0.2	82.0	Granule	Poorly sorted

3.2.11 San José (beach 17)

San José Island is a private island where tourism development has been proposed. It already has an airstrip, dirt roads and some buildings. Beach 17, known as Playa Grande is about 2,070m long and is a known turtle nesting site. It is, in fact, the only beach on which evidence of turtle nests were observed (*figure 3.15*). There are also known coral reefs in its vicinity.

Figure 3.15: photo of grooves from old turtle nests, the red and grey A4 folder and clipboard give an indication of the size of the nests.

Due to high swell and breaking waves, surveying equipment could not be unloaded from the boat safely and no profile could be obtained for this beach.

Instead photographs and GPS coordinates of important features were taken.

The southern highly weathered igneous headland was the extension of a rather high promontory (*figure3.16*). Some large to very large boulders had been deposited at the top of the beach adjacent to the headland by a small stream which was dry at the time of sampling.

Figure 3.16: promontory and weathered rocks of the southern headland at beach 17 on San José Island

North of the stream, the beach was backed by a talus-like mixture of dirt and rock (*figure 3.17*) which was vegetated with small trees and shrubs. Further north, the talus-like feature became a soft clay mound with similar vegetation (*figure 3.18*).

Figure 3.17: Talus-like feature on beach 17 on San José Island

Figure 3.18: photo of soft clay mound and detail of material. The pink pencil gives an indication of scale.

The central section of the beach was backed by mature mangrove with trees up to 35m (*figure 3.19*). The mangrove extended up to a large backwater system adjacent to which remnants of turtle nests were observed. Beyond where the water reached the beach, an area dominated by coconut trees, a talus-like feature, similar to that observed on the opposite end of the beach extended into the cliffed northern headland (*figure 3.20*). Large cobbles to medium boulders where found along the talus and headland.

Figure 3.19: photo of mature mangrove trees behind the central section of beach 17 on San José Island.

Figure 3.20: photo of northern headland on beach 17 on San José Island.

Sediments samples were collected from the southern section of the beach and the results from their analysis are shown in *table 3.17*.

Table 3.17: sediment characteristics for beach 17 on San José Island.

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
High	0.1	57.0	Coarse silt	Well sorted
Middle	0.8	54.6	Coarse silt	Well sorted
Low	0.3	82.0	Coarse sand	Moderately sorted

3.2.18 Bajo Boyarena (Sand bar 18)

GPS coordinates (*Appendix 5*) were collected at this exposed sand bar so that in the future, it can be assessed wether it is moving or not and if so patterns of movement can be identified. There was no vegetation on the sand bar and one sediment sample was collected at about mid-tide level (*table 3.18*).

Table 3.17: sediment characteristics for Bajo Boyarena

	Organic C (%)	*Carbonates (%)*	*Grain size*	*Sorting*
Middle	0.2	96.0	Medium sand	Well sorted

4. Discussion and recommendations

It is important to keep in mind that this study was not designed to produce data which could be used to interpret beach dynamics in Las Perlas. Fieldwork was carried out with the aim of setting a monitoring programme and producing the first of a larger baseline data set. One-off profiles and sediment analysis can not be interpreted as these are very much time and condition dependent.

Some of the most consistent relationships in beach studies were not confirmed here illustrating that one-off surveys are not sufficient to describe beach environments. In particular, there was no correlation between beach slope and grain size even though grain size is recognized as the one of, if not the most important, factor controlling beach slope (Komar, 1998; Masselink and Puleo, 2006).

4.1 Future monitoring programme

4.1.1 Methodology

This first series of data collection however provided very useful first hand information on field conditions and how a long-term monitoring programme can be implemented. The most limiting factors of monitoring are funding and time. It is therefore important to develop programmes that are cost and time efficient.

As expected for macro-tidal beaches (Masselink and Puleo, 2006), the beachface of most beaches (exceptions are sites 3 on Contadora and 6 and 8 on Mogo Mogo) was not marked as steeper than the rest of the beach and slopes were rather regular from the edge of the berm to the low tide mark. It is therefore proposed that ‘quick profile surveying’ be used in the future where all needed to be measured is the distance between the benchmark and low water mark.

This technique would allow saving time and would not require the use of the auto-level which was the most expensive, fragile and skill-requiring piece of equipment used in the present study.

The top of the beach and profiles could be surveyed in more details on a less regular basis, using the same method as in this study.

In Las Perlas, there appears to be an opportunity to involve the local community in such a monitoring programme. Campbell (2005) showed the willingness of the population to participate in many aspects of coastal management for their archipelago. Involving the population in future monitoring offers many advantages:

a) It might be possible to have a team of volunteers on each habited island which could do regular monitoring. Other teams who are likely to travel to or near other islands could also be involved.
b) participating in such activities could be a driving force to thinking about and understanding sedimentary processes; by actually measuring changes, people would become aware of these;

The drawbacks of having many people participating in monitoring are repeatability and coordination of data communication and equipment. However, with quick profile surveying, the method is rather straight forward and little equipment is required (a compass and tape measure).

For more detailed surveys, a team working with an auto-level would also be required. This could involve people who already know how to use this or it might be necessary to train people. It would be a good thing to have such a team on the islands as surveying skills are useful in many aspects of development beyond monitoring.

Accuracy could be improved by using an auto-level which also records distance as using tape can lead to errors due to the tape not being straight but following the profile of the beach and the effect of having to go over logs, rocks, etc. Furthermore, this would make surveying much faster as there would be no need for laying tapes down.

Accuracy could also be improved by using a spirit level to insure that the measuring pole is in vertical position as this can lead to relatively large error (Klein and Menezes, 2001).

4.1.2 Frequency of monitoring and site selection

The drawback of the lability of beaches is that it is difficult to differentiate change as a result of natural variation to that of anthropogenic sources. It is therefore important to carry out extensive baseline surveys to isolate background noise. In particular, it is important to distinguish cyclic patterns which might be seasonal fluctuation in the wave environment or tidal cycle from 'progressive' patterns such RSL rising or coastal erosion due to shore development or offshore and mining.

This work is made difficult by the fact that natural forces affecting beach sediment transport are numerous (wave, tide, wind, currents, sea level…) and work on different time-scales (Carter, 1988; Larson and Kraus, 1995).

The time-scale of monitoring in beach profile studies are highly variable and examples of previous studies varied between daily surveying over one tidal cycle (Austin and Masselink, 2006), monthly over two years or three years (Klein and Menezes, 2001; Krause, 2004, respectively).

Larson and Kraus (1995) recommend that profiles are surveyed over several years in order to identify median slope and predict long-term trends (years to centuries).

Depending on available resources, it is recommended that sites are initially surveyed monthly to every three months over one year in order to identify the most labile beaches. Very flat

(dissipative domain) beaches with slopes below 2% and very steep beaches (reflective domain) with slopes above 17% are usually very stable (Carter, 1988). Surveying effort could then be focussed on intermediate beaches.

On theses beaches, it is recommended that quick profile surveying be carried out on a fortnight basis over at least six months and until variation in data plateaus.

It is understood that resources might prevent fortnight surveying of many beaches simultaneously and it is recommended that this is carried out in priority where development or mining/dredging impacts are expected and where there are natural features of particular interest.

Priority beaches identified in this study include

a) Beach 13 on Viveros Island, where extensive tourism development is expected and which is close to the proposed mining site;
b) Beach 17 on San José Island where there appeared to be active and diverse geological features and habitats of important value (mature mangrove, turtle nesting sites and adjacent corals).
c) Beach 1 on Saboga Island where illegal mining may have affected sediment transport.
d) Beach 3 on Contadora Island where the proximity of tourism facilities and launching of the barge are expected to affect sediment transport and which is adjacent to a coral reef.
e) Beaches 6 and 7 on Mogo Mogo Island where the bottleneck feature constitute a fragile feature.

4.1.4 Hydrodynamic and aerodynamic environment

Prediction of sediment transport requires knowledge of seasonal and annual fluctuation in wave climate (Larson and Kraus, 1995), currents, tides and wind. These are very poorly documented at present. Two wind and current cycles have been identified:

a) a yearly cycle, with two seasons, the dry season (January to April) and wet season (May to December) is associated with movement of the Inter-Tropical Convergence Zone (ITCZ). During the dry season the ITCZ is slightly south of Panama, and prevailing strong northerly winds lead to upwelling of cold nutrient-rich water (Forsbergh, 1969; D'Croz et al., 1991). During the wet season, the ITCZ moves to the north of the country and winds are light and variable. During this season, the water in the bay of Panama is warm and has low salinity and nutrient levels, however the direction of currents is unknown (Forsbergh, 1969; D'Croz et al., 1991).
b) The El Niño Southern Oscillation (ENSO) works on 3 to 7 year cycle. Under normal conditions easterly tradewinds dominate while under 'El Niño' conditions westerly winds become prevalent (Kandel, 1999). This cycle is much less regular and difficult to predict.

More detailed information is necessary if sediment transport is to be understood in Las Perlas. Once these winds and currents hit the islands and mainland coast, they must be reflected and deflected to produce small scale patterns which are not yet known.

It is recommended that currents and wave heights be recorded on a regular basis to allow understanding how beach slope responds to these variables and how they affect the movement of sediment. Furthermore, it would be interesting to measure tidal range regularly in order to get a better estimate of intertidal width and relate heights to measured mean sea level. On the long term this would also allow measuring the extent of rising sea level.

4.2 SMZ management in relation to beaches and sedimentary processes

Until the monitoring programme has gathered enough data to make informed, reasoned decisions, the precautionary approach is recommended in the management of Las Perlas. It is recommended that areas be designated with different levels of protection of natural resources and allowed activities (*table 4.1*).

Table 4.1: Examples of possible management areas

TYPE	AIM	LOCATION
Natural reserve	Conservation/ research	Areas of high biological richness with rare or endangered species or communities (coral reefs and communities, turtle and bird nesting sites, mangroves, forest…)
No fishing	Fish stock, diversity and abundance	Important habitats (mangroves, coral reefs and communities, other reefs)
No power boat	Safety zones for bathing, snorkelling, diving, wildlife watching	Near tourism facilities, where most appropriate for activities
Jet-ski, fast boat	Safety, reduce disturbance to other users	Reasonable distance from tourism facilities
No construction	Landscape preservation and safety	High value scenery areas, where erosion is expected
No anchoring	Benthic communities protection	Where there are known rich, rare or endangered species or communities

In particular beaches where turtle nesting is known to take place should be given appropriate protection. It has been reported that sediment grain size affects nesting activity and success of marine turtles which 'test' sediment quality with their heads ('sand smelling') (Mortimer, 1981; Karavas, 2005). Karavas found that the Loggerhead turtle (*Caretta caretta*) nesting density was highest where grain size was the smallest (high Φ_{50}) and sorting was the best (low σ_1). This trend was verified at beach 11 and 17 on Bayoneta and San José islands respectively, but not on beach 15 on Rey Island. The vegetation on all three islands was similar with low shrubs and dense ground cover (for beach 17 this is true where nest sites were found but not

everywhere) and this could be a significant factor affecting which beaches are used by turtles which usually nest near on even in the vegetation (Mortimer, 1981; Karavas, 2005).

It is therefore recommended that the vegetation behind nesting beaches is not modified.

It is well known that turtle eggs are collected for food consumption in Panama and in the province of Las Tablas, we were offered to buy a dozen of eggs for US$1 or 21 dozens for US$15. The fact that eggs are offered to strangers in such large quantities and at such a low price, despite the fact that the activity is completely illegal, is a good indication of how wide the traffic is.

Conversations with habitants of Las Perlas confirmed that egg poaching occurs in the archipelago. In this light, and even though it is recommended that nesting site be as little disturbed as possible, the 'no development' option might not be the best and the presence of people near nesting sites might deter poachers.

It is also recommended that more information is gathered on nesting sites and it might be interesting to monitor nesting activity and success in the future to identify favourable factors.

Where development is to occur, siting should be carefully decided in the light of RSL rising and possible flooding or erosion. Areas of high biological and archaeological value should be ruled out and land clearing should be limited. In particular, mangroves should be maintained in their natural state or even introduced where coastline stabilisation is required. Mangrove clearing led to up to 10m annual coastline retreat and severe beach erosion on the Bragança Peninsula, North Brazil (Krause and Glaser, 2003).

On the mangal, Bragançan coast of Northern Brazil, Krause and Glaser 2003 identified small cells of 1 to 3km in extension. These small sizes are the results of different anthropogenic pressures on each cell, rather than natural forces variation.

Channel dredging and marinas should be located in areas where there is no expected shoaling and away from important benthic communities. Dredged material should whenever it is suitable be recycled into construction material, beach nourishment or other shore stabilization scheme and when this is not possible, be disposed of in appropriate designed areas.
Anchoring should be limited to certain areas as it has been shown have serious impacts on benthic and fish communities. Appropriately designed permanent moorings can significantly reduce this impact and it is recommended that these are installed where anchoring is expected to be frequent (e.g. on beach 3 on Contadora Island or other beaches near tourism facilities).
Where high levels of traffic (pedestrian or by vehicle) are expected, erosion and wildlife disturbance and trampling should be reduced through delimiting tracks or roads.

