RESEARCH PUBLICATION No.22

Field Survey for Carbonate, Silica and Quartzose Sediment Deposits

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Great Barrier Reef Marine Park Authority

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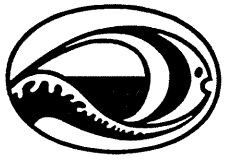

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CONTENTS

EXECUTIVE SUMMARY

1 The Great Barrier Reef Marine Park Authority commissioned the Department of Geography, James Cook University of North Queensland to conduct a field survey of carbonate, silica and quartzose sediment deposits that are located within or adjacent to areas of the Great Barrier Reef Region, but not within the Great Barrier Reef Marine Park.

2 Carbonate, silica and quartzose sands are sought for a variety of purposes:

i) Hobby aquarists in north Queensland have for many years collected small quantities of coral sand from the Great Barrier Reef. Retailers also supply sand for this market, and current demand is for about 5 m^3 or 7.5 tonnes annually.

ii) There have been some requests for bigger volumes of coral sand (up to 300 tonnes) by large commercial aquarium operators.

iii) Tourist operators have sought large volumes of coral sand to renourish or create resort beaches. They have also sought pure white silica sand as an alternative to coral sand.The Queensland National Parks and Wildlife Services assesses this demand at about 40,000 m^3.

iv) Quartzose sands are being sought to renourish numerous eroding beaches along the mainland coast. The Beach Protection Authority assesses current needs at about 500,000 m^3 with an annual maintenance of more than 10,000 m^3.

3 Section 38 of the Great Barrier Reef Marine Park Act prohibits operations for the recovery of minerals within the Marine Park, except for approved research. Because of their composition, and the fact that they are collected in large quantities, and/or for commercial purposes, these sediments are classed as minerals under the terms of the Act, and collection is prohibited. Collection can only be allowed for small quantities, obtained by hand, for non-commercial purposes. Thus, this study was undertaken to determine whether suitable sources of these sediments occurred outside the Great Barrier Reef Marine Park.

4 During the course of this study, coastal and island sites outside the Great Barrier Reef Marine Park were visited between Mossman and Sarina and offshore in the Coral Sea Islands Territories. Information was also obtained from the literature on sites from Cape Flattery in the north to Moreton Bay in the south.

5 Primary sources of carbonate sands suitable for use in the marine aquaria trade only occur well outside the Great Barrier Reef Region on coral cays on the Holmes and Flinders Reefs situated in the Coral Sea 330 and 240 km north-east of Townsville respectively. Combined sustainable yield is estimated to be about 75 m^3 or 115 tonnes annually. However, due to their distance offshore these sites are presently of marginal commercial viability.

6 As approximately 50% of the mainland coast of the Great Barrier Reef Region lies within the Marine Park, potential sources of carbonate, silica, and quartzose sands in the Great Barrier Reef Region are of very limited extent. Coral sands of suitable characteristics do not occur in commercial quantities. Available silica sands are unsuitable for beach renourishment purposes. Quartzose sands do occur in both onshore

and offshore environments, but detailed analysis is required to fully assess the suitability of these deposits.

7 Alternative sources of carbonate sediment for the marine aquaria trade include:

i) Coral sediment dredged from Moreton Bay fringing reefs. This would need to be washed, crushed, graded and transported to the north Queensland demand areas.

ii) Shell-grit from the established Hervey Bay source area, or from potential sites in Broad Sound. This is considerably cheaper than coral sand, but is not the preferred material of north Queensland aquarists.

1 INTRODUCTION

The Great Barrier Reef Marine Park Authority commissioned the Department of Geography, James Cook University of North Queensland to conduct a field survey of carbonate, silica and quartzose sediment deposits that are located within or adjacent to areas of the Great Barrier Reef Region, but not within the Great Barrier Reef Marine Park (GBRMP).

The *Great Barrier Reef Marine Park Act 1975,* section 38, prohibits operations for the recovery of minerals from the Marine Park, except for the purposes of research. The prohibition applies to carbonate sands (coral sand, star sand, shell-grit), coral limestone, silica and quartzose sands, that are collected in large quantities or for commercial purposes. In recent years the Great Barrier Reef Marine Park Authority (GBRMPA) has received numerous requests for permission to recover large quantities of these sediments for commercial purposes from within the Great Barrier Reef Marine Park (GBRMP). These include requests for, or enquires about:

i) carbonate sediments for use in the marine aquarium trade,
ii) coral or silica sands to improve tourist resort beach amenity, and
iii) quartzose sands for use in beach renourishment projects.

However, the requests have been denied as the Authority has no powers under the Act to grant such permission. Therefore, there is a need for further information on possible sources of carbonate, silica and quartzose sediments in the Great Barrier Reef Region, but outside the Marine Park boundaries. Thus, the objectives of this project were to identify possible sources of:

i) high carbonate sediment deposits suitable for collection and use by the marine aquaria trade, and
ii) silica and quartzose sand deposits for beach replenishment purposes,

that are located within or adjacent to areas of the Great Barrier Reef Region but not within the Great Barrier Reef Marine Park. The scope of the study has not extended to providing the full range of information that would be required in the event of any of these potential sites being used as sediment sources.

2 METHODOLOGY

The project was carried out in four phases:

1) literature survey, map and aerial photograph analysis, site selection,
2) field data collection,
3) laboratory analysis, and
4) report preparation.

The preliminary phase of the project involved an extensive literature survey to determine the general requirements for carbonate sediments in marine aquaria, and provide background information on the theory and practice of artificial beach renourishment. Also sought were descriptions of Queensland coastal areas and material examining process regimes in the Great Barrier Reef Region. This enabled the full range of likely sediment sources to be determined. Initial site selection was carried out after detailed map and aerial photograph analysis. Possible sites along the coastline were identified where likely sediment sources occurred in areas that were not in the Great Barrier Reef Marine Park.

Field examination of the potential sites determined whether they met the detailed criteria (see 6.1) requested by the Authority, and sediment sampling was then carried out. Some sites are described in detail in the literature and these were not visited in the field.

Laboratory analysis of the sediments was carried out in the Geography Department, James Cook University. Sediment size was determined using standard sieving techniques, and calcium carbonate content determined by acid digestion.

3 SOURCE MATERIALS

Primary source materials were maps and aerial photographs.

Maps consulted include:
- topographical sheets at scales of 1:100 000 and where available 1:50 000
- cadastral maps
- Great Barrier Reef Index Series sheets (1:250 000 scale) and Gazetteer
- Great Barrier Reef Marine Park zoning maps
- Queensland National Parks and Wildlife Service marine park zoning maps
- Queensland Beach Protection Authority Coastal Management Control District and Erosion Prone Area plans
- nautical charts.

Aerial photographs consulted include:
- low altitude photographs at scale 1:12 000 flown for the Queensland Beach Protection Authority (BPA)
- 1:50 000 scale photographs flown for the BPA
- higher altitude photography at a scale of 1:80 000 flown for the Commonwealth Government.

In addition to the above data, information was obtained from telephone interviews with relevant companies and individuals involved in the collection, mining and retailing of coral sediment, and from correspondence with State Government Departments and Authorities.

4 STUDY AREAS

4.1 Areas excluded from GBRMP

The project objective was to identify sources of carbonate sediments and deposits of silica and quartzose sands that are located within or adjacent to the Great Barrier Reef Region, but not within the GBRMP. Thus a preliminary step in the site selection procedure was to determine those areas of the Queensland coastline that have been excluded from the Marine Park.

When the Marine Park was established, a number of areas along the mainland coastline were excluded. Generally these extend to 5 km offshore and delimit areas considered to be of lesser environmental significance and/or potentially important development or harbour sites. The 26 areas that have been excluded from the Park cover approximately 1400 km, which is 40% of the Great Barrier Reef Marine Park coastline. They are summarised in Table 1.

GBRMP Section	Number of areas excluded	Length of coastline	% of Section coastline excluded
Far Northern	11	197 km	23%
Cairns	3	335 km	62%
Central	7	328 km	36%
Mackay/Capricorn	5	533 km	46%
TOTAL	26	1386 km	40%) of GBR Region
TOTAL (accessible)	13	1189 km	51%) coastline

Table 1. Coastal areas excluded from GBRMP

The Far Northern Section areas and the two northernmost areas in the Cairns Section are largely inaccessible and have not been investigated in the field. The 13 areas excluded from the Cairns, Central, and Mackay/Capricorn sections of the Marine Park were the primary field areas assessed in this study.

4.2 Jurisdiction

The situation with respect to mining in the GBRMP is essentially quite simple as it cannot be allowed under the terms of the GBRMP Act. Outside the Park the situation is rather more complex. While mining is not specifically prohibited, many other organisations are able to exercise controls over the extraction of carbonate, silica and quartzose sediments from areas of the coastal zone within their jurisdiction.

Shire and City Councils have jurisdiction to high water mark, but not over the foreshore or intertidal lands. In areas gazetted as ports and harbours, Port Authorities or the Harbours Corporation have jurisdiction over tidal lands up to the level of the high water mark. In addition, recovery of sands from the seabed or tidal reaches of river channels is under the control of the Department of Harbours and Marine. Non-tidal river channel areas are under the control of the Water Resources Commission. Marine Parks, managed by the Queensland National Parks and Wildlife Service of the Department of Environment and Heritage, extend up to high water mark. Other intertidal lands are administered by the Premier's Department. The Queensland Beach Protection Authority has declared a number of Coastal Management Control Districts (CMCD) and has prepared Erosion Prone Area Plans for all the Local Authorities in the study area.

