C2

VOLUME C: MIDDLE BANKS, MORETON BAY

Geology and Soils

Geology, Soils and Groundwater

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GLOSSARY

ANC	Acid Neutralising Capacity
ASS	Acid Sulfate Soil
BAC	Brisbane Airport Corporation
Bq/kg	Becquerel per Kilogram
D50	Nominal Particle Size Representing 50 percent of a Material
EIS/MDP	Environmental Impact Statement and Major Development Plan
EMP	Environmental Management Plan
PASS	Potential Acid Sulfate Soil
pH_{FOX}	Field pH after Oxidation
PSD	Particle Size Distribution
QASSIT	Queensland Acid Sulfate Soils Investigation Team
SPOCAS	Suspension Peroxide Oxidised Combined Acidity and Sulfide
S_{Cr}	Chromium Reducible Sulfur
S_{POS}	Percent Oxidisable Sulfur
S_{NAS}	Net Acid Soluble Sulfur
TAA	Total Actual Acidity
TSA	Total Sulfidic Acidity

KEY FINDINGS

- A comprehensive assessment of the sand banks occupying the northern end of Moreton Bay was given in the Moreton Bay Marine Park Extractive Industry Strategy Sand Resource Study (PPK 1998). These banks have been widely recognised in previous studies as elements within an extensive flood-tide delta that has developed in the Northern Entrance of Moreton Bay since the Holocene stillstand ca. 6,500 years ago.
- Continuous marine vibro-coring was conducted for the study at 16 sites on Middle Banks. The majority of core sites (12) conducted were located along the eastern margin of the banks which was considered the most prospective for extraction.
- The deposits at Middle Banks are predominantly sand, silt and clay dominated pro-delta deposits which extend to the south into Moreton Bay. It is the upper stratum comprising 'clean' sand that is of interest as a source of fill.
- Two sites were located in western Middle Banks to ground truth the seismic record, and consistent with past studies, both encountered the Pleistocene substrate.
- The cored Holocene stratigraphy of the eastern Middle Banks is remarkably uniform, and is characterized by predominantly well sorted, fine/medium ranging to very fine sized, quartzose sand.
- Particle Size Distribution testing indicated that the sand deposits present would be suitable for extraction and use as fill and are predominantly fine to medium grained, with the majority of particles in the sieved size range 300 µm (average 82 percent passing) to 150 µm (average 6 percent passing).
- Screening of samples of sediments for acid sulfate soils was carried out using the pH/pH_{FOX} test method supported by SPOCAS testing. Results indicate that the sand profiles tested from the main Middle Banks site (i.e. the proposed dredging footprint) do not contain detectable levels of acidity. Mostly this is because of the presence of considerable amounts of fine calcareous material (shell grit or coral debris) sufficient to buffer any potential acidity present. Buffering could also be due to some extent, to the salt water environment.
- Porewater (in situ water beneath the seabed surface) was sampled in several of the vibro-core sites and analysed in the laboratory. The results of the analysis showed detectable levels of dissolved nutrients (nitrogen and phosphorous) and indicated elevated concentrations of Toluene in several of the water samples.
- A number of representative sub-samples of sands from the main Middle Banks deposit were submitted to the Queensland Health laboratory for screening for radioactive particles (which can routinely be associated with marine sand deposits). All the samples analysed were below background levels for radioactivity.

Geology, Soils and Groundwater

2.1 Introduction

2.1.1 Background

This Chapter includes in its scope the current environmental status of baseline conditions in an area of the Middle Banks sand deposit in Moreton Bay, near Moreton Island. The site is proposed as a source of sand fill for the NPR. This chapter includes assessment of the suitability of the sand for use as surcharge and structural fill for the parallel runway and other areas of reclamation at the NPR site.

The information in this chapter has also been used in the assessments for other issues in Volume C, specifically in relation to water quality, coastal processes, ecology and cultural heritage.

2.1.2 Proposed Works

Investigations encompassed an area of Middle Banks of sufficient size as to allow some choice of location of the 'footprint' for sand extraction operations, (and possibly to exclude areas where the nature or depth of the deposit would limit its suitability for dredging or use as fill).

It is proposed to extract approximately 15 Mm^3 of clean sand fill for use as surcharge and in forming a fill platform for the proposed parallel runway and associated aeronautical facilities.

As discussed in Chapter C1, the sand will be dredged using a large trailer suction dredge and transported to a specified pump-out location near the mouth of the Brisbane River, where it will be pumped via an above ground pipeline to the development site.

2.1.3 Methodology

The baseline investigation of geology and soils at Middle Banks was conducted with following aims:

- To report the findings of sub-surface investigations, including depth and approximate limits of the Holocene sand layer;
- Undertake Particle Size Distribution (PSD) testing of the sand and assess silt and clay content;
- To assess the proportion of sands passing the 225-250 μm size range to allow design of the dredging and pumping plant and infrastructure;
- Undertake Particle Density, Permeability and Density Index testing of sands recovered from the deposits to assist with fill embankment and pavement design;
- Undertake analysis of Mineralogy, Particle Shape and shell ($CaCO_3$) content of the sands;
- Undertake preliminary sampling and analysis for the presence of Acid Sulfate Soils (ASS) within the deposits to be dredged; and
- Undertake screening for radioactive particles (i.e. total radionuclei, alpha and beta particles).

A hydrographic survey of the Middle Banks area and transects along part of the western shoreline of Moreton Island were carried out for the EIS/MDP by Mapping & Hydrographic Surveys Pty Ltd and made available to aid with the study.

The overwater sampling program and stratigraphical logging of the sediment cores was carried out by Geo Coastal Australia (the sampling methodology and stratigraphy reported by Geo Coastal Australia is included in this report). The overwater coring survey was co-ordinated with a recently completed seismic survey (also by Mapping and Hydrographic Surveys Pty Ltd) conducted as part of the investigation program.

The sedimentary and stratigraphical information derived from the coring survey will be used to support assessment of a range of environmental issues such as turbidity plumes and acid sulfate soils, while identification of the pre-Holocene substrate has implications for assessment of cultural sensitivity. Additional objectives included providing sediment data to assist preliminary assessment of the material behaviour of the sediment during dredging and construction.

2.1.4 Limitations and Assumptions

Investigations undertaken for this report were carried out at the proposed dredging investigation area at Middle Banks. Extraction from other areas of Moreton Bay are not included within the scope of this baseline analysis. Location of boreholes was undertaken by Geo Coastal Australia, with the aid of a differential GPS system, using coordinates supplied by Mapping & Hydrographic Surveys Pty Ltd, and following consultation with BAC.

2.1.5 Policies and Guidelines

The current Queensland Government (QASSIT) "Guidelines for sampling and testing of Acid Sulfate Soils in Queensland - 1998" and the "State Planning Policy 2/02 Guideline (SPP 2/02)" were referenced when scoping ASS investigations.

The Australian Government - Department of Environment and Heritage (DEH) "Guidelines for An Environmental Impact Statement On The Proposed Parallel Runway At Brisbane Airport", were referenced when choosing analysis for pore water samples from the investigation area.

2.2 Existing Condition – Geology and Soils

2.2.1 Setting

The area proposed for dredging is known as the Middle Banks and is located in Moreton Bay. Middle Banks is situated directly east of the Redcliffe peninsula, opposite the western shore of Moreton Island. The Middle Banks deposit is at the southern extent of the flood-tide delta of the Brisbane River and other local coastal streams.

The deposits at Middle Banks are predominantly sand, silt and clay dominated pro-delta deposits extending into the southern section of Moreton Bay. It is the upper stratum (Holocene age sediments) comprising clean sand that is of interest as a source of fill.

