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Magnetic Quay Water Quality and Sediment Baseline Study

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A REPORT TO THE GREAT BARRIER REEF MARINE PARK AUTHORITY

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SUMMARY

A study of water quality and water column sediment loads was carried out in the period mid-December 1988 to mid-February 1989 on the south-east facing fringing reefs of Magnetic Island. The study aimed at providing a baseline before construction commenced on the marina/hotel development planned for the northern end of Nelly Bay. Although it was realized that a complete baseline, allowing for natural seasonal and meteorological variability, could not be produced in two months, as much data as was logistically possible to obtain was collected including data from periods of contrasting weather conditions. An associated benthic biota and sedimentation study provided a benthos baseline and measured sediment deposition in sediment traps in the same areas.

Parameters measured were determined after consideration of the possible contaminants from the development project, both in the construction and operation stages and included those which could be produced by sewage effluents (nutrients, turbidity, organic matter and bacteria), boating activities (anti-fouling coating residues, petroleum hydrocarbons) and construction and run-off (sediment and nutrients). Sampling sites were chosen on the basis of proposed water circulation patterns in the area and these were designated either as likely impact sites or control sites depending on whether they would be influenced by the development. Sites were sampled on five occasions in the water quality study and on seven occasions in the sediment/turbidity study. To gauge natural water column variability in Nelly Bay a spatial and temporal (up to one week) variability pilot study was carried out before the general baseline study commenced. To supplement chemical determination of low levels of the anti-fouling chemical tributyltin, a baseline for a possible biological monitoring programme on the susceptible gastropods *Nassarius* spp. was also carried out.

Pilot studies were done during the baseline study to assess the relative magnitudes of spatial and temporal variation at a range of scales within Nelly Bay. For most components of water quality sites and days do not constitute important sources of variation . Cost benefit analyses of the data from the study of spatial variability indicated, further, that the most efficient allocation of sampling effort was to dispense with sampling sites and concentrate on replicates. This strategy would be satisfactory provided that the replicates were well dispersed within locations and thus effectively integrated variation at the scales of 5-10 m and 50-75 m.

Although some components of water quality varied with time of day, none of the patterns of variation suggested that a particular time of day or tidal phase should be favoured when sampling, given that sampling will be logistically constrained to daylight hours.

The suggested programme for the estimation of environmental impacts during the construction phase of the Magnetic Quay development is necessarily a compromise between logistics and the need to cater to both small scale spatial and short term temporal variability. The results of calculations of the expected power of the proposed programme indicates that it should prove a powerful method of detecting moderate perturbations (50% change or greater) to water quality on any given day (Power > 0.8 for most variables, with Type I error = 0.1). Detection of much smaller effects (say 25% of means) with the same power is unlikely to be viable for most variables without the dedication of considerably more effort to sampling and analyses.

The bays are well mixed with uniform salinity and little thermal stratification except possibly during intense rainfall events. Dissolved inorganic nitrogen levels are high with anomalously high nitrite levels and above those considered desirable for healthy coral reefs by some authorities. Phosphorus and silicate levels are normal while although no tributyltin residues were detected elevated levels of copper, compared to uncontaminated waters, were found. Levels of aromatic hydrocarbons and coliform bacteria were also normal for this area. Few differences were noted between the bays except for phosphorus levels where Nelly Bay levels were consistently lower than in the more northern bays. Suspended solid values were low, particularly compared to values measured in the south-easterly trade wind season. No useable relationship between Secchi Disc readings and suspended solid values could be derived.

1. PROJECT DESCRIPTION

Linkon Construction Limited plans to build a marina and resort development in Nelly Bay, Magnetic Island (Figs. 1,2). This will involve the construction of a breakwater from material removed from Bright Point, the formation of a harbour inside the breakwater and the construction of hotel, marina, recreational and shopping facilities on Bright Point and the northern Nelly Bay foreshore (Figs. 3,4). Part of the Nelly Bay fringing reef will be covered by the breakwater and an access channel will also have to be cut through a small section of the reef. The eventual development will be able to house 187 boats in the marina, include accommodation for about 1000 people and use an upgraded sewage treatment works.

2. PHYSICAL NATURE OF SITE

The site is in one of the larger bays on the eastern coast of Magnetic Island and faces into Cleveland Bay (Figs. 1 & 2). The depth of offshore water in Cleveland Bay varies from 2 to 10 m. Cleveland Bay receives water from Ross Creek, Ross River, Alligator and Crocodile Creeks and other smaller creeks. The majority of the coastal frontage of the city of Townsville (population 110,000) lies on Cleveland Bay and industrial activity including a copper refinery, meat works, cement works, a large commercial and military airfield and extensive light industry may also influence water quality in the Bay (Fig. 1). The major Townsville sewage works discharges into Sandfly Creek and hence into Cleveland Bay. The plant is a secondary treatment works. Townsville is a major port city and Platypus Channel passing through the centre of Cleveland Bay and only 3 km off Nelly Bay is dredged on a regular (roughly annually) basis.

Water quality in Cleveland Bay has previously been studied during the Three Bays Project (1974-1979), and published by Walker and O'Donnell (1981) and Belperio (1978) and reference to their results will be made later in this report. A project to study general water quality in Cleveland Bay particularly with respect to impacts from the sewage discharge and dredging has been proposed and results from this will aid in interpreting results from Nelly Bay in the long term. Nelly Bay data is available from Zann and Collins in unpublished reports.

Within Nelly Bay the reef rises sharply from the general Cleveland Bay floor to form a wide reef flat which dries at the lowest low tides (Fig.

Figure 1

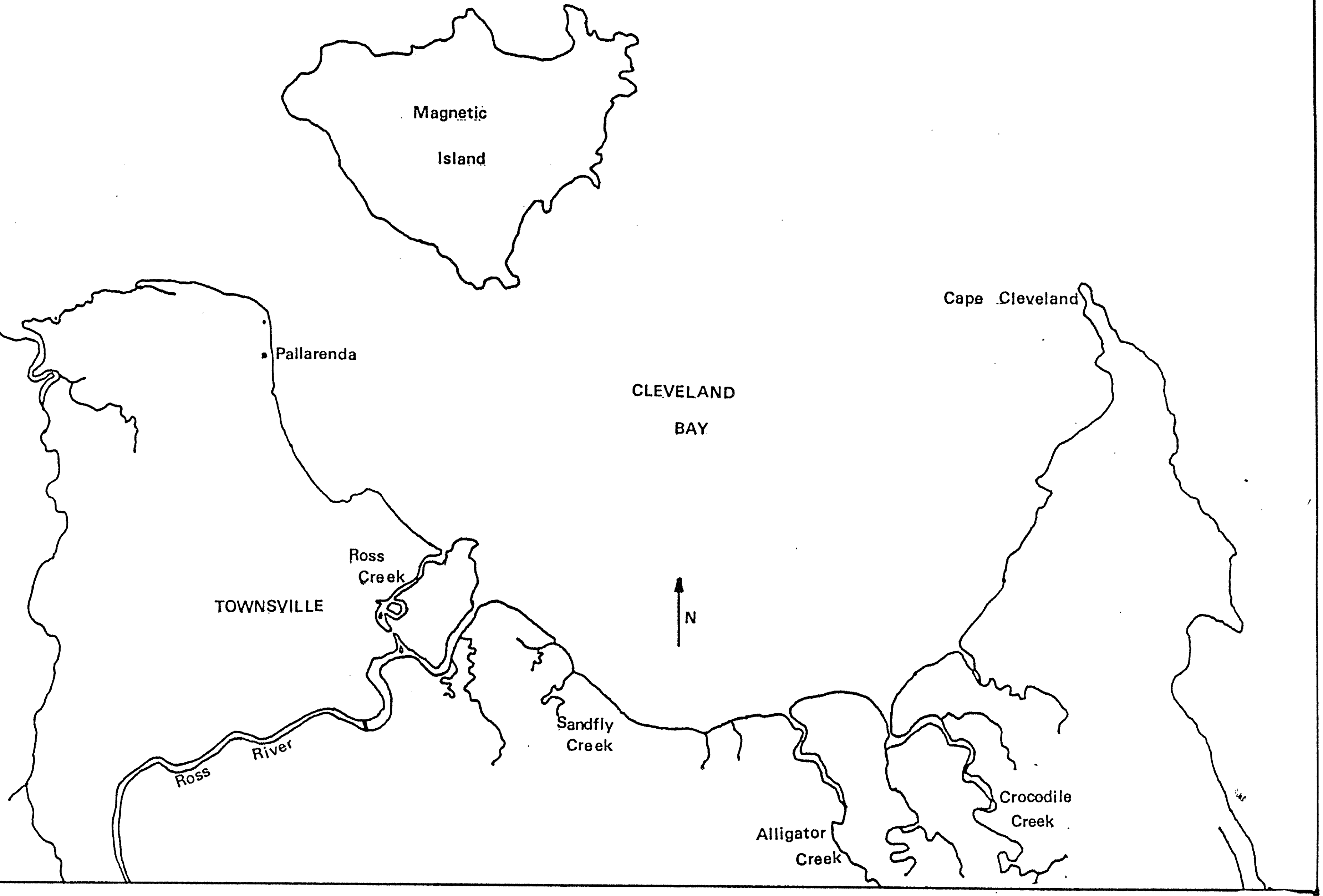

Magnetic
Island
Pallarenda
CLEVELAND
BAY
Cape Cleveland
Ross
Creek
TOWNSVILLE
N
Sandfly
Creek
Ross River
Alligator
Creek
Crocodile
Creek

Figure 2

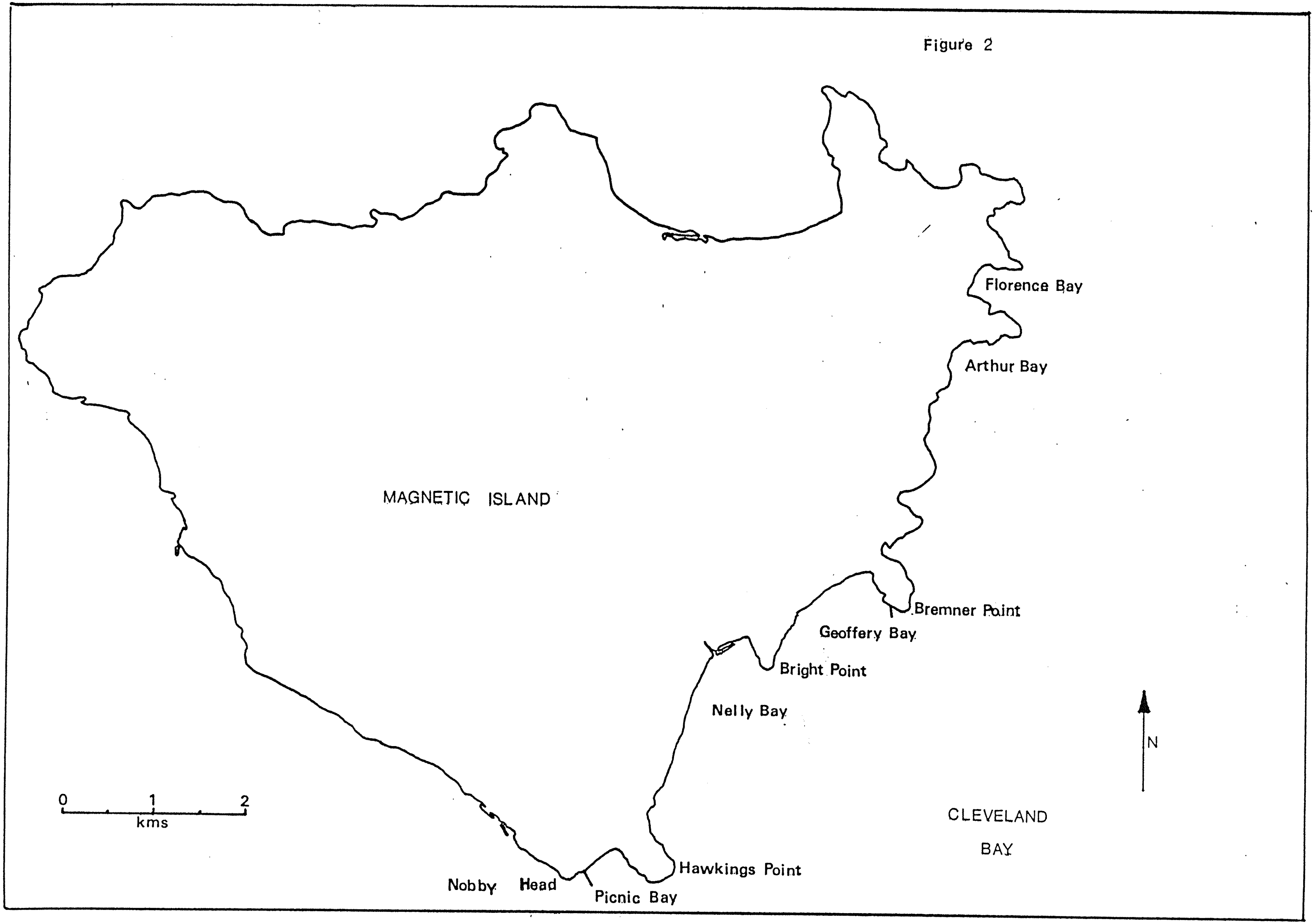
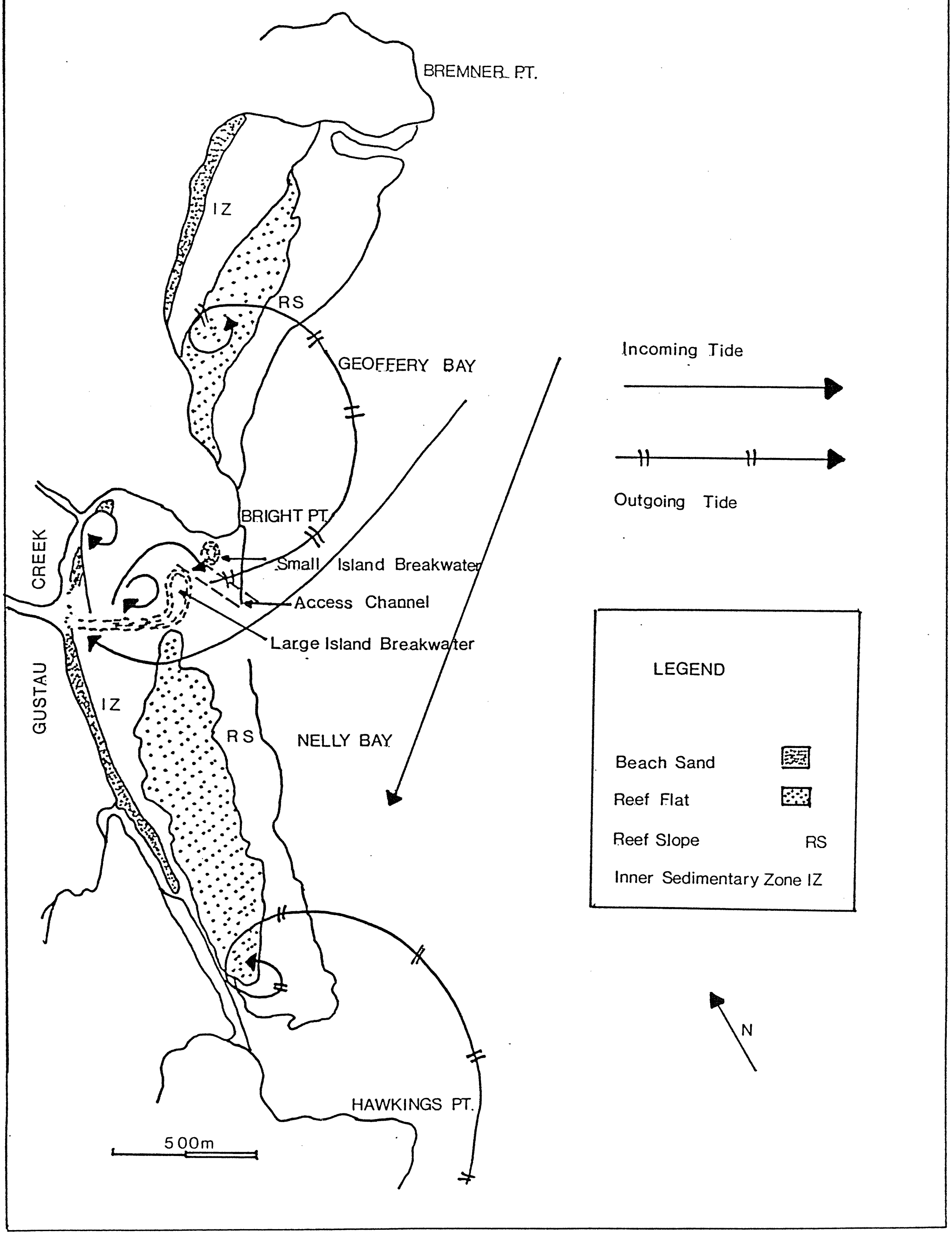

MAGNETIC ISLAND
Florence Bay
Arthur Bay
Bremner Point
Geoffery Bay
Bright Point
Nelly Bay
Hawkings Point
Picnic Bay
Nobby Head
CLEVELAND
BAY
N
0
1
2
kms

FIGURE 3


BREMNER PT.
IZ
RS
GEOFFERY BAY
BRIGHT PT.
Small Island Breakwater
Access Channel
Large Island Breakwater
CREEK
GUSTAU
IZ
RS
NELLY BAY
HAWKINGS PT.
500m
Incoming Tide
Outgoing Tide
LEGEND
Beach Sand
Reef Flat
Reef Slope RS
Inner Sedimentary Zone IZ
N

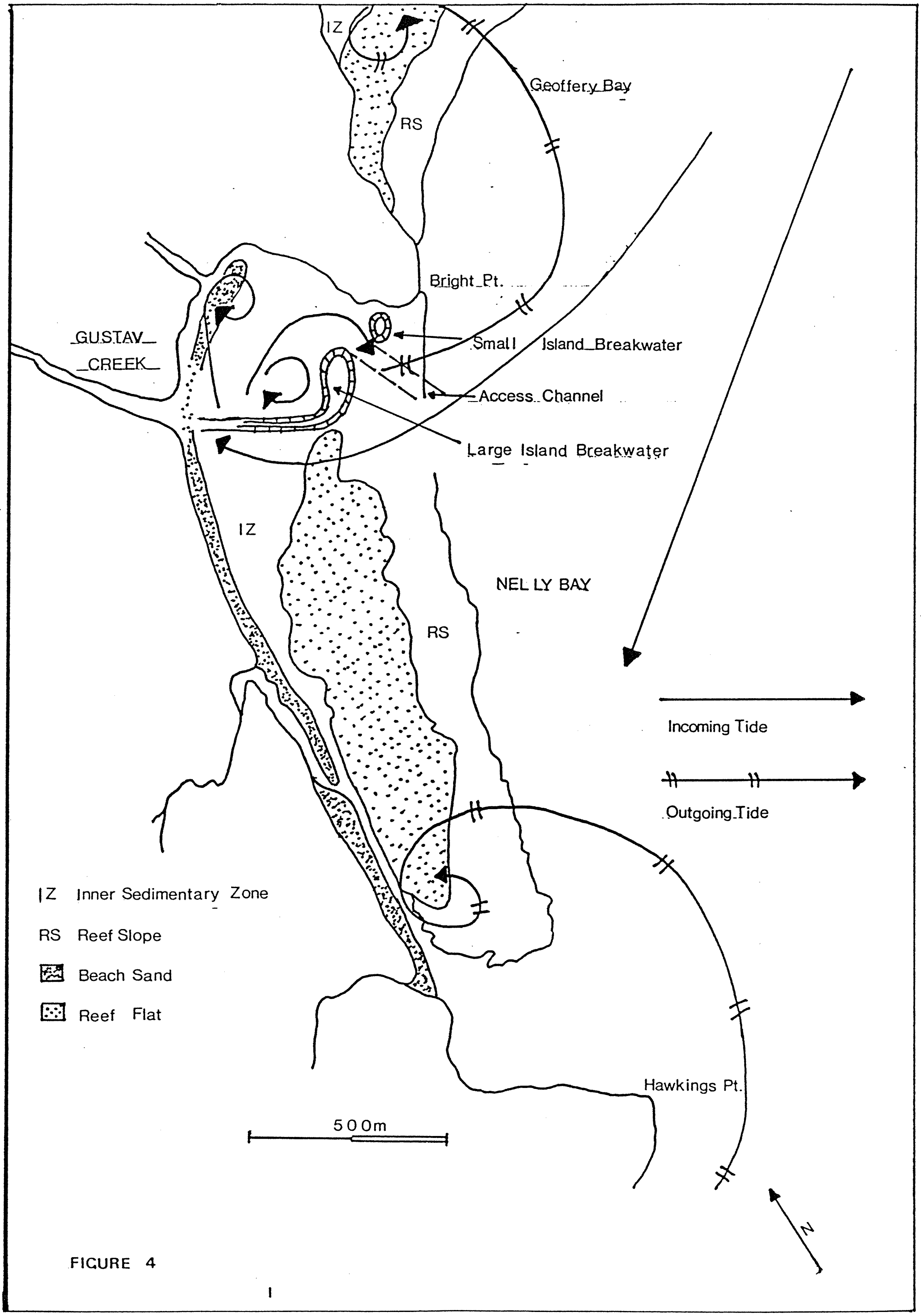

IZ
RS
Geoffery Bay
Bright Pt.
GUSTAV
CREEK
Small Island Breakwater
Access Channel
Large Island Breakwater
IZ
NELLY BAY
RS
Incoming Tide
Outgoing Tide
IZ Inner Sedimentary Zone
RS Reef Slope
Beach Sand
Reef Flat
500m
Hawkings Pt.
N

FIGURE 4

5). The reef slope area contains areas of abundant coral mixed with other areas dominated by brown algae. In the northern section of the Bay, where the marina is to be located, Gustav Creek enters but there is generally no surface flow through the front dune in the dry season and only intermittent flow in the wet season. However intense rainstorms in the Island interior can cause large surface freshwater flows across Nelly Bay and around into Geoffrey Bay. An event of this kind apparently occurred during the baseline monitoring period. Gustav Creek receives effluent from the small sewerage plant serving part of Nelly Bay and probably septic seepage and overflows from those parts of Nelly Bay not connected to the sewerage scheme. There is a history of faecal contamination in Gustav Creek (QWRC unpublished report, Brodie and Faithfull, unpublished data) but the levels found are typical of small urban streams receiving septic flows. The levels of faecal coliforms exceed primary contact water guidelines for Queensland.

Nelly Bay faces to the south-east and the prevailing wind and wave orientation is also from this direction but with a more north-east and easterly component in the summer months. The northern end of the Bay receives some protection from Bright Point when the winds are from the east or north-east but the rest of the Bay is open to the high frequency chop generated inside the Great Barrier Reef lagoon and inside Cleveland Bay itself. A low frequency swell component may also be present due to swells from the Coral Sea (outside the main reef) but this is strongly attenuated by the time it reaches Magnetic Island. During south-east winds waves in Nelly Bay tend to be lower and less confused than in the bays further north (e.g. Florence Bay) possibly due to some protection being afforded by Cape Cleveland.

Hydrodynamic studies in Nelly Bay and the adjacent Picnic and Geoffrey Bays were undertaken by Parnell and van Woesik and their results published in the Public Environment Report for the project in August 1988. They attempted to describe the hydrodynamics of Nelly Bay; to determine the likely hydrodynamic regimes that will prevail at various stages of development; to determine the pathways of sediment which may be put into suspension during the construction and to advise on construction procedures which will reduce the impact of sediment on the nearshore marine environment. Their conclusions draw attention to the tidal nature of circulation in Nelly Bay, extensive eddies at a number of sites and the strong influence of water movements from Nelly to Geoffrey Bay. Figures 3 and 4 show a stylized summary of their water movement findings.

Figure 5

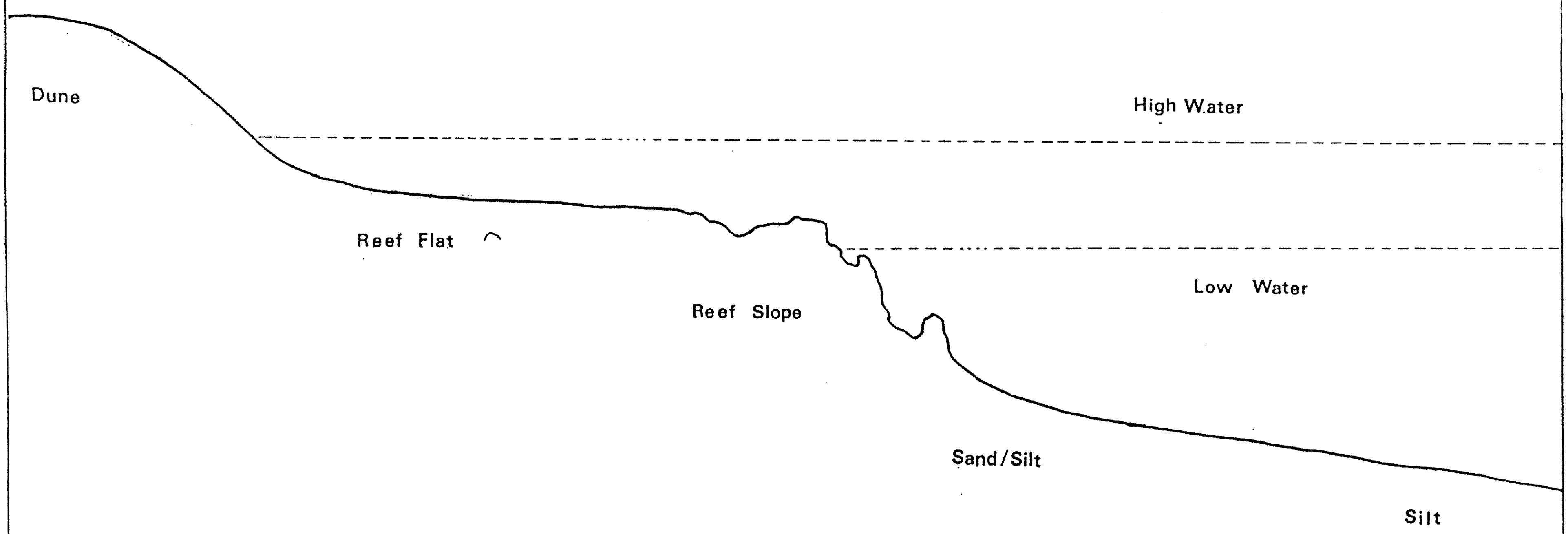


FIGURE 5 ; Schematic Bay Section

3. WATER QUALITY CONSIDERATIONS AND THE DEVELOPMENT

3.1 Introduction

The proposed development consists of the following stages:

(a) Excavation of material from Bright Point and construction of the breakwater with this material. The material will be sieved so that only size classes above 7.5 mm will be included in the breakwater;

(b) Excavation of the marina basin and reclamation of foreshore land;

(c) Excavation of a shipping access channel through the reef;

(d) Flooding of the marina basin;

(e) Construction of hotel, marina, retail and recreational facilities on Bright Point and the Nelly Bay foreshore (partly on reclaimed land);

(f) Operation of marina;

(g) Operation of hotel facilities.