The proposed law for an SMZ forbids mining in the management area. It is hoped that even if the law is not accepted as it has been presented, mining will not be allowed as the impact on the fragile environment of Las Perlas could be tremendous.
If the project was to go ahead, careful surveys of benthic communities should insure that no important species or habitats are found in the vicinity or down main currents from the site.
The site should be in at least 30m of water and 1km offshore (Price et al. 1978; Byrnes et al., 2004). Mining should be carried out during calm weather conditions and a careful monitoring should be carried out. In addition to the monitoring of beaches expected to be impacted on by the project, this should include wave dissipation and refraction, benthic organisms, turbidity, phytoplankton productivity and dissolved oxygen (Byrnes et al., 2004, Maa et al., 2004).

As exampled by observed illegal sand mining and acknowledged turtle egg poaching, a legal framework is not sufficient in itself to change mentalities and practices. If people do not understand the rational and benefits of a law, they can feel that it is not justified and break it.

Education is therefore a very important tool of management which can lead to better results. It should however go beyond rising awareness and provide skills that allow people to improve their lifestyles to better adapt to their environment.

It has been proposed for example, that tourism can provide an alternative source of revenue to fishing communities, thus reducing the pressure on fish stocks (Anderson, 2005). However, the facts show that tourism related employment is mainly attributed to non-natives of the archipelago. This could be due to the fact that fishing communities do not have the necessary skills and resources for this type of employment, for example they might not speak English or have any skill related to hospitality.

Similarly, they might not have the required skills for working in construction and as mentioned earlier, involving the population to the beach monitoring programme would provide surveying skills to at least a few people, possibly giving them a chance to be involved in other aspects of their islands development such as planning and construction.

5. Conclusion

The archipelago of Las Perlas has a very rich yet little known environment. There are a number of pressures on this environment: global warming and RSL rising, over-fishing, development, poaching, mining… and without proper management, it could loose a lot of its intrinsic value. This could lead to economical loss for developers but more importantly the loss of a lifestyle to the local population.

Given the context of small islands in a rising ocean, coastal retreat might not be an option in the worst case scenario where some of the islands may very well be completely drowned. Action can not be taken to protect Las Perlas until physical processes are understood and this can only be achieved through the gathering of data. In this study, data was collected for eighteen sites including 16 beaches where benchmarks were placed to serve in future monitoring.

A legal framework is being introduced for the management of Las Perlas. It is hoped that the information gathered through beach profile monitoring will be integrated into development planning and management and lead to their success.

References

Anderson, O.R.J., 2005. A qualitative and quantitative assessment of the small-scale snapper fisheries of the Las Perlas Archipelago, Panama. M.Sc. dissertation, Heriot-Watt University, Edinburgh.

Austin, M.J., Masselink, G., 2006. Observations of morphological change and sediment transport on a steep gravel beach. *Marine Geology,* 229 (2006) 59–77

Autoridad Nacional del Ambiente, 1998. Primer informe de la riqueza y estado de la biodiversidad de Panamá. Proyecto GEF:1200 86 48.

Bamrud, J., 2006. Latin real estate boom. *Latin Business Chronicle*, 09/08/2006 issue. Web: www.latinbusinesschronicle.com/app/article.aspx?id=82

Berman, J., 2004. Sponge diversity in coral frameworks and coral communities within the Las Perlas Archipelago, Panama. M.Sc. dissertation, Heriot-Watt University, Edinburgh.

Byrnes, M.R., Hammer, R.M., Thibaut, T.D., Snyder, D.B., 2004. Physical and biological effects of sand mining offshore Alabama, U.S.A. *Journal of coastal research,* 20 (1): 6-24

Campbell, I., 2005. The role of local communities in the designation of a marine protected area in Las Perlas Archipelago, Panama. M.Sc. dissertation, Heriot-Watt University, Edinburgh.

Carter, R.W.G., 1988. Coastal environments. Academic Press, London.

Comisión de población, ambiante y desarollo, 2005a. Proyecto n° 151 Que declara el archipiélago de Las Perlas como zona especial de manejo y se dicta otras disposiciones.

Comisión de población, ambiante y desarollo, 2005b. Ley No 13 del 5 de mayo de 2005 que declara a los mamíferos marinos especies de protección nacional.

Cooper, N.J., Hooke, J.M., Bray, M.J., 2001. Predicting coastal evolution using a sediment budget approach: a case study from Southern England. *Ocean and Coastal Management,* 44: 711-728.

D'Croz, L., Del Rosario, J., Gomez, J., 1991. Upwelling and phytoplankton in the Bay of Panama. *Revista de Biología Tropical*, 39 (2): 233-241.

Forsbergh, E.D.,1969. On the climatology, oceanography and fisheries of the Panama Bight. *Bulletin of the Inter-American Tropical Tuna Commission,* 14: 49-259.

Gálvez, R., 2005. Panama: Progress towards environmental sustainability. United Nations Development Programme. Web:www.undp.org/energyandenvironment/sustainabledifference/PDFs/LatinAmerica/Panama.pdf

Gardelis, P.C., 2004. Educational material for Las Perlas Archipelago, Panama. M.Sc. dissertation, Heriot-Watt University, Edinburgh.

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate change 2001, synthesis report. Web: PDF accessible from www.ipcc.ch

Jackson, N.B., 2006. Panama: a cross-road with two ocean views. *International Herald Tribune*, 02/06/06 issue.
Web: www.iht.com/articles/2006/05/25/items/repanama.php

Kandel, R., 1999. ENSO (El Niño Southern Oscillation). Dictionnaire de l'écologie. Albin Michel, Paris.

Karavas, N., Georghiou, K., Arianoutsou, M., Dimopoulos, D., 2005. Vegetation and sand characteristics influencing nesting activity of *Caretta caretta* on Sekania Beach. *Biological Conservation,* 121: 177-188.

Komar, P.D., 1998. Beach processes and sedimentation. Prentice-Hall, Englewood Cliffs, NJ.

Klein, A.H.F., and Menezes, J.T., 2001. Beach morphodynamics and profile sequence for a headland bay coast. *Journal of Coastal Research,* 17(4), 812-835

Krause, G., Glaser M., 2003. Co-evolving geomorphologic and socio-economic dynamics in a coastal fishing village of the Bragança region (Para, North Brazil). *Ocean and coastal management,* 46: 859-874.

Krause, G., 2004. The "Emery-Method" Revisited-Performance of an Inexpensive Method of Measuring Beach Profiles and Modifications. *Journal of Coastal Research*, 20 (1): 340-346

Larson, M., Kraus, N.C., 1995. Prediction of cross-shore sediment transport and temporal scales at different spatial scales. *Marine Geology,* 126 (1995) 11 l-127

Maa, J.P.-Y., Hobbs, C.H., Kim, S.C., Wei, E., 2004. Potential Impacts of Sand Mining Offshore of Maryland and Delaware: Part 1- Impacts on Physical Oceanographic Processes. *Journal of Coastal Research*, 20(1): 44-60

Masselink, G., Puleo, J.A., 2006. Swash-zone morphodynamics. *Continental Shelf Research,* 26: 661-680

Micallef, A., Williams, A.T., 2002. Theoretical strategy considerations for beach management. *Ocean and coastal management,* 45: 261-275

Mortimer, J.A., 1982. Factors influencing beach selection by Nesting Sea Turtles. In: Bjorndal, K. (Ed.), The Biology and Conservation of Sea Turtle. Smithsonian Institution Press, Washington, DC, pp.45–53.

Morton, J.W., 1977. Ecological effect of dredging and dredge spoil disposal: a literature review. *Technical papers of the U.S. Fish and Wildlife Service,* 94: 1-33

Price, W.A., Motyka, J.M., Affrey, L.J., 1978. The effect of offshore dredging on coastlines. Coastal Engineering 1978, Proceedings of the Coastal Conference 16th. American Society Of Civil Engineers (Editor) 1347-1358.

Rubio, A., 1949. Notas sobre geologia de Panama. Departamento de Cultura y Publicaciones del Ministerio de Educacion, Imprenta Nacional 1666-1948

Short, A.D., 1999. Handbook of Beach and Shoreface Morphodynamics. Wiley, Chichester.

Watts, G. M., 1963. Behaviour of offshore borrow zones in beach fill operations. Proceedings of the 10th Congress of the International Association for Hydraulic Research. London 1963 (1): 17-24

Woodroffe, C.D., 2002. Coasts, form, process and evolution. Cambridge University Press, UK.

List of Appendices

Appendix 1: Map of the study area and sites……I

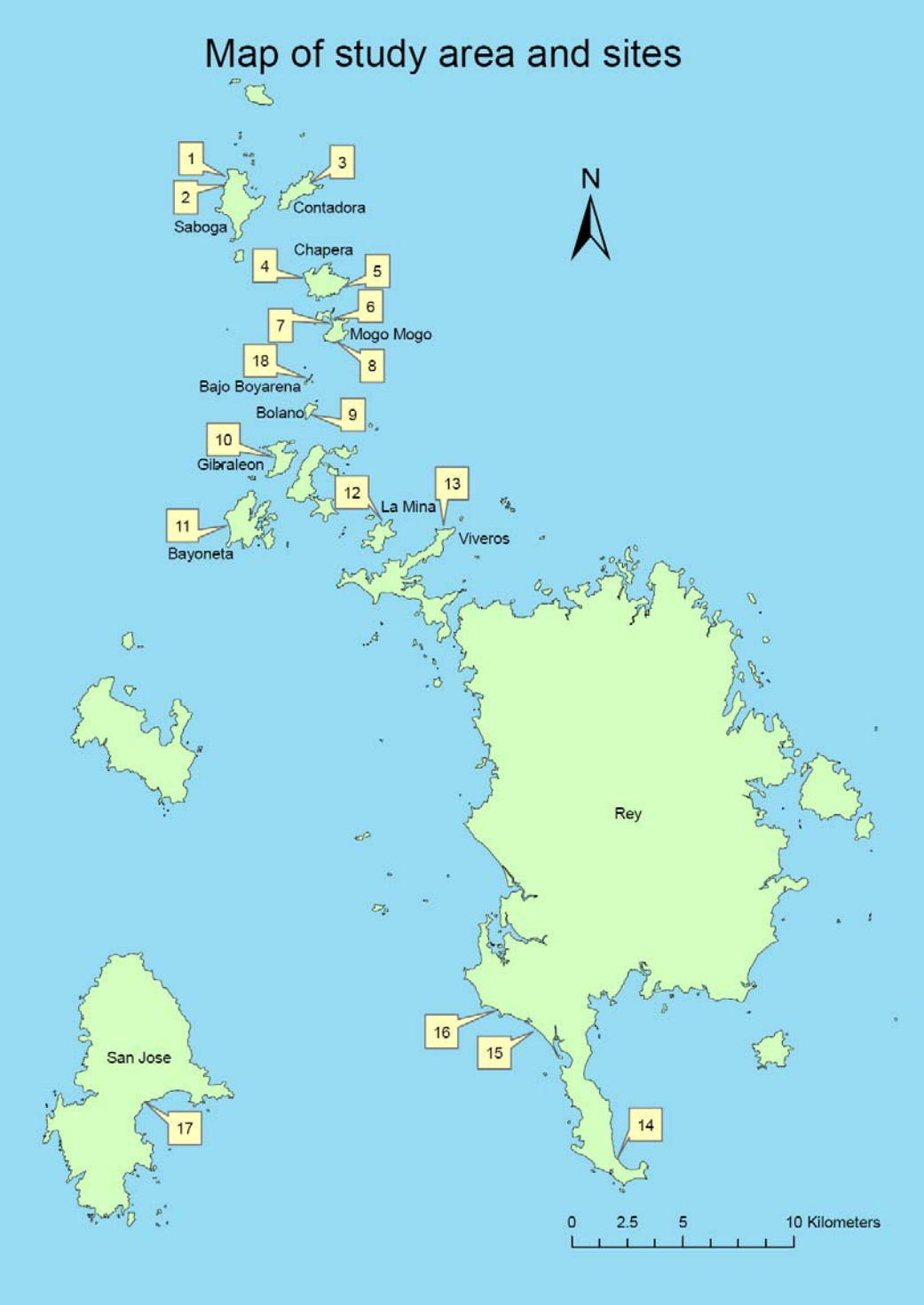
Appendix 2: Beach survey data and profiles……...……II

Appendix 3: Sediment analysis…….……XXXIV

Appendix 4: Analysis of the relationship between transect slope and sediment characteristics…….….XXXVII

Appendix 5: GPS coordinates……..XXXIX

Appendix 1: Map of study area and sites


Map of study area and sites
N
1
2
3
Saboga
Contadora
Chapera
4
5
6
7
Mogo Mogo
8
18
Bajo Boyarena
Bolano
9
10
Gibraleon
12
La Mina
13
Viveros
11
Bayoneta
Rey
San Jose
16
15
17
14
0
2.5
5
10 Kilometers

Appendix 2: Beach survey data and profiles *(0 on the x-axis corresponds to benchmark position, 0 on the y-axis corresponds to chart datum)*
Note that vertical exaggeration is different on each plot.

