3. INVESTIGATIONS

3.1 Objectives of Monitoring Programme

The overall objectives of the monitoring programme described in this report were to determine the following:

(i) the nature of the material stored within the spoil dump, the nature of the material released in the silt plumes and deposited on the reef flat, together with the extent and persistence of fine silt deposits on the reef flat;

(ii) the total amount of material stored within the spoil dump, the magnitude of losses occurring from it, the changes in its shape and their implications for shoreline stability;

(iii) the hydraulic and meteorological conditions responsible for reshaping the spoil dump and releasing silt from it and the frequency of occurrence of silt-producing events.

Having determined the nature, magnitude and causes of the continuing problem, it would then be possible to make recommendations concerning the future management of the spoil dump and any further monitoring activities required.

3.2 Field Work

Field work for this project was undertaken in two different ways:

(i) special visits to the site by the investigators;
(ii) continuing observations on site by Heron Island Research Station (HIRS) personnel.

Site visits were made as follows:

13-18 May 1988	Dr Gourlay
17-21 May 1988	Dr Jell
3-19 December 1988	Dr Jell
29 March to 7 April 1989	Dr Gourlay and Mrs Hacker
2-8 December 1989	Dr Jell
2-6 January 1990	Dr Gourlay
10-16 August 1990	Dr Jell
24-30 November 1990	Dr Jell
17-24 June 1991	Dr Gourlay

Dr Gourlay's site visits included surveying the spoil dump to determine changes to its size, etc., while Mrs Hacker investigated the nature of the material contained in it. Dr Jell collected sediment samples from the reef flat and observed the condition of the beach rock. Dr Jell had sampled the material in December 1987.

Observations of waves and other factors associated with the occurrence of silt plumes have been made by HIRS personnel commencing in December 1988 and continuing on a daily basis since early 1989. These observations are still being made. HIRS personnel also from time to time made measurements of the turbidity of the water over the reef flat.

The site visit during March-April 1989 was originally planned to take place earlier in the year to coincide with the scheduled excavation of a trench across the spoil dump for the construction of the research station's new saltwater intake pipeline. It was intended to monitor this operation

and record details of spoil dump sediments exposed during this activity. Delays in the pipeline project resulted in a change in plans and the site was visited before this operation occurred. Instead arrangements were made with the contractor constructing the pipeline to excavate temporary holes in the spoil dump for inspection purposes. At the time of this visit the excavation for the new pumphouse was also still open and this allowed examination of natural cay sediments behind the spoil dump. Details of the subsurface investigations are given in section 4.1.2.

3.3 Sedimentological Analyses

The sedimentological analyses were undertaken to determine the nature of the material stored in the spoil dump, the nature of the material released in the silt plumes and deposited on the reef flat, and the extent and persistence of fine silt deposits on the reef flat.

Sedimentological samples were obtained from the spoil dump during the subsurface investigations (section 4.1.2). Samples were also taken across the reef flat at intervals of 50m on nine traverses (Figure 4) on several occasions. Traverses A, B, G, H and I were taken in the area most likely to be affected by material from the dredging operation and from erosion of the spoil dump. Traverses C, D, E and F were taken to monitor areas away from the harbour and spoil dump, in order to ascertain if the material from the dredging was widely distributed, and also to determine changes in the sediment distribution in these areas that occur because of changing hydraulic conditions across the western end of the reef. All samples were taken by scooping a screw topped jar through the top 2 cm of sediment and applying the lid immediately so as to lose as little of the fines as possible.

On each traverse, samples were collected from the larger areas of sediment commonly showing ripple marks, rather than from small isolated patches between or within coral clumps or within the rubble material. All previous surveys used 50m sampling intervals and showed consistent gradients in parameter values. This suggests that the sampling procedure for reef flat sediments was appropriate.

A total of 388 sediment samples were either collected specifically for this project or were available from previous investigations. 308 sand size samples were sieved at 0.5ϕ intervals to give grain size distributions of the sand fraction. 22 samples were analysed using laser diffraction analysis to determine the grain size distribution of the silt fraction of samples or the size distribution of suspended solids from water samples. Where necessary the results of the sand and silt grain size distributions obtained from these two types of analysis were combined to give a single grain size distribution. Size distribution analysis was not undertaken for particles greater than 4mm.

The procedures used for the preparation of the samples for particle size analysis were as follows:

(i) Samples were treated with bleach (10% NaOCl) to remove organic material.