These jurisdictions are summarised in Table 2.

GBRMP Section	Shires	Cities	Port Autho-rities	Harbours Corpo-ration Ports	CMCD Number/ Length of coastline	Qld Marine Park Length of coastline
Cairns	3	1	1	4	2/47 km	170 km
Central	5	2	1	3	2/110 km	35 km
Mackay/Capricorn	7	2	3	3	7/137 km	244 km
TOTAL	15	5	5	10	11/294 km	449 km

Table 2. Summary of Local and Statutory Authorities and Queensland Marine Parks covering areas excluded from GBRMP

In addition, the Queensland Department of Primary Industries licenses the taking of Marine Products from Queensland waters (see below, Section 5.1).

4.3 Other sites investigated

Three sites well outside the GBR Region were also investigated. These were the coral sediment dredging operations in Moreton Bay, a coral cay in Flinders Reefs 240 km north-east of Townsville, and a coral cay on Holmes Reefs, 220 km east-north-east of Cairns.

5 CARBONATE SEDIMENTS

5.1 Definitions

Coral sand is the most sought-after carbonate sediment for the marine aquarium trade in north Queensland. It is derived from the break-down of the skeletons of hard corals and other calcareous skeletons, and as such is a marine product. There are several carbonate sediment marine products described in section 6 of the Queensland Fisheries Act 1976-1989 as follows:

> 'coral' means coelenterate animals of the class Anthozoa: the term includes the uncompacted skeletons of those animals;
>
> 'coral limestone' means a calcareous deposit derived from coral or other marine product but does not include shell-grit or star sand;
>
> 'shell-grit' means the broken remnants of sea-shells;
>
> 'star sand' means a form of sand composed of the calcareous skeletons of the unicellular animals known as foraminifera.

Collection of these marine products from Queensland waters is licensed under the terms of section 35 of the Act by the Division of Fisheries and Wetlands Management of the Department of Primary Industries (DPI).

5.2 Use of carbonate sediment in marine aquariums

Spotte (1973, 1979) describes the uses of, and requirements for, carbonate sediment in marine aquariums. The sediment is used as a substrate layer about 8 cm thick, and it functions as a buffer to maintain both seawater alkalinity and a pH of about 8.3. The buffering properties of the sediment decline over time, and replacement is necessary within about 2 years.

The characteristics of suitable carbonate sediments listed by Spotte (1973) are:

i) calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) content,
ii) grains 2-5 mm in diameter,
iii) uniform sized grains (graded, or well sorted) and
iv) grains of a rough and angular shape.

Crushed coral is particularly good but crushed shell and dolomite rock are also suitable. Limestone rock contains little $MgCO_3$, and is less desirable. This report considers potential sources of biogenic carbonate sediment, namely coral and shell materials.

5.3 Demand for carbonate sediments

Discussions with aquarium trade retailers indicate that there is a steady demand for carbonate sediment in north Queensland, although this appears to be mostly in the Townsville area. Retailers between Cairns and Mackay stock coral sand, but further south they deal mainly with shell-grit obtained from Hervey Bay. Costs of obtaining the material are high, and at $0.70/kg coral sand is considerably more expensive than the $0.20/kg charged for shell-grit by retailers in southern Queensland.

Demand for coral sand comes mainly from hobby aquarists. The total amount of sand required by these hobbyists is not known, but the needs of a typical individual aquarist can be assessed. Assuming two large display tanks (2 m x 1 m basal area) with 10 cm of coral sand the total volume of sediment required amounts to 2 x 1 x 0.1 x 2 = 0.4 m^3. Allowing for renewal every two years this amounts to an annual requirement of 0.2 m^3. Assuming a coral sand density of 1.5, this represents an initial requirement of 600 kg and a further 300 kg of sediment per year.

There have been occasional demands for large volumes of coral sand by commercial aquarium operators. For example, the Great Barrier Reef Aquarium used 300 tonnes of coral sand to cover its 600 m^2 to a depth of 0.4 m. Used in these large aquaria the coral sand does not need regular replacement.

Large volumes of coral sands have also been sought by tourist resort operators who wish to create or renourish resort beaches.

Some data is available on the amounts of carbonate sediments taken in Queensland waters. These come from the DPI, and are based on returns furnished by the licensed operators. Average yearly totals for 1985-1989 have been:

Coral sand	6,510 kg/yr
Coral rubble	940 kg/yr
Shell-grit	117,240 kg/yr
Star sand	860 kg/yr
Living coral	16,100 kg/yr

5.4 Carbonate sediment deposits

5.4.1 Introduction

There are numerous environments where suitable biogenic carbonate sediments may occur. These include:

1. reef flat sediment accumulations
2. beaches and spits associated with fringing reefs
3. shell beaches, chenier ridges, and shell banks
4. fossil reefs
5. coral cays and associated beaches
6. sub-tidal leeward detrital reef slopes
7. *Halimeda* banks.

Most of these environments are restricted to areas within the GBRMP and thus are not available as potential sediment sources. This section discusses only those environments that occur in the primary target areas outside the GBRMP but within the GBR Region. These are the reef flat sediment accumulations, beaches and spits associated with fringing reefs, and shell

beaches, chenier ridges and shell banks. Information on the other environments (4-7 above) is presented in Appendix 1.

5.4.2 The coral reef sediment system

As can be seen, most of the environments where suitable biogenic carbonate sediments occur are found in association with coral reefs. The production, transport and accumulation of reef sediments can be viewed as a simple system (Figure 1).

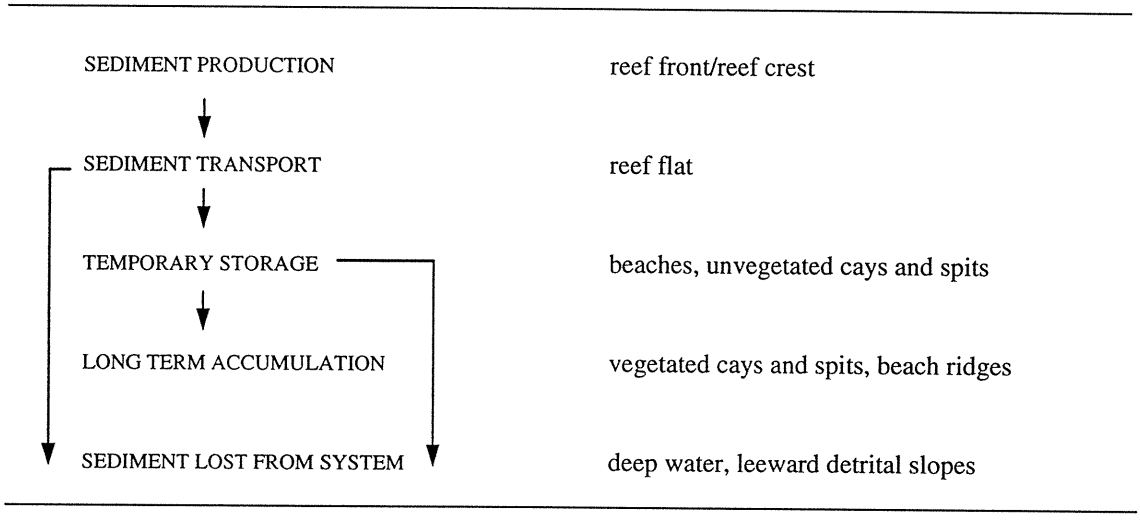

Figure 1. Coral reef sediment system

The action of high energy waves on the windward reef front and reef crest produces coral debris which is transported by waves and currents across the reef flat. Temporary storage of sediment may occur on the reef flat or in a beach, and long term accumulation occurs in coral cays, spits, and beach ridges. Sediment swept off the reef flat into deeper water (>10 m) is lost from the system.

In this way a sediment budget can be envisaged in which over the long term, the amount of sediment produced is balanced by the amount stored and lost from the system. Little is known of the rate of production or volume of material involved in coral reef sediment budgets. Clearly, removal of sediment from any part of such a system needs to be carefully considered so as to minimise possible effects in the system as a whole. This applies particularly to sediments in the transport and temporary storage elements of the system.

Production of sediment is very episodic, and probably only occurs when reefs are influenced by storm waves generated by tropical cyclones. Sediment transport is also infrequent, although probably occurs under a wider range of wave conditions.

When initially produced coral debris is coarse, comprising fragments 1-10 cm across known as coral shingle. As this material is transported it breaks down rapidly to fine sand (0.25 mm). Clearly, natural processes do not produce large volumes of the coral sediment sizes (2-5 mm) required by the marine aquaria trade.

5.4.3 Fringing Reefs

Fringing reefs are the only reef type occurring in the primary study areas along the mainland coastline of the GBR Region. These include reefs attached to the mainland and offshore islands. Thirty-nine fully developed fringing reefs covering a total area of nearly 51 km^2 occur, and these are summarised in Table 3.

Fringing Reefs Section	Number outside GBRMP	Total area covered (km^2)	Average size (km^2)	Number larger than 0.5 (km^2)
Cairns	23	40.05	1.74	15
Central	4	6.60	1.65	2
Mackay/Capricorn	12	4.13	0.34	2
TOTAL	39	50.78	1.30	19

Table 3. Fringing reefs in coastal areas excluded from GBRMP

It was considered likely that only the larger of these reefs, greater than 0.5 km^2, would produce suitable quantities of carbonate sediment. These areas (see below, Section 6.1) were targeted for field assessment.