The construction phases (both marine and terrestrial) are expected to take up to two years to complete. The completed development is expected to house 187 boats in the marina and provide accommodation for 1000 in various classes of hotels.

The types of contaminants which could enter Nelly Bay from such a marina development have been reviewed by Riedel & Byrne (Public Environment Report, August 1988) under the headings; Antifouling coating; Oils, fuels and greases; Bilge water discharges; Nutrient releases and they have also discussed tidal exchange and wind mixing. While aspects of this report have been criticised by reviewers it still forms a basis on which to examine those parameters which need to be included in the monitoring programme. In addition possible construction stage sediment release has also aroused concern which must be addressed.

3.2 Sediments and Turbidity

It is widely accepted that elevated sediment loads can have adverse effects on coral reefs. Sediment affects corals directly by deposition on exposed coral tissues and indirectly by lowering of light intensity by water column turbidity. Hudson (1981) showed that a key factor in the growth and survival of the Carribean coral Montastrea annularis was water turbidity. Kuhlmann (1985) found a link between the density of coral cover and water clarity in the Ryukus Islands. A number of studies have quantified the effects of dredging and construction work on reefs (Bak, 1978; Ricard, 1981; Galzin, 1981; Amesbury, 1981; Marszalek, 1981; Dodge and Vaisnys, 1977) but because of the wide variations in natural turbidity levels different reefs can tolerate, transfer of conclusions from studies in one area to other reefs is difficult.

3.3 Nutrients

The levels of nutrients in Nelly Bay could increase due to the development in a number of ways. These include release of sewage from moored boats, increased sewerage plant discharges into Gustav Creek and runoff from landscaping activities. Nutrients may also be mobilized from fine sediment during its release in the construction phase. It is planned to treat sewerage plant effluent by land spraying which should minimize its entry into Nelly Bay but some runoff may occur. The effects of increased nutrient loadings on coral reefs are well documented qualitatively although quantitative data as to tolerance levels are still patchy. Effects include decreased coral growth and skeletal changes (particularly in skeletal density); increased macroalgal growth and overgrowth of coral leading to ecosystem change from coral reef to algal reef; increased phytoplankton growth leading to increased turbidity and decreased light levels and in extreme cases red tide phenomenon; changed community structure in terms of species diversity and species present. Such effects have been extensively documented from the Kaneohe Bay sewage diversion scheme studies (Smith, et al., 1981; Laws and Redalze, 1982; Maragos et al., 1985) as well as many other investigations.

There are now reasonably comprehensive data sets of nutrient levels in the Great Barrier Reef lagoon area and some of these are summarized in Table 1.

3.4 Petroleum Hydrocarbons

Marina activities will inevitably lead to small scale spills of diesel and four and two stroke petrols and this material may impinge on areas outside the marina. Most work on the effects of petroleum products on coral reefs have dealt with spillage of crude oil and heavy fuel oil and there is far less data available on the effects of the lighter fuel fractions in diesel and petrol especially the long term implications of chronic low level contamination.

A number of studies have shown accumulation of petroleum hydrocarbons in sediments and biota around marinas (Marcus & Stokes, 1985; Hansen et al., 1977; Voudrias & Smith, 1986).

Data available on the toxicity of petroleum hydrocarbons to coral is growing with wide variations in the tolerance of different species being found. Studies have examined effects on reproduction and growth rates (Loya and Rinkevich, 1980), photosynthetic activity (Cook and Krap, 1983), species response differences (Reimer, 1975), growth (Dodge et al., 1985), pathological responses (Peters et al., 1981) and overall response (Harrison et al., 1986). Studies on chronic exposure to low levels has shown reduced fertility and zooxanthellae numbers and tissue death (Rinkevich & Loya, 1977; Peters et al., 1981).

3.5 Sewage Bacteria

With any release of sewage from moored boats or sewerage treatment plant effluent entering Gustav Creek, will come the possibility of unacceptable bacterial levels on the marina beaches. While the more severe pathogenic microorganisms such as cholera and typhoid can be water borne, swimming in sewage contaminated waters is more likely to lead to problems of gastroenteritis and skin, eye and ear infections. Standards exist for primary contact recreational water (i.e. water sports and swimming) under the Queensland Clean Waters Act in terms of coliform levels while the whole subject of microbiological water quality criteria in Australia has been extensively reviewed by the Australian Water Resources Council (AWRC, 1985).

3.6 Anti-Fouling Coating Residues

Anti-fouling paints contain biocides which prevent the growth of biota on boat hulls but also slowly leach into the water column and can exert their biocidal activity on benthic organisms. The two primary biocides in use are based on copper containing, or tri (n-butyl) tin (TBT) containing, compounds with the tin based types being more effective and replacing the copper types (Hall & Pinkney, 1985). TBT oxide (TBTO) has been shown to be ten times more toxic to marine copepods than copper (Uren, 1983) and in general the TBT coatings are far more of a problem than the copper based ones. Concern overseas with the effect of TBT compounds, particularly on oyster farms, has slowly led to bans on their use on small boats in France, Sweden, the UK and parts of the US, however with Australia's fragmented environmental response pattern they are still the most common anti-fouling coatings in use in Australia. While there are no data available to estimate their toxicity to coral or effects on a coral reef the figures for their toxicity to molluscs, fish, zooplankton, crustaceans, bacteria and fungi suggest similar effects would occur with coral. Effects occur at extremely low levels (down to a few ng/l) making analytical monitoring extremely difficult and the long term environmental effects of chronic low level contamination difficult to predict (Laughlin & Linden, 1985).

3.7 Other Contaminants

A number of other contaminants which have a deleterious effect on corals but are only likely to be present in small amounts from the development include detergents and other surfactants from moored boats and the sewage effluent, trace metals from bilge water and discarded metallic debris in the marina.

4. MONITORING PARAMETERS

The monitoring parameters chosen for the baseline study reflect the concerns highlighted in Section 3 and are directly related to possible contaminants from the construction and operation of the development.

As the sediment/turbidity study was run independently, in terms of sampling, from the general water quality study it is reported separately throughout the rest of this report.

4.1 General Water Quality Study

4.1.1 Physical and meteorological parameters

These were cloud cover (by visual estimation); wind speed (by digital anemometer); wind direction (by vane and compass); wave direction (by compass); wave height (by estimation); total depth (by marked, weighted line); temperature and visual observations such as sediment plumes, Trichodesmium (Oscillatoria) slicks and Gustav Creek conditions. (Details of methodology are provided in Appendix One and of sampling methods in Section 7).

4.1.2 Sediment parameters

Even though a separate sediment monitoring programme was being carried out sediment parameters were also measured at the general water quality survey sites. The parameters measured were clarity (by Secchi disc); turbidity (using a field nephelometric meter - discontinued after pilot project) and suspended solids (non filterable residue - by a gravimetric method).

4.1.3 Nutrient parameters

These were orthophosphate (by colorimetry); nitrate and nitrite (by colorimetry); ammonia (by colorimetry); silicate (by colorimetry); total phosphorus (by oxidation and colorimetry); particulate nitrogen (by filtration, combustion and thermal conductivity detection) and chlorophyll-a (by colorimetry).

4.1.4 Anti-fouling coating residues

These were tri-(n-butyl) tin oxide (by hydride formation and atomic absorption spectroscopy) and copper (by concentration on ion-exchange resin and atomic absorption spectroscopy). In addition a survey of Nassarius sp. gastropods was undertaken as a baseline for a biological-indicator monitoring programme for TBT residues (see Section 8).

4.1.5 Petroleum hydrocarbons

These were aromatic hydrocarbons (by fluorescence) and petroleum hydrocarbon utilizing bacteria in water and sediments (by culturing).

4.1.6 Faecal matter parameters

These were total coliforms; faecal coliforms and total heterotrophic plate count (all by membrane filtration and plate culturing).

4.1.7 Other physico-chemical parameters

These were salinity profile (by measurement of conductance on an SCT meter); dissolved oxygen profile (by polarographic membrane DO meter) and biochemical oxygen demand, 5 day (by dilution and dissolved oxygen reduction measurements).

4.2 Sediment/Turbidity Study

The parameters measured were as in the general water quality programme under Sections 4.1.1 and 4.1.2.

Table 1. GBR Water Quality Summary

AREA	Chlorophyll-a (μg/l)	NO_2	NO_3	NH_4 μg-at/l	PO_4	$Si(OH)_4$
Shelf 1						
Mean	0.35	0.00	0.02	0.15	0.16	1.06
S.D.	0.42	0.01	0.04	0.12	0.05	0.56
Reef lagoons[2]						
Mean	0.37	0.04	0.39	0.15	0.17	1.23
S.D.	0.32	0.04	0.33	0.15	0.04	0.46
Whitsundays[3]						
Mean	1.17	0.00	0.20	0.22	0.23	1.72
S.D.	0.25	0.00	0.14	0.14	0.03	0.41
Shelf[3]						
Mean	0.68	0.00	0.11	0.12	0.16	0.93
S.D.	0.13	0.00	0.11	0.06	0.04	0.43
Barron R.-Green Is.[4]						
Mean		0.16	1.62	0.098	0.17	
S.D.		0.06	3.59	0.037	0.11	
Cleveland Bay[5]						
Mean			0.26		0.20	
S.D.						
Hayman Island[6]						
Range of means	0.14 -0.64	0.01 -0.17	0.15 -0.56	1.74 -15.4	0.46 -0.73	
Whitsunday Fringing Reefs[7]						
Mean	0.04	0.35	0.70	0.43	5.9	
S.D.	0.06	0.12	0.39	0.17	4.8	

1. Furnas and Mitchell, 1984
2. Furnas and Mitchell, 1988
3. Furnas, et al., 1988
4. Brady, 1989
5. Walker and O'Donnell, 1981
6. Steven and van Woesik, 1989
7. Blake and Johnson, 1988

5. ASSESSMENT OF SPATIAL AND TEMPORAL VARIABILITY

5.1 Introduction

Environmental impacts on water quality caused by the activities of man can be conveniently considered in two classes: the pollution of the water column with substances not normally found in the water column, or found in very small quantities(such as detergents, refined petroleum, chemical wastes); and the perturbation of normal levels of naturally occurring dissolved and suspended components of the water column (such as nutrients, organic solids, suspended sediments). In the former case, the assessment of environmental impact takes the form of a determining whether those substances have reached some critical concentration. In the latter category, however, assertion of an impact is more difficult because it rests on a probabilistic assessment of whether levels of naturally occurring substances have risen to levels beyond those within the natural, but often very variable, range. In both instances, the decision of whether a perceived impact is cause for concern - for example, with respect to its effect on biological systems - is made only after the detection of an effect. In this pilot study, we are not concerned with either the detection of non-natural pollutants or the rules for deciding whether an impact is cause for management action. We deal here with the optimisation of the procedures for detecting perturbations to normal levels of naturally occurring components of the water column and the assigning of such perturbations to a specific source, vis the Magnetic Quay Development.

The assessment of changes in the levels of naturally occurring nutrients, solids and turbidity in the water column as a result of any development is likely to be complicated by the inherent variability over a variety of spatial and temporal scales. The correct interpretation of data collected during an impact assessment study rests on one's ability to discriminate natural variability from 'abnormal' changes likely to be caused by the development of interest (in this case, Magnetic Quay). Such distinctions can be made only with knowledge of the magnitudes of natural variability present prior to the commencement of activities likely to cause impact, and the temporal and spatial scales at which they occurred. This information should be obtained from a soundly designed baseline study, including pilot studies designed to facilitate the projection of optimal sampling designs by which impact can be identified during construction and operational phases of a development. The design of impact assessment studies based on such pilot studies will ensure the most powerful and economic tests of the effects of development and minimise, within sensible logistic constraints, the chances of making erroneous decisions about the presence or absence of environmental impacts.

We conducted the following two pilot studies to estimate the variability in water quality at local spatial scales and short-term temporal scales in Nelly Bay. This information provided the basis for the design of an impact assessment programme that could meet the requirements of detecting as small a perturbation to water quality as logistically possible with the smallest feasible probabilities of either falsely asserting that an impact had occurred (Type I error) or failing to detect an impact that had occurred (Type II error; see Box 2, Benthic Baseline Study).

5.2 Materials and Methods

Variables Considered

The following components of water quality were assessed in the pilot studies: nitrate; nitrite; ammonia; ortho-phosphates; suspended solids; turbidity; coliform bacteria; total heterotrophic bacteria. Various physico-chemical properties of the water column (dissolved oxygen, temperature, salinity, pH) were also measured when each water sample was collected as were a range of environmental variables (wind speed and direction, wave height and direction, etc.). Correlations between significant patterns in water quality and environmental factors were considered to see if any significant changes in water quality were conspicuously related to such parameters. The sampling and analytical procedures used to quantify all variables have been described elsewhere in this report.

Field Work and Sampling Design

Spatial Variability

Spatial patterns in the above variables were measured on December 8, 1988. The pilot study was not repeated on other days because of cost constraints, and it must therefore be assumed that the results obtained on December 8 were not atypical. This assumption was to some degree verified by the results of the pilot study of temporal variability which was repeated on two days and also contained a spatial component (see below). All water samples were collected from a moored vessel, as described elsewhere. Note that dissolved oxygen, temperature, salinity, and pH could not be measured for many of these samples because of equipment failure.

Five components of spatial variability in the composition of surface waters were considered: variation between the north and south ends of Nelly Bay; variation between the shallow, inshore, reef-flat environment and the deeper, offshore, reef-slope environment (locations); variation with depth over the reef slope; variation among sites separated by approximately 75m; and variation between replicate samples taken about 5-10m apart. At each end of Nelly Bay, three haphazardly selected sites were sampled over the reef flat and reef slope. At each site, two 1l samples of water were taken from a depth of 0.2m and about 5m apart. At the reef slope sites, two samples were also taken from about 1m above the bottom, a depth of 4-5m. Water over the reef flat was too shallow to consider a depth component of variability. Note that coliform and total bacteria were not cultured from the samples taken from near the bottom during this pilot.

The order in which ends of the bay and locations (inshore/offshore) were sampled was haphazard, but for logistic reasons, the order in which sites were sampled was not randomised over ends of the bay and location. This may have resulted in some confounding of any apparent systematic spatial pattern with the time of day at which sites were sampled, although all sampling was confined to the period between 1000 and 1600 hours. The extent to which temporal variability may have determined apparent spatial patterns was qualitatively examined, however, by considering the time of day at which groups of sites that differed significantly were sampled in the light of the results of the pilot study of temporal variability.

Temporal Variability

Diel variability in water quality was assessed at two locations over two periods of 24 hours in December 1988 (9-10/12/88 and 19-20/12/88). At each location on each day, two 1l samples of water were taken from within 1m of the surface every three hours from midday one day to midday on the following day. Locations could not be sampled simultaneously but were sampled within the same hour. Replicate samples were taken 15 minutes apart and within 5m of each other. Thus, this pilot study assessed variation between days, variation between locations (one inshore and one offshore), among times of the day, and between replicates. Variation between replicates necessarily contained components of small scale spatial and short term temporal variability.

Samples from the reef flat location could not be taken during night low tides because of navigation hazards and absence of flowing water. Consequently, the analyses were unbalanced. To compensate for these missing data and balance analyses, data from the similar time at the offshore location were deleted on each day. Deletion of data from some other cells was also occasionally necessary because data were lost through equipment failure or sample contamination.

Statistical Analyses

Data from both of the above pilot studies were analysed by multi-factorial, mixed model analyses of variance. The spatial variability study constituted separate three factor designs for the surface water samples (End of Bay x Location x Sites (EoB, L)) and the analysis of depth effects on the reef slope (EoB x Depth x Site). Ends of the bay, location, and depth were considered fixed effects and 'sites' was considered a random variable.

The study of temporal variability was also a three factor design, comprising Days (random) x Locations (fixed) x time of day (fixed). Because the time of day at which samples were taken differed slightly between locations, and the relation of time of day to tidal phase and local whether conditions etc. varied between days, time of day was considered nested within days and locations for analysis.

A factor was considered a significant source of variation if the probability of that assertion being wrong was less than 5%, and was considered potentially significant for error (Type I) probabilities of 5-10%. Cochran's statistic was used prior to analyses of variance to assess whether variances were likely to be heterogeneous, and data were transformed to normalise variances where appropriate. Where necessary, a posteriori comparisons among means were made by Ryan's Test. Components of variation were calculated as the ratios of the (unbiased) estimate of variation among levels of each factor (derived from the mean-square estimates) to the sum of all such estimates in an analysis. Such ratios are biased (but consistent within each analysis), but give approximate indications of the distribution of variation among multiple sources.

Analyses of the statistical power (= compliment of Type II error, or probability that a difference of specified magnitude would be detected if it existed) of the pilot studies followed the procedures recommended by Cohen (1977). When analyses indicated that sites did not constitute a significant source of variation, the 'sites' and 'residual' sources of variation were pooled and used as the estimate of residual variation for calculation of the power of tests of other terms in the spatial analyses. Similarly, in the analyses of temporal variability, when the days x location interaction was not significant (with $P > 0.25$) and accounted for very little of the variation (< 10%), that term was pooled with the residual and the power of tests of location effects based on the pooled residual variances and degrees of freedom.

5.3 Results

Spatial Variability in Surface Waters

The surface waters of Nelly Bay were spatially relatively homogeneous and apparently well mixed with respect to nutrients (nitrate, nitrite, ammonia, ortho- phosphate). There were no significant differences among ends of the bay, locations, or sites for any of these variables ($P > 0.25$ in all cases) and almost all variability was among replicates.

Turbidity varied significantly among sites within locations and ends of the bay ($F = 5.07$, 8,12 df, $P = 0.006$), but did not vary systematically in any respect. The only factors to account for any variation were the random variables sites and replicates.

For suspended solids, the interaction between location and end of the bay was significant ($F = 8.66$, 1,8 df, $P = 0.019$). The interaction occurred because at the north end of Nelly Bay the concentration of suspended solids inshore (4.2 mg/l) was greater than offshore (2.6 mg/l), whereas at the southern end of the bay the concentrations of suspended solids did not differ significantly between locations (inshore, 1.2 mg/l; offshore, 2.0 mg/l). Inshore, the north end of the bay had more suspended solids than the south, but offshore the ends of the bay did not differ significantly.

The interaction between ends of the bay and location was also significant for counts of total bacteria on plates from the collected water samples ($F = 104.7$, 1,8 df, $P < 0.0001$). The pattern of variation was the same as for suspended solids - that is, the samples from the inshore location at the north end of the bay contained more bacteria (2051.7 colonies per plate culture) than all other locations, which did not differ significantly (offshore-north, 226.7; offshore-south, 246.7; inshore-south, 448.3).

Coliform bacteria were found only in samples from the north end of the bay, a pattern that was also statistically significant ($F = 15.28$, 1,8 df, $P = 0.005$). The difference between ends of the bay accounted for approximately as much variation (47%) as all other sources combined.

Effects of Depth

Depth was not a significant source of variation in any of the water quality variables measured ($P > 0.25$ in all cases). The only significant terms in any analysis were the effects of end of the bay for suspended solids ($F = 12.99$, 1,4 df, $P = 0.02$), and the effect of random sites for turbidity ($F = 15.45$, 4,12 df, $P = 0.0001$). The difference between ends of the bay (North > South) when averaged over depth is suggestive that the slightly greater (though not significantly so) concentration of suspended solids in surface waters at the north end of the bay (see above) was reinforced by a similar difference at depth. As before, the major source of variation in all analyses was variation among replicate samples.

Temporal Variability

As with spatial patterns in variability, in most analyses of temporal variability the majority of variation occurred among replicate samples taken in close proximity. There were no significant effects of day or time of day on the concentrations of nitrite, ammonia, ortho-phosphate, suspended solids, or coliform bacteria ($P > 0.1$ in all cases). None of the variables measured differed significantly with location on either day.

Both turbidity and total counts of bacteria differed significantly between days (day 1 < day 2 in both cases) and among times of day within days and locations. Diel variations in turbidity were not consistently related to tidal phase or wind or sea conditions, but was significantly negatively related to salinity (day 1, r = -0.376, 20df, P < 0.1; day 2, r = - 0.617, 28df, P < 0.001). Although bacterial content of the water differed among times only on day 2, trends in abundance were similar at both locations on both days: bacteria tended to be more abundant nocturnally than diurnally. There were no conspicuous correlates of bacterial abundance.

Nitrate also varied in concentration with time of day (F = 3.37, 20,24 df, P = 0.003), but differences among times were significant only on the second day. There was no consistent correspondence between nitrate concentration and tidal phase or day-night cycle, or physico-chemical properties of the water on either day. The interaction between day and location was also significant for nitrate concentration (F = 5.02, 1,20 df, P = 0.035), but the interaction reflected only differences between days at the inshore location (day 1, 3.25 ugN/l < day2, 5.83 ugN/l). Concentrations did not differ significantly between days at the offshore location (4.9 ugN/l, 4.0 ugN/l) and locations did not differ significantly on either day.

Power of Tests in Pilot Studies

In almost all analyses, there was very low power (Power < 0.5) to detect relatively small (<= 25% of existing average levels) spatial or temporal differences in the measured variables. For turbidity, and concentrations of ortho- phosphates, nitrite and suspended solids, however, the analyses had great power to detect moderate differences (> half of average levels) between locations, ends of the bay, and days (Power > 0.9 in all cases). With the exception of turbidity (for which the a posteriori calculation of power was not appropriate - see below), the same was true for detecting differences among sites and times of day. Thus we are reasonably confident that the apparent absence of moderate differences between locations, ends of the bay, sites, times or days were not simply the result of high rates of Type II error.

The power to detect even moderate spatial or temporal differences in the concentration of nitrates, ammonia, and coliform bacteria was poor (Power < 0.4). Thus, even had large (> the average existing levels) differences in these variables occurred, we would have been unlikely to detect them with the above sampling programmes, even when using pooled estimates of residual variation. Note that it was inappropriate to calculate a posteriori the power of tests for which F-ratios were significant, since in those cases the only error that could have been made was in asserting a difference that had occurred by chance alone.

5.4 Discussion

With respect to most of the variables measured in these pilot studies, Nelly Bay seemed a relatively homogeneous environment. The major spatial patterns in water quality indicated that for some variables (coliform and total bacteria and suspended solids), the north end of the bay was subject to slightly different conditions of water quality than the southern end.

The possibility exists, however, that these results were attributable to temporal confounding. The inshore-north location was the first sampled, though this did not correspond to any particular environmental conditions except tidal phase: these samples were collected during flood tide, whilst all others were collected between high and low tide. There was no significant diel cycle in concentration of suspended solids, and diel patterns in the abundances of bacteria did not correspond to tidal phase or indicate differences in abundance between mornings and afternoons. It thus seems unlikely that the above spatial patterns can be attributed to specific temporal or tidal characteristics.

Suggested Impact Assessment Programme

The design of an impact assessment programme where the variables of interests are potentially both spatially and temporally labile even at small scales presents several problems. Both spatial and temporal scales must be taken into account when designing the sampling protocol if it is expected (on the basis of prior information) that both constitute important sources of variation. Balanced against this, the sampling design must be affordable, but powerful enough to detect any important environmental impact that may occur (see also discussion in report on benthic biota).

Repeating spatially comprehensive sampling several times within a short interval (e.g. over several days within one or two weeks) is likely to be extremely costly. Further, with random components of both spatial and temporal sources of variation (such as sites and days respectively) included in a single analysis, tests of the effects of a development are often low in power. Unless sites and/or days do not constitute significant effects, and can be pooled legitimately with residual variation, the power of the tests can only be improved by either sampling on many days and at several sites,

In the case of the Magnetic Quay development, we have demonstrated that for most components of water quality sites and days do not constitute important sources of variation. Cost benefit analyses of the data from the study of spatial variability indicated, further, that the most efficient allocation of sampling effort was to dispense with sampling sites and concentrate on replicates. This strategy would be satisfactory provided that the replicates were well dispersed within locations and thus effectively integrated variation at the scales of 5-10m and 50- 75m. Although some components of water quality varied with time of day, none of the patterns of variation suggested that a particular time of day or tidal phase should be favoured when sampling, given that sampling will be logistically constrained to daylight hours.

The suggested programme for the estimation of environmental impacts during the construction phase of the Magnetic Quay development is necessarily a compromise between logistics and the need to cater to both small scale spatial and short term temporal variability. We suggest that within any day of sampling, samples be collected at four stations near to the development (and expected to suffer any effects of construction), and at four stations sufficiently removed from the development to be insulated from any perturbations caused by the development. Here, 'station' is used to describe a tract of fringing reef stretching from the coast to the sandy bottom beyond the reef slope, consistent with its usage in the description of studies of benthic organisms in this report. At each station, three replicate samples should be taken in inshore waters over the reef flat and three from offshore waters over the reef slope. There is no indication from the pilot studies that depth is likely to be an important source of variability, but this may change in the event of an impact and so samples should be taken from near the substratum as well as near the surface where possible. Replicate samples should be well dispersed over an area of approximately 100m (longshore) x 75m (perpendicular to the shore) in each location.

It is highly desirable that the stations at which water quality is assessed correspond to those at which benthic biota are sampled, so that any perturbation to nutrient levels etc. in the water column can be related to the condition of the benthic organisms at that location. We therefore suggest that the four impact stations correspond to the Nelly Bay stations 1, 2, and 5 and Geoffrey Bay station 4 described in the report of the baseline study of benthic organisms (Figure 2 that document). We suggest that Florence Bay, Arthur Bay, Geoffrey Bay station 1, and Picnic Bay station 2 be used as control stations. It may also be considered important to sample at specific other locations, such as in Gustav Creek and off Bright Point.

