From: Bob Carter laptop [mailto:bob.carter@jcu.edu.au]
Sent: 27 October 2002 3:20 PM
To: gmurtough@pc.gov.au
Subject: Review of GBR water quality

Mr Greg Murtough
Productivity Commission

October 27, 2002

Dear Mr Murtough,

Measures to Address "Declining" GBR Water Quality

With reference to our previous correspondence:
I attach to this email an electronic copy of the Report and Chapter summaries from a recent comprehensive environmental envestigation into the water motions and sediment distribution in Trinity Bay, Cairns region.

I wish this material to be included in the Submissions to your review, and posted on the web.
Our research investigations have showed an absence of major environmental problems to do with suspended or deposited sediment in the Cairns area. Particularly relevant to the Terms of Reference of your review is that this thorough investigation has provided no evidence which suggests any widespread decline in water quality in the Cairns region, and particularly so so far as the Great Barrier Reef is concerned.

I draw the attention of your Review to the well documented fact that all coastal waters in North Queensland are naturally muddy, and that no scientific basis exists for the widespread public alarm which has been generated by mischievous claims that muddy water poses a threat to the Great Barrier Reef.

The body and figures of the Report contain material which is scientifically privileged until it has been published. For that reason, I am not providing you with an electronic copy of that detailed material for web posting. Please note, however, that you have been provided with a printed copy of the full Report, and that members of the Commission are welcome to access and use the detailed information within it for the purposes of your Commission's review.

Finally, I repeat my offer to meet with members of the Commission at your request, in order to answer questions, or to amplify any relevant points.

Yours sincerely,
Bob Carter

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Chapter Summaries

from

The Environmental Sedimentology of Trinity Bay, Far North Queensland

FINAL REPORT

(June, 2002)

A CPA - JCU Collaborative Project

ARC Strategic Partnerships with Industry Scheme
Grant C-39700058

Authors

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Heron, M.L., Prytz, A., Purdon, R. and Ridd, P.

Executive Summary, Science

- Trinity Bay contains a landward and seaward tapering prism of up to 20 m of largely mid-Holocene and younger sediment, most of which has been deposited as a seaward-prograding, shore-attached body of sand and mud since c. 6,000 ybp, at rates of up to 1 km/ky; this process continues today.

- Significant volumes of sand and mud have been provided to the bay from the landward side by the Barron River and by northward longshore transport around Cape Grafton; mud, suspended during cyclonic events, enters the bay from the mid-shelf, and is derived from both the reef tract and sea-bed resuspension, or from far field river flooding.

- Accumulations of mid-Holocene sediment >15 m thick occur in inner Trinity Bay (off the Cairns Esplanade), in the middle bay off the Barron River mouth, and in and around Mission Bay.

- Computer modelling, synoptic COSRAD current maps, and beach observations all predict that a current parting exists at Ellies Point between northward coastal transport along the Northern Beaches and southward coastal transport into the southeast corner of Trinity Bay.

- On geological timescales of hundreds of years, sediment input into the bay by the Barron River is therefore partitioned along several transport pathways. Sand is retained on the beaches, and passes north along the shoreline; finer sand and coarse silt is moved south to accumulate in pro-delta depocentres in southeastern Trinity Bay; and fine silt and clay passes offshore and along-shelf to the northwest.

- Bottom currents in the offshore bay generally flow offshore or northwest alongshelf during periods of strong trade wind; and strong northwest longshore currents up to 1.6 m/s in speed characterise the passage of cyclones, causing unmixing and shore-parallel transport of bottom sediment to the northwest.

- Currents within Trinity Inlet and the nearshore bay are dominated by semi-diurnal tidal movements. Current speeds are influenced by intertidal topography. Spring tides ebb from the inlet as a concentrated jet with velocities up to 0.8 m/s. The tidal asymmetry results in a net landward flux of mud during neap and intermediate tides, and a net seaward flux of sand and mud at spring tides.