5.4.4 Shell beaches, chenier ridges and shell banks

As noted above, shell-grit is a possible cheap alternative to coral sand suitable for use in marine aquaria, and widely used in southern Queensland. Further descriptions of these environments are given in Appendix 1. Two such sites are discussed below as potential secondary sources of carbonate sands (Section 6.6.2, 6.6.3).

5.4.5 Summary

Although a variety of environments where high carbonate sediments may occur are found in the GBR Region, most occur only within the GBRMP and are thus not available as potential sources.

The size, shape and sorting characteristics of the carbonate sediments that are available outside the GBRMP are generally not suitable for marine aquaria. In particular, the 2 mm - 5 mm size range required is quite rare in natural sediments, and most material would need crushing and grading for it to fit this criterion.

Most of the potential sources are associated with coral reef sediment systems. No reef sediment budgets have yet been established, and thus it is not possible to accurately determine levels of sustainable carbonate sediment yield from these systems.

Collectors of coral sand for the marine aquaria trade have in recent years operated mainly on reef flats. These sediments are the source materials that make up nearby beaches, cays and some spits. Collection of these sediments will have an effect on the sediment budgets of any associated beaches and should therefore be carefully monitored.

6 POTENTIAL CARBONATE SEDIMENT SOURCES

6.1 Introduction

From the selection process detailed above (Section 5.4.3), 18 fringing reefs were targeted for field assessment. These were:

- Mossman-Trinity Bay (6 reefs: 16-007*, 16-008, 16-009, 16-010, 16-039, 16045)
- Double Island (2 reefs 16-047, 16-048)
- Fitzroy Island (1 reef: 16-054)
- Double Point (1 reef: 17-039)
- Ganers Beach-Bingil Bay-Clump Point (3 reefs: 17-049, 17-050, 17-052)
- Stone Island-Adelaide Point (2 reefs: 20-004, 20-005)
- Hay Point-Flat Top Island-Victor Island (2 reefs: 21-007, 21-013, 21-015).

* These are reef identification numbers as shown on the GBRMP zoning maps.

Additional sites were also identified offshore, outside the GBR Region, in the Coral Sea Islands Territorial waters. These were coral cays known to occur in the Holmes and Flinders Reefs. Potential sources of carbonate sediments were then selected which met the following criteria:

i) carbonate content greater than 50%,
ii) grain sizes of 2 mm - 6 mm, and of a rough angular shape,
iii) deposits accessible for collection, and
iv) deposit volumes sufficient to sustain small scale collection (5,000 - 10,000 kg/year).

Criteria 1-3 were easily measurable, or could be readily observed in the field. Criteria 4 required assessment of the sediment budget for each site and this was beyond the scope of the present study. However, an estimate of the sustainability of small scale collection was made. Assuming bulk densities of 1.5 for wet coral sand and 1.1 for coral shingle, collection of 5,000 - 10,000 kg amounts to an annual removal of 3.5 - 6.5 m^3 of coral sand and 4.5 - 9.0 m^3 of coral shingle.

Two sites were found that met all the above criteria. These were coral cays in Flinders and Holmes Reefs, and they are described below as primary sources of coral sands.

Along the mainland coastline of GBR Region, no sites were found that met all the above criteria. Only three, Double Island, Fitzroy Island, and Stone Island, contained sediments with carbonate content greater than 50%. However, none of these contained appreciable quantities of sands in the 2-6 mm size range. They are described below as secondary sources of coral sediment.

6.2 Primary sources of coral sands

Coral cays in the Holmes and Flinders Reefs have already proved suitable as sources of large volumes of coral sand. They were investigated and found to be the only primary sources of coral sand identifiable in this study.

6.2.1 Holmes Reef cay

Holmes Reef lies 220 km east-north-east of Cairns in the Coral Sea Islands Territories. Two large reef complexes, each covering about 125 km^2, lie side by side some 7 km apart. The

western reef complex contains 5 small unvegetated cays. The potential source of coral sands is the northernmost cay of this group.

Location:	16°28'45"S/147°53'0"E. Shown as 'Sand Cay (about 6ft. high)' on Navigation Chart AUS864. A Meteorological Bureau automatic weather station is situated on the cay.
Site description:	The potential sediment source is a small unvegetated cay covering about 0.5 ha at high tide, and 1.2 at low tide. It is a highly mobile feature, and when visited its highest parts rose some 1-1.5 m above the level of high tide. The sand is derived from natural erosion and wave working of coral sediment from the surrounding reef.
Accessibility:	Access is by boat, Cairns being the nearest port.
Environmental/aesthetic impact of sand removal:	Minimal.
Legal Status:	Holmes Reefs and cays are under Commonwealth jurisdiction through the *Coral Sea Islands Act 1969* and the *Seas and Submerged Lands Act 1973*. Administration is through Norfolk Island.
Volume available:	Total volume of coral sand in the whole cay is estimated to be 23,000 m^3. Sustainable yield is estimated to be 23m^3/year (34,500kg).
Sediment analysis:	Mean particle size: beach samples 2.5 mm and 2.0 mm; middle of cay 1.4 mm. Of the 3 samples analysed 33% were sediments >2 mm, and 94% >1 mm. Carbonate content: 100% Colour: white
General comments:	This coral sand is very suitable for the marine aquaria trade. The cay is apparently a highly mobile feature and probably varies considerably in area and volume after each major storm. Removal of sand would appear to have very limited environmental consequences.
Other Holmes Reefs cays:	Four other small unvegetated intertidal cays occur between 1.8 and 5.0 km south-west of the main cay. These were not visited, but appear to be potential coral sand sources together totalling an estimated volume of about 50,000 m^3.

6.2.2 Flinders Reefs cay

Flinders Reefs lie 240km north-east of Townsville in the Coral Sea Islands Territories. The group consists of some 12 reefs scattered over an area of 1500 km^2, and 4 of the southern reefs contain small unvegetated cays. The potential sources of coral sand is the eastern most cay of this group.

Location:	17°44'0"S/148°26'40"E Shown as 'Sand Cay about 10ft. high' on Navigation Chart AUS864. A Meteorological Bureau automatic weather station is situated on the main part of the cay.
Site description:	The potential sediment source is a 1.5 ha spit or 'tail' extending west from the main part (3.5 ha) of the cay. The spit is 250 m long and up to 60 m wide, rising to about 2 m above the level of high water, and extending to just below low water level. The sand is derived from longshore drift of material along the beaches from the main part of the cay.
Accessibility:	Access to the site is by boat, Townsville being the nearest port.
Environmental/aesthetic impact of sand removal:	Minimal.
Legal status:	Flinders Reefs and cays are under Commonwealth jurisdiction through the Coral Sea Islands Act 1969, and the Seas and Submerged Lands Act 1973. Administration is through Norfolk Island.
Volume available:	Total volume of coral sand in the spit is estimated to be 55,000 m^3. Sustainable yield is estimated to be: 55m^3/year (82,500 kg).
Sediment analysis:	Mean particle size: 0.85 mm % of sample >1mm:15% Carbonate content: 100% Colour: white
General comments:	The sand in this part of the cay is generally somewhat finer than is required for marine aquaria. Coarser sand does occur on the main part of the cay, immediately to the east of the spit. However, mining of this part of the cay would have some environmental impact as over one thousand seabirds (common noddy, brown booby, masked booby, black naped tern) use the area for nesting sites.
Other Flinders Reefs cays:	Three other small, unvegetated intertidal cays occur 11.0 and 5.8 km west, and 8.7 km south-south-west of the main cay. These were not visited, but appear to be potential coral sand sources together totalling an estimated volume of about 40,000 m^3.

6.3 Secondary sources of coral sediments

6.3.1 Double Island

Double Island lies 1.3 km off Buchan Point, 23 km north of Cairns. The small island (21 ha) is almost completely surrounded by a large reef flat covering 1.65 km^2. The potential sediment source occurs on the western side of the reef flat.

Location:	16°43'48"S / 145°40'42"E Grid reference: CB 592497 on 1:50,000 topographical map 'Macalister Range', Series R733/Sheet 8064-4. Height: 1-2 m above chart datum (CD), or approximately between mean low water and mean high water marks. Shown as intertidal on Navigation Chart AUS830.
Site description:	The potential sediment source is a 6 ha area of sanded reef flat containing a sand wave 300 m long, 7 m wide and about 0.8 m high. The sand wave is mobile, as the 1979 aerial photograph shows it 85-90 m west of its 1965 position.
Accessibility:	Access to site is by boat. There is a public boat ramp on the mainland 1.5 km south-west at Palm Beach.
Environmental/aesthetic impact of sand removal:	Minor aesthetic impact. The sediment wave and sanded reef flat probably contribute sediment to the small beach at the south-west end of the island. Some beach erosion is occurring here and this may worsen if large quantities of sand are taken from the reef flat.
Legal status:	There appear to be no legal obstacles to sand removal.
Volume available:	Total volume of carbonate sediment is estimated to be: Sanded reef flat: 6,000-10,000 m^3 Sediment wave: <1,000 m^3 Sustainable yield is estimated to be: Sanded reef flat: 6-10 m^3/year (9,000-15,000 kg) Sediment wave: 1 m^3/year (1,500 kg)
Sediment analysis:	Mean particle size: 0.75 mm % of sample >2 mm: 27% Carbonate content: 92% Colour: grey
General comments:	Sediment at this site is of limited value for marine aquaria. Its overall size is too fine and the colour is unsuitable due to apparent algal staining. Total volume available could only sustain very small scale removal.