1. Saboga (Beach 1 and 2)

Beach 1

Date of surveying: 13/06/06
Length: 100m

Transect 1:
Benchmark position: N08°38.065' W079°03.730'
Direction of transect: 273°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.01	0.0	Benchmark
5.89	1.8	
5.74	3.5	
5.67	3.8	Highest Water Mark (Extrapolated)
4.60	9.2	
3.79	17.9	
2.86	29.9	
1.18	59.9	
0.87	89.1	
0.75	119.0	Low Water Mark for that day
-0.55	292.3	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 289m (extrapolated)
Slope of intertidal portion: 2.1% (extrapolated)
3.8% (observed)

Transect 2:
Benchmark position: N08°38.058' W079°03.719'
Direction of transect: 275°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-3.3	Highest Water Mark (Extrapolated)
5.231	0	Benchmark
5.156	2.05	
4.491	4.48	
4.291	7.2	
4.226	8.85	
3.006	24.35	
2.116	44.6	
2.046	46.45	
2.051	47.75	
1.841	54.9	
1.091	64.8	
1.006	77.05	
0.491	114.55	
0.131	129.55	Low Water Mark for that day
-0.55	180.8	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 184m (extrapolated)
Slope of intertidal portion: 3.4% (extrapolated)
3.9% (observed)

Transect 3:

Benchmark position: N08°38.047' W079°03.695'

Direction of transect: 275°

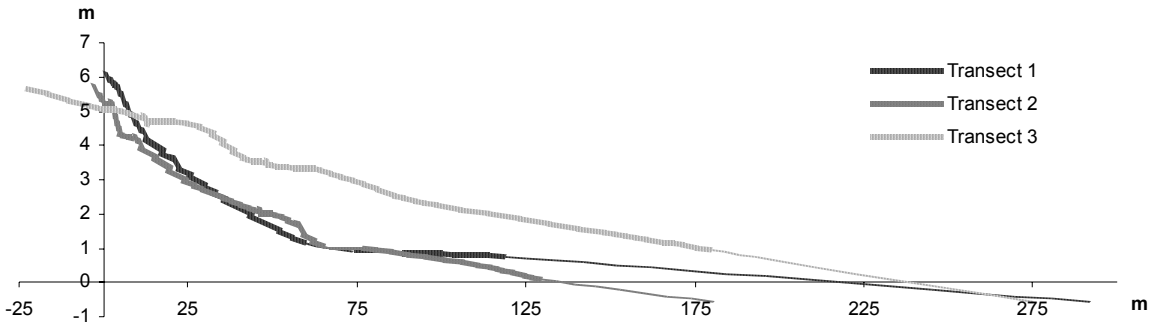
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-22.5	Highest Water Mark (Extrapolated)
5.09	0.0	Benchmark
5.06	3.3	
4.81	11.6	
4.62	12.7	
4.71	13.7	
4.55	29.1	
3.66	41.1	
3.55	46.6	
3.46	49.2	
3.37	58.8	
3.37	62.1	
2.98	74.0	
2.41	92.7	
1.37	154.6	
0.97	179.7	Low Water Mark for that day
-0.55	275.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 298m (extrapolated)

Slope of intertidal portion: 2.1% (extrapolated)

2.3% (observed)

Profiles:



Beach 2:
Date of surveying: 14/06/06
Length: 260m

Transect 1:
Benchmark position: N08°37.580' W079°04.090'
Direction of transect: 299°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.44	0.0	Benchmark
6.55	4.4	
6.19	5.3	
5.95	7.9	
5.86	12.0	
5.67	14.9	Highest Water Mark (Extrapolated)
4.99	25.5	
2.74	49.6	
1.34	62.2	
0.59	79.6	Low Water Mark at 10:43AM
-0.55	106.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 91.1m (extrapolated)
Slope of intertidal portion: 6.8% (extrapolated)
8.1% (observed)

Transect 2:
Benchmark position: N08°37.527' W079°04.111'
Direction of transect: 302°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
7.35	0.0	Benchmark
7.37	1.6	
6.83	2.8	
6.58	6.0	
7.36	10.7	
6.09	14.9	
5.67	18.8	Highest Water Mark (Extrapolated)
4.40	30.6	
2.63	50.0	
1.46	60.1	
0.74	75.1	
0.68	80.0	Low Water Mark at 10:28AM
-0.55	180.8	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 162.0m (extrapolated)
Slope of intertidal portion: 3.8% (extrapolated)
7.5% (observed)

Transect 3:

Benchmark position: N08°37.551' W079°04.104'

Direction of transect: 312°

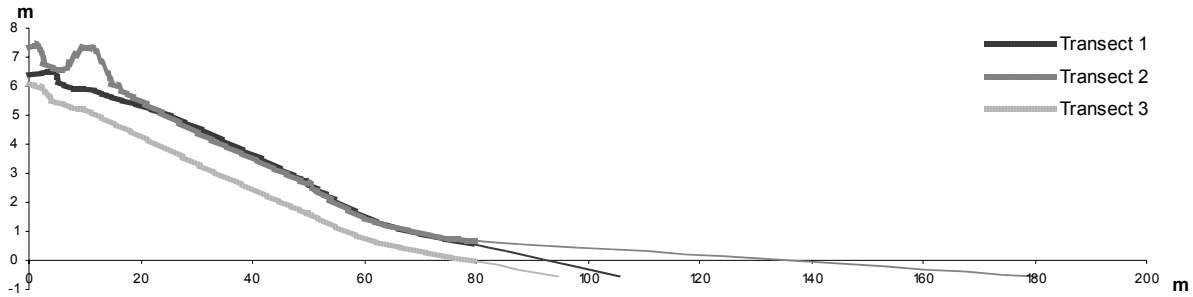
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.12	0.0	Benchmark
5.95	2.1	
5.67	3.4	Highest Water Mark (Extrapolated)
5.54	4.1	
5.26	8.8	
5.14	11.4	
3.08	33.3	
1.66	49.9	
0.65	62.2	
0.00	79.9	Low Water Mark at 10:15AM
-0.55	95.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 91.6m (extrapolated)

Slope of intertidal portion: 6.8% (extrapolated)

7.3% (observed)

Profiles:



2. Contadora (beach 3)

Date of surveying: 15/06/06
Length: 530m

Transect 1:
Benchmark position: N08°37.721' W079°01.822'
Direction of transect: 15°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
2.22	0.0	Benchmark
3.18	1.7	
2.19	2.9	
2.89	5.0	
1.81	6.3	
1.97	9.0	
2.57	9.2	
2.57	15.0	
2.24	16.0	
2.22	20.2	
1.84	26.1	
1.69	26.4	
1.94	27.9	
1.86	49.0	
0.20	86.4	
1.14	92.5	
0.62	153.7	
-0.06	179.0	Low Water Mark at 12:46PM
-0.55	478.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion:
Slope of intertidal portion: 0.8% (extrapolated)
1.8% (observed)

Transect 2:
Benchmark position: N08°37.774' W079°01.895'
Direction of transect: 45°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-1.6	Highest Water Mark (Extrapolated)
5.57	0.0	Benchmark
4.11	24.7	
2.27	49.1	
0.72	70.8	Low Water Mark at 1:06PM
-0.55	88.7	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 90.3m (extrapolated)
Slope of intertidal portion: 6.9% (extrapolated)
6.9% (observed)

Transect 3:

Benchmark position: N08°37.844' W079°01.954'

Direction of transect: 87°

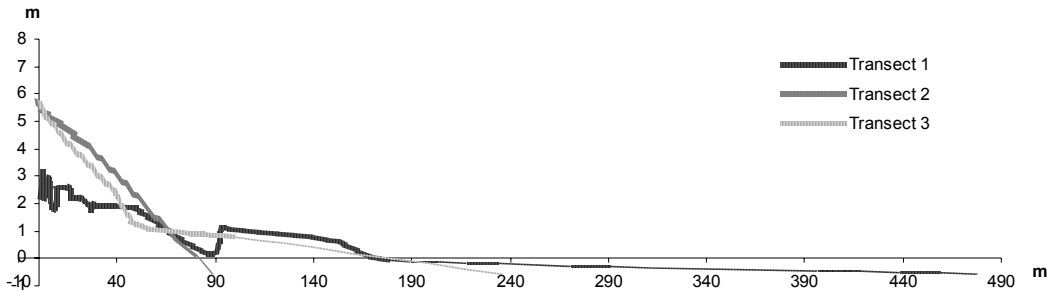
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-0.4	Highest Water Mark (Extrapolated)
5.63	0.0	Benchmark
5.33	2.6	
5.11	3.6	
2.48	38.5	
1.27	50.4	
0.92	80.8	
0.80	99.5	Low Water Mark at 11:19AM
-0.55	236.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 236.6m (extrapolated)

Slope of intertidal portion: 2.6% (extrapolated)

4.8% (observed)

Profiles:



3. Chapera Island (beach 4 and 5)

Beach 4:

Date of surveying: 15/06/06
Length: 550m

Transect 1:
Benchmark position: N08°35.708' W079°01.527'
Direction of transect: 236°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.62	0.0	Benchmark
6.50	1.9	
5.93	10.0	
5.67	14.9	Highest Water Mark (Extrapolated)
3.40	51.0	
1.82	77.8	
1.53	92.2	
0.61	129.7	Low Water Mark at 12:05PM
-0.55	177.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 162.3m (extrapolated)
Slope of intertidal portion: 3.8% (extrapolated)
4.6% (observed)

Transect 2:
Benchmark position: N08°35.734' W079°01.544'
Direction of transect: 242°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.57	0.0	Benchmark
6.43	1.0	
5.91	6.5	
5.67	10.4	Highest Water Mark (Extrapolated)
3.54	39.4	
1.62	67.6	
1.05	82.1	
0.82	99.8	Low Water Mark at 11:32AM
-0.55	205.1	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 194.7m (extrapolated)
Slope of intertidal portion: 3.2% (extrapolated)
5.8% (observed)

Transect 3:

Benchmark position: N08°35.761' W079°01.549'

Direction of transect: 247°

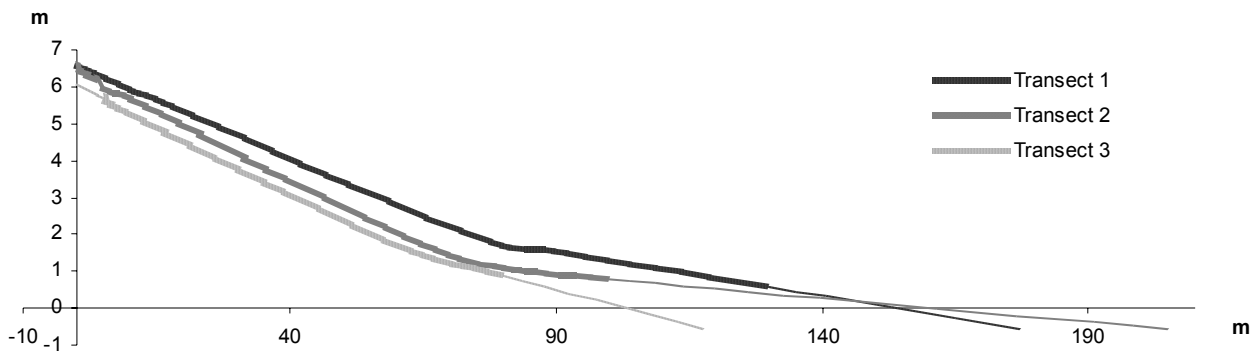
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.10	0.0	Benchmark
5.67	5.4	Highest Water Mark (Extrapolated)
5.52	6.8	
3.17	39.1	
1.55	62.9	
0.90	79.9	Low Water Mark at 11:21AM
-0.55	118.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 112.6m

Slope of intertidal portion: 5.5% (extrapolated)

6.5% (observed)

Profiles:



Beach 5:
Date of surveying: 19/05/06
Total length: 410m

Transect 1:
Benchmark position: N 08°35'05.4" W 079°01'19.2"
Direction of transect: 140°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.20	0.0	Benchmark
5.67	5.9	Highest Water Mark (Extrapolated)
4.15	23.6	
3.13	30.3	
1.35	50.5	Low Water Mark at 3:43PM
-0.55	70.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 64.1m (extrapolated)
Slope of intertidal portion: 9.7% (extrapolated)
9.6% (observed)

Transect 2:
Benchmark position: N 08°35'07.9" W 079°01'17.9"
Direction of transect: 119°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.09	0	Benchmark
6.13	3.4	Highest Water Mark (Extrapolated)
5.67	5.8	
5.54	7.5	
2.21	37.2	
1.13	48	Low Water Mark at 3:12PM
-0.55	63.3	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 57.5m
Slope of intertidal portion: 10.8% (extrapolated) 10.3% (observed)

Transect 3:

Benchmark position: N 08°35'09.7" W 079°01'17.5"

