CHAPTER 4

An Assessment of the Influence of Dredging on Sediment Movement, and Growth of Mangroves, Corals and Seagrass in Cleveland Bay.

From sidescan seismic profiling and vibracore sampling, Carter and Johnson (1987) have produced an isopach map of dredge spoil distribution in Cleveland Bay and a map showing surficial sediment facies distribution beneath the spoil (Figure 24). A maximum thickness of 50cm of dredged material from Townsville Harbour and the Platypus Channel was found in the vicinity of the two present dump sites east of Magnetic Island and seaward of Ross River mouth. The 50cm isopach was closely surrounded by the 30cm isopach near the landward dump site, but from the main seaward dumping ground the 30cm isopach extended south-eastwards and broadened towards the south-east coast of the bay. The 10cm isopach surrounded the two centres of concentrations in a triangular shape with its apex near the north-east tip of Magnetic Island and its base broadly paralleling the south and south-east coasts of the bay between the 5m and 2m isobaths. A further concentration of dredge spoil with a maximum thickness of 30cm was identified west of Platypus Channel and south-east of Middle Reef and probably relates to the dump site used before about the mid-1960's.

The aim of the present project has been to assess the influence of dredging on the coastline and intertidal zone as revealed by aerial surveys between 1941 and 1988 and the two series of ground surveys which exist. The higher quality air photographs taken at times of clear under-water visibility, and some of the ground surveys, have enabled this assessment to include the adjacent part of the subtidal zone at certain dates. For the period prior to aerial surveys, it is possible to make only a general assessment of the likely

effects, based on relatively scant dredging data and contemporary observations, but drawing on present knowledge of processes.

1 Influence of Dredging between 1883 and 1964

Taking into account availability not only of aerial surveys but also of detailed dredging records and process data, the influence of dredging will be assessed for two time periods, 1883-1964 and 1965-1988. For the former period, the history of dredging has been examined in Chapter 1, data on dredged depths has been compiled into Table 1 and the intermittent annual dredging records are listed in Table 2.

Whilst a fair record of dredging exists in relation to the development of Townsville Harbour and the maintenance of depths suitable for shipping, only two written records have been found concerning the dump sites used for disposal of the dredged material. In 1883 it was "deposited close to Magnetic Island, about 5 miles distant from where it is raised" (Annual Reports of the Engineer of Harbours & Rivers on Works, 1876-1928), that is off Cockle Bay or the south end of Nelly Bay. The report for 1891-92 notes that "The cost of carrying (dredge spoil)... will possibly be slightly greater in the coming year as all the dredgings will be carried to Cockle Bay, in Magnetic Island, it not being advisable to deposit any eastward of the Eastern Breakwater". (The comparison with earlier costs probably takes into account the fact that much early dredging provided infill for reclamations, and it is not a direct comparison with the dumping described in 1883). It seems probable that these two references are to the same site, but how long this was used is unknown. The next information about dump sites is that before the early to mid 1960's dumping was carried out south of Middle Reef, but for how long is again unknown (N. Butterworth, personal communication 1988).

When considering dredge spoil it is important to differentiate between that obtained during developmental and maintenance dredging. Developmental dredging was of major importance in the late 1800's and early 1900's when the harbour was being constructed initially and the Platypus Channel was being excavated. Many references were made in the early reports to the difficulties of removing the "tenacious clay", "stiff clay" and "sandstone" which were encountered as well as softer mud and clay. Excavations for the Casino complex, now built adjacent to the Western Breakwater, have revealed not only the rapid rate of sedimentation there since that breakwater was constructed in the 1880's, but that the weathered Pleistocene basement is almost at the 1880's surface with only a thin bay-sediment veneer over it in places (Carter and Johnson 1987). Elsewhere a sticky mangrove mud intervenes between the bay-sediment and the Pleistocene deposits. The top of the Pleistocene marks an abrupt increase in lithification and below it is a sequence, over 7m thick, of deeply weathered clays, quartz sand and a marine shellbed. Many of the beds contain carbonate or ferro-magnesian nodules resulting from deep sub-aerial weathering in the tropical climate. When this more lithified material forms dredge spoil it is probably relatively immobile after dumping and is likely to cause the raising of the seabed at the dump site. It will almost permanently bury the sediment, coral or seagrass previously on the surface of the seabed. This may have had a pronounced effect off Cockle Bay in the late 1800's and for as long as this dump site was in use and developmental dredging was being carried out. The sediment which is released from this more lithified state is likely to be more mobile and will be transported in suspension or as bedload and be more widely dispersed by waves and currents. More research is needed into tidal and wind-induced current flows and wave directions in West Channel to resolve the apparent contradictions in the results of different measurements made

to date. Only then will it be possible with reasonable certainty to determine in which direction finer sediment would be carried from a dump site off Cockle Bay. Nevertheless it does seem likely that some fine sediment would settle in the shallow water on the extensive coral reef flat north-west of the bay and its presence there has been noted by Spenceley (1977), seaward of the mangrove fringe.