6.3.2 Fitzroy Island

Fitzroy Island is a popular tourist destination 22.5 km east of Cairns. The potential source occurs at the south-western corner of the island on Nudey Beach.

Location:	16°56'10"S / 145°58'55"E Grid reference: CB 917273 on 1:50,000 topographical map 'Cairns', Series R733/Sheet 8064-2. Height: -1 to 2.5 m above CD, or approximately from just below lowest astronomical tide to just above mean high water spring tide.
Site description:	Site is a small beach 120 m long and up to 35 m across, lying between two small rocky headlands. The coral shingle beach is derived from nearby fringing reef materials.
Accessibility:	Beach is easily accessible by boat from Cairns. Although not part of the resort lease on the island, the beach is very popular with visitors, being accessible by walking track from the main resort complex.
Environmental/aesthetic impact of sand removal:	Probable low environmental impact, but due to popularity of beach there would be high aesthetic impact.
Legal status:	Site lies within the Mulgrave-Johnstone Management Area of the Cairns Marine Park, under the jurisdiction of QNPWS. Current zoning is Marine National Park 'A' Zone, and proposed zoning is Marine Park Recreation Zone. Collecting of marine products is not allowed in these zones.
Volume available:	Total volume of the spit is estimated to be: 15,000 m^3. The easily accessible portion above mean sea level is estimated to be: 4,200 m^3. Sustainable yield is estimated to be: 4-5 m^3/year, 5000-6000 kg/year.
Sediment analysis:	Particle size: highly variable coral shingle - coarse sand, of 3 samples analysed 53% were sediments >2 mm. Carbonate content: 82%-95% Colour: white.
General comments:	The material in Nudey Beach is suitable for marine aquaria, although some crushing and grading of the sediment may be necessary. However, under current QMP zoning collection of marine products is prohibited.

6.3.3 Stone Island

Stone Island lies 4 km south-east of Bowen. It is surrounded by 1.7 km^2 of reef flat which contains a number of sanded reef flat areas, and coral shingle beaches constituting potential sources of carbonate sediment.

Location:	20°12'20"S / 148°16'43"E Grid Reference: 337835 on 1:100,000 topographical map 'Bowen', Sheet 8557. Height: reef flat is at about 1.6 m above CD. Highest active beaches occur up to 3 m above CD. Reef flat shown as intertidal on Navigation chart AUS826.
Site description:	Potential sediment sources occur as areas of sanded reef flat in Shoal Water Bay on the north side and near the intertidal spit on the west side of the island. An intertidal sand wave/ spit complex extends for 335 m and there are also some 4 km of coral sand and shingle beaches around the island. These sediments may have been formed in 1918 when the reef was devastated by a cyclone (Hedley, 1925).
Accessibility:	Site is easily accessible by boat from Bowen.
Environmental/aesthetic impact of sand removal:	Probably limited
Legal status:	No legal obstacles to removal of carbonate sediment from intertidal zone.
Volume available:	Total volume of carbonate sediment is estimated to be: Sanded reef flat: 16,000 m^3 Sand wave/spit: 3,750 m^3 Coral sediment beaches: 18,000 m^3 Coral shingle beaches: 2,375 m^3 Sustainable yield is estimated to be: Sanded reef flat: 16 m^3/year, 10,000 kg Sand wave/spit: 3-4 m^3/year, 2,000-2,500 kg Coral sediment beaches: 18 m^3/year, 12,000 kg Coral shingle beaches: 2 m^3/year, 1,800 kg
Sediment analysis:	Particle size: most of the sediments are finer than 2 mm. Four samples had mean sizes of 0.56-0.95 mm. Only 6.5% of the sediments in the samples were >2mm. Some coral shingle beaches occur on the south and west sides of the island. Carbonate content:sands 75-90%. Colour: Cream
General comments:	Sediment at this site is of limited value for marine aquaria due to the small volume of material larger than 2 mm.

6.4 Other sources of carbonate sand

6.4.1 Introduction

A number of possible sources of carbonate sediment were identified from the literature. However, they were not considered to be viable options within the terms of reference of this study. Brief descriptions of these sites are given below.

6.4.2 Moreton Bay coral sediment dredging

Coral sediments have been dredged from fringing reefs in Moreton Bay for many years by the Queensland Cement and Lime Company. Reefs occur around Mud, St Helena, Green, Peel, Coochiemudlo, Bird, Goat and Macleay islands, and along the mainland coast from Wellington Point to Victoria Point (Flood 1978, Orme and Day 1978). The GSQ maps 18.5 km^2 of potential source areas (O'Flynn et al. 1983, Willmott et al. 1978), and mining leases are currently held for Mud Island (site exhausted), St Helena Island, Green Island, and Wellington Point to Cleveland Point. Up to 600,000 tonnes/year of coral reef debris is produced and used exclusively in cement manufacture. The material is approximately 75% $CaCO_3$ and consists of coral rubble, shingle and sand, with terrigenous silt and mud. It is grey to reddish when mined, but bleaches to dull white colour when stockpiled.

These coral sediments constitute a possible source of carbonate material. They would need to be washed, crushed and graded to fit the requirements for marine aquaria.

6.4.3 Maryborough shell-grit

Shell-grit has been collected for some years from beaches around Point Vernon in Hervey Bay. The shell-grit accumulates as a thin ribbon of sediment on the rocky shore platforms that extend for about 6 km around the point (BPA,1989). It is used in the poultry industry, and in 1987 some 200 tonnes were collected.

Shell-grit is listed by Spotte (1973, 1979) as satisfactory for use in marine aquariums. Apparently most aquarists in southern Queensland use this material, and it is much cheaper than coral sand. Thus it could be considered as an alternative source of carbonate sediment.

6.4.4 Broad Sound chenier ridges

Shell-rich chenier ridges occur extensively along the western shores of Broad Sound (Cook and Polach, 1973; Cook and Mayo, 1978) some 55 km of cheniers are mapped, and based on descriptions in Cook and Mayo (1978), there are probably some 4,000,000 m^3 of shell-rich sediments. The ridges are mostly vegetated, and the shell material is probably somewhat contaminated with soil matter. Two kilometres of active shell beaches also occur around Turtle Island and Charon Point. Total clean shell resource is probably about 40,000 m^3. These deposits are another possible source of carbonate material suitable for use in the marine aquaria trade.

7 SILICA AND QUARTZOSE SANDS

7.1 Definitions

Silica sands are pure white sands containing in excess of 98% quartz, and are mainly used in glass manufacture and as foundry sand.

Quartzose sands are predominantly quartz, but also contain appreciable quantities of other minerals. Colour is variable, with grey, brown and yellow being common.

The requirements of this study were to assess potential sources of silica sands. It is clear that in this context 'silica sands' included both silica and quartzose materials. Accordingly, in this report, both silica and quartzose sands have been considered, and they are referred to in terms of the above definitions.

7.2 Uses and demand for silica and quartzose sand

Silica and quartzose sands are being sought by local authorities and tourist resort operators for beach renourishment purposes to:

i) increase the volume of the buffer zone between the sea and land developments for safety and erosion protection purposes and
ii) improve the visual quality and beach amenity.

Silica sands are the preferred choice of tourist operators wishing to improve their beach amenity and some has been used in past for this purpose (Hopley, 1989). Current need assessed by the QNPWS (quoted in Holmes, 1987) is for about 40,000 cubic metres of material, to renourish resort beaches in the Whitsunday Islands.

Quartzose sands are required for numerous renourishment projects recommended by the BPA for beaches along the mainland coastline of the Great Barrier Reef Region. The BPA has identified at least 10 mainland beaches that require renourishment, needing a total of about 500,000 m^3 of sand, and an annual maintenance of more than 10,000 m^3.

Sites where beach erosion problems have been reported in the GBR Region include (from north to south):

Marlin Coast beaches (north from Cairns) (CMCD #10)
Brampston beach (near Babinda) (CMCD #9)
Flying Fish Point (near Innisfail)
Mission Beach (near Tully)
Cardwell beach
Lucinda (near Ingham) (CMCD #21)
Halifax Bay beaches (Thuringowa City)
Townsville beaches
Bowen beaches (CMCD #18)
Airlie Beach (near Proserpine)
Whitsunday islands beaches
Conway Beach, Midge Point (near Proserpine)
Mackay beaches (CMCD # 5, 6, 7)
Sarina Beach, Grasstree Beach (near Sarina)
Capricorn Coast beaches (near Yeppoon) (CMCD #15)
Gladstone beaches (CMCD # 12, 24, 25).

7.3 Beach renourishment

In recent years beach renourishment has become the preferred method of dealing with erosion problems on sandy beaches. This is a flexible approach to coastal management that is more in harmony with the environment than the previously favoured rigid structures such as groynes, seawalls and coastal revetments. Generally, renourishments are cheaper, although maintenance costs are higher due to their shorter lifetimes. However, costs of beach renourishment are spread over a longer period, allowing for simpler financial management of the project.

The characteristics of the sand required depends in each case on the nature of the beach that is to be replenished. Details of beach renourishment procedures are given by CERC (1984) and CUR (1987). In the context of the present study two aspects are important.

1) Assessment of the beach erosion problem in particular to determine the sediment budget. From this can be calculated the characteristics and volume of sand required to redress the erosion problem.