Executive Summary, Management

- The location of the present dredge spoil heap is close to optimum. During fair weather conditions, near-bed currents are generally < 20 cm/s and the small amounts of resuspended sediment which occur are transported seawards or alongshelf to the northwest. During cyclonic conditions, although bottom currents attain 1.6 m/s, and larger amounts of sediment are entrained, the net sediment transport pathways remain similar.

- Dredge tailings which are dumped at the spoil site, 8 km NE of Machans Beach, are initially retained within the area. Geochemical analysis and volumetric calculations indicate that over a period of years about 50% of the spoil is later dispersed over the adjacent seabed. The dispersed sediment mostly moves alongshore and offshore, and merges undetectably within the surrounding background sediment. Thus the disposal of tailings at the dump site is leading neither to significant offshore pollution, nor to enhanced turbidity on the Northern Beaches.

- Mud-lumps which occur at times along the Northern Beaches are caused by normal longshore movement of the limited cover of available beach sand, which intermittently (and especially after storm erosion of the beach) exposes the underlying substrate of late Holocene mangrove mud. The occurrence of mud lumps on the Northern Beaches is therefore not in any way connected with redistribution of material from the offshore spoil dump.

- When the current dredge dump site is judged to have reached capacity, consideration should be given to an alternative site in similar depths and a little southeast of the present site. Such a site would offer cost advantages by shortening the round-trip time from the harbour channel.

- No significant pollution exists in sediments from Trinity Bay, and only limited pollution can be identified in the Port and inlet areas. Heavy metal concentrations generally fall below international pollutant levels, except for a small number of samples from Smith's Creek. The outer parts of Trinity Inlet, which are nearby to sites of potentially polluting industrial and commercial activity, are generally well flushed by vigorous tidal exchanges.

- From the extensive geochemical data now available from Trinity Bay, a preliminary set of natural abundance levels has been established for various metal pollutants. These levels are recommended as a new baseline against which to assess potential pollution effects.

- Though sediment yields to Trinity Bay have probably increased in post-European times, neither the Esplanade beach nor the nearest reefs (e.g. Green Island) are under any immediate threat of burial by enhanced sedimentation. However, relatively rapid foreshore and beach progradation is a continuing (natural) process in the southern corner of Trinity Bay. This needs to be taken into account for future planning purposes, especially given the possibility of sea-level rise over future decades.

Chapter 1 - Introduction

SUMMARY

- The prime aim of this study is to understand the sediment sources, transport paths and sinks which operate in the vicinity of Trinity Bay and the Port of Cairns, with especial reference to:

  Beach and foreshore stability and longevity
  Anthropogenic influences, including pollution
  Disposal of dredging materials
  Vulnerability of offshore reefs to coastal influences

- The study was undertaken by research personnel of the ***Marine Geophysical Laboratory, James Cook University***, supported by funding from the ***Australian Reseach Council*** (ARC) and the ***Cairns Port Authority*** (CPA) under the ARC Collaborative and ARC Strategic Partnerships with Industry Research and Development grants schemes.

- Field investigations were conducted mainly between late 1996-99, using r.v. *Floreat II*, r.v. *James Kirby*, and small craft of opportunity. Laboratory studies and report preparation were accomplished in 1999-2000.

- Field instrumentation which was deployed included current meters, nephelometers, sediment-deposition sensors, CTD profilers, an ORE 3.5 kHz seismic profiler, and HF and VHF coastal ocean-surface radars (COSRAD).

- More than 320 surface sediment grab samples, 120 short-cores (^25 cm long), and 37 vibrocores (^4.5 m long) were collected from Trinity Bay and Trinity Inlet.

- Laboratory analysis techniques used in the project include mineralogic studies (petrology, quantitative x-ray diffraction), geochemical studies (x-ray fluorescence), textural analysis (laser particle sizer), and radiocarbon dating (Radiocarbon Laboratory, University of Waikato).

- Project outputs have included:

  Project reports, including this Final Report and data CD
  Training of honours students
  Public dissemination of results (workshops; press)
  Publication of two scientific papers
  Development of a large sample archive
  Enhancement of applied research skills by the project team

Chapter 2 - Regional Setting

SUMMARY

- The economy of the city and port of Cairns is heavily dependent upon tourism, for which an unspoiled natural environment is a major asset. Attractions such as the Northern Beaches, pristine mangrove stands, and offshore coral cays and islands are all vulnerable to industrial, agricultural, residential and tourist impact.