Maintenance dredging, to retain the depth excavated by developmental dredging, involves the removal of unconsolidated sand and mud deposited in the harbour and Platypus Channel by Ross Creek and as a result of general sediment movements in the bay controlled by wind, wave and tidal processes. Taylor (1980) claimed that 0.9-1.2m of sediment per year accumulated in the berths in "normal weather" and even greater thicknesses in Platypus Channel. Throughout the period of dredging from 1883 onwards it has been observed that deposition of sediment in the harbour and channel is especially rapid when a tropical cyclone occurs followed by major river flooding. The first such occurrence noted in the reports was in March 1890, followed by 24 January 1892, April 1894, January 1896 (Cyclone Sigma), March 1903, 1908, two in 1910, 18 February 1940, 7 April 1940, 28 March 1944, March 1946, 6 March 1956 (Cyclone Agnes), 24 December 1971 (Cyclone Althea) and February 1976. After such events a considerable amount of maintenance dredging was necessary to restore depths and therefore large quantities of fine sediments were carried out to the dump site(s). From the site off Cockle Bay it is likely that some of this sediment was transferred onto the neighbouring coral reef flats, although some was probably moved further away by tidal currents south-eastwards (Townsville Port Authority drogue measurements) or north-westwards by sea-bed currents induced by strong south-east winds (Belperio's sea-bed drifter investigations). A third influence, north-east tidal currents across West Channel reported by Carter and Johnson

would have transferred most of the dredged sediment onto the south-west coast of Magnetic Island and its adjacent coral reef. As noted earlier however a tidal current flowing in this direction is very difficult to explain and appears improbable.

The dump site south of Middle Reef, which was used prior to the early to mid-1960's, would have been in a more central position on a cross-section of the eastern end of West Channel. It is important to note however that no written record or detailed description of its location has been found. Fine mobile sediment is likely to have affected Middle Reef itself but it probably had less effect on the nearby coasts, than that from the Cockle Bay dump site. This sediment was probably either carried into Cleveland Bay by tidal currents or moved north-westwards by currents induced by strong south-east winds. In the latter instance some of the fine sediment is likely to have been deposited on the Cape Pallarenda-Shelly Beach foreland.

2 Influence of Dredging between 1965 and 1988

From 1965 onwards much more detailed information exists about dredging and wind and wave conditions in Cleveland Bay. Monthly dredging records for the S.D. 'Townsville' 1965-1983 are presented in Table 3 and Figure 5. Records for the T.S.D. 'Sir Thomas Hiley' 1974-1976 are given in Table 2, and for 1983-1988 in Table 4. Annual dredging records amalgamating all these are plotted in Figure 4. All these records are examined in Chapter 1. Throughout this period it is understood that the present shallow draft dump site south-east of Magnetic Island (Figure 1) has been in use, although no written record has been found of when it was first used. Similarly it is not known when the deep draft dump site east of Magnetic Island began to be used, but it is believed to have been from the early 1970's onwards. As

indicated in Chapter 3 monthly summary wind data has been obtained for Cape Cleveland from 1965 to 1987 and wave data from the nearby wave recorder from 1975 to 1987. The dredging data, wind and wave data and general information on tides and currents will be used in the following assessment of the influence of dredging on the changes identified from the aerial surveys and described in Chapter 2.

a) Coastline and Intertidal Changes

Along most of the coasts of Cleveland Bay and Magnetic Island these changes were slight between about 1941 and 1988. East of the east mouth of Shelly Creek the sand beach which was originally seaward of the mangroves was driven landward through them. Erosion near the mouths of the rivers and creeks between Ross River and Cocoa Creek between 1941 and 1973 were noted by McIntyre and Associates (1974). In all these cases the erosion is attributable to natural cyclone effects and is of a similar type to that observed along the east Burdekin delta coast during the same period (Pringle, 1983 and 1984). Erosion of the upper sand beach at the south-eastern end of The Strand in Townsville during the period was not a natural process but resulted from the Harbour interrupting the natural longshore sediment movement north-westwards from the south coast of Cleveland Bay.