(ii) Samples with a significant proportion of fines were wet sieved through a 63μm (4ϕ)sieve. The fine residue was allowed to settle, water was decanted and the wet sieve residue (WSR) air dried.

(iii) The material retained on the 63μm sieve and the samples which were not wet sieved were oven dried ($\leq 100^{o}$C).

(iv) Both the retained material from the wet sieved samples and the other samples were sieved through 0.5ϕ sieves with a range from -2ϕ to 4ϕ (4mm to 63μm). The fine residue from this operation is designated the dry sieve residue (DSR). All sieve fractions have been kept.

(v) Both WSR and DSR were analysed with the laser size analyser and the results combined with those from the sieve analysis to give grain size distributions for the size range 9 to -2ϕ (2μm to 4mm).

(vi) Grain size distributions were plotted using software compiled using FORTRAN and HGRAPH. Each plot shows a histogram of proportions of each particle size fraction and a cumulative size distribution curve. Both ϕ and mm sizes are indicated with mm size increasing from left to right in accordance with normal engineering practice.

(vii) Where required for detailed comparison of sediment size distributions, e.g. on the reef flat, the standard statistical parameters, i.e. graphic mean and graphic standard deviation, were computed for each grain size distribution using the method of Folk and Ward (1957).

The equipment used to determine the size distribution of the material finer than 63μm was a Malvern laser size analyser. The software used in operating the system allows 16 size ranges to be measured within the range of the lens used. For this investigation two lenses were used - the 100 lens which measures particles in the size range 1.9 to 188 μm and the 300 lens which measures the size range 5.8 to 564μm. Particles larger than the upper limit of the size range are not detected by this instrument but it does give an indication of the proportion of material finer than the designated size range. The laser size fractions were converted to standard 0.5ϕ fractions before the grain size distributions were plotted.

The laser size analyser used only a very small subsample (≈1g) of the total sample and care was required to ensure that a representative subsample was collected. For example subsamples were taken from what appeared to be typical portions of the sample and, where appropriate, the sample was well mixed or shaken before subsampling. Very wet samples were sampled speedily after shaking, using a pipette. Repeat analyses of the same subsample using the same lens gave similar results but sometimes there were discrepancies when different lenses were used. For 16 samples two or more subsamples were analysed independently and for 12 of these samples, analyses of given subsamples were repeated. The results were generally found to be consistent. If any of the inconsistencies were due to limitations of the methodology those results were rejected. The combined grain size distribution curves were sometimes rather strange in form. Microscopic examination of selected samples where this effect was most pronounced indicated that for the wet sieved residue fine silt material was aggregated or clumped together. Small particles were clumped together and several small particles often adhered to larger particles. Hence the grain size distribution of this material is shifted towards the coarser size fractions - coarse silt and fine sand. It is probable that this is a result of the washing/drying process used in the laboratory and consequently greater reliance was placed on the size analysis of fine material which had not been subjected to any drying process. To what extent this clumping occurs naturally is not known.

A total of 21 water samples were collected for the purpose of determining concentrations of silt in silt plumes. Unfortunately not many such samples were obtained and those that were obtained were not always useful. The samples were analysed by the Chemical Engineering Department, The University of Queensland to give the concentration of suspended solids in g/L. Four of these samples were also analysed using laser diffraction analysis to give grain size distributions of the suspended material in the silt plumes.

3.4 Surveys of Spoil Dump Size and Shape

The surveys of the spoil dump size and shape were undertaken to determine the total amount of material stored within it, the magnitude of losses occurring from it, the changes in its shape and their implications for shoreline stability.

The location of the shoreline of the spoil dump and changes in its volume were obtained from the four field surveys made in May 1988, April 1989, January 1990 and June 1991. The total volume of material within the spoil dump was estimated by comparison with the August 1984 survey by the Department of Harbours and Marine (DHM 1984).

Surveys were made by the stadia method using a Sokkisha B2 automatic level and a 5m extendable aluminium staff, this equipment being available at the research station. It was found impossible to locate suitable fixed reference points in the spoil dump so each survey had to be recommenced from reference points on the helipad and the end of the resort seawall. This difficulty arises from the various uses being made of the spoil dump from time to time - as a storage area for building material or boats which block lines of sight - or the movement of vehicles over it and the regrading of eroded areas to facilitate this movement which is likely to displace any reference marks left in situ. Placement of marks on the landward side of the spoil dump is also not an option as levels and sight distances are unsuitable for the available surveying equipment and visibility is restricted by vegetation.

