CORAL COAST MARINA DEVELOPMENT PTY LTD

CORAL COAST RESORT PUBLIC ENVIRONMENTAL REPORT

VOLUME II

VERSION 1

AUGUST 2001

REPORT NO: 2001/94

ATA Environmental
environmental scientists

CORAL COAST MARINA DEVELOPMENT PTY LTD

CORAL COAST RESORT PUBLIC ENVIRONMENTAL REPORT

VOLUME II

VERSION 1

AUGUST 2001

REPORT NO: 2001/94

LIST OF APPENDICES

1. Guidelines For A Draft Public Environmental Report On The Coral Coast Marina Resort Development At Mauds Landing Townsite In Western Australia.

2. Review of Options for Base Load Power Generation for the Coral Coast Resort.

3. Coastal Engineering Study

4. Mauds Landing Biological, Marine Water and Sediment Quality Survey, May 2000

5. Indicative Specific Area Marine Management Plan

6. Boat Source Data and Assumptions

7. Draft Natural Resources Management Agreement

8. Strategy for the Management of Turtles in Bateman Bay and Adjacent Commonwealth Waters

9. Correspondence from the Baiyungu People Providing an Undertaking to Assist in Turtle and Cetacean Management.

10. Coral Coast Resort Qualitative Risk Assessment

APPENDIX 1

GUIDELINES FOR A DRAFT PUBLIC ENVIRONMENTAL REPORT ON THE CORAL COAST MARINA RESORT DEVELOPMENT AT MAUDS LANDING TOWNSITE IN WESTERN AUSTRALIA

GUIDELINES FOR THE CONTENT OF A DRAFT PUBLIC ENVIRONMENT REPORT

ON

THE CORAL COAST MARINA TOURIST DEVELOPMENT AT MAUDS LANDING TOWNSITE IN WESTERN AUSTRALIA

Environment Protection and Biodiversity Conservation Act 1999 (Reference Number 2000/98)

Table of Contents

PREAMBLE 1
GENERAL ADVICE ON GUIDELINES 1
1 General Content 1
2 Format and Style 2
SPECIFIC CONTENT 4
1 General information 4
2 Description of the Action 4
3 Feasible alternatives 4
4 Description of the Environment 5
5 Relevant impacts 5
6 Proposed safeguards and mitigation measures 6
7 Other approvals and conditions 6
8 Consultation 7
9 Information sources provided in the PER 7
10 Environmental record of person proposing to take the action 7
11 Conclusion 8
ATTACHMENT 1 9
The objects and principles of the 9
Environment Protection and Biodiversity Conservation Act 1999 9
Sections 3 and 3A 9
3 Objects of the Act 9
3A Principles of Ecologically Sustainable Development 9
ATTACHMENT 2 10
Matters that must be addressed in a PER 10
(Schedule 4 of the EPBC Act Regulations 2000) 10
1 General information 10
2 Description 10
3 Relevant impacts 11
4 Proposed safeguards and mitigation measures 11
5 Other Approvals and Conditions 12
6 Environmental record of person proposing to take the action 12
7 Information sources 12

GUIDELINES FOR A DRAFT PUBLIC ENVIRONMENT REPORT ON THE CORAL COAST MARINA TOURIST DEVELOPMENT AT MAUDS LANDING TOWNSITE IN WESTERN AUSTRALIA

PREAMBLE

Coral Coast Marina Development Pty Ltd proposes to construct and operate a resort village and inland marina at the Mauds Landing Townsite near Coral Bay in the Shire of Carnarvon, WA. The site is adjacent to Ningaloo Marine Park. The development is intended to provide a range of short-stay and holiday accommodation, permanent residential accommodation, and recreational tourist and commercial services. The proposal also includes the construction and operation of infrastructure and services, including sewerage and wastewater treatment, power and water supply and a landfill site. Construction is anticipated to occur over a seven-year period.

The proposal was referred under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) to the Minister for Environment and Heritage on 28 November 2000. The Minister determined on 8 December 2000 that approval was required as the action has the potential to have a significant impact on the following matters of national environmental significance.

- Commonwealth Marine area (Sections 23 and 24A);
- Listed threatened species and communities (Sections 18 and 18A); and
- Listed migratory species (Sections 20 and 20A).

Following the provision of preliminary information, the Minister determined on 29 January 2001 that the proposed activity be assessed by a Public Environment Report.

Information about the action and its relevant impacts, as outlined below, is to be provided in the draft Public Environment Report. This information should be sufficient to allow the Minister to make an informed decision on whether or not to approve, under Part 9 of the EPBC Act, the taking of the action for the purposes of each controlling provision.

GENERAL ADVICE ON GUIDELINES

1 General Content

The PER should be a stand-alone document. It should contain sufficient information to avoid the need to search out previous or supplementary reports.

The PER should enable interested stakeholders and the assessing agency to understand the environmental consequences of the proposed development. Information provided in the PER should be objective, clear, and succinct and, where appropriate, be supported by maps, plans, diagrams or other descriptive detail. The body of the PER is to be written in a clear and concise style that is easily understood by the general reader.

Technical jargon should be avoided wherever possible and a full glossary included. Cross-referencing should be used to avoid unnecessary duplication of text.

Detailed technical information studies or investigations necessary to support the main text should be included as appendices to the PER. Any additional supporting documentation and studies, reports or literature not normally available to the public from which information has been extracted should be made available at appropriate locations during the period of public display of the PER.

A reference list and bibliography should be included and should be concise and include the address of any Internet "web" pages used as data sources.

If there is a necessity to make use of material that is considered to be of a confidential nature, the proponent may request that such information remain confidential and not be included in any publicly available document.

The PER should state the criteria adopted in assessing the proposal and its impacts, such as: compliance with relevant legislation, policies and standards; community acceptance; maximisation of environmental benefits (if any); and minimisation of risks and harm.

The level of analysis and detail in the PER should reflect the level of significance of the expected impacts on the environment. Any and all unknown variables or assumptions made in the assessment must be clearly stated and discussed. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

The proponent should ensure that the PER assesses compliance of the action with principles of Ecological Sustainable Development as set out in the EPBC Act, and the objectives of the Act at Attachment 1. A copy of Schedule 4 of the EPBC Regulations, - *Matters to be addressed by draft public environment report*, is at Attachment 2.

2 Format and Style

The PER should comprise three elements, namely:

- the executive summary;
- the main text of the document, which should be written in a clear and concise manner so as to be readily understood by general readers; and
- appendices containing detailed technical information or other sensitive commercial or cultural information.

The guidelines have been set out in a manner which may be adopted as the format for the PER. This format need not be followed where the required information can be more effectively presented in an alternative way. However, each of the elements must be addressed to meet the requirements of the EPBC Act and Regulations.

The PER should be written so that any conclusions reached can be independently assessed. To this end all sources must be appropriately referenced using the Harvard standard.

The main text of the PER should include a list of abbreviations, a glossary of terms and appendices containing:

- a copy of these guidelines;
- a list of persons and agencies consulted during the PER;
- contact details for the referral agency; and
- the names of, and work done by the persons involved in preparing the PER.

Maps, diagrams and other illustrative material should be included in the PER. The PER should be produced on A4 size paper capable of being photocopied, with maps and diagrams on A4 or A3 size.

SPECIFIC CONTENT

1 General information

This should comprise the background of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated proponent;

(c) a clear outline of the objective of the action;

(d) legislative background for proposal, including requirements and approvals under the EPBC Act.

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action; and

(h) the consequences of not proceeding with the action.

2 Description of the Action

All components of the action should be described in detail including:

(a) all the components of the action that impact on matters of national environmental significance including associated tourist activities in the Commonwealth marine area;

(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts; and

(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts.

3 Feasible alternatives

Any feasible alternatives to the action to the extent reasonably practicable, including:

(a) if relevant, the alternative of taking no action;

(b) a comparative description of the impacts of each alternative on the matters protected by Part 3 of the EPBC Act; and

(c) sufficient detail to make clear why any alternative is preferred to another.

Short, medium and long-term advantages and disadvantages of the options should be discussed.

4 Description of the Environment

A description of the environment of the proposal site and the surrounding areas which may be affected by associated tourist activities with a particular focus on matters protected under Part 3 of the EPBC Act, including:

(a) Ningaloo Commonwealth Marine Park – all aspects of the emvironment;

(b) baseline data on the following listed threatened (LT), listed vulnerable (LV) and listed migratory (LM) species:

- Loggerhead turtle (*Caretta caretta*) (LT)
- Humpback whale (*Megaptera novaeangliae*) (LV) (LM)
- Green turtle (*Chelonia mydas*) (LV) (LM)
- Hawksbill turtle (*Eretmochelys imbricata*) (LV) (LM)
- Whale shark (*Rhincodon typus)* (LM)
- Dugong (*Dugong Dugon*) (LM)
- any additional listed threatened or migratory species which may be impacted by the proposal and which are not listed above including any migratory waterbirds listed under JAMBA and CAMBA.

5 Relevant impacts

(a) A description of the relevant impacts of the action, with a particular focus on matters protected under Part 3 of the EPBC Act, including but not restricted to:

- the impact of tourist activities associated with the resort on the general environment of Ningaloo Commonwealth Marine Park including;

  commercial, charter and recreational fishing;

  increased vessel strike;

  vessel noise.

- the impact of tourist activities associated with the resort on the following listed threatened (LT), listed vulnerable (LV) and listed migratory (LM) species:

  Loggerhead turtle (*Caretta caretta*) (LT)
  Humpback whale (*Megaptera novaeangliae*) (LV) (LM)
  Green turtle (*Chelonia mydas*) (LV) (LM)
  Hawksbill turtle (*Eretmochelys imbricata*) (LV) (LM)
  Whale shark (*Rhincodon typus)* (LM)
  Dugong (*Dugong Dugon*) (LM)
  any additional listed threatened or migratory species which may be impacted by the proposal and which are not listed above.

- loss of occupancy of nesting habitat for the Loggerhead, Green and Hawksbill turtles, as a result of construction of the marina and associated breakwalls and the increased use of off road vehicles on beaches;
- impacts of direct human disturbance on nesting populations of turtles;

- attraction of hatchling turtles to the lights of the development;
- predation on marine turtles, eggs and hatchlings by increased in feral and domestic animal populations as a result of township development and increase in organic waste;
- impact of the development on the Dugong habitat including:

  water quality degradation from stormwater and wastewater discharge, fuel emmisions, antifouling treatments and litter;

  loss of seagrass beds as a result of decreased water quality.

(b) a detailed assessment of the nature and extent of the likely short-term and long-term relevant impacts;

(c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;

(d) analysis of the significance of the relevant impacts;

(e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

6 Proposed safeguards and mitigation measures

Information on mitigation measures given, with a particular focus on matters protected under Part 3 of the EPBC Act. Specific and detailed measures must be provided and substantiated, and must include:

(a) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including:

  (i) a description of proposed safeguards and mitigation measures to deal with relevant impacts of the action including mitigation measures proposed to be taken by State governments, local governments or the proponent;

  (ii) assessment of the expected or predicted effectiveness of, the mitigation measures;

  (iii) any statutory or policy basis for the mitigation measures; and

  (iv) the cost of the mitigation measures;

(b) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing; and

(c) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.

7 Other approvals and conditions

Information on any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action given must include:

(a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including:

   (i) what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy; and

   (ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required; and

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

8 Consultation

Any consultation about the action, including:

(a) any consultation that has already taken place;

(b) proposed consultation about relevant impacts of the action;

(c) if there has been consultation about the proposed action, any documented response to, or result of, the consultation; and

(d) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

9 Information sources provided in the PER

For information given in a draft public environment report, the draft must state:

(a) the source of the information; and

(b) how recent the information is; and

(c) how the reliability of the information was tested; and

(d) what uncertainties (if any) are in the information.

10 Environmental record of person proposing to take the action

Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

(a) the person proposing to take the action; and

(b) for an action for which a person has applied for a permit, the person making the application.

If the person proposing to take the action is a corporation — details of the corporation's environmental policy and planning framework.

11 Conclusion

An overall conclusion as to the environmental acceptability of the proposal should be provided, including discussion on compliance with principles of ESD and the objectives and requirements of the EPBC Act. Reasons justifying undertaking the proposal in the manner proposed should also be outlined.

Measures proposed or required by way of offset for any unavoidable impacts on NES criteria, and the relative degree of compensation, should be highlighted.

ATTACHMENT 1

The objects and principles of the *Environment Protection and Biodiversity Conservation Act 1999* Sections 3 and 3A

3 Objects of the Act

(a) to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance

(b) to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources

(c) to promote the conservation of biodiversity

(d) to promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples

(e) to assist in the co-operative implementation of Australia's international environmental responsibilities

(f) to recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and

(g) to promote the use of indigenous peoples' knowledge of biodiversity with the involvement of, and in co-operation with, the owners of the knowledge.

3A Principles of Ecologically Sustainable Development

The following principles are principles of ecologically sustainable development:

(a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;

(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;

(c) the principle of inter-generational equity – that the present generation should ensure that the health , diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making;

(e) improved valuation, pricing and incentive mechanisms should be promoted.

ATTACHMENT 2

Matters that must be addressed in a PER
(Schedule 4 of the EPBC Act Regulations 2000)

1 General information

1.01 The background of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated proponent;

(c) a clear outline of the objective of the action;

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action;

(h) the consequences of not proceeding with the action.

2 Description

2.01 A description of the action, including:

(a) all the components of the action;

(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts;

(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts;

(d) relevant impacts of the action;

(e) proposed safeguards and mitigation measures to deal with relevant impacts of the action;

(f) any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action;

(g) to the extent reasonably practicable, any feasible alternatives to the action, including:

(i) if relevant, the alternative of taking no action;

(ii) a comparative description of the impacts of each alternative on the matters protected by the controlling provisions for the action;

(iii) sufficient detail to make clear why any alternative is preferred to another;

(h) any consultation about the action, including:

(i) any consultation that has already taken place;

(ii) proposed consultation about relevant impacts of the action;

(iii) if there has been consultation about the proposed action — any documented response to, or result of, the consultation;

(i) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

3 Relevant impacts

3.01 Information given under paragraph 2.01 (d) must include

(a) a description of the relevant impacts of the action;

(b) a detailed assessment of the nature and extent of the likely short term and long term relevant impacts;

(c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;

(d) analysis of the significance of the relevant impacts;

(e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

4 Proposed safeguards and mitigation measures

4.01 Information given under paragraph 2.01 (e) must include:

(a) a description, and an assessment of the expected or predicted effectiveness of, the mitigation measures;

(b) any statutory or policy basis for the mitigation measures;

(c) the cost of the mitigation measures;

(d) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing;

(e) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program;

(f) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including mitigation measures proposed to be taken by State governments, local governments or the proponent.

5 Other Approvals and Conditions

5.01 Information given under paragraph 2.01 (f) must include:

(a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including:

(i) what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy;

(ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required;

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

6 Environmental record of person proposing to take the action

6.01 Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

(a) the person proposing to take the action; and

(b) for an action for which a person has applied for a permit, the person making the application.

6.02 If the person proposing to take the action is a corporation — details of the corporation's environmental policy and planning framework.

7 Information sources

7.01 For information given the PER must state:

(a) the source of the information; and

(b) how recent the information is; and

(c) how the reliability of the information was tested; and

(d) what uncertainties (if any) are in the information.

APPENDIX 2

REVIEW OF OPTIONS FOR BASE LOAD POWER GENERATION FOR THE CORAL COAST RESORT

CORAL COAST MARINA DEVELOPMENT PTY LTD

STRATEGIC POWER GENERATION FOR THE CORAL BAY REGION

VERSION 1

AUGUST 2001

REPORT NO: 2001/109

DISCLAIMER

This document is published in accordance with and subject to an agreement between ATA Environmental **("ATA")** and the client for whom it has been prepared Coral Coast Marina Development Pty Ltd **("Client")** and is restricted to those issues that have been raised by the client in its engagement of ATA and prepared using the standard of skill and care ordinarily exercised by Environmental Scientists in the preparation of such Documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by ATA and the Client without first obtaining the prior written consent of ATA, does so entirely at their own risk and ATA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this Document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

ATA Environmental has implemented a comprehensive range of quality control measures on all aspects of the company's operation and has Quality Assurance certification to ISO 9001.

An internal quality review process has been applied to each project task undertaken by us. Each document is carefully reviewed by core members of the consultancy team and signed off at Director level prior to issue to the client. Draft documents are submitted to the client for comment and acceptance prior to final production.

Document No: 20057-fed_013_hvw_V1

Report No: 2001/109

Checked by: Signed: [signature]

Name: H. van der Wiele Date: 13 August, 2001

Approved by: Signed: [signature]

Name: M. Shepherd Date: 13 August, 2001

TABLE OF CONTENTS

1. INTRODUCTION 1

2. REVIEW OF OPTIONS FOR BASE LOAD POWER GENERATION 2
   - 2.1 Hydroelectric Power 2
   - 2.2 Tidal Power 2
   - 2.3 Wind Energy 3
   - 2.4 Solar Energy 3
   - 2.5 Biomass Generators 4
   - 2.6 Dual Fuel Gas Generators 5

3. OPPORTUNITIES FROM DEVELOPING TECHNOLOGIES 6
   - 3.1 Reticulation of Hot Artesian Water 6
   - 3.2 Reticulation of LPG (or LNG) Gas 6
   - 3.3 Wind Energy 6
   - 3.4 Energy Management and Integrated Energy Strategy 7

REFERENCES 8

1. INTRODUCTION

The power supply systems selected for Coral Bay must meet certain criteria relating to such matters as reliability of supply, redundancy and consider the characteristics of supply requirements.

Examples of a base load power generation from renewable sources are briefly described below.

2. REVIEW OF OPTIONS FOR BASE LOAD POWER GENERATION

2.1 Hydroelectric Power

An example of a base load power generation from a renewable source that has been implemented in the Kimberley is the Ord River hydro-electricity scheme. A 30MW hydroelectric power station at the Ord River Dam on Lake Argyle, 80km south of Kununurra, was completed in April 1996. The project also involved the construction of 132kV transmission cables to the Argyle Diamond Mine (located to the south) and the townsite of Kununurra (to the north). Western Power 'on-sells' power to householders and businesses in Kununurra, Wyndham and the Argyle village.

This power source is too remote to be economically viable for Coral Bay, and no ready sources of water stored energy occur within the region.

2.2 Tidal Power

The Office of Energy notes that there is considerable potential for tidal energy production in the North West of Western Australia where there are large tidal basins and high tides (Office of Energy, 2001).

The Environmental Protection Authority (EPA) recently considered a proposal for establishment of a Tidal Power Base Load Energy Project at Doctors Creek near Derby (Environmental Protection Authority, 1999 and 2000). Derby Hydro Power Ltd has proposed construction of a 48 MW double basin tidal power station on the natural forked bay at Doctors Creek near Derby. The tides would supply energy for power generation with supplementary generation by conventional plant during neap tides. The proposal includes transmission lines linking Derby to Broome and Derby to Fitzroy Crossing and the nearby Blendevale mine.

Capital cost of tidal power stations could extend to AUD 3 million per MW of installed generation capacity, (Australian Greenhouse Office, 2000) dependant on site requirements, design and electricity demand, compared to A$900,000 per MW by gas turbine.
The EPA, in its consideration of the whole of lifecycle impacts of this proposal, commented that the potential for environmental benefit from savings in greenhouse gas emissions is reduced due to other impacts.

In concluding statements within its Report and Recommendations (Environmental Protection Authority, 1999), the EPA said of the proposal for tidal power that:

> *.....more conventional forms of power generation would have different and lower environmental impacts (with the exception of greenhouse gas) with a higher level of certainty about the ability to manage impacts that would result.*

Coral Bay is considered to be in the transitional zone between the small, primarily diurnal tides (one tidal cycle per day) of the southwest coast and the large semi-diurnal tides (two tidal cycles per day) of the North West Shelf. The mean spring (largest) tidal range being about 0.9m, and about 0.4m during neap tides is insufficient to economically pond water to economically generate electricity even if an appropriate landform existed within the region.

2.3 Wind Energy

Wind power is also being used in an increasing number of isolated stand-alone generation systems for households or small communities in remote areas.

Applications in Western Australia include:

- Nine 225 kW variable pitch wind turbines connected to Esperance's conventional diesel power station at Ten Mile owned and operated by Western Power.
- The first of three 50m high variable speed wind turbines at Denham supplying up to 70 percent of the towns electricity requirements.
- A mini wind farm at Exmouth, 1300km North of Perth. Plant consists of three 20kW Australian made Westwind turbines with tilt-down towers.

Western Power Corporation is currently constructing a 21.6MW installation wind farm near Albany, to be connected to the interconnected grid, which should produce around 70-80 GW hours per annum.

Given the right conditions, electricity generated from wind energy may be appropriate for remote communities that currently rely on diesel fuel for electricity generation. Western Power notes that in some places of the world, wind can also be competitive with large-scale coal and gas generation on big grid systems, but this is not yet the case in Australia (Western Power, 2001).

The average wind velocity in Coral Bay is too low for the economic use of wind farms in isolation, but some potential exists for supplementing existing conventional power sources with energy derived from the wind during periods of high wind velocity.

2.4 Solar Energy

Office of Energy (2001) notes that there are currently two systems used for converting solar energy into electricity:

- photovoltaic (PV) systems which convert sunlight directly into electricity; and
- solar thermal power systems which produce electricity indirectly from solar radiation by converting it into thermal energy and then producing electricity using an engine.

In Western Australia only PV is used to produce electricity. Applications in current use include:

- A 20kW Kalbarri Photovoltaic System owned by Western Power Corporation.

- Uses a 3.6kW privately owned solar/diesel hybrid system installed at the Broome Bird Observatory.

- Various grid connected rooftop PV systems connected to the southwest interconnected grid in 1997 under Western Power's Renewable Energy Buyback Scheme. The scheme applies to home renewable energy systems from 250W to 5kW.

Office of Energy (2001) notes that the cost of electricity from PV is generally higher than from fossil fuels or alternative renewable energy sources within Western Australia. A recent proposal to install a solar farm at Broken Hill, 42 solar dishes covering 20ha are required to generate 1MW of power, will cost A$8 million (Waste Management and Environment, 2000).

Western Power (2001) notes that solar power is still one of the most expensive ways to produce renewable energy and will only be used in limited circumstances, or with the aid of government subsidies, unless the capital cost is considerably reduced by a breakthrough in PV production techniques.

For base-load power applications the use of solar energy is capital intensive, required substantial storage capacity for periods of low light intensity and extensive collector area.

Due to the brackish nature of artesian water used for most non-potable applications in the Coral Bay region, solar hot water heaters have very high maintenance costs.

2.5 Biomass Generators

Power can be produced in two main ways from biomass:

- The sustainable growing of crops that can then be burnt to produce power. Because crops absorb carbon dioxide from the atmosphere when growing, and then release it when burnt to produce heat (which is captured to generate power), the entire cycle has an almost neutral impact.
- The capturing of methane from rotting organic matter in landfill sites (rubbish tips), sewage works, or other waste treatment sites, which is then used in small gas-fired power stations. In this process, the methane that would normally escape into the atmosphere is put to good use producing power as it is burnt and converted to carbon dioxide. Methane is a much more potent greenhouse gas than carbon dioxide and so the whole process lessens the impact of the captured gas from decomposing waste by around 80%.

Western Power currently purchases around 40 Gigawatt hours of power from landfill gas power producers (Western Power, 2001).

There are no sources of biomass or landfill gases that would allow economic generation of power from biomass generation in the Coral Bay region.

2.6 Dual Fuel Gas Generators

The adoption of dual fuel gas fired engines and use of LPG or LNG as primary fuel provides the most acceptable option for power generation within the Coral Bay region when considered in terms of reduction in greenhouse emissions, reliability of supply and certainty of outcomes.

The amount of $C0_2$ emitted from fossil fuel depends on the type and amount of fuel consumed during generation, the fraction of the fuel that is oxidised, and the carbon content of the fuel. This relationship can be described in two parts:

1) The amount of carbon contained in the fuel per unit of energy produced varies for different fuel types. For example, coal contains the highest amount of carbon (and accordingly CO_2 produced) per unit of energy. For petroleum the amount of carbon per unit of energy is about eighty percent of that for coal; for natural gas, it is about fifty percent (Environmental Protection Authority, 1999; Environmental Protection Authority, 2000). LPG has similar characteristics.

   Simplistically, the fuels are constructed from different combinations of carbon (C) and hydrogen (H) molecules. The following is a list of the fuels in descending complexity of carbon/hydrogen combinations and in descending ratio of carbon molecules to hydrogen molecules:

FUEL	APPROX. CHEMICAL FORMULA	RATIO CARBON TO HYDROGEN
Diesel	$C_{12}H_{26}$	1:2.167
Petrol	C_8H_{17}	1:2.125
Natural Gas (Methane)	CH_4	1:4.000

   The relevance of the ratio of carbon to hydrogen molecules is that greenhouse gas emissions are inversely proportional to this ratio. Thus diesel with a low ratio of hydrogen to carbon molecules (given all other things being equal) will produce more carbon dioxide when used as a fuel.

2. Not all carbon in fuel products is oxidised to CO_2 for two reasons. Firstly, inefficiencies in the combustion process leave carbon unburnt, which causes a small fraction of the carbon to remain unburnt as soot or ash. As noted earlier, some carbon is not immediately oxidised to CO_2 and is emitted in the form of other hydrocarbons. Secondly, fossil fuels are also used for non-energy purposes, primarily as a feedstock for such products as fertiliser, lubricants, and asphalt.

If distillate/kerosene were the primary fuel source, CO_2 emissions from power generation would be approximately 25% greater.

3. OPPORTUNITIES FROM DEVELOPING TECHNOLOGIES

Coral Coast Marina Development will continually review power-generating technologies, including developing renewable energy sources, with a view to reducing environmental impacts, reducing costs to the consumer and improved performance from power generation. As improved technologies become available and affordable, opportunities for their introduction will be sought.

Options being considered to utilise renewable technologies or reduce energy demand include the following.

3.1 Reticulation of Hot Artesian Water

The source water for the Resort is artesian, from the Birdrong Formation at a depth of 800m. The artesian water has a 40m free head at the surface, is hot (65C) and saline (about 6000ppm TSS).

It is proposed that the raw artesian water is aerated and cooled by using fountains and ponds and thereafter a portion will be desalinated for the Resort's potable water supply. Dual reticulation of cooled artesian (for non-potable uses and irrigation) and cooled potable water will be provided throughout.

Reticulation of a third supply of hot artesian water will also be examined, which would save on water heating costs (for showers, baths, laundry etc), provided that adequate measures such as in line filtration, aeration, distribution etc can be implemented to remove iron from the water without excessive cooling.

3.2 Reticulation of LPG (or LNG) Gas

LPG (or LNG) stored at the services area for power generation will also be reticulated throughout the Resort, primarily for cooking purposes.

Maximum use of gas in appliances throughout the Resort, including air conditioning and water heating will be examined.