Estimates of within cell and among sites variation obtained from the pilot studies were pooled and used to estimate the power and sample size characteristics of the above suggested impact assessment programme, based on the power/sample size tables in Cohen (1977). An arbitrary effect size of 50% of existing levels of components of water quality was used in these calculations. The results of these calculations indicated that the above sampling programme should prove a powerful method of detecting moderate perturbations to water quality on any given day (Power > 0.8 for most of the above variables, Type I error = 0.1; worst cases: coliform bacteria, Power = 0.15; ammonia, Power = 0.34). Detection of much smaller effects (say 25% of means) with the same power is unlikely to be viable for most variables.

The steps involved in deciding whether an impact has occurred during construction of Magnetic Quay are discussed in the report of the study of benthic organisms (Box 8). Consistent with that protocol, we suggest that if a development-related perturbation to water quality is detected on a given day, the above sampling programme be repeated on one or more days shortly after the impact was detected to assess whether it persisted. In this way, the potential for erroneous management action to arise from what was really a chance event resulting from daily fluctuations in water quality will be minimised and the prohibitive expense of routinely sampling every few days averted.

6. SAMPLING SITE SELECTION

6.1 General Water Quality Study

Sampling sites were chosen based on the various aims of the study in terms of the different possible contaminants. Figure 6 show the sites selected and their designation. Each site and its selection criteria are listed below. The parameter codes are given at the end of the list.

Station One (S1). Gustav Creek above the road bridge.

Station Two (S2). Gustav Creek below the road bridge. Stations One and Two provide information on the quality of water entering the marina site from Gustav Creek and identify inputs from the small existing sewerage plant and existing surrounding residential and tourist development. S2 has an intermittent salt water flushing when high tides coincide with Gustav Creek being open through the barrier dune while S1 is primarily freshwater from the Gustav Creek catchment. Parameters measured were A,B,C,D,E,F,G, H,I,J,K,L,M,N,O.

Station Three (S3). This site was selected to try and quantify the composition of groundwater flows under the existing beach. Water was collected on two occasions from hand dug wells and attempts made to install a small pumped bore but the water obtained in all cases was extremely turbid with soil contamination and the water analysis results are not considered particularly reliable as an indicator of groundwater composition.

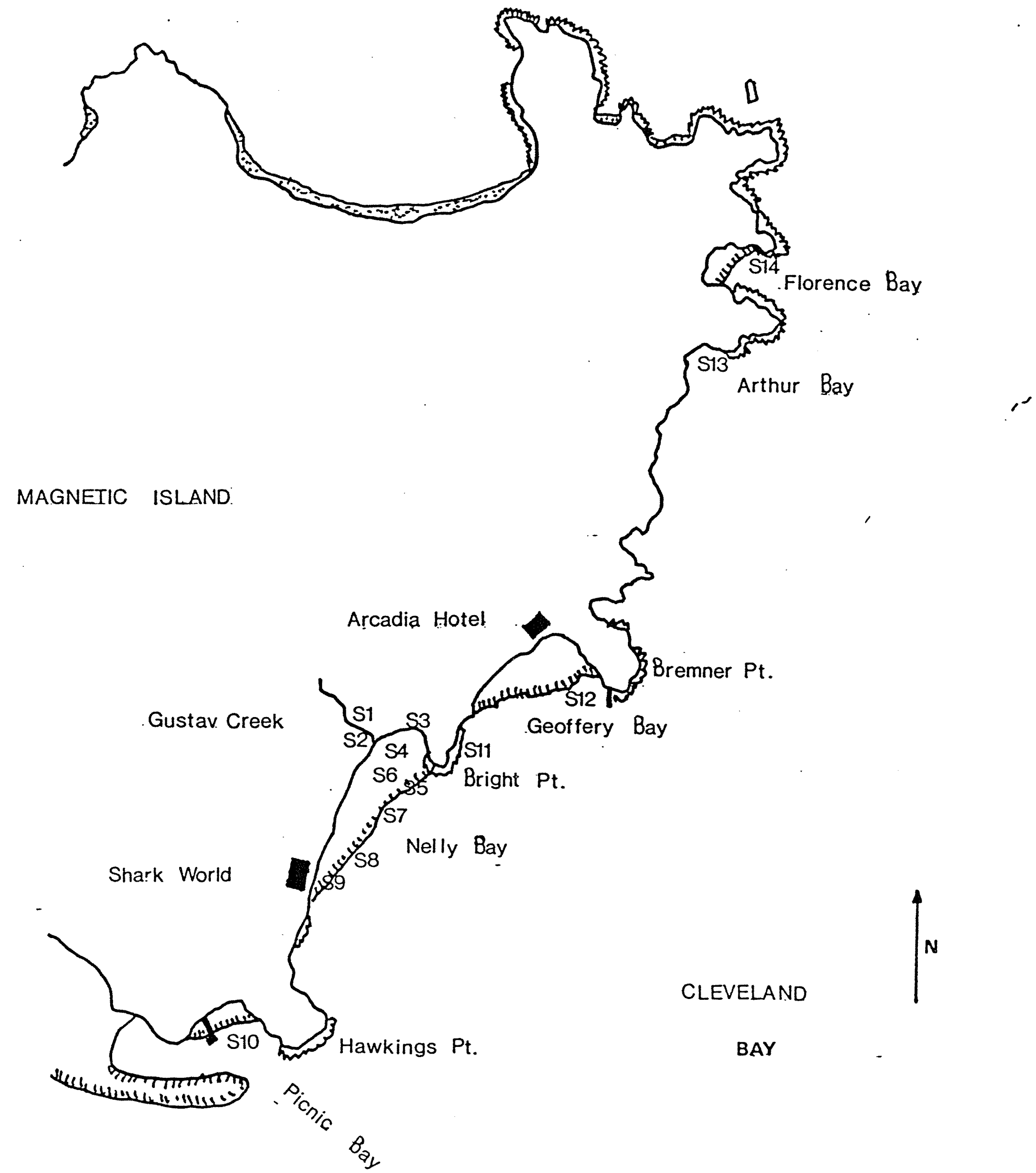
Station Four (S4). A baseline site for hydrocarbon utilizing bacteria from water and sediment. It is in eventual marina area and was monitored for parameter P.

Station Five (S5). This site lies near the eventual access channel to the harbour. Parameters measured were A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,Q,S,T.

Station Six (S6). A tidal current concentration site. Parameters measured were A,B,C,D,E,M,N,O,P.S.

Station Seven, Eight (S7 & S8). Baseline sites above reef transects. Parameters measured were the same as S5.

Figure 6


MAGNETIC ISLAND
S14
Florence Bay
S13
Arthur Bay
Arcadia Hotel
Bremner Pt.
S12
Geoffery Bay
Gustav Creek
S1
S2
S3
S4
S11
S6
S5
Bright Pt.
S7
Nelly Bay
S8
S9
Shark World
N
CLEVELAND
BAY
S10
Hawkings Pt.
Picnic Bay

Station Nine (S9). Tidal current concentration site particularly for water from Picnic Bay to quantify contaminants entering Nelly Bay from Picnic Bay. Parameters measured were as for S6.

Station Ten, Twelve (S10 & S12). Picnic Bay and Geoffrey Bay sites. Parameters measured were as for S5.

Station Eleven (S11). Tidal current concentration site particularly for water flowing around Bright Point from development site into Geoffrey Bay. Parameters measured were as for S6.

Station Thirteen, Fourteen (S13, S14). Florence Bay and Arthur Bay reference sites. Parameters measured were as for S5.

Parameter List and Key

Suspended solids	A
Clarity	B
Salinity (profile)	C
Dissolved oxygen (profile)	D
Biochemical oxygen demand	E
Nitrate	F
Nitrite	G
Ammonia	H
Orthophosphate	I
Total phosphorus	J
Particulate nitrogen	K
Silicate	L
Total coliforms	M
Faecal coliforms	N
Heterotrophic plate count	O
Hydrocarbon utilizing bacteria	P
Chlorophyll-a	Q
Petroleum hydrocarbons	R
TBT and copper	S
Temperature (profile)	T

Other details.

Sites were not physically marked but were identified by sighting lines based on physical landmarks.

6.2 Sediment/Turbidity Study

Sampling sites were chosen to lie near or over the benthos transects where the sediment traps were placed and also to give good spatial coverage of Nelly and Geoffrey Bays from inshore to well offshore. The sites were arranged in a number of lines radiating from inshore to offshore and are shown in Figures 7 & 8. The designation of the lines and sites are also shown in these figures. The position of the sites was taken from sighting lines based on physical landmarks.

7. SAMPLING METHODS

Water samples were collected at the surface and at depth. Surface samples were collected approximately 20 cm beneath the surface with minimal collection of the surface film. Samples from depth were collected in a PVC van Dorn sampler. Only one (the surface) sample was collected when water depth was less than three metres.

Samples for aromatic hydrocarbons were collected in 2.5 l glass winchesters with aluminium foil protected lids (for all containers cleaning procedure details are included in the methodology section in Appendix ...). Extraction of the 2 l sample was begun as soon as posible after return to the laboratory.

Samples for suspended sediments and chlorophyll-a were collected in one litre high density polythene bottles. Chlorophyll-a extraction was begun on return to the laboratory. Tri-(n-butyl) tin samples and copper samples were collected in 500 ml high density polythene bottles (see also discussion of results for TBT concerning collection bottles), the TBT samples were stored at 1-3^{o}C while the copper samples were stabilized with redistilled nitric acid.

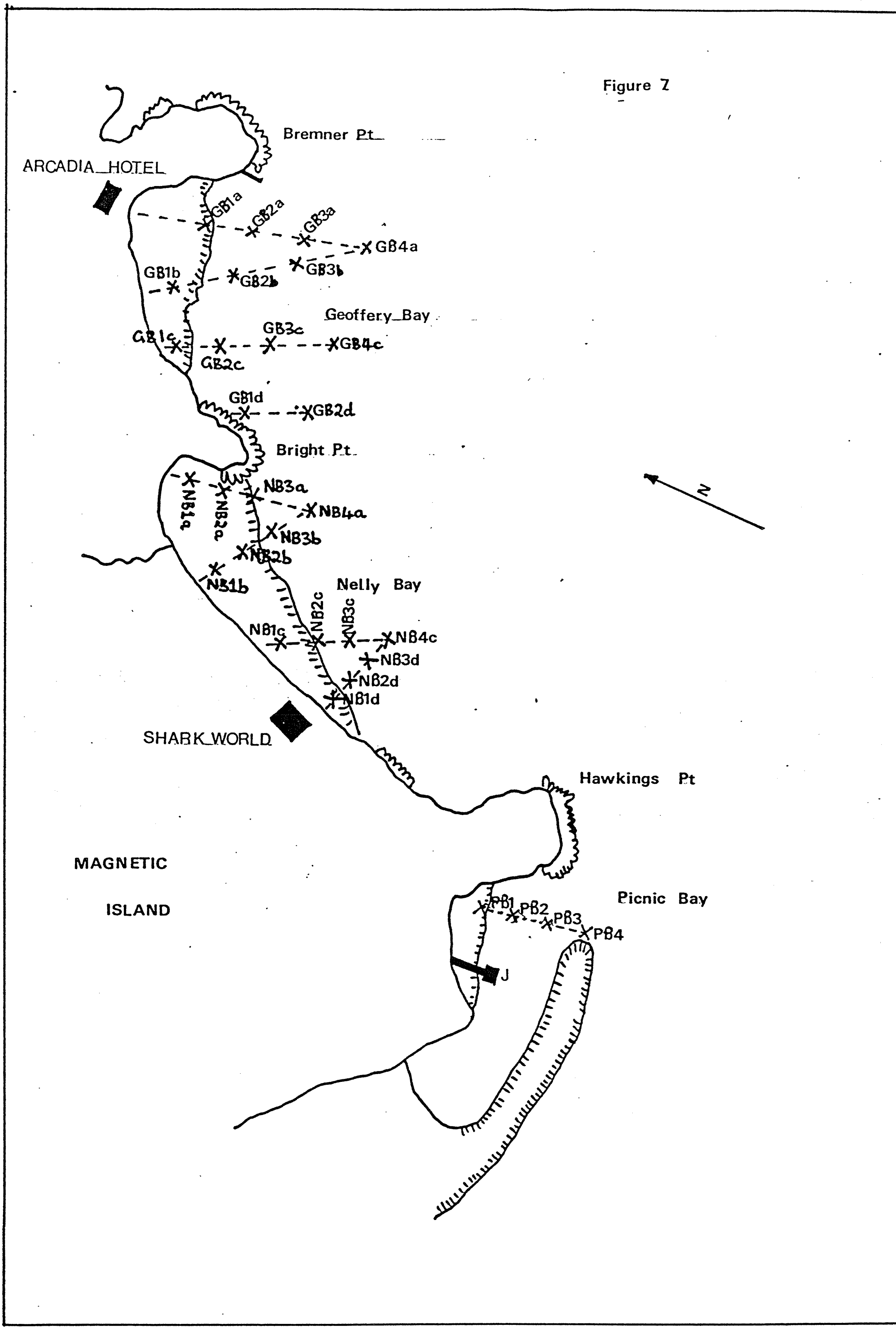
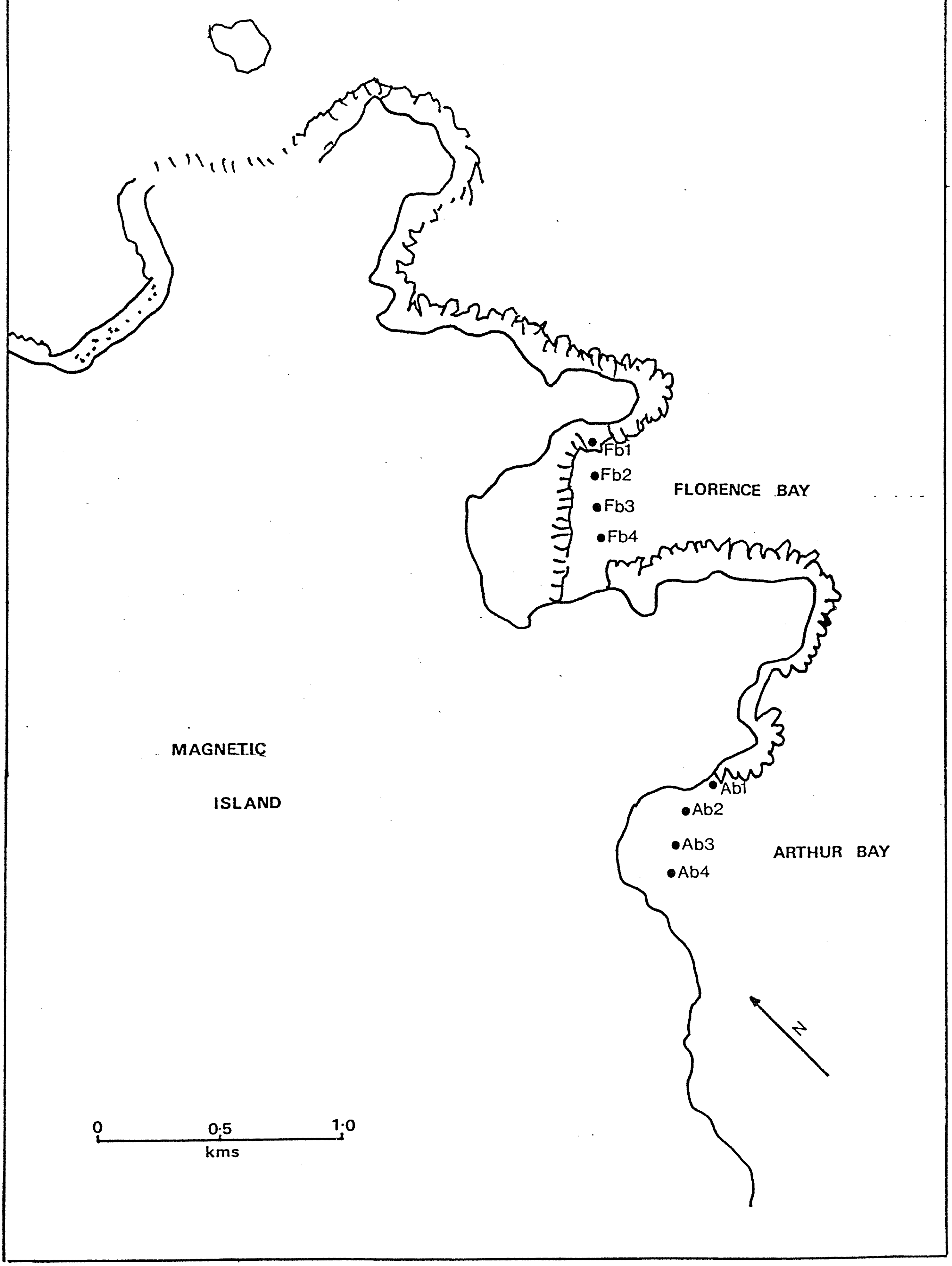


Figure 7
Bremner Pt
ARCADIA HOTEL
GB1a
GB2a
GB3a
GB4a
GB1b
GB2b
GB3b
Geoffery Bay
GB3c
GB1c
GB2c
GB4c
GB1d
GB2d
Bright Pt
NB3a
NB4a
NB1a
NB2a
NB3b
NB2b
NB1b
N
Nelly Bay
NB2c
NB3c
NB1c
NB4c
NB3d
NB2d
NB1d
SHARK WORLD
Hawkings Pt
MAGNETIC
ISLAND
Picnic Bay
PB1
PB2
PB3
PB4
J

Figure 8


Fb1
Fb2
Fb3
Fb4
FLORENCE BAY
MAGNETIC
ISLAND
Ab1
Ab2
Ab3
Ab4
ARTHUR BAY
N
0
0·5
1·0
kms

Samples for bacteria and nutrients were collected in the van Dorn sampler and transferred to individual small (about 140 ml) or large (about 400 ml) sterile 'Whirlpacs'. Nutrient samples were placed directly on ice packs and stored frozen while bacterial samples were kept cool for return to the laboratory where analysis was commenced immediately.

Samples for BOD_5 were collected in dark glass BOD bottles, kept cool and in the dark until return to the laboratory where analysis was commenced immediately.

Sediment samples for hydrocarbon utilizing bacteria analysis were collected in sterile glass containers by diving.

Meteorological conditions varying during the five water quality sampling trips from calm (10 January and 31 January) with wind speeds generally less than 3 m/sec and wave heights less than 0.2 m to rough (24 January) with wind speeds approximately 4 to 8 m/sec and wave heights greater than 1 m. Heavy rain fell in late December with Gustav Creek breaking through the foredune in early January.

8. TRIBUTYLTIN BIOLOGICAL EFFECTS STUDY

8.1 Introduction

Tributyltin (TBT) residues in water have been shown to exhibit effects on biota at levels of 2.5 ng/l (Goldberg, 1987). This suggests that water quality guideline values should be considerably less than this, allowing for standard effect margins. The problem is that regular measurements of TBT at less than 1 ng/l in water samples is technically difficult and it has been suggested that biological effects monitoring may effectively supplement water analysis.

Gastropods of the genera Nucella and Nassarius have been shown to develop imposex (i.e. where female snails develop male sex organs) by exposure to low concentrations of TBT (Smith 1981; Bryan et al., 1986). This type of monitoring has been applied in the field as an aid to chemical monitoring (Davies et al., 1987).

It was decided to carry out a preliminary survey of Nassarius species and numbers in Nelly Bay and measure male/female ratios and evidence of natural imposex and its extent.

8.2 Experimental Procedure

The snails used in this study were found predominantly in the intertidal zone and were collected approximately two hours either side of the low tide. Sampling was by sight along random paths of the collector and collecting was by hand. The collected individuals were transported back to the laboratory where they were maintained in aquaria for no longer than 72 hours (for samaples taken 24/2/89 and 1/3/89 this time was reduced to 48 hours and 3 hours respectively).

In the laboratory each individual was identified to species level by the following key:

1a. Has development of columellar callus...........Go to 2
 b. No columellar callus..........................Nassarius luridus

2a. Has axial ribs................................Nassarius pullus
 b. Has smooth body whorl.........................Nassarius coronatus

(adapted from Cernohorsky, 1972)

Once identified the snails were measured for shell height and then inspected for the following sexual characteristics.

1. Presence of a ventral pedal gland in females. This is observed on a live snail by inspecting the anterio-ventral surface of the foot (against a clean glass surface) with a X 10 handlens. This structure appears as a small glandular pit or groove if present (Fretter, 1941).

2. Presence of a penis in males and imposex females. This is a wing like structure located posterior to the right cephalic tentacle and generally cloaked by a sheet of free mantle tissue (Smith, 1980). This may be resorbed in some males, although this has been associated with seasonal breeders (Jenner & Chamberlain, 1955), or these males may be immature.

3. Histological examination of gonads for evidence of spermatozoa or ova to confirm sexual identification.

The recording of penis presence or absence and the preparation for histological procedures required decalcification of the shell in a formic acid- formalin mix. Histological staining was with a Mayer's Haemalum and Eosin regime as described in Winsor (1984).

8.3 Results

The data is compiled in chronological order of collection and in species groups. The data in Table 2 is a summary of the raw data in Appendix 5.

Table 2.

	Males		Females		Imposex females		Resorbed males		Immature		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
N.pullus	65	39.4	46	27.9	18	10.9	3	1.8	1	0.6	133	80.6
N.luridus	12	7.3	6	3.6	3	1.8	1	0.6	0	0	22	13.3
N.coronatus	2	1.2	6	3.6	1	0.6	0	0	1	0.6	10	6.1
Total	79	47.9	58	35.1	22	13.3	4	2.4	2	1.2	165	100

9. RESULTS

9.1 General Water Quality Study

The raw data is compiled in Appendix 2, one sheet for each sampling site. A number of pieces of data are missing due to malfunctioning instruments on sampling trips, bad weather on 24 January preventing deep water sampling, some parameters not measured on the early sampling trip and some data eliminated due to unreliability.

Table 3 summarizes the data in terms of mean values, standard deviations and ranges for parameters for sites S5 to S14. Table 1 summarizes comparable data from other areas in GBR waters. There is some reservation about using arithmetic means to summarize data such as this due to its common non-normal distribution (Talbot & Simpson, 1983) but since most comparable data from the GBR (see Table 1) have been summarized in this way it will be used in this report. However later analysis of the data for comparative purposes with future monitoring results may use other types of averaging which are more satisfactory.

Mean values from the pilot variability study are shown in Table 4.

9.2 Sediment/Turbidity Study

The raw data is compiled in Appendix 3. Many Secchi disc clarity measurements are shown as >n. In these cases of course the Sechi depth was greater than the total depth and no true vertical Secchi depth could be measured. To test whether horizontal Secchi disc measurements, which could be used in shallow water, were comparable to vertical measurements at the same site, a small trial was carried out on 16.2.1989. Four stations to one side of the shipping channel were chosen and horizontal and vertical measurements taken.

Table 3. Data Summary (Sites S5 to S14)

Parameter	Data Points	Mean	S.D.	Range
Suspended Solids (Sediment study)(mg/l)	335	3.95	4.29	0.3 - 47.2
Suspended Solids (W.Q. study)(mg/l)	53	3.62	2.88	0.2 - 15.7
Nitrite-N (μg-at/l)				
Surface	31	0.90	0.61	<0.07 - 3.1
Depth	12	0.90	0.44	0.50 - 2.0
Total	43	0.90	0.56	<0.07 - 3.1
Nitrate-N (μg-at/l)				
Surface	31	0.84	0.33	0.21 - 2.1
Depth	12	0.91	0.34	0.50 - 2.0
Total	43	0.86	0.33	0.21 - 2.1
Ammonium-N (μg-at/l)				
Surface	31	0.49	0.53	0.07 - 2.8
Depth	11	0.46	0.19	0.21 - 0.79
Total	42	0.48	0.46	0.07 - 2.8
Phosphate-P (μg-at/l)				
Surface	33	0.20	0.20	0.03 - 1.1
Depth	12	0.55	1.4 +	0.03 - 4.8
Total	45	0.29	0.71	0.03 - 4.8
Silicate-Si (μg-at/l)				
Surface	31	3.7	1.6	1.6 - 7.3
Depth	11	2.7	0.75	1.9 - 4.3
Total	42	3.4	1.5	1.6 - 7.3
BOD_5 (mg/l)	45	1.1	0.64	0.02 - 2.8
Copper (μg/l)				
Surface	42	1.61	1.76	<0.07 - 8.0
Depth	10	4.25	4.53	0.68 - 16
Total	52	2.12	2.68	<0.07 - 16
Total Phosphorus (μg-at/l)				
Surface	31	0.63	0.37	0.19 - 2.0
Depth	13	0.69	0.26	0.39 - 0.9
Total	44	0.64	0.34	0.19 - 2.0
Particulate Nitrogen(μg-at/l)				
Surface				
Depth				
Total				
Chlorophyll a (mg/l)	18	0.59	0.54	0.05 - 2.0
Aromatic Hydrocarbons μg/l chrysene equivalents	11	0.47	0.62	0.1 - 2.0

+ High SD for phosphate mostly due to one very high result.
Without this value the total results appear as: Mean 0.19, S.D. 0.18

Table 4. Parameter mean values in the pilot variability study

Parameter	Temporal Study	Spatial Study
Suspended solids (mg/l)	2.8	2.3
Nitrate (μg-at/l)	0.29	0.23
Nitrite (μg-at/l)	0.79	0.83
Ammonia (μg-at/l)	0.57	0.76
Orthophosphate (μg-at/l)	0.19	0.17

The results shown in Table 5 suggest that in this case the difference is small and there is good correspondence between the vertical and horizontal readings.

Table 5.

Site	Horizontal Value (m)	Vertical Value (m)
HS1	2.7	2.5
HS2	3.2	3.0
HS3	2.5	2.3
HS4	1.5	1.9

10. DISCUSSION

10.1 General Water Quality

The purpose of the baseline study was to gain a measure of the ambient, natural levels of a number of parameters in Nelly and Geoffrey Bays as possible future impact sites and Florence, Arthur and Picnic Bays as reference sites. Each of the parameters will be examined in turn and general comments made where appropriate.