- Cairns is located in the tropics at latitude 17^0 S. The climate is monsoonal, with heavy wet season rain between December and March, and a drier winter period between April and November.

- Cairns city and the surrounding area is situated on a narrow coastal plain, up to 15 km wide, which is backed inland by the steep scarp of the Great Dividing Range rising to heights of c. 700 m.

- The basement geology comprises Paleozoic (c. 420-360 Ma) schists, quartzites and flysch, intruded by late Paleozoic (c.290-250 Ma) granites; the coastal plain is underlain by sediments which were deposited mostly during interglacial (highstand) sea-level phases of the last 2.5 million years (late Pliocene-Holocene).

- During the wet summer months, modern sediment supply and distribution in the Cairns-Trinity Bay area is controlled mainly by tropical cyclones and by flooding of the Barron River; during the winter dry season, southeasterly trade winds predominate.

- The surficial parts of the coastal plain and delta on which Cairns is situated have developed over only the last ~10,000 years, in intimate relationship with first a rising, and then a falling, sea-level.

- Historic time-series tide records from Cairns suggest that sea-level has fallen at a rate of 0.02 mm/yr over the last 35 years; this trend contradicts the established globally averaged rate of sea-level rise of 1-2 mm/yr over the last 100 years, and requires further investigation and substantiation.

- ***The relationship between sea-level change, sediment supply, and climatic events in the Cairns region is dynamic, persists at the present-day, and must be taken into account in long-term planning.***

Chapter 3 - Oceanography

SUMMARY

- Shelf waters off Cairns attain depths of c.20 m at the outer edge of Trinity Bay, and a maximum of 42 m on the mid-shelf between Cape Grafton and Green Island. Apart from buoyant fresh-water flood plumes after heavy rain, the innner-middle shelf water column is usually well mixed, and turbid with suspended mud (10 to >200 mg/l).

- During winter months the shelf water mass is under the influence of 15-25 knot southeasterly trade winds, which drive a northerly long-shelf flow. During the wet summer season, more variable north and northeasterly winds and tropical cyclones occur. Shelf waters are then periodically influenced by the discharge of mud-laden river flood plumes, and by intermittent, strong, cyclone-driven, northerly, long-shelf flow.

- Within Trinity Bay, the tide floods to the west or northwest at 20-30 cm/s, and ebbs northeastward. On the mid-shelf off Cape Grafton, stronger (wind-driven) currents greater than 50 cm/s flow persistently northward on all phases of the tidal cycle. Therefore, except in the presence of a strong converse prevailing wind, the regional tides and wind produce a net flow of water long-shelf to the north.

- Periods of strong southeasterly (trade) wind cause coastal set-up, which results in near-bed currents flowing offshore at up to 20 cm/s.

- At the entrance to the Cairns port and Trinity Inlet, water movements are dominated by bank-parallel tidal flows up to 80 cm/s in speed. Within the inlet, speeds of the early ebb tide may exceed that of the flood tide by 20 cm/s, and this tidal asymmetry causes net seaward transport of sediment from within the inlet out into the bay.

- During spring tides, the seawards-directed ebb-tide jet from Trinity Inlet carries a 450 m wide anticlockwise eddy on its left (west) side for more than 2 hours. Suspended sediment is thereby directed onto the eastern end of the Esplanade mudflat.

- An analysis of tidal flow divergence and vorticity reveals a consistent association between convergence and large eddies on both the ebb tide (located northeast of the Airport) and flood tide (located northwest of Cape Grafton); such conditions are consistent with downwelling and sediment deposition, and both locations correspond to late Holocene depocentres.

Chapter 4 - Surficial Sediment

SUMMARY

- Sediment input to the shelf off Cairns comes from three main sources; ***terrigenous sand and mud*** supplied by rivers; ***carbonate detritus*** derived from benthic organisms and from fringing and offshore reefs; and ***mixed material*** derived by erosion of the seafloor.