2.2.2 Geology and Stratigraphy

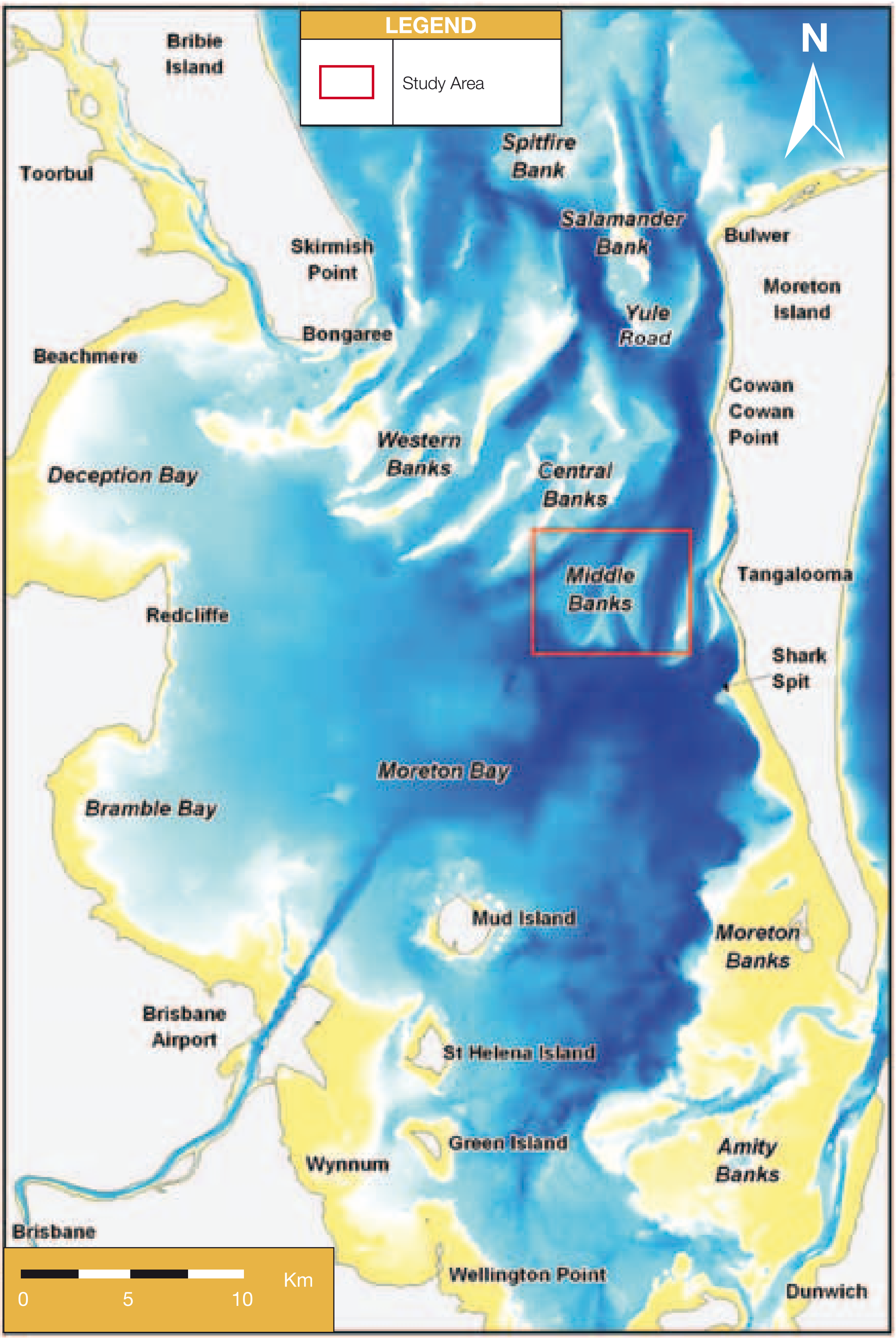
2.2.2.1 Previous Investigation

A comprehensive assessment of the sand banks occupying the northern end of Moreton Bay was given in the Moreton Bay Marine Park Extractive Industry Strategy Sand Resource Study (PPK 1998). These banks have been widely recognised in previous studies as elements within an extensive flood-tide delta that has developed in the Northern Entrance of Moreton Bay since the Holocene still stand ca. 6,500 years ago. A number of these earlier studies (Harris & Jones, 1988, Harris et.al., 1992, Stephens, 1992, PPK, 1988) have identified that these banks are commonly underlain by pre-Holocene substrate (presumed Pleistocene age), composed of both white and humic ('coffee') sands and stiff mottled clays. These sands are considered likely to be relict flood-tide delta sediments, particularly relating to the penultimate sea level high stand (ca. 125,000 yrs BP) when sea level was estimated to be ~ 5 m above present. Estimates of littoral drift in South-east Queensland by a number of authors (Pattearson & Patterson, 1983; Tomlinson & Foster, 1986; Jones, Holmes & Searle, 1990; Jones & Holmes, 1993) have generally agreed on a figure of ~500,000 m^3 per year. Refer to **Figure 2.2a** for the location of Middle Banks investigation areas.

Of this quantity potentially passing along the outer barrier created by North Stradbroke and Moreton Islands, Stephens (1992) estimated that 200,000 m^3 was captured by the South Entrance to Moreton Bay between the islands, leaving a quantity of ~300,000 m^3 available for the initial building and replenishment of the tidal deltas in the Northern Entrance. Stephens (1992) proposed that the volume of Holocene sand presently in the banks could not have been supplied entirely by this littoral supply, and therefore it is highly probable that considerable reworking of the existing Pleistocene sands has occurred in the development of the Holocene delta.

It is likely that the morphology of the pre-Holocene palaeo-landscape including these relict delta sand bodies and the palaeo-Brisbane River tract have been strong determinants on the position of the Holocene banks and passages, particularly toward their less wave influenced southern extension. Based on seismic and echo sounding records, Harris et al., (1990) reported that the approximate 14 Mm^3 dredged from the eastern flank of Middle Banks in 1983 for previous airport expansion had largely been refurbished by July 1989.

Figure 2.2a: Location of the Study Area.



Harris et al., (1992) interpreted that the source of this sand were sand banks immediately to the north and supplied via East Channel. This is a surprising quantity of sand transport (i.e. equal to approximately 45 - 50 years of the entire littoral budget at Cape Moreton), and recent evaluation within the present study (refer Chapter C3) appears to have arrived at a conflicting conclusion.

Middle Banks is situated at the most southerly extent of the sand dominated flood-tide delta, with only silt/clay dominated prodelta sediments extending further south into Moreton Bay.

A number of previous studies have incorporated Middle Banks including:

Drilling/Coring Surveys

1. Coffey & Hollingsworth Pty Ltd (1972) – a total of 10 boreholes were completed during July/August 1972 covering Middle Banks and Four Fathom Bank. Initial attempts at rotary circulation drilling proved unsuccessful, and after refitting samples were retrieved at intervals by bailer. Due to the loose flowing nature of the sands, they were not able to be sampled by SPT technique. In general summary, this drilling identified the presence of shallow underlying 'coffee' sand and stiff clay substrate beneath Four Fathom Bank to the west of the study area, while along the eastern Middle Bank area that is of interest to the present extraction proposal, deep uniform, clean Holocene sands were encountered.
2. Coastline Drilling (1998) – 1 reverse circulation sampled hole was completed in May 1998 on Four Fathom Bank as part of the Moreton Bay Marine Park Extractive Industry Strategy Sand Resource Study (PPK 1998). This hole encountered Pleistocene coffee sand at ~ 1 m below the sea bed, and stiff clay substrate at ~4.5 m.
3. Harris (1989) – conducted 4 vibro-cores in the southwestern sector of Middle Banks and on Four Fathom Bank. The vibro-core sited on Four Fathom Bank encountered shallow Pleistocene clay substrate (1.26 m) similar to previous studies, while the sites more centrally located on southern Middle Banks revealed uniform Holocene sands to ~ 4 m maximum penetration. The remaining site on the southwestern flank recovered 2.2 m of shelly Holocene sand.

Figure 2.2b shows borehole locations of current and relevant past investigations at Middle Banks.

Seismic surveys

1. Harris et. al. (1990) – reported on a comprehensive seismic survey including 18 lines over Middle Banks.
2. Queensland University of Technology (1998) – a survey conducted as part of the Moreton Bay Marine Park Extractive Industry Strategy Sand Resource Study (PPK 1998) under the supervision of Dr. Simon Lang transected Middle Banks with four regional lines.

These investigations are mentioned in other Chapters within this EIS/MDP, including Chapter C3, Coastal Processes.

2.2.3 Overwater Sampling and Sample Analysis Program

2.2.3.1 Sampling Methodology

Continuous marine vibro-coring was conducted for the study, initially at 14 sites on Middle Banks, within the proposed dredging area (**Figure 2.2b**). Core sites were pre-selected by the seismic contractor. A review of test results from the 14 mentioned sites, resulted in an extension of the scope of work to include an additional two sites at the edge of the proposed dredging area.

Vibro-coring has been the preferred method for marine seabed coring for a number of decades for three primary reasons:

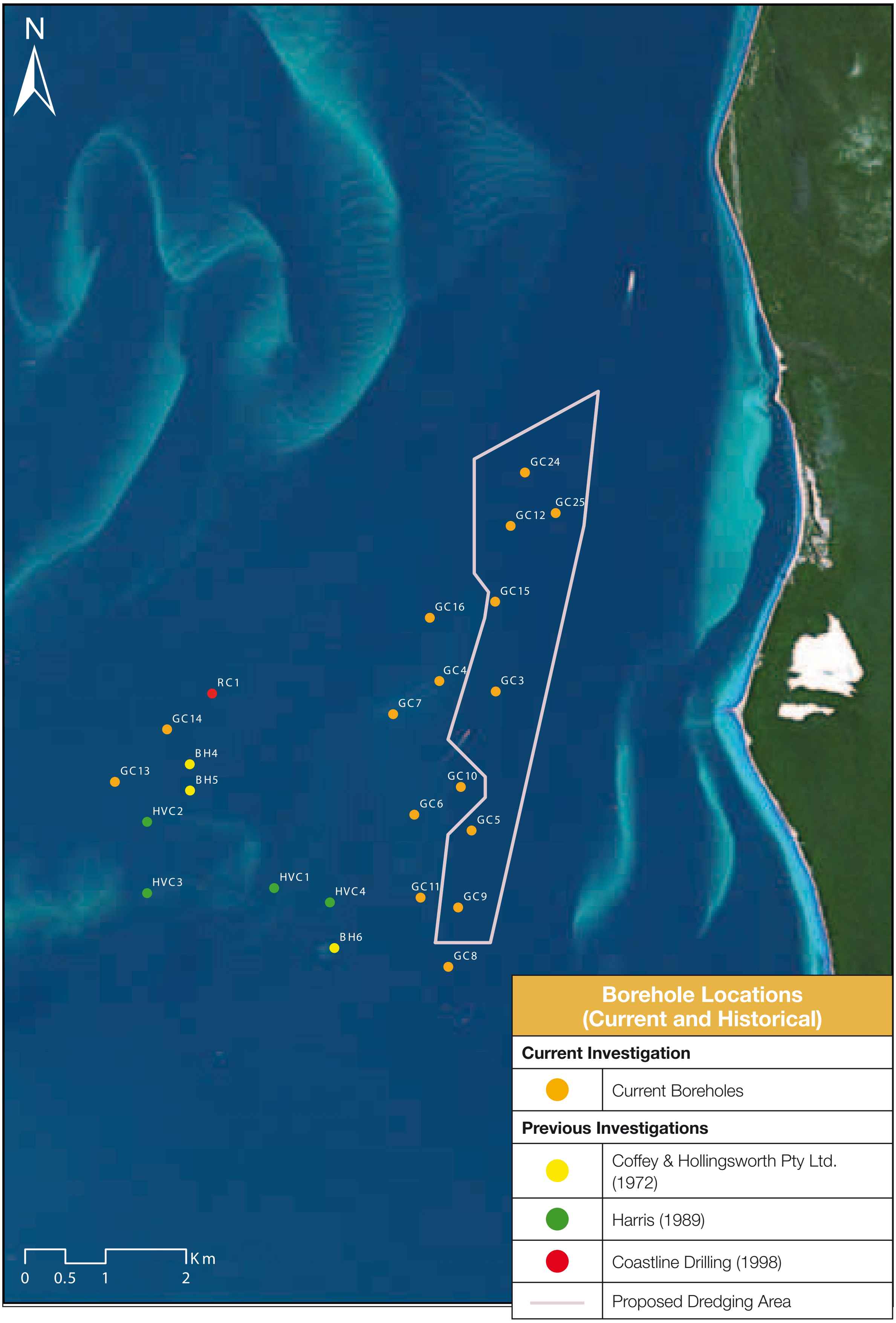
(i) It is dislocated from vessel movement;

(ii) It retrieves continuous core; and

(iii) If used with appropriate core retaining devices it can recover flowing sands.

However, its historic limitation has been that it can generally only achieve a single corer penetration to a maximum of 6 to 6.5 m, and is generally limited in its ability to penetrate dense sands and or indurated layers. A range of developments implemented by GeoCoastal during the past few

Figure 2.2b: *Borehole Locations of Current and Relevant Past Investigations at Middle Banks.*



years have considerably progressed this capability, and continuous core ranging to a maximum of 17.7 m was achieved during this survey. Cores were collected in a 63 mm diameter marine-grade stainless steel tube.

Vibro-coring was conducted from a specialised tri-pontoon barge, tendered by a twin outboard vessel. Cores were extruded on-site into plastic sheathes, which were labelled and stored on the barge in cooler bags containing ice. Barrels were cleaned thoroughly between sites.

2.2.3.2 Fieldwork

The overwater investigations were conducted in December 2005 over a four week period and again in March 2006 for a week.

The two investigation phases involved:

- December 2005 - 14 boreholes (BH3 to BH16) cored and sampled; and
- March 2006 – 2 boreholes (BH24 and BH25) cored and sampled plus the repeat sampling of pore waters from BH15 and BH16 (designated BH15a and BH16a), due to possible discrepancies in some laboratory test results from the December investigation.

Boreholes were numbered sequentially and as the work was conducted concurrently with investigation in the Brisbane River Estuary and some target locations were not cored, thus the location numbering sequence is broken. Sample locations investigated are as follows:

- 2 boreholes on the northern edge of the Middle Banks area (BH24 and BH25);
- 12 boreholes in the main Middle Banks area (BH3-BH12, BH15-BH16); and
- 2 boreholes on the western edge of Middle Banks (BH13 and BH14).

Note that while laboratory test results and summary tables show BH3, BH4 etc. the nomenclature used by Geo Coastal on figures and bore log reports is GC#3, GC#4 etc. (e.g. results for BH3 equate to location GC#3).

2.2.3.3 Core Sampling and Logging

Each sheathed core was placed onto cleaned PVC ‘splits’ to support them, then the top of the sheath sliced lengthways to expose the core for logging and sub-sampling. The stratigraphic facies encountered were logged, with characteristics including texture, proportional grain size estimations, colour and presence of accessory material (biological matter, jarosite, organic debris, shells etc.) recorded against depth below natural surface. These details were incorporated into a composite graphic format as a precursor to stratigraphic modelling.

Samples from all cores were selected for particle size/other physical characteristics, pore water and Acid Sulfate Soils (ASS) analyses. Sample locations ‘down the core’ were selected by a senior geomorphologist on-site with consideration of facies boundaries and stratigraphic uniformity / variability. The depths from which samples for contaminant analyses were collected depended on visual estimation of the amount of recently accreted surface sediment (i.e. anthropogenically influenced) with a minimum of three samples obtained per core.

Sediment was subsampled from the core using decontaminated utensils (washed in Extran solution followed by tap water rinse then a deionised water rinse). Samples for ASS testing were collected into ziplock bags, which were sealed to exclude air. Sediment for contaminant analyses was mixed in a decontaminated stainless steel bowl then divided between 2 x 250g glass jars provided by the laboratory and a small ziplock bag for particle size determination. Pore water, contaminant and ASS samples were immediately refrigerated on-site in order to suppress biological and/or chemical activity, and were transported in cooler bags or eskies containing ice bricks for collection.

Particle size estimates were made during logging with reference to a visual comparator, and particle size distribution analysis was conducted on select samples. Particle sizes expressed in this report follow the AS 1289.3.6.1 classification for engineering soils.

A generic description of the very uniform sand found along the eastern margin was arrived at by microscope examination of the sediment. Grain shape was assessed against the visual comparators of Powers (1953), while sphericity was assessed against the visual comparators of Rittenhouse (1943).

2.2.3.4 Laboratory Sub-Sampling and Testing

Details of the soil and pore water samples recovered from sediment cores taken at Middle Banks are as follows:

- It was intended to sample approximately half of the sediment cores for pore water and the remainder were to be screened for ASS. The total recoverable volume of pore water was less than was estimated (i.e. approximately 1-1.2L from about 8 m of core), therefore it was not possible to collect pore water samples representative of 0.0-1.0 m, and 1.0-2.0 depth intervals and composite samples representing about 7-8 m of core length were taken.
- Pore water was sampled by first cutting a small air hole at the top of each sample section, then cutting a second hole at the bottom of the sample section. Water was then drained into a clean bucket, and transferred to laboratory sample bottles.
- For each section of core from which pore water is extracted, two sample bottles and duplicate 40 ml acid rinsed phials were filled. One of the bottles was then filtered through a 0.40 μm disposable filter using a milli-pore vacuum filter pump. Sample bottles were kept cold until dispatched for analysis (within 48 hours of sampling). The sample buckets were rinsed thoroughly with tap water between samples. Five sections of core were sampled in this manner.
- The cores were then sub-sampled for PSD and other physical testing. Disturbed samples of approximately 750 g were taken at approximately 2 m intervals along the sample core (commencing at the surface). In addition, from each core a 6 kg composite sample was set aside for possible additional physical testing (Max/Min Density, and Permeability testing).
- Results of analysis indicated elevated concentrations of Toluene in several of the water samples and subsequently it was decided to re-visit two of the sample locations (BH15 and BH16) and sample selectively for Toluene and other volatile organic compounds. Pore water was extracted at approximately 1 m intervals and placed in 40 ml acid rinsed phials. A total of 14 sections of core were sampled in this manner. A comprehensive Quality Control program was adopted for this phase of work, which comprised taking rinsate samples from the vibro-core sample barrel, the plastic sheaths used to store the samples and the buckets used to collect the pore water. In addition, sea water 'blanks' from the sampling locations and samples of the deionised water used were also submitted for analysis.
- 11 cores (including the 2 cores from BH13 and BH14 on the western edge of Middle Banks) were screened and tested for the presence of ASS. These cores were subsampled at vertical intervals of 0.5 m (minimum). Samples were placed in bags marked with depth increment (i.e. 0.5-1.0 m), sealed with all air excluded, and kept cold until taken to Golder's Mansfield laboratory for screening pH_{FOX}. Any discrete 'layers' identified on the logs were sub-sampled for pH_{FOX} screening.
- These cores were also sub-sampled by GeoCoastal in the field for PSD and other physical analyses. Disturbed samples of approximately 750 g were taken at 2 m intervals along the sample core (commencing at the surface), and samples placed in clearly marked plastic bags. Where changes in stratigraphy were evident, the discrete layers were sampled. From each core, one 6 kg sample of the predominant sand layer was taken for additional testing physical testing (Max/Min Density, and Permeability testing).