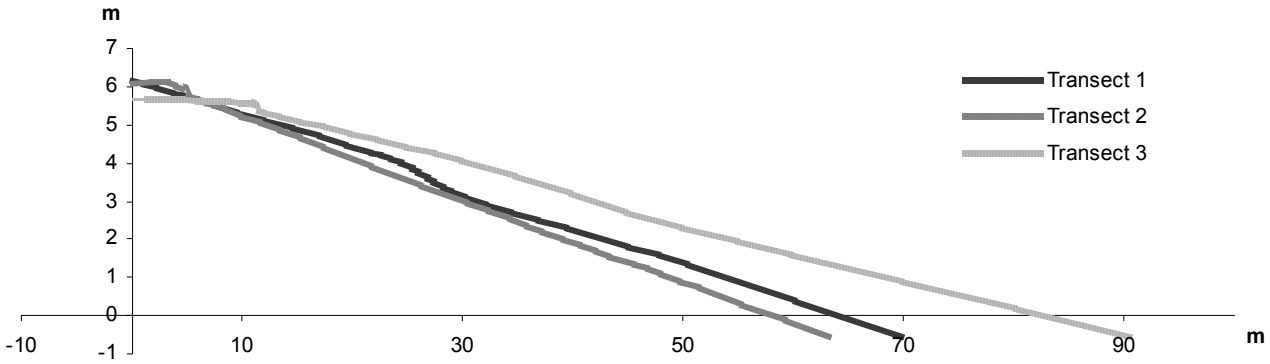
Direction of transect: 118°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.69	0.0	Benchmark
5.67	1.3	Highest Water Mark (Extrapolated)
5.57	10.6	
5.34	12.0	
4.09	30.0	
2.31	50.0	
0.91	70.0	Low Water Mark for that day
-0.55	90.7	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 89.4m

Slope of intertidal portion: 7.0% (extrapolated)
6.8% (observed)

Profiles:



4. Mogo Mogo (beach 6, 7 and 8)

Beach 6:

Date of surveying: 11/05/06 Length: 770m

Transect 1:

Benchmark position: N 08°34'27.5" W 079°01'28.8"

Direction of transect: 45°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-1.4	Highest Water Mark (Extrapolated)
5.57	0.0	Benchmark
5.01	6.1	
4.57	12.0	
4.18	17.0	
3.59	22.0	
3.03	27.0	
2.62	32.0	
2.24	37.0	
1.84	42.0	
1.36	47.0	
1.36	52.0	
1.26	57.0	
1.20	62.0	
1.07	67.0	
1.16	80.0	
0.83	89.8	Low Water Mark at 8:42AM
-0.55	221.9	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 223.3m (extrapolated)

Slope of intertidal portion: 2.7% (extrapolated)

5.3% (observed)

Transect 2:

Benchmark position: N 08°34'29.0" W 079°01'30.1"

Direction of transect: 60°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-0.8	Highest Water Mark (Extrapolated)
5.59	0	Benchmark
5.17	5	
4.95	7	
4.52	12	
3.91	17	
3.19	22	
2.66	27	
2.27	32	
1.82	37	
1.41	42	
1.12	44.2	
1.11	47	
1.04	52	
0.94	57	
0.91	62	
0.87	67	Low Water Mark at 8.50AM
-0.55	270.1	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 270.9m

Slope of intertidal portion: 2.3% (extrapolated)

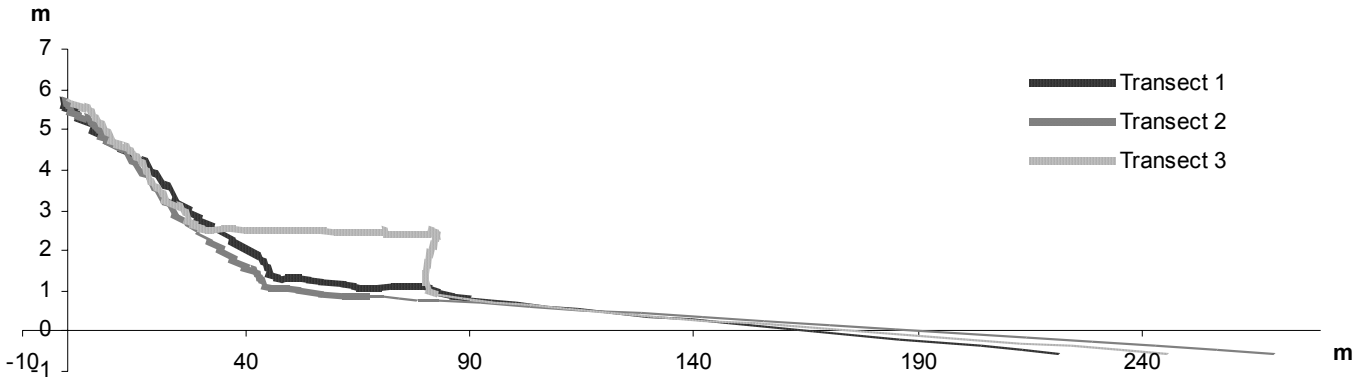
7.0% (observed)

Transect 3:
Benchmark position: N 08°34'32.9" W 079°01'31.9"
Direction of transect: 75°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.79	0	Benchmark
5.67	1.98	Highest Water Mark (Extrapolated)
5.44	5	
4.78	10	
4.28	15	
3.51	20	
3.06	25	
2.58	30	
2.57	35	
2.52	40	
2.51	45	
2.51	50	
2.5	55	
2.47	60	
2.47	65	
2.46	70	
2.43	71	
2.42	75	
2.41	80	
2.37	82.6	
0.96	82.7	Low Water Mark for that day
-0.55	246.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 244.0m (extrapolated)
Slope of intertidal portion: 2.5% (extrapolated)
5.8% (observed)

Profiles:



Beach 7:
Date of surveying: 12/05/06
Length: 400m

Transect 1:
Benchmark position: N08°34.524' W079°01.620'
Direction of transect: 195°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
3.19	0.0	Benchmark
3.20	2.6	
2.82	4.3	
3.45	8.4	
3.17	23.2	
1.46	51.1	
0.90	65.9	Low Water Mark at 11:55AM
-0.55	104.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion:
Slope of intertidal portion: 3.6% (extrapolated)
3.5% (observed)

Transect 2:
Benchmark position: N08°34.482' W079°01.546'
Direction of transect: 238°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.13	0.0	Benchmark
6.03	2.3	
5.67	4.5	Highest Water Mark (Extrapolated)
5.61	5.2	
5.18	7.2	
3.62	21.7	
1.51	47.2	
1.02	53.3	Low Water Mark at 9:03AM
-0.55	72.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 67.7m (extrapolated)
Slope of intertidal portion: 9.2% (extrapolated)
9.6% (observed)

Transect 3:

Benchmark position: N08°34.365' W079°01.478'

Direction of transect: 264°

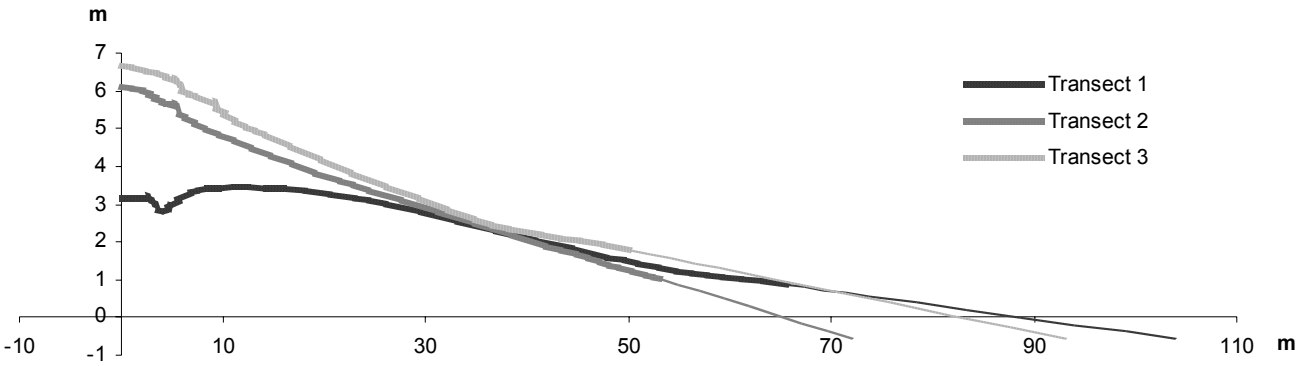
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.68	0	Benchmark
6.40	4.6	
6.04	6.1	
5.67	9.1	Highest Water Mark (Extrapolated)
5.04	12.3	
2.60	35.0	
1.78	50.2	Low Water Mark for that day
-0.55	93.4	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 84.3m (extrapolated)

Slope of intertidal portion: 7.4% (extrapolated)

9.8% (observed)

Profiles:



Beach 8:
Date of surveying: 12/06/06
Length: 310m

Transect 1:
Benchmark position: N08°34.013' W079°01.196'
Direction of transect: 330°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-3.3	Highest Water Mark (Extrapolated)
5.33	0.0	Benchmark
2.80	24.7	
1.96	36.2	
1.76	50.8	
2.45	52.4	
1.41	62.8	
0.87	77.1	Low Water Mark at 11:00AM
-0.55	114.5	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 117.8m (extrapolated)
Slope of intertidal portion: 5.3% (extrapolated)
5.8% (observed)

Transect 2:
Benchmark position: N08°34.036' W079°01.178'
Direction of transect: 347°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-7.1	Highest Water Mark (Extrapolated)
5.01	0.0	Benchmark
3.30	18.4	
1.34	39.0	
0.76	50.2	Low Water Mark at 10:41AM
-0.55	75.4	Lowest Water Mark (Extrapolated)

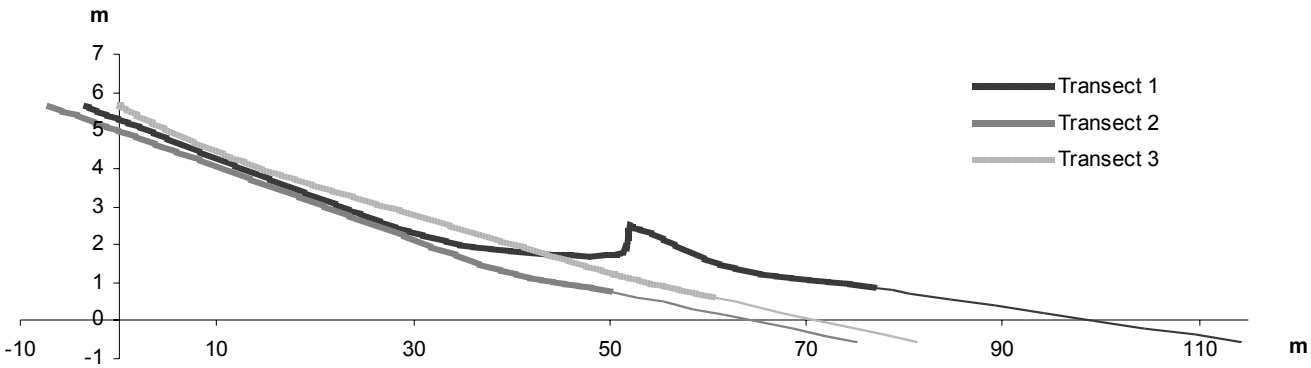
Width of intertidal portion: 82.5m (extrapolated)
Slope of intertidal portion: 7.5% (extrapolated)
8.5 (observed)

Transect 3:
Benchmark position: N08°34.081' W079°01.130'
Direction of transect: 350°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.68	0.0	Benchmark
5.67	0.1	Highest Water Mark (Extrapolated)
5.04	4.9	
4.41	10.8	
3.86	16.7	
1.22	50.5	
1.22	50.5	
0.64	60.6	Low Water Mark at 10:19AM
-0.55	81.4	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 81.3m (extrapolated)
Slope of intertidal portion: 7.6% (extrapolated)
8.3% (observed)

Profiles:



5. Bolaňo (beach 9)
Date of surveying: 14/06/06
Total length: 390m

Transect 1:
Benchmark position: N08°32.070' W079°02.042'
Direction of transect: 127°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.48	0.0	Benchmark
5.71	1.2	
5.67	1.3	Highest Water Mark (Extrapolated)
4.32	7.3	
3.49	18.8	
3.22	20.4	
3.09	21.9	
3.17	34.7	
2.05	38.2	
2.05	38.2	
1.01	59.3	Low Water Mark at 10:22AM
-0.55	90.9	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 89.6m (extrapolated)
Slope of intertidal portion: 6.9% (extrapolated)
9.2% (observed)

Transect 2:
Benchmark position: N08°32.107' W079°02.015'
Direction of transect: 120°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-10.0	Highest Water Mark (Extrapolated)
4.91	0.0	Benchmark
3.76	15.2	
1.51	43.8	Low Water Mark at 9:36AM
-0.55	69.9	Lowest Water Mark (Extrapolated)