- Redistribution and deposition of this sediment takes place under the influence of wind, waves, tides and cyclones in ways which both shape the bathymetry and demarcate the sediment types (facies), as follows:

Inner shelf	0-20 m	Land-sourced terrigenous sand, mud
Middle shelf	20-40 m	Pleistocene clay at or near the seabed
Outer shelf	40-80 m	Reef-sourced carbonate gravel,-sand, mud

- The ***inner shelf*** terrigenous sediment prism is shore-connected, fills embayments, is up to 17 m thick, and tapers rapidly seawards; the ***mid-shelf*** is a flat, sediment-starved plain with patches of sediment veneer up to 1-2 m thick; ***outer shelf*** carbonate sediment accumulates as 1-3 km wide aprons around individual reefs, or in inter-reef pockets as micrite or *Halimeda* banks.

- Trinity Bay, and the environs of the port of Cairns, lie entirely within the inner shelf terrigenous realm. Six major sediment facies (A-F) occur in this terrigenous realm, and two more (G-H) are distributed further seaward on the middle and outer shelf, as follows:

(A) Clean well-sorted sand	Beach-shoreface, delta mouthbar
(B) Muddy sand	Shoreface to inner shelf (0.8-5 m)
(C) Sandy mud, mud	Inner shelf (5-20 m)
(D) Muddy shell hash	Storm-emplaced shellbed

(E) Poorly sorted (pebbly) sand	Tidal channel lag
(F) Organic-rich mud	Mangrove swamp
(G) Muddy, sandy, shell hash	Starved mid-shelf
(H) Carbonate facies (>90%)	Reef tract (outer shelf)

- Textural analysis shows that most sediment samples are polymodal. The four main sediment modes are:

  3-5 um fine silt
  100-300 um fine-medium quartz sand
  >500 um coarse quartz sand
  shell hash and fragments

- Heavy mineral studies, and determination of quartz:feldspar ratios, are consistent with a northward coastal sediment transport path from the Barron River mouth along the Northern Beaches, a southward transport path from the Barron River into the Cairns' Esplanade, and also suggest that coastal drift occurs northwards around Cape Grafton and into Trinity Bay.

Chapter 5 - Stratigraphy

SUMMARY

- Sea-level, rising from a 20 ka post-glacial low of -130 m, reached depths of -20 m at the outer edge of Trinity Bay at c. 8 kybp, a mid-Holocene high of c. +1.5 m at c. 5.5 ka, and since then has declined to its modern level. Best estimates indicate that the modern sea-level in Cairns is still falling slowly, at rates of .02 mm/yr.

- Thus surficial (Holocene; <10 ka) sediments within the area of Trinity Bay and the Cairns coastal plain have accumulated under the influence of first a rising, and then a falling, sea-level..

- Seismic profiling, and cores, demonstrate that the unconsolidated mid-late Holocene sediments rest upon a widespread reflector, termed Reflector A in previous studies. Reflector A comprises a consolidated late Pleistocene-early Holocene clay, is incised by fluvial channels, and corresponds to the coastal plain land surface as it existed prior to marine transgression.

- In ascending order, within Trinity Bay the sediments above Reflector A comprise:

Lag gravel, bedded sand and mud	Aggradational channel fill
Sticky carbonaceous mud	Overbank mangrove stand
Well sorted sand (inferred from seismics)	Transgressing beach
Poorly sorted sandy mud to mud	Deepening shoreface to bay
Poorly sorted mud to sandy mud to sand	Shallowing bay to shoreface

- On the Cairns coastal plain, and beneath the immediate foreshore, the stratigraphy is punctuated by layers of sand or shell-hash, some of which correspond to cyclone-emplaced storm beds; others were emplaced by long-shore drift from the Barron River or another coastal source.

- Radiocarbon dating indicates that three successive shell-layers which occur beneath the Cairns' Esplanade foreshore were emplaced at 3,100, 2,980 and 2,830 ybp respectively, i.e. at intervals of 120 and 150 years. This data is consistent with major cyclones occurring with a periodicity of one to several hundred years.