2.2.4 Geotechnical Assessment

2.2.4.1 Sediment Stratigraphy

The results of coring during the survey are displayed in graphic borelogs appended (**Appendix C2: A**), and incorporated in stratigraphic cross-sections (**Figures 2.2c and 2.2d**).

Figure 2.2c: *Middle Banks South - North Stratigraphic Transect #1.*

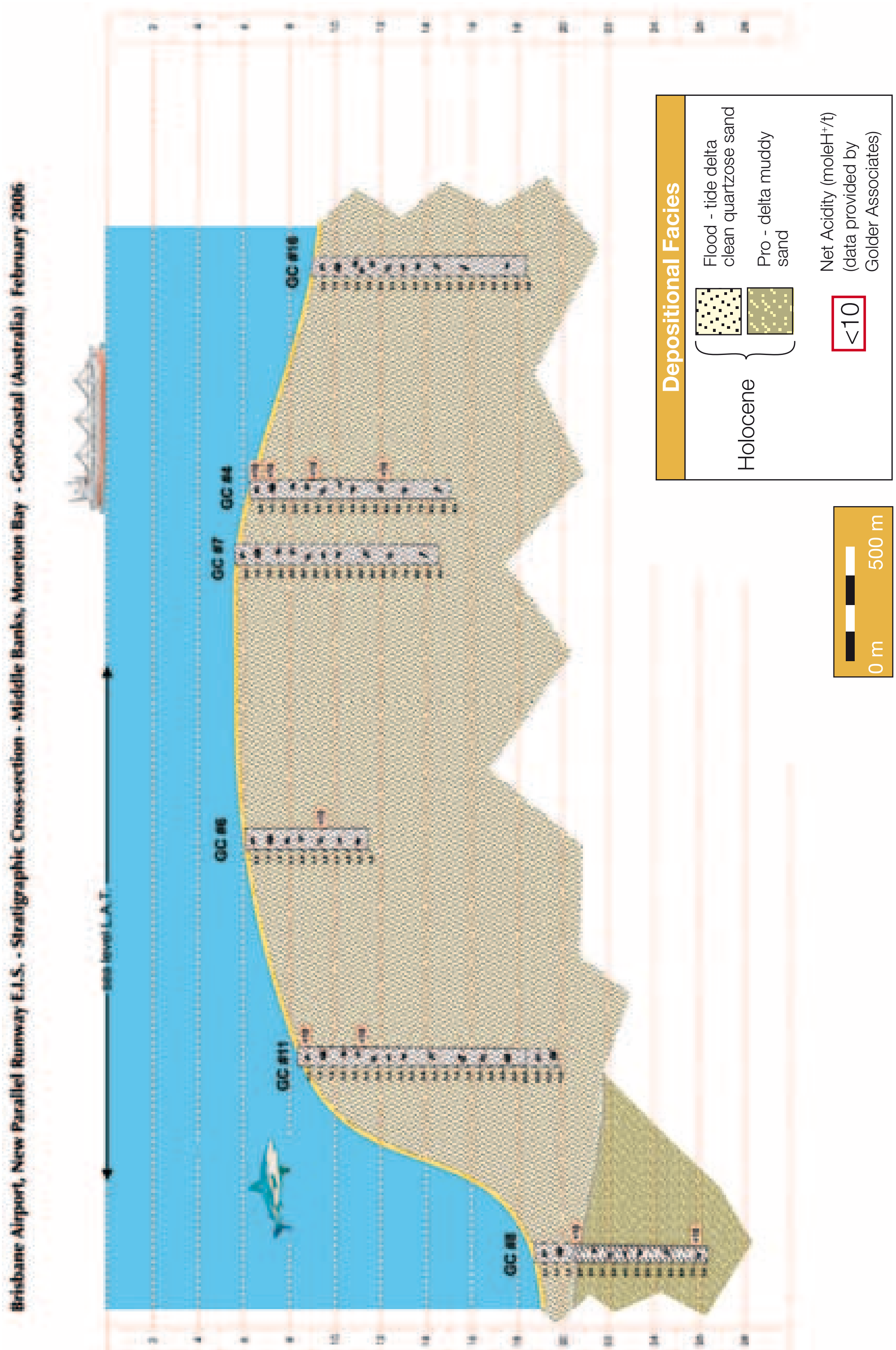
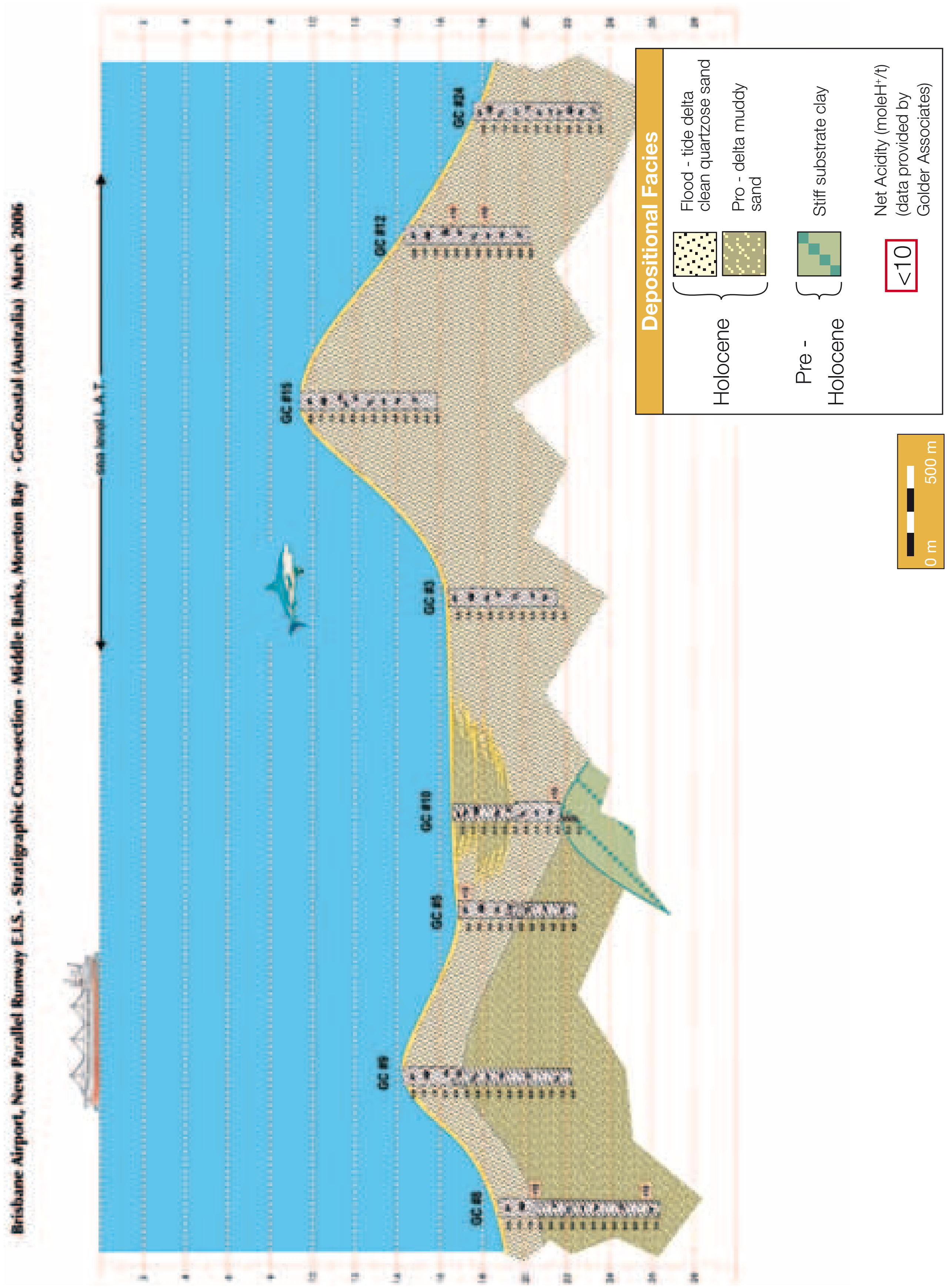


Figure 2.2d: *Middle Banks South - North Stratigraphic Cross-section of Transect #2.*



The majority of core sites (12) conducted on Middle Banks were located along the eastern margin of the banks which was considered the most prospective for extraction. The central banks are occupied by existing permit areas, and previous studies had identified the western banks as being underlain by Pleistocene-age facies.

The sedimentary units encountered at Middle Banks are summarised in **Tables 2.2a and 2.2b.**

Table 2.2a: Major Stratigraphic Units of Holocene Aged Sediments in Middle Banks.