Only near Ross River mouth have larger scale coastal changes taken place and these are directly linked to dredging. Reclamations along the west coast of Ross River mouth have been taking place for a long period as the Harbour and adjacent industrial area have expanded. Between 1968 and 1970, 2,319,660m^3 of sand were pumped ashore from the adjacent intertidal sandbanks for a major reclamation here. In 1979-80 about 400,000m^3 of sand was removed from the Ross River bed immediately upstream of Goondi Creek for an 8ha reclamation east of the Harbour's Eastern Breakwater. As

relatively little sediment is being delivered to the coast by Ross River because of the presence of the Ross River dam completed in 1973, this sand is likely to be replaced only very slowly. In addition to this sediment removal, developmental dredging took place in the Ross River channel between 1977 and the early 1980's and this sediment was mainly pumped ashore although small quantities were taken to the shallow draft dump site south-east of Magnetic Island. Maintenance dredging has been undertaken here since and the sediment has been disposed of similarly. As was noted in Chapter 3, sediment in Ross River mouth and seaward of it, was found in the early 1980's to be heavily polluted by sewage effluent from the outfall on the east side of the mouth. This was likely to have been the case from at least the beginning of the period at present under consideration, namely 1965. Polluted sediment would therefore have been incorporated in the land reclamations and would also have been carried to the shallow draft dump site in Cleveland Bay. Further changes have been brought about by the construction between 1981 and 1985, of an angled harbour wall east of the Eastern Breakwater and extending across part of the intertidal sandbanks. The result of all this dredging and construction work in the Ross River mouth area has been to move the main channel westwards from its former position across the intertidal zone, so that it now lies almost due north of the mouth. The presence of the angled harbour wall has caused some sedimentation landward of it on the west side of the channel.

b) Changes to the Mangrove Coasts

Changes to the outline of the mangrove coasts were generally slight during this period. East of the east mouth of Shelly Creek mangroves have been killed due to exposure to wave action, after the sand beach which had protected them was driven landward through them. In the most sheltered part off Rowes Bay mangroves extended a little. Along the south

and south-east Cleveland Bay coasts, McIntyre and Associates (1974) had earlier, between 1941 and 1959, observed about 50m of recession between Sandfly and Alligator Creeks and about 30m of recession along the west banks of the mouths of Alligator, Crocodile and Cocoa Creeks. This was attributed to cyclone effects. During the period now under consideration the extent of the coastal mangrove belt changed very little. There was a slight extension along the coast at the north-east end of Laun's Beach and mangrove colonization began on the north-east side of White Rock Bay. Such changes must be considered as natural.

The only more marked change to the mangrove coasts occurred along the south-west coast of Magnetic Island. The 1974 aerial survey showed considerable damage to what had been a dense and continuous belt of mangroves at the times of the 1959 and 1961 aerial surveys. By 1974 a broad strip of mangroves had been destroyed landward of, but parallel to, the seaward fringe. Further investigations have revealed that Cyclone Althea in December 1971 caused this destruction (Spenceley, 1977). It occurred primarily in the Rhizophora zone, where some wind throw took place immediately, but progressively, during the next 6 years, over 50% of the Rhizophora spp. were killed. The reason for this is unclear, but may be the result of an influx of fresh water, sediment overloading and blocking of pores, or fungal activity. Furthermore Gill and Tomlinson (1969) found that Rhizophora spp. lost their ability to regenerate by shoot development on reaching maturity. Only if sediment overloading was the cause, could dredging and more specifically the dumping of dredge spoil be in any way to blame. This cause was not proved, but if it was a contributory factor, the dumping of enormous quantities of dredge spoil in the early and mid 1970's may have played a significant part. (This will be examined in more detail below in relation to changes in seagrass cover). Later aerial surveys, especially those of

1981 and 1985 revealed the steady recovery of this damaged strip of mangroves.

c) Changes to the Coasts with Fringing Coral Reefs

As shown in Chapter 2, fringing coral reefs have developed in the Cleveland Bay area only along the coasts of Magnetic Island. The most extensive coral reef lies off the south-west coast. The likelihood of fine sediment being carried onto this reef flat from the earlier dump sites near Cockle Bay and south of Middle Reef has been considered above. During the period 1965-1988 it is believed that neither of these sites was in use. No marked change in sediment distribution was identified from the aerial surveys, although there were changes in seagrass growth in the sediment, which will be considered below. Movement of fine sediment to this locality from the present deep draft and shallow draft dump sites (Figure 1) is possible by tidal flood currents. It might be possible also by currents induced by strong north-east winds, but deflected north-westwards through West Channel.