10.1.1 Dissolved oxygen, salinity and temperature

Dissolved oxygen levels in the marine sites are uniformly high and show no changes with depth. There is also uniform salinity and little thermal stratification, all consistent with the bay being well mixed. Dissolved oxygen levels in Gustav Creek are very variable as are salinity levels and detailed studies would probably show connections between salinity and dissolved oxygen and the salinity gradients set up by occasional saltwater entry into the Creek. Three samples of water collected in South, Central and North Geoffrey Bay around 4/1/89 by a member of the public after Gustav Creek had broken through the foredune were forwarded to GBRMPA and were analysed for salinity. It was stated that 'polluted' water had flowed from Nelly Bay around into Geoffrey Bay at the time of collection. The results (Table 6) show the considerable possible impact of contaminated water from Nelly Bay moving into Geoffrey Bay, at least under one set of weather conditions.

Table 6.

Site	Salinity (‰)
South Geoffrey Bay (near Bright Point)	5.0
Central Geoffrey Bay	5.9
Arcadia End of Geoffrey Bay	8.8

10.1.2 Nitrate and nitrite

Nitrate and nitrite values from the marine stations show no depth variability. The ranges and mean values for nitrate are considerably higher than those found in studies around the Whitsundays (Furnas et al., 1988), previously in Cleveland Bay (Walker and O'Donnel, 1981) and much higher than those found in shelf waters (Furnas and Mitchell, 1984; Furnas et al., 1988). However higher nitrate values have been found close to the coast (Brady, 1989) and on fringing reefs in the Whitsundays (Steven and van Woesik, 1989, Blake and Johnson, 1988).

The nitrite values are uniformly high and in many cases equal to or greater than the nitrate levels, at the surface as well as at depth. This is in contrast to all studies offshore where low or not detectable levels of nitrite were normally found (Furnas and Mitchell, 1984; Furnas et al.,

1988) and in reef lagoons where low levels were found (Furnas and Mitchell, 1988). Some elevated nitrite levels have been measured off Cairns (Brady, 1989) and in the Whitsundays (Blake and Johnson, 1988) but these have still been considerably lower than the mean values found in the present study. Further monitoring will concentrate on verifying these elevated, unexpected nitrite levels. Nitrate and nitrite levels in Gustav Creek are variable with high spot values of both nitrate and nitrite.

10.1.3 Ammonium

Ammonia values also show no obvious depth variability but the mean value found (0.49 μM) for all marine stations is significantly higher than found offshore in the Whitsundays (0.22 μM) or in shelf areas (0.12 μM and 0.15 μM) (see Table 1). High values have previously been noted around Hayman Island (ranging from 1.0 to 15 μM) and Hamilton Island (0.2 to 1.6 μM).

10.1.4 Total dissolved inorganic nitrogen (DIN)

The total DIN value has a mean of 2.24 μg-at N/l. This is very high compared to what is considered normal (or desirable) for healthy coral reefs (Bell et al., 1987). Bell et al. suggest that levels of DIN in excess of 1.1 μg-at N/l are undesirable for coral reef although their conclusions are based on Carribean data and we have little GBR data to verify this. Recent work in the Whitsundays (Blake and Johnson, 1988) has also found DIN levels of the magnitude and it may be that normally levels on fringing reefs are far higher than was recently believed. The high levels found in the present study can be interpreted in two ways. If indeed natural levels on the Magnetic Island reefs were once lower than now found then the reefs may be under stress at present DIN levels and any further anthropogenic increase in DIN levels must be prevented. Alternatively the Magnetic Island reefs may be surviving naturally at DIN levels higher than on the GBR main reefs or in the Carribean and some increase in DIN levels will not cause problems. Such is the case with GBR coastal coral reefs and sedimentation levels where tolerance to sediment and turbidity appear far higher than for offshore reefs.

10.1.5 Orthophosphate and total phosphorus

Levels of these nutrients (mean 0.19 μM) were generally similar to those found in other areas such as the Whitsundays (0.23 μM and 0.43 μM) in shelf waters (0.16 and 0.16 μM) and in Cleveland Bay in the past (0.20 μM) (see Table 1). There was an appreciable difference between bottom samples and surface samples in both orthophosphate and total phosphorus values with greater levels at depth. Levels of total phosphorus were generally twice to eight times the dissolved inorganic phosphorus levels and this is similar to results found elsewhere (Furnas et al., 1988). The orthophosphate levels are just below levels suggested to be critical for coral (0.22 μM) (Bell et al., 1987) but this value seems low considering recent data on ambient levels on fringing reefs.

10.1.6 Silicate

Silicate levels (mean 3.7 μM) are higher than those found in shelf waters (1.06 and 0.93 M) and near the Whitsundays (1.72 μM) but the effects of runoff must be of great importance to silicate levels as any fresh water inputs could significantly affect silicate as shown by the relatively high levels found in Gustav Creek waters compared to the marine sites.

10.1.7 BOD_5

BOD_5 levels averaged 1.1 mg/l similar to average values found in unpolluted Carribean reefs (0.7 mg/l) (Bell et al., 1987). There is little comparable data from the GBR but traditional measurement of BOD levels as low as this, is fraught with difficulties.

10.1.8 Copper

Copper values appear to be far higher than those found in offshore (shelf) and reef waters and near Orpheus Island (generally 0.2 - 0.3 μg/l) (Denton and Burdon-Jones, 1986), but more comparable to other waters close to large metal smelting and refining industries, e.g. in the Mediterranean (levels with mean 1.2 μg/l) (Scoullos and Dassenakes, 1983) and in Australian harbours (Moran, 1984; Roy and Crawford, 1984).

This will complicate monitoring to detect elevated levels from anti-fouling paints but also suggests that the Magnetic Island fringing reefs are already living in waters containing copper levels considered by some authors to be above their recommended guideline for this metal (Bell et al., 1987).

10.1.9 Tri-(n-butyl) tin (TBT)

No TBT residues were detected at above 5 ng/l (the detection limit of the method) in the samples from this study, but there was evidence of the presence of methylated tin compounds presumably from natural sources. The present suggested tolerance levels in water for TBT are 5-10 ng/l (Goldberg, 1987) but with increasing evidence of effects at even lower levels than these viz. 2.5 ng/l (Bryan et al., 1986), these guidelines will be reduced. The analytical method used in this baseline study will be improved for the monitoring programme by use of more suitable sampling bottles (polycarbonate rather than polythene) and better trapping and detection such that the detection limit will be below 1 ng/l. TBT is not believed to occur naturally and the data from this study is as one would expect from an area with almost no moored boats.

10.1.10 Aromatic hydrocarbons

The levels were generally low and typical of relatively uncontaminated waters (Smith and Maher, 1984; Smith et al., 1987) but not open coastal waters. The regular boating and shipping activity around this side of Magnetic Island has probably contributed to these slightly elevated levels.

There is the possibility of some correlation between the aromatic hydrocarbon data and hydrocarbon degrader bacteria concentrations, particularly at S11 but the data is not extensive enough to draw statistically valid conclusions.

The hydrocarbon degrading bacteria levels (Table 7) are higher than levels previously found around Townsville (Saunders Beach and John Brewer Reef) (Larsen, 1986) particularly Site 11. However sediment grain size may affect measured numbers and further studies may confirm these results.

10.1.11 Coliform bacteria

Most samples with significant coliform levels were clustered around the north and central sections of Nelly Bay. Values also seemed to be higher after Gustav Creek had broken through the fore-dune and was discharging into Nelly Bay suggesting the positive coliform levels were linked to discharge from Gustav Creek. This also tends to confirm the findings of the variability study in this area. Samples from Florence and Arthur Bays on the other hand were devoid of coliform bacteria. Gustav Creek is consistently contaminated with faecal coliform bacteria, both while flowing or not and this no doubt originates from the sewerage treatment works and incomplete septic action from urban septic tanks. Levels routinely exceed

Table 7. Hydrocarbon Degrading Bacteria (HDB) and Aromatic hydrocarbons (AH)

	Water /100 ml	Sediment /100 g	AH, Water $\mu g/l$ C.E.
Site 4			
23/12/88	1.6×10^2	1.6×10^5	
10/1/89		2.2×10^5	0.2
24/1/89	1.6×10^2		0.1
31/1/89	2.2×10^2	2.2×10^4	
16/2/89	5.1×10^3	1.6×10^5	
Site 6			
23/12/88	2.2×10^2	2.2×10^5	
10/1/89	5.1×10^3	9.2×10^5	0.1
24/1/89	1.6×10^3		0.3
31/1/89	1.6×10^2	5.1×10^4	
16/2/89	2.2×10^3	9.2×10^5	2.0
Site 9			
23/12/88	5.1×10^2	9.2×10^5	
10/1/89	5.1×10^3	9.2×10^5	0.1
24/1/89	1.6×10^3		0.3
31/1/89	1.6×10^2	2.2×10^5	
16/2/89		2.2×10^5	0.2
Site 11			
23/12/88		1.6×10^5	
10/1/89	1.6×10^4	5.1×10^5	0.1
24/1/89	1.6×10^5		0.5
31/1/89	2.2×10^2	6.0×10^6	
16/2/89	9.2×10^3	5.1×10^5	1.3

the Queensland guideline for primary contact water (zoo Faecal coliforms/100ml). If the expanded treatment plant discharges directly or indirectly into Gustav Creek even higher faecal matter levels can be expected in Gustav Creek and in the northern end of Nelly Bay i.e. inside the proposed marina and on the new swimming beaches.

10.2 Sediment/Turbidity

10.2.1 Levels

The mean values of suspended solids (non filterable residue) found in the water quality study and the sediment/turbidity study were similar (3.62 mg/l and 3.95 mg/l). These levels are within the ranges suggested to be background levels in the GBR viz. 6 mg/l (inner region) to 2 mg/l (outer region) (Bell et al., 1987) and far lower than levels found on the Daintree fringing reefs (mean 1093 mg/l) in March 1985 (Hopley, 1985 as cited in Hoyal, 1986) and in January, 1988 (mean 118.5 mg/l) (PER, August 1988). They can be compared also to previous measurements in Nelly Bay of 2.75 to 7.9 mg/l in February 1986 (Collins in PER, 1986) and in July and August, 1988 where higher values of between 35.0 and 115.6 mg/l were found (PER, August 1988).

Tomascek and Sander (1985) suggest levels above 4 mg/l can cause reduction in coral growth but this data derives from Carribean reefs where natural sediment loadings may be far less than on the fringing reefs of Eastern Australia. On the Daintree reefs corals survive turbidity levels and sedimentation rates far higher than expected from overseas studies (Ayling and Ayling, 1987; Fisk and Harriott, 1987).

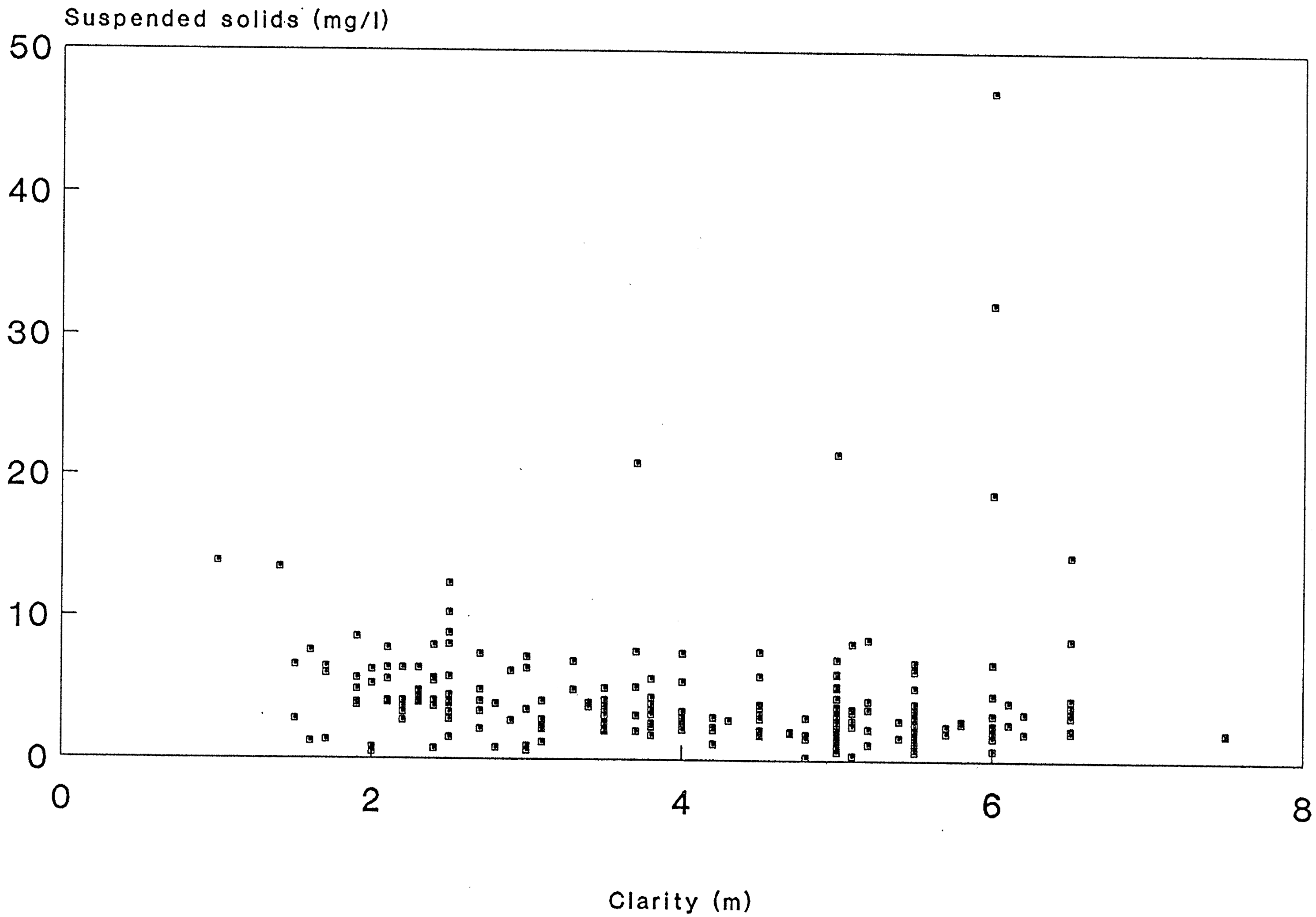
Results of sediment deposition measurements in the study areas are discussed in the biological monitoring report.

10.2.2 Secchi disc measurements, turbidity and suspended solids

As part of this study the relationship, if any, between Secchi disc readings and suspended solid levels was also investigated. Initially turbidity readings using a portable nephelometric turbidity meter were also included for comparison but early in the study it was decided this instrument was not giving and was probably not capable of giving accurate,

Figure 9

Magnetic Quays Sediment Data: Clarity vs. suspended solids



significant results at the turbidity levels found in Cleveland Bay waters. The measurement of Secchi disc depth (known also as clarity or transparency) is complicated in shallow water as the Secchi depth may often be greater than the total depth and so no vertical Secchi depth can be measured. Over one third of the readings in the sediment/turbidity study and over one half in the water quality study suffer this disadvantage.

Horizontal Secchi disc measurements can be made with two divers and may be relatable to vertical measurements under certain conditions, in particular a vertically homogeneous water column. However it appears from the present study that Secchi disc depth is not a good indicator of suspended solid concentrations particularly when wave action is resuspending bottom sediments and the water column is thus not homogeneous for sediment concentration. Figure 9 shows a plot of Secchi disc depths versus suspended solids for those samples taken where a true Secchi depth could be obtained. Manipulation of the data to only include surface samples does not dramatically improve the relationship although some relationship is then apparent. These results contrast with those from Walker's work (1982) where for open Cleveland Bay waters a relationship could be shown. The difference is likely to be in the degree of bottom resuspension and water column inhomogeneity in the shallower reef slope and reef flat waters compared to those of the deeper open bay. Secchi disc clarity is inversely related to wind speed but this is also complicated by total water depth, the relationship being stronger in shallower water. This is also governed by the fact that the suspended material in the water was generated primarily by bottom resuspension from wave turbulence.

10.3 Comparison of reef slope sites in all bays

The sites for the water quality and sediment/turbidity studies were initially chosen as 'impact' and 'control' sites with those in Nelly Bay and Geoffrey Bay being in the first category and those in Picnic, Arthur and Florence Bay in the second. The movement of water from Gustav Creek around Bright Point and into Geoffrey Bay on the occasion of the breakout of Gustav Creek through the foredune verified the selection of Geoffrey Bay sites as impact sites at least under some weather conditions.

Table 8 shows data from the reef slope sites in these two areas grouped together. Data from bottom and surface samples and from all five sampling occasions have been pooled and mean values and standard deviations listed.

Table 8. Comparison of Reef Slope Sites (averaged over all samples)

		SS	NO_2 -N	NO_3 -N	NH_3 -N	DIN	PN	PO_4 -P	TP	Sil. -Si	Chl$_a$	BOD_5	Cu	TC	FC'
		mg/l	µg-at/l								mg/l	mg/l	µg/l	org/ 100ml	org/ 100ml
Impact Area															
Nelly Bay North (S5)	$\bar{x}$	2.5	0.68	0.76	0.34	1.78	4.0	0.15	0.54	3.3	0.47	0.73	3.2	7.4	0.8
	SD	2.2	0.31	0.20	0.26		1.1	0.11	0.29	1.5	0.46	0.44	2.3	12	1.8
Nelly Bay Centre (S7)	$\bar{x}$	2.7	0.89	0.99	0.41	2.29	4.7	0.17	0.65	2.8	0.34	1.0	0.95	4.4	0
	SD	2.3	0.55	0.47	0.24		1.2	0.13	0.35	0.83	0.20	0.68	0.30	8.8	0
Nelly Bay South (S8)	$\bar{x}$	3.2	1.0	0.86	0.57	2.43	3.1	0.16	0.52	3.6	0.32	1.1	4.0	12	0
	SD	2.3	0.45	0.08	0.37		0.2	0.05	0.19	1.7	0.28	0.28	6.0	16	0
Geoffrey Bay North	$\bar{x}$	4.9	0.94	0.72	0.34	2.00	5.5	0.12	0.56	3.0	0.30	1.3	1.8	0.4	0
	SD	2.3	0.33	0.19	0.23		1.6	0.07	0.23	0.84	0.19	0.33	1.8	0.9	0
Control Area															
Picnic Bay (S10)	$\bar{x}$	6.6	1.0	0.86	0.43	2.29	4.7	0.24	0.89	3.3	1.1	0.93	2.3	0.4	0
	SD	5.6	1.2	0.09	0.36			0.15	0.58	0.10	0.59	0.54	3.5	0.9	0
Arthur Bay (S13)	$\bar{x}$	2.6	0.70	1.2	0.65	2.55	4.3	0.39	0.82	5.0	1.4	0.81	2.1	3.0	0
	SD	0.67	0.24	0.59	0.34		1.9	0.48	0.48	1.8	0.8	0.43	1.9	4.8	0
Florence Bay (S14)	$\bar{x}$	9.7	0.98	0.89	0.28	2.15	4.2	0.28	0.66	3.7	0.4	1.6	1.3	0	0
	SD	13.7	0.71	0.45	0.19		1.4	0.23	0.14	2.4	0.3	1.0	0.8	0	0

The data has not been statistically analysed although this will be done later. However some apparent differences can be noted by inspection.

While there appears to be some differences in suspended sediment mean values are so critically dependent on water depth and subsequent bottom resuspension that the results have to be treated with caution.

The most striking difference appears to be in phosphorus levels, both orthophosphate and total phosphorus, and in the chlorophyll-a values. In both cases the levels in the control areas are higher than in the impact areas by a factor of roughly two. The standard deviations in the means for these parameters, while only derived from a small data set, also strengthen this apparent difference.

11. PERSONNEL

The following personnel worked on this project, a number of them in a voluntary capacity and the coordinator would like to acknowledge all their contributions.

Design

J. Brodie, R. Volker, B. Mapstone, D. Sutton

Water Sampling and Analysis

J. Faithfull, P. Bachiella, G. Brodie, J. Orr, K. Vernes, P. Brodie, S. Brodie, J. Coghlan, D. Payne, A. Hesse, J. Brodie.

Microbiological Analysis

R. Stockwell, S. Smith

Nassarius Study

R. Mitchell, M. Morrice

Data Handling and Analysis

K. Vernes, G. Brodie, B. Mapstone, I. Kneipp, R. Pearson

Report Preparation

J. Brodie, B. Mapstone, R. Mitchell

Typing and Diagrams

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PLEASE QUOTE 9.17.15.3

YOUR REFERENCE

Professor H. Choat
Department of Marine Biology
James Cook University
Townsville Qld 4810

Dear Professor Choat,

I refer to our recent discussions concerning the review of:

1) The Fringing Reefs of Magnetic Island: Benthic Biota and Sedimentation Study - a Baseline Survey by the Quantitative Ecology Division, Department of Marine Biology, James Cook University, and,

2) Magnetic Quay Water Quality and Sediment Baseline Study by the Australian Centre for Tropical Freshwater Research, James Cook University.

As a general comment, both reviewers and Authority staff have commented favourably on the benthic biota and sedimentation study. While the water quality study would appear to have met our requirements, the report appears to be in need of some revision. As you will be aware our main concern is the development of a feasible and quick reactive monitoring protocol for sedimentation.

Please find enclosed reviewers comments on the two reports (Attachment A refers). The reviewer's comments are to be addressed in finalising your baseline study reports and the impact assessment program for the proposed Magnetic Quay development at Nelly Bay, Magnetic Island. In particular the following points should be noted:

<u>The Fringing Reefs of Magnetic Island: Benthic Biota and Sedimentation Study - a Baseline Survey by the Quantitative Ecology Division, Department of Marine Biology, James Cook University</u>

a) <u>Report Structure</u>

An executive summary should be included in the report.

b) <u>Anova Models</u>

Using percent cover data, Model 4 Anova can detect a 20% change in most reef forming taxa (page 53 refers). However, what is not indicated is the percentage change that could be detected, if for various reasons, Model 4 is inapplicable.

c) Attributes

There is still considerable information in the data that could be analysed if time and resources permitted. Your comment is sought on the suggestion to examine size frequency and analysis of 'runs' after the assessment program is completed.

d) Evaluation of Nelly Bay Reef

The reviewer's comments regarding the demonstration of gross biological pattern (cluster analysis) using pooled taxonomic data, biotic uniqueness, rare species and resource evaluation should be noted. It would be useful if the aesthetic value of each of the different surveyed reefs and bays could be rated by the field survey personnel (for eg: using similar ratings to manta tow ratings). Similarly, trends or qualitative observations from the field survey team, which are not statistically verifiable should be noted and reported where possible.

Considering that discussions were held with reviewers prior to both the baseline field work and the report preparation I assume that species which are likely to be less tolerant of the projected increase in sediment loads or changes in water quality parameters were taken into account in your comments regarding comparison between bays etc. However it is suggested that this avenue be further examined as we discussed in our recent meeting.

e) Cluster Analysis

The designated impact stations are shown by cluster analysis to be biotically different from the controls (Figure 6B and Table 6 refers). How does this affect their suitability as controls?

f) Comparative Abundances

The critical issue for the interpretation of all future monitoring data is the assumption by the authors that if no impacts were to occur they would expect "...that changes in abundance would be the same, on average, at all sites, and unrelated to the patterns in absolute abundance among sites, stations etc on any given occasion" (page 31, para 1 refers). The reviewer has suggested that verification of this assumption be obtained by resurveying all or some of the transects prior to the commencement of the construction activities. Your advice regarding this assumption and the suggested verification proposal would be welcomed. What additional information which may influence the design of the monitoring program would be provided?

g) Sedimentation Levels

The indicated figures for the upper limit of average sedimentation at a reef slope station (page 36 para 4 refers) are for wind speeds greater than 25 knots. What limits are envisaged for calm conditions? Given that sedimentation rates are averaged over a week or so from sediment trap data, if a reactive monitoring strategy required at least say 24 hours to provide sediment level results, could serious effects have already occurred (or do we have a day or twos grace).

h) Pooling of Taxa

The reviewers note that the pooling of taxa may combine inappropriate features and obscure certain changes resulting from the development. For example, the combination of species and species groups on taxonomic grounds may combine sediment susceptible forms with tolerant growth forms and thus obscure what may be a major effect on the former. Accordingly it is suggested that some scale of sediment trapping feature of morphology be recorded so that an analysis of treatment versus morphology could be examined.

i) Pre-construction Monitoring

"The potential for erroneously concluding that differences in sedimentation between Nelly Bay and control stations are cause for management action is great owing to the limited period over which the range of differences were assessed." In order to address this problem it is recommended that:

(1) continued regular measurements of sedimentation, and,
(2) further baseline work to establish whether there are short term relations between turbidity and sedimentation

be undertaken in the period prior to the commencement of construction activities. The critical question here is what additional information would be provided by such studies and how would we use it?

j) Reactive Monitoring Strategy

A rapid management response to any unforeseen sediment effects which occur during the construction phase of the proposed Magnetic Quay development is dependent upon the on site supervisor having some quick and expeditious measurement of suspended sediment which is indicative of physical or stressful effects on the corals.

While I appreciate the logic behind the 5 step process on which to basis a decision on when an impact has occurred, I am very concerned about the practicality of the procedures. Particularly, it seems to me that a decision to implement a "reactive sampling" procedure when a significant difference is detected in an environmental variable is likely to result in gross time delays in decisions about whether to halt construction or not. An observed characteristic of large construction projects is that they are very difficult to stop indeed and that such decisions have to be based on simple criteria if they are to be implemented by supervision personnel. Furthermore, the construction organisation itself prefers simple decision making procedures, preferably based on a single criterion, even if this sometimes leads to a decision being made to cease construction when more complex analyses might show that such cessation is unnecessary.

I believe that it is important to stress that the baseline study must provide guideline figures of certain sediment concentration or equivalent which would lead to certain management actions.

While I appreciate that the figures will be guidelines, it should be emphasised that they may be subject to modification during the course of the construction in the light of experience. I believe that it is better to approach this issue conservatively and relax the levels, if required, rather than go the other way. Accordingly, I would suggest that a flow or decision diagram be developed inconjunction with the Authority to assist both the developer and the on site supervisor in the use of the short-term, quick and expeditious reactive monitoring program.