HOLOCENE	**Tidal Delta Sand** Uniform light grey sand with trace of silt/clay. The unit is widely distributed across the eastern middle banks from the top of the banks to below –20 m LAT.	
	Size	predominantly fine - medium (150 to 300 µm). There is also a variable component of medium grained sand in the 300 to 475 µm range that accounts for between 0 & 70 % (average <16 percent)
	Silt/Clay	trace silt clay average <2 percent
	Sorting	very well sorted
	Roundness	sub-angular to sub-rounded
	Sphericity	slightly spherical
	Grain type	predominantly clear quartz, trace limonite stained grains
	Accessories	trace opaques (<1 percent) includes minor heavy minerals
	Shell	minor variable fine-grained shell
	Pro Delta Muddy Sand This sand is dark grey with variable silt/clay and is similar to the tidal delta sands, but with a higher silt/clay content and slightly finer. The unit is distributed across the southern margin of Middle Banks at depths in excess of about –16 m LAT.	
	Size	very fine to fine grained (75 to 200 µm).
	Silt/Clay	variable, averaging between 7 and 15 percent
	Sorting	moderately well sorted
	Roundness	sub-angular to sub-rounded
	Sphericity	slightly spherical
	Grain type	predominantly clear quartz, trace limonite stained grains
	Accessories	trace opaques (<1 percent) includes minor heavy minerals
	Shell	minor

Table 2.2b: Major Stratigraphic Units of Pleistocene Aged Sediments in Middle Banks.

PLEISTOCENE	**Tidal Delta Sand** This unit was encountered in holes #13 and #14 along the western side of Middle Banks.	
	Size	predominantly fine grained, minor very fine grained (75 to 300 µm).
	Silt/Clay	variable, averaging between 5 and 20 percent
	Sorting	very well sorted
	Roundness	sub-angular to sub-rounded
	Sphericity	slightly spherical
	Grain type	Quartz with variable discolouration from clear to heavily stained grains
	Substrate Clay The brownish grey substrate clay was encountered in borehole #10 located along the eastern margin of Middle Banks.	
	Consistency	stiff
	Plasticity	Plastic

Pleistocene Facies

Two sites were located in the western margin of Middle Banks to ground truth the seismic record, and consistent with past studies, both encountered the Pleistocene substrate. Borehole #13 encountered the Pleistocene boundary at 7.6 m into the sedimentary section (-18.45 m LAT), identified as a greenish grey sand with a mature clay matrix. Borehole #14 encountered Pleistocene 'coffee' sands at 30cm below the current seafloor (-10.8 m LAT), which was underlain by a variable sequence of muddy (i.e. to 22 percent silt/clay) and slightly muddy sands. These sands are considered to be the Pleistocene-age, relict analogue of the Holocene tidal delta sand on which soil forming processes have acted during sea level lowstands. During the transgression period (when sea level rose), this deposit would have been reworked and contributed as a source for the modern Holocene tidal delta. The tidal delta sand varies from white loose sand to a dark brown weakly coherent organic duripan crust (coffee rock).

Borehole #10 on the eastern flank of Middle Banks was situated to target a Pleistocene topographic high identified in the seismic record, and encountered a stiff brownish grey clay substrate 5.1 m into the sedimentary section (-21.7 m LAT). This substrate high forms part of a more extensive linear feature mapped by Mapping and Hydrographic Surveys (2006) in the seismic record.

Two boreholes from the Coffey and Hollingsworth (1972) drilling along the eastern margin are also of interest:

- Borehole #1 intersected clayey sands at approximately -20 m LAT which are interpreted as the Pleistocene substrate. Borehole #1 falls centrally between the four holes GC#5, GC#6, GC#9 and GC #11 in the present study (refer **Figures 2.2c** and **2.2d**).
- Borehole #9 in the northern extension of the presently proposed dredge footprint encountered wood material at -19.65 m which is characteristic of facies influenced by the Holocene transgression. This borehole terminates in this facies at -21.2 m LAT, however, it is suspected that the Pleistocene surface lies within close proximity beneath.

The following observations are offered for consideration of whether cultural artefacts and occupied surfaces may have been preserved:

- The Pleistocene surfaces encountered are characteristic of B-horizons of soils (i.e. coffee sands and stiff clays), suggesting A-horizons have been removed by erosion. This erosional truncation is further attested to by the sharp nature of boundary between the Pleistocene substrate and overlying Holocene sediments.
- In Borehole #14 a thin veneer of marine sediment (30 cm) overlies the B-horizon 'coffee layer', and in borehole #10 there appears to be no preservation of intermediate environments between full marine and Pleistocene B-horizon clays suggesting that any former surface environments have been swept away by marine erosion. However, in Borehole #13 there is preservation of a near shore transgressive sand environment that would have deposited within proximity to a migrating shoreline.

Holocene Facies

The cored Holocene stratigraphy of the eastern Middle Banks as illustrated in **Figures 2.2c** and **2.2d** is remarkably uniform, and is characterized by predominantly well sorted, fine/medium ranging to very fine sized, quartzose sand. Only an average of ~16 percent of this sand falls within the coarser 0.3-0.475 mm range (i.e. mid-medium size), but this coarser bracket may represent as high as 73 percent of the total in some intervals (e.g. GC #7). There is no consistent lateral or vertical trend to the occurrence of these medium sand dominated zones, for example, GC #3 and GC #6 are medium sand dominated and are situated on the deeper flank and upper bank respectively.

The only significant change in the sedimentary character of the Holocene sequence that justifies a separate facies classification is a consistently muddier sand in the deeper south-eastern sector (refer **Figures 2.2c** and **2.2d**). Silt/clay content in these sediments range to a maximum of 22 percent in GC #8.

The position of this sediment is consistent with an interpretation as a phase of proselyte deposition preceding the onset of the flood-tide delta proper, and may have been influenced by its location in the lee of the linear Pleistocene ridge interpreted in the seismic record and intersected in GC #10 (refer **Figure 2.2d**).

The Holocene facies in GC #13 situated on the western margin of Middle Banks displays a sequence that is more responsive to the elevated Pleistocene substrate in that area. The initial phase of Holocene deposition has a visible organic component including mangrove debris, identifying it as having deposited in proximity to a mangrove shoreline transgressing an elevated substrate. An abbreviated (~ 1 m) silt/clay layer overlying this deposition testifies to a period of offshore isolation from energy as sea level continued to rise, before the higher energy environment of the protruding flood-tide delta sands overtook the site.

2.2.4.2 Particle Size and Sediment Composition

Particle Size Distribution

Particle Size Distribution (PSD) analysis was carried out on a series of sub-samples taken from each core at approximately 2 m vertical intervals. In the main Middle Banks area sampling and analysis was limited to the clean sand deposit, with the exception of some silty/clayey sands from BH8 (at the southern extent of Middle Banks). In the BH13 and BH14 in the West Middle Banks area, the clean sand deposit was shallow and samples of the underlying clayey sands and clay were also included for analysis. Samples were also recovered from BH24 and BH25, drilled as part of the follow-up investigation.

Particle analysis was by sieving, and limited distribution down to 75 µm particle size. Materials with a significant silt and clay fines fraction may be analysed by the Hydrometer method which allows a plot of particle distribution down to 1 µm. Most sand samples analysed from the main Middle Banks area had very few silt and clay fines so analysis by the Hydrometer method was not undertaken.

Results of the PSD tests are summarised in **Table 2.2c.**

Table 2.2c: Summary of PSD Test Results.