Chapter 6 - Geochemistry

SUMMARY

- The continental margin off Cairns comprises a ***mixed terrigenous-carbonate province.*** Terrigenous sediment rich in quartz, feldspar and other silicate minerals is contributed from the eastern Australian landmass, and calcareous sediment rich in calcite and aragonite is contributed from the Great Barrier Reef, and from organisms with hard parts which live in either surface waters or on the seabed.

- Because of the diversity of source, bulk sediment from offshore North Queensland displays an exceptional breadth and limited variance of major oxide composition. On a margin-wide scale, most samples lie on mixing lines between end-members which correspond to common source minerals. For instance, plotting SiO_2 against CaO, K_2O or Al_2O_3 delineates strong ordered, linear trends between groups of samples which originate from the following environments: beach - delta bar - bay prism - middle shelf - reef tract.

- Element concentrations within the surface sediments of Trinity Bay fall into three main groupings which are concentrated in different locations:

Group 1	As, Cr, Ga, Ni, Pb, Rb, V, Zn	Central bay
Group 2	Ba, Nb, Ti, Y, Zr	Nearshore bay
Group 3	Co, Mn, Sc, Sr	Individual, irregular

  This distribution most probably results from grainsize and mineralogical partitioning of incoming fluvial sediment. Group 1 samples are sandy, generally rich in $Si0_2$ and heavy minerals (e.g. Sphene, TiO_2), and concentrate along the shoreface. Group 2 samples are rich in Al and Fe, and represent clay-mineral rich muds which have been bypassed offshore to the central bay. Group 3 elements relate to individual sources, e.g. Sr with the presence of shell materials.

- There is no evidence for pollution in offshore Trinity Bay. Enhanced spot values of some metal pollutants do occur within Trinity Inlet in the vicinity of Smiths Creek and the Port. Unusually, the high metal values do not correlate well with the fine sediment fraction, and it seems likely that the pollutants lie in the silt-sand grain sizes which are regularly flushed out of the Port area, and diluted in the natural background sediment, by ebb-dominated tidal currents.

- Two silica-rich grab samples from the spoil site in offshore Trinity Bay differ from their surrounding bay sediments, and do not fall on any of the established compositional mixing trends. The samples represent an unnatural amalgum, produced by dredging and dumping, and that similar samples are not more widespread is an indication that material remobilised from the dumpsite is rapidly homogenized within the natural bay sediment prism.

- As reported by other workers in Great Barrier Reef nearshore waters, carbon isotope ratios from Trinity Bay display a pattern of higher values offshore. Nearshore samples have ^{8}13C values lower than -23%, as is typical of terrestrial vegetation, while ^{8}13C samples from offshore range up to -20%, consistent with derivation from algae or tropical grasses such as sugar cane.

Chapter 7 - Sediment Transport

SUMMARY

- Water motions, and therefore sediment transport, within the Cairns coastal region are strongly influenced by:

  Southeasterly trade winds in winter
  Variable north and northeasterly winds during summer
  A daily easterly coastal sea-breeze
  Diurnal tidal currents (southeast flood; northwest ebb)
  Intermittent tropical cyclones

- In combination, these processes are responsible for the generally high background turbidity which is present in Cairns' coastal waters (20-200 mg/l), which is caused by the resuspension of mud from the seabed. They also individually, or in combination, drive the following flows, which are often strong enough (>20 cm/s) to move sand at the seabed:

  Northward long-shelf flow (stronger offshore)
  Coastal setup, and return bottom flow
  Tidal jetting (Trinity Inlet)
  River mouth jetting (Barron River in flood)
  Northerly longshore drift (Northern Beaches; Cape Grafton)
  Southerly longshore drift (Ellie Point-Esplanade)

- Accordingly, sediments within Trinity Bay are strongly partitioned. Coarser grainsizes concentrate at the Barron River mouth, along beaches, and within tidal inlet channels. In contrast, mud is bypassed either into mangrove swamps by high-tide flooding, or offshore where it settles in the bay centre.

- Computer modelling studies on geological time scales of several thousand years replicate this general pattern, and suggests that the major sediment depocentre should lie in the southeastern part of Trinity Bay. This prediction is confirmed by seismic data.