2) Determination of a suitable borrow area. Ideally the sand should have the same composition, size and sorting characteristics as the beach that needs renourishment. In addition, removal of sand should not result in the transference of the erosion problem from the beach to the borrow area.

Precise matching of the supply and demand sands is often not possible. In these cases the preferred option is to obtain borrow sands coarser than the eroding beach material. This sand is likely to remain on the foreshore for a longer period, although the renourished beach may have a steeper slope. Replenishing a beach with material finer than the natural sediments is generally to be avoided. These tend to be more rapidly eroded and lost from the foreshore, and a larger volume of finer sand is therefore required to produce the desired renourishment effect.

7.4 Borrow-sand deposits

7.4.1 Introduction

There are numerous environments where sand deposits occur. They include a variety of onshore and offshore environments in the coastal zone:

i) foredunes, dunes,
ii) beach foreshores and beach ridges,
iii) river channels and floodplains,
iv) intertidal bars, and tidal deltas in estuaries, rivermouths, and lower foreshores,
v) sub-tidal shoals and deltas in estuaries, river mouths and nearshore environments (shallower than about 10 m water depth) and
vi) shoals and sands in nearshore waters or on the continental shelf (deeper than 10 m).

All these are quite common along the mainland coast of the GBR Region, particularly in areas where rivers deliver large volumes of sand to the coastal zone. However, as outlined below (7.4.4) not all of these environments can be considered as potential borrow-sand deposits.

7.4.2 The coastal zone

The coastal zone covers several onshore and offshore environments and may be defined in many different ways. This study concentrates on sediment transport and deposition, and thus the significant boundaries of the coastal zone are related to these processes. The inland boundaries are taken as the inner edges of coastal dune complexes, and those lower reaches of

rivers actively delivering sediment to the marine environment. Offshore the coastal zone boundary is somewhat arbitrarily placed at 10 m water depth. Below this depth wave-induced sediment movement is very limited, and there is no effective transfer of sediment towards the coast, although movement offshore does occur.

7.4.3 Coastal zone processes and sediments

Process regimes operating in the coastal zone include rivers, wind, waves and tides. These have widely varying characteristics, and combine in numerous ways to produce sediment bodies of quite different type. For example, river sediments are commonly coarser and more poorly sorted than beach sands, while dune sands are generally finer than beach sands. Clearly, acceptable matching of supply and demand sand will require careful sediment sampling and analysis.

7.4.4 Coastal zone sediment system

The environments listed above (Section 7.4.1) are parts of complex systems of sediment transfer and deposition. Figure 2 demonstrates the complexities of the coastal zone sediment system. Removal of sediment from an environment will cause responses in other parts of the system and this usually takes the form of erosion. Foredunes, beach foreshores and some intertidal environments are the most sensitive elements of the system and removal of sand from them is inappropriate. The safest sources of borrow sand are those which contribute little sediment to other parts of the coastal system. These include inner sand dunes and continental shelf sands. Sand could also be taken from rivers that deliver large sediment volumes to actively prograding coastlines.

7.4.5 Continental shelf sands

Sand deposits on the inner continental shelf constitute an important potential source of material for beach renourishment. Generally these sands occur in waters deeper than 10 m, although isolated banks and shoals may rise high enough to become dry during very low tides. These deposits were formed by a variety of marine and fluvial processes prior to about 6000 years ago when sea level was lower than its present height. As sea level rose, these deposits were submerged, and they are now no longer part of coastal zone sediment transfer system. These sediments are likely to have size characteristics suitable for beach renourishment purposes, and their removal from the continental shelf will have no effect on the coastal zone sediment system. However, continental shelf sands are not available as they occur with the boundaries of the GBRMP.

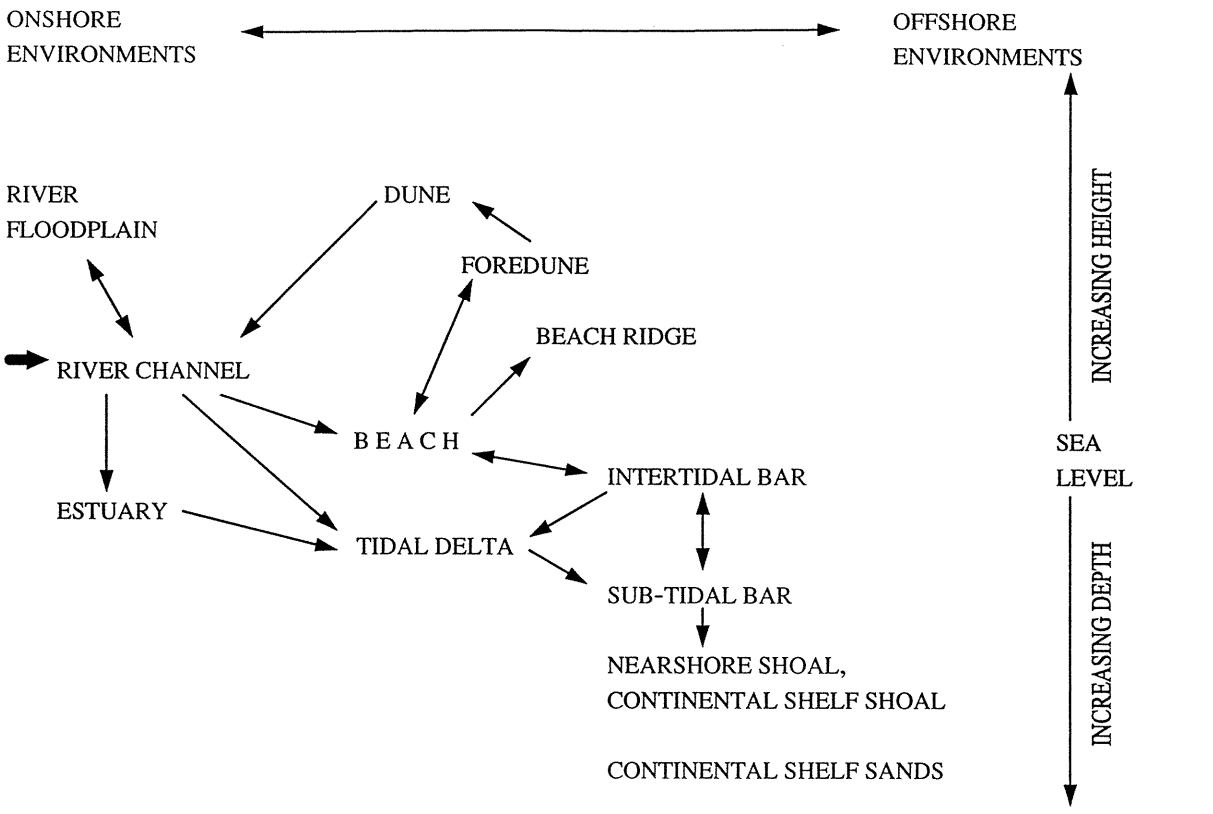

Figure 2 Coastal zone sediment transfer systems. Arrows indicate direction of potential sediment transfer. Not all the listed dispositional environments occur in all coastal settings.

8 SILICA SAND SOURCES

Pure white silica sands occur in dune systems, beach ridges, and tidal deltas along the coastline of Cape York Peninsula, Cape Clinton (north of Rockhampton), and in southern Queensland from the Gold Coast to Bundaberg (Sawers and Cooper, 1985). Several of these are mined, and the total reserves of silica sand are described as extremely large.

The only large volume silica sand mining operation is at Cape Flattery where about 500,000 tonnes per year are produced, all for export. This has been suggested as a potential source of sand for the Whitsunday resort beaches. However, it is over 700 km north, and the fine dune sands (0.3 mm) would be unlikely to match the sediments of the beaches in need of renourishment. Smaller silica sand mining operations in southern Queensland are described by Cooper (1982) and Sawers and Cooper (1985). About 150,000 tonnes per year are produced for use in glass manufacture, as foundry sand and in asbestos-cement products. These sands are also fine (0.2-0.4 mm) and unlikely to be suitable for beach replenishment purposes.

Tourist resort operators in the Whitsunday region have on several occasions requested permission to dredge silica sand from Hill Inlet on the eastern side of Whitsunday Island. As with the above sources, this sand is significantly finer than the beaches to be nourished and is thus not suitable. In addition, removal of the sand is likely to pose a severe threat to the stability of the nearby Whitehaven Beach (Holmes, 1987).

Renourishment of the Whitsunday resort beaches with currently available silica sands may also produce unacceptable environmental consequences in the systems to be replenished. Beaches on the resort islands are largely composed of carbonate sediments derived from fringing reefs (Valentine, 1985), and large volumes of silica sands are not a natural element of these environments. Fine silica sands placed on the foreshore will be eroded by wave action and tidal currents, and this sediment may damage the nearby reef complexes. The same problems could occur with quartzose sands, in these carbonate sediment environments.

9 POTENTIAL QUARTZOSE SAND SOURCES

9.1 Introduction

Quartzose sand sources were sought in the areas where beach erosion problems have occurred (see above, Section 7.2). Selection of potential sites was based on the guidelines outlined in Sections 7.3 and 7.4. Both onshore and offshore sites were identified, and these are discussed below.

Several areas have already been intensively studied, and results of these are contained in the following reports:

- Marlin Coast beaches: BPA (1984),
- Whitsunday islands: Holmes (1987),
- Mackay: Gourlay and Hacker (1986), Holmes (1987), Jones (1987) and
- Capricorn Coast beaches: BPA (1979).