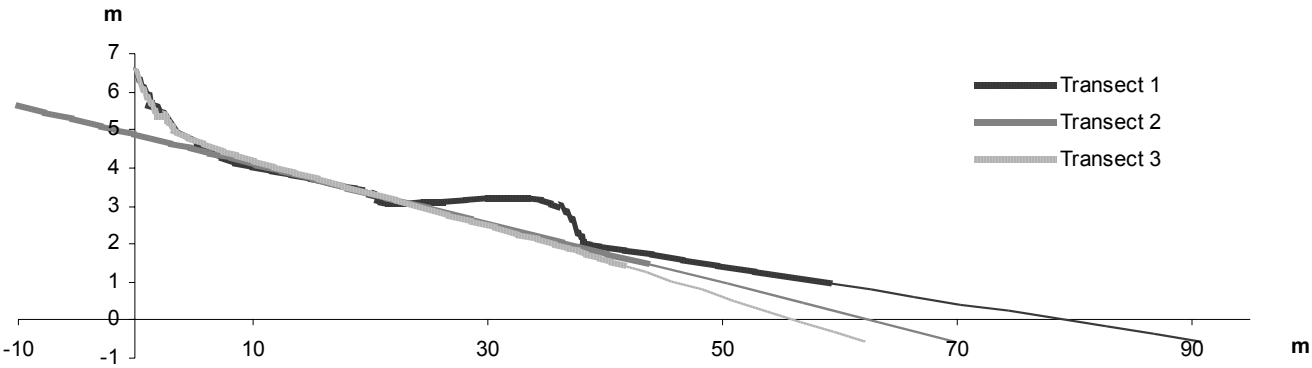
Width of intertidal portion: 79.9m
Slope of intertidal portion: 7.8% (extrapolated)
7.8% (observed)

Transect 3:
Benchmark position: N08°32.128' W079°02.003'
Direction of transect: 119°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.51	0.0	Benchmark
5.67	1.2	Highest Water Mark (Extrapolated)
5.37	1.7	
5.36	2.4	
5.08	3.1	
4.47	7.5	
1.90	36.9	
1.44	41.7	Low Water Mark at 9:32AM
-0.55	62.3	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 63.5m (extrapolated)
Slope of intertidal portion: 9.8% (extrapolated)
12.1% (observed)

Profiles:



6. Gibraleón (beach 10)
Date of surveying: 14/06/06
Total length: 800m

Transect 1:
Benchmark position: N08°31.090' W079°02.830'
Direction of transect: 275°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
7.78	0.0	Benchmark
7.15	12.7	
6.57	13.5	
5.67	24.3	Highest Water Mark (Extrapolated)
5.66	24.8	
4.10	41.0	
1.54	61.1	
0.65	66.5	Low Water Mark at 11:09AM
-0.55	77.3	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 53.0m (extrapolated)
Slope of intertidal portion: 11.7% (extrapolated)
10.7% (observed)

Transect 2:
Benchmark position: N08°30.955' W079°02.851'
Direction of transect: 278°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.68	0	Benchmark
6.66	0.58	
6.12	3.24	
5.67	8.3	Highest Water Mark (Extrapolated)
4.345	20.1	
0.47	50	Low Water Mark at 11:07AM
-0.55	57.9	Lowest Water Mark (Extrapolated)

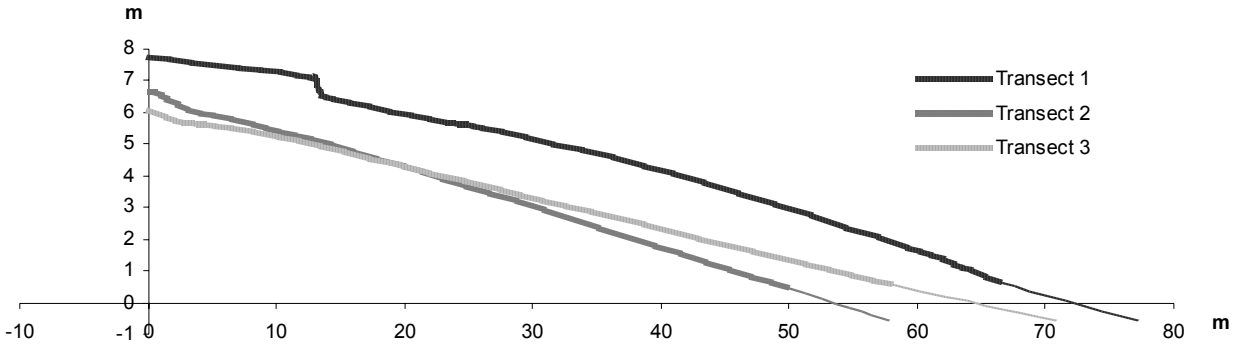
Width of intertidal portion: 49.6m (extrapolated)
Slope of intertidal portion: 12.5% (extrapolated)
13.4% (observed)

Transect 3:
Benchmark position: N08°30.813' W079°02.902'
Direction of transect: 298°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.10	0	Benchmark
5.71	2.7	
5.67	4.5	Highest Water Mark (Extrapolated)
5.24	10.3	
3.59	27.5	
0.61	58.0	Low Water Mark at 12:04PM
-0.55	70.9	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 66.4m (extrapolated)
Slope of intertidal portion: 9.4% (extrapolated)
9.5% (observed)

Profiles:



7. Bayoneta (beach 11)
Date of surveying: 12/05/06
Total length: 720m

Transect 1:
Benchmark position: N 08°29'31.3" W 079°04'01.7"
Direction of transect: 261°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.69	0.0	Benchmark
5.67	6.5	Highest Water Mark (Extrapolated)
5.58	10.0	
5.34	13.4	
4.61	17.7	
3.33	30.0	
0.99	50.0	
0.14	57.1	Water Mark at 9:45AM
-0.55	65.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 58.5m (extrapolated)
Slope of intertidal portion: 10.6% (extrapolated)
10.3% (observed)

Transect 2:
Benchmark position: N 08°29'13.4" W 079°03'58.4"
Direction of transect: 282°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.19	0.0	Benchmark
5.96	3.3	
5.67	3.8	Highest Water Mark (Extrapolated)
5.32	4.9	
4.92	10.0	
3.91	20.0	
2.74	30.0	
1.71	40.0	
0.67	50.8	Low Water Mark for that day
-0.55	61.0	Lowest Water Mark (Extrapolated)

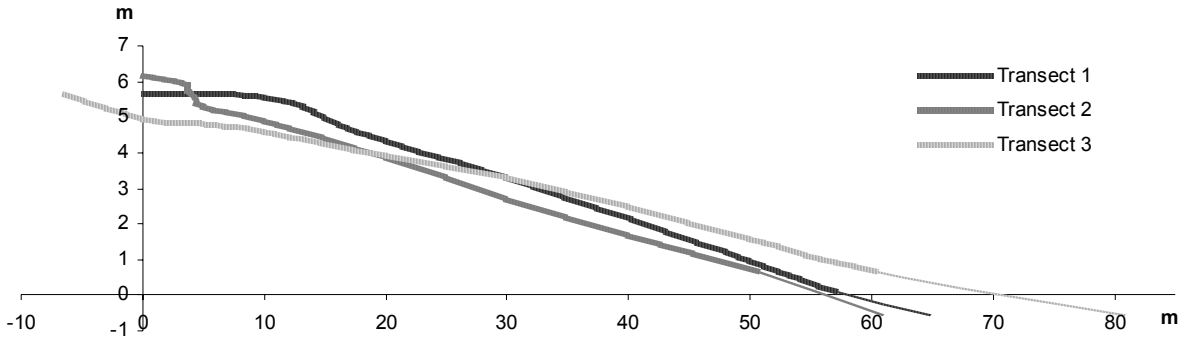
Width of intertidal portion: 57.2m (extrapolated)
Slope of intertidal portion: 10.9% (extrapolated)
10.9% (observed)

Transect 3:
Benchmark position: N 08°29'04.4" W 079°04'00.6"
Direction of transect: 286°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-6.4	Highest Water Mark (Extrapolated)
4.95	0.0	Benchmark
4.85	3.5	
4.82	6.0	
4.62	10.0	
3.92	20.0	
3.34	30.0	
2.52	40.0	
1.62	50.0	
0.67	60.4	Low Water Mark for that day
-0.55	81.0	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 87.4m
Slope of intertidal portion: 7.1% (extrapolated)
6.6% (observed)

Profiles:



8. La Mina (beach 12)
Date of surveying: 13/05/06
Length: 410m

Transect 1:
Benchmark position: N 08°29'18.1" W 078°58'59.2"
Direction of transect: 40°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-7.7	Highest Water Mark (Extrapolated)
4.89	0.0	Benchmark
3.93	10.0	
1.99	25.6	
1.78	26.4	
1.58	34.4	
1.86	35.0	
1.46	49.0	
0.30	50.4	
1.14	51.4	
0.94	61.0	
1.11	61.4	
1.11	72.4	
0.67	75.5	
0.61	82.0	
0.61	82.1	Low Water Mark at 9:58AM
-0.55	209.9	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 217.6m (extrapolated)
Slope of intertidal portion: 2.9% (extrapolated)
5.2% (observed)

Transect 2:
Benchmark position: N 08°29'19.7" W 079°00'01.4"
Direction of transect: 44°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-3.8	Highest Water Mark (Extrapolated)
5.17	0.0	Benchmark
4.01	10.0	
2.73	20.0	
2.14	24.6	
1.93	41.2	
2.13	41.7	
2.08	50.0	
1.72	58.0	
1.44	70.2	
1.22	74.0	
1.22	74.0	
0.62	127.2	Low Water Mark at 10:09AM
-0.55	190.1	Lowest Water Mark (Extrapolated)

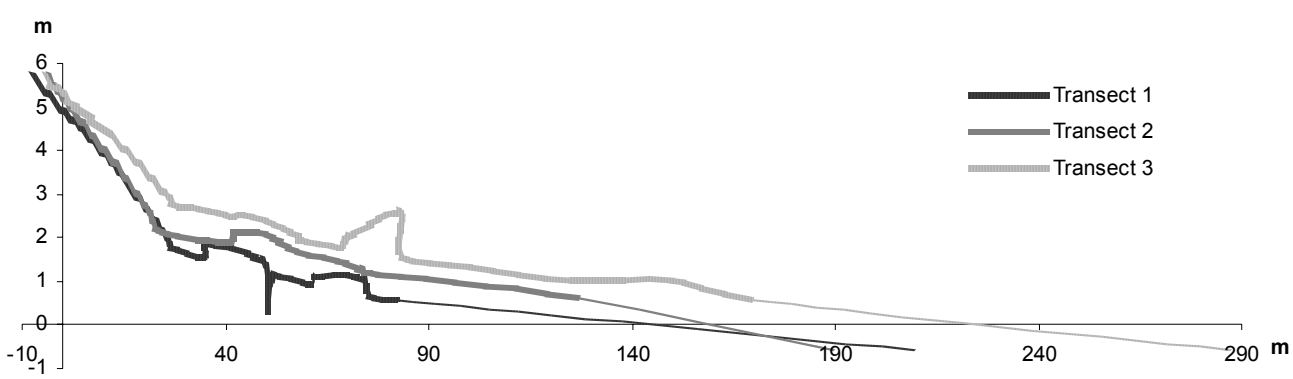
Width of intertidal portion: 195.9m (extrapolated)
Slope of intertidal portion: 3.2% (extrapolated)
3.6% (observed)

Transect 3:
Benchmark position: N 08°29'23.1" W 079°00'04.5"
Direction of transect: 53°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-4.6	Highest Water Mark (Extrapolated)
5.30	0.0	Benchmark
4.00	15.0	
2.83	27.2	
2.73	29.4	
2.74	31.7	
2.55	40.1	
2.50	42.1	
2.54	44.3	
2.42	50.3	
2.05	57.6	
1.96	58.0	
1.80	68.8	
1.92	69.0	
2.60	82.3	
1.57	83.4	
1.37	100.4	
1.04	125.0	
1.02	150.0	
0.59	169.4	Low Water Mark at 9:50AM
-0.55	287.6	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 292.2m
Slope of intertidal portion: 2.1% (extrapolated)
2.8% (observed)

Profiles:



9. Viveros (beach 13)
Date of surveying: 14/05/06
Length: 610m

Transect 1:
Benchmark position: N 08°29'20.1" W 078°58'33.2"
Direction of transect: 006°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.70	0.0	Benchmark
5.67	0.4	Highest Water Mark (Extrapolated)
4.55	13.2	
4.31	16.0	
3.48	30.0	
2.46	50.0	
1.87	60.0	
1.06	71.7	
0.34	80.5	
0.62	80.9	
0.73	81.7	
0.40	82.4	
0.60	86.1	Low Water Mark at 10:50AM
-0.55	98.1	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 97.7m (extrapolated)
Slope of intertidal portion: 6.4% (extrapolated)
6.8% (observed)

Transect 2:
Benchmark position: N 08°29'19.0" W 078°58'44.9"
Direction of transect: 004°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-4.4	Highest Water Mark (Extrapolated)
5.19	0	Benchmark
5.19	10	
4.53	16.2	
4.24	18.4	
3.41	36	
3.21	37	
2.57	50	
1.39	70	Low Water Mark at 10:42AM
-0.55	104.3	Lowest Water Mark (Extrapolated)