- In summary, mineralogic, textural, process and modelling studies suggest that the following natural sediment transport paths operate in the Trinity Inlet-Trinity Bay area:
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Sand and gravel transport	
Cyclone unmixing	Shellbeds and cheniers, Trinity Bay shorelines
Sand transport	
Longshore drift	North along the Northern Beaches
(from Barron mouth)	South and west around Ellie Point
(from King Beach)	West around Cape Grafton
Seaward-directed jets	Northeast into bay, mouth of Trinity Inlet
	North into bay, Barron River mouth
Mud transport	
Tidal channel flow	Overbank into mangrove swamps

River flood plumes	Offshore into Trinity Bay
Turbid underflows	Offshore into Trinity Bay
Cyclone-induced advection	Clinoform accretion, sourced from mid-shelf

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Chapter 8 - Managing a Changing Environment

SUMMARY

- The development of Cairns City, the Barron delta and the Northern Beaches has taken place on a coastal fringe which is subject naturally to flooding, shoreline fluctuation, and cyclone impact. Development, or well-meaning mitigation attempts, can perturb this system on timescales of decades to centuries, and in ways which are difficult to predict precisely.

- Minor pollution by heavy metals and other industrial contaminants does occur adjacent to the Port of Cairns. However, the port area appears to be well flushed by daily, ebb-tide dominated water movements. ***The great majority of sediment samples from throughout Trinity Bay and Inlet fall within recommended environmental limits for pollutants.***

- No substantial fringing reefs occur within Trinity Bay. The nearest reef which is potentially vulnerable to anthropogenic damage is Green Island. This cay is located 35 km seawards of Cairns city, and about 20 km east of Cape Grafton, and is separated from the shoreline and its attached terrigenous sediment prism by the 15 km wide, 20-35 m deep mid-shelf plain. This plain is largely swept clean of mobile sediment by pervasive, shelf-parallel trade-wind-
- generated current drift, aided by intermittent cyclone-generated long-shelf flow. Offshore-directed turbid flows generated at the coast, be they surficial or bed-hugging, generally pass along-shelf to the north as they enter the mid-shelf flow. ***There is therefore no significant threat to Green Island from coastal sediment pollution.***

- The position of the narrow Esplanade beach and its mudflat foreshore has been stable for about 80 years, since the construction of the concrete wall at the eastern end. A 2,310 ybp date for a storm-emplaced shellbed about 1m below the mudflat surface indicates that little accretion has occurred in historic times, and that new mud is being added to the system at the seaward edge of the flat, which has advanced up to 1 km seawards. Meanwhile, at the western end of the Esplanade, new areas of mangrove swamp have become established in the lee of a southward-advancing sand bar sourced from Ellie Point. ***The Esplanade beach and mudflat is stable apart from (i) encroaching sand (and mud trapped behind it) from Ellie Point; and (ii) its vulnerability to erosion during a major cyclone.***

- Intermittently, residents of the Northern Beaches report "mud lumps" washing up on the beach and "enhanced turbidity" of coastal water, which they attribute to reworking from the offshore CPA spoil dump. Our studies show (i) that most transport from the spoil dump takes place in either an offshore or a northerly long-shelf direction; and (ii) that the "mud lumps" are derived by intermittent erosion of a sticky, grey Holocene mangrove clay which forms the substrate to e.g. Clifton Beach, and which becomes exposed during periods of beach erosion. ***Thus neither the water turbidity, nor the presence of mud-lumps, on the Northern Beaches is in any way related to the presence of the offshore spoil heap.***

- Material deposited at the CPA spoil dumpsite forms a lensoid mass on the seafloor with a maximum thickness in the centre of 2m. Grab and core samples indicate that the materially is geochemically different from the surrounding bay sediment. Sediment flux calculations show that as much as half the material dumped may be gradually reworked off the site and incorporated within the natural seabed. Transport of this sediment is largely long-shelf to the north, or seawards. ***Reworked dumpsite sediment has no discernable geochemical effect at distant locations, and its volume is insignificant compared with the natural sediment flux*** *through the system.*