While potential sedimentation is obviously the prime cause for concern during construction, are there any other parameters that we should be concerned about for the short-term, quick and expeditious reactive monitoring program.

Magnetic Quay Water Quality and Sediment Baseline Study by the Australian Centre for Tropical Freshwater Research, James Cook University

a) Report Structure and Content

The quality of the report is very patchy and somewhat repetitive requires revision in lines with the reviewer's comments prior to submission to this Authority. An executive summary should be included in the report. Further analysis of the data should be considered in an attempt to identify whether relationships exist between the bays.

b) Analytical Methods

The number of replicates collected and analysed or controls run are unknown. No data was presented on the sensitivity or precision of the methods used, nor of variability due to sample handling in the field and laboratory. Similarly, it is not known whether the analytical tests were run blind or whether a percentage (~ 10%) of the samples were retested as is the usual laboratory procedure.

Reviewers have previously expressed doubts about the use of plate-count or MPN methods for bacterial counts prefering instead the use of epifluorescence microscopy after staining with a fluorescent nuclear stain. The comment does not appear to have been accepted and your advice for this decision is sought. There is no estimate given for the reliability of total bacteria numbers and they should be taken as relatively guides only unless calibrated.

Your advice regarding the suggested modification to the chlorophyll analysis would be welcomed.

I understand no clear relationship could be demonstrated between secchi disc reading, suspended solids and sedimentation rates. Were secchi disc readings taken daily or only weekly to correlate with sedimentation rates etc.

c) Verification

The reviewers note that the concentration of nitrite, in particular, seems very high. It is suggested that these results be confirmed.

Some verification of the accuracy of the coliform counting measurements is required.

Proposed Monitoring Program

a) Sampling of Sediment Traps

How will the sampling of the sediment traps fit in with the short-term, quick and expeditious reactive monitoring program?

After 18 months of construction (end of 1991) I would have thought annual re-surveys would have been sufficient.

b) Experimental Study Payment by Developer

I am concerned about getting the developer to pay for the lipid investigation and the reproductive condition investigation given the experimental nature of these studies. While I agree that they are valuable studies the developer should be made aware of the likelihood of their producing useful information for impact assessment.

I look forward to our further discussions with you and your associates at the Authority's office at 2pm on 10 April 1989.

Yours sincerely,

Wendy Craik
Assistant Executive Officer
Research and Monitoring

cc Mr J. Neal (Linkon Construction Pty Ltd)

Review of the Magnetic Quay Water Quality and Sediment Baseline Study by the Australian Centre for Tropical Freshwater Research, James Cook University

The quality of the report is uneven. Some portions were soundly done, some gaps exist and some data seems to be considerably at odds with historical data from the GBR region and should be verified by independent means.

Sampling

The spatial and temporal extent of the sampling scheme was adequate only to resolve important short-term water quality characteristics in the area of the proposed Magnetic Quay development. With regard to the full range of conditions (floods, cyclones, harbor dredging) which could considerably affect water quality in Nelly Bay, insufficient environmental variability prevailed during the study period to allow a realistic assessment of longer-term fluctuations. The values obtained, in the absence of other considerations discussed below, would likely reflect general patterns under normal weather conditions.

Analytical methods

On the face of it, most of the analytical methods selected were or should be appropriate for a survey of this type. The number of replicates collected and analyzed or controls run are unknown.

I have considerable doubts about plate-count or MPN methods for bacterial counts, though recognized as "standard" methods for counting certain types of bacteria, in that local expertise in culture procedures, media preparation, sample inoculation can all affect results. Culture methods chronically under-estimate total bacterial numbers. There is no estimate given for the reliability of these numbers and they should be taken as relative guides only unless calibarated.

Does the CHN analyzer really use IR detection?

In the future, it is recommended that the chlorophyll analyses be run shortly after proper grinding and extraction rather than overnight extraction to minimize degradation of the clorophyll. This would be particularly important in shallow water samples where high phaeophytic concentrations from resuspended sediment might interfere. Use of fluorometric detection would also improve sensitivity and reduce the sample size needed.

No data was presented on the sensitivity or precision of the methods used, nor of variability due to sample handling in the field and laboratory. This is a serious omission.

Results and Reporting

The format used for reporting the results is very confusing. Table 2, which summarizes the mean values (pg. 34), is generally lacking in units, as are the Appendix Tables for the spatial and temporal variability studies. Consultation of the Appendix Table 2 (?) suggests concentrations of nitrate-N and nitrite-N are on the order of 1 ug-at/l (ug-N/l divided by 14.01) while the conversion of the mean value in Data summary table 2 (pg 34) apparently divides the reported values by the total mass of the ions. The tables should be recalculated, with appropriate labelling and have all values presented either as the mass, but preferably the concentration, of the element, not ion of interest (e.g. uM-N or uM-P). This would facilitate comparison with other studies in the GBR region.

The concentrations of nitrite, in particular, seem very high (see Table 1, pg 15) and bear confirmation. The summed concentrations of nitrate and nitrite approach values suggested as being deleterious to corals. If such values represent conditions widely occurring in Cleveland Bay, certain corals on Magnetic Island may be stressed already and susceptable to accelerated degradation by localized inputs of nitrate/nitrite which exceed threshold values for damage.

The disparity between secchi disk depth (or water clarity) and suspended solids concentrations is not surprising. Close correspondence would imply homogeneity in the material attenuating light in the water. This is probably not the case in inshore waters such as Nelly Bay. Light can be attenuated quite effectively by particulate organic and dissolved substances which do not have the mass of suspended clay particles or other mineral materials also recovered on filters.

Report Recommendations

The proposed changes to the sampling strategy for monitoring during the construction phase are sensible. Water movements and water residence times in Nelly Bay are overwhelmingly driven by events in Cleveland Bay. Given the apparent degree of temporal variability in measured values of parameters at one site and lack of strong spatial variability, a reduction in the number of sites with an increase in the number of replicates taken per site will still give an adequate indication of water quality in Nelly Bay. A capability to undertake contingency sampling in response to perceived events should be maintained.

Review Recommendations

1. The reporting format should be modified to include consistant units throughout and to clarify the results. The data tables from the baseline report should be redone in this new format to be consistant with all following reports and to provide a less ambiguous data set for comparison with future values.

1a. It may be desirable for GBRMPA to consider specifying one, or perhaps two, standard formats for reporting water quality, chemical and hydrographic variables measured in baseline, impact and monitoring studies that could be readily incorporated into any computer data base maintained by GBRMPA. This would make it easier for reviewers and managers to compare data sets in printed form or by computer techniques. While rigid formats can cause inconvenience in specific studies, computers can usually deal with these problems. Many of the same variables will be measured in most impact and monitoring studies and a range of contractors may eventually become involved in monitoring activities, making some formalized basis for review and comparison essential.

2. The consistantly high nitrite values measured in Nelly Bay were surprising and should be independently confirmed. These values are significantly higher (10-fold) than usually measured in shelf waters of the GBR and rival values observed after cyclone events. As stated above, the summed concentrations of nitrate and nitrite approach (on average) and not infrequently exceed concentrations reported (but not experimentally verified) to cause deleterious effects to some corals. In view of the values measured, some rigorous experiments to confirm direct nitrate 'toxicity' or indirect negative effects on corals should be conducted. In the long term, if such high concentrations and the nitrate 'toxicity' problem are real, inputs of nitrate+nitrite attributable to the Magnetic Quay project could cause localized problems. The greater danger may still come from chronic, non-point inputs of nutrients from development around Cleveland Bay and natural nitrification processes in Cleveland Bay which are influenced by these inputs.

3. Given the obvious importance of estimating direct inputs of human sewage from developments, boats and surrounding areas, generally monitored as coliform bacteria, some evidence of the accuracy of coliform counting measurements is important. How are the methods calibrated within laboratories and is there an

independent method for quality control of reported results? Some interaction between contractor laboratories and state health laboratories normally conducting these measurements would be useful.

4. As stated above, the report lacks data on the sensitivity and precision of individual analyses or reported values. It was therefore impossible to objectively examine the quality of individual numbers, though some look suspiciously high or low. Some indication of precision and sensitivity should be included in contractor reports to allow this.

5. I do not feel that measuring pH is worth the effort. Seawater is generally well buffered and making quality pH measurements requires considerable care and proper instrumentation. Interpretation of the results would also require careful consideration of spatial and temporal variations. All of this may be beyond the scope of a monitoring program unless specific problems are identified which justify the considerable effort required.

6. The attempt to monitor Tri-butyl-tin (TBT) by its effect on the sexuality of resident snails is an interesting and potentially cost-effective method. It should be pursued. Clearly, some lab work is needed to verify that local snails are reliable TBT indicators and the results are not confounded by unforseen factors. If this technique can work, it offers the potential to monitor TBT effects cheaply throughout the marine park. Field work is also needed to assure that the sampling method obtains an unbiased selection of snails appropriate for analysis.

Attachment A

GREAT BARRIER REEF MARINE PARK AUTHORITY
REPORT OF ASSESSOR

PROJECT TITLE
Review of Nelly Bay Baseline Study
PROJECT NO.

INVESTIGATOR INSTITUTION

(Please see notes before writing report)

1. Sampling design ok to resolve temporal + spatial variability
2. No estimate of sensitivity + precision of methods used in survey, precluding detailed examination of data. Basic methods, possibly excluding bacterial counts, should be reliable if properly performed.
3. Nitrite values very high. Need to be verified by independent means
4. Formatting and reporting of results clumsy, lacking units in some cases, making comparisons difficult. Should be re-done. GBRMPA should consider a standardized report format for database archiving and reviews.
5. Snail monitoring for TBT a potentially useful and cost-effective method for monitoring TBT pollution. Worthy of support for calibration and verification.

PUBLICATION: (Recommended) - ~~in present form~~
- (with modification) - see attached notes
~~not recommended~~

(Please add further comments on extra sheets if necessary)

NAME OF ASSESSOR SIGNATURE

TI

INSTITUTION

ASSESSMENT PROPOSAL INVESTIGATOR REPORT 24/3/1989
Please enter grade B - C

REFEREEING FEE (Required)/ ~~Not Required~~ (m

Comment on Magnetic Quay water quality and sediment baseline study of March 1989.

The duration of measurements is not sufficient to draw many conclusions on year-round conditions In Nelly Bay but the work carried out is adequate within this constraint. A few suggestions follow with regard to methodology.

Although this is environmental impact work rather than scientific work more detail would be appreciated on methodology. For example were automated or manual methods used for nutrients? What path length cuvette was used for the chlorophyll measurements? It is difficult to work out when replicate measurements were made. If temperature and salinity are to be measured using field probes the accuracy should be given and measurements using sensitive mercury thermometer and laboratory inductive salinometer should be reported simultaneously from time to time to confirm calibration. Perhaps some indication of accuracy of other data or methods could be given where possible. Evaluation of the data is made difficult by choice of units of measurement reported (or not reported in several places such as tables 2 and 3). The convention for nutrients in marine waters is to use *ug*-atom/litre or *u*M and this should be adhered to throughout the report.

(Chlorophyll measurements will require more than one litre of sample water to obtain accurate values on many days if a spectrophotometric method is used.)

(In table 1 the final value of 0.20 in Cleveland Bay should be under phosphate not ammonia.)

Australian Centre for Tropical Freshwater Research

James Cook University, Townsville, Qld 4811 Australia

JEB:LD/(077)81 4191

10 April, 1989

Dr. Wendy Craik,
Assistant Executive Officer,
Research & Monitoring,
Great Barrier Reef Marine Park Authority,
TOWNSVILLE. QLD. 4810

Dear Dr. Craik,

I refer to your comments on the Magnetic Quay Water Quality and Sediment Baseline Study expressed in your letter to Professor Choat of about 31 March.

We have modified the report in line with your own and the reviewers' comments and our own review, and are resubmitting it with this letter. I will also comment directly in this letter on the points you raise.

(a) Covered in revised report as far as time allows.

(b) Quality control of analytical data is now summarized in the revised report.

The methods used (heterotrophic plate count and MPN) were chosen specifically to allow correlations with currently used methods for microbiological examination of water and wastewater. This study was not an ecological study of the reef environment, but a specific examination for particular organisms. The heterotrophic plate count is used to detect bacteria capable of growth in high nutrient environments such as those occurring where sewage or wastewater outfall is occurring or will occur. The occurrence of low nutrient and non-viable bacteria detected using epifluorescence, would not provide data of relevence to assessment of heterotrophic bacteria. To quote the standard text of "Methods for the Examination of Water and Wastewater" (16th Edition, 1985: Part 900 Microbiological Examination of Water) "the heterotrophic plate count is the best available measure of water treatment plant efficiency, after growth in transmission lines, and general bacterial composition of source water".

For the faecal and total coliform bacteria, and the hydrocarbon utilizing bacteria, the methods used were the only available to meet guidelines for water quality assessment (see Microbiological Methods Manual, Rural Water

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Commission of Victoria, Water, Materials and Environmental Science Branch, Report No. MB2, January 1988) and could not be performed by epifluorescence microscopy.

I have no comments at present regarding the modification to the Chlorophyll method suggested but we will look further into this and if it seem appropriate will adopt the modified method for further monitoring.

Secchi disc readings were taken weekly. There has been no attempt to correlate daily readings with suspended sediment values or sedimentation rates.

(c) We will attempt to verify high nitrite values by using manual analysis methods for some of the construction phase monitoring.

Reference to "Microbiological Water Quality Criteria: A review for Australia" (Department of Resources and Energy, Australian Water Resources Council, Technical Paper No. 85, Aust. Govt. Publishing Service, Canberra, 1985) has shown that in Australia different coliform methods are used in different laboratories for different sample types. Assessment of methods relating to seawater samples led to the selection of two standard methods which were compared during initial sampling. One of these using Membrane Enriched Teepol medium had consistently higher counts and was therefore selected for use in this study. No calibration with other laboratories was attempted as no set standard method exists, and sample differences (e.g. temperate vs tropical) would not facilitate comparisons between laboratories using similar methods. (Dr. A. McNeil, Victorian Water Resources Commission, pers. comm.). The sample variability detected for most water quality parameters including bacteria supports the reviewers' observation that numbers obtained are relative guides only to these parameters.

Yours faithfully,

J. Brodie,
Coordinator

Encl.

APPENDIX ONE

Analytical Methods

Quality Assurance

Within the laboratory quality assurance is based on reference standard control charts, sample replication for batch methods and repetition of samples where replicates do not meet prescribed criteria. Precision of methods has been estimated from a preliminary error analysis based on repeated analysis of a single standard. While this gives an over optimistic estimate of long term precision (due to batch to batch variability) the reference standard used for the control chart is used to verify long term (batch to batch) precision. Accuracy is followed using the control chart where the reference standard used in each batch has been prepared from a stock standard prepared from chemicals independent of the calibration stocks and standards. This system has been used for the following analysis: nitrite, nitrate, ammonia, orthophosphate, total phosphorus, silicate, BOD_5. Essentially only one batch of TBTO, copper and aromatic hydrocarbons were run and the reference standard used in these cases was not independent of the calibration standard.

For the following parameters in-laboratory replicates were routinely run, i.e. the single field sample was split and run as a pair through the method: nitrite, nitrate, ammonia, orthophosphate, total phosphorus and silicate. Where replicates did not agree within 20% of the higher value (i.e. $s/\bar{x}$ for the pair > 0.16) the sample was repeated in the next batch. Samples which were outside the standards range were also repeated after appropriate dilution. No replicates were run for Chlorophyll-a, suspended sediments, particulate nitrogen, copper, TBTO or aromatic hydrocarbons. BOD_5 samples were replicated in the sense that serial dilutions were made but in marine samples values were so low that only the first dilution was used in the result calculation.

The limits of detection and sensitivity shown with each method reflect the particular method and instrumentation used. While general precision values are also given, as explained above, it should also be realized that these have been estimated from a standard near the upper end of the expected range of values and that precision near the limit of detection will not be as good.

Suspended Solids

The one litre water samples were filtered, with vacuum assistance, through pre-weighed 4.7 cm GF-C glass fibre filters, the filters dried at 95°C and the residue weighed. Limit of detection, 0.6 mg/l; sensitivity 0.4 mg/l.

Nutrient Samples

Samples were collected in individual sterile Whirl-pacs, frozen and stored frozen until required for analysis.

Orthophosphate

Analysis was by a molybdenum blue colour development method using ascorbic acid reductant and measurement at 885 nm (Grasshof, 1983). Limit of detection, 0.05 μg-at/l; sensitivity 0.03 μg-at/l; precision 15% at 0.2 μg-at/l.

Ammonia

Analysis was by an indophenol blue colour development method and measurement at 630 nm (Grasshof, 1983). Limit of detection, 0.07 μg-at/l; sensitivity 0.05 μg-at/l; precision 18% at 2 μg-at/l.

Nitrate and Nitrite

Nitrate was reduced to nitrite on a copper coated cadmium reduction column using a Flow Injection Analysis (FIA) system and nitrite measured on this system using the sulphonilamide/N-1-Naphthylethylene diamine colour reaction at 520 nm. Nitrate was calculated from the nitrate plus nitrite value and the nitrite value by difference. Nitrite limit of detection, 0.07 μg-at/l; sensitivity 0.03 μg-at/l; precision 5% at 2 μg-at/l. Nitrate limit of detection, 0.07 μg-at/l; sensitivity 0.03 μg-at/l; precision 11% at 2 μg-at/l.

Total Phosphorus

The sample was digested using alkaline persulphate and analysis of the resultant phosphate carried out using a molybdenum blue colour development on the FIA. Limit of detection 0.06 μg-at/l; sensitivity 0.04 μg-at/l; precision 20% at 0.5 μg-at/l.

Particulate Nitrogen

400 ml samples were filtered through GF-C filters and the residue analysed for nitrogen using a C,H,N analyser.

Silicate

Analysis was by a molybdenum blue colour development method using ascorbic acid reductant and measurement at 810 nm (Grasshof, 1983). Limit of detection 0.2 μg-at/l; sensitivity 0.1 μg-at/l; precision 8% at 5 μg-at/l.

Chlorophyll-a

1l water samples were filtered through GF-C filters, the residue and filter, ground, soaked in acetone overnight in the dark, extraction completed, the extract centrifuged and the pigments read at 750 and 665 nm (Strickland and Parsons, 1968). Limit of detection 0.05 mg/l; sensitivity 0.02 mg/l.

Copper

500 ml or 1l water samples were stabilized by distilled nitric acid addition for storage. Analysis consisted of concentration on a Chelex-100 resin column, elution and analysis using flame Atomic Absorption Spectroscopy (Denton and Burdon-Jones, 1986). The bottles used for collection and storage were cleaned with nitric acid and rinsed with double distilled, deionized water. Limit of detection 0.06 μg/l; sensitivity 0.02 μg/l; precision 5% at 0.5 μg/l but this is only calculated from a standard run at the AAS stage and does not include variability in the concentration stage.

Aromatic Hydrocarbons

2.5 l water samples collected in precleaned glass bottles were extracted with dichloromethane, the extracts reduced in volume using a rotary evaporator followed by blowing down with nitrogen and transferred to U.V. grade cyclohexane (Smith and Maher, 1984). Analysis was by fluorescence against chrysene standards (Anon, 1976). The results are expressed as equivalent concentrations of chrysene. Limit of detection 0.05 μg/l C.E.; sensitivity 0.02 μg/l C.E., precision 5% at 0.2 μg/l C.E. but this is only calculated from a standard run at the spectrofluorimeter stage and does not include variability in the extraction stage.

Tri-(n-butyl) tin

500 ml of 11 water samples were collected in polythene bottles and stored at 2-4°C. Analysis was by reduction to the hydride using borohydride, flushing from the water using a helium stream and trapping of the hydrides on silanized glass wool at liquid nitrogen temperatures. The hydrides were removed from the trap in the helium stream by warming and separation of stannane, methyl tin hydrides and butyl tin hydrides on a temperature of elution basis. The eluted hydrides were analysed by passing into a heated silica tube in the Atomic Absorption Spectrometer (Balls, 1987; Maher, 1982). Limit of detection 5 ng/l; sensitivity 3 ng/l; precision approximately 20% at 10 ng/l (calculated from limited data set).

Total and Faecal Coliforms

Analysis was by sterile serial dilution, membrane filtration and incubation at 35°C or 44.5°C with METB agar medium (RWCV, 1988).

Petroleum Utilizing Bacteria

Analysis was serial dilution, addition of hexadecane, incubation at 25°C for 10 days and ennumeration using MPN tables (Larsen, 1986).

Biochemical Oxygen Demand (BOD_5)

Analysis was by serial dilution (in general for the marine samples, addition of seed only and 1:1 dilution with BOD dilution water and addition of seed) and measurement after 5 days at 20°C (± 1°C). Initial and final dissolved oxygen readings were made using a YSI 57 D.O. meter calibrated against moist air. Limit of detection 0.08 mg/l; sensitivity 0.05 mg/l; precision 50% at 1 mg/l.

* all nitrite values are wrong by a factor of 10 (ie. correct values = $\frac{x}{10}$) Jon Brodie pers. comm. to P. Marshall 03/09/2001

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2-N * (µg-at/l)	NO_3-N (µg-at/l)	NH_3-N (µg-at/l)	PN (µg-at/l)	PO_4-P (µg-at/l)	TP (µg-at/l)	SIL.-Si (µg-at/l)	CHL.-a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1355	3/8.	3.2	80					0.2		5.6		4.5	0.14	0.21	1.4		0.39		168						109	41	83
100189	1245	1/8.	1.5	60					0.2	4.6	4	30	12			4.4	11.8	0.16		146		2.0				1600	370	11
240189	1330	4/8.	2.5	110					0.2																			
310189	1200	8/8.	2	97					0.2	5.8	0.9	28.2	10	0.21	10.7		12.0	0.29	1.2	143	1.0	5.1	3.5	<5		515	130	11
160289	1240	7/8.	1.1	16					0.2 0.5	6.4 2.5	10.2 9.0	29 29		0.28	1.6	0.14	5.5		0.39	429		1.7	1.7			2200	680	97

SITE 1

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N μg-at/l	NO_3 -N	NH_4 -N	PN	PO_4 -P	TP	SIL. -Si	CHL. -a mg/l	BOD mg/l	Cu μg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1345	3/8.	3.2	80					0.2	2.1	10		5.9	0.43	0.71	13		0.48		536		0.5				20	0	10
100189	1230	1/8.	1.5	60					0.2 1.0	5 6	26	30	4.4	0.43	0.71	0.29	12.4	0.13	0.52	28		1.9				1400	360	24
240189	1310	4/8.	2.5	110					0.2					1.1	0.71													
310189	1145	8/8.	2.0	97					0.2 1.0	2.7 0.3	2.5 29	29 30	4.5	0.36	0.07	0.14	11.4	0.16	0.74	182		0.5	24	<5		185	84	
160289	1250	8/8.	1.1	16					0.2 0.5	7.1 6.6	0.02 15.2	28.5 30	2.1	3.8	0.07		5.3	0.29	0.90		0.5	2.8	3.5			800	318	2.6

SITE 2

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2-N µg-at/l	NO_3-N µg-at/l	NH_3-N µg-at/l	PN µg-at/l	PO_4-P µg-at/l	TP µg-at/l	SIL.-Si µg-at/l	CHL.-a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC Org./100ml	FC Org./100ml	TH x 10 Org./100ml
231288	1440	3/8.	3.2	90	0.2	80	2	>2	0.2	9	36		1.1	0.93	0.64			0.19	0.84	3.0		0.36		<5		0	0	3.1
									1.0	8.8																		
									2.0	8.9													6.7					
100189	1312	1/8.	2.8	60	0.02	80	5.5	>5.5	0.2	8.6	32	29	2.9	0.14	0.50	0.4	3.3	0.10	0.39	2.6	1.0	1.4	1.2	<5		0	0	3.6
									1.0	8.7	32	30																
									2.0	8.7	32	30																
									3.0	8.7	32	30																
									4.0	8.8	32	30	1.8	0.79	0.79	0.79	3.4	0.36	0.90	2.4			3	<5				
240189	1315	6/8.	7.7	110	0.8	110	3	2	0.2				5			<0.07	5.6	0.07	0.19	3.9	0.2	0.94	0.15	<5		0	0	2.8
310189	1045	8/8.	1.5	0	0.03	70	3.2	>3.2	0.2	6.3	33	28.2	0.2	0.79	0.71	0.29	4.4	0.10	0.32	2.6		0.38	2.2	<5		29	0	0.69
									1.0	6.5	33	28																
									2.0	7	33	28	0.8	0.93	1.1			0.10	0.58	2.3			5.0	<5				
160289	1202	6/8.	1.4	108	2.0	124	2.3	2	0.2	6.8	32	30	5.8	0.50	0.79	0.14	3.1			6.6	0.2	0.58	4.0	<5		8	4	40
									1.0	7.4	32	29.5																
									2.0	7.8	31	29.5				0.4												

SITE 5

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1500	3/8.	3.0	90	0.05	80	1.0	>1	0.2		35		3.3										0.15	<5		0	0	1.1
100189	1150	1/8.	1.4	80	0.05	90	3.0	>3	0.2		32.5	29	1.9									1.8	1.2	<5	0.1	0	0	2.4
240189	1415	4/8.	6.7	110	0.4	110	1.5	1.3	0.2				12.9									2.4	0.15	<5	0.3	1712	4	1.8
310189	1240	8/8.	3.3	30	0.1	70	1.0	>1	0.2	8.1	33	29	1.0									0.98	2.2	<5		0	0	1
160289									0.2													0.88	4.5	<5	2	24	16	50