3.3 Wind Energy

The potential exists for wind energy to be used during the summer months (November to March) to supplement the power supply when air conditioning usage is at its peak. However, present studies indicate that this option is not cost effective or efficient at this point in time.

3.4 Energy Management and Integrated Energy Strategy

As the Resort develops, development of a site wide energy strategy and monitoring of energy use across the Resort, with systems similar to those implemented at Couran Cove Resort, Queensland, will be investigated and implemented where efficiencies can be demonstrated.

REFERENCES

Australian Greenhouse Office (2001) The Australian Renewable Energy Website, Renewable Technologies, Tidal Power. Online. Available: http://renewable.greenhouse.gov.au/technologies/ocean/tidal/html Last accessed 26th July 2001.

Environmental Protection Authority (1999) *Derby Tidal Power Project*. Bulletin 942, June 1999

Environmental Protection Authority (2000) *Derby Tidal Power Project – Recommended Conditions*. Bulletin 984, July 2000.

Integrated Energy Services Pty Ltd (2000) *Sustainable Energy Solutions for Eco-tourism Projects*. Brisbane.

Office of Energy (2001) www.energy.wa.gov.au/html/renewable_energy_and_energy. Downloaded May 21, 2001.

Waste Management and Environment (2000) *Mirrors for Success*. Volume 11, Number 9, p32.

Western Power (2001) www.westernpower.com.au/our_environment/natural power /renewable_energy Downloaded 21 May 2001.

APPENDIX 3

COASTAL ENGINEERING STUDY

September 2000

Coral Coast Marina Development Pty Ltd

Mauds Landing Coastal Engineering Study

M P ROGERS & ASSOCIATES

Coastal & Port Engineers

Job J123/1 Report R088 Rev 0

September 2000

Coral Coast Marina Development Pty Ltd

Mauds Landing Coastal Engineering Study

Job J123/1 Report R088 Rev 0 - Record of Document Revisions

Rev	Purpose of Document	Prepared	Reviewed	Approved	Date
A	Draft for MRA & Client review	D Pang	M Rogers	M Rogers	18/9/00
0	Issued for Client use	D Pang	M Rogers	M P Rogers	25/9/00

Form 035 27/8/00

M P ROGERS & ASSOCIATES - Coastal & Port Engineers
Unit 2, 133 Main Street, Osborne Park WA 6017, AUSTRALIA
Phone: +618 9444 4045, Fax: +618 9444 4341
Email: rogers@tpgi.com.au

Limitations of this Report

This report has been prepared for use by Coral Coast Marina Development Pty Ltd in accordance with the agreement between Coral Coast Marina Development Pty Ltd and M P Rogers & Associates Pty Ltd. This agreement includes constraints on the scope, budget and time available for the services. The consulting services and this report have been completed with the degree of skill, care and diligence normally exercised by members of the engineering profession performing services of a similar nature. No other warranty, expressed or implied, is made as to the accuracy of the data and professional advice included in this report. This report has not been prepared for use by parties other than Coral Coast Marina Development Pty Ltd and it's consulting advisers. It may not contain sufficient information for the purposes of other parties or for other uses.

M P Rogers & Associates takes no responsibility for the completeness or form of any subsequent copies of this report. Copying this report without the permission of the Coral Coast Marina Development Pty Ltd or M P Rogers & Associates Pty Ltd is not permitted.

Table of Contents

1.	Introduction	1
2.	Meteorology and Oceanography	2
3.	Climate Change	9
4.	Water Quality in the Marina	12
5.	Computer Modelling of the Marina Water Quality	15
6.	Building & Development Levels	27
7.	Coastal Processes and Shoreline Stability	29
8.	Marine Infrastructure and Structures	35
9.	Summary and Recommendations	40
10.	References	43
11.	Figures	45
12.	Appendices	96

1. Introduction

Coral Coast Marina Development Pty Ltd (CCMD) has an agreement with the State of Western Australia for the proposed development of a Resort at Mauds Landing in Bateman Bay, about 2 km north of Coral Bay. The site is about 200 km north of Carnarvon and 140 km south of Exmouth. The town site is wholly within the Shire of Carnarvon.

The proposed Resort development is known as Coral Coast Resort and will be an integrated residential and commercial development. When fully developed, it will include an inland marina, caravan park, backpackers' hostel, a variety of tourist accommodation including serviced apartments, commercial centre, and fully serviced residential lots (refer to Figures 1.1 and 1.2).

As part of the planning and design process, CCMD has engaged M P Rogers & Associates Pty Ltd (MPRA) to examine the coastal engineering issues of:

- water quality in the marina,
- ocean storm surge and building levels,
- coastal stability and development set back, and
- marine structures.

This report outlines the investigations completed and the results of the study.

2. Meteorology and Oceanography

2.1 General Meteorology and Winds

The general circulation of the lower atmosphere over Australia is largely dominated by the position of the Subtropical High Pressure Belt and the migratory low pressure systems that exist on the poleward side of the high pressure belt. The high pressure belt is a series of discrete anticyclones (high pressure cells) that encircle the southern hemisphere at subtropical latitudes.

The high pressure cells are continuously moving, throughout the year, from west to east across the southern portion of Australia. A notional line joining the centres of these cells is known as the High Pressure Ridge, or the Subtropical Ridge, and is oriented predominantly in an east-west direction.

In the southern hemisphere, the winds circulate in an anti-clockwise direction about the centres of the high pressure cells. Consequently, on the northern side of the High Pressure Ridge the winds tend to be easterly, while on the southern side of the ridge the winds are predominantly westerly.

In winter, the ridge lies across the Australian continent at between 25°S to 30°S. In summer, the ridge is typically 35°S to 40°S. This seasonal change in the location of the High Pressure Ridge is responsible for the seasonal change in the wind patterns in the Carnarvon region.

In winter the ridge is located immediately south of the Mauds Landing area (23° 05'S) and the synoptic winds are generally easterly and southeasterly. Successive high pressure cells do little to disturb the direction of the wind, but can have a marked effect on the speed of the winds. The wind speed increases in response to an increasing pressure gradient, and decreases as the pressure gradient relaxes.

In the summer months, the High Pressure Ridge is well south of Mauds Landing and the Australian continent. Over the north of Australia, a zone of low pressure develops due to the considerable heating of the Earth's surface. This effect causes the direction of the winds to be predominantly west to southwesterly.

In addition to these synoptic scale effects, the mesoscale phenomenon of the diurnal land / sea breezes has an important influence on the local wind patterns in the region. The land / sea breeze system results from a marked atmospheric temperature difference that develops during the day between the land and the nearby sea. During the afternoon when the land becomes hotter than the ocean, the hot air over the land rises. This lowers the pressure and induces a replacement by the cooler air over the sea. This process (the sea-breeze) continues until the evening when the temperature difference decreases. The land breeze results from early morning conditions when the sea temperature may be higher than the land temperature, in which case a reverse flow occurs.

Locally, the wind climate of the area primarily results from the superposition of the diurnal land / sea breezes over the prevailing synoptic winds. As a result, throughout the year the prevailing winds are generally from the south, with strong southerly sea breezes occurring on approximately three quarters of the afternoons.

To date there have been no systematic wind measurements taken at Coral Bay or Mauds Landing. However, the Bureau of Meteorology has measured the wind speed and direction at the Carnarvon Airport since 1945. This data is believed to be reasonably representative of the winds experienced at Mauds Landing. Using this data, winter and summer wind roses were prepared for the morning and afternoon readings. These are shown in Figures 2.1 to 2.4. The winter roses show the dominance of easterly winds in the morning that shift to southerly in the afternoons. The wind speeds are typically between 6 and 16 knots.

The summer wind roses in Figure 2.3 and 2.4 show southerly winds in the mornings and southwesterly winds in the afternoons. The summer winds tend to be slightly stronger than in winter, and are usually between 11 and 21 knots.

2.2 Tropical Cyclones

The storm winds of high intensity in the area are associated with the passage of tropical cyclones, thunderstorms and pressure gradient intensifications. The most severe conditions are caused by tropical cyclones that occur between November and April. Steedman Science & Engineering (1989) reports that 27 cyclones have passed within 200 km of Mauds Landing in the period from 1960 to 1986. This is approximately one cyclone per cyclone season.

The effects of any one cyclone depend upon the intensity of the central pressure deficit, the radius to maximum wind, and the actual track of the cyclone. Differences in these features between cyclones result in significant variations between the physical effects of each event (wind and wave conditions, storm surge, etc.).

Steedman Science & Engineering (1989) examined the severity of the 27 cyclones experienced between 1960 and 1986 and concluded that Tropical Cyclone Hazel, in March 1979 was very severe and had an approach track that would cause extreme wave conditions at Mauds Landing. It was assessed as being representative of the 100 year return period wave conditions.

The Standards Association of Australia Loading Code, Part 2 Wind Loads (AS1170.2-1989) shows the site to be in an area subject to severe tropical cyclones. This engineering design code recommends that structures should be designed using a basic regional wind gust speed for serviceability, Vs, equal to 50 m/s. These estimates include the effects of Category 5 cyclones in the region.

2.3 Tides and Storm Surges

The Department of Transport, Western Australia (DOT) has measured the tidal variations at Monk Head between 1990 and 1993. This site is only 5 km south of Mauds Landing and the tides are believed to be virtually identical for all practical purposes, (pers comm Don Wallace, DOT).

The astronomical tides are semidiurnal (two cycles per day). DOT has established the following tidal levels.

• Highest Astronomical Tide (HAT)	= 1.92 m Chart Datum (CD)
• Mean High Water Springs (MHWS)	= 1.44 m CD
• Mean High Water Neaps (MHWN)	= 1.21 m CD
• Mean Sea Level (MSL)	= 0.99 m CD
• Australian Height Datum (AHD)	= 0.86 m CD
• Mean Low Water Neaps (MLWN)	= 0.80 m CD
• Mean Low Water Springs (MLWS)	= 0.54 m CD
• Lowest Astronomical Tide (LAT)	= 0.11 m CD

From this it can be seen that during spring tides the daily range is typically about 0.9 metres, and that during neap tides the daily range is about 0.4 metres.

Figure 2.5 has been prepared by DOT, and shows the percentage of time that various levels are exceeded (submerged). This figure also shows that during the measurement period, (less than three years), the highest water level recorded was 2.07 metres above Chart Datum which is about 1.2

metres above AHD. The lowest recorded water level was 0.01 metres above Chart Datum that is about 0.85 metres below AHD.

In addition to the astronomical tide, tropical cyclone storm conditions can cause significant increases in the ocean water level through the combined effects of low atmospheric pressure, strong onshore winds and large waves breaking nearshore. This increase in the water level is known as storm surge.

Steedman Science & Engineering (1989) used various techniques to examine the storm surges in the region. This work concluded that tidal residuals from 20 years (mid 1966 to mid 1986) of record from the Carnarvon tide gauge provide the best guide to storm surge at Coral Bay and Mauds Landing. The 100 year return period storm surge at Carnarvon was estimated by extreme analysis to be 1.65 metres. Other calculations suggest that the storm surge at Coral Bay and Mauds Landing could be slightly more severe than at Carnarvon because of the nearshore reef system and the effects of wave induced set-up. It was reckoned that the storm surge at Mauds Landing might be roughly 15% higher than that at Carnarvon. Using this factor, it is estimated that the 100 year return period storm surge (excluding the astronomical tide) at Mauds Landing would be about 1.9 metres.

The tidal records taken by the Department of Transport at Carnarvon between 1968 and May 2000 were obtained and analysed. Various Weibull Distributions were fitted to the data and the distribution that provided the best fit to the data was used to estimate the still water level with an Average Recurrence Interval (ARI) of 100 years. The estimated still water level at Carnarvon for the 100 year ARI was 1.9 metres above AHD. This data includes the effects of Tropical Cyclone Vance in March 1999. Again using a factor of 15% higher at Mauds Landing, the estimate would be 2.2 metres above AHD for the 100 year ARI still water level. It should be noted that this still water level includes the effect of the astronomical tide and storm surge.

2.4 Current Regime

Measurements reported in Hearn & Parker (1988) indicate that in Osprey Bay, about 120 km further north of Mauds Landing on the Ningaloo Reef, the lagoon has a flushing time of less than 24 hours. The action of waves breaking onto the reef was shown to cause significant transfer of ocean water across the reef and then drive the currents along the lagoon to the north. In this location the wave-driven current is strongly modulated by tidal changes in water level.

Bateman Bay is generally wider and shallower than Osprey Bay. This will tend to reduce the relative importance of the wave-driven transport across the reef in the nearshore currents. Currents in Bateman Bay are believed to be controlled by the relative magnitude of the wind, tide and wave forcing.

The surface currents in the nearshore lagoon of Bateman Bay have been measured by a brief drogue tracking exercise carried out during flood and ebb spring tides. During the drogue tracking exercise the winds varied from 10 to 15 knots from the southwest. Drogues released near the proposed marina entrance during an ebb tide, travelled at about 0.1 m/s directly downwind. The drogues released from the same location during the flood tide and southwesterly winds showed little movement during the tracking exercise.

The largest currents in the southern portion of Bateman Bay are believed to be caused by the persistent and strong southerly winds and the mass transport of water over the Ningaloo Reef caused by wave breaking onto the shallow reefs. It is estimated that mild currents would often be present in Bills Bay (see Figure 1.1) and the southern portion of Bateman Bay. They would be primarily driven by wave and wind forcing and modulated by tidal action.

Typically the currents would be in the order of 0.1 m/s. Some of the water would flow out of the reef gaps in Bills Bay and the rest would continue north into Bateman Bay. It is reasonable to expect a localised increase in the current speed through the narrow channel near Point Maud. Rough estimates indicate that in this narrow channel, the currents may reach 0.5 m/s.

The above estimate of the current regime would mean that Bills Bay is regularly flushed with new ocean water, and water from the northern portions of Bills Bay would flow north into the southern portion of Bateman Bay, and then out to sea through Cardabia Passage (see Figure 2.6).

2.5 Wave Climate

No detailed directional wave measurements have been collected near the site. The most relevant data are the visual estimates of wave height, period and direction taken from ships passing through the ocean to the west of Point Maud. These are reported in the US Navy Marine Climate Atlas (1976). Naturally, ships try to avoid storm areas, especially severe tropical cyclones, so the data have a bias that tends to underestimate the severe storm wave conditions.

The most applicable data is for Site 26, which covers a large area of the ocean about 400 nautical miles to the west of Point Maud. The data for this site has been aggregated into frequency of occurrence tables of wave height versus wave direction for the four seasons. These are included on Figure 2.7. These visual estimates of the offshore wave conditions are in accord with the non-directional, wave measurements taken by the Department of Transport in 1988 offshore from Tantabiddi Creek, about 120 km north of Bateman Bay.

As site 26 covers an area hundreds of kilometres from the shore, waves can approach from any direction. Only the wave directions from north through west to south are relevant to the conditions at Mauds Landing.

Although this data is very limited and based on visual estimates they do indicate that the offshore waves mainly come from the south during summer and the heights are typically 1 to 2 metres. During winter the direction shifts to southwest and the heights increase slightly to be generally between 2 and 3 metres.

These waves from the south and southwest are believed to include a significant proportion of long period (10 to 16 seconds) swell waves. These waves are generated by distant and severe storms in the southern Indian Ocean.

In addition to the background swell, the sea-breeze winds would generate short, steep sea waves. These would have heights between 1 and 2 metres, and because of fetch limitation the periods would be expected to be roughly 4 to 6 seconds.

A third class of waves in the offshore area would be the extreme waves generated by tropical cyclones as they travel through the area.

Steedman Science & Engineering (1989) completed numerical modelling of the waves generated by Tropical Cyclone Hazel. This storm was reckoned to create wave conditions representative of the 100 year return period condition for the Mauds Landing site. These were estimated to be significant wave heights of more than 6.2 metres immediately outside the reef-line and 3.7 metres in 7 metres of water near Mauds Landing.

This illustrates the effect of the reef-line in attenuating waves as they travel from the deep offshore waters towards the shore at Mauds Landing. The principal physical mechanisms include:

- refraction, by varying bathymetry;
- diffraction through reef gaps;
- breaking on to reefs and in shallow water;

- reflection from submerged reef faces, and
- dissipation due to turbulence in the bottom boundary layer.

The reef-line also provides significant protection from the more usual wave conditions of southerly swell and sea-breeze seas. The 1 to 4 metre southerly swells would be refracted to the west-southwest and travel through the gap in the reef known as Cardabia Passage where they would be further refracted by the bathymetry in Bateman Bay and reach the shore with crests almost parallel to the shore. They would break near the shore having been reduced generally to 0.5 to 1 metres in height.

Because this beach is a north facing beach, the southerly sea-breeze seas would have little effect in Bateman Bay.

3. Climate Change

Although the so called "Greenhouse Effects" receive much publicity there is still no definitive evidence available that proves that the Greenhouse changes are occurring to the extent of the more extreme predictions made in the 1980s. There is certainly clear evidence that the amount of Carbon Dioxide and other "Greenhouse Gases" has increased dramatically over the last century and is continuing to rise. However, the link to global warming and associated sea level rise is still largely based on predictive numerical models of the global atmospheric and oceanic processes. These general circulation models are currently run on coarse grids and have rather rudimentary treatment of ice melting, cloud cover and albedo feed back links and impacts. Pielke (1991) presents a good review of the scientific uncertainty with the present predictions of "Greenhouse Effects".

Some of the possible impacts on the southwest coast of Western Australia of Greenhouse Gas Warming could be:

- increase in cyclone frequency;
- increase in sea level; and
- change in position of synoptic features causing a changed wave climate.

The current knowledge about such possible changes is extremely limited. This coupled with the uncertainty about global warming, has lead many organisations and authorities to take a low key approach to the issue until more definitive proof is available.

The Institution of Engineers, Australia (1991), put forward suggestions for assessing the impacts of possible climate change on coastal engineering projects. The report is aimed at ensuring that a responsible review of the possible impacts is made. Designs should be robust and minimise future risk. This document suggests that it is now likely that some Climate Changes will happen, and therefore engineering design should take this risk into consideration.

The Institution of Engineers, Australia (1991), presents scenarios for possible changes in the Global Mean Sea Level. The predictions for the years 2030, 2050 and 2100 are reproduced below in Table 3.1.

Table 3.1 Possible Global Sea Level Rise - 1991 Estimates

	2030	2050	2100
Low Scenario	0.10 metre	0.16 metre	0.32 metre
Medium Scenario	0.20 metre	0.32 metre	0.68 metre
High Scenario	0.32 metre	0.51 metre	1.13 metres

Source: Institution of Engineers Australia (1991)

The latest research from IPCC (1995) provides new projections for the future change in sea levels (refer to Table 3.2 below). The increase in sea level over the next century is projected to be lower than previous estimates. The differences are due in large to lower temperature projections and changes to the glacier model used.

Table 3.2 Possible Global Sea Level Rise - 1995 Estimates

	2030	2050	2100
Low Scenario	0.03 metre	0.06 metre	0.13 metre
Medium Scenario	0.11 metre	0.20 metre	0.49 metre
High Scenario	0.23 metre	0.40 metre	0.93 metre

Source: IPCC (1995)

It should be noted that based on work completed by US EPA (1995) it is estimated that there is about a 75% probability that a sea level rise of 0.5 metres will not be reached or exceeded by 2100. Also, the US EPA estimates that there would be a 50% chance that a sea level rise of 0.3 metres would not be reached or exceeded by 2100.

The issue of possible climate change and resultant effects on coastal processes is quite complex and the impact of a small rise in sea level would be quite site specific. To date there have been no studies done for the west coast of Western Australia. The most relevant of other works are Bruun (1962), which presents the results of some generalised material, and Gordon (1988) that presents some of the results of research on the east coast of Australia. In very coarse and general terms, both papers suggest that a rise in sea level would generally lead to recession of a sandy coastline at a ratio of roughly 100 to 1. That is, a 0.3 metre rise in sea level may eventually cause a 30 metre recession of a sandy coastline.

It is appropriate that this magnitude of possible erosion in the coming 100 years should be included in any determination of set-backs to coastal developments on sandy coasts.

This tendency for shoreline recession could be offset by other local effects. For example, in Bateman Bay the southern beaches are presently generally accreting at rates between 0.3 and 0.9 m/year (refer Section 7.4). Consequently, it is reasonable to anticipate that in Bateman Bay, a rise in sea level of 0.3 metres over the next 100 years would not necessarily cause a nett recession of the shoreline but merely decrease the rate of advance.

In view of these factors, it is believed that if climate change does occur in the next 100 years, the effects on the beaches in the southern portion of Bateman Bay are likely to be minor and manageable.

4. Water Quality in the Marina

4.1 General

The intended uses of the Marina and associated waterways are:

- direct contact recreation (eg swimming);
- boating;
- adjacent residential development; and
- passive recreation (eg enjoying the scenery).

The Environmental Protection Authority (1993) put forward various categories of environmental value for marine and estuarine waters in Western Australia. The above falls in the category titled "Recreation and Aesthetics". The marina and associated waterways will be designed and managed to meet these requirements for Recreation and Aesthetics.

The resultant water quality in the marina and associated waterways is dependent upon the following:

- the quality of the source water;
- the management of nutrient and pollutant inflow; and
- the mixing and exchange processes.

4.2 Source Water

The source water for the marina and associated waterways will be the ocean water of the southern portion of Bateman Bay. As outlined in Section 2.4, this area is flushed by tidal and wind driven currents and the influx of ocean water caused by waves breaking on the nearby Ningaloo Reef. These persistent flushing mechanisms will ensure that the source water is clean and clear ocean water. The only possible source of pollution would be from the flow of nutrient rich ground water from the sewerage ponds that service Coral Bay. The extent of such pollution is presently unknown, but with the development of the Coral Coast Resort, the existing settlement at Coral Bay will be able to be connected to a comprehensive, reticulated sewerage system. This would remove the need for the sewerage ponds and remove this potential source of nutrients flowing into Bills Bay.

4.3 Management of Nutrient and Pollutant Inflow

The influx of nutrients and pollutants into the Marina and associated waterways will be minimised by careful design and management of the water bodies.

The design elements include the following:

- The development will be serviced with a reticulated sewerage system.
- A sewage pumpout facility will be provided in the Marina and all boats with onboard sullage tanks will be required to discharge to the facility.
- Storm water run off from the roads will generally be collected and discharged to inland soakage areas to the east and south of the Marina.

The ongoing management of nutrient and pollutant inputs will include the following:

- Rubbish disposal and effluent discharge into the marina and associated waterways will be banned and policed by the waterways manager.
- The use of plant species that require minimal watering and fertilising will be encouraged.
- Arid zone landscaping (Xeriscape) will be predominantly used in the eastern part of the development to minimise nutrient inputs via the use of artesian water for irrigation.
- The use of tributyl tin oxide antifoulants on boats is prohibited under State Law.
- Prohibition under Council By-Laws on the importation, sale and use of fertilisers within the Resort.
- Prohibition under Council By-Laws on the keeping of dogs and cats within the Resort.

4.4 Water Mixing and Exchange

The water bodies of the marina and waterways will be mixed by winds, waves, advecting currents and boat traffic. All of these mechanisms will ensure that the water bodies are regularly mixed.

There are several physical processes that cause water exchange between harbours and the adjacent source waters. These include:

- density currents;
- inflow of ground water;
- astronomical tidal fluctuations; and
- wind induced currents.

In general, the density of the marina water is expected to be almost identical to that of the source water in Bateman Bay and as such, there will be little or no density gradients between the marina and the bay that could set up density driven currents. Rockwater (1994 & pers comm 2000) predicts the ambient ground water flow into the marina to be very small with very low levels of nutrients.

However, during and immediately after significant rain events, less dense surface run-off and sub-surface flow from infiltration will enter into the marina. Under these conditions the effect of density driven flow may be a significant mechanism for water exchange. It should be noted that these inflows could carry nutrients from gardens into the marina.

In general though, the most important water exchange mechanisms will be wind induced currents and the astronomical tidal fluctuations. The likely water exchange and water quality of Coral Coast Resort is investigated in detail using 3 dimensional hydrodynamic and transport modelling techniques in Section 5.

5. Computer Modelling of the Marina Water Quality

5.1 Model Description

The model used to investigate the water quality in Coral Coast Resort was a computer package called Delft3D. Delft3D is a general 3-dimensional numerical model package developed by WL | Delft Hydraulics of the Netherlands. This package has been successfully used on numerous major projects around the world. The flow module of the Delft3D system is a multi-dimensional (2D or 3D) hydrodynamic and transport simulation program which calculates non-steady flow and transport phenomena taking into account bathymetry and density variations, as well as external forcings such as tides, winds, and discharges.

The Delft3D model solves the full Navier-Stokes equations (with the shallow water approximation applied) using a staggered grid finite difference scheme. The main elements of the Delft3D model include:

- Density gradients due to salinity concentration and a non-uniform temperature distribution,
- Inclusion of density (pressure) gradient terms in the momentum equation (density driven flows),
- Spatially varying wind and barometric pressure,
- Turbulence model to account for the vertical turbulent viscosity and diffusivity based on the eddy viscosity concept,
- Shear stresses exerted by turbulent flow on the bottom based on a quadratic Chézy or Manning's formula,
- Wind stresses on the water surface modelled by a quadratic friction law, and
- Coriolis force.

The effect of surface run-off and groundwater inflow from sporadic tropical cyclone events and winter rainfall events, both by bringing pollutant into the system and creating density currents (horizontally and vertically) were considered to be an important aspect of the water quality modelling. Therefore, it was necessary to undertake transport-dispersion modelling of the development using a 3-dimensional model that included the effects of both horizontal and vertical density gradients. The Delft3D modelling system can simulate these processes and is appropriate for the intended modelling. A more detailed description of the Delft3D model is provided in Appendix A.

5.2 Model Set-Up

5.2.1 Modelling Events

For this water quality investigation, 2 events were chosen to be computer modelled. The first is for a representative summer event, and the second for a typical winter event. As outlined in Section 4, significant inputs of nutrient into the marina will only occur during and immediately after major rainfall events. As such, in order to properly assess the likely water quality in the Coral Coast Resort waterway both simulations included a significant rainfall event representative of that particular season. A description of each modelled event is described below.

Summer Event

For the summer simulation, the period from 9 April 1998 to 29 April 1998 was chosen to be modelled. This period of time was chosen because it coincided with a rain event under typical "summer" conditions. This period was also chosen because the wind speeds were lower than during early summer. For this case, freshwater inflow was input into the model over the first 2 days of the simulation to represent a significant rain event (from a nearby tropical cyclone) during the summer period. The inputs into the model over the winter simulation period are described in more detail in the following sections.

Winter Event

For the winter simulation the period from 11 July 1998 to 31 July 1998 was selected to be modelled. Analysis of the rainfall data from Carnarvon suggests that there was a reasonable rainfall event at the beginning of this time period. The significant winter rainfall event was simulated by the continuous input of freshwater at the development boundaries over a period of 5 days. The inputs into the model over the winter simulation period are described in more detail in the following sections.