	Passing Sieve Size (%)										
Location	2.36 mm	425 µm	300 µm	150 µm	75 µm	Location	2.36 mm	425 µm	300 µm	150 µm	75 µm
Middle Banks						**Middle Banks**					
BH3 0.0-1.0 m	100	99	64	2	1	BH10 0.0-0.2 m	100	99	97	9	4
BH3 1.0-2.0 m	100	98	50	2	2	BH10 1.3-1.5 m	100	96	91	19	12
BH3 2.0-5.1 m		100	73	3	2	BH10 3.3-3.5 m	99	96	75	4	3
BH4 0.1-0.5 m		100	92	2	1	BH11 0.0-0.2 m	100	99	88	3	2
BH4 2.0-2.5 m		100	98	3	2	BH11 2.3-2.5 m	100	99	97	4	-1
BH4 4.0-4.5 m		100	99	5	2	BH11 4.3-4.5 m	100	99	93	4	2
BH4 5.5-6.0 m	100	100	99	5	2	BH11 6.3-6.5 m	100	99	91	4	2
BH4 3.5-5.0 m	100	98	50	2	1	BH11 8.3-8.5 m	100	99	82	7	6
BH5 0.2-0.8 m		100	97	3	1	BH11 10.3-10.5 m	100	99	92	10	1
BH5 3.0-3.3 m		100	99	11	7	BH12 0.0-0.2 m		100	90	3	2
BH5 5.2-5.5 m		100	99	15	9	BH12 1.3-1.5 m		100	74	2	1
BH6 0.2-0.8 m	100	94	40	2	1	BH12 3.3-3.5 m	100	99	90	2	2
BH6 2.5-4.0 m	100	94	30	1	1	BH12 5.3-5.5 m	100	99	90	3	2
BH6 3.0-3.3 m	100	98	53	1	1	BH 15 0.0-0.2 m	100	99	56	1	1
BH6 5.1-5.4 m	100	97	60	5	3	BH 15 2.0-2.2 m	100	99	87	2	1
BH7 2.2-2.4 m	100	96	37	5	3	BH 15 4.0-4.2 m		100	79	1	1
BH7 3.4-3.6 m		100	99	3	1	BH 15 6.0-6.2 m	100	99	92	3	2
BH7 4.7-4.9 m		100	97	2	1	BH16 0.0-0.2 m	100	99	94	2	1
BH7 5.9-6.1 m	100	99	79	5	2	BH16 2.0-2.2 m	100	99	93	2	1
BH7 6.9-7.1 m	100	98	71	5	4	BH16 4.0-4.2 m	100	99	93	2	1
BH7 7.6-8.6 m	100	99	68	2	1	BH16 6.0-6.2 m		100	93	2	1
BH8 1.8-2.0 m		100	97	13	7	BH16 8.0-8.2 m	100	99	93	4	2
BH8 3.8-4.0 m	100	99	99	24	13	BH24 0.0-0.25 m	100	97	86	2	1
BH8 5.8-6.0 m	100	99	98	23	13	BH24 2.0-2.25 m		99	90	1	0
BH8 7.4-7.6 m	100	99	99	24	14	BH24 4.0-4.25 m		99	89	1	0
BH9 0.0-0.2 m	100	99	4	3	1	BH24 6.0-6.25 m	99	93	77	2	1
BH9 2.3-2.5 m		100	99	10	5	BH25 0.0-0.25 m	100	97	53	1	1
BH9 4.8-5.0 m		100	99	12	7	BH25 2.0-2.25 m		99	60	1	1
BH9 7.3-7.5 m		100	99	16	9	BH25 4.0-4.25 m		98	57	1	0
						BH25 6.0-6.25 m	99	93	42	1	1
West Middle Banks											
BH13 7.3-7.5 m	100	98	93	25	17	BH14 0.0-0.2 m	90	83	78	9	5
BH13 0.0-0.2 m	99	85	68	3	2	BH14 2.3-2.5 m	100	99	94	10	6
BH13 2.3-2.5 m	97	93	89	25	16	BH14 4.3-4.5 m	100	99	95	36	22
BH13 4.8-5.0 m	100	99	91	19	15	BH14 5.5-6.0 m		100	97	15	7
BH13 10-10.5 m		100	100	27	19	BH14 8.3-8.5 m		100	95	19	8

Table 2.2c: Summary of PSD Test Results (contd).

Passing Sieve Size (%)											
Location	2.36 mm	425 µm	300 µm	150 µm	75 µm	Location	2.36 mm	425 µm	300 µm	150 µm	75 µm
Follow-Up Tests - Middle Banks											
BH3 1.0-2.0 m	99	69	16	3	2	BH15A 2.0-3.0 m	99	81	16	2	1
BH3 2.4-2.6 m	99	72	16	2	1	BH15A 6.0-6.25 m	100	94	20	3	2
BH4 2.25-2.5 m	99	97	22	3	1	BH24 2.0-2.25 m	99	89	17	2	1
BH4 5.75-6.0 m	100	99	41	6	2	BH24 6.0-6.25 m	96	84	20	3	2
BH12 3.3-3.5 m	99	85	12	1	1						

Test results indicate that the sand deposits present, that would be suitable for extraction and use as fill are predominantly fine to medium grained, with the majority of particles in the sieved size range 300 µm (average 82 percent passing) to 150 µm (average 6 percent passing).

Nominal (D50) Particle Size

Fine sands passing 225 to 250 µm are of particular interest, as it is this size which dictates the dredging/pumping characteristics of the sand, and further analysis was required to more accurately predict the proportion of sand in this particle size range.

Twelve samples of the predominant sand type from boreholes representative of the main Middle Banks area were submitted to James Cook University in Townsville, to undergo particle sizing by Laser Sizing techniques, to attempt to determine a more accurate estimate of the proportion of fine sand passing 225 µm and 250 µm.

Results of laser sizing indicate variable particle size in the 250 µm to 225 µm range (of the order of 12 - 37 percent passing 250 µm and 6 - 22 percent passing 225 µm). However, the composite sample from BH8 was distinctly finer, with 74 - 64 percent passing the target size range.

Comparison of PSD plots from sieving and laser sizing techniques indicated a distinct 'shift' towards a coarser distribution, typically of the order of 20 - 30 percent. The laser sizing test method is not yet recognized in the materials testing industry, and is not a NATA accredited test method. The sizing is based on volumetric measurement rather than mass. Therefore the nominal particle sizes attained using laser sizing may not be as accurate as traditional sieving.

Following review of the Laser Sizing test results, a further 9 samples were sieved over an extended range of sieve sizes, including a 'non-standard' 212 µm sieve. Results were generally consistent with the original PSDs, but allowed a more accurate estimation of the nominal D50 (i.e. the particle size which represents 50 percent of the material). The D50 for these 9 samples was interpolated as ranging from 275 to 225 µm, (7 of the samples had a D50 of approximately 250 µm). Results of this analysis are included in **Table 2.2d.**

Particle Shape and Sediment Composition

An assessment of particle shape and sphericity was conducted by Geo Coastal Australia, and is reported on the Borehole Logs attached in **Appendix C2: A**. In addition, seven samples of the predominant sand type from boreholes representative of the main Middle Banks area were submitted to Griffith University for assessment of mineralogical composition, which included an accurate estimate of the proportion of deleterious organic matter and carbonate content derived from shell fragments and/or coral debris (expressed as $CaCO_3$ percent).

Table 2.2d: Summary of Laser Sizing Test Results.

Location	Approximate % Passing 250 µm	Approximate % Passing 225 µm
BH3 0.0 - 1.0 m	23.4% passing 250 µm	12.7% passing 225 µm
BH3 0.0 - 1.0 m	23.4% passing 250 µm	12.7% passing 225 µm
BH6 2.3 - 2.5 m	17.9% passing 250 µm	8.9% passing 225 µm
BH8 2.8 - 7.0 m	74.0% passing 250 µm	63.6% passing 225 µm
BH12 3.3 - 3.5 m	23.9% passing 250 µm	12.1% passing 225 µm
BH16 4.0 - 4.2 m	37.2% passing 250 µm	21.7% passing 225 µm
BH24 0.0-0.25 m	30.5% passing 250 µm	17.5% passing 225 µm
BH24 2.0 - 2.25 m	30.5% passing 250 µm	16.7% passing 225 µm
BH24 4.0 - 4.25 m	21.7% passing 250 µm	11.8% passing 225 µm
BH24 6.0 - 6.25 m	26.7% passing 250 µm	15.7% passing 225 µm
BH25 0.0 - 0.25 m	17.1% passing 250 µm	10.4% passing 225 µm
BH25 2.0 - 2.25 m	15.9% passing 250 µm	9.1% passing 225 µm
BH25 4.0 - 4.25 m	12.2% passing 250 µm	6.0% passing 225 µm
BH25 6.0 - 6.25 m	14.5% passing 250 µm	7.8% passing 225 µm

The mineralogical assessment report is attached in **Appendix C2: B**. In summary, the assessment indicated the following components:

- Organic Matter: 0.08-0.43 (wt percent) LOI_{550}; and
- Carbonate: 0.07-2.40 (wt percent) LOI_{950}.

The assessment indicates that the sands analysed comprised between 97 and 99.5 percent silica, which is a hard, chemically inert substance.

The presence of carbonate indicates that the sand generally has some alkaline buffering capacity (with respect to any acidity that may be present). The organic matter content is relatively low and indicates that any decomposition of fines following disturbance of the sand would be expected to be minimal.

2.2.4.3 Sand Compaction Characteristics

The sand that will be dredged from Middle Banks, will be used as granular fill in the proposed parallel runway reclamation area. The dredged sand will be used as surcharge to promote settlement and as structural fill beneath the runway pavement following the removal of excess surcharge material.

A laboratory testing program was conducted to evaluate the likely compaction and drainage characteristics of the sand, once it has been placed.

The aim of the testing program was to assess the influence of the degree of compaction, on the subsequent permeability of the sands and to determine whether grain shape and/or size would influence compaction.

Results of PSD tests indicate a range of particle sizes present in the sands, and reference to geomorphologic descriptions (supplied by Geo Coastal) indicate the sand particles are sub-angular to sub-rounded and slightly spherical. Such characteristics should not adversely influence compaction.

Summary of Particle Density, Compaction and Density Index

Bulk samples of sand from seven borehole locations within the main Middle Banks area were used to evaluate the following compaction parameters:

- Particle Density; Maximum Density and Minimum Density.

The samples were then subjected to Constant Head Permeability tests at two selected densities representing the maximum theoretical compacted density (i.e. a Density Index of 100 percent or the maximum theoretical density) and the least level of compaction that would be expected to be achieved (i.e. a Density Index of 60 percent). In practice, Density Indices of the order of 70-80 percent would be expected to be required for structural fill under runway pavements. Results of testing undertaken are summarised in **Table 2.2e** below.