SITE 6

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1510	3/8.	3.5	80	1.0	70	5.0	>5	0.2	8.4	35		1.7	0.79	0.71	0.07		0.19	0.52	1.7		0.24	1.2	<5		0	0	0.39
									1.0	8.3																		
									2.0	8.1																		
									3.0	8.1																		
									4.0	8.1	35		3.7	0.93	1.9	0.7		0.47	1.3	2.0			1.2	<5				
100189	1030	1/8.	0.43	60	0.2	80	8.5	5.5	0.2	7.7	32.5	29	1.3			0.43		0.13	0.52	4.1		1.0	0.68	<5		0	0	3.8
									1.0	7.6	32	29																
									2.0	7.4	32	29																
									3.0	7.4	32	29																
									4.0	7.4	32.5	29																
									5.0	7.4	32.5	29																
									6.0	7.5	32.5	29																
									7.0	7.6	32.5	29	1.7	0.21	0.87	0.43	4.5	0.13	0.77	3.4								
240189	1430	3/8.	6.2	110	1.2	110	3.2	3.0	0.2				6.8	0.5	0.58	0.21	4.6	0.10	0.44	2.9	0.4	1.6	0.7	<5		20	0	5.9
310189	1355	8/8.	3.2	10	0.2	8	4.0	>4	0.2	8.2	33	28	0.7	1.8	0.93		6.2	0.07	0.22	2.3	0.5	0.24		<5		0	0	0.51
									1.0	7.8	33	28																
									2.0	7.4	33	28																
									3.0	7.6	33	28		1.1	0.93			0.07	0.44	2.4		1.4		<5				
160289	1328	2/8.	4.1	95		95	1.3	>1.3	0.2	9.9	32.5	30	4			0.58	3.4	0.22	1.0	3.5	0.11	1.8		<5		2	0	48
									1.0	10.0	32.5	30																

SITE 7

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1530	3/8.	4.9	80	0.4	50	4.0	>4	0.2	10.3	35		4.2	1.1	0.93	1.4		0.19	0.65	3.6		1.3		<5		0	0	0.41
									1.0	10.2																		
									2.0	8.8																		
									3.0	8.3	36		7.2	0.93	0.87	0.36		0.19	0.58	4.3			0.68	<5				
100189	1050	1/8.	0.9	70	0.1	80	9.0	5.5	0.2	7.5	32	29	2.0	1.1	0.71	0.66		0.16	0.44	3.1	0.05	1.0	0.68	<5		0	0	2.0
									1.0	7.5	32	29																
									2.0	7.4	32	29																
									3.0	7.3	32	29																
									4.0	7.4	32	29																
									5.0	7.5	31.5	29																
									6.0	7.3	32	30																
									7.0	7.4	32	30	2.5	0.50	0.87	0.21	3.3	0.19	0.52	3.6								
240189	1440	3/8.	6.0	100	1.3	100	5.0	3.3					3.2	0.87	0.93	0.69		0.10	0.36	2.7	0.6	0.7	0.56	<5		28	0	1.3
310189	1420	8/8.	3.0	20	0.1	50	4.5	>4.5	0.2	8.5	33	28.3	0.5	0.93	0.93	0.37	3.0	0.10	0.32	1.6		1.2	4.5	<5		0	0	
									1.0	8.5	33	28.3																
									2.0	7.8	33	28.3																
									3.0	7.6	33	28.2	0.6	2.0	0.79	0.35		0.10	0.39	2.6			16	<5				
160289	1329	2/8.	2.7	93		93	2.1	>2.1	0.2	10.0	32.5	30	5.5	0.66	0.87	0.50	3.1	0.22	7.3	205	0.31	1.4	1.8			30	0	12
									1.0	10.4	32.5	30																
									2.0	10.4	32.5	30																

SITE 8

DATE	TIME	CLOUD COVER	WIND SPEED	WIND DIR.	WAVE HEIGHT	WAVE DIR.	TOTAL DEPTH	CLARITY (SECCHI DEPTH)	SAMPLE DEPTH	DO	SAL.	TEMP.	SS	NO_2 -N	NO_3 -N	NH_3 -N	PN	PO_4 -P	TP	SIL. -Si	CHL. -a	BOD	Cu	TBTO	AR. HYD.	TC	FC	TH x 10
			m/s		m		m	m	m	mg/l		°C	mg/l	µg-at/l							mg/l	mg/l	µg/l	ng/l	g/l C.E.	0/100ml	0/100ml	0/100ml
231288	1545	2/8.	3.8	50	0.4	80	1.0	>1	0.2		35		1.3									0.82	0.15	<5		0	0	0.65
100189	1030	1/8.	1.5	90		90	4.0	>4	0.2		32		1.9									0.40	2.6	<5	0.1	4	0	5.5
240189	1450	3/8.	5.2	90	0.8	90	4.8	4.6	0.2				2.6									0.50	<0.07	<5	0.3	860	0	0.76
310189	1410	8/8.	2.7	40	0.1	80	3.0	>3	0.2	14.5	33	29	0.4									0.84	0.12	<5		0	0	0.37
160289	1350	3/8.	4.4	82		82	3.1	>3.1	0.2				3.5								0.93	1.7	1.4	<5	0.2	4	0	11

SITE 9

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1600	3/8.	2.0	70	0.05	100	2.0	2.0	0.2 1.0	9.6 8.9	35		4.8	0.93	0.71	0.14		0.22	0.77			0.12	<0.07	<5		0	0	0.91
100189	1000	1/8.	1.2	120	0.1	120	3.0	>3	0.2 1.0 2.0	7.7 7.8 7.9	31.5 31.5 31.5	29 29 30	15.7	<0.07	0.87	0.36 0.58		0.13	0.52 0.58	3.2		1.4	<0.07	<5		0	0	2.0
240189	1510	4/8.	6.4	90	0.4	90	1.5	>1.5	0.2				3.3	0.36	0.93	1.1		0.47	2.0	3.3	0.4	1.2	<0.07			2	0	0.85
310189	1450	8/8.	0.83	50	0.03	100	1.6	>1.6	0.2	8.0	33	28.2	1.2	0.58	0.93	0.21		0.10	0.45	3.2	1.3	1.1	8.0	<5		0	0	0.4
160289	1418	3/8.	3.1	96		96	3.1	2.8	0.2 1.0 2.0	8.1 7.9 7.9	32 32 32	30 30 29.5	7.8	3.1	0.87	0.21	4.7	0.26	1.0	3.4	1.5	0.95	3.5	<5		0	0	0.52

SITE 10

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2-N µg-at/l	NO_3-N µg-at/l	NH_3-N µg-at/l	PN µg-at/l	PO_4-P µg-at/l	TP µg-at/l	SIL.-Si µg-at/l	CHL.-a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1255	1/8.	2.5	80	0.1	80	1.8	>1.8	0.2 1.0	10.1 10.0	36		2.6	13	6	39		5				0.66	1.2	<5		0	0	2.1
100189	1347	1/8.	3.0	60	0.01	60	2.3	>2.3	0.2				1.6									1.9	2.5	<5	0.1	0	0	4.3
240189	1245	5/8.	3.6	120	0.6	120	2.0	>2	0.2				6.3									1.5	0.7	<5	0.5	20	0	4.5
310189	1500	0/8.	2.0	30	0.1	70	1.5	>1.5	0.2	14.5	33	29	3.1									2.8	1.4	<5		0	0	1.8
160289	1130	7/8.	2.1	62		122	4.5	3.0	0.2				4.3									0.08	4.0	<5	1.3	10	0	9.1

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l
231288	1235	6/8.	2.9	90	0.2	90	4.0	>4	0.2	7.9	35		3.3
									1.0	8.0			
									2.0	8.0			
									3.0	8.0	36		6.4
100189	1400	1/8.	1.6	60	0.02	70	5.5	>5.5	0.2	8.1	32	30	8.0
									1.0	8.1	32	30	
									2.0	8.3	32	30	
									3.0	8.2	32	30	
									4.0	8.0	32	30	2.8
240189	1230	5/8.	6.4	120	0.8	120	4.2	4.0	0.2				6.3
									3.0				
310189	1450	8/8.	0.93	50	0.03	110	1.6	>1.6	0.2	8.4	33	28.0	1.6
									1.0	7.9	33	28.2	
									2.0	8.1	33	28.4	4.1
160289	1112	6/8.	1.9	120		140	2.2	>2.2	0.2	8.8	32	30	6.9
									1.0	8.9	32	30	
									2.0	8.6	32	30	

DATE	TIME	SAMPLE DEPTH m	NO_2-N	NO_3-N	NH_3-N	PN	PO_4-P	TP	SIL. -Si	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
			µg-at/l														
231288	1235	0.2	0.87	0.36	0.50		0.16	0.58	2.8	0.45	1.6	<0.07	<5		0	0	0.64
		1.0															
		2.0															
		3.0	0.87	0.58	0.66		0.19	0.90	1.9	0.15		2.7	<5				
100189	1400	0.2	0.66	0.87	0.43	6.6	0.13	0.39	2.9	0.05	1.4	<0.07	<5		0	0	2.8
		1.0															
		2.0															
		3.0															
		4.0	0.66	0.87		6.2	0.16	0.77				3.8	<5				
240189	1230	0.2	0.96	0.87	0.07	3.3	0.03	0.26	4.5	0.4	1.1	0.56			2	0	2.0
		3.0										2.2					
310189	1450	0.2	0.87	0.58	0.07	7.0	0.07	0.45	2.9		1.6	0.56	<5		0	0	0.28
		1.0															
		2.0	0.93	0.79	0.21	6.4	0.03	0.39	2.8				<5				
160289	1112	0.2	1.7	0.87	0.43	3.6	0.19	0.77		0.47	0.84	4.5	<5		0	0	11
		1.0															
		2.0															

SITE 12

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1210	6/8.	2.9	110	0.1	80	2.5	>2.5	0.2 1.0 2.0	8.5 8.5 8.5	35		2.2	0.79	2.1	0.64		1.1	1.5	5.2			2.2	<5		0	0	1.4
100189	1510	0/8.	3.5	70	0.01	90	2.5	>2.5	0.2	8.2	32	30	2.0	0.36	0.93	0.58	6.4	0.16	0.68	3.3		1.3		<5		0	0	3.4
240189	1130	4/8.	6.8	120	1.5	120	6.2	4.5	0.2				2.5	0.93	0.93	0.29	3.0	0.07	0.39	4.0	0.8	0.58	0.15	<5		10	0	1.4
310189																												
160289	1018	2/8.	2.8	122		120	3.3	>3.3	0.2 1.0 2.0 3.0	7.6 7.5 7.7 7.9	31 31 32 32	29 29 29 29	3.5	0.71	0.93	1.1	3.4	0.22	0.71	7.3	2	0.54	4.0	<5		2	0	30

SITE 13

DATE	TIME	CLOUD COVER	WIND SPEED m/s	WIND DIR.	WAVE HEIGHT m	WAVE DIR.	TOTAL DEPTH m	CLARITY (SECCHI DEPTH) m	SAMPLE DEPTH m	DO mg/l	SAL.	TEMP. °C	SS mg/l	NO_2 -N µg-at/l	NO_3 -N µg-at/l	NH_3 -N µg-at/l	PN µg-at/l	PO_4 -P µg-at/l	TP µg-at/l	SIL. -Si µg-at/l	CHL. -a mg/l	BOD mg/l	Cu µg/l	TBTO ng/l	AR. HYD. g/l C.E.	TC 0/100ml	FC 0/100ml	TH x 10 0/100ml
231288	1125	6/8.	2.8	110	0.5		4.0	>4	0.2	8.6	35		34	0.87	0.36	<0.07		0.19	0.71	2.1				<5		0	0	5.2
									1.0	8.6																		
									2.0	9.0																		
									3.0	9.3	37		5.5	0.93	0.71	0.50		0.22	0.84	2.1			1.2	<5				
100189	1525	0/8.	2.6	60	0.01	120	1.3	>1.3	0.2	11.1	32	30	3.5	0.14	0.87	0.36	5.8	0.68		1.8		2.6	0.86	<5		0	0	11
240189	1100	4/8.	7.8	120	1.5	120	2.0	>2	0.2				1.4	2.1	0.93	0.21	3.0	0.10	0.52	6.9	0.20	1.6	0.7	<5		0	0	1.5
310189																												
160289	1043	2/8.	3.0	124		124	3.0	>3	0.2	7.6	32	29.5	3.9	0.87	1.6		3.8	0.19	0.58	5.8	0.60	0.56	2.5	<5		0	0	6.1
									1.0	7.7	32	29.5																
									2.0	7.9	32	29.5																
									3.0	8.2	32	29.5																

MAGNETIC QUAYS BASELINE SEDIMENT DATA*

SITE	DATE	TIME	W/SPD m/min	W/DIR DEG	WV/HT m	WV/DIR DEG	SDEP m	TDEP m	CLAR m	CLOUD	SS mg/l
FB1	21/12/88	1120	67	-	-	-	0.2	2.5	>2.5	1/8	1.6
FB2	21/12/88	1139	-	-	-	-	0.2	3.0	>3.0	1/8	2.8
FB2	21/12/88	1139	-	-	-	-	2.0	3.0	>3.0	1/8	2.3
FB3	21/12/88	1149	67	-	-	-	0.2	5.2	5.1	1/8	3.6
FB3	21/12/88	1149	67	60	0.50	70	4.2	5.2	5.1	1/8	8.2
FB4	21/12/88	1200	67	60	0.50	70	0.2	10.0	4.0	1/8	2.7
FB4	21/12/88	1200	67	60	0.50	70	9.0	10.0	4.0	1/8	5.5
AB1	21/12/88	1220	83	140	-	-	0.2	2.3	>2.3	1/8	3.3
AB2	21/12/88	1225	83	110	-	-	0.2	5.6	>5.6	1/8	1.6
AB2	21/12/88	1225	83	110	-	-	4.6	5.6	>5.6	1/8	18.5
AB3	21/12/88	1250	67	-	-	-	0.2	6.5	5.5	1/8	3.0
AB3	21/12/88	1250	67	-	-	-	4.5	6.5	5.5	1/8	3.5
AB4	21/12/88	1240	100	320	-	-	0.2	8.4	5.5	1/8	5.1
AB4	21/12/88	1240	100	320	-	-	7.4	8.4	5.5	1/8	6.9
GB1a	21/12/88	1335	133	340	-	-	0.2	1.5	>1.5	2/8	2.7
GB2a	21/12/88	1345	67	30	0.10	90	0.2	3.7	>3.7	2/8	5.0
GB2a	21/12/88	1345	67	30	0.10	90	2.7	3.7	>3.7	2/8	6.9
GB3a	21/12/88	1400	142	40	0.20	70	0.2	8.5	4.5	2/8	2.0
GB3a	21/12/88	1400	142	40	0.20	70	7.5	8.5	4.5	2/8	5.9
GB4a	21/12/88	1405	175	40	0.20	60	0.2	9.3	3.5	2/8	5.0
GB4a	21/12/88	1405	175	40	0.20	60	8.3	9.3	3.5	2/8	3.1
GB1b	21/12/88	1445	167	70	0.10	80	0.2	1.3	>1.3	3/8	0.6
GB2b	21/12/88	1440	67	68	0.10	68	0.2	7.8	4.8	3/8	1.5
GB2b	21/12/88	1440	67	68	0.10	68	6.8	7.8	4.8	3/8	3.0
GB3b	21/12/88	1430	217	50	0.40	50	0.2	9.0	3.7	3/8	7.6
GB3b	21/12/88	1430	217	50	0.40	50	8.0	9.0	3.7	3/8	5.1
GB4b	21/12/88	1420	217	50	0.30	50	0.2	9.5	3.5	3/8	3.8
GB4b	21/12/88	1420	217	50	0.30	50	8.5	9.5	3.5	3/8	4.2
GB1c	21/12/88	1450	217	75	0.10	75	0.2	1.5	>1.5	3/8	2.3
GB2c	21/12/88	1455	217	40	0.20	54	0.2	7.0	5.0	3/8	1.4
GB2c	21/12/88	1455	217	40	0.20	54	6.0	7.0	5.0	3/8	1.0
GB3c	21/12/88	1505	241	50	0.20	54	0.2	8.5	3.8	3/8	2.3
GB3c	21/12/88	1505	241	50	0.20	54	7.5	8.5	3.8	3/8	2.3
GB4c	21/12/88	-	200	24	0.30	50	0.2	9.5	3.8	3/8	2.6
GB4c	21/12/88	-	200	24	0.30	50	8.5	9.5	3.8	3/8	3.5
GB1d	21/12/88	1525	267	35	0.20	95	0.2	1.5	>1.5	3/8	1.4
GB2d	21/12/88	1530	233	30	0.30	60	0.2	7.0	4.5	4/8	1.7
GB2d	21/12/88	1530	233	30	0.30	60	6.0	7.0	4.5	4/8	7.6
NB1a	21/12/88	1540	67	40	0.10	40	0.2	1.2	>1.2	4/8	1.7
NB2a	21/12/88	1540	183	74	0.20	74	0.2	2.9	>2.9	4/8	3.2
NB3a	21/12/88	-	217	34	0.30	54	0.2	6.7	4.0	4/8	2.9
NB3a	21/12/88	-	217	34	0.30	54	5.7	6.7	4.0	4/8	7.5
NB4a	21/12/88	1555	200	44	0.20	44	0.2	8.0	3.8	4/8	3.9
NB4a	21/12/88	1555	200	44	0.20	44	7.0	8.0	3.8	4/8	5.7
NB1c	21/12/88	1605	183	40	0.20	78	0.2	1.2	>1.2	4/8	1.2
NB2c	21/12/88	1610	150	80	0.30	80	0.2	1.9	>1.9	4/8	1.3
NB3c	21/12/88	1615	167	70	0.30	60	0.2	7.9	4.5	4/8	3.2
NB3c	21/12/88	1615	167	70	0.30	60	6.9	7.9	4.5	4/8	3.7
NB4c	21/12/88	1620	200	25	0.40	46	0.2	8.5	3.4	5/8	4.0
NB4c	21/12/88	1620	200	25	0.40	46	7.5	8.5	3.4	5/8	3.7

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
FB4	29/12/88	1045	341	137	1.00	137	0.2	1.8	1.0	8/8	13.9
FB3	29/12/88	1050	341	135	1.00	135	0.2	4.5	2.5	8/8	8.9
FB3	29/12/88	1050	341	135	1.00	135	3.5	4.5	2.5	8/8	12.4
FB4	29/12/88	1100	340	135	1.00	135	0.2	9.5	4.5	8/8	2.9
FB4	29/12/88	1100	340	135	1.00	135	8.5	9.5	4.5	8/8	2.1
AB2	29/12/88	1130	410	135	1.25	135	0.2	7.0	1.5	8/8	6.6
AB2	29/12/88	1130	410	135	1.25	135	6.0	7.0	1.5	8/8	2.8
FB1	5/01/89	1435	130	130	0.15	130	0.2	1.5	>1.5	6/8	3.1
FB2	5/01/89	1440	130	130	0.25	130	0.2	2.6	>2.6	6/8	4.0
FB30	5/01/89	1445	194	100	0.30	100	0.2	5.0	>5.0	6/8	1.2
FB3	5/01/89	1445	194	100	0.30	100	4.0	5.0	>5.0	6/8	3.3
FB4	5/01/89	1450	195	100	0.30	100	0.2	9.0	6.5	6/8	2.0
FB4	5/01/89	1450	195	100	0.30	100	8.0	9.0	6.5	6/8	14.4
AB1	5/01/89	1455	77	140	0.15	140	0.2	2.2	>2.2	6/8	1.1
AB2	5/01/89	1500	155	90	0.25	105	0.2	6.5	6.5	6/8	3.8
AB2	5/01/89	1500	155	90	0.25	105	5.5	6.5	6.5	6/8	3.4
AB3	5/01/89	1505	204	90	0.25	110	0.2	7.0	6.5	6/8	2.2
AB3	5/01/89	1505	204	90	0.25	110	6.0	7.0	6.5	6/8	4.3
AB4	5/01/89	1510	210	90	0.25	110	0.2	9.2	6.5	6/8	8.5
AB4	5/01/89	1510	210	90	0.25	90	8.2	9.2	6.5	6/8	3.1
NB1a	5/01/89	1135	268	70	0.05	70	0.2	1.6	>1.6	6/8	0.9
NB2a	5/01/89	1130	268	70	0.10	70	0.2	3.0	>3.0	6/8	2.7
NB3a	5/01/89	1125	268	70	0.05	70	0.2	7.0	5.2	5/8	2.2
NB3a	5/01/89	1125	268	70	0.05	70	6.0	7.0	5.2	5/8	8.5
NB4a	5/01/89	1115	268	70	0.05	70	0.2	8.4	5.0	5/8	3.7
NB4a	5/01/89	1115	268	70	0.05	70	7.4	8.4	5.0	5/8	3.2
NB1b	5/01/89	1212	228	70	0.20	70	0.2	1.5	>1.5	6/8	2.6
NB2b	5/01/89	1210	228	70	0.20	70	0.2	3.0	>3.0	6/8	3.4
NB3b	5/01/89	1200	228	70	0.20	70	0.2	6.5	5.0	6/8	4.4
NB3b	5/01/89	1200	228	70	0.20	70	5.5	6.5	5.0	6/8	2.7
NB1c	5/01/89	1105	118	70	0.05	90	0.2	2.0	>2.0	5/8	1.3
NB2c	5/01/89	1102	118	70	0.05	90	0.2	2.7	>2.7	5/8	2.9
NB3c	5/01/89	1100	118	70	0.05	90	0.2	8.8	5.5	5/8	3.3
NB3c	5/01/89	1100	118	70	0.05	90	7.8	8.8	5.5	5/8	2.9
NB4c	5/01/89	1050	118	70	0.05	90	0.2	9.3	6.0	5/8	3.2
NB4c	5/01/89	1050	118	70	0.05	90	8.3	9.3	6.0	5/8	3.2
NB1d	5/01/89	1030	72	100	0.05	100	0.2	3.0	>3.0	4/8	6.7
NB2d	5/01/89	1035	70	100	0.05	100	0.2	6.6	6.0	4/8	3.2
NB2d	5/01/89	1035	70	100	0.05	100	5.6	6.6	6.0	4/8	6.8
NB3d	5/01/89	1040	70	100	0.05	100	0.2	8.5	5.5	5/8	6.3
NB3d	5/01/89	1040	70	100	0.05	100	7.5	8.5	5.5	5/8	6.5
GB1a	5/01/89	1340	160	110	0.05	110	0.2	1.5	>1.5	6/8	2.5
GB2a	5/01/89	1345	152	95	0.15	105	0.2	5.0	>5.0	6/8	3.5
GB2a	5/01/89	1345	152	95	0.15	105	4.0	5.0	>5.0	6/8	3.2
GB3a	5/01/89	1350	126	90	0.20	90	0.2	8.5	5.5	6/8	2.0
GB3a	5/01/89	1350	126	90	0.20	90	7.5	8.5	5.5	6/8	3.6
GB4a	5/01/89	1355	79	80	0.25	90	0.2	10.5	5.5	6/8	1.2
GB4a	5/01/89	1355	79	80	0.25	90	9.5	10.5	5.5	6/8	2.5
GB1b	5/01/89	1425	90	75	0.05	90	0.2	0.5	>0.5	6/8	2.6
GB2b	5/01/89	1415	87	75	0.10	90	0.2	4.5	>4.5	6/8	3.6
GB2b	5/01/89	1415	87	75	0.10	90	3.5	4.5	>4.5	6/8	3.4
GB3b	5/01/89	1405	100	75	0.20	90	0.2	9.0	6.0	6/8	2.3

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
GB3b	5/01/89	1405	100	75	0.20	90	8.0	9.0	6.0	6/8	4.6
GB1c	5/01/89	1230	195	90	0.10	90	0.2	0.9	>0.9	5/8	0.6
GB2c	5/01/89	1235	200	90	0.20	90	0.2	1.4	>1.4	5/8	1.9
GB3c	5/01/89	1240	250	90	0.30	90	0.2	8.0	5.5	5/8	1.6
GB3c	5/01/89	1240	250	90	0.30	90	7.0	8.0	5.5	5/8	1.4
GB4c	5/01/89	1245	275	90	0.40	90	0.2	10.5	6.0	5/8	1.9
GB4c	5/01/89	1245	275	90	0.40	90	9.5	10.5	6.0	5/8	47.2
GB1d	5/01/89	1215	204	80	0.25	80	0.2	3.0	>3.0	6/8	3.2
GB2d	5/01/89	1220	357	80	0.30	80	0.2	8.0	5.0	6/8	3.1
GB2d	5/01/89	1220	357	80	0.30	80	7.0	8.0	5.0	6/8	3.6
PB1	5/01/89	1000	136	128	0.10	128	0.2	2.0	>2.0	4/8	4.7
PB2	5/01/89	1005	136	128	0.10	128	0.2	2.7	>2.7	4/8	7.1
PB3	5/01/89	1007	136	128	0.10	128	0.2	4.5	2.5	4/8	8.1
PB3	5/01/89	1007	136	128	0.10	128	3.5	4.5	2.5	4/8	10.3
PB4	5/01/89	1010	90	95	0.15	110	0.2	6.0	5.0	4/8	6.1
PB4	5/01/89	1010	90	95	0.15	110	5.0	6.0	5.0	4/8	5.2
FB1	12/01/89	1525	67	52	0.00	52	0.2	2.2	>2.2	1/8	0.4
FB2	12/01/89	1521	133	52	0.00	52	0.2	2.7	>2.7	1/8	1.5
FB3	12/01/89	1514	133	52	0.00	52	0.2	7.2	5.5	1/8	1.6
FB3	12/01/89	1514	133	52	0.00	52	6.2	7.2	5.5	1/8	1.8
FB4	12/01/89	1507	133	52	0.00	52	0.2	8.2	6.0	1/8	0.7
FB4	12/01/89	1507	133	52	0.00	52	7.2	8.2	6.0	1/8	3.2
AB1	12/01/89	1441	133	142	0.00	142	0.2	3.0	>3.0	3/8	0.6
AB2	12/01/89	1445	233	120	0.05	60	0.2	6.0	>6.0	2/8	1.1
AB2	12/01/89	1445	233	120	0.05	60	5.0	6.0	>6.0	2/8	3.5
AB3	12/01/89	1451	266	61	0.05	61	0.2	9.0	6.0	2/8	2.5
AB3	12/01/89	1451	266	61	0.05	61	8.0	9.0	6.0	2/8	1.6
AB4	12/01/89	1459	233	49	0.10	49	0.2	9.7	7.5	2/8	1.9
AB4	12/01/89	1459	233	49	0.10	49	8.7	9.7	7.5	2/8	2.0
PB1	12/01/89	1407	150	172	0.05	210	0.2	2.1	>2.1	2/8	7.3
PB2	12/01/89	1410	117	168	0.05	198	0.2	3.7	2.5	2/8	4.1
PB2	12/01/89	1410	117	168	0.05	198	2.7	3.7	2.5	2/8	4.5
PB3	12/01/89	1416	67	168	0.05	198	0.2	5.1	2.1	2/8	6.4
PB3	12/01/89	1416	67	168	0.05	198	4.1	5.1	2.1	2/8	7.8
PB4	12/01/89	1421	67	224	0.10	224	0.2	5.8	4.2	2/8	2.3
PB4	12/01/89	1421	67	224	0.10	224	4.8	5.8	4.2	2/8	3.0
NB1a	12/01/89	1025	67	184	0.00	184	0.2	2.0	>2.0	4/8	17.7
NB2a	12/01/89	1028	-	-	0.00	184	0.2	4.9	>4.9	3/8	18.0
NB2a	12/01/89	1028	-	-	0.00	184	3.9	4.9	>4.9	3/8	20.3
NB3a	12/01/89	1035	-	-	0.00	150	0.2	8.0	6.0	3/8	18.8
NB3a	12/01/89	1035	-	-	0.00	150	7.0	8.0	6.0	3/8	32.3
NB4a	12/01/89	1041	67	150	0.00	150	0.2	9.1	5.0	3/8	21.6
NB4a	12/01/89	1041	67	150	0.00	150	8.1	9.1	5.0	3/8	0.8
NB1b	12/01/89	1103	133	192	0.05	192	0.2	3.0	>3.0	3/8	0.9
NB2b	12/01/89	1056	167	220	0.05	220	0.2	6.2	5.2	3/8	4.2
NB2b	12/01/89	1056	167	220	0.05	220	5.2	6.2	5.2	3/8	2.2
NB3b	12/01/89	1049	67	150	0.00	150	0.2	7.9	6.1	3/8	2.6
NB3b	12/01/89	1049	67	150	0.00	150	6.9	7.9	6.1	3/8	4.1
NB1c	12/01/89	1112	67	-	0.00	-	0.2	2.5	>2.5	3/8	1.6
NB2c	12/01/89	1117	83	144	0.00	114	0.2	3.0	>3.0	3/8	0.5
NB3c	12/01/89	1123	117	161	0.05	161	0.2	9.0	4.5	3/8	3.9
NB3c	12/01/89	1123	117	161	0.05	210	8.0	9.0	4.5	3/8	1.8