5.2.2 Model Grids

The grid used in the modelling of Coral Coast Resort is 4,080 metres by 2,180 metres in its 'x' and 'y' directions respectively, and has a resolution (grid spacing) of 20 metres in both directions. The bathymetry of the marina was digitised using the final Structure Plan of the development and the proposed dredging depths within the marina. The nearshore bathymetry of the model grid was digitised from a detailed hydrographic survey of the nearshore area adjacent to the proposed development area in March 1994 and available navigation charts covering the Mauds Landing area.

The model grid has been rotated 30 degrees anti-clockwise so that the coastline was aligned with the x-axis of the model grid. The horizontal extent of the model grid was selected to properly model Coral Coast Resort and have a dissipation zone to represent the nearshore area of Bateman Bay.

In the vertical direction, the model grid has 5 equally spaced layers regardless of the water depth (ie sigma co-ordinate system). As such, at each horizontal location in the grid, the thickness of the vertical layers is dependent on the depth.

A plot of the bathymetry used in the water quality modelling is shown in Figure 5.1.

5.2.3 Wind Input

For all of the model simulations undertaken, measured wind data from the automatic weather station at Carnarvon was used to warm up and run the model.

Over the summer simulation period the wind patterns exhibit the characteristic irregular change in wind direction during the passage of a rain event, and the typical land / sea breeze cycle after the passage of the rain event. The wind speeds during the summer simulation period are slightly lower than those experienced during early summer. The measured wind data used to model the summer conditions are shown in Figure 5.2.

Over the winter simulation period the wind speed was on average around 4 to 5 m/s. The wind direction is typically variable, but the existence of the land / sea breeze cycle can be observed in various parts of the data. The wind data used in for the winter modelling of Coral Coast Resort is shown in Figure 5.3.

5.2.4 Tide Input

Water level measurements have been recorded by the Department of Transport at Monk Head from 1990 to 1993 (refer to Section 2.3). The water level record of 1992 was the most complete data set and was obtained for use in this water quality modelling study.

In general, it is more desirable to use the measured tide data as opposed to predicted tide data generated from tidal constituents. This is because measured tide data includes other factors, such as meteorological and barometric effects, that affect the water level and are not included in the generated tide data. However, the available tide measurements are for a different period in time compared to the selected modelling period. In order to overcome this, the 1992 data needed to be adjusted to best represent the 1998 situation.

Tidal constituents were obtained for Coral Bay from the year 2000 Australian National Tide Tables. Using these constituents, the tide levels for April 1998 and July 1998 were generated. These generated tide levels were compared to the 1992 measurements in order to determine the phasing of the tide data. The timing of the 1992 tides was appropriately adjusted so as to best replicate the generated 1998 tides. The adjusted tides from 1992 were then used as input into the model. A comparison between the adjusted 1992 measured tide levels and the generated tide levels for the summer and winter conditions is shown in Figure 5.4.

It should be noted that prior to 1997 the Bureau of Meteorology's automatic weather station at Carnarvon did not record continuous wind data. The Carnarvon automatic weather station was upgraded in 1997 to include the measurement of wind information. As such, the wind data that coincides with the 1992 tide data could not be used in the modelling.

5.2.5 Inflows and Nutrient Input

Analysis of the likely groundwater regime in the proposed marina after development by Ewing Consulting Engineers and ATA Environmental suggests that the ambient groundwater flow can be considered to be negligible. However, significant inflows into the proposed marina in the form of direct run-off and sub-surface flow from infiltrated rainfall will occur during and immediately after periods of heavy rainfall such as a cyclone. As such, nutrients from gardens will only enter the marina during such rainfall events.

ATA Environmental estimated the inflow from run-off and infiltration, and the amount of nitrogen and phosphorus entering the proposed development waterway for the modelling (this report has been included as Appendix B). The estimates of the inflows and the input of nutrients into the proposed development waterway by ATA Environmental vary spatially throughout the development. The various inflows and input of nutrients for the summer and winter cases are shown in Tables 5.1 and 5.2 below. The locations of the different regions listed in Tables 5.1 and 5.2 below are shown in Figure 5.5. It should be noted that for the summer case, a short but intense rainfall event of 140 mm in 1 day was simulated, and therefore, the inputs shown in Table 5.1 occur over a period of 2 days as there would be a lag between rainfall and groundwater flow. For the winter case, a large rainfall event of 140 mm occurring over a period of 3 days was simulated. Consequently, the winter inputs shown in Table 5.2 occur over a period of 5 days as there would be a lag between rainfall and groundwater flow.

Table 5.1 – Marina Inputs – Summer Conditions

Region	Nutrient Concentration (mg/L)		Daily Inflow Volume into Marina* (m^3)
	Nitrogen	Phosphorus	
A	0.4	0.07	2,898
B	0.2	0.035	3,898
C	1.04	0.25	1,925
D	1.04	0.25	1,680
E	1.04	0.25	2,226
F	0.72	0.16	2,079
G	0.4	0.07	2,499
H	0.2	0.035	840
I	0.72	0.16	1,764
J	0.4	0.07	1,400
K	0.2	0.035	5,082
L	0.2	0.035	609
M	0.4	0.07	1,855
N	0.4	0.07	1,750
O	0.4	0.07	910

*NOTE: These are the daily volumes entering the marina and occur only over a 2 day period representative of an intense rainfall event (such as a cyclone).

Table 5.2 – Marina Inputs – Winter Conditions

Region	Nutrient Concentration (mg/L)		Daily Inflow Volume into Marina* (m^3)
	Nitrogen	Phosphorus	
A	0.4	0.07	1,159
B	0.2	0.035	1,559
C	1.04	0.25	770
D	1.04	0.25	672
E	1.04	0.25	890
F	0.72	0.16	832
G	0.4	0.07	1,000
H	0.2	0.035	336
I	0.72	0.16	706
J	0.4	0.07	560
K	0.2	0.035	2,033
L	0.2	0.035	244
M	0.4	0.07	742
N	0.4	0.07	700
O	0.4	0.07	364

*NOTE: These are the daily volumes entering the marina and occur only over a 5 day period representative of a significant winter storm event.

Based on the values shown in Tables 5.1 and 5.2, it is calculated that over the duration of either the summer or winter rainfall event the *total* load of Dissolved Inorganic Nitrogen entering into the development waterway is around 31 kg, and the *total* load of Phosphorus is around 7 kg. This is an annual load of about 62 kg of DIN and about 14 kg of Phosphorus. To put this loading into perspective, measurements at Jervoise Bay Northern Harbour suggests that the *daily* DIN loading into the harbour is around 65 kg.

The annual nutrient load at Coral Coast resort will be two orders of magnitude less than at Jervoise Bay Northern Harbour.

The background concentration of Dissolved Inorganic Nitrogen (DIN) and phosphorus in the ocean waters used in the modelling was obtained from water quality measurements described in Department of Environmental Protection (1995). The background values used were 0.008 mg/L for DIN and 0.004 mg/L for phosphorus.

5.3 Boundary Conditions

In general, the current regime in the nearshore waters adjacent to the coastline is predominantly shore parallel. Measurements inside the Ningaloo Reef system at Osprey Bay about 120 km north of Mauds Landing by Hearn & Parker (1988) suggest that the current speeds in the region have a mean of around 0.05 to 0.1 m/s. In addition, drogue tracking in Bateman Bay indicated that the currents are generally parallel to the shore and less than 0.1 m/s.

In order to simulate the alongshore transport process the northern and southern boundaries were specified by real tide levels recorded at Coral Bay (as described in Section 5.2.3) and the western boundary was made a no-flow boundary. The tide levels were checked to ensure that the water level throughout the model grid was essentially the same as the tide level applied at the model boundaries. The applied tide levels at the boundaries produced nearshore currents that were parallel to the shore and typically less than 0.1 m/s and were in general agreement with observations and measurements in the area.

At the landward boundary, the inflow (as per the rates described in Tables 5.1 and 5.2) was parameterised by a series of source points along the landward boundary inside the marina area. The vertical locations of these source points were located in the top layer of the model grid along the land boundary. This simulates the surface run-off and the shallow sub-surface flow from infiltration entering the marina during the rainfall event.

5.3.1 Salinity and Temperature

Based on monitoring results documented in Environmental Protection Authority (1995), the background salinity of the ocean water used in the modelling was 35 ppt. The input surface run-off and groundwater inflows were assumed to be fresh and had a modelled salinity of 1 ppt.

For this modelling salinity was assumed to be the dominant descriptor of water density. In addition, it is believed that the likely variations in the temperature that would be experienced would only have a minor secondary effect on the hydrodynamics of the area modelled. Therefore, a constant temperature of 27°C for both the ocean water and the inflows was used for the summer conditions, and a constant temperature of 20°C was used for the winter conditions. These values were based on measurements taken by Department of Conservation and Environment (1986) and discussions with Phil Chalmers from ATA Environmental.

5.3.2 Other Parameters

Based on previous modelling experience of semi-enclosed waterways a horizontal diffusion co-efficient of 1 m^2/s was used. The computational timestep used for this modelling investigation was 30 seconds.

A constant Chézy bed friction value of 50 was used in all of the model runs. The constant turbulent closure model with a constant value of 10^{-6} m^2/s in the vertical and 1 m^2/s in the horizontal was chosen. The values chosen for the bed friction and the turbulent closure model are typical of values that have been previously used in comparable model simulations.

5.4 Harbour Flushing Times

A measure of the flushing time of the various waterways modelled can be determined by calculating the e-folding time. The e-folding time is the time taken for the concentration of a conservative tracer to be reduced to 1/e of its original concentration (ie 37%).

For this modelling investigation, the e-folding time was determined by dosing the entire modelled waterway (ie excluding the ocean) with a known concentration of conservative tracer. The model was then run and the concentration of the tracer recorded at the surface, mid-depth and seabed at several key locations within the modelled waterway. The concentration of tracer at each location was then plotted to determine the e-folding time for each of the modelled waterways.

It should be noted that the e-folding time is very much dependent on the prevailing conditions over the period which it is calculated. For instance, the e-folding time of a waterway would be larger during periods of calm winds and low groundwater inflow.

Additionally, it is considered that the parameters developed for the model are very conservative and potentially represent the worst case scenarios.

5.5 Water Quality Modelling Results

5.5.1 Summer Conditions

Spatial plots of the modelled DIN and Phosphorus concentrations in the surface layer for the summer case are shown in Figures 5.6 to 5.9. These plots generally show that the concentration of nutrients increases with distance from the entrance. The model results suggest that the highest concentration of both DIN and Phosphorus can be expected at the northern end of the development waterway. Also, there is negligible effect on the concentration of DIN and Phosphorus in the ocean waters external to the development. It should be noted that these spatial plots only represent a single snapshot in time, and that the model was run for a period of 21 days.

Figures 5.6 and 5.7 show the distribution of the respective nutrient at the end of the 2 day summer inflow period (00:00, 11 April 1998) and represents the peak modelled summer nutrient loading in the waterway. Figures 5.6 and 5.7 show that at the peak of the summer nutrient input there is no area within the development waterway where the concentration of DIN exceeds 0.03 mg/L, or the concentration of Phosphorus exceeds 0.008 mg/L.

Figures 5.8 and 5.9 show the spatial distribution of the respective nutrient 2 weeks after the peak (00:00, 25 April 1998). These figures show that after a period of 2 weeks, the concentration of DIN and Phosphorus inside the entire development waterway has almost returned to the background concentrations. It is believed that this is the level of DIN and Phosphorus that is likely to be experienced in the development waterway during summer and spring.

Figure 5.10 shows the location of 12 key output locations inside the model grid of the Coral Coast Resort. Plots showing the variation in time of DIN and Phosphorus at the surface, mid-depth, and at the bottom have been produced at these 12 locations for the summer conditions. Decay curves at the surface, mid-depth, and bottom at the 10 locations inside the development waterway have also been produced. For convenience, the percentage concentration equivalent to $^1/e$ of the original concentration (ie 37%) is shown on the decay plots.

Figures 5.11 to 5.16 show the time history plots of DIN and Phosphorus for Locations 1, 5, and 10. Plots at the other locations can be found in Appendix C. These figures show that at each location the concentration of the respective nutrient increases over the 2 day summer inflow event, and then decreases over the remainder of the model simulation. By the end of the model simulation, the concentrations of DIN and Phosphorus throughout the development waterway have essentially returned to the background levels. At the worst location (Location 1) Figures 5.11 and 5.14 show that the concentration of DIN peaks at just under 0.025 mg/L, and the concentration of Phosphorus peaks just below 0.007 mg/L.

Decay curves at Locations 1, 5, and 10 are shown in Figures 5.17 to 5.19. Decay curves at the other locations are included in Appendix D. These decay curves suggest that under summer conditions, the waterway of Coral

Coast Resort has an e-folding time of around 17 days at the northern end, 14 days at the centre of the main canal, and less than a two days at the entrance.

5.5.2 Winter Conditions

Figures 5.20 to 5.23 show the spatial plots of the modelled DIN and Phosphorus concentrations in the surface layer for the winter case. These plots generally show that the concentration of nutrients increases with distance from the entrance. The model results suggest that under winter conditions the highest concentration of both DIN and Phosphorus can be expected at the northern end of the development waterway. Also, there is negligible effect on the concentration of DIN and Phosphorus in the ocean waters external to the development. It should be noted that these spatial plots only represent a single snapshot in time, and that the model was run for a period of 21 days.

Figures 5.20 and 5.21 show the distribution of the respective nutrient at the end of the 5 day winter inflow period (00:00, 16 July 1998) and represents the peak modelled winter nutrient loading in the Resort waterway. Figures 5.20 and 5.21 show that at the peak of the winter nutrient input there is no area within the development waterway where the concentration of DIN exceeds 0.02 mg/L, or the concentration of Phosphorus exceeds 0.006 mg/L.

Figures 5.22 and 5.23 show the spatial distribution of the respective nutrient 2 weeks after the peak (00:00, 30 July 1998). These figures show that after a period of 2 weeks, the concentration of DIN and Phosphorus inside the entire development waterway has almost returned to the background concentrations. It is believed that this is the level of DIN and Phosphorus that is likely to be experienced in the development waterway during winter and autumn.

Figure 5.10 shows the location of 12 key output locations inside the model grid of the Coral Coast Resort. Plots showing the variation in time of DIN and Phosphorus at the surface, mid-depth, and at the bottom have been produced at these 12 locations for the winter conditions. Decay curves at the surface, mid-depth, and bottom at the 10 locations inside the development waterway have also been produced. For convenience, the percentage concentration equivalent to $^1/e$ of the original concentration (ie 37%) is shown on the decay plots.

Figures 5.24 to 5.29 show the time history plots of DIN and Phosphorus for Locations 1, 5, and 10. Plots at the other locations can be found in Appendix C. These figures show that at each location the concentration of the respective nutrient steadily increases over the 5 day winter inflow event, and then decreases over the remainder of the model simulation. By the end of the model simulation, the concentrations of DIN and Phosphorus throughout the development waterway have essentially returned to the background levels. At the worst location (Location 1) Figures 5.24 and 5.27 show that the concentration of DIN peaks at just under 0.017 mg/L, and the concentration of Phosphorus peaks just below 0.006 mg/L.

Decay curves at Locations 1, 5, and 10 are shown in Figures 5.30 to 5.32. Decay curves at the other locations are included in Appendix D. These decay curves suggest that under winter conditions, the waterway of Coral Coast Resort has an e-folding time of around 19 days at the northern end, 17 days at the centre of the main canal, and less than two days at the entrance.

5.6 Discussion and Conclusion

The results of the water quality modelling suggests that the concentration of DIN in the development waterway does not exceed 0.025 mg/L and the concentration of Phosphorus does not exceed a level of 0.007 mg/L under potentially the worst summer and winter conditions (in terms of nutrient loading). In addition, the model results suggest that the elevated levels of nutrients occur mainly over the period of rainfall. The concentration of DIN and Phosphorus throughout the entire development waterway is essentially returned to the background levels within 2 weeks of either rainfall event (intense summer rainfall event or heavy winter rainfall event).

The relationship between the concentration of nutrients such as nitrogen and phosphorus and the production of algae is complex and is affected by many factors including temperature, light intensity, turbidity, other nutrients and the species of algae. EPA (1993) provides a rough guide to the level of nitrogen and phosphorus in coastal waters where nuisance algal growth has been known to occur.

These guidelines however, only provide a range of values at or above which excessive algal growth had been known to occur. They suggest that if the nitrate-nitrogen (a component of DIN) level exceeds 0.01 to 0.1 mg/L, and the phosphate level exceeds 0.005 and 0.015 mg/L then there is a reasonable chance that excessive algal growth could occur. The model results are essentially at the lower end of these ranges.

To put the modelled DIN levels into a better perspective, the measured DIN background concentration in the nearshore waters of Owen Anchorage in Fremantle is on average around 0.025 mg/L. In addition, water quality measurements at Hillarys Boat Harbour in Sorrento suggest that the average concentration of DIN in the harbour is around 0.02 mg/L. It should be noted that it is generally perceived that Hillarys Boat Harbour has acceptable water quality.

Based on the results of this detailed modelling investigation, it is concluded that acceptable water quality (similar to the water quality of the source water) will be achieved in the waterway of the Coral Coast Resort development and that the water quality will comply with EPA (1993) criteria for "Recreation and Aesthetics".

6. Building & Development Levels

In assessing the minimum finished floor levels for buildings in Coral Coast Resort, various physical processes and the design of the development must be considered. The physical processes are:

- astronomical tides;
- severe ocean storm surge;
- possible 'Greenhouse' induced Climate Change; and
- wave run-up.

The design of the development incorporates a built-up area around the Marina and associated waterways, and connecting back into the high coastal dunes. This built-up area will provide protection from the full effects of severe ocean storm surge to the development behind it. Consequently, in the proposed development, the buildings can be categorised into three distinct classes of exposure to ocean storm surge flooding.

- Buildings on coastal dunes;
- Marina and waterway buildings; and
- Buildings behind the built-up coastal area.

The first category covers the buildings along the coastal dunes. The waves in Bateman Bay during the severe storm attack are quite significant and will cause appreciable run up on the beaches. The following is an assessment of the minimum finished floor levels for these buildings on the coastal dunes.

Table 6.1 FFL for Buildings on Coastal Dunes

Factor	Value
Still Water Level 100 year ARI	+2.2 m AHD
Climate change allowance	+0.3 m
Wave set-up on shore of Bateman Bay	+0.2 m
Wave run-up on shore of Bateman Bay	+1.5 m
Freeboard and factor of safety	+0.5 m
Recommended minimum finished floor level	**+4.7 m AHD**

This level is readily achieved as the lots fronting the Bateman Bay will be developed on the relict foredune plain that are around 6 metres above AHD.

The second category covers buildings behind the coastal dunes and around the marina and associated waterways. Here, the waves during the severe storm will be greatly reduced by the protection of the marina breakwaters, and therefore wave run-up effects would be very small. The following is an assessment of the minimum finished floor levels for these buildings around the marina.

Table 6.2 FFL for Marina and Waterway Buildings

Factor	Value
Still water level 100 year ARI	+ 2.2 m AHD
Climate change allowance	+ 0.3 m
Local wave effects	+ 0.3 m
Freeboard and factor of safety	+ 0.5 m
Recommended minimum finished floor level	**+ 3.3 m AHD**

For comparison, Tropical Cyclone Vance caused water levels of 1.6 mAHD at Carnarvon and 3.5 mAHD at Exmouth. Egis (1999) assessed the severity of Vance for the Department of Transport and found that for Exmouth it had an ARI of more than 500 years. Coral Coast Marina Development Pty Ltd has decided to add an extra factor of safety to the development and set the ground level around the marina and waterways at 3.5 mAHD and the finished floor levels at 3.65 mAHD.

The built-up area around the Marina and associated waterway will also be 3.5 mAHD at its lowest point. This will provide a protective barrier against ocean storm surge to the development behind it.

The development behind the built-up area is protected from the full influence of ocean storm surge, but must be able to accommodate the rainfall runoff generated in infrequent but torrential downpours. This aspect is covered in the work completed by Ewing Consulting Engineers (refer to Ewing Consulting Engineers, 1994).

7. Coastal Processes and Shoreline Stability

7.1 General

The coastal geomorphology is briefly described by the Department of Planning and Urban Development (DPUD) (1991). Figure 7.1 has been taken from that report and shows that there are parabolic dunes to the southeast of Point Maud. The active parabolic dune extending north in line with the prevailing southerly winds is also shown. Recent foredunes have formed at Point Maud and on the coast northeast of the old jetty known as Mauds Landing. These more northern foredunes are backed by a relict foredune plain.

The background current regime in the southern portion of Bateman Bay is generally mild and is believed to play only a minor role in the beach dynamics of this area. Wave induced processes are believed to be dominant in the active coastal processes of the beaches in the southern portion of Bateman Bay. These can be categorised as longshore drift and cross shore movement.

7.2 Longshore Drift

The transport of sand along the coast is one of the fundamental mechanisms in beach dynamics. A simplistic description of this mechanism is that in the surf zone of sandy beaches, the breaking waves agitate the sand and place it in suspension. If the waves are approaching at an angle to the beach, then a longshore current can form and this can transport the suspended sand along the beach. This suspended load is accompanied by bed-load transport where sand is rolled over the bed by the shear of the water motion.

As described in Section 2.5, the prevailing waves in Bateman Bay are refracted swell waves that pass through Cardabia Passage. In order to assess the influence of these refracted swell waves, a refraction / diffraction analysis was completed for swell waves approaching the Ningaloo Reef fringing the southern portion of Bateman Bay. This analysis indicated that the southwest swell is refracted significantly and approaches the shore with wave crests virtually parallel to the beach. This means that the angle of approach would be close to zero and there would be little longshore sand transport along the beach.

In the portion of beach 0.5 to 5 km northeast of Point Maud, beach cusps were observed during the August 1994 site visit and can be seen on a variety of aerial photographs. These beach cusps were about 1 metre from crest to trough and have wave lengths in the range of 30 to 50 metres.

When low swell waves approach beaches with steep slopes and the wave crests are parallel to the shore, sub-harmonic edge waves can form. The calculated response to low amplitude swell waves with periods between 10 and 14 seconds is sub-harmonic edge waves with wavelengths ranging from 25 metres to 50 metres. This fits very well with observed conditions of swell period and beach cusp wavelength. The period of the incident swell waves typically varies in the range of 10 to 14 seconds. As the period changes, the wavelength of the edge wave and beach cusps will also change from 25 metres to 50 metres. This will result in the reworking of the beach sands to form the new cusp formation. This reworking will keep the crests of the beach cusps loosely packed and boggy.

The presence of the edge waves is a good indicator that the prevailing swell waves are arriving at the shore with wave crests parallel to the shore. In turn, this means that the prevailing swell waves that enter Bateman Bay through Cardabia Passage would cause little longshore transport along beaches of the southern portion of Bateman Bay.

In section 2.5, it was also outlined that the common southerly breezes would be blowing offshore from the north facing beaches of the southern portion of Bateman Bay. Consequently, these winds would have little influence on the waves that approach the beaches near the proposed development.

Port and Harbour Consultants (1989) examined the issue of longshore sediment transport in Bateman Bay during extreme cyclone events. Numerical modelling was used to assess the amount of longshore sediment transport during Tropical Cyclone Hazel. This storm was assessed by Steedman Science & Engineering (1989) as being representative of the 100 year return period wave conditions.

This analysis indicated that sediment transport during the cyclone storm conditions is generated in a southerly direction along the Maud Townsite coastline. The calculated sand transport decreases from a maximum of about 30,000 m^3 at the northern extremity of the sandy shore, to a negligible amount at Point Maud.

At the marina entrance site, the sediment transport potential in a southerly direction across the entrance was calculated to be about 10,000 m^3 during Tropical Cyclone Hazel. Further south at the western extremity of Point Maud the calculated longshore sediment transport was close to zero.

The above work indicates that during the very common conditions of southerly swells and local winds, the longshore sediment transport is reckoned to be very small. The extreme cyclone storms would create conditions that would transport sand in a southerly direction along the sandy shore of Bateman Bay towards Point Maud. At the proposed marina entrance the calculated transport was about 10,000 m^3 during an extreme cyclone, such as Tropical Cyclone Hazel. This episodic movement of sand along the beach during rare storms can readily be accommodated by the proposed breakwaters that form the marina entrance.

It should be noted that in the months and years that follow such a rare storm, the persistent, low amplitude, background swell will rotate the beach back to its pre-storm alignment.

7.3 Cross Shore Transport

Wave action can cause sediment to be moved onshore or offshore depending upon the wave characteristics and ocean water levels.

Long, low swell waves tend to move sand from the nearshore area onto the beach. The measured beach profiles in the southern portion of Bateman Bay are in line with swell build profile slopes. Onshore movement of sand from the fringing reef and the bay area is likely to be the main feed mechanisms for these sandy beaches.

During storm conditions, the strong winds generate high steep waves. The associated storm surge raises the ocean water level and permits the waves to attack the high portions of the beach. Initially during the storm, the width of the surf zone is not sufficient to dissipate increased energy in the storm waves. The surplus energy is spent in eroding the beach, foredune, and sometimes the primary dunes. The eroded sand is carried offshore and is deposited to form an offshore bar. Eventually this bar may grow large enough to cause the storm waves to break further offshore and spend most of their energy in the surf zone such that no further erosion takes place. This action is described in the Shore Protection Manual (US Army Corps of Engineers, 1984) and is shown diagrammatically in Figure 7.2.

Swart (1976) put forward a technique for calculating the amount of offshore transport during storm events. This method was used to assess the storm profile and the amount of coastal recession that would occur during a very severe storm. The storm conditions used were those calculated for Tropical Cyclone Hazel.

Figure 7.3 shows the calculated erosion during this rare and extreme storm. The calculated erosion extends 70 metres from the present water line at mean sea level. In total, about 50 metres of vegetated coastal dune would be eroded during this extreme storm. In the months and years that follow such a rare and extreme storm, the persistent, low amplitude, background swell would bring some of this eroded sand back onshore and naturally build up the beach. In addition, the background swell will also rotate the beach back to its pre-storm alignment.

7.4 Analysis of Shoreline Movement Plan

Using aerial photographs taken in 1949 and 1981, the longer term trends of shoreline stability were examined. Controlled photogrammetry was used to plot the vegetation line along the shore of the southern portion of Bateman Bay from both photographs. The shoreline movement plan, Figure 7.4, indicates that from Mauds Landing to about 1.8 km northeast, the shore has advanced over the 32 years between photographs. This accretion varies between 5 and 65 metres, and represents rates of between 0.1 and 2 m/year. Most of this section of coast has advanced between 10 and 30 metres over the period between photographs that are rates between 0.3 and 0.9 m/year.

For the first 300 metres to the southwest of Mauds Landing the coast has also advanced at comparable rates. Closer to Point Maud the coast has generally shown little change, although, there are a few areas of recession. These are believed to result from mobile dune sand covering the foredune vegetation in the later photograph.

The shoreline movement plots also show that the tip of Point Maud itself has advanced seaward about 80 metres between 1949 and 1981. This is a rate of about 2.5m/year.