Permeability

Results of permeability testing indicate a distinct trend in increased permeability with decrease in DI and increase in porosity. Permeability increases an average of 2.3 E-5 m/sec with an increase of the order of 14 percent in effective porosity. Although the trends are quite clear, a change in permeability of the order indicated is negligible in terms of effect on drainage of sand subgrades and therefore a permeability of the order of 1 to 5 E-5 m/sec would be considered as representative for purposes of pavement design.

2.2.5 Assessment of Acid Sulfate Soils

2.2.5.1 Origins of ASS

Pyritic soils or ASS, were deposited in coastal zones throughout the world during the last 6,500 to 10,000 years. When drained for development or otherwise disturbed, the iron pyrite in these sediments oxidises producing sulfuric acid which subsequently lowers the pH in runoff and groundwater, leading to the release of toxic aluminium and iron from the sediments. Acidic water introduced into coastal streams can cause fish kills, alterations to ecosystems and corrosion of civil structures.

The source of the acid is naturally occurring pyrite (FeS_2). Environmental degradation occurs when this pyrite oxidises and sulfuric acid is produced and discharged into receiving waters. If receiving waters in ASS areas are saline and subject to tidal exchange, low level acidity naturally generated is often adequately buffered by the salinity.

2.2.5.2 Existing Mapping of ASS

The Middle Banks area is in Moreton Bay, beyond the edge and immediate area of influence of estuarine deposits emanating from the Brisbane River and other coastal streams. Although the sand deposits are Holocene in origin their ASS potential has not been mapped.

2.2.5.3 Laboratory Analysis (ASS)

All sediment samples recovered were screened by the pH/pH_{FOX} test method and a representative number of samples were selected and subjected to SPOCAS test suites.

The SPOCAS analysis suite has been adopted by the Queensland Acid Sulfate Investigation Team (QASSIT) for the testing of ASS in Queensland. The method includes analysis and quantification of actual acidity, naturally occurring alkaline materials (i.e. calcite, coral debris, fine shell fragments) and 'retained acidity' which includes sulfur held in stable oxidation minerals such as 'jarosite' which was historically not included in estimates of potential acidity.

Table 2.2e: Permeability and Compaction Parameters.

Sample Location	Nom. PS (D90) (mm)	Particle Density (t/m3)	Max dry Density (t/m3)	Min, Dry Density (t/m3)	Permeability (k) at 100% DI (m/sec)	Permeability (k) at 60% DI (m/sec)	Porosity 100% DI (%)	Porosity 60% DI (%)
BH3 0.0-1.0 m	<0.4	2.62	1.70	1.38	5.4 E-5	1.2 E-4	35.1	47.3
BH4 3.5-5.0 m	<0.3	2.62	1.71	1.37	2.0 E-5	7.8 E-5	34.7	47.7
BH7 7.6-8.6 m	<0.4	2.62	nd	nd	8.9 E-6	2.5 E-5	nd	nd
BH8 2.8-7.0 m	<0.3	2.64	nd	nd	1.5 E-6	2.5 E-6	nd	nd
BH12 3.3-3.5 m	0.3	2.62	1.68	1.40	7.4 E-6	1.9 E-5	35.9	46.6
BH14 5.5-6.0 m	<0.3	2.62	1.77	1.29	1.2 E-6	4.3 E-6	32.4	50.8
BH16 4.0-4.2 m	0.3	2.62	1.68	1.28	7.4 E-6	1.6 E-5	35.9	51.1
Averages	0.3	2.62	1.71	1.34	1.5 E-5	3.8 E-5	34.8	48.7

Note: nd - not determined

An overall acid-base accounting method has been derived to calculate a 'net acidity' value which is used to qualify analytical test results and to calculate liming rates. The equation used is:

'net acidity' = actual acidity (as TAA) + retained acidity (as S_{NAS}) + remaining potential acidity (as TSA) - in situ acid neutralising capacity (ANC).

Preliminary Screening

Sediment profiles were sampled at 0.5 m intervals and screened using the pH/pH_{FOX} test method, which consists of two steps; initially determining the field pH of a 1:5 soil/water suspension, followed by the addition of 30 percent Hydrogen Peroxide, allowing the sample time to oxidise, before determining the pH_{FOX} (pH after oxidation) of the reacted sample. A significant drop in pH is indicative of the presence of potential acidity.

Screening of samples of sediments carried out using the pH/pH_{FOX} test method indicate that the sand profiles tested from the main Middle Banks site (i.e. the proposed dredging 'footprint') do not contain detectable levels of acidity. Mostly this is because of the presence of considerable amounts of fine calcareous material (shell grit or coral debris) sufficient to buffer any potential acidity present. Buffering could also be due to some extent, to the salt water environment.

Screening of samples of sediments from BH13 and BH14 on 'West' Middle Banks indicates a shallow layer of 'clean' sand with alkaline buffering capacity overlying inter-layered clayey sands and clays which include one or more Potential Acid Sulfate Soils (PASS) strata. Results indicate that some samples contain high levels of PASS materials that are not apparently 'buffered'. The pH and pH_{FOX} readings in the different areas investigated are summarised here:

- Middle Banks - pH_{FOX} ranged from 6.4 to 8.0 (mostly higher than 7.0). Field pH values ranged from 6.1 to 8.8. Soil pH at or above 7.0 indicate the absence of detectable acidity.
- West Middle Banks - In the surface sand deposits, pH_{FOX} ranged from 6.8 to 7.9 (mostly higher than 7.0) and field pH values ranged from 8.1 to 9.0. In the underlying clayey sands/clays, pH_{FOX} ranged from 1.7 to 7.0 and field pH values ranged from 5.8 to 8.4, but were generally above 5.5-6.0, indicating little or no actual ASS.

Summaries of screening and analytical test results are attached in **Appendix C2: B**.

Quantitative Analysis

There were no positive screening test results from the sand deposits in the main Middle Banks area, so a number of randomly distributed samples were selected for confirmatory quantitative analysis. A number of clay samples from the West Middle banks area were also selected, based on results of preliminary screening tests. A total of 21 samples were submitted to undergo laboratory analysis by the SPOCAS test suite, 13 tests from Middle Banks and eight tests from West Middle Banks.

Results of laboratory testing undertaken are included in **Appendix C2: B** and summarised in **Tables 2.2f and 2.2g.** Values shown in bold on the tables exceed the QASSIT texture based 'Action Criteria' for 'net acidity'. It should be noted that for disturbances of greater than 1000 tonnes (i.e. dredging excavations), an 'action criteria' of 18 moles H+/tonne should be adopted for materials of all textures that are to be disturbed for any purpose.

A summary of soil acidity for each site investigated is given here.

Middle Banks

Given the screening test results indicated an apparent absence of ASS in the sand deposit from the main Middle Banks area this was considered sufficient analysis to confirm the absence of ASS/PASS. Should any significant ASS have been detected, then further analysis would have been undertaken. No quantitative analysis was carried out on samples from sand profiles in which indicator tests showed negligible 'net acidity', which may be due to natural buffering capacity derived from fine calcareous material present throughout the soil profile or a lack of pyritic fines (PASS).

Table 2.2f: Summary of Quantitative Test Results - Middle Banks.

Location	Action Criteria (mole H+/t)	TAA (mole H+/t)	TPA (mole H+/t)	Texture Description	S_{POS} (%)	'Net Acidity' (mole H+/t)	pH_{OX}
BH4 0.0-0.2 m	18	<2	<2	S, grey-brown	0.02	<10	7.4
BH4 0.4-1.1 m	18	<2	<2	S, grey-brown	0.02	<10	7.4
BH4 2.8-3.0 m	18	<2	<2	S, grey-brown	0.02	<10	7.5
BH4 5.8-6.0 m	18	<2	<2	S, grey-brown	0.06	<10	7.7
BH5 0.3-0.5 m	18	<2	<2	S, dk grey	<0.02	<10	7.5
BH6 3.3-3.5 m	18	<2	<2	S, grey	<0.02	<10	7.8
BH8 1.8-2.0 m	18	<2	<2	S, grey	0.07	<10	7.7
BH8 6.8-7.4 m	36	<2	<2	CS, grey	0.18	<10	7.7
BH10 4.8-5.0 m	36	<2	<2	CS, dk grey	<0.02	<10	7.6
BH11 0.2-0.5 m	18	<2	<2	S, dk grey	<0.02	<10	7.7
BH11 2.8-3.0 m	18	<2	<2	S, dk grey	<0.02	<10	7.6
BH12 2.3-2.5 m	18	<2	<2	S, dk grey	<0.02	<10	7.4
BH12 3.8-4.0 m	18	<2	<2	S, dk grey	<0.02	<10	7.6
Averages	18	<2	<2	Coarse Textured	0.028	<10	n/a

Table 2.2g: Summary of Quantitative Test Results - West Middle Banks.