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
NB4c	12/01/89	1131	67	220	0.05	235	0.2	9.9	5.0	3/8	1.9
NB4c	12/01/89	1131	67	220	0.05	235	8.9	9.9	5.0	3/8	6.0
NB1d	12/01/89	-	67	150	0.00	150	0.2	4.0	>4.0	2/8	2.9
NB1d	12/01/89	-	67	150	0.00	150	3.0	4.0	>4.0	2/8	2.1
NB2d	12/01/89	1147	67	150	0.00	150	0.2	6.4	6.0	2/8	2.4
NB2d	12/01/89	1147	67	150	0.00	150	5.4	6.4	6.0	2/8	0.7
NB3d	12/01/89	1139	67	192	0.05	192	0.2	9.5	5.0	3/8	2.5
NB3d	12/01/89	1139	67	192	0.05	192	8.5	9.5	5.0	3/8	5.1
GB1a	12/01/89	1311	117	150	0.05	150	0.2	3.0	>3.0	2/8	3.4
GB2a	12/01/89	1315	117	150	0.05	150	0.2	7.8	>5.0	3/8	7.1
GB2a	12/01/89	1315	117	150	0.05	150	6.8	7.8	>5.0	3/8	2.1
GB3a	12/01/89	1325	67	150	0.05	150	0.2	10.0	5.5	3/8	2.1
GB3a	12/01/89	1325	67	150	0.05	150	9.0	10.0	5.5	3/8	0.6
GB4a	12/01/89	1247	100	160	0.05	150	0.2	10.0	5.5	2/8	2.1
GB4a	12/01/89	1247	100	150	0.05	150	9.0	10.0	5.5	2/8	4.0
GB1b	12/01/89	1306	117	150	0.05	150	0.2	2.0	>2.0	2/8	2.5
GB2b	12/01/89	1302	100	150	0.05	150	0.2	2.5	>2.5	2/8	4.1
GB3b	12/01/89	1255	100	150	0.05	150	0.2	10.0	5.0	2/8	3.0
GB3b	12/01/89	1255	100	150	0.05	150	9.0	10.0	5.0	2/8	3.2
GB1c	12/01/89	1225	67	150	0.00	150	0.2	2.2	>2.2	2/8	1.2
GB2c	12/01/89	1230	100	150	0.00	150	0.2	3.0	>3.0	2/8	2.2
GB3c	12/01/89	1234	83	150	0.05	140	0.2	9.0	5.8	2/8	2.6
GB3c	12/01/89	1234	83	150	0.05	140	8.0	9.0	5.8	2/8	2.8
GB4c	12/01/89	1240	100	150	0.05	150	0.2	10.0	5.0	2/8	3.8
GB4c	12/01/89	1240	100	150	0.05	150	9.0	10.0	5.0	2/8	3.2
GB1d	12/01/89	1212	67	150	0.00	150	0.2	4.7	>4.7	2/8	3.7
GB1d	12/01/89	1212	67	150	0.00	150	3.7	4.7	>4.7	2/8	12.4
GB2d	12/01/89	1219	100	150	0.05	150	0.2	9.5	5.7	2/8	1.9
GB2d	12/01/89	1219	100	150	0.05	150	8.5	9.5	5.7	2/8	2.4
FB1	19/01/89	1625	80	119	0.05	119	0.2	1.8	>1.8	1/8	1.5
FB2	19/01/89	1623	128	92	0.10	92	0.2	2.0	>2.0	1/8	3.2
FB3	19/01/89	1618	155	92	0.50	92	0.2	9.2	3.5	1/8	3.5
FB3	19/01/89	1618	155	92	0.50	92	8.2	9.2	3.5	1/8	2.6
FB4	19/01/89	1611	136	65	0.50	65	0.2	8.6	3.5	1/8	2.4
FB4	19/01/89	1611	136	65	0.50	65	7.6	8.6	3.5	1/8	3.5
AB1	19/01/89	1604	138	126	0.10	126	0.2	2.0	>2.0	1/8	2.9
AB2	19/01/89	1456	181	102	0.20	102	0.2	5.3	5.0	0/8	0.6
AB2	19/01/89	1456	181	102	0.20	102	4.3	5.3	5.0	0/8	3.2
AB3	19/01/89	1549	172	64	0.40	64	0.2	10.0	3.7	1/8	2.0
AB3	19/01/89	1549	172	64	0.40	64	9.0	10.0	3.7	1/8	3.1
AB4	19/01/89	1541	204	75	0.30	75	0.2	10.2	4.0	1/8	2.1
AB4	19/01/89	1541	204	75	0.30	75	9.2	10.2	4.0	1/8	2.7
PB1	19/01/89	1043	90	154	0.10	194	0.2	2.0	>2.0	1/8	3.2
PB2	19/01/89	1050	38	154	0.10	154	0.2	2.5	>2.5	1/8	2.6
PB3	19/01/89	1056	91	110	0.20	110	0.2	5.5	3.1	1/8	2.4
PB3	19/01/89	1056	91	110	0.20	110	4.5	5.5	3.1	1/8	4.1
PB4	19/01/89	1103	57	82	0.20	82	0.2	5.3	3.1	1/8	1.2
PB4	19/01/89	1103	57	82	0.20	82	4.3	5.3	3.1	1/8	2.1
NB1a	19/01/89	1254	68	140	0.00	140	0.2	1.5	>1.5	1/8	1.9
NB2a	19/01/89	1247	87	90	0.05	90	0.2	3.4	>3.4	1/8	1.1
NB2a	19/01/89	1247	87	90	0.05	90	2.4	3.4	>3.4	1/8	1.1
NB3a	19/01/89	1239	42	90	0.00	90	0.2	7.0	5.5	1/8	0.8

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
NB3a	19/01/89	1239	42	90	0.00	90	6.0	7.0	5.5	1/8	2.9
NB4a	19/01/89	1232	18	88	0.00	88	0.2	8.1	5.0	1/8	1.8
NB4a	19/01/89	1232	18	88	0.00	88	7.1	8.1	5.0	1/8	0.9
NB1b	19/01/89	1210	70	129	0.00	129	0.2	1.5	>1.5	1/8	0.2
NB2b	19/01/89	1216	35	129	0.00	129	0.2	2.0	>2.0	1/8	0.3
NB3b	19/01/89	1221	44	129	0.00	129	0.2	6.6	6.2	1/8	1.9
NB3b	19/01/89	1221	44	129	0.00	129	5.6	6.6	6.2	1/8	3.3
NB1c	19/01/89	1145	23	110	0.05	110	0.2	1.9	>1.9	1/8	0.9
NB2c	19/01/89	1151	52	125	0.05	125	0.2	5.5	5.0	1/8	1.7
NB2c	19/01/89	1151	52	125	0.05	125	4.5	5.5	5.0	1/8	1.5
NB3c	19/01/89	1200	52	142	0.05	142	0.2	8.8	5.1	1/8	0.3
NB3c	19/01/89	1200	52	142	0.05	142	7.8	8.8	5.1	1/8	2.8
NB4c	19/01/89	1115	0	66	0.05	103	0.2	9.2	5.5	1/8	3.1
NB4c	19/01/89	1115	0	66	0.05	103	8.2	9.2	5.5	1/8	1.4
NB1d	19/01/89	1140	0	127	0.05	127	0.2	2.7	>2.7	1/8	1.3
NB2d	19/01/89	1134	0	127	0.05	127	0.2	7.1	4.8	1/8	0.2
NB2d	19/01/89	1134	0	127	0.05	127	6.1	7.1	4.8	1/8	1.8
NB3d	19/01/89	1127	0	104	0.05	104	0.2	9.0	5.2	1/8	3.6
NB3d	19/01/89	1127	0	104	0.05	104	8.0	9.0	5.2	1/8	1.1
GB1a	19/01/89	1506	201	122	0.05	122	0.2	1.5	>1.5	1/8	3.1
GB2a	19/01/89	1512	168	104	0.10	104	0.2	6.8	4.7	1/8	2.0
GB2a	19/01/89	1512	168	104	0.10	104	5.8	6.8	4.7	1/8	1.9
GB3a	19/01/89	1519	171	84	0.20	84	0.2	8.9	3.8	1/8	3.2
GB3a	19/01/89	1519	171	84	0.20	84	7.9	8.9	3.8	1/8	2.5
GB4a	19/01/89	1526	220	75	0.30	75	0.2	10.0	4.0	1/8	3.4
GB4a	19/01/89	1526	220	75	0.30	75	9.0	10.0	4.0	1/8	2.4
GB1b	19/01/89	-	220	122	0.10	122	0.2	0.7	>0.7	1/8	1.8
GB2b	19/01/89	1451	100	95	0.10	95	0.2	4.5	>4.5	1/8	1.7
GB2b	19/01/89	1451	100	95	0.10	95	3.5	4.5	>4.5	1/8	1.7
GB3b	19/01/89	1443	199	95	0.30	95	0.2	8.5	5.1	1/8	3.4
GB3b	19/01/89	1443	199	95	0.30	95	7.5	8.5	5.1	1/8	2.4
GB1c	19/01/89	1406	172	108	0.00	108	0.2	1.0	>1.0	1/8	5.2
GB2c	19/01/89	1412	167	95	0.10	95	0.2	4.8	>4.8	1/8	0.9
GB2c	19/01/89	1412	167	95	0.10	95	3.8	4.8	>4.8	1/8	1.2
GB3c	19/01/89	1420	147	64	0.40	64	0.2	8.7	5.0	1/8	1.8
GB3c	19/01/89	1420	147	64	0.40	64	7.7	8.7	5.0	1/8	1.6
GB4c	19/01/89	1431	128	54	0.30	54	0.2	9.4	4.2	1/8	1.1
GB4c	19/01/89	1431	128	54	0.30	54	8.4	9.4	4.2	1/8	2.1
GB1d	19/01/89	1359	84	89	0.20	89	0.2	2.5	>2.5	1/8	1.4
GB2d	19/01/89	1350	161	88	0.30	88	0.2	8.3	5.4	1/8	1.6
GB2d	19/01/89	1350	161	88	0.30	88	7.3	8.3	5.4	1/8	2.8
FB2	2/02/89	1430	473	68	0.50	68	0.2	2.3	1.4	8/8	13.5
FB3	2/02/89	1430	473	68	0.50	68	0.2	4.5	2.0	8/8	0.8
FB4	2/02/89	1430	473	68	0.50	68	0.2	9.0	2.0	8/8	0.5
AB2	2/02/89	-	486	92	1.00	92	0.2	4.6	3.0	8/8	0.6
AB3	2/02/89	-	486	92	1.00	92	0.2	9.3	3.8	8/8	4.4
AB4	2/02/89	-	486	92	1.00	92	0.2	9.5	3.7	8/8	3.1
PB1	2/02/89	-	200	70	0.80	70	0.2	1.1	>1.1	8/8	4.2
PB2	2/02/89	-	200	70	0.80	70	0.2	3.1	1.7	8/8	1.3
PB3	2/02/89	-	200	70	0.80	70	0.2	4.2	2.1	8/8	4.1
PB4	2/02/89	-	200	70	0.80	70	0.2	4.0	2.4	8/8	3.7

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
NB1a	2/02/89	-	156	84	0.50	84	0.2	3.0	>3.0	8/8	2.4
NB2a	2/02/89	-	156	84	0.50	84	0.2	5.1	3.5	8/8	2.0
NB3a	2/02/89	1151	156	84	0.50	84	0.2	6.0	4.3	8/8	2.8
NB1c	2/02/89	-	156	84	0.50	84	0.2	2.2	>2.2	8/8	8.1
NB2c	2/02/89	-	156	84	0.50	84	0.2	2.6	1.9	8/8	8.6
NB3c	2/02/89	-	156	84	0.50	84	0.2	7.0	3.5	8/8	2.1
NB4c	2/02/89	-	156	84	0.50	84	0.2	7.0	2.5	8/8	3.9
NB1d	2/02/89	-	156	84	0.50	84	0.2	2.6	2.4	8/8	5.5
NB2d	2/02/89	-	156	84	0.50	84	0.2	5.0	2.5	8/8	5.8
NB3d	2/02/89	-	156	84	0.50	84	0.2	7.4	3.7	8/8	20.9
GB1a	2/02/89	-	346	110	0.50	110	0.2	1.6	>1.6	8/8	3.9
GB2a	2/02/89	1049	346	110	0.50	110	0.2	5.0	4.5	8/8	1.7
GB3a	2/02/89	-	346	110	0.50	110	0.2	9.0	3.5	8/8	2.5
GB1b	2/02/89	-	346	110	0.50	110	0.2	-.9	-.9	8/8	3.8
GB2b	2/02/89	-	346	110	0.50	110	0.2	-.9	-.9	8/8	1.8
GB3b	2/02/89	-	346	110	0.50	110	0.2	7.3	-.9	8/8	0.7
GB1d	2/02/89	-	346	110	0.50	110	0.2	3.3	2.2	8/8	6.4
GB2d	2/02/89	-	346	110	0.50	110	0.2	7.0	3.8	8/8	1.7
FB1	9/02/89	1010	251	109	0.50	109	0.2	2.8	2.2	8/8	2.7
FB2	9/02/89	1021	251	109	0.50	109	0.2	2.5	2.2	8/8	4.1
FB3	9/02/89	1025	251	109	0.50	109	0.2	7.3	1.9	8/8	3.8
FB3	9/02/89	1025	251	109	0.50	109	6.3	7.3	1.9	8/8	4.0
FB4	9/02/89	1029	251	109	0.50	109	0.2	10.0	2.8	8/8	0.8
FB4	9/02/89	1029	251	109	0.50	109	9.0	10.0	2.8	8/8	3.9
AB1	9/02/89	-	315	140	0.40	126	0.2	5.0	1.7	8/8	6.0
AB1	9/02/89	-	315	140	0.40	126	4.0	5.0	1.7	8/8	6.5
AB3	9/02/89	-	315	140	0.40	126	0.2	9.7	3.0	8/8	0.9
AB3	9/02/89	-	315	140	0.40	126	8.7	9.7	3.0	8/8	3.5
AB4	9/02/89	-	315	140	0.40	126	0.2	11.0	3.1	8/8	2.8
AB4	9/02/89	-	315	140	0.40	126	10.0	11.0	3.1	8/8	2.2
PB1	9/02/89	1425	380	90	0.30	90	0.2	1.2	>1.2	6/8	-.9
PB2	9/02/89	1423	380	90	0.30	90	0.2	3.6	1.6	6/8	7.6
PB2	9/02/89	1423	380	90	0.30	90	2.6	3.6	1.6	6/8	1.2
PB3	9/02/89	1420	380	90	0.30	90	0.2	4.8	1.9	6/8	4.9
PB3	9/02/89	1420	380	90	0.30	90	3.8	4.8	1.9	6/8	5.7
PB4	9/02/89	1415	380	90	0.30	90	0.2	5.0	2.1	6/8	4.0
PB4	9/02/89	1415	380	90	0.30	90	4.0	5.0	2.1	6/8	5.6
NB2a	9/02/89	1320	235	120	0.20	120	0.2	1.3	>1.3	7/8	3.2
NB3a	9/02/89	1320	235	120	0.20	120	0.2	6.5	3.3	7/8	4.9
NB3a	9/02/89	1320	235	12	2.00	120	5.5	6.5	3.3	7/8	6.9
NB4a	9/02/89	1305	235	120	0.20	120	0.2	7.0	2.9	7/8	6.2
NB4a	9/02/89	1305	235	120	0.20	120	6.0	7.0	2.9	7/8	2.7
NB1b	9/02/89	1315	235	120	0.20	120	0.2	1.8	>1.8	7/8	2.1
NB2b	9/02/89	1315	235	120	0.20	120	0.2	2.3	2.3	7/8	5.8
NB3b	9/02/89	1309	235	120	0.20	120	0.2	5.3	4.0	7/8	3.0
NB3b	9/02/89	1309	235	120	0.20	120	4.3	5.3	4.0	7/8	3.4
NB1c	9/02/89	1339	235	120	0.20	120	0.2	1.7	>1.7	8/8	4.3
NB2c	9/02/89	1342	235	120	0.20	120	0.2	7.0	2.5	8/8	4.0
NB2c	9/02/89	1342	235	120	0.20	120	6.0	7.0	2.5	8/8	2.8
NB3c	9/02/89	1345	235	120	0.20	120	0.2	8.0	2.3	8/8	4.1
NB3c	9/02/89	1345	235	120	0.20	120	7.0	8.0	2.3	8/8	4.0
NB4c	9/02/89	1350	235	120	0.20	120	0.2	9.0	2.4	8/8	4.1

SITE	DATE	TIME	W/SPD	W/DIR	WV/HT	WV/DIR	SDEP	TDEP	CLAR	CLOUD	SS
NB4c	9/02/89	1350	235	120	0.20	120	8.0	9.0	2.4	8/8	5.7
NB1d	9/02/89	1358	235	120	0.20	120	0.2	2.8	>2.8	8/8	7.7
NB2d	9/02/89	1253	235	120	0.20	120	0.2	5.7	2.7	8/8	2.1
NB2d	9/02/89	1353	235	120	0.20	120	4.7	5.7	2.7	8/8	4.1
NB3d	9/02/89	1400	235	120	0.20	120	0.2	7.6	2.0	8/8	5.3
NB3d	9/02/89	1400	235	120	0.20	120	6.6	7.6	2.0	8/8	6.3
GB1a	9/02/89	1210	300	142	0.30	142	0.2	2.8	>2.8	8/8	3.2
GB2a	9/02/89	1210	300	142	0.30	142	0.2	7.7	2.5	8/8	1.5
GB2a	9/02/89	1211	300	142	0.30	142	6.7	7.7	2.5	8/8	3.3
GB3a	9/02/89	1209	300	142	0.30	142	0.2	10.0	2.2	8/8	3.3
GB3a	9/02/89	1209	300	142	0.30	142	9.0	10.0	2.2	8/8	3.7
GB4a	9/02/89	1215	300	142	0.30	142	0.2	11.0	2.4	8/8	0.7
GB4a	9/02/89	1215	300	142	0.30	142	10.0	11.0	2.4	8/8	8.0
GB1b	9/02/89	1149	300	142	0.30	142	0.2	2.3	>2.3	8/8	1.1
GB2b	9/02/89	1152	300	142	0.30	142	0.2	2.3	>2.3	8/8	1.2
GB3b	9/02/89	1156	300	142	0.30	142	0.2	9.3	2.3	8/8	4.3
GB3b	9/02/89	1156	300	142	0.30	142	8.3	9.3	2.3	8/8	4.7
GB1c	9/02/89	1130	300	142	0.30	142	0.2	2.1	>2.1	8/8	3.9
GB2c	9/02/89	1135	300	142	0.30	142	0.2	2.5	>2.5	8/8	3.8
GB3c	9/02/89	1140	300	142	0.30	142	0.2	5.1	2.7	8/8	3.4
GB3c	9/02/89	1140	300	142	0.30	142	4.1	5.1	2.7	8/8	4.1
GB4c	9/02/89	1145	300	142	0.30	142	0.2	9.3	2.3	8/8	4.8
GB4c	9/02/89	1145	300	142	0.30	142	8.3	9.3	2.3	8/8	6.4
GB1d	9/02/89	1110	300	142	0.30	142	0.2	4.5	3.0	8/8	6.4
GB1d	9/02/89	1110	300	142	0.30	142	3.5	4.5	3.0	8/8	7.2
GB2d	9/02/89	1115	300	142	0.30	142	0.2	9.7	2.7	8/8	7.4
GB2d	9/02/89	1115	300	142	0.30	142	8.7	9.7	2.7	8/8	4.9

* W/SPD = wind speed, m/s; W/DIR = wind direction, °; WV/HT = wave height, m; WV/DIR = wave direction, °; SDEP = sample depth, m; TDEP = total depth, m; CLAR = clarity, m; CLOUD = cloud cover; SS = suspended solids, mg/l.

TEMPORAL VARIABILITY STUDY

SITECODE	TIME	CC	WDIR	WSPD	WVHT	WVDIR	CLAR	TURB	SS
			DEG	m/s	m	DEG	m	NTU	mg/l
NBD1I-1145	1145	3/8	100	12	0.15	-	>2.0	5	3.0
NBD1I-1215	1215	3/8	60	15	0.2	-	>2.0	10	2.4
NBD1I-1445	1445	7/8	20	20	0.15	-	>1.5	11	3.1
NBD1I-1515	1515	2/8	40	12	0.2	-	>1.5	-	2.2
NBD1I-1800	1800	4/8	80	5	0.15	-	>1.5	13.1	7.5
NBD1I-1830	1830	5/8	60	<4	0.15	-	>1.5	14.6	4.8
NBD1I-2100	2100	-	60	5	0.1	-	>2.0	15.2	4.8
NBD1I-2130	2130	-	70	10	0.1	-	>1.7	13.9	3.7
NBD1I-0000	0000	-	50	8	0.05	-	>1.0	13.6	3.0
NBD1I-0030	0030	-	30	12	0.05	-	>0.5	15.2	3.6
NBD1I-0300	0300	-	-	-	-	-	-	-	-
NBD1I-0330	0330	-	-	-	-	-	-	-	-
NBD1I-0600	0600	-	60	<4	0.05	-	>1.5	15.9	5.0
NBD1I-0630	0630	8/8	70	<4	0.05	-	>1.5	13.8	2.0
NBD1I-0900	0900	8/8	0	<4	0.02	-	>2.8	15.5	2.2
NBD1I-0930	0930	8/8	340	<4	0.1	-	>2.5	13.0	2.6
NBD1O-1230	1230	3/8	80	15	0.6	-	>5.5	11	0.8
NBD1O-1300	1300	3/8	70	25	0.6	-	>5.5	10	0.9
NBD1O-1530	1530	3/8	60	13	0.6	-	>5.0	-	1.0
NBD1O-1600	1600	4/8	60	15	0.7	-	>4.5	-	0.9
NBD1O-1840	1840	4/8	80	12	0.5	-	>4.0	13.7	2.1
NBD1O-1910	1910	-	80	12	0.5	-	-	14.6	1.6
NBD1O-1910	1910	-	80	12	0.5	-	-	12.2	2.8
NBD1O-2210	2210	-	50	10	0.3	-	-	13.7	3.0
NBD1O-0040	0040	-	80	10	0.2	-	-	14	2.9
NBD1O-0110	0110	-	70	<4	0.2	-	>2.5	14	2.7
NBD1O-0340	0340	-	50	6	0.5	-	>2.0	14.0	6.8
NBD1O-0410	0410	-	70	<4	0.3	-	>2.5	15.2	5.8
NBD1O-0640	0640	8/8	90	8	0.3	-	>3.5	13.7	2.5
NBD1O-0710	0710	8/8	260	-	0.35	-	>4.0	13.0	1.5
NBD1O-0940	0940	8/8	270	<4	0.3	-	>4.8	13.8	4.8
NBD1O-1010	1010	8/8	240	<4	0.3	-	>5.0	14.9	3.5
NBD2I-1200	1200	1/8	340	<3	0.05	340	>1.0	12.5	4.9
NBD2I-1230	1230	1/8	340	10	0.05	-	>1.0	14.8	1.5
NBD2I-1500	1500	1/8	90	15	0.15	-	>1.5	14.8	3.1
NBD2I-1530	1530	1/8	80	15	0.2	-	>1.75	14.2	3.3
NBD2I-1800	1800	4/8	80	9	0.1	120	>2.5	17.4	5.9
NBD2I-1830	1830	5/8	50	3	0.05	110	>2.5	18.1	2.5
NBD2I-2100	2100	-	350	15	0.0	-	-	16.5	5.4
NBD2I-2130	2130	-	20	12	0.0	-	-	15.5	1.4
NBD2I-0000	0000	-	-	-	-	-	-	-	-
NBD2O-0030	0030	-	-	-	-	-	-	-	-
NBD2I-0300	0300	-	70	<4	0.0	-	-	17.1	3.2
NBD2I-0330	0300	-	50	<4	0.0	-	-	14.6	1.8
NBD2I-0600	0600	4/8	-	0	0.05	80	-	14.4	1.3
NBD2I-0630	0630	4/8	-	0	0.05	60	>3.0	12.8	2.2
NBD2I-0900	0900	2/8	90	<4	0.0	-	>2.5	16.2	3.2
NBD2I-0930	0930	2/8	50	<4	0.05	110	>2.5	16.9	1.4
NBD2O-1240	1240	1/8	340	9	0.1	-	2.75	14.2	3.1
NBD2O-1310	1310	1/8	70	14	0.1	-	3.75	12.4	3.8
NBD2O-1540	1540	1/8	80	16	0.20	-	4.0	13.4	4.3
NBD2O-1610	1610	1/8	80	16	0.2	-	3.75	12.9	3.4
NBD2O-1840	1840	4/8	50	6	0.4	80	5.0	16.8	2.5
NBD2O-1910	1910	2/8	10	8	0.3	70	-	17.2	1.6
NBD2O-2140	2140	-	0	12	0.1	70	-	16.9	1.9
NBD2O-2210	2210	-	0	14	0.1	70	-	17.3	2.8
NBD2O-0040	0040	-	40	<4	0.1	80	-	15.7	4.1
NBD2O-0110	0110	-	10	11	0.1	80	-	17.2	2.9
NBD2O-0340	0340	-	40	<4	0	-	-	15.3	1.3
NBD2O-0410	0410	-	40	<4	0	-	-	17.1	3.2
NBD2O-0640	0640	3/8	-	0	0.05	80	4.0	16.7	3.1
NBD2O-0710	0710	3/8	90	<4	0.2	50	4.5	14.5	0.8
NBD2O-0940	0940	2/8	20	5	0.1	70	>5.8	17.1	1.7
NBD2O-1010	1010	2/8	30	<4	0.1	70	>6.0	15.9	2.1