The benchmark for levels on the island is PM 61221 which is located at the centre of the helipad. Its level is 4.511m on low water datum, the latter being located below reef flat surface level. Low water datum is convenient for surveys of the spoil dump and cays in general since all levels are positive numbers. Both the location of the benchmark on the helipad and the proximity of the spoil dump meant that surveying activities had to be planned around helicopter operations - and nonoperations - since a helicopter parked on the centre of the helipad could be an impediment to survey activities. For each survey a series of temporary star picket pegs was placed around the outside of the generally level surface of the spoil dump and located relative to one another by triangulation. After some initial omissions, all locations were checked by backsights to two other pegs wherever possible. Sight distances were restricted as far as possible to 50m to give locations to 0.5m and elevations to 0.01m.

Some difficulty was experienced in surveying profiles of the spoil dump beach as the level difference between the edge of the sand at the base of the beach and the top of the spoil dump was too much to be measured from one location with the available equipment. Additional secondary reference pegs were required lower down the beach for this operation.

Each day's work was planned to fit in with helicopter operations, the tide, availability of research station personnel to assist with holding the staff, etc.. On completion of each day's field work, the results were reduced and plotted that evening. Subsequent days work were planned to fill in any gaps noted until the survey covered the whole spoil dump. About 12 to 16 hours field work spread over 3 to 4 days was generally required to complete each field survey.

Contoured plans to a scale of 1 in 500 have been prepared for each survey. The original plans show the spot levels but the latter are omitted from the figures presented in this report (Figures 5, 6, 7 and 8). As well as determining the shape of the spoil dump the opportunity was taken to accurately locate any identifiable natural features or artificial constructions close to the spoil dump.

Changes in the shape of the base of the spoil dump beach were surveyed directly for comparison with information available concerning shoreline location before enlargement of the boat harbour. For the determination of the spoil dump volume and changes to it, a set of standard lines 10 or 20m apart was superimposed on the contoured plans and crossectional areas along each line above datum level calculated. The volume of material between each pair of lines was obtained by multiplying the average of their areas by the spacing between them. These incremental volumes were then either summed over the total area covered by the profiles to obtain a total volume for each survey or compared directly with the corresponding volume for other surveys to determine the volume change for that portion of the spoil dump.

Additional information concerning changes to the spoil dump was obtained from quasivertical aerial photographs taken from time to time by Queensland National Parks and Wildlife personnel on surveillance flights. In this case black and white negatives were made from the colour slides supplied and enlargements printed at a scale of 1 to 2000 for comparison with earlier observations of the shoreline position. One of the photographs taken in December 1987 is particularly significant as it gives the only known record of the shape and location of the spoil dump soon after its completion and before any significant erosion of its seaward face had occurred (Photo 5). The location of both the base of the spoil dump and the top of the wave-formed scarp/berm on 7 December 1987 were determined from the photograph and, after comparison with levels on the reef flat and the top of the spoil dump surveyed in May 1988, it was possible to determine the initial volume of the spoil dump.

The initial volume is not as reliable as those determined subsequently by direct survey, although two independent estimates by different persons gave values which differed by less than 1%. Errors of between 100 and 200m^3, that is of the order of 1% of the total volume, are to be expected. These are of the same order of magnitude as the measured volume changes between each survey. Nevertheless the latter reduce consistently showing little evidence of the effect of random errors (see Table 2 and Figure 11).

In the vicinity of the jetty, the piles of the jetty are used as reference points. However, it should be noted that the two pairs of piles at the landward end of the jetty, which were not connected by horizontal railings to the other piles, were cut off sometime between May and September 1988. All references to pile numbers in this report refer to piles which extend above deck level to form the supports for the horizontal railings along the jetty. Pile No.1 is located 10m seaward of the concrete slab at the landward end of the jetty.

3.5 Hydraulic and Meteorological Data Analyses.

The hydraulic and meteorological analyses were undertaken to determine the conditions responsible for reshaping the spoil dump and releasing silt from it and the frequency of occurrence of silt-producing events.

The stability of the spoil dump, realignment of the shoreline and release of fine sediments from it are all largely determined by the actual physical conditions to which it is subjected. Tides, waves, winds, currents, rain, etc. may all be involved. These conditions together with observed changes to the spoil dump beach are being recorded daily by members of the Heron Island Research Station (HIRS) staff.