7.5 Recommended Set-back Distances

The Western Australian Planning Commission (1996) suggests that responsible planning of coastal developments should have the coastal development set-back an appropriate distance to allow for the following possible causes of erosion.

- Recession of the coastline equal to 100 times the average annual net erosion rate.
- Erosion during a very severe storm event or series of storms.
- Climate Change as a result of the so called "Greenhouse Effect". This may occur and could lead to an increase in the general level of the ocean, changes to the intensity and frequency of storms, and erosion of some shorelines.

When assessing the appropriate setback distance, a site specific evaluation of each of these factors should be completed. Depending on the level of certainty associated with each of the factors, it may be appropriate to add a

Factor of Safety to account for unknowns and the likely accuracy of each of the estimates.

Allowance for Long Term Shoreline Movement Trends

The shoreline movement analysis completed above in Section 7.4 showed that the shoreline has been advancing seaward over the 32 year period between 1949 and 1981. Based on this assessment, an allowance for long term erosion would not be required.

Allowance for Severe Storm Erosion

The largest movements of sand are believed to occur under the action of severe tropical cyclones. In the work completed by Port & Harbour Consultants (1989) the longshore transport during an extreme cyclone was examined. This analysis indicated that during a very severe cyclone, there was significant transport of sand along the sandy beaches in the southern portion of Bateman Bay. The calculated sand transport was to the south toward Point Maud and varied from about 30,000 m^3 opposite Cardabia Passage to about 10,000 m^3 at the proposed marina site to a negligible amount at Point Maud.

The analysis completed in Section 7.3 suggested that the cross shore transport during such a storm would also be significant. Calculations of the storm erosion during a very rare cyclone event were estimated to cause erosion of up to 50 metres from the present vegetation line. In the months and years that follow such an extreme storm, the persistent, low amplitude, background swell would bring some of this eroded sand back onshore and naturally build up the beach.

Allowance for Climate Change

The above work on coastal stability indicates that the southern shores of Bateman Bay are quite stable. In recent decades, there has been a trend of mild accretion of this coast. This accretionary trend would tend to offset the erosive effects of sea level rise due to Climate Change in the coming century.

Factor of Safety

Based on the methods of determining the allowances for the above factors for a sandy beach, it is appropriate to allow an additional buffer as a Factor of Safety to account for possible inaccuracies in these coastal engineering calculations, gradients in the longshore drift, and storm erosion modelling. A Factor of Safety of 30 metres has been assessed to be appropriate for the sandy beaches along the southern shores of Bateman Bay.

A summary of the above factors as well as the recommended minimum setback distance to development is shown in Table 7.1 below.

Table 7.1 Recommended Setback Distance to Development

Factor	Allowance
Allowance for Long Term Erosion (0 metres x 100 yrs)	0 metres
Severe Storm Erosion – Longshore Movement	10 metres
Severe Storm Erosion – Cross-Shore Movement	50 metres
Allowance for Climate Change (30 m erosion largely offset by future accretion)	10 metres
Factor of Safety	30 metres
Recommended Setback Distance to Development	**100 metres**

It is recommended that that the development line be set-back at least 100 metres from the present vegetation line on the coastal dunes. The set-back distance north of the marina breakwaters should be between 120 and 130 metres from the present vegetation line to ensure that the buildings in the development are located on the relic foredune plain shown in Figure 7.1.

Actual set-backs adopted for the development are between 140 and 170 metres from the present vegetation line and 30 metres inland of the toe of the relict dune formation.

8. Marine Infrastructure and Structures

8.1 Assessment of Demand

The development of the Coral Coast Resort involves the provision of suitable infrastructure. As the Ningaloo Reef will be a significant attraction to the development, it is appropriate that a variety of marine related facilities be provided. In planning for these facilities, an assessment of the likely numbers and sizes of the boats is needed.

By law, all boats with motors must be registered with Department of Transport (DOT). In November 1994, the DOT records show the 'current' registrations at about 52,000. Undoubtedly, there would be a small number of boat owners that disregard the law and do not register their boats. In addition, there are numerous small sailing boats that do not have motor power and are not required to be registered. Nevertheless, the 'current' registration figures do provide a reasonable basis for assessing the likely demand at Coral Coast Resort. Table 8.1 has been compiled using the 'current' boat registration statistics kept by DOT and the estimates of population from the Australian Bureau of Statistics. The data has been compiled for the state, Exmouth, Mandurah and Busselton.

Table 8.1 Boat Ownership Statistics

Location	Number of Boats	Estimated Population	Boats per 1,000 People
Western Australia	52,000	1,695,700	30.7
Shire of Exmouth	199	2,344	85.3
City of Mandurah	3,415	34,202	99.8
Shire of Busselton	1,133	16,333	69.3

Note: The table has been derived from 1994 data.

In an analysis of the boating numbers and sizes throughout the state, PA Australia (1981) concluded that about 80% of the boats in WA are on trailers and about 75% of all boats are kept at home.

Using the available data, and making a few simplifying assumptions, an assessment was made of the boat numbers that would be likely in Coral Coast Resort when fully developed. The results are shown in Table 8.2 below.

Table 8.2 Assessment of Boat Numbers

Item	Boats on Trailers	Boats in Pens	Total Boats
Permanent residents 405 persons at 100 boats per 1,000 people	33	8	41
Residential staff 339 persons at 100 boats per 1,000 people	27	7	34
Caravan park & chalets 120 units at 1 boat per 2 units	60	0	60
Visiting yachts & power boats	0	20	20
Commercial operators	40	10	50
CALM & Dept of Fisheries	3	2	5
Large boats from Bills Bay	0	30	30
Totals for development	**163**	**77**	**240**

In order to cater for this number of boats, it was assessed that the following marine infrastructure would be needed for the ultimate development.

- 2 lanes of boat launching ramps with parking for about 120 trailers and cars.
- 50 to 100 boat pens in the marina and associated waterways.
- 100 metres of public jetties for general use and mooring of the Sail Training Ship "Leeuwin".
- 1 refuelling jetty with appropriate safety measures.

As the boat number would increase progressively with the development, the provision of the marine infrastructure should be staged to suit the demand. An approximate analysis suggests that the actual number of boats in use on any given day could typically be up to 120.

8.2 Marina Entrance Breakwaters

The breakwaters that define the entrance to the Marina, have been designed to provide suitable protection to the Marina and associated waterways during severe storms. The layout is shown on Figure 1.2 and the breakwaters will prevent the incoming waves from penetrating into the Marina. A preliminary diffraction analysis of the entrance configuration indicates that during the 100 year return cyclone, the significant wave height at the Marina pens would be about 0.8 metres.

The construction of the breakwaters must be able to withstand the force of tropical cyclone storms. Port & Harbour Consultants (1989) completed a preliminary design of the breakwater cross sections. These are shown on Figure 8.1. The breakwaters will be conventional rubble mound breakwaters with two layers of large armour stone protecting a core of smaller mixed rock.

The adopted preliminary design utilises 5 to 9 tonnes armour stone and corestone that could be run of quarry rock. This method is economic because it will utilise the produce of nearby quarries in Trealla Limestone. All fractions of the quarry rock can be used in the proposed breakwater design, thereby minimising any need for over quarrying.

It is likely that the breakwater materials will come from quarries near Learmonth. This limestone is strong and quite dense with the saturated surface dry density of around 2.45 t/m^3. Similar rock was used by the Department of Transport in the construction of the Exmouth Boat Harbour. The rock will be transported by road trains to the Mauds Landing site. Each road train will carry about 75 tonnes and about 15 trips would be made each day. In fact, it is anticipated that most journeys will be made at night. The breakwater materials will be placed into temporary stockpiles on the southern side of the entrance channel. The breakwater material will then be moved to its final position using land based equipment. The amount of fine material in the corestone will be deliberately kept to minimal levels to reduce the amount of material carted. This will have the additional benefit of reducing the extent of any turbid plumes formed during breakwater construction. The construction of the breakwaters will take about 6 to 8 months to complete.

8.3 Edge Walling and Internal Beaches

The boundary between the land and the water of the Marina and associated waterway, will be either a simple rock revetment or a sandy beach to suit swimming. Preliminary designs for these edge treatments have been completed as part of the planning studies. The simple rock revetment is shown on Figure 8.2 and the proposed sections for the internal beaches are shown on Figure 8.3.

Both of these edge treatments have been used in many other developments throughout the state over the last few decades. They use locally available materials and provide an effective and economical edge to the water areas.

8.4 Marine Safety and Navigation Issues

The issue of marine safety has been discussed with officers from the Department of Transport. The following summarises the agreed approach to ensuring appropriate marine safety in and around the proposed development.

The pile stumps from the old timber jetty at Mauds Landing will be relocated to the tourist cove within the marina development. This will eliminate the existing boating hazard that would become critical with the increased boat traffic generated by the development.

In order to properly mark the various navigation passages there will be a sector light erected on Mauds Hill to provide safe navigation through Cardabia Passage, which will be mains powered with battery backup. In addition, port and starboard navigation lights will be erected on the entrance breakwaters. These will be solar powered with backup batteries.

The Department of Transport has indicated that it would probably use staff from Fisheries WA, CALM or the Marina Manager to assist in the policing of marine regulations. Transport has also indicated that the speed limit should be 4 knots within the marina and 8 knots in Bateman Bay within 2 km of the marina entrance. This would ensure safe boating conditions and minimise disturbance marine life.

Bateman Bay is well protected from the sea breeze waves but often experiences swell activity. The swell waves shoal and increase in height as they approach the shore until they finally break on the shore. Consequently, it is often dangerous and difficult to launch a boat from the beach near Maud's Landing. This problem will be eliminated with the construction of the marina with entrance breakwaters and hence protected launching ramps. Boats will be able to be safely launched inside the marina then they can safely proceed to Bateman Bay via the marina entrance. Boats underway will safely navigate the nearshore waters of Bateman Bay. They would only be in danger if they travelled into the zone of wave breaking near the shore. This zone is less than 100 metres wide under all but cyclone conditions and well inshore of the marina entrance. The proposed marina and protected boat ramp will provide safe and convenient boat launching and retrieval conditions for all boats that use Bateman Bay.

The design vessel adopted for the marina is the Sail Training Ship Leeuwin as strong interest has been expressed by the Leeuwin Foundation for the berthing of the Leeuwin during the winter months. It is proposed that the entrance channel, core marina area and berthing pocket for the STS Leeuwin be dredged to –4.5 mAHD. The waterway depth for the central area would be dredged to –3.5 mAHD for use by 15 metre yachts boats with drafts up to

2.0 metres. The northern areas would be dredged to –2.8 mAHD to accommodate 10 to 12 metre power boats with drafts up to 1.3 metres.

8.5 Design Standards and Approvals

All of the marine structures will be designed to the relevant Australian Standards, accepted industry standards and the requirements of the Department of Transport. The detailed designs of the entrance breakwaters will include numerical modelling of waves in Bateman Bay during a severe cyclone to confirm the preliminary design estimates. In addition, the breakwater design will be refined using laboratory testing in a wave flume to confirm the stability and crest levels.

The final designs for the marine structures will be submitted to the Department of Transport to obtain the necessary approvals and Jetty Licences.

9. Summary and Recommendations

The oceanographic conditions vary markedly from the open ocean to the sheltered conditions behind the Ningaloo Reef. The position and extent of the reef provides substantial protection to the southern portion of Bateman Bay. The most severe conditions will occur during the passage of Tropical Cyclones. The 100 year return period storm surge is estimated to be about 1.9 metres above the astronomical tide. The wave conditions during an extreme cyclone with a similar return period are estimated to reach significant wave heights of about 6.2 metres outside the reef and about 3.7 metres in 7 metres of water near the proposed marina entrance.

The waters of Bateman Bay would be regularly flushed by the wind, tide and wave forced currents. Because of the wave-driven water transfer across the Ningaloo Reef and tidal flows through the reef gaps the nearshore water will be regularly mixed and exchanged with new ocean water. Except for the possible influx of pollutants and nutrients from the waters of Bills Bay, the water in Bateman Bay should be virtually identical in composition to that of the near by ocean.

The Marina and associated waterways have been designed and will be managed to ensure that there will be minimal inflow of pollutants and nutrients. The small lot size and careful landscaping have helped keep nutrient loads to very small levels.

The results of detailed water quality modelling suggests that the peak concentration of DIN in the development waterway does not exceed 0.025 mg/L and the concentration of Phosphorus does not exceed a level of 0.007 mg/L under potentially the worst summer and winter conditions (in terms of nutrient loading). In addition, the model results suggest that the elevated levels of nutrients occur mainly over and immediately after periods of rainfall. The concentration of DIN and Phosphorus throughout the entire development waterway is essentially returned to the background levels within 2 weeks of either rainfall event (intense summer rainfall event or heavy winter rainfall event).

Based on the results of this detailed modelling investigation, it is concluded that acceptable water quality (similar to the water quality of the source water) will be achieved in the waterway of the Coral Coast Resort development and that the water quality will comply with the EPA (1993) criteria for "Recreation and Aesthetics".

The 100 year return period steady water level (storm surge coupled with the astronomical tide) was estimated to be 2.2 mAHD. Using this and accounting for the wave run-up during the design cyclone, and making an allowance for the possible increase in mean sea level due to possible climate change, the minimum finished floor levels were recommended to be 4.7 metres above AHD for the buildings behind the coastal foredunes on Bateman Bay and 3.3 metres above AHD for the buildings around the marina and associated waterways. Higher levels respectively of 6 metres and 3.65 metres above AHD have been adopted.

The work on coastal stability indicates that the southern shores of Bateman Bay are quite stable. In recent decades, there has been a trend of mild accretion of this coast.

The largest movements of sand are believed to occur under the action of severe tropical cyclones. An analysis indicated that during a very severe cyclone, there would be significant transport of sand along the sandy beaches in the southern portion of Bateman Bay. The calculated sand transport for the 100 year cyclone was to the south toward Point Maud and varied from about 30,000 m^3 opposite Cardabia Passage to about 10,000 m^3 at the proposed marina site to a negligible amount at Point Maud.

The cross shore transport during such a storm would also be significant. Calculations of the storm erosion during a 100 year cyclone event were estimated to cause erosion of up to 50 metres from the present vegetation line. In the months and years that follow such an extreme storm, the persistent, low amplitude, background swell would bring some of this eroded sand back onshore and naturally build up the beach.

In order to allow for possible inaccuracies in these coastal engineering calculations, gradients in the longshore drift, and to provide an appropriate buffer as a factor of safety, it is recommended that the development line be set-back at least 100 metres from the present vegetation line on the coastal dunes. The actual setback north of the marina breakwaters will be between 140 metres and 170 metres to ensure that the buildings in the development are located 30 metres inland of the toe of the relict foredune plain.

Coral Coast Resort will be a significant attraction for boating activities. It was assessed that when fully developed, there would be in the order of 240 boats in the various sectors of the development. As most of the boats are expected to be trailerable boats, the development will have two lanes of launching ramps with parking for 120 cars and trailers. The ultimate demand for pens in the marina and associated waterways has been estimated to be between 50 and 100, although the marina waterbody is large enough to accommodate a much greater number of pens. It was also estimated that on a typical day, up to 120 boats could be in use.

The breakwaters that define the entrance to the marina have been designed to provide suitable protection to the marina and associated waterways during severe cyclonic storms. The breakwaters will be conventional rubble mound breakwaters with two layers of large armour stone protecting a core of smaller mixed rock. Suitable rock can be obtained from quarries in the region.

The marina entrance breakwaters will provide safe access to any boats using Bateman Bay.

10. References

Bishop, J.M., 1979. *A Note on Surface Wind Driven Flow*. Ocean Engineering, v6, pp273-284.

Coastal Engineering Research Centre, 1984. *Shore Protection Manual.* Report prepared by US Army Corps of Engineers. Published by the US Government Printing Office, Washington DC.

Department of Conservation and Environment, 1986. *Tide and seawater temperature data from the Ningaloo Reef Tract, Western Australia, and the implications for coral mass spawning*. Bulletin No. 253, March 1986. Published by the Department of Conservation and Environment.

Egis, 1999. *Exmouth Boat Harbour – Assessment of the Severity of Tropical Cyclone Vance.* Prepared for the Department of Transport.

Environmental Protection Authority, 1993. *Western Australian Water Quality Guidelines for Fresh and Marine Waters.* Published by the Environmental Protection Authority.

Environmental Protection Authority, 1995. *Survey of water quality, groundwater, sediments and benthic habitats at Coral Bay, Ningaloo Reef, Western Australia.* Report prepared for the Department of Conservation and Land Management.

Ewing Consulting Engineers, 1994. *Coral Coast Resort - Mauds Landing, Report on Engineering Considerations.* Report prepared for Coral Coast Marina Development Pty Ltd, December 1994.

Department of Planning & Urban Development, 1991. *Coral Bay Planning Strategy.* Published by the Department of Planning and Urban Development, Perth, Western Australia.

Hearn & Parker, 1988. *Hydrodynamic Processes on the Ningaloo Coral Reef, Western Australia.* Proceedings of the 6th International Coral Reef Symposium, Australia.

Institution of Engineers, Australia, 1991. *Climate Change and Coastal Engineering.* Published by the National Committee on Coastal and Ocean Engineering.

IPCC, 1995. *Climate Change 1995 - The Science of Climate Change.* Published by Cambridge University Press for the Intergovernmental Panel on Climate Change.

McKeehan, D.S., 1975. *Water Motion in Closed-end Canals*. RSMAS Technical Report 75-1. Published by the University of Miami, USA.

Pielke, R.A., 1991. *Overlooked Scientific Issues in Assessing Hypothesized Greenhouse Gas Warning*. Published by Environmental Software, v6(2).

Port & Harbour Consultants, 1989. *Maud Townsite - Coral Bay Marina, Extreme Events Study*. Report prepared for Coral Coast Marina Development Pty Ltd.

Rockwater, 1994. *Evaluation of Groundwater Conditions near Mauds Landing in the Coral Bay Area for the Public Environmental Review*. Report prepared for Coral Coast Marina Development Pty Ltd.

Standards Associations of Australia, 1989. *Loading Code, Part 2 Wind Loads AS1170.2 – 1989*. Published by Standards Australia.

Steedman Science & Engineering, 1989. *Preliminary Extreme Wave and Storm Surge Study, Coral Bay*. Report R440 prepared for Coral Coast Marina Development Pty Ltd.

Swart D.H., 1976. *Predictive Equations Regarding Coastal Transports*. Proceedings of the 15th Coastal Engineering Conference, Hawaii. Published by the American Society of Civil Engineers.

US EPA (US Environmental Protection Authority), 1995. *The Probability of Sea Level Rise*. Report Published by the US Environmental Protection Authority, Office of Policy Planning, and Evaluation.

US Navy, 1976. *Marine Climate Atlas of the World, Volume 3, Indian Ocean*. Published by the US Government Printing Office, Washington DC.

Western Australian Planning Commission, 1996. *Coastal Planning and Development in Western Australia - Towards a Policy Framework*. Released for Public Comment by the Government of Western Australia

11. Figures

Figure 1.1 – Bateman Bay	48
Figure 1.2 – Proposed Development Layout	49
Figure 2.1 – Wind Rose, Winter Mornings	50
Figure 2.2 – Wind Rose, Winter Afternoons	51
Figure 2.3 – Wind Rose, Summer Mornings	52
Figure 2.4 – Wind Rose, Summer Afternoons	53
Figure 2.5 – Tidal Submergence Curve	54
Figure 2.6 – Estimated Typical Currents	55
Figure 2.7 – Offshore Wave Climate	56
Figure 5.1 – Coral Coast Resort Bathymetry	57
Figure 5.2 – Measured Wind Data – Summer	58
Figure 5.3 – Measured Wind Data – Winter	59
Figure 5.4 – Tidal Data	60
Figure 5.5 – Locations of Regions	61
Figure 5.6 – Modelled DIN Levels at Summer Peak	62
Figure 5.7 – Modelled Phosphorus Levels at Summer Peak	63
Figure 5.8 – Modelled DIN Levels after Summer Peak	64
Figure 5.9 – Modelled Phosphorus Levels after Summer Peak	65
Figure 5.10 – Model Output Locations	66
Figure 5.11 – Summer DIN Levels – Location 1	67
Figure 5.12 – Summer DIN Levels – Location 5	68
Figure 5.13 – Summer DIN Levels – Location 10	69
Figure 5.14 – Summer Phosphorus Levels Location 1	70

Figure 5.15 – Summer Phosphorus Levels Location 5 71

Figure 5.16 – Summer Phosphorus Levels Location 10 72

Figure 5.17 – Summer Decay Curve – Location 1 73

Figure 5.18 – Summer Decay Curve – Location 5 74

Figure 5.19 – Summer Decay Curve – Location 10 75

Figure 5.20 – Modelled DIN Levels at Winter Peak 76

Figure 5.21 – Modelled Phosphorus Levels at Winter Peak 77

Figure 5.22 – Modelled DIN Levels after Winter Peak 78

Figure 5.23 – Modelled Phosphorus Levels after Winter Peak 79

Figure 5.24 – Winter DIN Levels – Location 1 80

Figure 5.25 – Winter DIN Levels – Location 5 81

Figure 5.26 – Winter DIN Levels – Location 10 82

Figure 5.27 – Winter Phosphorus Levels Location 1 83

Figure 5.28 – Winter Phosphorus Levels Location 5 84

Figure 5.29 – Winter Phosphorus Levels Location 10 85

Figure 5.30 – Winter Decay Curve – Location 1 86

Figure 5.31 – Winter Decay Curve – Location 5 87

Figure 5.32 – Winter Decay Curve – Location 10 88

Figure 7.1 – Coastal Geomorphology 89

Figure 7.2 – Storm Wave Attack 90

Figure 7.3 – Extreme Storm Erosion 91

Figure 7.4 – Shoreline Movement Plan 92

Figure 8.1 – Breakwater Cross Section 93
Figure 8.2 – Typical Edge Treatment 94
Figure 8.3 – Beach Edge Treatment 95