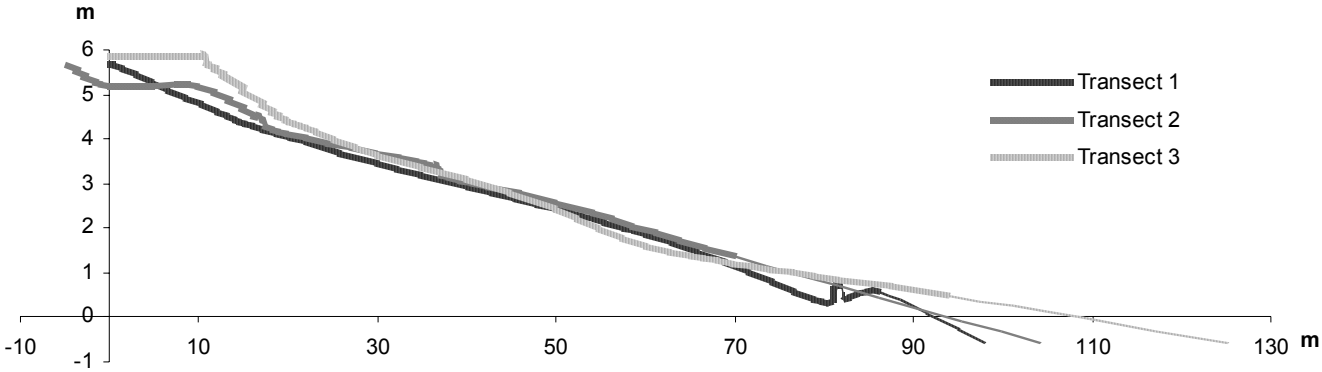
Width of intertidal portion: 108.7m (extrapolated)
Slope of intertidal portion: 5.7% (extrapolated)
5.4% (observed)

Transect 3:
Benchmark position: N 08°29'20.7" W 078°58'53.6"
Direction of transect: 003°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.87	0	Benchmark
5.85	10	
5.67	11.2	Highest Water Mark (Extrapolated)
4.55	19	
4.30	21.4	
3.66	30	
3.11	40	
2.46	50	
1.61	60	
1.15	71.8	
0.49	93.9	Low Water Mark for that day
-0.55	125.4	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 114.2m (extrapolated)
Slope of intertidal portion: 5.4% (extrapolated)
5.4% (observed)

Profiles:



10. Rey (beach 14, 15 and 16)
Beach 14
Date of surveying: 17/05/06
Length: 1590m

Transect 1:
Benchmark position: N 08°13'39.5" W 078°54'13.4"
Direction of transect: 25°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.26	0.0	Benchmark
5.86	4.2	
5.67	6.2	Highest Water Mark (Extrapolated)
4.07	25.0	
1.52	50.0	
0.67	65.3	Low Water Mark for that day
-0.55	75.5	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 69.3m (extrapolated)
Slope of intertidal portion: 9.0% (extrapolated)
10.0% (observed)

Transect 2:
Benchmark position: N 08°13'39.9" W 078°54'19.5"
Direction of transect: 54°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
6.01	0.0	Benchmark
5.67	1.5	Highest Water Mark (Extrapolated)
5.55	1.6	
4.73	10.0	
3.19	24.0	
2.17	32.0	
0.67	48.1	Low Water Mark for that day
-0.55	57.6	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 56.1m (extrapolated)
Slope of intertidal portion: 11.1% (extrapolated)
10.5% (observed)

Transect 3:

Benchmark position: N 08°13'41.6" W 078°54'22.2"

Direction of transect: 83°

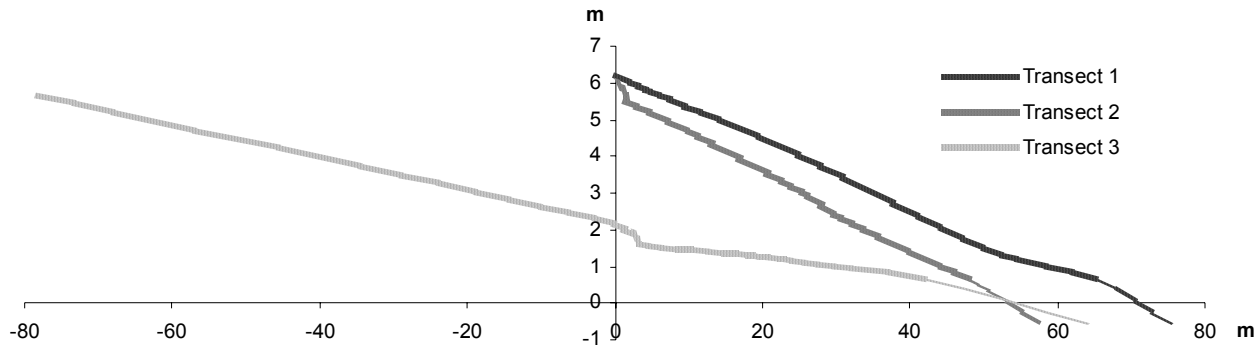
Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
5.67	-78.3	Highest Water Mark (Extrapolated)
2.19	0.0	Benchmark
1.61	3.5	
1.33	18.0	
1.17	24.0	
0.67	42.3	Low Water Mark for that day
-0.55	64.4	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 142.7m (extrapolated)

Slope of intertidal portion: 4.4% (extrapolated)

3.6% (observed)

Profiles:



Beach 15:
Date of surveying: 16/05/06
Length: 3220m

Transect 1:
Benchmark position: N 08°16'52.9" W 078°56'21.4"
Direction of transect: 213°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
7.93	0.0	Benchmark
5.93	4.6	
6.42	6.6	
5.85	8.5	
5.88	12.8	
5.88	27.0	
5.67	28.8	Highest Water Mark (Extrapolated)
5.31	32.3	
4.08	50.0	
2.43	72.4	
2.16	81.2	
2.52	84.4	
2.24	87.6	
2.13	92.7	
1.62	93.6	
1.19	95.7	
1.12	97.0	
1.64	97.6	
1.64	101.0	
0.72	103.0	Low Water Mark at 11:20AM
-0.55	133.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 104.4m (extrapolated)
Slope of intertidal portion: 6.0% (extrapolated)
7% (observed)

Transect 2:
Benchmark position: N 08°16'53.8" W 078°56'19.7"
Direction of transect: 225°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
8.34	0.0	Benchmark
7.56	10.3	
7.35	15.0	
6.75	17.1	
6.51	21.0	
5.93	21.9	
5.67	27.6	Highest Water Mark (Extrapolated)
5.04	30.0	
3.40	50.0	
1.42	70.1	Low Water Mark at 10:50AM
-0.55	88.7	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 61.1m (extrapolated)
Slope of intertidal portion: 10.2% (extrapolated)
9.9% (observed)

Transect 3:

Benchmark position: N 08°16'58.7" W 078°56'25.9"

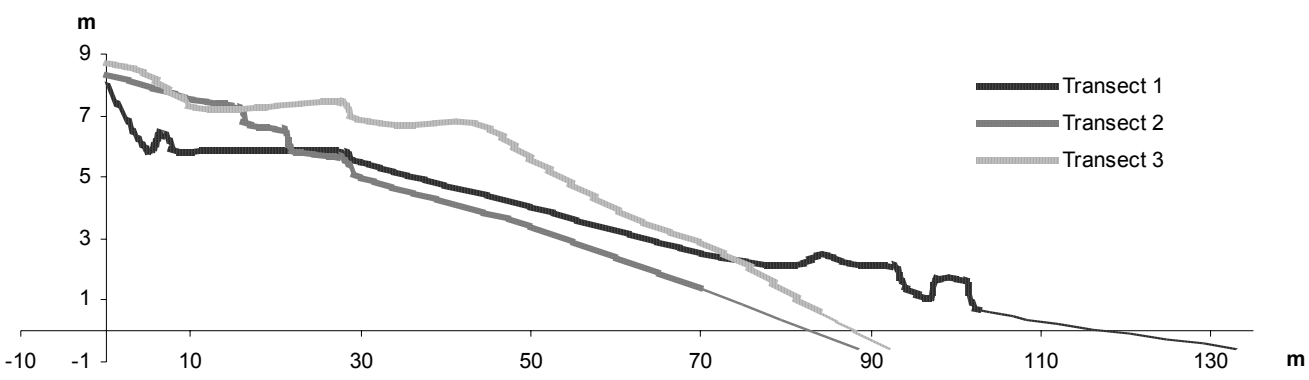
Direction of transect: 228°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
8.74	0	Benchmark
8.45	4.6	
7.32	10.6	
7.27	17.8	
7.49	27.4	
7.02	28.6	
6.73	34.1	Highest Water Mark (Surveyed)
6.78	43.7	
5.67	50	
3.95	60.3	
2.57	73	
0.64	84	Low Water Mark at 11:07AM
-0.55	92.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 42.2m

Slope of intertidal portion: 14.7% (extrapolated)
10.4% (observed)

Profiles:



Beach 16:
Date of surveying: 14/05/06
Total length: 710m

Transect 1:
Benchmark position: N 08°17'35.8" W 078°57'34.0"
Direction of transect: 223°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
8.86	0.0	Benchmark
7.43	7.7	
6.68	12.4	
6.14	14.0	Highest Water Mark (Extrapolated)
5.67	19.2	
5.16	21.4	
4.26	33.0	
0.64	65.0	Low Water Mark for that day
-0.55	78.8	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 64.8m (extrapolated)
Slope of intertidal portion: 9.6% (extrapolated)
10.4% (observed)

Transect 2:
Benchmark position: N 08°17'34.9" W 078°57'32.2"
Direction of transect: 210°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
9.17	0	Benchmark
7.43	8.3	
7.01	9.4	
5.99	17	
5.67	18.5	Highest Water Mark (Extrapolated)
4.99	23.4	
4.32	26.6	
4.32	26.6	
2.41	40	
0.55	58.6	Low Water Mark for that day
-0.55	67.2	Lowest Water Mark (Extrapolated)

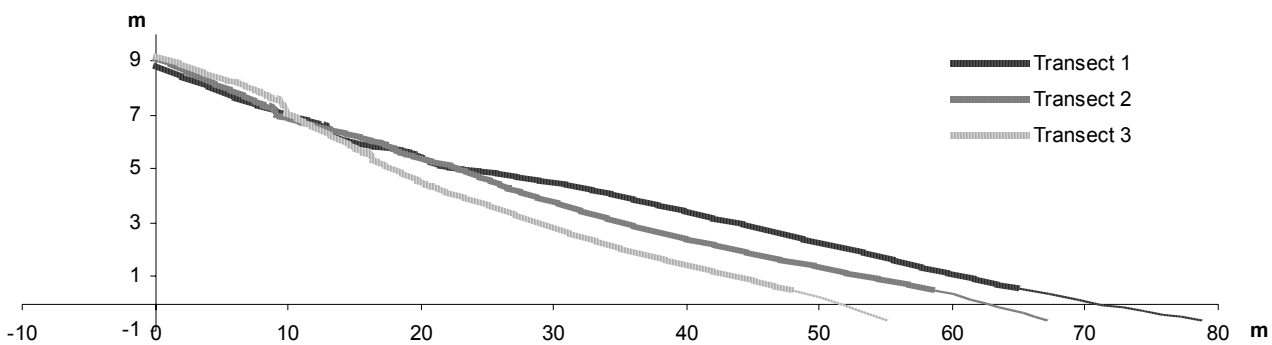
Width of intertidal portion: 59.6m (extrapolated)
Slope of intertidal portion: 10.4% (extrapolated)
10.4 (observed)

Transect 3:
Benchmark position: N 08°17'29.0" W 078°57'16.2"
Direction of transect: 218°

Height (in meters above chart datum)	Distance (in meters from benchmark)	Comments
9.21	0.0	Benchmark
8.11	6.9	
7.72	8.9	
6.91	10.7	
5.67	15.6	Highest Water Mark (Extrapolated)
5.36	16.3	
4.37	20.7	
4.37	20.7	
2.11	35.0	
0.55	48.0	Low Water Mark for that day
-0.55	55.2	Lowest Water Mark (Extrapolated)

Width of intertidal portion: 39.6m (extrapolated)
Slope of intertidal portion: 15.7% (extrapolated)
15.2% (observed)

Profiles:



Appendix 3 : Sediment analysis

Site number	Station	organic C %	Carbonate %	Particle Size Analysis												
				Granule %	V C Sand %	C Sand %	M Sand %	F Sand %	V F Sand %	Silt-Clay %	phi 5	phi 16	phi 50	phi 84	phi 95	sigma 1
1	Low	0.2	90.0	33.6	12.7	42.4	11.1	0.2	0.0	0.0	-2.30	-2.00	-0.35	0.30	1.15	1.10
1	Middle	0.3	80.4	32.6	13.8	42.3	11.2	0.1	0.0	0.0	-2.30	-2.00	-0.35	0.30	1.15	1.10
1	High	0.3	65.5	34.0	2.9	16.0	36.1	10.7	0.3	0.1	-2.30	-2.00	0.30	1.30	2.15	1.50
2	Low	0.1	82.0	44.5	2.2	5.3	44.5	3.4	0.0	0.1	-2.30	-2.20	0.15	1.25	1.40	1.42
2	Middle	0.1	58.8	0.0	1.0	7.5	58.8	30.5	0.9	0.2	-0.50	0.20	1.20	2.50	2.35	1.01
2	High	0.9	61.1	3.9	0.0	3.3	62.0	30.5	0.3	0.0	-0.70	0.70	1.20	1.95	2.30	0.77
3	Low	0.1	72.0	12.7	16.2	36.3	27.7	6.9	0.2	0.0	-2.00	-1.20	0.10	1.20	1.75	1.17
3	Middle	0.4	90.4	13.3	15.1	38.7	24.9	7.9	0.1	0.0	-2.20	-1.20	0.10	1.20	1.80	1.21
3	High	0.1	80.0	0.0	0.7	8.2	88.7	2.4	0.0	0.0	0.05	0.60	0.95	1.30	1.45	0.39
4	Low	0.1	76.0	46.5	2.4	5.6	42.8	2.7	0.0	0.0	-2.30	-2.25	-0.30	1.20	1.40	1.42
4	Middle	0.3	88.9	56.3	10.7	29.8	1.8	0.9	0.5	0.0	-2.30	-2.25	-1.65	0.10	0.40	1.00
4	High	1.3	78.0	0.0	0.1	5.4	37.8	48.1	8.1	0.5	0.40	0.05	1.70	2.30	2.40	0.87
5	Low	0.3	90.3	14.8	4.3	35.9	43.3	1.6	0.0	0.1	-2.70	-1.25	0.30	1.15	1.40	1.22
5	Middle	0.2	94.0	3.6	4.0	56.3	9.6	0.1	0.0	26.4	-1.20	-0.35	0.25	0.20	1.40	0.53
5	High	0.4	85.6	0.0	0.0	1.0	42.6	35.9	0.3	20.2	-0.90	-0.40	0.05	0.30	0.45	0.38
6	Low	0.1	90.9	0.0	0.3	8.6	88.5	2.5	0.0	0.1	0.00	0.60	0.95	1.35	1.45	0.41
6	Middle	0.1	88.4	0.0	0.1	5.4	91.8	2.8	0.0	0.1	0.50	0.65	1.00	1.35	1.45	0.32
6	High	0.6	84.1	2.3	0.2	3.6	86.4	7.0	0.1	0.5	0.25	0.65	1.00	1.40	2.80	0.57
7	Low	0.2	87.5	7.9	18.3	40.3	28.3	4.3	0.7	0.2	-0.90	-0.10	1.15	2.20	2.60	1.11
7	Middle	0.2	82.0	7.3	18.3	40.5	25.4	4.2	0.8	3.4	-0.90	-0.10	1.15	2.25	3.50	1.25
7	High	0.2	98.0	0.1	1.7	52.4	41.8	0.5	0.0	3.5	0.55	0.75	1.35	2.20	2.50	0.66

Appendix 3 continued

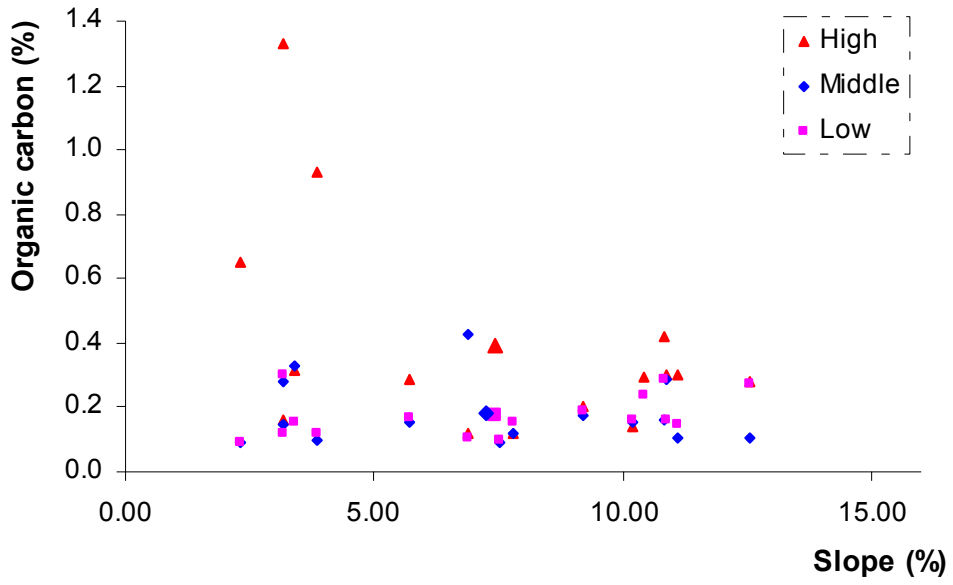
Site number	Station	organic C %	Carbonate %	Particle Size Analysis												
				Granule %	V C Sand %	C Sand %	M Sand %	F Sand %	V F Sand %	Silt-Clay %	phi 5	phi 16	phi 50	phi 84	phi 95	sigma 1
8	Low	0.1	90.0	47.8	2.6	4.5	42.3	2.8	0.0	0.0	-2.30	-2.20	-0.50	1.20	1.40	1.41
8	Middle	0.1	66.0	0.0	1.1	7.3	60.1	30.5	0.9	0.1	0.00	0.65	1.20	2.05	2.35	0.71
9	Low	0.2	91.9	47.8	2.6	4.5	42.3	2.8	0.0	0.0	-2.35	-2.20	-0.30	1.20	1.45	1.43
9	Middle	0.1	94.5	4.4	1.8	5.9	75.6	12.2	0.0	0.1	-1.75	0.60	1.00	1.35	2.15	0.78
9	High	0.1	78.0	0.0	1.0	21.2	41.6	31.4	0.2	4.6	-2.15	-1.20	0.35	1.65	2.05	1.35
10	Low	0.3	84.2	13.6	5.4	20.8	40.0	19.1	0.1	0.9	-2.20	-0.30	0.75	1.70	2.35	1.19
10	Middle	0.1	84.5	0.0	0.9	21.0	42.1	31.2	0.4	4.5	-0.30	-1.10	1.25	2.20	2.50	1.25
10	High	0.3	66.0	2.4	0.1	3.6	62.5	30.9	0.4	0.1	0.60	1.20	1.25	2.15	2.30	0.50
11	Low	0.2	94.0	0.1	1.8	48.3	42.2	7.6	0.0	0.0	0.60	0.75	1.50	2.30	2.80	0.72
11	Middle	0.3	100.0	65.7	4.4	17.2	10.8	1.3	0.5	0.1	-1.40	-1.25	-0.75	1.30	2.20	1.18
11	High	0.3	88.0	0.0	0.1	5.8	70.2	23.5	0.0	0.4	-0.60	-0.10	0.90	1.80	2.30	0.91
12	Low	0.3	92.2	5.2	23.5	46.7	21.7	2.1	0.3	0.5	-1.10	-0.50	0.00	0.80	1.50	0.72
12	Middle	0.1	98.2	0.1	1.6	55.3	41.6	0.6	0.0	0.8	-0.50	-0.25	0.40	1.20	1.40	0.65
12	High	0.2	97.7	0.5	8.2	51.6	32.1	7.3	0.2	0.1	-0.10	-0.35	0.25	1.25	1.90	0.70
13	Low	0.2	98.0	0.6	7.3	52.3	31.5	7.5	0.2	0.5	-1.00	-0.25	0.30	1.25	2.00	0.83
13	Middle	0.2	96.0	3.6	3.9	56.5	9.2	0.1	0.0	26.6	-1.25	-0.25	0.25	3.75	4.25	1.83
13	High	0.3	96.2	0.2	0.6	26.0	55.3	16.6	0.6	0.7	-0.35	1.15	0.90	1.60	2.25	0.51
14	Low	0.2	85.3	53.5	3.5	9.9	9.8	16.6	6.7	0.0	-2.35	-2.25	-1.60	1.95	2.80	1.83
14	High	0.3	81.8	43.2	10.7	19.3	17.5	8.3	1.0	0.1	-2.35	-2.20	-0.80	1.15	2.05	1.50

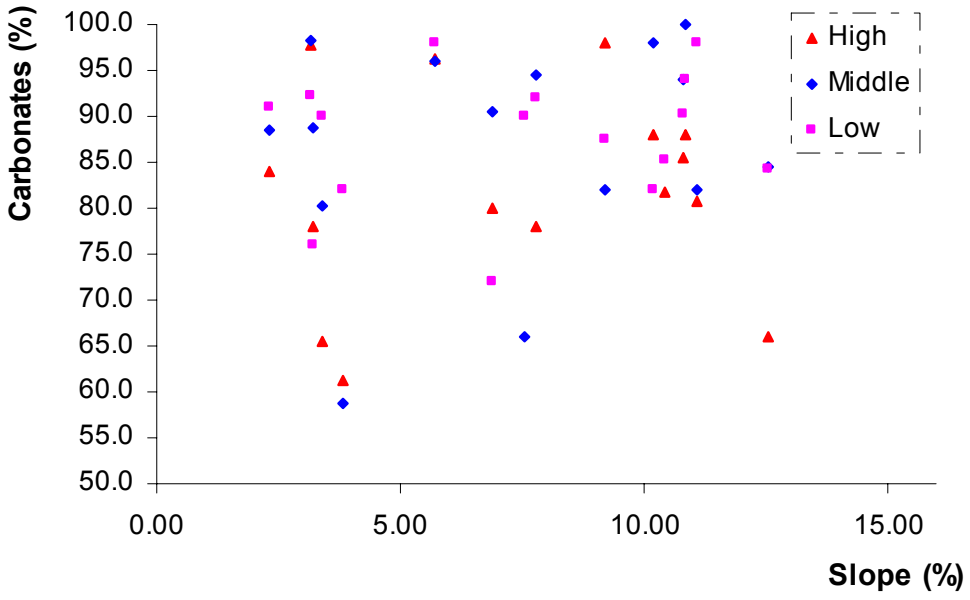
Appendix 3 continued

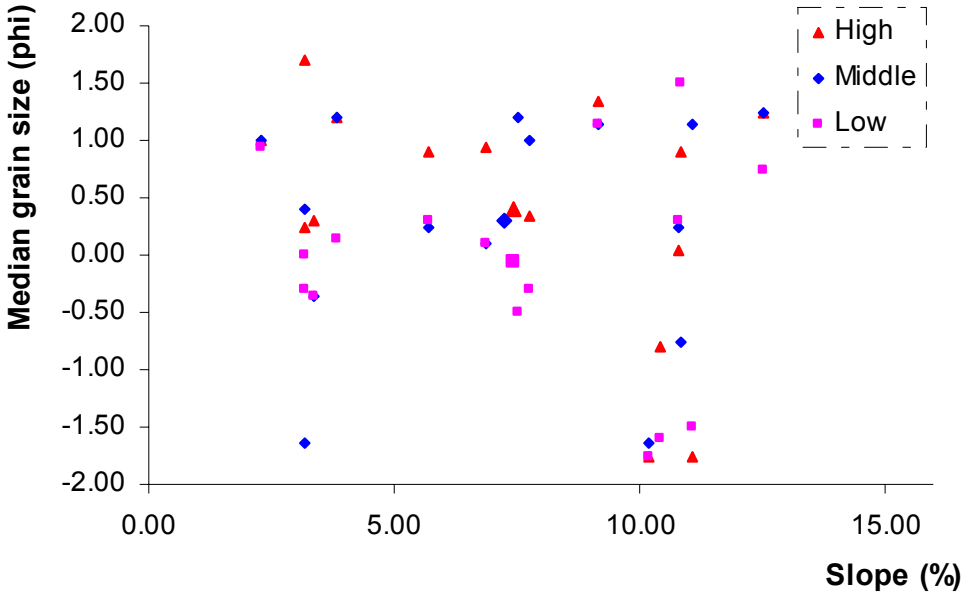
Site number	Station	organic C %	Carbonate %	Particle Size Analysis												
				Granule %	V C Sand %	C Sand %	M Sand %	F Sand %	V F Sand %	Silt-Clay %	phi 5	phi 16	phi 50	phi 84	phi 95	sigma 1
15	Low	0.1	98.0	50.3	2.7	14.2	16.9	2.2	0.1	13.5	-2.40	-2.20	-1.50	1.50	4.15	1.92
15	Middle	0.1	82.0	0.0	0.2	3.3	72.5	23.6	0.2	0.2	0.55	0.70	1.15	1.80	2.25	0.53
15	High	0.3	80.8	64.0	2.7	17.3	13.8	2.1	0.0	0.1	-2.35	-2.25	-1.75	0.50	1.25	1.23
16	Low	0.2	82.0	62.9	2.4	18.5	14.0	2.1	0.1	0.1	-2.40	-2.25	-1.75	0.50	1.25	1.24
16	Middle	0.2	98.0	53.6	3.1	27.0	14.1	2.0	0.0	0.2	-2.40	-2.20	-1.65	0.50	1.25	1.23
16	High	0.1	88.0	63.3	2.9	15.5	15.8	2.1	0.2	0.1	-2.40	-2.25	-1.75	0.70	1.25	1.29
17	Low	0.3	82.0	0.3	0.8	24.9	55.9	16.4	0.9	0.7	-0.30	0.15	0.80	1.65	2.30	0.77
17	Middle	0.8	54.6	0.0	0.0	0.3	0.8	6.0	91.0	1.9	1.80	2.65	3.95	3.35	3.45	0.43
17	High	0.1	57.0	0.0	0.4	1.6	0.7	5.9	90.6	0.9	2.10	2.65	3.95	3.35	3.45	0.38
18	Middle	0.2	96.0	0.1	1.6	55.9	41.6	0.7	0.0	0.1	0.55	0.75	1.40	2.15	1.35	0.47

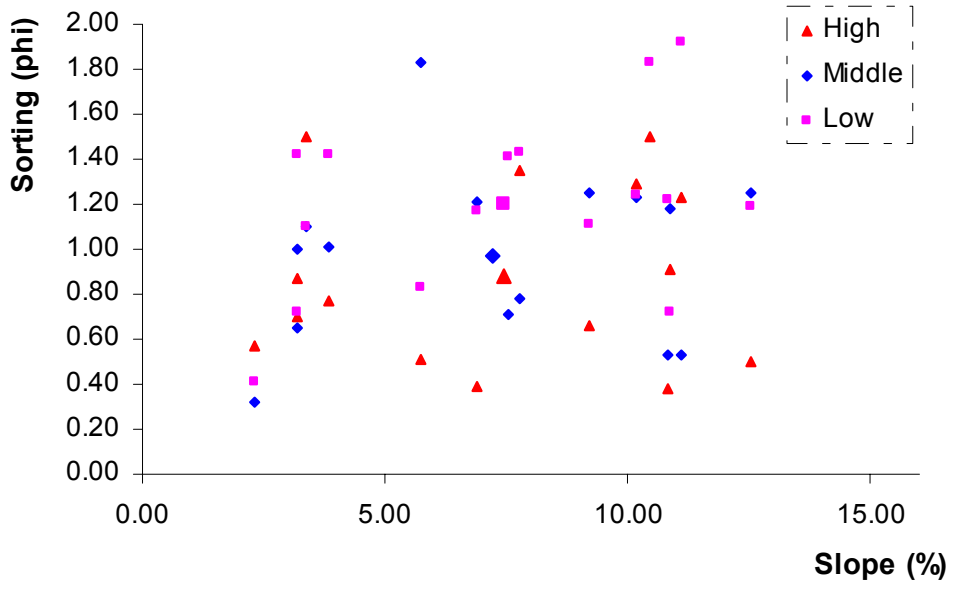
Appendix 4: analysis of relationship between transect slope and sediment characteristics.