9.2 Onshore sources

River channels, beach ridges and dunes constitute potential onshore sources of quartzose sand for beach renourishment purposes. These have not been investigated in detail for this report, as a considerable body of information on them has been published by the Queensland Geological Survey. This includes details of current and potential sand sources, sediment composition and sizes, site ownership, and licensing arrangements. The relevant papers covering each area are:

- Mossman-Cairns: Willmott (1990), Willmott and Muller (1980),
- Innisfail-Tully-Ingham: Willmott (1980),
- Townsville: Martin (1978),
- Ayr-Bowen-Proserpine: Martin and Neville (1978), Holmes (1987),
- Mackay: Willmott and Neville (1979), Holmes (1987),
- Gladstone: Holmes (1980),
- Rockhampton: Willmott (1976), Trezise et al. (1983),
- Bundaberg: GSQ (1981).

9.3 Offshore sources

Intertidal and sub-tidal shoals, bars and deltas constitute potential offshore sources of sand for beach renourishment purposes. From the selection process detailed above, 11 sites were targeted for field work or further investigation. These were:

- Mossman-Port Douglas intertidal shoals,
- Flying Fish Point-Johnstone River mouth (near Innisfail),
- Cowley Beach (near Tully),
- Lucinda shoals (near Ingham),
- Burdekin delta,
- Clark shoals (near Bowen),
- Don River delta,
- Proserpine River mouth,
- Sandringham Bay (south of Mackay),
- Yeppoon intertidal shoals,
- Gladstone harbour entrance.

Potential sources were then selected on the basis of the following criteria:

i) large volumes of suitable sediments are available,
ii) the site is not actively supplying sediment to other parts of the coastal system and
iii) there is no existing erosion problem.

Several of the sites were composed of sediments with particle sizes unsuitable for beach renourishment (Mossman-Port Douglas, Cowley Beach, Sandringham Bay), while others had persistent coastal erosion problems (Flying Fish Point, Proserpine River mouth). The Yeppoon area is dealt with in detail by the BPA (1979). The remaining sites, Lucinda shoals, Burdekin Delta, Clark shoals, Don River delta, Gladstone Harbour entrance, are discussed below. Full analysis of the suitability of these sites is beyond the scope of this report. The following section provides general information on the location, characteristics and suitability of the sites.

9.3.1 Lucinda shoals

The sugar-loading port of Lucinda is 23 km north-east of Ingham. Extensive areas of intertidal and sub-tidal sands occur here in waters shallower than 10 m. These sands constitute the marine portion of the Herbert River delta that occupies the southern end of Hinchinbrook Channel (Pringle, 1986). On Nautical chart AUS828, this marine portion of the delta covers some 70 km^2, with 24 km^2 shown as intertidal. Thus very large volumes of sediment occur in this area.

The northern part of the delta lies within the GBRMP, so that the area potentially available occurs south of a line running approximately parallel to and 1200 m north of the sugar loading pier. In addition, Coastal Management Control District 21 extends 1.6 km offshore presumably further limiting the available area to sub-tidal waters.

Three sand samples taken from the intertidal part of the shoals had mean sizes of 0.35 mm, which would be appropriate for renourishing beaches. Removal of sand from the sub-tidal parts of the deposit should result in little aesthetic or environmental impact.

9.3.2 Burdekin delta

The Burdekin River delivers very large amounts of sediment to the coastal zone. Some 450,000 tonnes/year of sand are deposited in the delta, although this amount will begin to decline now that the Burdekin Falls Dam has been commissioned. Patterns of sedimentation and coastal change have been recently described by Pringle (1983, 1986).

The area excluded from the GBRMP extends for 33 km along the whole delta coastline. On Nautical chart AUS826, 27 km^2 is shown as intertidal, and sub-tidal waters to 10 m depth cover a further 54 km^2. Clearly there is an enormous volume of sand in this system.

Sand samples collected in this study, and by Pringle (1983) from beaches at the northern end of the delta have mean sizes ranging from 0.23 - 1.74 mm. Removal of sand from the deeper sub-tidal parts of the system should have limited environmental or aesthetic consequences.

9.3.3 Clark Shoal

Clark Shoal is situated to the west of Abbot Point, 25 km north-west of Bowen. It lies in water depths of 1.8 - 3.7 m below CD and is shown on Nautical chart AUS826 as sand and covers 22 km^2. It is probably the downdrift extension of the Don River longshore drift system, and does not appear to be contributing sediment to the nearby coastal zone. Thus it may be a suitable source of borrow sand.

9.3.4 Don River delta

The Don River delta is 10 km north-west of Bowen. The sub marine part of the delta covers some 65 km^2 measured down to 10 m water depth, with about 27 km^2 in the shallower sub-tidal parts between 0 - 5 m (chart AUS826). Very little of this part of the delta area is exposed at low tide. The river appears to be delivering large volumes of sand to the coastal zone. Samples collected near the mouth have mean sizes of 0.66 mm and 0.37 mm, and exhibit a considerable range of particle sizes. These sediments may be appropriate for renourishing nearby beaches.

The delta is situated in CMCD #18 which extends to 1.7 km off shore. Only the deeper sub-tidal parts of the delta lie outside this zone.

9.3.5 Gladstone Harbour entrance

A large shoal area known as East Banks lies at the entrance to Gladstone Harbour, and extends 10 km south-east from southern end of Facing Island. Three small sand banks covering a total area of about 70 ha dry at low tide. However the bulk of the shoal is sub tidal, covering some 20 km^2 to a depth of 5 m below chart datum (nautical chart AUS819). This very large sand body was probably deposited by the Calliope and Boyne rivers during times of lower sea level. It appears to be largely unrelated to the present-day coastal zone sediment transfer system.

Conaghan (1966) maps the shoal as poorly sorted, fine-medium sand (0.13 - 0.5 mm). It is potentially suitable for beach renourishment purposes, and removal would appear to have minor environmental or aesthetic impacts.

10 SUMMARY

As approximately 50% of the mainland coastline of the GBR Region lies within the GBRMP, potential sources of carbonate, silica and quartzose sands are of very limited extent. Indeed, the level of protection afforded to the GBRMP under the terms of its Act, places considerable pressure on adjoining areas, particularly as it is possible that the most environmentally sound sources of sand occur within the Park boundaries.

Coral sands of suitable characteristics do not occur in commercial quantities in the primary field survey areas along the GBR region coastline. However, alternative, but expensive, sources of supply may be obtainable from the coral dredging operations in Moreton Bay, or the coral cays of Flinders and Holmes Reefs 250 - 350 km north-east of Townsville. In addition, shell-grit from Hervey Bay or Broad Sound may be considered as a cheap alternative to coral sand.

Available silica sands are of unsuitable composition and size particle for use in beach renourishment or to improve beach amenity on Whitsunday island resort beaches.

Quartzose sands are available in both onshore and offshore locations. There is now, and will continue to be a major demand for this material. However, more detailed analyses are required to fully assess both the suitability of the borrow-sands to renourish each particular beach, and the ability of the source area to withstand the removal of the sand.

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APPENDIX 1

The full range of environments where suitable biogenic carbonate deposits may occur include:

1 reef flat sediment accumulations
2 beaches and spits associated with fringing reefs
3 shell beaches, chenier ridges, and shell banks
4 fossil reefs
5 coral cays and associated beaches
6 sub-tidal leeward detrital reef slopes
7 *Halimeda* banks.

1 Reef flat sediment accumulations

Coral debris produced by high-energy wave action on the windward reef front and crest may be transported onto the reef flat. Subsequent movement of the sediment is episodic and it may be temporarily stored in a variety of accumulations including rubble zones, sanded reef flats, shingle ramparts and unvegetated cays. A wide range of sediment particle sizes occurs, although wave action can selectively sort the material into well sorted accumulations.

2 Beaches and spits associated with fringing reefs

Temporary storage of coral sediment can occur in beaches behind or downdrift of fringing reefs. Sediments are commonly fine grained (0.25–1 mm), although some coral shingle beaches occur, and may contain appreciable amounts of terrigenous (i.e. non-carbonate) materials. This is particularly true of beaches backed by large catchment areas, from which considerable quantities of terrigenous sediment can be delivered to the coastal zone. Thus, in mainland locations and on the larger high islands, beach sediments near fringing reefs are predominantly composed of non-carbonate materials.

Long term storage of carbonate sediment can occur in spits, beach ridges, and raised beaches. Such deposits are known from numerous islands between Cairns and the Whitsundays (Hopley 1971, 1975), and essentially represent fossil beach deposits that now occur above the level of high tide. Extraction of these deposits would amount to mining of a non-renewable resource. These sites have not been investigated in this report.

3 Shell banks, chenier ridges, and shell beaches

In some estuarine settings large populations of bivalves occur in the mud of the intertidal and shallow sub-tidal zones. Erosion of the mud by tidal currents exposes the shells to wave action which can then sweep them up into shell banks or beaches. If the shoreline advances the beach becomes abandoned in the supra tidal flats and is called a chenier ridge. Shell content in the cheniers is variable, and older ridges have considerable vegetation and soil development. They represent a potential on-land source of shell-grit but the material would require washing and crushing for use in marine aquaria. Shell-rich chenier ridges are known from numerous parts of the Queensland coastline (Short, 1990). However, only those in Broad Sound are easily accessible.