The only changes on the coral reefs along the south-east coast of Magnetic Island, which could be identified from the aerial surveys at the scale of 1:12,000, were in the lower beach sand cover on the Picnic Bay, Nelly Bay and Geoffrey Bay reefs. The characteristics of this sediment which is partly terrigenous and derived from granite weathering primarily, and partly carbonate from the erosion of the reef are considered in detail by Smith (1974 and 1978). The smaller Picnic and Geoffrey Bays which are sheltered by headlands from wind, wave and tidal effects from the north-east and east, showed the smallest changes in the extent of lower beach cover over the inner reef flat. Conversely the larger and more exposed Nelly Bay showed

greater lower beach change associated with sand bar development along its seaward edge. The changes seen in all three bays will have partly resulted from the effects of refracted waves generated by the prevailing south-east winds on the continental shelf landward of the Great Barrier Reef. However as noted in Chapter 3, the south-east wind is capable also of generating waves over the 18km fetch within Cleveland Bay and these unrefracted waves are probably responsible for the orientation of the beaches along the south-east coast of Magnetic Island, together with the changes which have been observed on them. No clear trend of expansion or contraction of these lower beaches was identifiable over the period 1965-1988 and it therefore appears unlikely that dumped dredge spoil is being redistributed onto those beaches. Collins (1987) notes that there have been many unsubstantiated claims locally that dredging is having a harmful effect on these coral reefs. Despite many years of detailed biological studies on them he has found no evidence of this, but notes that two natural events did temporarily damage the corals. The first was the freshwater dilution associated with the rainfall from Cyclones Althea and Bronwyn in December 1971 and January 1972 which caused the deaths of many shallow water colonies. The effects however were obliterated in about 10 years, after some regrowth and some new growth on the dead skeletons. The second event was a large scale 'bleaching' in 1982 which caused the depletion of certain species. Small scale 'bleaching' is common on Magnetic Island reefs and may be the result of such stress factors as high summer temperatures or rain dilution of sea water. The reefs had largely recovered from the 1982 event within 5 years. Thus searching for causes of change, it must be remembered that there are a range of natural events as well as human effects which can influence these.

d) <u>Changes to the Seagrass Beds</u>

Changes to the seagrass beds around Cleveland Bay and Magnetic Island, as identified from the aerial surveys, were the most marked coastal changes to be found. Although slightly outside the period under consideration at present, 1965-1988, the 1959 and 1961 aerial surveys will be referred to, as well as the later surveys.

The distribution of seagrass beds in the Great Barrier Reef lagoon have been mapped recently during a series of field studies by the Northern Fisheries Research Centre (Coles et al, 1987a & 1987b). Their field survey of the Cleveland Bay area was carried out in October 1987 and is currently being analysed, but their draft maps were made available for this project (Figure 25). The maps were drawn from data collected on a series of diving transects at right angles to the coast, as well as by inspection of the intertidal zone on the transect lines.

Determining seagrass distribution from aerial surveys can never be as accurate as from detailed ground and under-water surveys, because of the height from which the coastal area is being viewed. Aerial surveys do have the advantage however of providing a broad overview of the area and this may be especially important in more inaccessible places. There can be specific problems in identifying seagrass beds on aerial photographs (R.G. Coles personal communication, 1988), firstly because the common algae <u>Caulerpa</u> may be difficult to separate from seagrass. (As little <u>Caulerpa</u> is thought to be present in Cleveland Bay, this is not a serious problem here). Secondly water depth limits the area over which seagrass can be recognised and Coles believes it is not generally visible in water with a

depth over 1m. In Cleveland Bay the densest seagrass growth is between +1.0m and -0.5m Chart Datum (CD), however it generally extends to about -2.0m CD, eg. seaward of The Strand, Townsville, and reaches -10m CD near Magnetic Island. From the aerial surveys used in this project it was certainly not possible to see the sea-bed in the deeper areas, where seagrass was located in the field surveys (Figure 25). Seagrass was not visible also along the south-west coasts of Cleveland Bay where greater turbidity occurs than along the more sheltered south and south-east coasts. Even in the intertidal zone it is not possible to locate low growing and thinly spread seagrass on the aerial photographs. Before seagrass distribution was mapped from these aerial photographs they were carefully inspected and discussed with R. G. Coles and W. J. Lee Long at the Northern Fisheries Research Centre, to ensure as high a level of accuracy as possible. When seagrass distribution is to be compared on a series of aerial surveys further difficulty may arise unless all the surveys are flown at the same time of year, because there can be marked changes in the pattern of growth between summer and winter. The aerial surveys referred to below were all flown in winter between late-May and mid-August, except for the 1973 survey which was flown in early October and the 1978 survey which was flown on 28 November (Table 5). Location of seagrass beds is surer on colour aerial photographs, which were available from the surveys between 1974 and 1985; however, using experience gained with these, seagrass could be identified with reasonable certainty on the black and white photographs from the earlier surveys.