Figure 1.1 – Bateman Bay

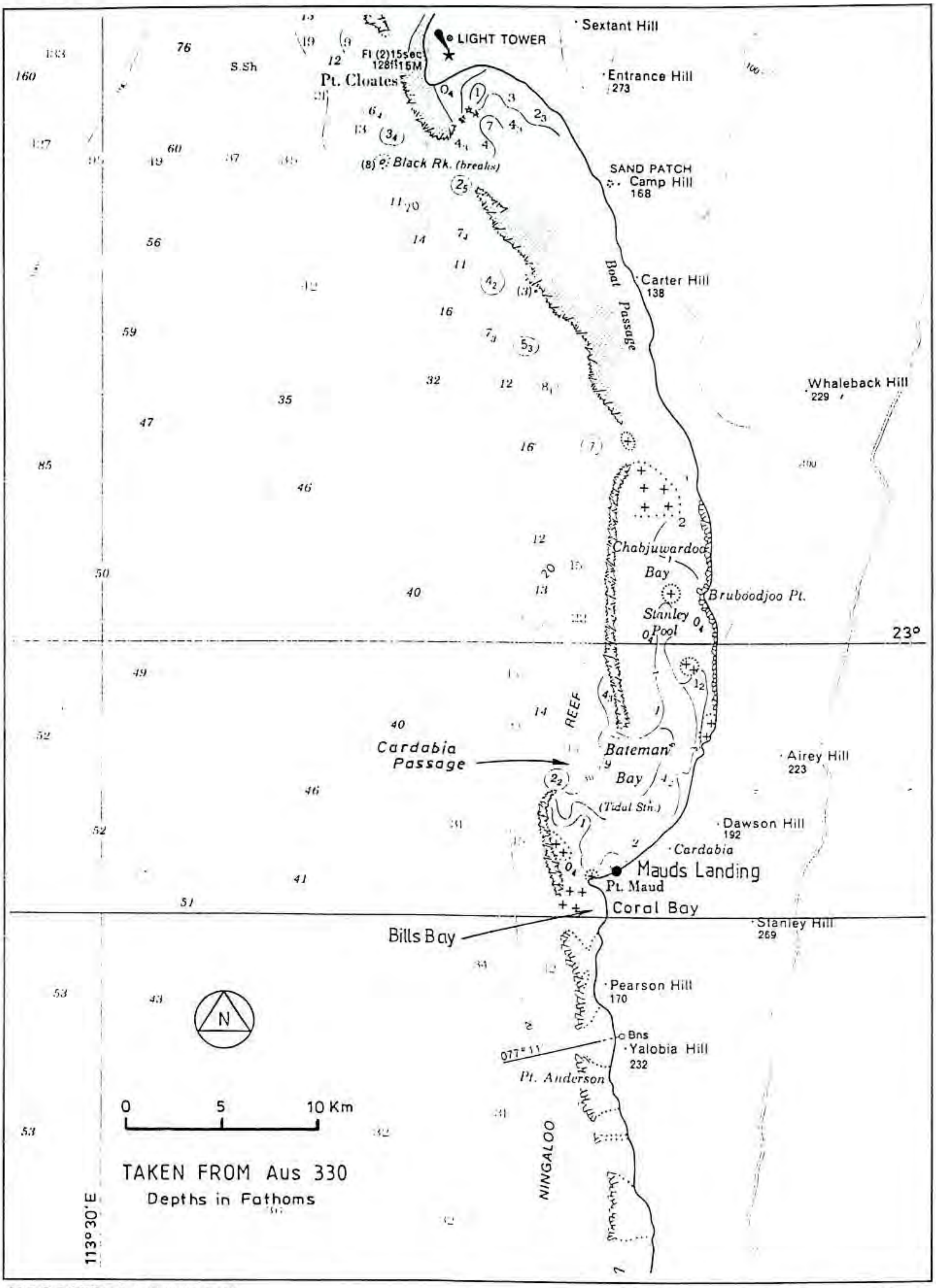


Figure 1.2 - Proposed Development Layout

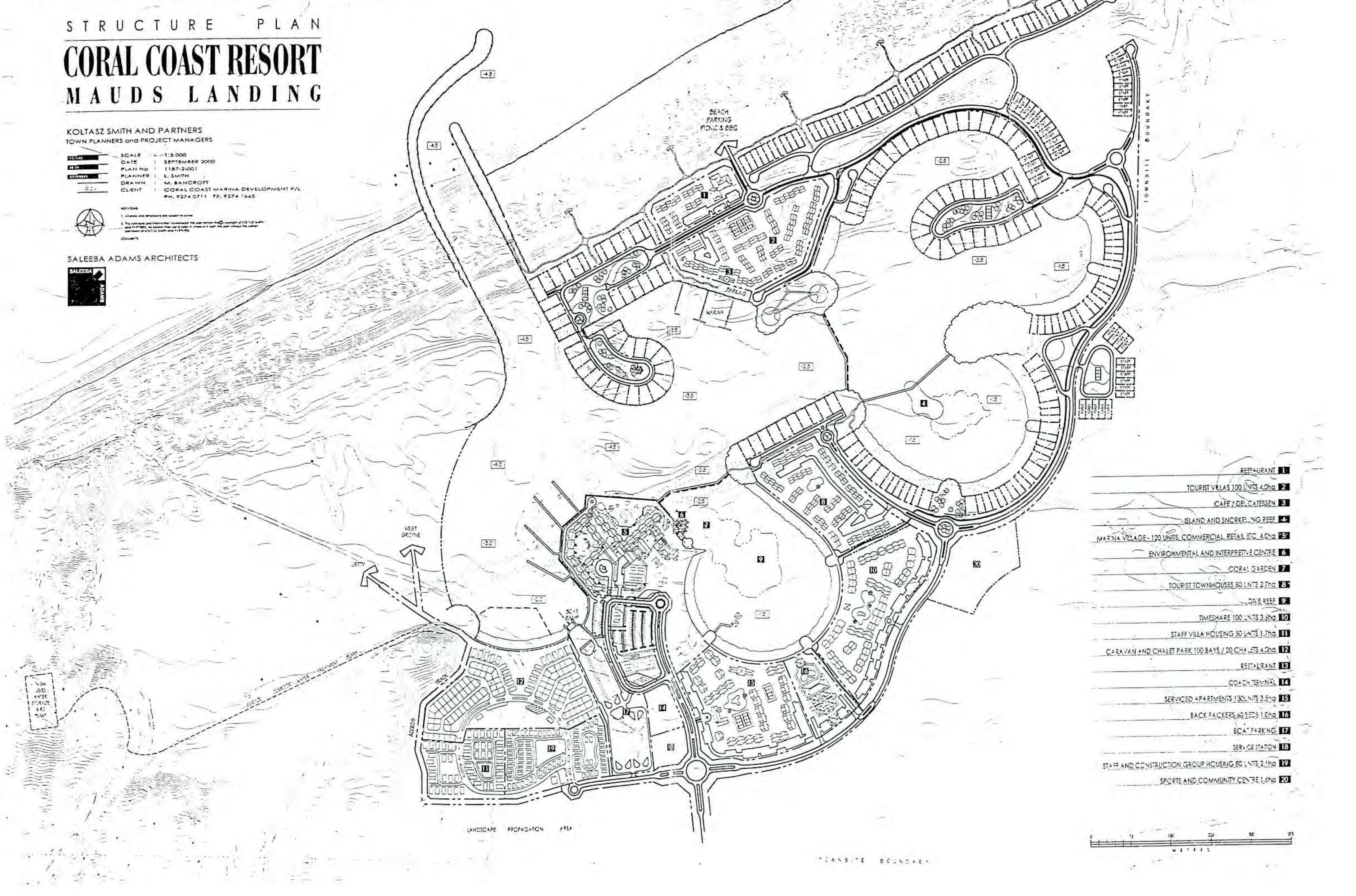
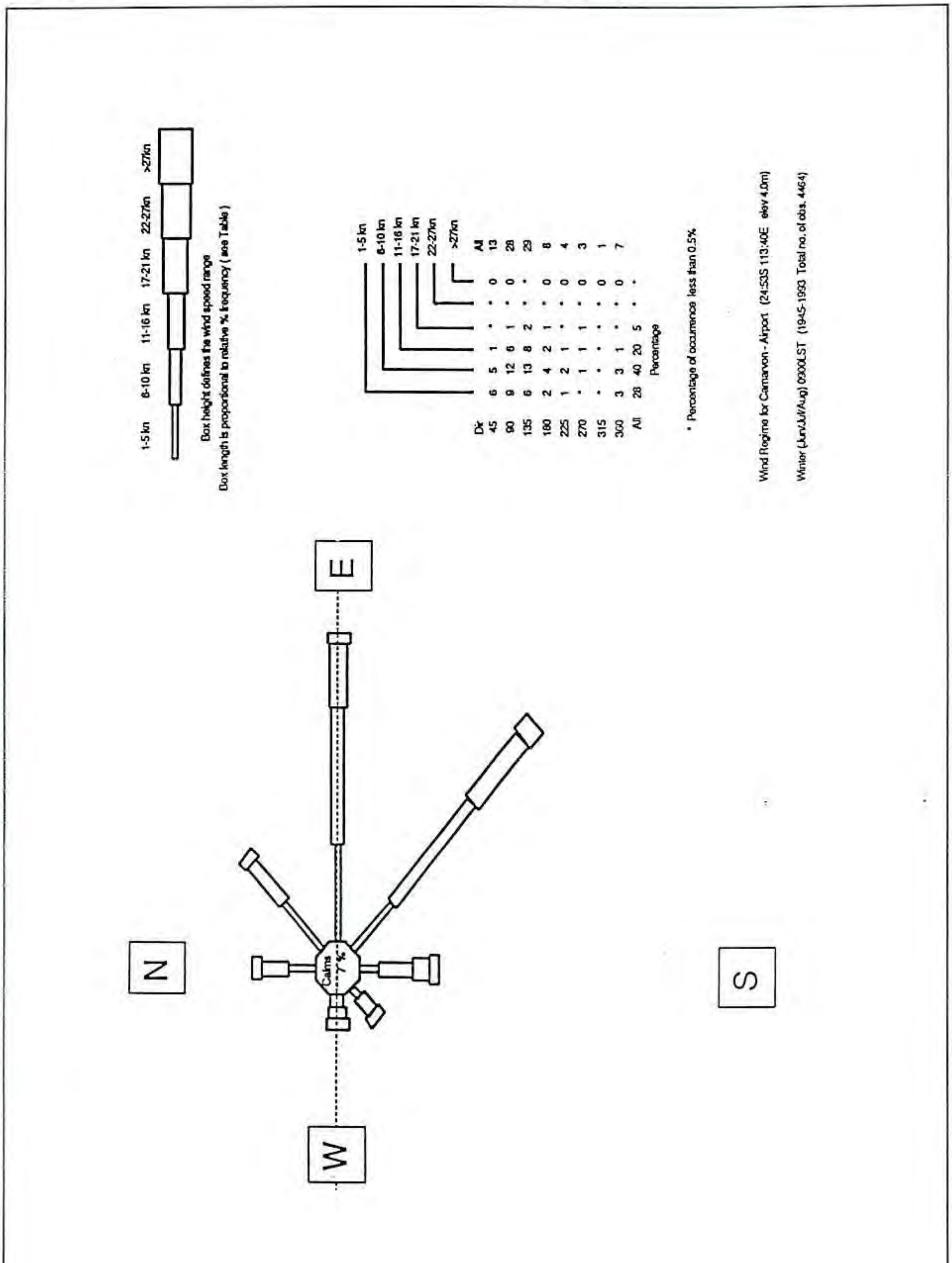


Figure 2.1 – Wind Rose, Winter Mornings



Dir	1-5 kn	6-10 kn	11-16 kn	17-21 kn	22-27kn	>27kn	All
45	6	5	1	*	*	0	13
90	9	12	6	1	*	0	28
135	6	13	8	2	*	*	29
180	2	4	2	1	*	0	8
225	1	2	1	*	*	0	4
270	*	1	1	1	*	0	3
315	*	*	*	*	*	0	1
360	3	3	1	*	*	0	7
All	28	40	20	5	*	*	

Percentage

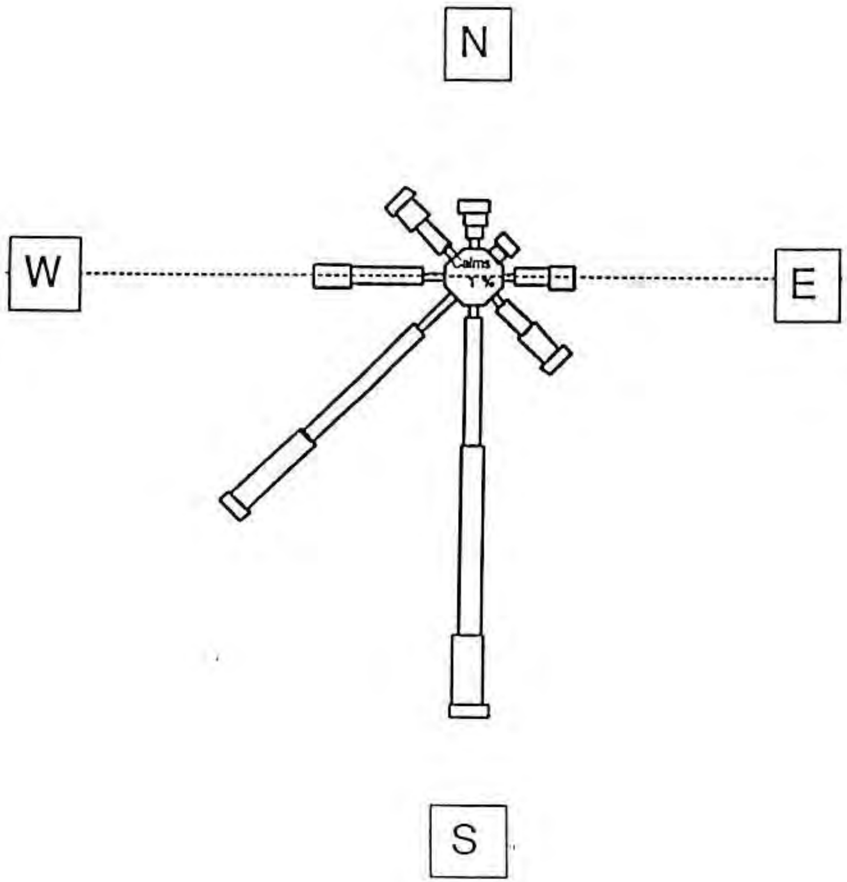
* Percentage of occurrence less than 0.5%

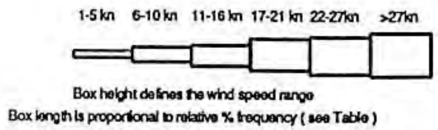
Wind Regime for Carnarvon - Airport (24:53S 113:40E elev 4.0m)

Winter (Jun/Jul/Aug) 0300LST (1945-1993 Total no. of obs. 4464)

Source: Bureau of Meteorology

Figure 2.2 – Wind Rose, Winter Afternoons





Dir	1-5 kn	6-10 kn	11-16 kn	17-21 kn	22-27kn	>27kn	All
45	*	1	1	*	*	*	2
90	1	3	2	*	*	0	6
135	1	3	3	1	*	0	8
180	1	11	16	6	1	*	34
225	4	13	8	1	*	*	26
270	2	6	3	*	*	*	11
315	1	3	2	1	*	*	7
360	1	1	1	1	*	*	4
All	11	41	34	10	1	*	

Percentage

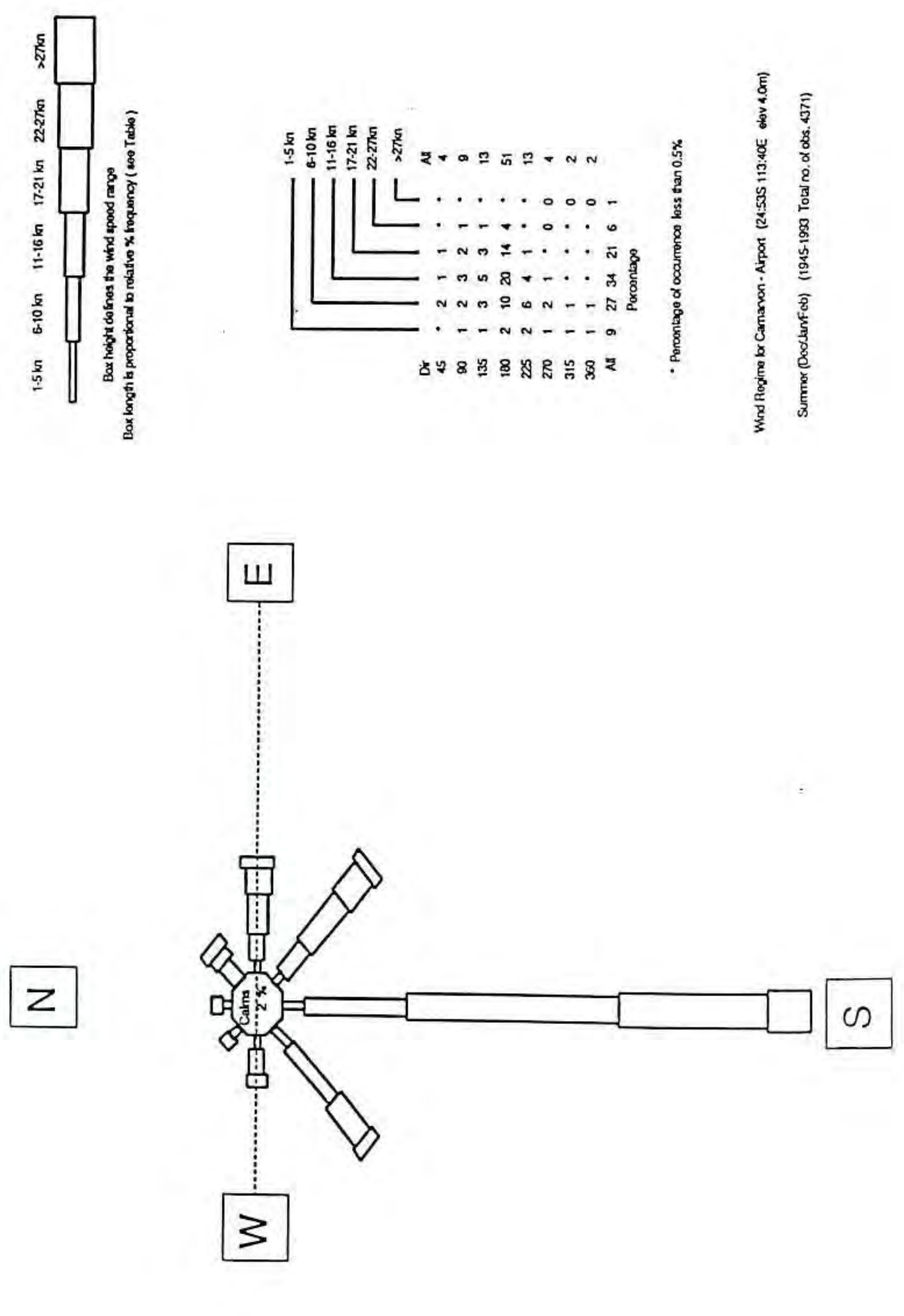
* Percentage of occurrence less than 0.5%

Wind Regime for Carnarvon - Airport (24:53S 113:40E elev 4.0m)

Winter (Jun/Jul/Aug) 1500LST (1945-1993 Total no. of obs. 4399)

Source: Bureau of Meteorology

Figure 2.3 – Wind Rose, Summer Mornings



Dir	1-5 kn	6-10 kn	11-16 kn	17-21 kn	22-27kn	>27kn	All
45	*	2	1	1	*	*	4
90	1	2	3	2	1	*	9
135	1	3	5	3	1	*	13
180	2	10	20	14	4	*	51
225	2	6	4	1	*	*	13
270	1	2	1	*	0	0	4
315	1	1	*	*	*	0	2
360	1	1	*	*	*	0	2
All	9	27	34	21	6	1	

Percentage

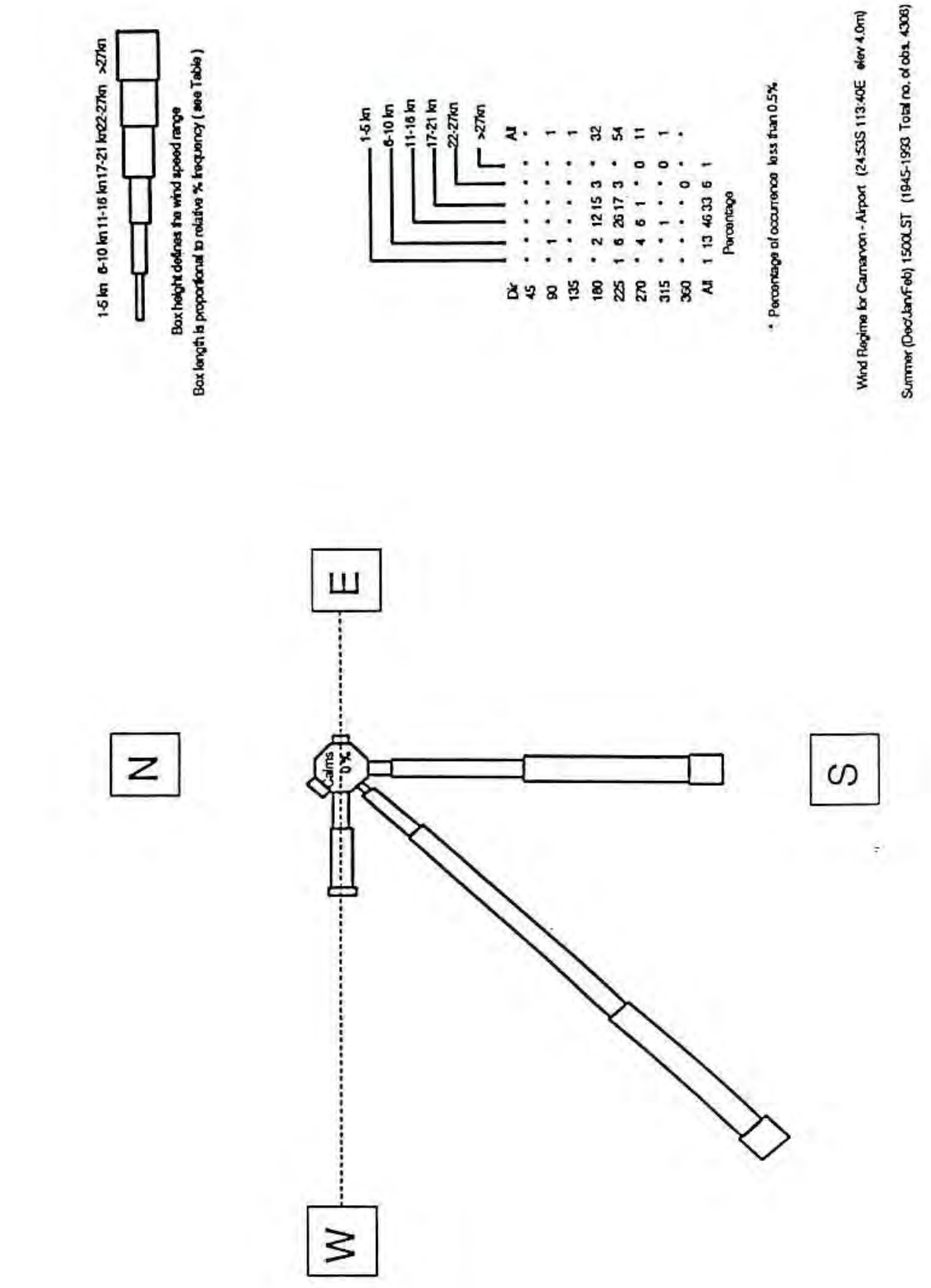
* Percentage of occurrence less than 0.5%

Wind Regime for Carnarvon - Airport (24:53S 113:40E elev 4.0m)

Summer (Dec/Jan/Feb) (1945-1993 Total no. of obs. 4371)

Source: Bureau of Meteorology

Figure 2.4 – Wind Rose, Summer Afternoons

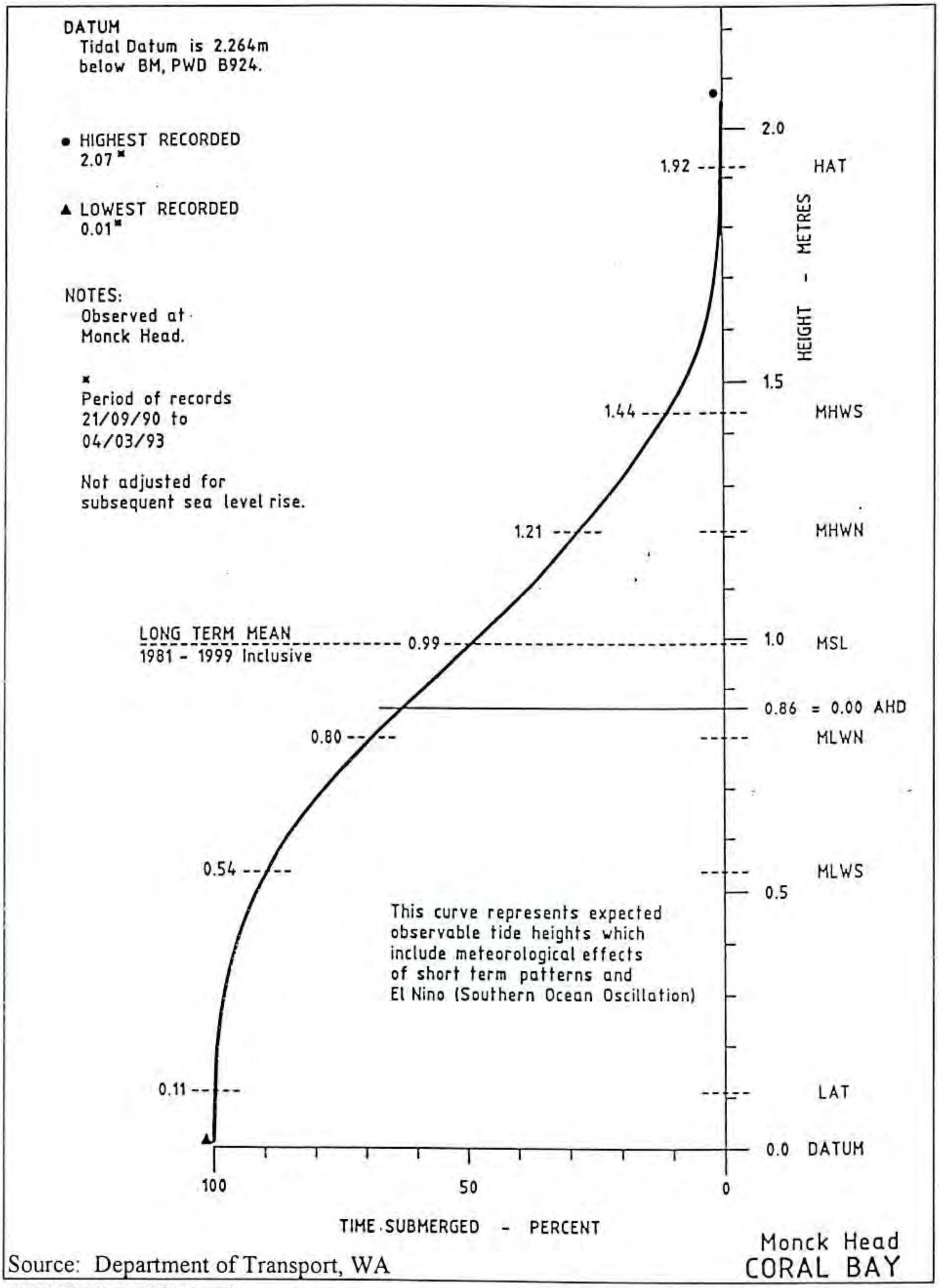


Dir	1-5 kn	6-10 kn	11-16 kn	17-21 kn	22-27kn	>27kn	All
45	*	*	*	*	*	*	*
90	*	1	*	*	*	*	1
135	*	*	*	*	*	*	1
180	*	2	12	15	3	*	32
225	1	6	26	17	3	*	54
270	*	4	6	1	*	0	11
315	*	*	1	*	*	0	1
360	*	*	*	*	0	*	*
All	1	13	46	33	6	1	

Percentage

Source: Bureau of Meteorology

Figure 2.5 – Tidal Submergence Curve



Source: Department of Transport, WA

Figure 2.6 – Estimated Typical Currents

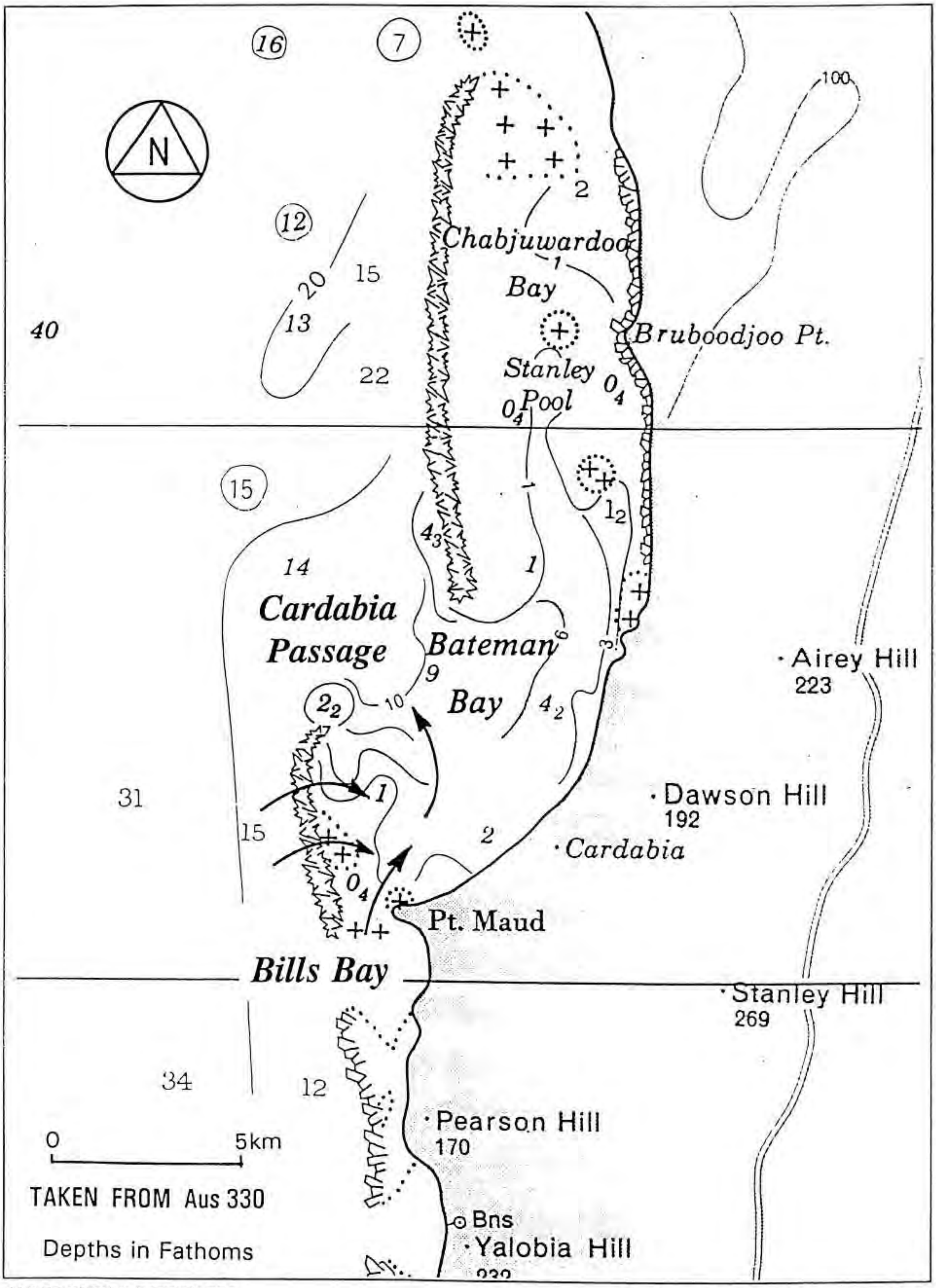


Figure 2.7 – Offshore Wave Climate

WAVE HEIGHT AND DIRECTION FREQUENCY DISTRIBUTION (SITE 26)