4 Fossil reefs

Fossil or dead reef complexes have not been investigated in the Great Barrier Reef Region. However, such structures are known from around islands in central and southern Moreton Bay (Orme and Day, 1978), and have been dredged for many years to provide raw materials for the cement industry in Brisbane (Willmott et al., 1978; O'Flynn et al., 1983). Ten of these have been mapped as significant sources of coral sediment, and 6 are currently leased for dredging operations

5 Coral cays and beaches

Coral cays and their beaches are composed almost entirely of carbonate sediments, swept up from the reef flat by wave action. Two types are recognised, those composed of coral shingle, and those composed of fine coral sands (0.25-1 mm). Generally the sediment sizes are unsuitable for marine aquaria. All these cays are vegetated, although to greatly varying extents and their environmental sensitivity renders them unsuitable as carbonate sediment sources. None occur in the coastal areas excluded from the GBRMP. However, a number are known to occur in the Flinders and Holmes Reefs, some 250 km and 325 km NE of Townsville. Cays in the Flinders Reef have already been used as a bulk source of coral sand.

6 Sub-tidal leeward detrital reef slopes

A prominent feature on the lee sides of large crescentic, lagoonal, planar and ribbon reefs is a detrital slope of fine to medium coral sands (0.125-0.5 mm), that may extend down into water 30 m deep. This material represents a loss of sediment from the reef flat, and as such would constitute an environmentally sound potential source of carbonate sediment. However, the sediment sizes are probably too fine for marine aquaria, and cost of extraction would be prohibitive. None occur in areas excluded from the GBRMP.

7 *Halimeda* Banks

Extensive banks of *Halimeda* derived carbonate sediments occur in some areas of the Great Barrier Reef Region (Drew and Abel, 1985). The sediments are up to 75% carbonate and consist of 20-30% *Halimeda* fragments 2-5 mm in diameter. The banks lie in 20-50 m water depths and occur near the outermost barrier reefs. While they do contain sediments suitable for use in the marine aquaria trade, costs of recovery would be prohibitive, and they only occur inside the GBRMP.

APPENDIX 2

Particle size and composition analyses

1.	Location:	Port Douglas, sand bar near Morey Reef (16-010)
	Grid reference[1] :	7965/347775
	Mean size:	0.18mm (fine sand)
	Sorting:	0.47 (well sorted)
	Composition:	non-carbonate
2.	Location:	Double Island, upper foreshore
	Grid reference:	8064/594501
	Mean size:	1.73mm (granule)
	Sorting:	0.52 (moderately well sorted)
	Carbonate%:	86%
3.	Location:	Double Island, sand spit, upper foreshore
	Grid reference:	8064/592498
	Mean Size:	0.89mm (very coarse sand)
	Sorting:	0.53 (moderately well sorted)
	Carbonate%:	93%
4.	Location:	Double Island, reef flat sand spit
	Grid reference:	8064/592497
	Mean size:	0.73mm (coarse sand)
	Sorting:	0.67 (moderately well sorted)
	Carbonate%:	92%
5.	Location:	Fitzroy Island, Nudey Beach, upper foreshore
	Grid reference:	8064/919275
	Mean size:	>4.00m (gravel)
	Sorting:	n.d.[2]
	Carbonate%:	95%
6.	Location:	Fitzroy Island, Nudey Beach, back shore
	Grid reference:	8064/919275
	Mean size:	0.62mm (coarse sand)
	Sorting:	1.18 (poorly sorted)
	Carbonate%:	82%

1 1:100 000 scale sheet number and Australian Map Grid Reference

2 n.d. = no data

7. Location: Fitzroy Island, Nudey Beach, inner back shore
Grid reference: 8064/919275

Mean size: 0.55mm (coarse sand)
Sorting: 0.75 (moderately sorted)
Carbonate%: 83%

8. Location: Fitzroy Island, Resort Beach, upper foreshore
Grid reference: 8064/922278

Mean size: 0.23mm (fine sand)
Sorting: 0.45 (well sorted)
Carbonate%: 85%

9. Location: Flying Fish Point, mid foreshore
Grid reference: 8162/019649

Mean size: 1.18mm (very coarse sand)
Sorting: 0.49 (well sorted)
Composition: non-carbonate

10. Location: Johnstone River mouth, Coconut Point, mid foreshore
Grid reference: 8162/005638

Mean size: 0.80mm (very coarse sand)
Sorting: 0.83 (moderately sorted)
Composition: non-carbonate

11. Location: Browns Beach, upper foreshore
Grid reference: 8162/087497

Mean size: 0.20mm (fine sand)
Sorting: 0.42 (well sorted)
Composition: non-carbonate

12. Location: Browns Beach, mid foreshore
Grid reference: 8162/088497

Mean size: 0.71mm (coarse sand)
Sorting: 1.20 (poorly sorted)
Composition: non-carbonate

13. Location: Lindquist Island
Grid reference: 8162/105479

Mean size: n.d
Sorting: n.d
Carbonate%: 92%

14. Location: North Cowley Beach, mid foreshore
Grid reference: 8162/092481

Mean size:
Sorting: 0.43 (well sorted)
Composition: non-carbonate

15. Location: Garners Beach, mid foreshore
Grid reference: 8162/045303

Mean size: 1.72mm (coarse sand)
Sorting: 1.60 (poorly sorted)
Carbonate%: 33%

16. Location: Garners Beach, upper foreshore cusps
Grid reference: 8162/045303

Mean size: 3.90mm (granule)
Sorting: 0.98 (moderately sorted)
Carbonate%: 19%

17. Location: Bingil Bay, mid foreshore
Grid reference: 8162/045282

Mean size: 0.42mm (medium sand)
Sorting: 0.58 (moderately sorted)
Carbonate%: 6%

18. Location: Lucinda Point, intertidal bar
Grid reference: 8160/309514

Mean size: 0.36mm (medium sand)
Sorting: 0.42 (well sorted)
Composition: non-carbonate

19. Location: Lucinda Point, intertidal zone
Grid reference: 8160/305511

Mean size: 0.35mm (medium sand)
Sorting: 0.67 (well sorted)
Composition: non-carbonate

20. Location: Lucinda Point, crest of sand spit
Grid reference: 8160/301513

Mean size: 0.35mm (medium sand)
Sorting: 0.50 (well sorted)
Composition: non-carbonate

21. Location: Alva, Lynchs Beach, intertidal bar
Grid reference: 8359/490504

Mean size: 0.23mm (fine sand)
Sorting: 0.48 (moderately well sorted)
Composition: non-carbonate

22. Location: Don River mouth, mid foreshore
Grid reference: 8558/280918

Mean size: 0.66mm (coarse sand)
Sorting: 1.07 (poorly sorted)
Composition: non-carbonate

23. Location: Don River mouth, upper foreshore
Grid reference: 8162/087497

Mean size: 0.37mm (medium sand)
Sorting: 1.07 (poorly sorted)
Composition: non-carbonate

24. Location: Stone Island, NW beach, mid foreshore
Grid reference: 8557/338847

Mean size: 0.85mm (very coarse sand)
Sorting: 0.53 (moderately well sorted)
Carbonate%: 88%

25. Location: Stone Island, SE beach, mid foreshore
Grid reference: 8557/350837

Mean size: 0.69mm (coarse sand)
Sorting: 0.52 (moderately well sorted)
Carbonate%: 90%

26. Location: Stone Island, Shoalwater Bay beach, mid foreshore
Grid reference: 8557/342842

Mean size: 0.56mm (coarse sand)
Sorting: 0.55 (moderately well sorted)
Carbonate%: 87%

27. Location: Stone Island, sand spit upper foreshore
Grid reference: 8557/335837

Mean size: 0.95mm (very coarse sand)
Sorting: 1.17 (poorly sorted)
Carbonate%: 75%

28. Location: Conway Beach, upper foreshore
Grid reference: 8657/813342

Mean size: 0.20mm (fine sand)
Sorting: 0.42 (well sorted)
Composition: non-carbonate

29. Location: Conway Beach, lower foreshore
Grid reference: 8657/813341

Mean size: 0.11mm (very fine sand)
Sorting: 0.54 (moderately well sorted)
Composition: non-carbonate

30. Location: Flinders Reef, 'tail' of AWS[1] cay, upper foreshore

Grid reference: 17°44'O"S/148°26'40"E

Mean size: 0.85mm (very coarse sand)
Sorting: 0.23 (very well sorted)
Carbonate%: 100%

31. Location: Holmes Reef, AWS Cay, east end, upper foreshore

Grid reference: 16°28'45"S/147°53'0"E

Mean size: 2.52mm (granule)
Sorting: 1.25 (poorly sorted)
Carbonate%: 100%

32. Location: Holmes Reef, top of AWS cay

Grid reference: 16°28'45"S/147°53'0"E

Mean size: 1.38mm (granule)
Sorting: 0.41 (well sorted)
Carbonate%: 100%

33. Location: Holmes Reef, AWS cay, westend upper foreshore

Grid reference: 16°28'45"S/147°53'0"E

Mean size: 2.00mm (granule)
Sorting: 0.76 (moderately sorted)
Carbonate%: 100%

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1 AWS = Automatic Weather Station

APPENDIX 3

Field Survey for Carbonate and Silica Sediment Deposits - Progress Report, November 1989.

INTRODUCTION

The Great Barrier Reef Marine Park Authority has commissioned the Department of Geography, James Cook University of North Queensland to conduct a field survey for carbonate and silica sediment deposits. The purpose of this study is to identify possible sources of:

1. high carbonate sediment deposits suitable for collection and use by the marine aquaria trade, and,

2. silica sediment deposits for beach replenishment purposes,

that are located within or adjacent to areas of the Great Barrier Reef Region, but not within the Great Barrier Reef Marine Park.