The actual observations and the methods of making them are based upon the COPE programme of the Beach Protection Authority (Robinson and Jones 1977, BPA 1990) and some previous experience over a two week period at Raine Island. The standard COPE observations are made at fixed locations at the same time each day and this procedure was followed by observers on Green Island (BPA 1989). However the observation programme at Heron Island has used two fixed locations and a variable time of observation determined by the time of the day time high

tide. There are two reasons for this. Firstly larger waves occur at high tide and observations at that time are more likely to give useful information about the occurrence of silt plumes. Secondly HIRS staff make routine daily observations of water temperature, etc. one hour before day time high water and it was convenient to combine the two sets of observations.

The observations were initiated during December 1988 and reviewed during the field inspection in March-April 1989. Useful information is available from this initial period but complete data is only available from April 1989. In particular the presence or absence of a silt plume was not recorded prior to this date. Observations are made at two stations on the spoil dump and also from the jetty. Separate recording forms are used for each location, copies of which are included in Appendix A. Station 1 is located at the southern end of the spoil dump near the entrance to the research station while station 2 is just south of the jetty. Observations recorded include various characteristics of the waves breaking on the beach (height, period, direction, etc.,) occurrence, width and movement of a silt plume, evidence of erosion and accretion of the beach, tide level and wind strength and direction.

The measurement methods are adapted from those of the COPE programme. Wave heights are visually estimated to the nearest 0.1m; wave periods are averaged over 10 waves by timing the interval between the first and eleventh successive waves with a stop watch; wave directions are measured with a magnetic compass; surf zone and silt plume widths are estimated visually to the nearest 1m.

The daily field observations have been supplemented with Bureau of Meteorology observations from Heron Island automatic weather station (HIAWS). These include three hourly wind speeds and directions, maximum daily wind gust, and twenty four hour rainfalls. Predicted high and low tide levels based upon Harbours and Marine Department tide tables (DHM 1989, 1990) are also used in the analysis of the observations. These predictions are based on Gladstone and the tidal planes, etc are given in Table 1. It should be noted that the zero of the tide board installed on the jetty in April 1989 for this project is 65mm above low water datum used for the tide predictions.

The observed data is forwarded to the University at the end of each month. However this is not always possible owing to problems with HIRS photocopier which prevents the making of a security copy. Indeed delays of several months in transmitting the data have occurred and consequently the analysis programme has also been delayed.

The observed data, together with meteorological and tidal data, is processed in spreadsheet format using Microsoft WORKS. All data is checked as far as possible for consistency and reliability and a number of data plots is made as part of this process. The reliability of the observers is evidenced by the fact that during the period 1 May 1989 to 30 April 1990 observations were made on 363 days out of the possible 365 days.

Over the period of monitoring there has been a number of observers recording the data. On many occasions where apparent inconsistencies were noted, closer examination of conditions indicated that the differences were likely to be real. However, differences in some of the more subjective observations, such as the width of the silt plumes or even the existence of a silt plume, will influence the results of the data analysis. On the other hand, where data could be independently checked, for example wind speed estimates against data recorded by HIAWS, good agreement was obtained on most occasions. A recent assessment of the LEO programme (Smith and Wagner 1991), the coastal engineering observation programme in the United States, indicates that wave heights estimated by observers are likely to be within 30% of correct values and wave period measurements are likely to overpredict the period. The capability of individual observers is the most important factor determining the accuracy of observations. Most of the Heron Island observers have some scientific training.

A considerable number of analyses has been carried out to establish the most suitable forms of presentation. A selection of these is used in the discussion of the results of the analysis. Data is presented in three basic formats - bar charts, scatter plots and time series. Since complete observations are only available since April 1989, the available data was processed initially for the twelve month period May 1989 to April 1990 and analyses were made on a monthly, four monthly or annual basis as considered appropriate. Subsequently data for the second twelve month period May 1990 to April 1991 was processed. The implications of both twelve month analyses are considered in the appropriate sections of this report.

A review of the coastal observation programme, including some typical results, is given in Gourlay (1991b).

Table 1. Tidal Planes at Heron Island Sandard Port Gladstone

Tidal Plane		Elevation above low water datum, m
HAT		3.4
MHWS		2.7
MHWN		2.1
ML		1.61
MLWN		1.1
MLWS		0.6
LAT		0.1
Av. time difference.	HW = –43 min	LW = –38 min
Ratio = 0.70	Constant = –0.01m	