The seagrass distribution pattern mapped from a series of aerial surveys for different sections of the coast of Cleveland Bay and Magnetic Island were described in detail in Chapter 2 and are shown in Figures 6,10 and 13. In the Shelly Beach - Cape Pallarenda section (Figure 6) areas of

seagrass were clearly visible in the central and coastward parts of the foreland on the 1959, 1981 and 1985 aerial photographs, but none showed on the 1974 photographs despite their high quality and good under-water visibility. Between Sandfly and Cocoa Creeks (Figure 6) no seagrass could be located on the 1974 aerial photographs, however it was present north-eastwards from the mouth of Crocodile Creek in 1978 and 1981, and had extended along the whole section by the 1985 survey. Between Cocoa Creek and Cape Cleveland some seagrass was visible in 1961, none was observed on the 1973 survey and very little on the 1974 survey, but in the later case some might have been obscured by very turbid water conditions between Cape Cleveland and Long Beach. The subsequent aerial surveys in 1978, 1981 and 1985 revealed a steady increase in extent and density of seagrass beds. Along the south-west coast of Magnetic Island (Figure 13) seagrass was visible seaward of Bolger and Young Bays, on the landward side of the coral reef flat further south and along the shore between Cockle Bay and Nobby Head, on the 1959 and 1961 aerial photographs. In 1974 however none was visible, despite the high quality of the photographs and clear under-water visibility. By the 1978 survey, limited areas of seagrass were visible again, and these subsequently extended as shown on the 1981 and 1985 surveys.

The overall sequence of change in seagrass cover in the Cleveland Bay and Magnetic Island area was from a moderate cover in 1959 and 1961, to almost none in 1974, followed by a steady increase in cover again from 1978 to 1985. The relatively long gap between the 1961 and 1974 aerial surveys makes it impossible to determine the date of disappearance precisely. (The 1973 survey was useable only along some coasts owing to part of it being flown at HW). However there were some noteworthy natural events between December 1971 and February 1974 which may have played a part, and also in 1972 the largest dredging programme ever undertaken by the Port of

Townsville in a short period began. The importance of such ecological factors as substrate stability, water clarity and salinity in determining the distribution of different species of seagrass is poorly understood (Lanyon, 1986) and this increases the difficulty of determining the likely cause.

The major natural events were associated with Cyclone 'Althea' in December 1971, Cyclone 'Bronwyn' in January 1972 which affected the Townsville Area as a rain depression, Cyclone 'Una' in December 1973 and a long period of heavy rainfall which followed in January and February 1974. Major floods were produced in the Burdekin River in January 1972 and January 1974 (Table 10) and therefore there was a massive input of fresh water into the nearshore zone, carrying with it a large quantity of terrigenous sediment. As shown in Chapter 3 such a sediment plume curves north and north-westward from the mouth of the Burdekin and its influence may reach Cleveland Bay. In addition there would be a fresh water and sediment influx to the bay from the smaller rivers draining directly into it. In Chapter 1 it was noted that 458,733m^3 of sediment had been deposited in the Platypus Channel, reducing its depth by 1.4m, after Cyclone 'Althea'. This was subsequently removed by the S.D. 'Townsville' in 1972 and deposited at the shallow draft dump site east of Magnetic Island.

The enormous developmental dredging programme began in the latter part of 1972 and caused the total annual dredging figures to soar to a peak of 2,112,879 tonnes in 1973/4. It began with the dredging of a new 'dog-leg' channel to extend the Platypus Channel seaward, as shown in Chapter 1. It was cut in relatively soft material, probably the Holocene mud identified by Carter and Johnson (1987), and this dredge spoil was deposited at the deep draft dump site. Both this, and the sediment from the Ross River/Ross Creek floods following Cyclone 'Althea', is likely to have been fine so

that it could have been readily redistributed in the bay from the two dump sites in response to tidal and wind-induced currents, especially during the subsequent high energy event of Cyclone 'Una'. Developmental dredging within the Harbour would have been in the more lithified Pleistocene deposits and probably this material would have been less liable to redistribution from the dump sites.

It seems likely therefore that a large quantity of fine sediment was spread widely over the bed and coastal zone of Cleveland Bay as a result partly of the natural cyclone events and the subsequent river floods and partly as a result of the huge dredging programme which reached its peak between 1972 and 1975. It is possible therefore that much of the seagrass was buried or was so adversely affected by the high turbidity and/or high levels of fresh water that much of it died. The seagrass was able to recover and showed early signs of this by 1978, and a more complete recovery by the early 1980's.