Location	Action Criteria (mole H+/t)	TAA (mole H+/t)	TPA (mole H+/t)	Texture Description	S_{POS} (%)	'Net Acidity' (mole H+/t)	pH_{OX}
BH13 4.8-5.0 m	36	<2	217	LC, sandy, dk grey	0.51	251	2.6
BH13 6.3-6.5 m	36	<2	159	CS, sandy, dk grey	0.35	218	2.7
BH13 7.3-7.5 m	36	<2	395	CS, sandy, dk grey	0.97	465	2.4
BH13 9.3-9.5 m	36	<2	407	CS, pale grey	0.92	463	2.3
BH14 2.8-3.0 m	18	<2	42	S, dk grey	0.06	40	3.6
BH14 4.3-4.5 m	36	5	121	CS, sandy, dk grey	0.30	192	2.8
BH14 5.3-5.5 m	36	6	174	CS, sandy, dk grey	0.38	243	2.5
BH14 8.8-9.0 m	18	<2	35	S, pale grey	0.04	25	3.7
Averages	62	<2	194	Fine Textured	0.44	237	n/a

Test results indicate low levels of oxidisable sulfur present in some of the sand samples tested (the highest being 0.18 percent in BH8 at 6.8 - 7.4 m depth). However, inherent acid neutralising capacity (ANC) is more than adequate to supply the necessary buffering capacity in all sample analysed.

Test results returned 'net acidity' values of <10 moles of acid / tonne in all samples analysed, and no samples exceeded the 'Action Criteria' for bulk excavations (i.e. 18 moles of acid / tonne). Actual acidity levels were <2 moles of acid / tonne (i.e. below the detection limit of the test method employed). Results of Percent Oxidisable Sulfur analysis, indicate some low levels of oxidisable sulfur (sulfides) present in the samples analysed. However, analysis for ANC showed high levels of alkaline material in most of the samples analysed. Many samples with potentially high ANC were not analysed (as screening tests did not indicate significant acid potential in these samples).

West Middle Banks

The small number samples selected from West Middle Banks area, were based on positive screening results. The samples were analysed to confirm the presence of ASS in the underlying clay layer and 'dirty' clayey sand layers, and since the surface 'clean' sand deposit is not sufficiently deep to warrant extraction, no disturbance of sediments in this area is expected. Subsequently, more detailed characterisation of ASS in this area is not required. The proposed Dredging 'Footprint' is well to the east of BH13 and BH14, (refer to Chapter C1 for a description of the dredge footprint).

Test results indicate that some small amount of actual acidity and substantial potential acidity is present in the samples of sediment analysed. The 'net acidity' varies considerably, but is generally high where ANC is not adequate to supply natural buffering capacity. This occurs in samples from both borehole locations.

Test results returned 'net acidity' values ranging from 25 up to 463 moles of acid / tonne. The actual acidity levels were negligible (i.e., < 10 moles of acid / tonne), which indicates no previous oxidation of sulfidic fines has occurred (as expected, given the sediments have remained below sea level). Of the eight samples analysed, PASS levels in all exceeded the appropriate QASSIT 'Action Criteria', with an average 'net acidity' of 237 moles of acid / tonne. Results of Percent Oxidisable Sulfur tests, indicate that the level of oxidisable sulfur (sulfides) present in the alluvium is in the range 0.1-1.0 percent, and ANC was either absent or not sufficient to adequately buffer the potential acidity present.

Samples of the surface sand layer with potentially high ANC were not analysed (as results of screening tests indicated significant alkalinity in the upper 1.0 m or so of the sediment profile).

2.2.5.4 Extent of ASS/PASS

Results of sampling and analysis undertaken indicate the absence of any appreciable ASS in the Holocene sand deposits present at Middle Banks. The low to moderate levels of oxidisable sulfur that are present are adequately buffered by alkaline material present throughout the sand profile.

On the western edge of the Middle Banks deposit (in BH13 and BH14), the depth of adequately buffered, 'clean' sand is less than 3 - 4 m, and the underlying clayey sands and clays contain moderate to high levels of potential ASS (i.e. sulfidic fines). It is not planned to disturbed these materials.

2.2.6 Porewater sampling

Laboratory analysis was undertaken on porewater samples recovered from six vibro-core locations as shown in **Table 2.2h.** GC 15 and 16 were re-sampled in early 2006 to confirm the presence of Toluene which occurred above detection levels in previous sampling at those two locations (shown as GC 15a and GC16a in the table). This information has been used in the assessment of potential changes to water quality as described in Chapter C4.

Table 2.2h: Summary of Porewater Quality - Middle Banks.

ANALYSIS SUMMARY (MIDDLE BANKS PORE WATER QUALITY)		pH	Electrical Conductivity (@25°C)	NH3 (NH4+)	NOx	Total N	Total P	Reactive P	TOC	Volatile Organic Compounds (VOCs)*				
										MAHs*			Sulfonated (Carbon Disulfide)	All other VOCs
										Toluene	Styrene	Other MAHs		
	Units		(mS/cm)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
BH	Sample Date													
BH 7 0.0-8.9 m	4/12/2005	7.7	55.50	1750	97	3200	190	42	10	12	<5	<LOR** (5)	<5	<LOR** (5-50)
BH 9 0.0-7.9 m	9/12/2005	8.0	54.40	10800	111	13000	670	188	21	<5	<5	<LOR (5)	<5	<LOR (5-50)
BH 15 0.0-6.45 m	14/12/2005	7.8	56.10	1600	179	2500	110	<10	9	220	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 0.0-1.0 m	7/03/2006									13	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 1.0-2.0 m	7/03/2006									23	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 2.0-3.0 m	7/03/2006									13	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 3.0-4.0 m	7/03/2006									28	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 4.0-5.0 m	7/03/2006									38	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 5.0-6.0 m	7/03/2006									<5	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 6.0-7.0 m	7/03/2006									16	<5	<LOR (5)	<5	<LOR (5-50)
BH 15A 7.0-8.2 m	7/03/2006									19	<5	<LOR (5)	<5	<LOR (5-50)
BH16 0.0-6.0 m	14/12/2005	7.7	55.50	3350	121	3800	230	52	5	304	5	<LOR (5)	<5	<LOR (5-50)
BH16 4.0-9.4 m	14/12/2005	7.6	53.80	5570	108	6300	140	30	4	227	<5	<LOR (5)	<5	<LOR (5-50)
BH16A 0.0-1.0 m	10/03/2006									13	<5	<LOR (5)	<5	<LOR (5-50)
BH16A 1.0-2.0 m	10/03/2006									158	<5	<LOR (5)	<5	<LOR (5-50)
BH16A 2.0-3.0 m	10/03/2006									82	<5	<LOR (5)	<5	<LOR (5-50)
BH16A 3.0-4.0 m	10/03/2006									108	<5	<LOR (5)	<5	<LOR (5-50)
BH16A 4.0-5.0 m	10/03/2006									42	<5	<LOR (5)	6	<LOR (5-50)
BH16A 5.0-6.0 m	10/03/2006									16	<5	<LOR (5)	<5	<LOR (5-50)
BH24 0.0-6.3 m	8/03/2006	7.8	56.2	1860	28	3400	2880	30	4	20	<5	<LOR (5)	<5	<LOR (5-50)
BH25 0.0-6.5 m	9/03/2006	7.9	56.3	1690	43	2200	90	49	8	20	<5	<LOR (5)	<5	<LOR (5-50)

**VOCs include Monocyclic Aromatic Hydrocarbons (MAHs), Oxygenated compounds, Sulfonated compounds, Fumigants, Halogenated Aliphatic compounds, Halogenated Aromatic compounds, Trihalomethanes, Naphthalene ** <LOR - Below the laboratory Limit of Reporting*

2.2.7 Radiation Survey

Whilst not required by the EIS Guidelines, a radiation survey has been undertaken for this EIS/MDP. A number of representative sub-samples of sands from the main Middle Banks deposit were submitted to the Queensland Health laboratory at Coopers Plains for screening for radioactive particles (i.e. total radionuclei, alpha and beta particles) by Gamma Spectrometry. Elements scanned for include: U-238, Ra-226, Pb-210, U-235, Th-232 and K-40.

Samples were selected from the predominant sand fraction at the following seven locations distributed within the main Middle Banks area:

- BH3 0.0-1.0 m.
- BH4 3.5-5.0 m.
- BH7 7.6-8.6 m.
- BH8 2.8-7.0 m.
- BH12 3.3-3.5 m.
- BH14 5.5-6.0 m.
- BH16 4.0-4.2 m.

Results of all analysis undertaken are included in **Appendix C2: B** and summarised below.

Radiation Survey Results

Results of the Gamma Spectrometry analysis undertaken indicate low level traces of the following elements (radionuclides):

- K-40 (highest value detected was 170-230 Bq/kg in BH8).
- U-238 (highest value detected was 50-70 Bq/kg in BH8).
- Ra-226 (highest value detected was 17-23 Bq/kg in BH14).
- Th-232 (occurring only at BH8 at 10-14 Bq/kg).
- No U-235 or Pb-210 was detected.

Reference to “Environmental Radioactivity Monitoring in Australia 2003 and 2004 - Technical Report Series No. 143” (Table 7), published by the Australian Radiation Protection and Nuclear Safety Agency, indicates that the levels of radionuclides detected in the samples analysed are below background levels reported for ‘Marine Sediments’.

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