TEMPORAL VARIABILITY STUDY

SITECODE	DO2	TEMP	SALI	PH	NO3	NO2	NH4	PHOS	TCOLI	TFC
	mg/l	°C	‰		µg/l N			µg/l P	/100ml	/100ml
NBD1I-1145	5.7	26.6	34.9	8.05	2	9	10	4	0	610
NBD1I-1215	5.8	28.4	33.5	8.22	6	13	2	4	30	1000
NBD1I-1445	7.3	28.9	35.2	8.21	5	13	3	4	1	3480
NBD1I-1515	7.6	29.0	35.5	8.26	5	13	4	5	200	1020
NBD1I-1800	6.2	28.0	34.4	8.26	8	13	11	7	1	910
NBD1I-1830	6.1	28.0	34.0	8.31	4	14	15	4	0	2290
NBD1I-2100	5.8	27.9	34.0	8.27	1	9	3	5	0	7260
NBD1I-2130	5.8	27.8	31.0	8.27	3	14	6	5	0	9400
NBD1I-0000	5.2	27.0	34.0	8.39	0	13	27	5	1	3200
NBD1I-0030	4.7	26.8	33.6	8.27	1	14	4	5	0	1920
NBD1I-0300	-	-	-	-	-	-	-	-	-	-
NBD1I-0330	-	-	-	-	-	-	-	-	-	-
NBD1I-0600	4.9	27.4	33.0	8.09	5	15	16	13	1	1000
NBD1I-0630	4.8	27.4	33.5	8.10	6	9	34	5	0	420
NBD1I-0900	-	-	-	8.05	2	11	0	5	0	530
NBD1I-0930	-	-	-	8.09	3	11	8	7	1	320
NBD10-1230	6.6	28.1	35.0	8.21	9	13	30	4	0	120
	.3									
NBD10-1300	6.8	27.8	34.9	8.22	3	12	5	4	0	120
NBD10-1530	6.4	28.0	34.5	8.20	1	13	3	4	0	80
NBD10-1600	7.0	28.0	35.0	8.22	3	12	4	4	0	220
NBD10-1840	6.9	22.0	31.0	8.32	4	15	39	7	0	1870
NBD10-1910	6.2	28.0	31.0	8.31	5	14	8	5	0	2120
NBD10-1910	5.6	27.9	34.0	8.28	6	14	5	6	0	1030
NBD10-2210	5.4	27.9	34.0	8.27	5	15	25	6	0	18000
NBD10-0040	5.1	27.2	34.2	8.10	1	14	19	7	0	4540
NBD10-0110	5.1	27.2	34.0	8.30	7	12	2	3	200	1320
NBD10-0340	4.5	27.6	34.0	8.07	10	15	3	7	0	1690
NBD10-0410	4.6	27.6	34.2	8.09	10	14	10	13	6	5660
NBD10-0640	5.3	27.4	35.5	8.17	5	14	11	5	2	490
NBD10-0710	-	-	-	-	2	8	15	9	7	330
NBD10-0940	-	-	-	8.14	3	15	6	7	22	400
NBD10-1010	-	-	-	8.17	4	13	11	7	52	580
NBD2I-1200	9.2	29	37.5	7.95	6	13	16	2	0	2040
NBD2I-1230	9.3	30	39.0	8.12	7	12	9	3	50	1400
NBD2I-1500	9.8	30	37.5	8.23	5	6	20	7	200	600
NBD2I-1530	9.5	30	38.5	8.24	-	-	16	3	1	400
NBD2I-1800	9.1	30.5	32.0	8.13	0	13	0	9	1	30000
NBD2I-1830	10.	30.5	32	8.14	1	14	15	2	150	20000
	1									
NBD2I-2100	9.5	29.5	32.5	8.12	3	9	0	5	0	15000
NBD2I-2130	9.1	29.5	32.5	8.11	1	14	0	3	0	20000
NBD2I-0000	-	-	-	-	-	-	-	-	-	-
NBD20-0030	-	-	-	-	-	-	-	-	-	-
NBD2I-0300	6.2	29	31.0	8.02	12	13	8	8	0	20000
NBD2I-0330	6.2	29	31	8.01	6	14	0	7	0	15000
NBD2I-0600	6.5	29	31.0	8.07	10	13	7	15	0	2070
NBD2I-0630	6.7	29	31.0	8.07	9	13	3	6	1	20000
NBD2I-0900	5.9	29.5	31.0	7.97	8	13	2	6	0	1880
NBD2I-0930	5.7	30.0	31.0	8.03	7	13	10	6	0	1810
NBD20-1240	7.3	31.0	38.5	7.98	-	-	-	27	100	230
NBD20-1310	7.5	31.0	38.0	8.14	3	14	16	4	0	450
NBD20-1540	7.9	30.0	37.0	8.32	1	14	12	6	200	150
NBD20-1610	7.8	29.0	38.0	8.95	7	12	8	13	0	230
NBD20-1840	7.9	29.5	32.0	8.08	4	13	0	14	0	20000
NBD20-1910	9.3	30.0	33.0	8.12	4	13	11	2	4	30000
NBD20-2140	8.4	29.0	32.5	8.12	1	14	0	4	1	30000
NBD20-2210	8.1	29.5	32.5	8.10	2	11	0	2	0	40000
NBD20-0040	6.9	29.0	31.5	8.07	6	14	1	6	0	30000
NBD20-0110	7.1	29.0	31.5	8.06	4	13	0	6	0	30000
NBD20-0340	7.4	29.0	31.5	8.10	9	12	2	7	0	20000
NBD20-0410	7.3	29.0	31.5	8.11	7	13	4	7	0	8400
NBD20-0640	7.5	29.0	31.0	8.11	5	10	3	8	0	1110
NBD20-0710	7.4	29.0	31.0	8.12	8	11	28	8	0	30000
NBD20-0940	7.4	30.0	31.0	8.01	0	12	6	4	0	590
NBD20-1010	7.5	30.0	31.5	8.11	0	15	7	6	0	1360

SITECODE	TIME	CLOUDCOVER	WINDDIRECT	WINDSPEED	WAVEHEIGHT	WAVEDIRECT
NBD1I-1145	1145	3/8	100	12	0.15	-
NBD1I-1215	1215	3/8	60	15	0.2	-
NBD1I-1445	1445	7/8	20	20	0.15	-
NBD1I-1515	1515	2/8	40	12	0.2	-
NBD1I-1800	1800	4/8	80	5	0.15	-
NBD1I-1830	1830	5/8	60	<4	0.15	-
NBD1I-2100	2100	-	60	5	0.1	-
NBD1I-2130	2130	-	70	10	0.1	-
NBD1I-0000	0000	-	50	8	0.05	-
NBD1I-0030	0030	-	30	12	0.05	-
NBD1I-0300	0300	-	-	-	-	-
NBD1I-0330	0330	-	-	-	-	-
NBD1I-0600	0600	-	60	<4	0.05	-
NBD1I-0630	0630	8/8	70	<4	0.05	-
NBD1I-0900	0900	8/8	0	<4	0.02	-
NBD1I-0930	0930	8/8	340	<4	0.1	-
NBD1O-1230	1230	3/8	80	15	0.6	-
NBD1O-1300	1300	3/8	70	25	0.6	-
NBD1O-1530	1530	3/8	60	13	0.6	-
NBD1O-1600	1600	4/8	60	15	0.7	-
NBD1O-1840	1840	4/8	80	12	0.5	-
NBD1O-1910	1910	-	80	12	0.5	-
NBD1O-1910	1910	-	80	12	0.5	-
NBD1O-2210	2210	-	50	10	0.3	-
NBD1O-0040	0040	-	80	10	0.2	-
NBD1O-0110	0110	-	70	<4	0.2	-
NBD1O-0340	0340	-	50	6	0.5	-
NBD1O-0410	0410	-	70	<4	0.3	-
NBD1O-0640	0640	8/8	90	8	0.3	-
NBD1O-0710	0710	8/8	260	-	0.35	-
NBD1O-0940	0940	8/8	270	<4	0.3	-
NBD1O-1010	1010	8/8	240	<4	0.3	-
NBD2I-1200	1200	1/8	340	<3	0.05	340
NBD2I-1230	1230	1/8	340	10	0.05	-
NBD2I-1500	1500	1/8	90	15	0.15	-
NBD2I-1530	1530	1/8	80	15	0.2	-
NBD2I-1800	1800	4/8	80	9	0.1	120
NBD2I-1830	1830	5/8	50	3	0.05	110
NBD2I-2100	2100	-	350	15	0.0	-
NBD2I-2130	2130	-	20	12	0.0	-
NBD2I-0000	0000	-	-	-	-	-
NBD2O-0030	0030	-	-	-	-	-
NBD2I-0300	0300	-	70	<4	0.0	-
NBD2I-0330	0300	-	50	<4	0.0	-
NBD2I-0600	0600	4/8	-	0	0.05	80
NBD2I-0630	0630	4/8	-	0	0.05	60
NBD2I-0900	0900	2/8	90	<4	0.0	-
NBD2I-0930	0930	2/8	50	<4	0.05	110
NBD2O-1240	1240	1/8	340	9	0.1	-
NBD2O-1310	1310	1/8	70	14	0.1	-
NBD2O-1540	1540	1/8	80	16	0.20	-
NBD2O-1610	1610	1/8	80	16	0.2	-
NBD2O-1840	1840	4/8	50	6	0.4	80
NBD2O-1910	1910	2/8	10	8	0.3	70
NBD2O-2140	2140	-	0	12	0.1	70
NBD2O-2210	2210	-	0	14	0.1	70
NBD2O-0040	0040	-	40	<4	0.1	80
NBD2O-0110	0110	-	10	11	0.1	80
NBD2O-0340	0340	-	40	<4	0	-
NBD2O-0410	0410	-	40	<4	0	-
NBD2O-0640	0640	3/8	-	0	0.05	80
NBD2O-0710	0710	3/8	90	<4	0.2	50
NBD2O-0940	0940	2/8	20	5	0.1	70
NBD2O-1010	1010	2/8	30	<4	0.1	70

SITECODE	CLARITY	TURBIDITY	SUS_SOLIDS	DISS_O2	TEMPERATUR	SALINITY
NBD1I-1145	>2.0	5.0	3.0	5.7	26.6	34.9
NBD1I-1215	>2.0	10.0	2.4	5.8	28.4	33.5
NBD1I-1445	>1.5	11.0	3.1	7.3	28.9	35.2
NBD1I-1515	>1.5	0.0	2.2	7.6	29.0	35.5
NBD1I-1800	>1.5	13.1	7.5	6.2	28.0	34.4
NBD1I-1830	>1.5	14.6	4.8	6.1	28.0	34.0
NBD1I-2100	>2.0	15.2	4.8	5.8	27.9	34.0
NBD1I-2130	>1.7	13.9	3.7	5.8	27.8	31.0
NBD1I-0000	>1.0	13.6	3.0	5.2	27.0	34.0
NBD1I-0030	>0.5	15.2	3.6	4.7	26.8	33.6
NBD1I-0300	-	0.0	0.0	-	-	-
NBD1I-0330	-	0.0	0.0	-	-	-
NBD1I-0600	>1.5	15.9	5.0	4.9	27.4	33.0
NBD1I-0630	>1.5	13.8	2.0	4.8	27.4	33.5
NBD1I-0900	>2.8	15.5	2.2	-	-	-
NBD1I-0930	>2.5	13.0	2.6	-	-	-
NBD1O-1230	>5.5	11.0	0.8	6.6.3	28.1	35.0
NBD1O-1300	>5.5	10.0	0.9	6.8	27.8	34.9
NBD1O-1530	>5.0	0.0	1.0	6.4	28.0	34.5
NBD1O-1600	>4.5	0.0	0.9	7.0	28.0	35.0
NBD1O-1840	>4.0	13.7	2.1	6.9	22.0	31.0
NBD1O-1910	-	14.6	1.6	6.2	28.0	31.0
NBD1O-1910	-	12.2	2.8	5.6	27.9	34.0
NBD1O-2210	-	13.7	3.0	5.4	27.9	34.0
NBD1O-0040	-	14.0	2.9	5.1	27.2	34.2
NBD1O-0110	>2.5	14.0	2.7	5.1	27.2	34.0
NBD1O-0340	>2.0	14.0	6.8	4.5	27.6	34.0
NBD1O-0410	>2.5	15.2	5.8	4.6	27.6	34.2
NBD1O-0640	>3.5	13.7	2.5	5.3	27.4	35.5
NBD1O-0710	>4.0	13.0	1.5	-	-	-
NBD1O-0940	>4.8	13.8	4.8	-	-	-
NBD1O-1010	>5.0	14.9	3.5	-	-	-
NBD2I-1200	>1.0	12.5	4.9	9.2	29	37.5
NBD2I-1230	>1.0	14.8	1.5	9.3	30	39.0
NBD2I-1500	>1.5	14.8	3.1	9.8	30	37.5
NBD2I-1530	>1.75	14.2	3.3	9.5	30	38.5
NBD2I-1800	>2.5	17.4	5.9	9.1	30.5	32.0
NBD2I-1830	>2.5	18.1	2.5	10.1	30.5	32
NBD2I-2100	-	16.5	5.4	9.5	29.5	32.5
NBD2I-2130	-	15.5	1.4	9.1	29.5	32.5
NBD2I-0000	-	0.0	0.0	-	-	-
NBD2O-0030	-	0.0	0.0	-	-	-
NBD2I-0300	-	17.1	3.2	6.2	29	31.0
NBD2I-0330	-	14.6	1.8	6.2	29	31
NBD2I-0600	-	14.4	1.3	6.5	29	31.0
NBD2I-0630	>3.0	12.8	2.2	6.7	29	31.0
NBD2I-0900	>2.5	16.2	3.2	5.9	29.5	31.0
NBD2I-0930	>2.5	16.9	1.4	5.7	30.0	31.0
NBD2O-1240	2.75	14.2	3.1	7.3	31.0	38.5
NBD2O-1310	3.75	12.4	3.8	7.5	31.0	38.0
NBD2O-1540	4.0	13.4	4.3	7.9	30.0	37.0
NBD2O-1610	3.75	12.9	3.4	7.8	29.0	38.0
NBD2O-1840	5.0	16.8	2.5	7.9	29.5	32.0
NBD2O-1910	-	17.2	1.6	9.3	30.0	33.0
NBD2O-2140	-	16.9	1.9	8.4	29.0	32.5
NBD2O-2210	-	17.3	2.8	8.1	29.5	32.5
NBD2O-0040	-	15.7	4.1	6.9	29.0	31.5
NBD2O-0110	-	17.2	2.9	7.1	29.0	31.5
NBD2O-0340	-	15.3	1.3	7.4	29.0	31.5
NBD2O-0410	-	17.1	3.2	7.3	29.0	31.5
NBD2O-0640	4.0	16.7	3.1	7.5	29.0	31.0
NBD2O-0710	4.5	14.5	0.8	7.4	29.0	31.0
NBD2O-0940	>5.8	17.1	1.7	7.4	30.0	31.0
NBD2O-1010	>6.0	15.9	2.1	7.5	30.0	31.5

SITECODE	PH	NITRATE	NITRITE	AMMONIA	ORTHO_PHOS	TOTAL_COLI	TOTAL_FC
NBD1I-1145	8.05	2	9	10	4	0	610
NBD1I-1215	8.22	6	13	2	4	30	1000
NBD1I-1445	8.21	5	13	3	4	1	3480
NBD1I-1515	8.26	5	13	4	5	200	1020
NBD1I-1800	8.26	8	13	11	7	1	910
NBD1I-1830	8.31	4	14	15	4	0	2290
NBD1I-2100	8.27	1	9	3	5	0	7260
NBD1I-2130	8.27	3	14	6	5	0	9400
NBD1I-0000	8.39	0	13	27	5	1	3200
NBD1I-0030	8.27	1	14	4	5	0	1920
NBD1I-0300	–	0	0	0	0	–	–
NBD1I-0330	–	0	0	0	0	–	–
NBD1I-0600	8.09	5	15	16	13	1	1000
NBD1I-0630	8.10	6	9	34	5	0	420
NBD1I-0900	8.05	2	11	0	5	0	530
NBD1I-0930	8.09	3	11	8	7	1	320
NBD1O-1230	8.21	9	13	30	4	0	120
NBD1O-1300	8.22	3	12	5	4	0	120
NBD1O-1530	8.20	1	13	3	4	0	80
NBD1O-1600	8.22	3	12	4	4	0	220
NBD1O-1840	8.32	4	15	39	7	0	1870
NBD1O-1910	8.31	5	14	8	5	0	2120
NBD1O-1910	8.28	6	14	5	6	0	1030
NBD1O-2210	8.27	5	15	25	6	0	18000
NBD1O-0040	8.10	1	14	19	7	0	4540
NBD1O-0110	8.30	7	12	2	3	200	1320
NBD1O-0340	8.07	10	15	3	7	0	1690
NBD1O-0410	8.09	10	14	10	13	6	5660
NBD1O-0640	8.17	5	14	11	5	2	490
NBD1O-0710	–	2	8	15	9	7	330
NBD1O-0940	8.14	3	15	6	7	22	400
NBD1O-1010	8.17	4	13	11	7	52	580
NBD2I-1200	7.95	6	13	16	2	0	2040
NBD2I-1230	8.12	7	12	9	3	50	1400
NBD2I-1500	8.23	5	6	20	7	200	600
NBD2I-1530	8.24	0	0	16	3	1	400
NBD2I-1800	8.13	0	13	0	9	1	30000
NBD2I-1830	8.14	1	14	15	2	150	20000
NBD2I-2100	8.12	3	9	0	5	0	15000
NBD2I-2130	8.11	1	14	0	3	0	20000
NBD2I-0000	–	0	0	0	0	–	–
NBD2O-0030	–	0	0	0	0	–	–
NBD2I-0300	8.02	12	13	8	8	0	20000
NBD2I-0330	8.01	6	14	0	7	0	15000
NBD2I-0600	8.07	10	13	7	15	0	2070
NBD2I-0630	8.07	9	13	3	6	1	20000
NBD2I-0900	7.97	8	13	2	6	0	1880
NBD2I-0930	8.03	7	13	10	6	0	1810
NBD2O-1240	7.98	0	0	0	27	100	230
NBD2O-1310	8.14	3	14	16	4	0	450
NBD2O-1540	8.32	1	14	12	6	200	150
NBD2O-1610	8.95	7	12	8	13	0	230
NBD2O-1840	8.08	4	13	0	14	0	20000
NBD2O-1910	8.12	4	13	11	2	4	30000
NBD2O-2140	8.12	1	14	0	4	1	30000
NBD2O-2210	8.10	2	11	0	2	0	40000
NBD2O-0040	8.07	6	14	1	6	0	30000
NBD2O-0110	8.06	4	13	0	6	0	30000
NBD2O-0340	8.10	9	12	2	7	0	20000
NBD2O-0410	8.11	7	13	4	7	0	8400
NBD2O-0640	8.11	5	10	3	8	0	1110
NBD2O-0710	8.12	8	11	28	9	0	30000
NBD2O-0940	8.01	0	12	6	4	0	590
NBD2O-1010	8.11	0	15	7	6	0	1360

APPENDIX 5

DATE	SPECIES	LENGTH	PEDAL GLAND	PENIS	GONAD	CATEGORY
8/2/89	*N.pullus*	18.6	a	p	m	M
		16.3	a	p	m	M
		17.7	p	p	f	P
		18	a	p	m	M
		17	p	a	f	F
		18.7	a	p	m	M
		18.4	a	a	m	RM
		17.8	a	p	m	M
		18.6	p	p	f	P
		16.8	a	p	m	M
		18	a	p	m	M
		17.6	a	p	m	M
		17.3	a	p	m	M
		19	a	p	m	M
		18.4	a	p	m	M
		18	a	a	m	RM
		18	a	p	m	M
		16.5	p	a	f	F
		16	p	a	f	F
		17.8	p	a	f	F
		17.7	p	a	f	F
		18.1	p	a	f	F
		18.6	a	p	m	M
		17.6	p	a	f	F
		18.3	a	p	m	M
		17.7	a	p	m	M
		18.9	p	a	f	F
		18.3	a	p	m	M
		17.3	a	p	m	M
		17.7	p	p	f	P
	N.luridus	16	a	p	m	M
		20.3	a	a	m	RM
		17.1	p	p	f	P
		18.5	p	p	f	P
		20.2	a	p	m	M
		19.6	p	a	f	F
		16.6	a	p	m	M
		17.7	a	p	m	M
		16.4	a	p	m	M
		18.1	p	a	f	F
		17.1	p	p	f	P
	N.coronata	28.6	p	a	f	F
		23	a	p	m	M
		20.7	p	a	f	F
		20.6	p	a	f	F
		20	p	a	f	F
		19.5	p	a	f	F
24/2/89	*N.pullus*	17.5	a	p	m	M
		15.8	p	a	f	F
		17.7	p	a	f	F
		17.2	p	a	f	F

LEGEND
a: absent
p:present
m:male
f: female
i:indeterminate
M:male
F:female
P:Imposex female
I: Immature
RM: Resorbed or immature male

	N.pullus	17.9	a	p	m	M
		17.4	p	a	f	F
		18.1	a	p	m	M
		17.6	a	p	m	M
		19.1	p	a	f	F
		19.4	p	a	f	F
		18.7	a	p	m	M
		18.5	a	p	m	M
		18	p	p	f	P
		18	p	a	f	F
		17.5	p	a	f	F
		19.5	p	a	f	F
		17.8	p	a	f	F
		17.1	a	p	m	M
		17.2	a	p	m	M
		17.1	p	a	f	F
		16.8	a	p	m	M
		18.5	a	p	m	M
		17.3	p	a	f	F
		17.1	a	p	m	M
		19.6	p	p	f	P
		17.2	p	p	f	P
		17	a	p	m	M
		17.6	p	p	f	P
		16.5	p	a	f	F
		20	p	a	f	F
		17.3	p	a	f	F
		18	p	a	f	F
		17.8	a	p	m	M
		18.4	a	a	m	RM
		18.3	a	p	m	M
		18.5	p	a	f	F
		19.8	a	p	m	M
		16.6	a	p	m	M
		18.6	p	p	f	P
		17.2	a	p	m	M
		17.7	a	p	m	M
		19.1	a	p	m	M
		16.5	p	p	f	P
		18.7	p	a	m	M
		17.8	a	p	m	M
		17.5	p	a	f	F
		16.7	p	a	f	F
		18.6	a	p	m	M
		18.6	p	p	f	P
		18.5	a	p	m	M
		18.7	p	a	f	F
		18.2	p	a	f	F
		17.8	a	p	m	M
	N. luridus	18.3	p	a	f	F
		16.1	p	a	f	F
		18.1	a	p	m	M

	N.luridus	18.1	p	a	f	F
	N.coronata	22.3	p	a	f	F
		21.6	a	p	m	M
		21	p	p	f	P
3/3/89	N.pullus	16.6	p	a	f	F
		16.7	p	a	f	F
		17	p	p	f	P
		18.1	a	p	m	M
		16.5	p	a	f	F
		17.7	p	a	f	F
		16.7	a	p	m	M
		18.3	a	p	m	M
		18	a	a	i	I
		18.5	a	p	m	M
		19	a	p	m	M
		17	a	p	m	M
		17.4	p	a	f	F
		19.4	p	a	f	F
		18.5	a	p	m	M
		16.8	p	a	f	F
		19.6	a	p	m	M
		18.7	p	p	f	P
		18.9	a	p	m	M
		17.9	p	a	f	F
		16	a	p	m	M
		17	a	p	m	M
		19	a	p	m	M
		16.6	a	p	m	M
		15.7	p	a	f	F
		17.7	a	p	m	M
		19.6	p	p	f	P
		16.5	p	a	f	F
		19.1	p	a	f	F
		17.7	p	a	f	F
		20	a	p	m	M
		18	p	p	f	P
		18.6	a	p	m	M
		17.9	a	p	m	M
		17.9	a	p	m	M
		17	a	p	m	M
		17	a	p	m	M
		17	p	a	f	F
		17.2	p	p	f	P
		16	a	p	m	M
		16.7	p	a	f	F
		18	p	p	f	P
		17.1	p	a	f	F
		18	p	p	f	P
		18.3	a	p	m	M
		18.7	p	a	f	F
		18.1	p	p	f	P
		17	p	a	f	F

	N.pullus	17.8	a	p	m	M
		18.8	a	p	m	M
	N.luridus	22	a	p	m	M
		18.5	a	p	m	M
		18	p	a	f	F
		18.3	a	p	m	M
		17.5	a	p	m	M
		19	a	p	m	M
		17.2	a	p	m	M
	N.coronata	18.1	a	a	i	I

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