SUMMER

Direction	Significant Wave Height (m) 0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	1	0	0	0	0	0	0	0	1
NE	0	0	0	0	0	0	0	0	0
E	1	0	0	0	0	0	0	0	1
SE	2	17	10	6	0	0	0	0	34
S	4	23	16	6	1	0	0	0	50
SW	1	3	4	3	0	0	0	0	11
W	0	1	0	1	0	0	0	0	2
NW	0	0	0	0	0	0	0	0	0
Indet	0	0	0	0	0	0	0	0	0
Total	10	43	30	16	1	0	0	0	100

(n = 196)

AUTUMN

Direction	Significant Wave Height (m) 0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	1	0	0	0	0	0	0	1
NE	0	0	0	0	0	0	0	0	1
E	0	1	3	0	0	0	0	0	5
SE	2	15	16	12	2	0	0	0	47
S	0	14	10	5	2	0	0	0	31
SW	0	3	5	3	0	0	0	0	10
W	0	1	0	0	0	0	0	0	2
NW	1	1	0	0	0	0	0	0	2
Indet	0	1	1	0	0	0	0	0	2
Total	4	37	35	20	4	0	0	0	100

(n = 164)

WINTER

Direction	Significant Wave Height (m) 0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0
E	0	2	2	1	0	0	0	0	4
SE	0	6	9	1	1	0	1	0	19
S	0	10	15	10	0	0	0	0	35
SW	0	7	12	10	0	3	0	0	31
W	0	5	1	1	0	0	0	0	7
NW	0	0	0	0	0	0	0	0	0
Indet	1	0	3	0	0	0	0	0	4
Total	1	29	42	23	1	3	1	0	100

(n = 83)

SPRING

Direction	Significant Wave Height (m) 0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0
E	0	3	0	0	0	0	0	0	4
SE	1	9	20	5	0	0	0	0	35
S	0	12	17	8	0	0	0	0	37
SW	2	8	5	2	2	0	0	0	19
W	0	0	2	0	0	0	0	0	2
NW	0	0	0	0	0	0	0	0	0
Indet	1	2	1	0	0	0	0	0	3
Total	5	34	45	14	2	0	0	0	100

(n = 116)

Source: US Navy (1976)

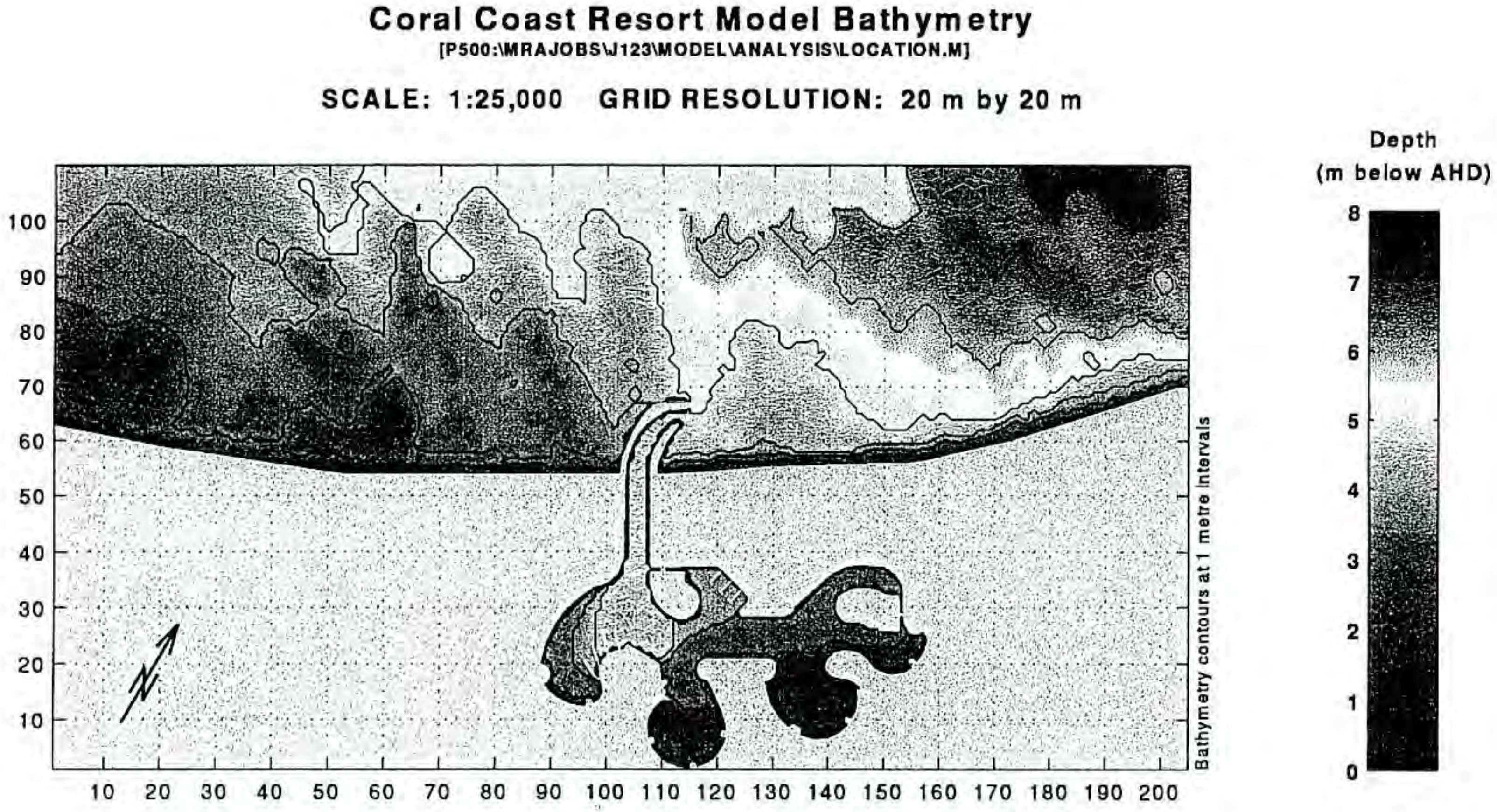
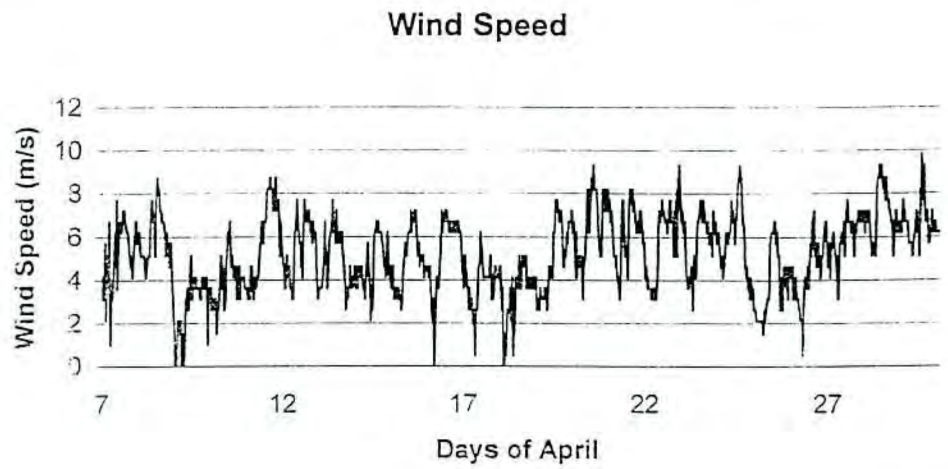


Figure 5.1 – Coral Coast Resort Bathymetry

Figure 5.2 – Measured Wind Data – Summer



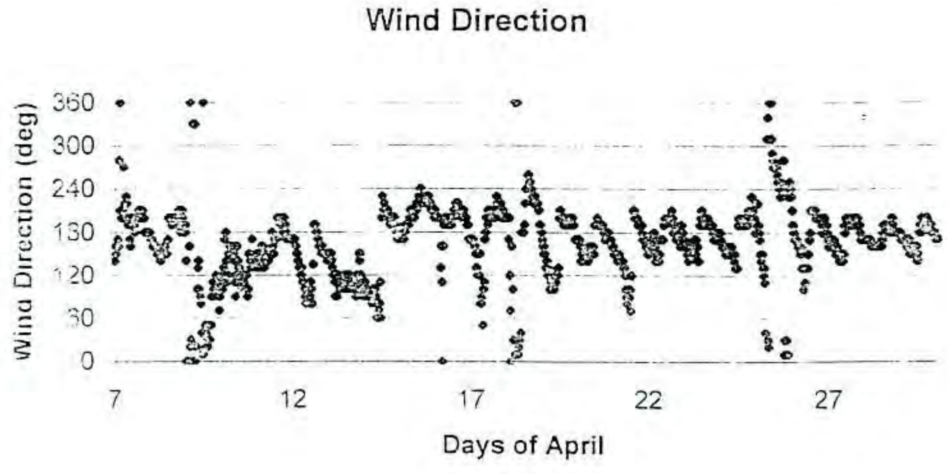
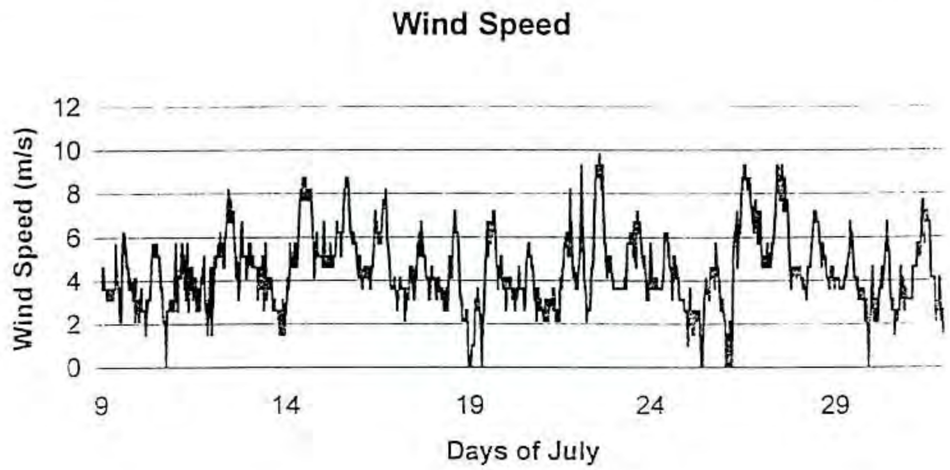


Figure 5.3 – Measured Wind Data – Winter



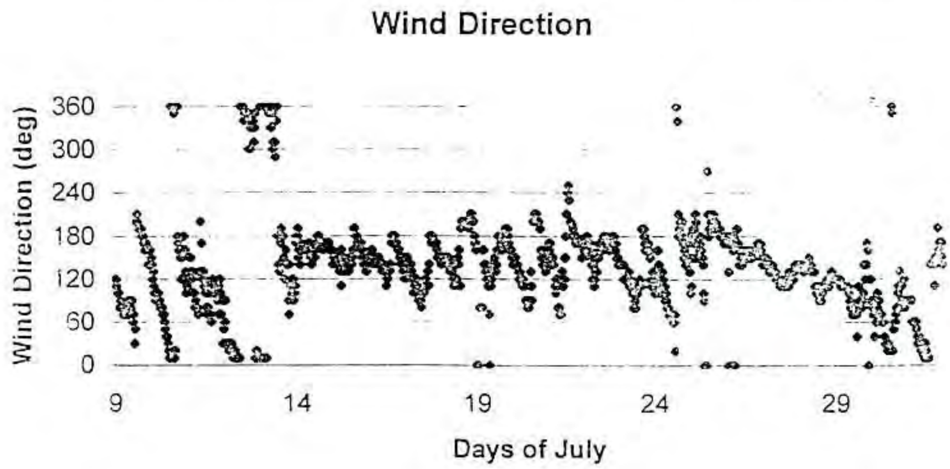


Figure 5.4 – Tidal Data

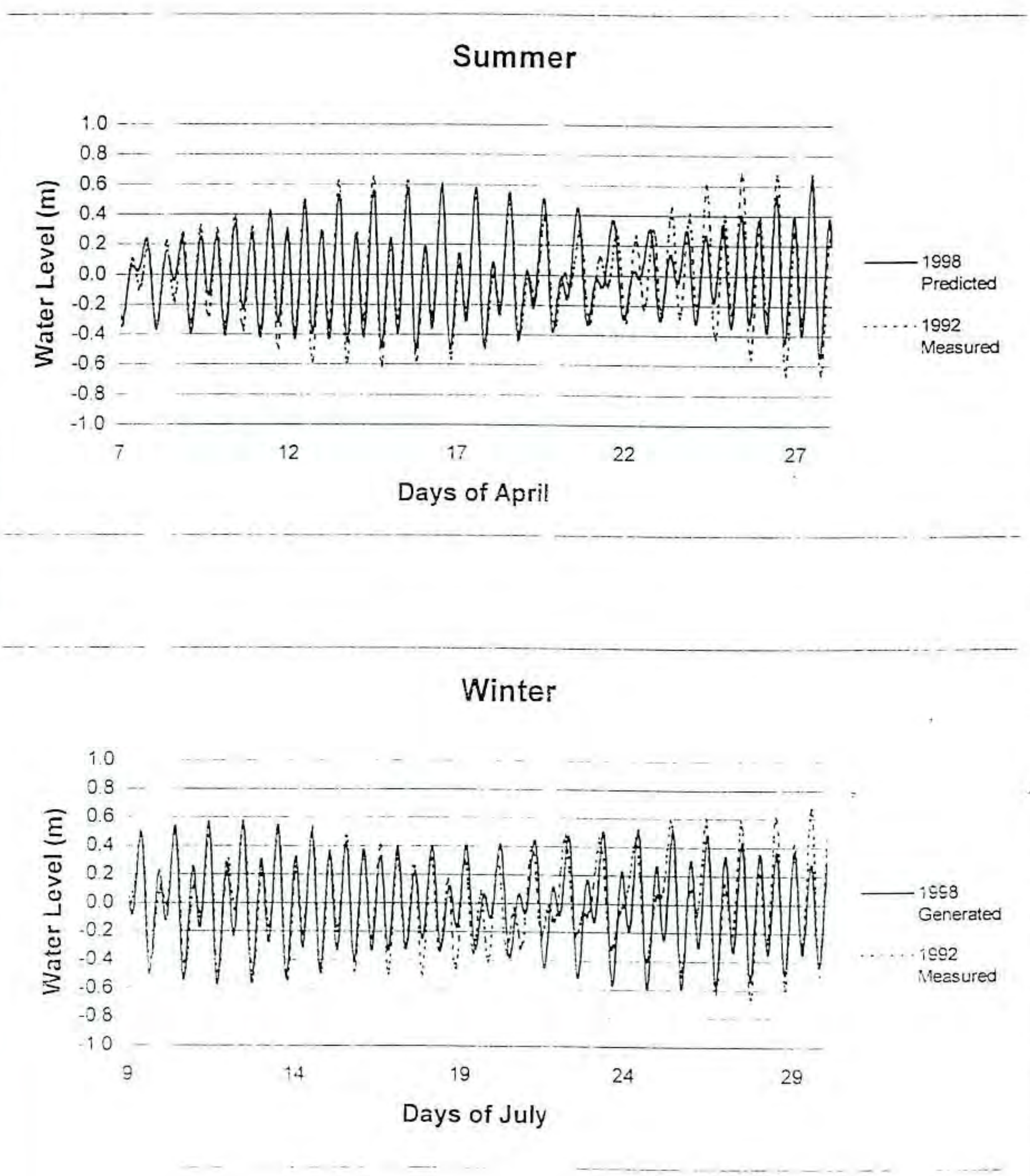
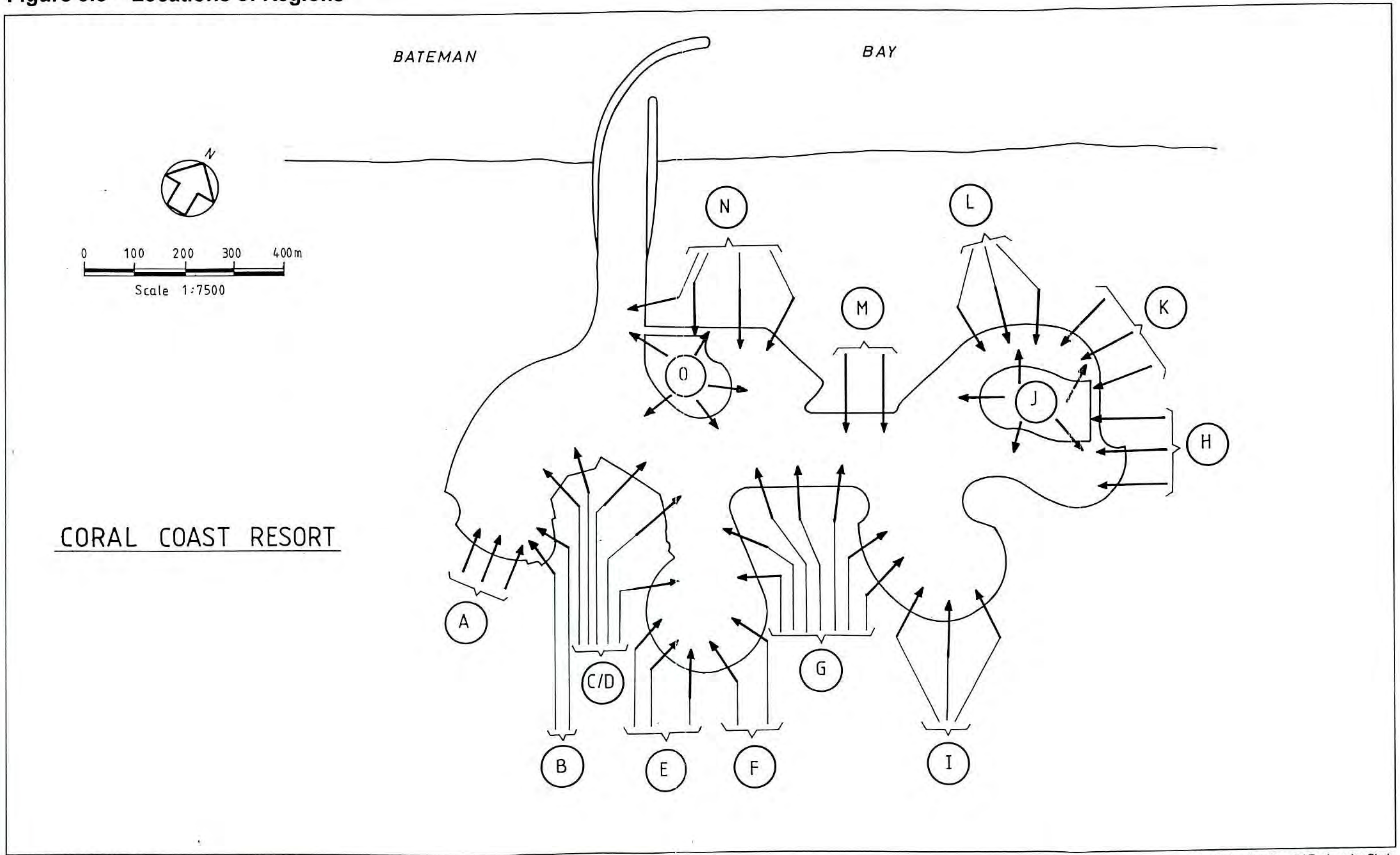