Collecting or taking of calcium carbonate and silica sediments from within the Great Barrier Reef Marine Park, in large quantities, or for commercial purposes is prohibited under Section 38 (2) of the *Great Barrier Reef Marine Park Act 1975*. However, such activities may be permitted in areas outside the Great Barrier Reef Marine Park where other statutory bodies are able to grant the necessary permission. The study aims to identify potential sources in such areas adjacent to the Great Barrier Reef Marine Park. The scope of the study does not extend to providing the full range of information that would be required in the event of any of these potential sites being used as carbonate or silica sediment sources.

PROJECT TIMETABLE

The project is being carried out in four phases:

1 October-November 1989; literature survey, map and aerial photograph analysis, site selection,
2 December 1989-January 1990; field work,
3 February-March 1990; laboratory analysis,
4 April 1990; Report preparation for submission by 30th April 1990.

Results of phase 1 are summarised in this report.

LITERATURE SURVEY

Literature consulted has included works on:

- marine aquaria,
- beach replenishment,
- Queensland coastal environments,
- descriptions of local coastal environments.

Relevant information has been published by, or is available from numerous bodies, including the Queensland Beach Protection Authority, Geological Survey of Queensland, CSIRO, Bureau of Mineral Resources, Great Barrier Reef Marine Park Authority, Queensland Department of Environment and Conservation (QNPWS), University of Queensland, James Cook University, and a wide range of academic journals and texts. There is little detailed information on

potential carbonate sediment sources along the Queensland coastline. However, there is a considerable body of relevant literature on silica sediment sources. This published information will be reviewed in the final report.

MAP ANALYSIS

Maps consulted include:

- topographical sheets (1:100 000 and 1:50 000)
- cadastral maps
- hydrographic charts
- Great Barrier Reef Marine Park zoning maps
- Department of Environment and Conservation/Queensland National Parks and Wildlife Service zoning plans
- Great Barrier Reef Index Series sheets and Gazetteer.

AERIAL PHOTOGRAPH ANALYSIS

Aerial photographs in the collections of the Great Barrier Reef Marine Park Authority and James Cook University Department of Geography have been examined. Most useful have been those flown at low levels for the Beach Protection Authority at a scale of 1:12,000. Higher altitude photographs obtained for the State and Commonwealth governments has also been used. This work has allowed identification of potential sediment sources in both onshore, and shallow nearshore environments. The usefulness of Landsat satellite images is also being assessed.

STUDY AREAS

The project objective is to identify sources of carbonate and silica sediment that are located within or adjacent to areas of the Great Barrier Reef Region, but not within the Great Barrier Reef Marine Park. The first step in the site selection procedure was to determine those areas of the Queensland coastline that have been excluded from the Great Barrier Reef Marine Park.

A total of 26 areas along the coastline have been excluded from the Park. They cover approximately 1400 km, which is 40% of the Great Barrier Reef Marine Park coastline. These areas may be subdivided as follows:

GBRMP Section	Number of areas excluded from GBRMP	Length of coastline	% of Section coastline excluded
Far Northern	11	197 km	23%
Cairns	4	367 km	70%
Central	6	289 km	31%
Mackay/Capricorn	5	533 km	46%
TOTAL	26	1386 km	39.8 %) of GBRMPA
TOTAL (excl. Far Northern)	15	1189 km	45%) coastline

The Far Northern Section areas are largely inaccessible and will not be investigated in the field. The study will concentrate on the 15 areas excluded from the Cairns, Central, and Mackay-Capricorn sections of the Park. While outside the jurisdiction of the GBRMPA, other organisations are concerned with coastal zone management in these areas. The Queensland Beach Protection Authority has prepared Erosion Prone Area Plans for many coastal Local Authorities, as well as having declared a number of Coastal Management Control Districts. Also, the Queensland Department of Environment and Conservation has established a number of Marine Parks that extend into these areas. Removal of carbonate or silica sediments from these areas may be unacceptable.

SITE SELECTION

Identification of potential sediment sources was based on the type of sediment sought, considerations of where these sediments generally occur, and the identification of such sites in the study areas.

1 Carbonate Sediment Sources

Carbonate sediments are required by the marine aquarium trade as a substrate and as a filter material. The requirements are:

i) high calcium carbonate content
ii) grains 2-5 mm in diameter
iii) uniform sized grains (well sorted)
iv) grains of a rough and angular shape.

Coral debris is particularly suitable, although shell grit, limestone and dolomite can be used.

The range of environments were suitable biogenic carbonate deposits may occur include:

- beaches composed of sediment derived from nearby fringing reefs
- coral cays
- sub-tidal detrital slopes of crescentic, lagoonal or planar reefs
- *Halimeda* banks
- shell banks, shell beaches, chenier ridges.

While these areas may be expected to contain a high percentage of carbonate sediments, the size, sorting and shape characteristics may not be suitable. For example, the 2-5 mm size range is quite rare in natural sediments, and most material would need crushing and grading for it to fit the above criteria. Most of the environments listed above occur within the Great Barrier Reef Marine Park and thus cannot be investigated. However, some reefs occur along the mainland coast in areas excluded from the Park.

A total of 39 fully developed fringing reefs covering an area of approximately 51 km^2 occur in coastal areas excluded from the park.

Section	Number of fringing reefs out-side GBRMP	Total area covered	Average reef size	Numbers of reefs larger than 0.5 km^2
Cairns	23	40.05 km^2	1.74 km^2	15
Central	4	6.60 km^2	1.65 km^2	2
Mackay/Capricorn	12	4.13 km2	0.34 km^2	2
TOTAL	39	50.78 km2	1.30 km^2	19

It is likely that only the larger of these fringing reefs, greater than 0.5 km^2, would produce suitable quantities of carbonate sediment. Accessible coastline associated with reefs in the following areas will be investigated:

- Mossman - Port Douglas - Trinity Bay (7 reefs: 16-007, 16-008, 16-009, 16-010, 16-045, 16-047)
- Fitzroy Island (2 reefs: 16-054, 16-055)
- Double Point (near Innisfail) (1 reef: 17-039)
- Garners Beach - Bingil Bay - Clump Point (near Tully) (3 reefs: 17-049, 17-050, 17-052)
- Stone Island - Adelaide Point (near Bowen (2 reefs: 20-004, 20-005)
- Flat Top Island, Victor Island, Hay Point (near Mackay) (3 reefs: 21-007, 20-013, 20-015)

Suitable quantities of carbonate sediment in the form of shell material may be associated with shell banks, shell beaches and chenier ridges. These environments are known to occur in the Broad Sound area and they will also be assessed. Potential sources of carbonate sediment may also occur in reef areas to the east in the Coral Sea, and to the north in Torres Strait. Flinders Reefs and Holmes Reefs, the two most accessible of these areas, will be surveyed in this study.

2 Silica Sediment Sources

Silica sand is being sought by local authorities and tourist resort operators for beach replenishment purposes to:

i) increase the volume of the buffer zone between the sea and land developments for safety and erosion protection purposes, and,
ii) improve the visual quality and beach amenity.

The characteristics of the sand required will depend in each case on the nature of the beach that is to be replenished. Ideally the borrow sand should have the same composition, size and sorting characteristics as the areas that needs renourishment.

Environments where silica sediments may occur include:

- river channels
- dune systems
- beaches
- intertidal shoals and bars
- subtidal shoals in water shallower than 10 m depth
- shoals in water deeper than 10 m.

Sediments in these environments have been deposited by a variety of processes regimes and the resulting deposits are usually of quite different characteristics. River sediments are commonly coarser and more poorly sorted than beach sands, while dune sands, intertidal shoals and sub-tidal shoals are generally finer than beach materials. Thus, acceptable matching of supply and demand sediments may be difficult to achieve.

Source areas also need to be carefully chosen, as along the coastline these environments form closely interrelated sediment transfer and depositional systems. Removal of sand from an environment may cause erosion in other parts of the system. This is particularly true of beaches, which are the most active components of those systems. Deeper water shoals and inland sand dunes are the most acceptable potential sources as thy contribute little sediment to other parts of coastal systems.

Potential sites have been identified in areas where:

i) rivers deliver large volumes of sediment to the coastal zone
ii) large volumes of sediment are available
iii) the site is not actively supplying sediment to other parts of the coastal system, and
iv) there is no existing erosion problem.

Sites to be investigated are:

Cape Flattery dune field
Mossman-Port Douglas intertidal shoals
Johnstone River-Flying Fish Point
Cowley Beach
Lucinda shoals
Burdekin delta
Clark shoals
Don R. delta
Proserpine River
Sandringham Bay
Yeppoon intertidal shoals
Gladstone Harbour entrance.

SUMMARY

1 Areas of the Queensland coastline adjacent to, but outside the Great Barrier Reef Marine park are being investigated for potential sources of carbonate and silica sediments.

2 Due to the lack of reefs in these areas, deposits of carbonate sediments, suitable for use in the marine aquaria trade, are likely to be of limited extent.

3 Possible alternative sources may occur offshore on Flinders and Holmes reefs in the Coral Sea.

4 Sources of silica sediments are likely to occur in association with a number of the larger river sediment inputs to the coastal zone.

5 However, suitable matching of these source sediments with the beaches needing replenishment may be difficult to achieve.