Extrapolated slopes of transect 2 for each beach were used as sediment samples were collected along these.






Median grain size (phi)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
0.00
5.00
10.00
15.00
Slope (%)
High
Middle
Low


Sorting (phi)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
5.00
10.00
15.00
Slope (%)
High
Middle
Low

Appendix 5 : GPS coordinates of survey reference points, sediment samples and other features.

T1, T2 and T3 stand for Transect 1, 2 and 3 respectively
BM stands for Benchmark
SSL, SSM and SSH stand for Sediment Sample Low, Middle and High, respectively
LWM stands for Low Water Mark

Coordinates where collected with Etrex Garmin 12 channel GPS in WAAS mode.

Site number	Description	Latitude	Longitude
1	T1BM	N08°38.065'	W079°03.730'
1	T1LWM	N08°38.114'	W079°03.653'
1	T2BM	N08°38.058'	W079°03.719'
1	T2LWM	N08°38.099'	W079°03.670'
1	T3BM	N08°38.047'	W079°03.695'
1	T3LWM	N08°38.119'	W079°03.669'
2	T1BM	N08°37.580'	W079°04.090'
2	T1LWM	N08°37.591'	W079°04.103'
2	T2BM	N08°37.527'	W079°04.111'
2	T2LWM	N08°37.562'	W079°04.129'
2	T3BM	N08°37.551'	W079°04.104'
2	T3LWM	N08°37.554'	W079°04.135'
3	T1BM	N08°37.721'	W079°01.822'
3	T2BM	N08°37.774'	W079°01.895'
3	T3BM	N08°37.844'	W079°01.954'
4	T1BM	N08°35.708'	W079°01.527'
4	T1LWM	N08°35.785'	W079°01.493'
4	T2BM	N08°35.734'	W079°01.544'
4	T2LWM	N08°35.749'	W079°01.509'
4	T3BM	N08°35.761'	W079°01.549'
4	T3LWM	N08°35.764'	W079°01.517'
5	Edge north platform	N 08°35'02.6"	W 079°01'20.7"
5	Edge north platform	N 08°35'02.8"	W 079°01'20.9"
5	Edge north platform	N 08°35'03.0"	W 079°01'20.9"
5	Edge north platform	N 08°35'03.1"	W 079°01'20.6"
5	Edge north platform	N 08°35'03.2"	W 079°01'20.6"
5	Edge north platform	N 08°35'03.3"	W 079°01'20.7"
5	Edge north platform	N 08°35'03.4"	W 079°01'20.7"
5	Edge south rocks	N 08°35'11.1"	W 079°01'14.7"
5	Edge south rocks	N 08°35'11.1"	W 079°01'15.0"
5	Edge south rocks	N 08°35'11.2"	W 079°01'15.8"
5	Edge south rocks	N 08°35'11.3"	W 079°01'14.4"
5	Exposed rocks near T1	N 08°35'04.2"	W 079°01'17.9"
5	Exposed rocks near T1	N 08°35'04.2"	W 079°01'18.1"
5	Exposed rocks near T1	N 08°35'04.2"	W 079°01'18.2"
5	Exposed rocks near T1	N 08°35'04.3"	W 079°01'18.3"
5	Exposed rocks near T1	N 08°35'04.3"	W 079°01'18.3"
5	Exposed rocks near T1	N 08°35'04.4"	W 079°01'18.1"
5	Exposed rocks near T1	N 08°35'04.5"	W 079°01'17.7"
5	Exposed rocks near T1	N 08°35'04.5"	W 079°01'18.0"

Appendix 5 continued

Site number	Description	Latitude	Longitude
5	Exposed rocks near T1	N 08°35'04.5"	W 079°01'18.1"
5	Exposed rocks near T1	N 08°35'04.5"	W 079°01'18.1"
5	Isolated rock near T2	N 08°35'07.7"	W 079°01'16.5"
5	Isolated rocks near north platform	N 08°35'02.8"	W 079°01'20.7"
5	Isolated rocks near north platform	N 08°35'02.9"	W 079°01'20.7"
5	Isolated rocks near north platform	N 08°35'03.1"	W 079°01'20.3"
5	Isolated rocks near north platform	N 08°35'03.3"	W 079°01'20.5"
6	Angle of North platform	N 08°34'31.3"	W 079°01'30.0"
6	Edge of North mangrove	N 08°34'26.4"	W 079°01'25.1"
6	Edge of North platform	N 08°34'27.6"	W 079°01'26.1"
6	North edge of mangrove	N 08°34'34.0"	W 079°01'30.7"
6	SSH	N 08°34'29.6"	W 079°01'29.2"
6	SSM	N 08°34'33.3"	W 079°01'31.4"
6	T1BM	N 08°34'27.5"	W 079°01'28.8"
6	T2BM	N 08°34'29.0"	W 079°01'30.1"
6	T2BM and SSL	N 08°34'30.2"	W 079°01'28.1"
6	T3BM	N 08°34'32.9"	W 079°01'31.9"
6	T3LWM	N 08°34'33.9"	W 079°01'29.3"
7	SSH	N08°34.477'	W079°01.550'
7	T1BM	N08°34.524'	W079°01.620'
7	T1LWM	N08°34.027'	W079°01.167'
7	T1LWM	N08°34.488'	W079°01.631'
7	T2BM	N08°34.482'	W079°01.546'
7	T2LWM	N08°34.460'	W079°01.567'
7	T2LWM	N08°34.469'	W079°01.561'
7	T3BM	N08°34.365'	W079°01.478'
7	T3LWM	N08°34.355'	W079°01.501'
8	T1BM	N08°34.013'	W079°01.196'
8	T2BM	N08°34.036'	W079°01.178'
8	T3BM	N08°34.081'	W079°01.130'
9	T1BM	N08°32.070'	W079°02.042'
9	T2BM	N08°32.107'	W079°02.015'
9	T3BM	N08°32.128'	W079°02.003'
10	T1BM	N08°31.090'	W079°02.830'
10	T1LWM	N08°31.091'	W079°02.866'
10	T2BM	N08°30.955'	W079°02.851'
10	T2LWM	N08°30.956'	W079°02.879'
10	T3BM	N08°30.813'	W079°02.902'
10	T3LWM	N08°30.827'	W079°02.925'
11	SSH	N 08°29'13.5"	W 079°03'58.8"
11	SSM	N 08°29'13.6"	W 079°03'59.3"
11	T1BM	N 08°29'31.3"	W 079°04'01.7"
11	T1LWM	N 08°29'30.7"	W 079°04'03.4"
11	T2BM	N 08°29'13.4"	W 079°03'58.4"
11	T2LWM and SSL	N 08°29'13.7"	W 079°04'00.2"
11	T3BM	N 08°29'04.4"	W 079°04'00.6"

Appendix 5 continued

Site number	Description	Latitude	Longitude
11	T3LWM	N 08°29'05.3"	W 079°04'02.4"
12	T1BM	N 08°29'18.1"	W 078°58'59.2"
12	T2BM	N 08°29'19.7"	W 079°00'01.4"
12	T3BM	N 08°29'23.1"	W 079°00'04.5"
13	T1BM	N 08°29'20.1"	W 078°58'33.2"
13	T2BM	N 08°29'19.0"	W 078°58'44.9"
13	T3BM	N 08°29'20.7"	W 078°58'53.6"
14	Clay mound near T1	N 08°13'39.5"	W 078°54'13.4"
14	Edge south boulders	N 08°13'38.8"	W 078°54'12.7"
14	Edge south boulders	N 08°13'38.9"	W 078°54'13.2"
14	Edge south boulders	N 08°13'39.1"	W 078°54'13.6"
14	Edge south platfrom	N 08°13'38.8"	W 078°54'12.6"
14	Edge south platfrom	N 08°13'39.0"	W 078°54'12.3"
14	Edge south platfrom	N 08°13'39.0"	W 078°54'12.4"
14	Edge south platfrom	N 08°13'39.0"	W 078°54'12.7"
14	Edge south platfrom	N 08°13'39.1"	W 078°54'12.9"
14	Edge south platfrom	N 08°13'39.2"	W 078°54'12.6"
14	Edge south platfrom	N 08°13'39.4"	W 078°54'13.1"
14	Edge south platfrom	N 08°13'40.0"	W 078°54'12.7"
14	SSH	N 08°17'14.1"	W 078°57'42.9"
14	SSM	N 08°17'18.4"	W 078°57'38.3"
14	T1BM	N 08°13'39.5"	W 078°54'13.4"
14	T1BM	N 08°16'52.9"	W 078°56'21.4"
14	T1BM	N 08°17'35.8"	W 078°57'34.0"
14	T1LWM	N 08°15'23.5"	W 079°05'57.0"
14	T1LWM	N 08°17'07.5"	W 078°57'53.3"
14	T1LWM	N 08°17'25.5"	W 078°57'16.0"
14	T2BM	N 08°13'39.9"	W 078°54'19.5"
14	T2BM	N 08°16'53.8"	W 078°56'19.7"
14	T2BM	N 08°17'34.9"	W 078°57'32.2"
14	T2LWM and SSL	N 08°16'53.6"	W 078°56'20.2"
14	T3BM	N 08°13'41.6"	W 078°54'22.2"
14	T3BM	N 08°16'53.6"	W 078°56'20.3"
14	T3BM	N 08°17'29.0"	W 078°57'16.2"
14	T3LWM	N 08°16'58.7"	W 078°56'25.9"
14	T3LWM	N 08°17'33.8"	W 078°57'32.8"
15	T1BM	N 08°30'18.7"	W 078°58'48.4"
15	T1LWM	N 08°30'18.7"	W 078°58'48.4"
17	Bottom of talus-like structure near at rock edge	N 08°14'39.2"	W 079°06'22.7"
17	Boundary of soft and hard ridges	N 08°15'25.8"	W 079°05'56.9"
17	Boundary of talus-like structure and mangrove	N 08°14'50.0"	W 079°06'22.7"
17	Edge north platform	N 08°14'37.4"	W 079°06'17.1"
17	Edge north platform	N 08°16'25.9"	W 078°57'21.4"
17	Edge of cliff	N 08°15'23.6"	W 079°05'56.9"
17	Edge of gravels along cliff	N 08°15'26.2"	W 079°05'56.5"
17	Edge of ridge along water and beach	N 08°15'21.2"	W 079°06'05.3"

Appendix 5 continued

Site number	Description	Latitude	Longitude
17	Middle of scarce rocks at middle of beach	N 08°14'55.1"	W 079°06'21.2"
17	SSL	N 08°14'44.4"	W 079°06'19.0"
17	SSM	N 08°14'44.4"	W 079°06'20.9"
17	Track and sand mound	N 08°15'09.2"	W 079°06'14.9"
17	Turtle nests	N 08°15'15.0"	W 079°06'11.3"
17	Turtle nests	N 08°15'17.4"	W 079°06'09.3"
18	Middle of exposed sand	N 08°32'58.5"	W 079°01'58.4"
18	NE edge	N 08°32'58.9"	W 079°01'57.3"
18	NW edge	N 08°32'59.5"	W 079°01'58.6"
18	SE edge	N 08°32'57.3"	W 079°01'58.5"
18	SSM	N 08°32'58.7"	W 079°01'57.3"
18	SW edge	N 08°32'57.8"	W 079°02'01.8"
18	SW tip	N 08°32'58.2"	W 079°01'58.7"