Figure 5.5 – Locations of Regions



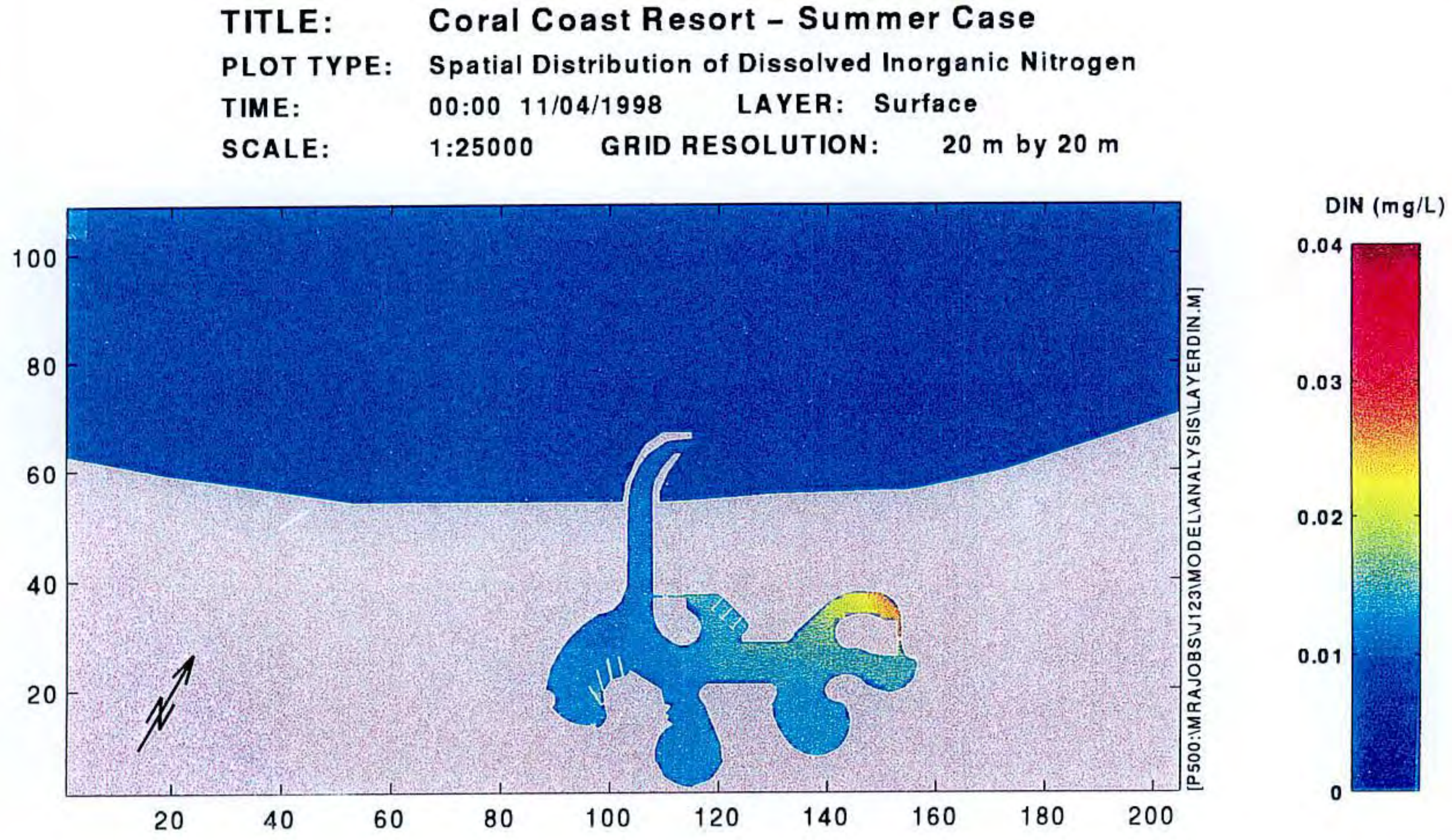


Figure 5.6 – Modelled DIN Levels at Summer Peak

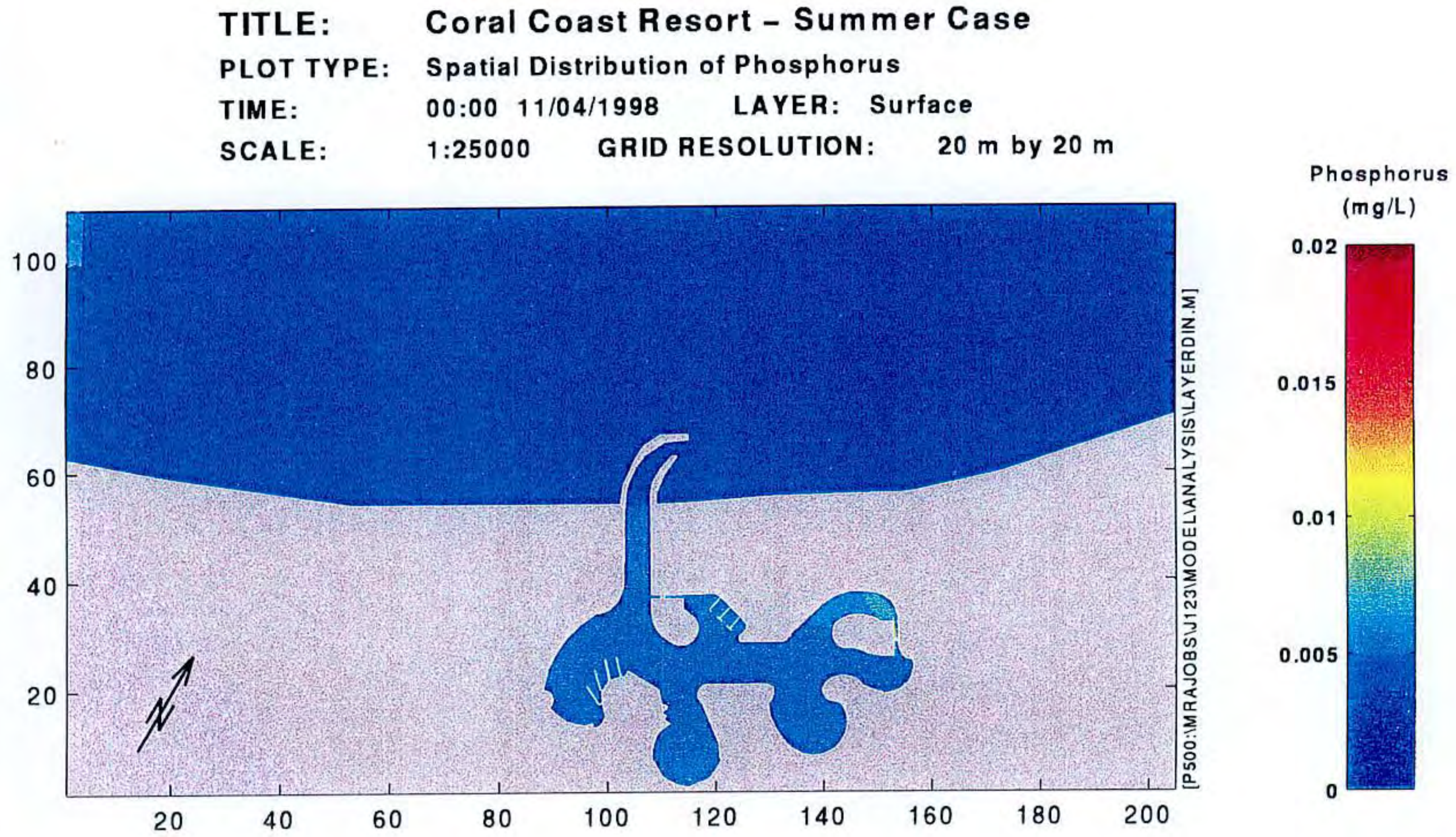


Figure 5.7 – Modelled Phosphorus Levels at Summer Peak

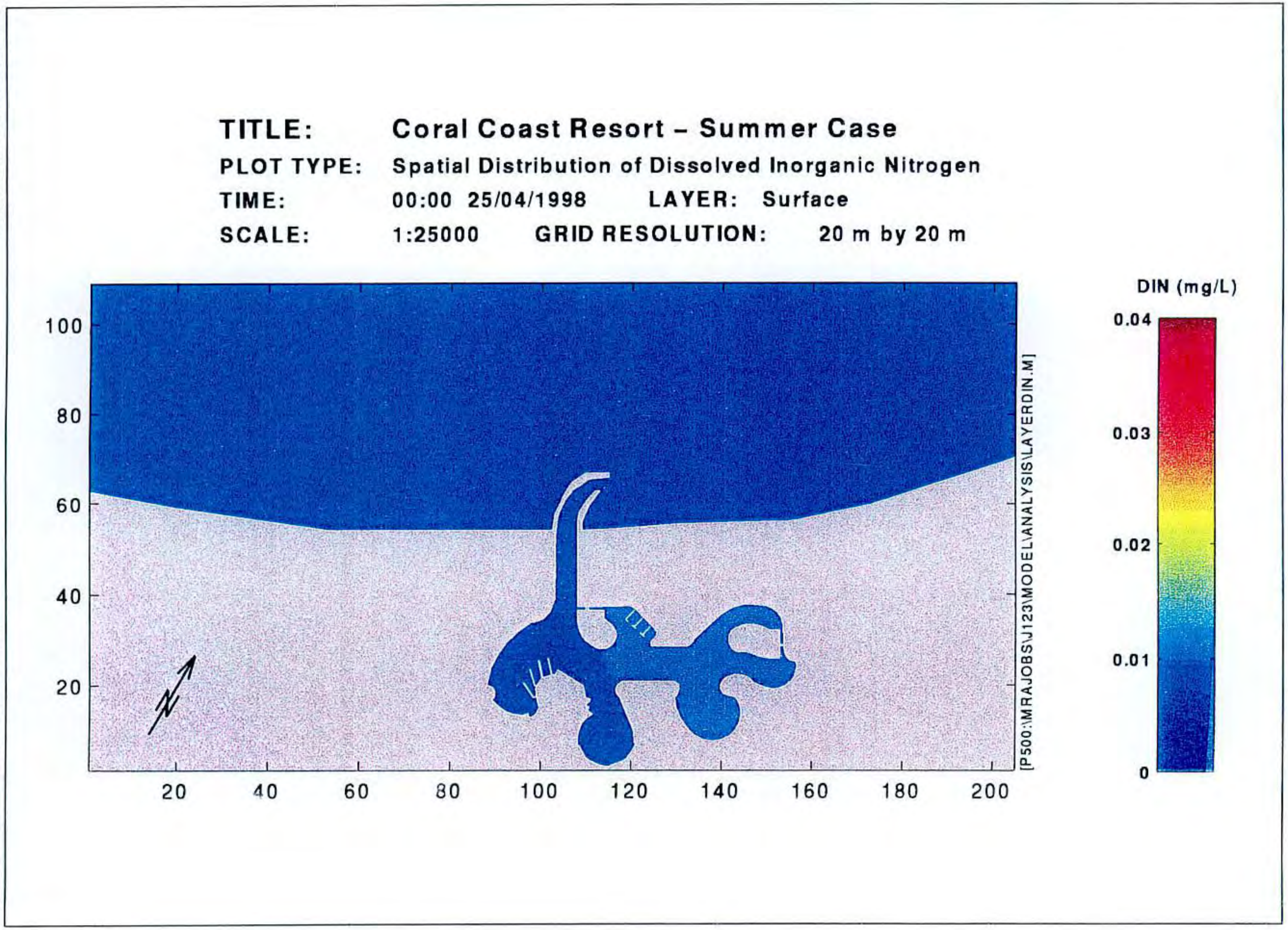


Figure 5.8 – Modelled DIN Levels after Summer Peak

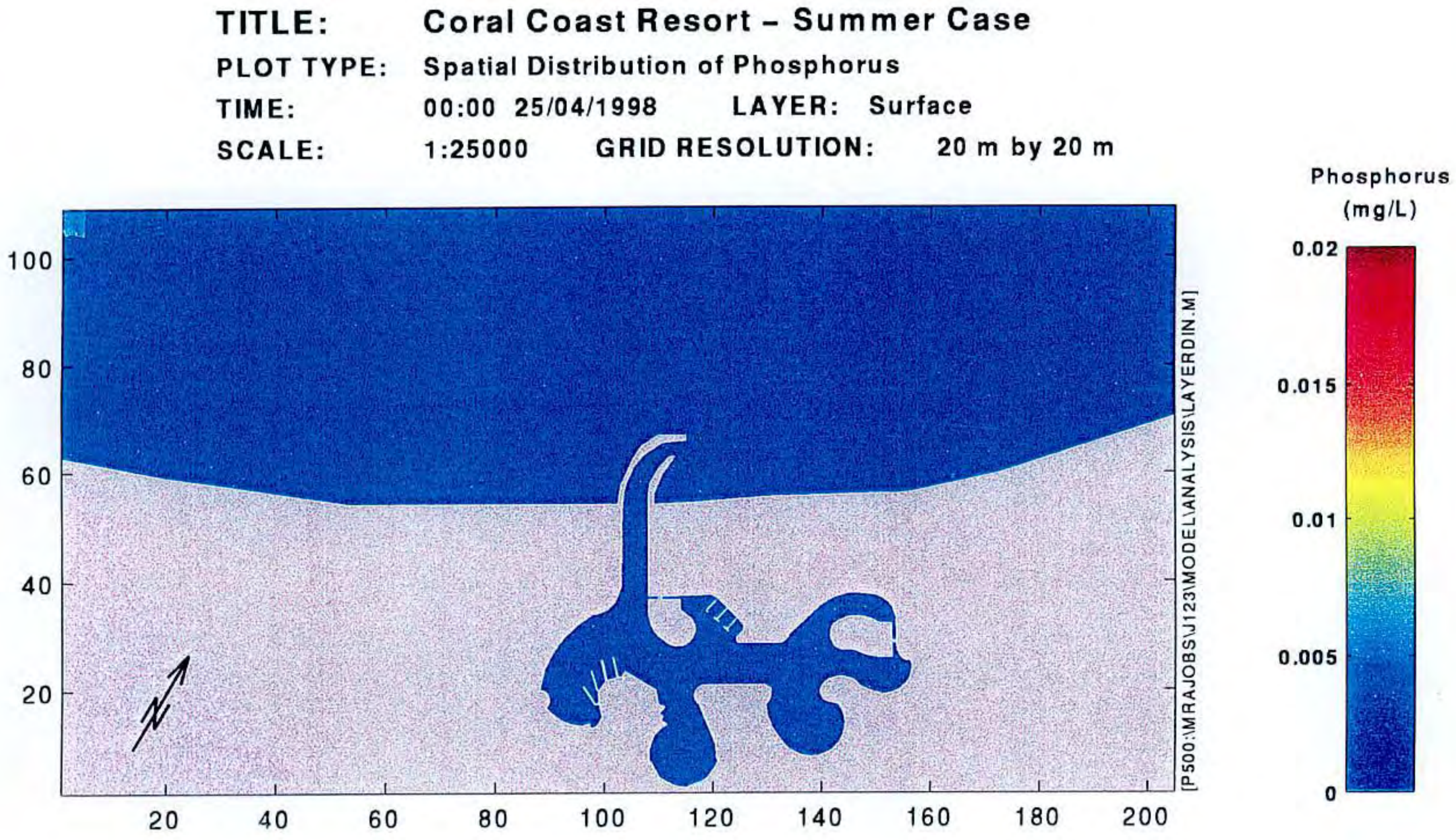
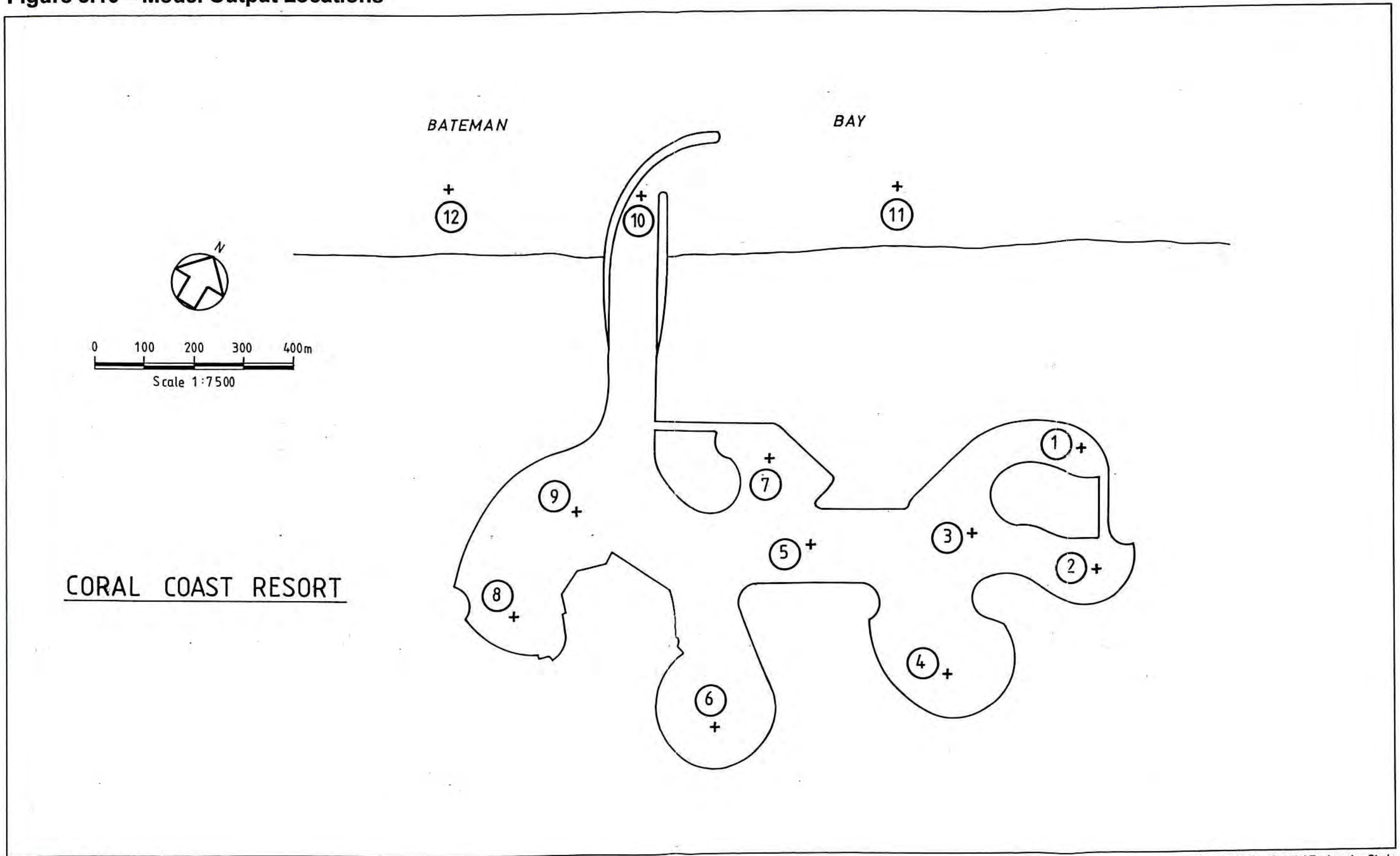


Figure 5.9 – Modelled Phosphorus Levels after Summer Peak

Figure 5.10 – Model Output Locations



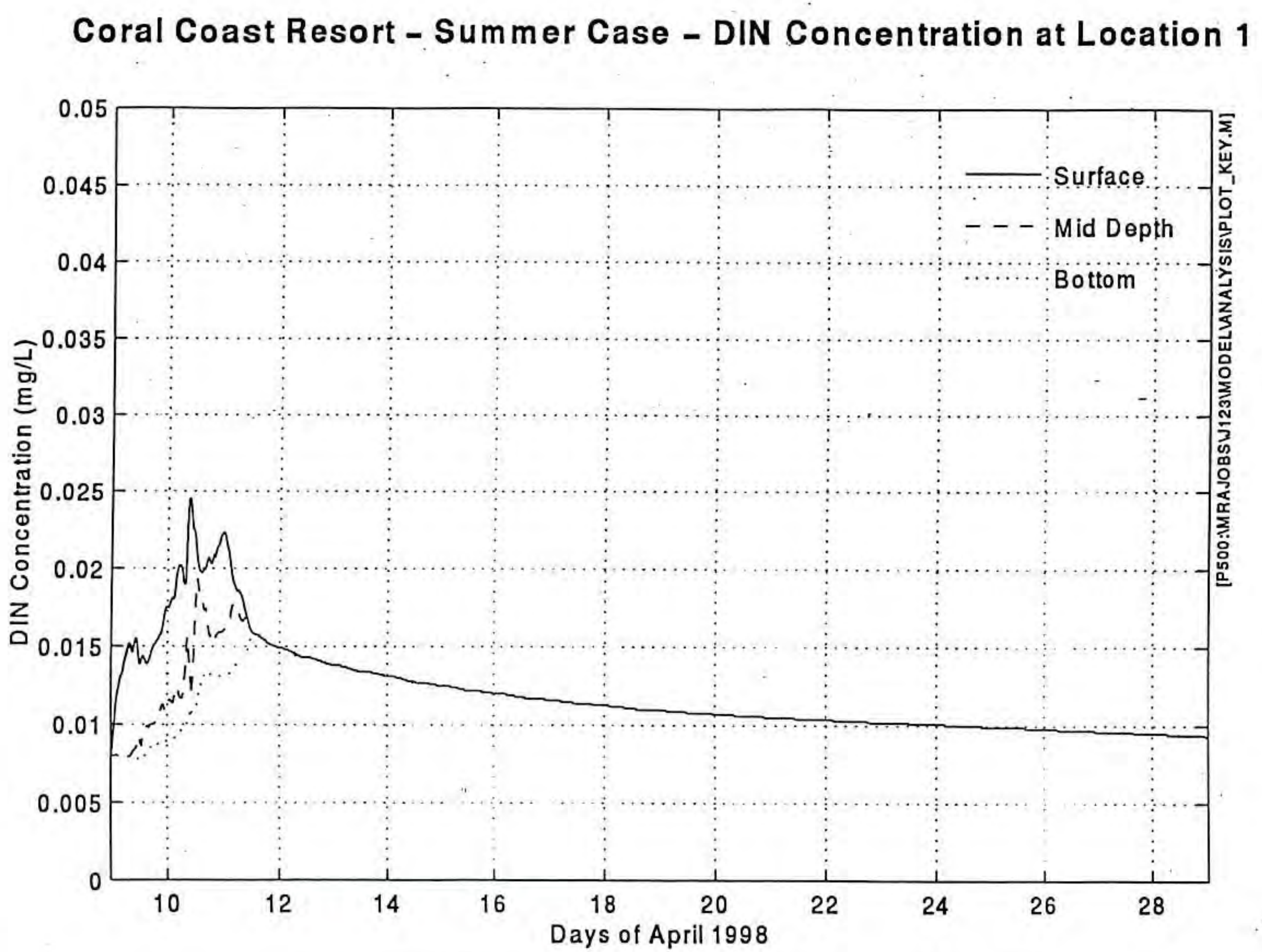
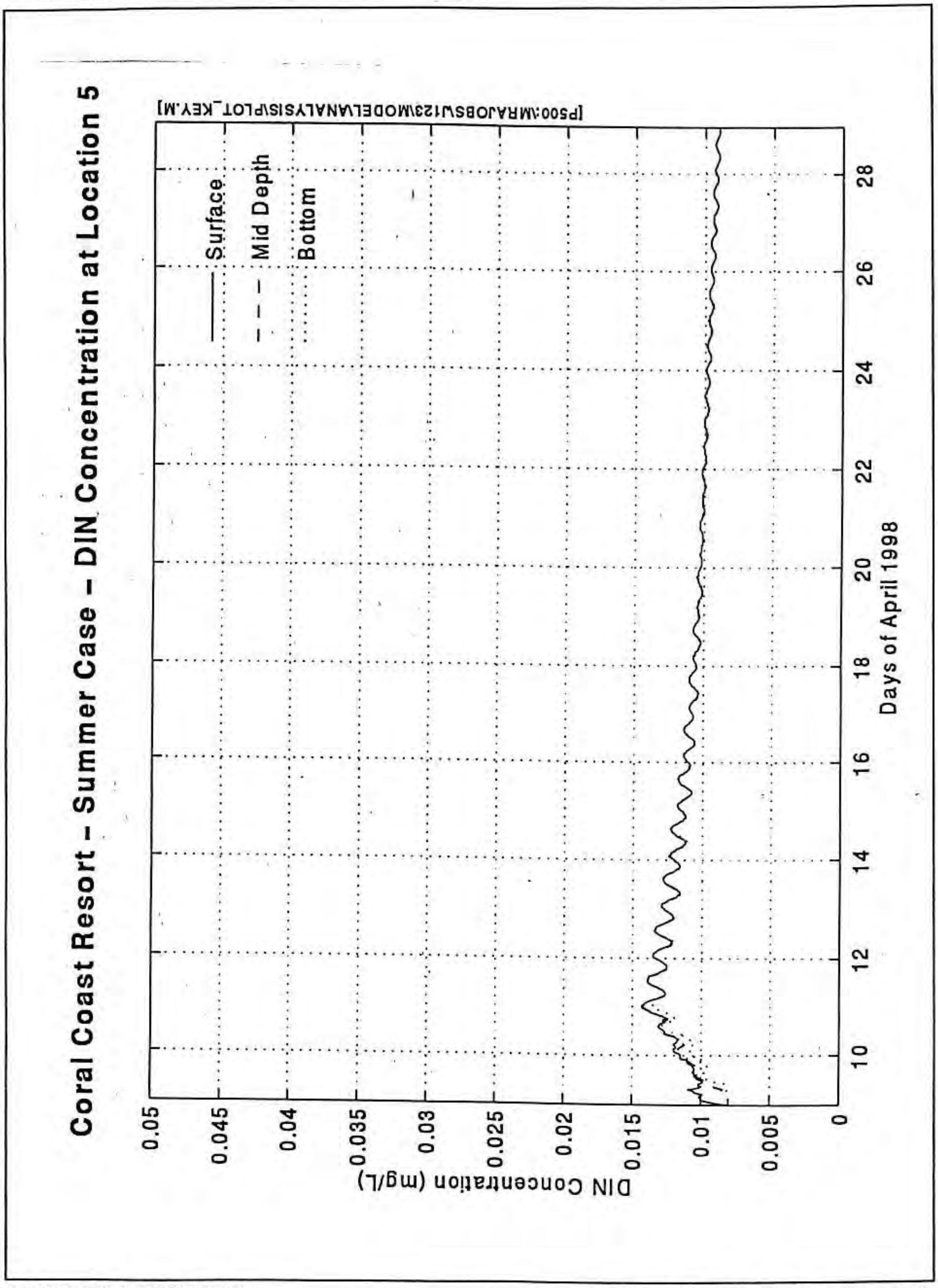


Figure 5.11 – Summer DIN Levels – Location 1

Figure 5.12 – Summer DIN Levels – Location 5



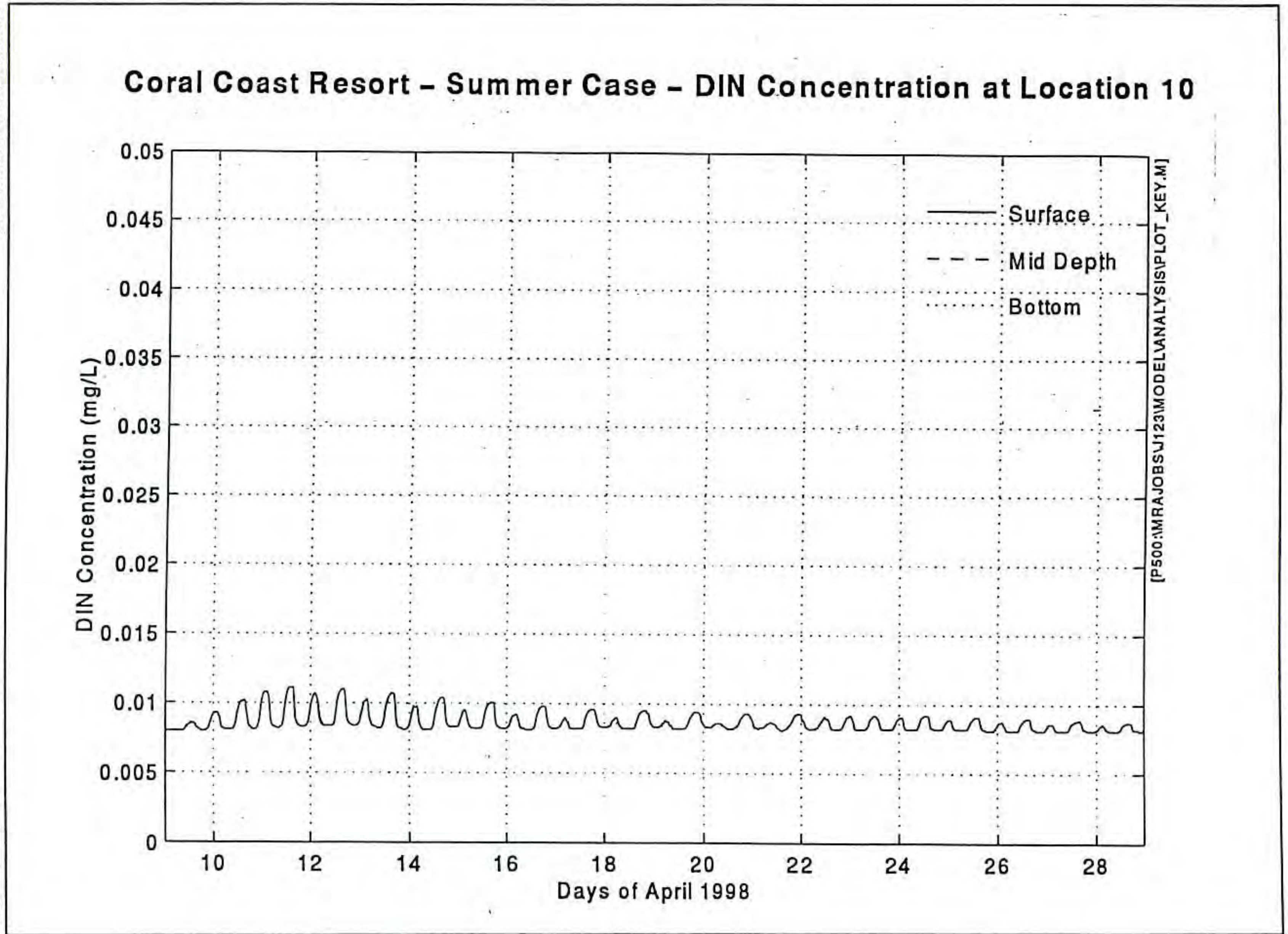


Figure 5.13 – Summer DIN Levels – Location 10

Figure 5.14 – Summer Phosphorus Levels – Location 1

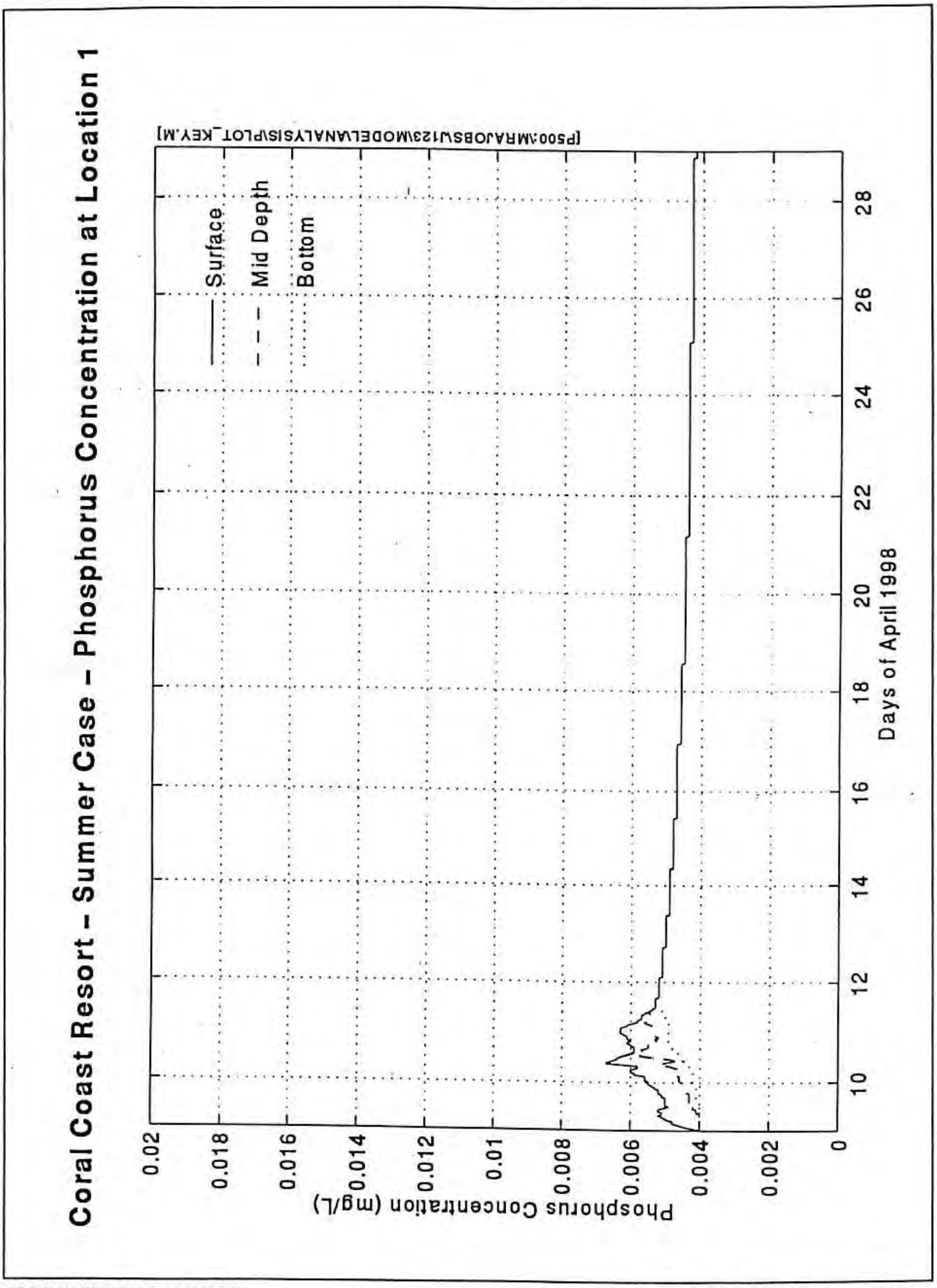


Figure 5.15 – Summer Phosphorus Levels – Location 5

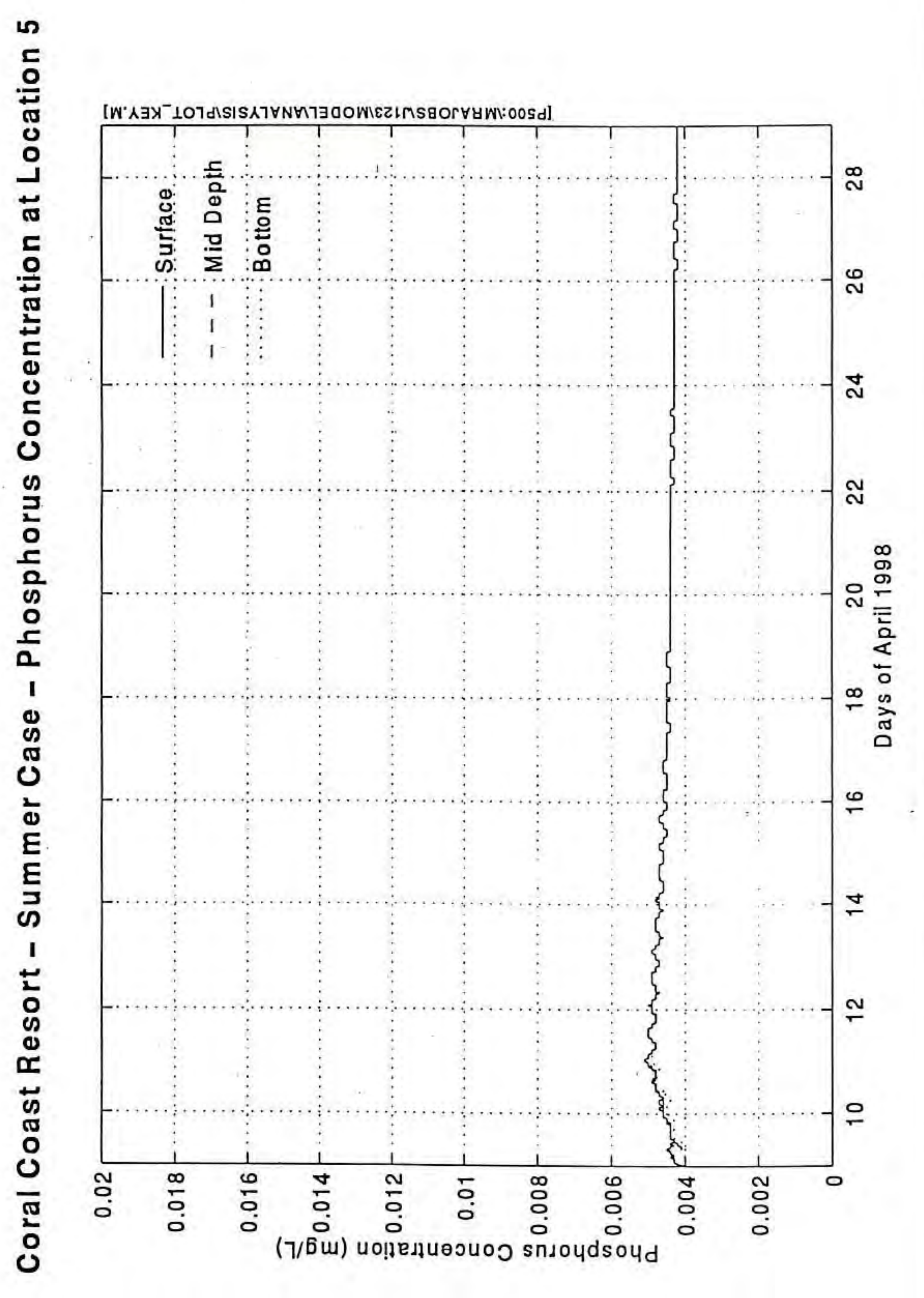
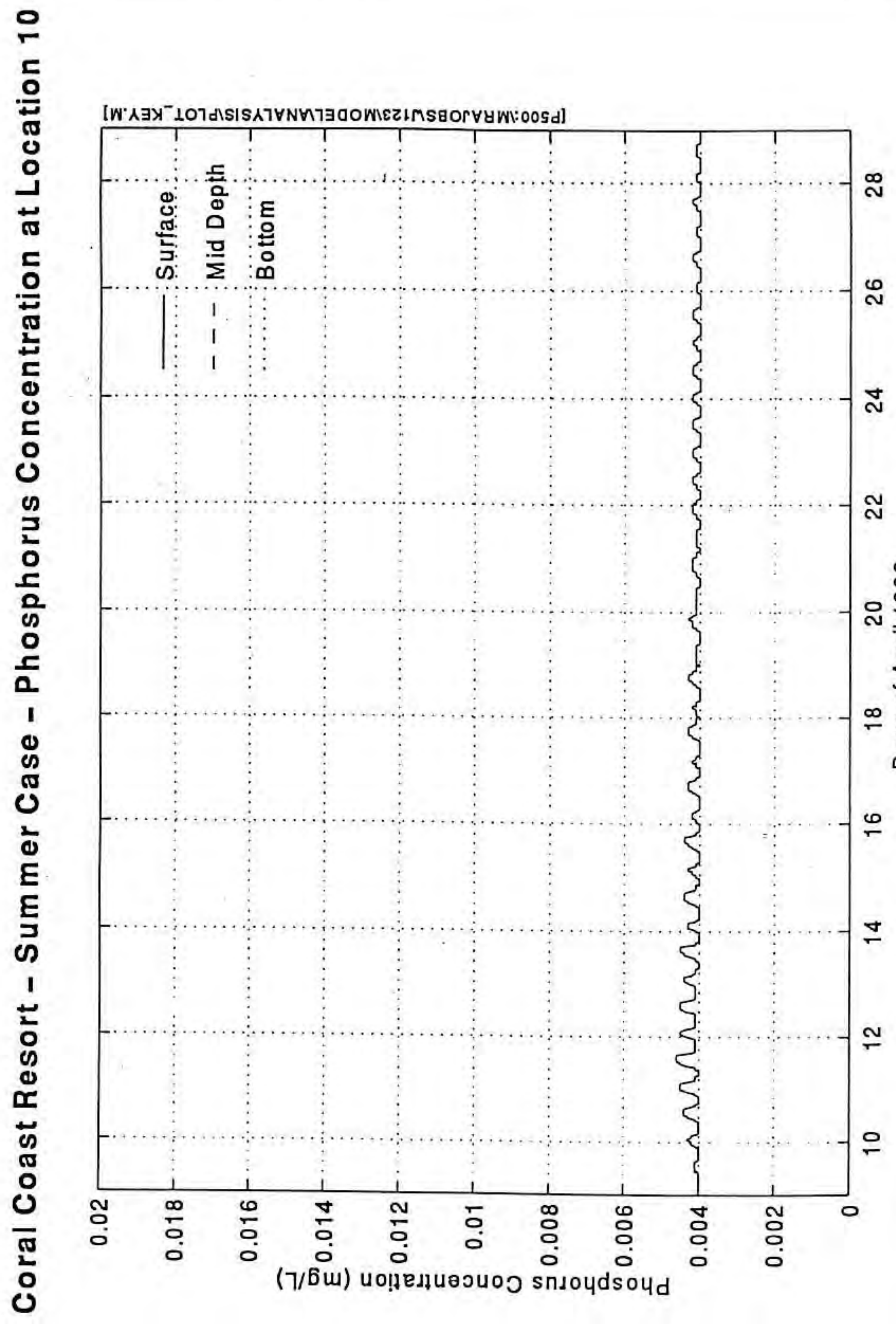


Figure 5.16 – Summer Phosphorus Levels – Location 10



Coral Coast Resort – Summer Case – Decay of Conservative Tracer at Location 1

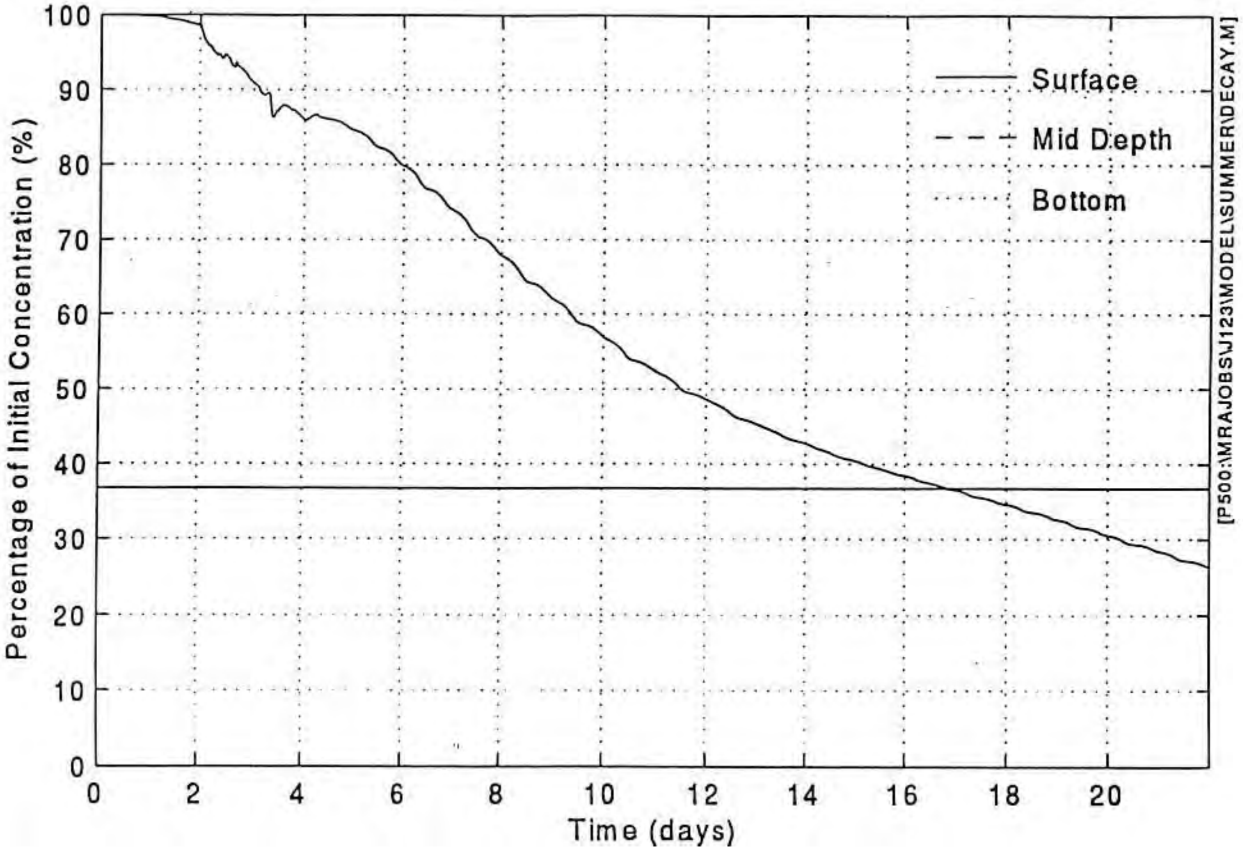
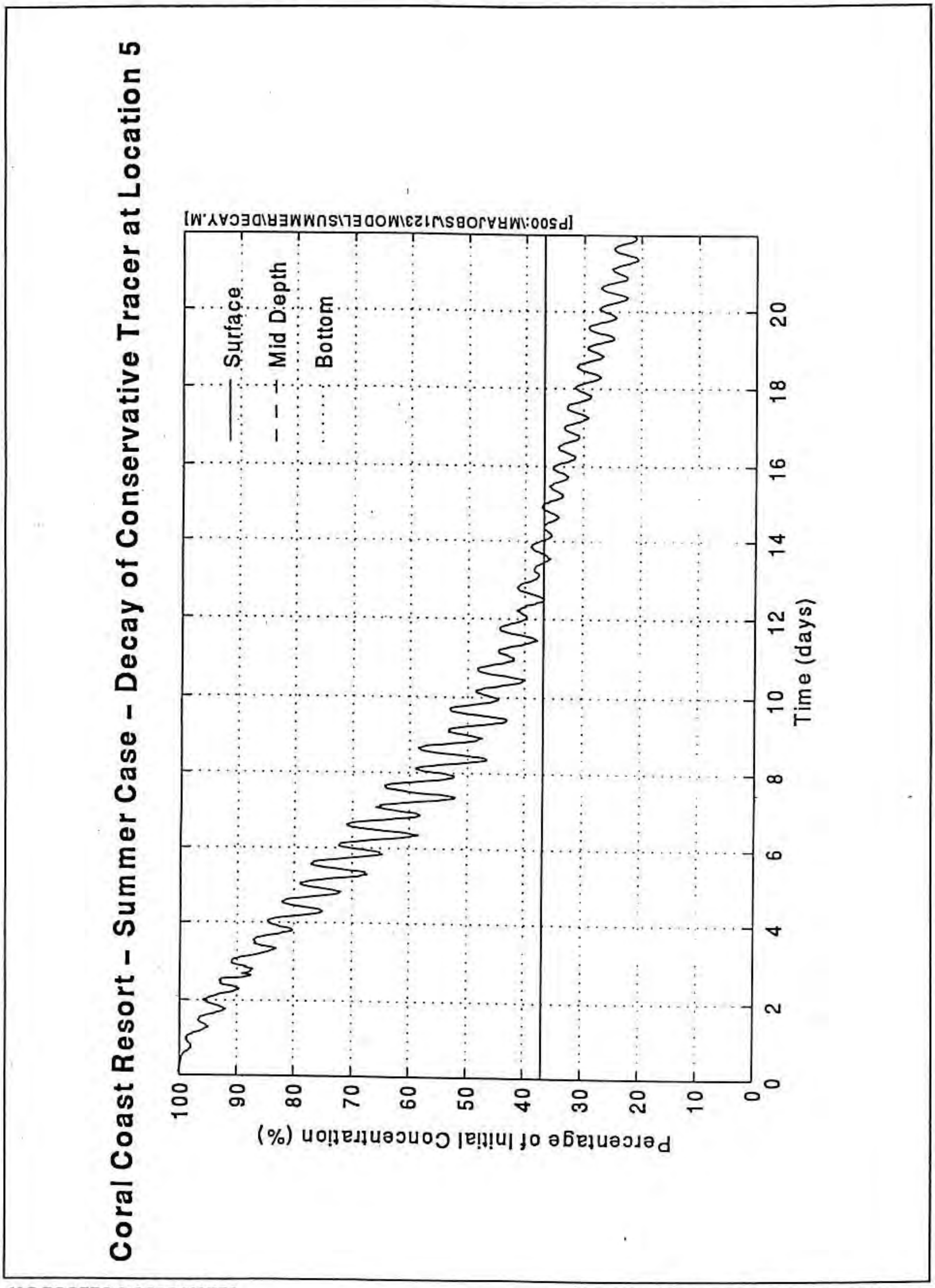


Figure 5.17 – Summer Decay Curve – Location 1

Figure 5.18 – Summer Decay Curve – Location 5



Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 10

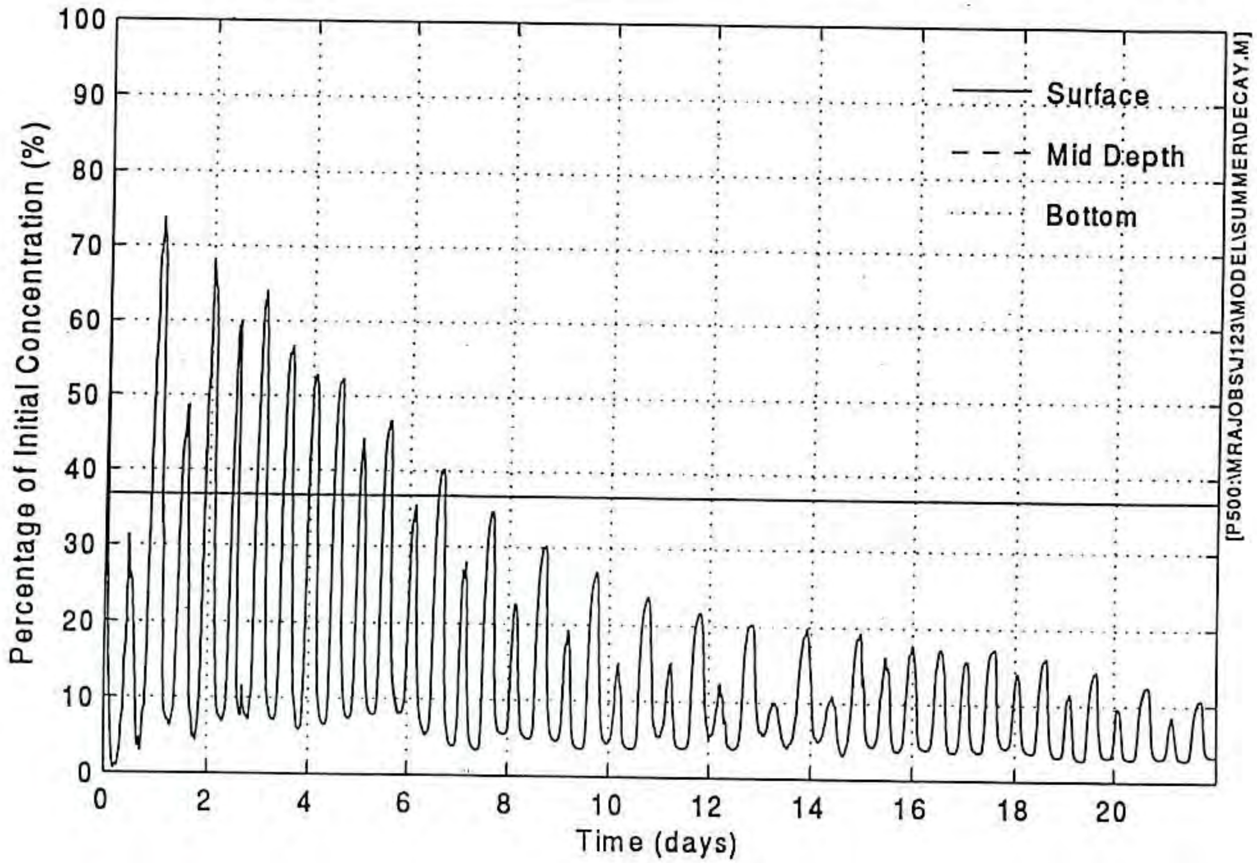


Figure 5.19 – Summer Decay Curve – Location 10

TITLE: Coral Coast Resort – Winter Case
PLOT TYPE: Spatial Distribution of Dissolved Inorganic Nitrogen
TIME: 00:00 16/07/1998 **LAYER:** Surface
SCALE: 1:25000 **GRID RESOLUTION:** 20 m by 20 m

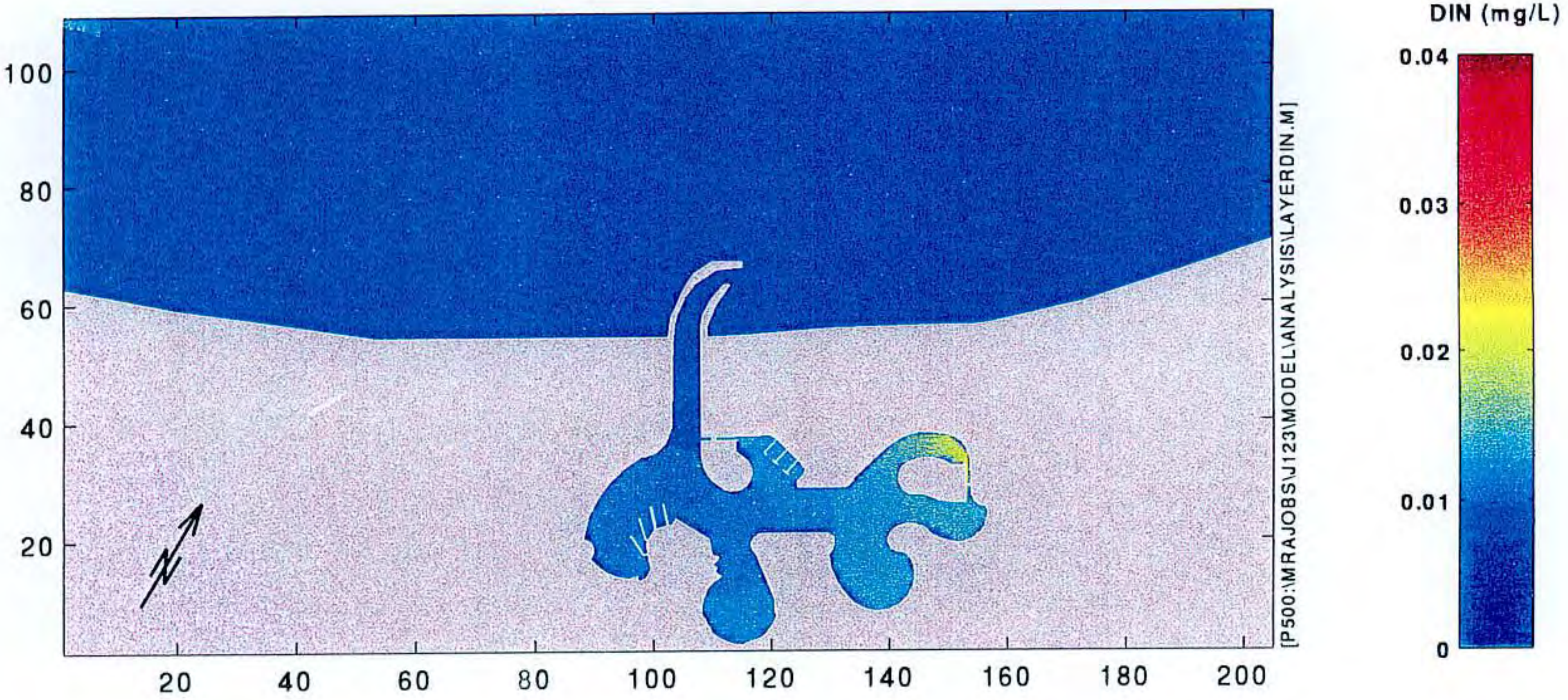


Figure 5.20 – Modelled DIN Levels at Winter Peak

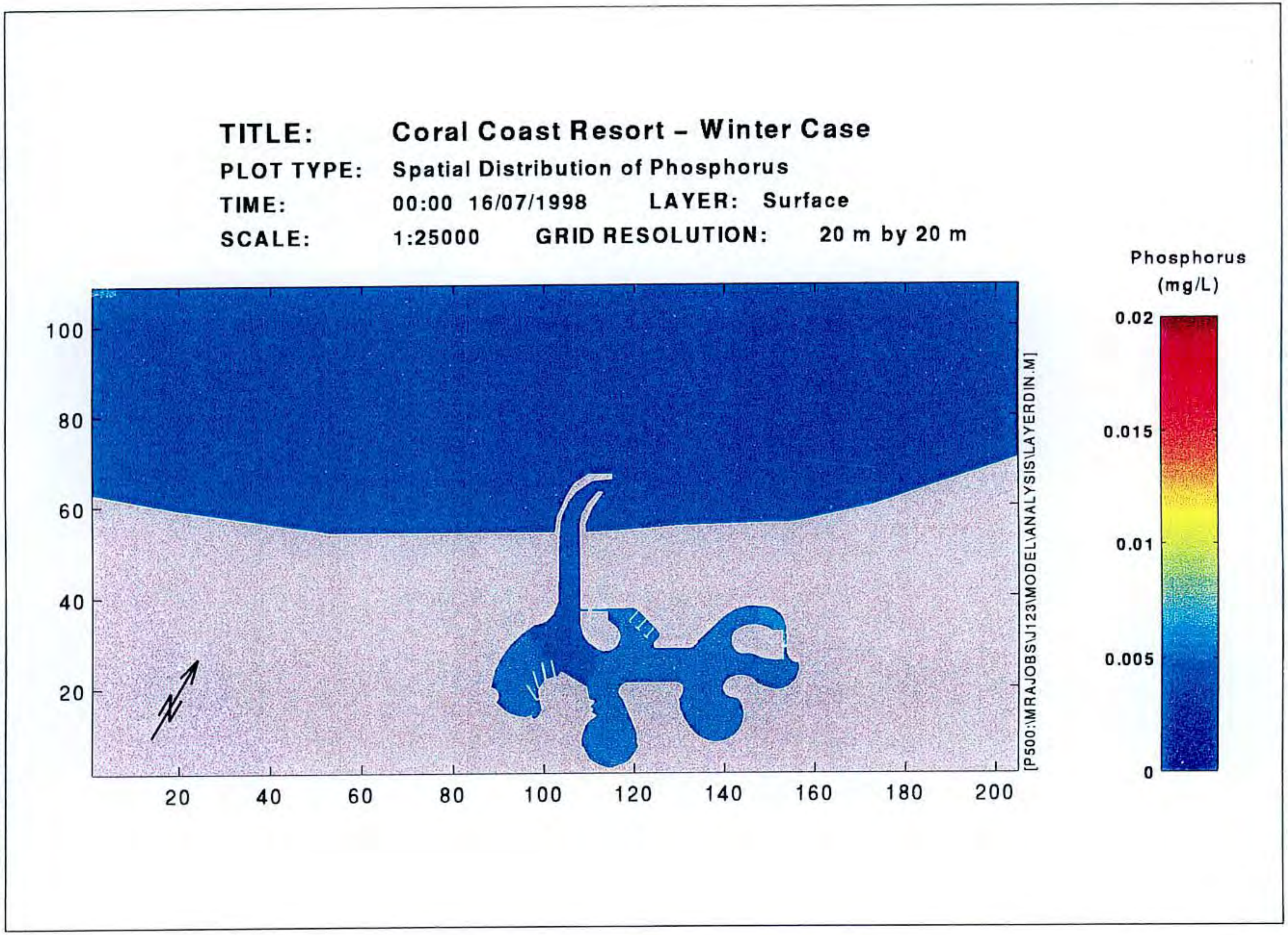


Figure 5.21 – Modelled Phosphorus Levels at Winter Peak

TITLE: Coral Coast Resort - Winter Case

PLOT TYPE: Spatial Distribution of Dissolved Inorganic Nitrogen

TIME: 00:00 30/07/1998 **LAYER:** Surface

SCALE: 1:25000 **GRID RESOLUTION:** 20 m by 20 m

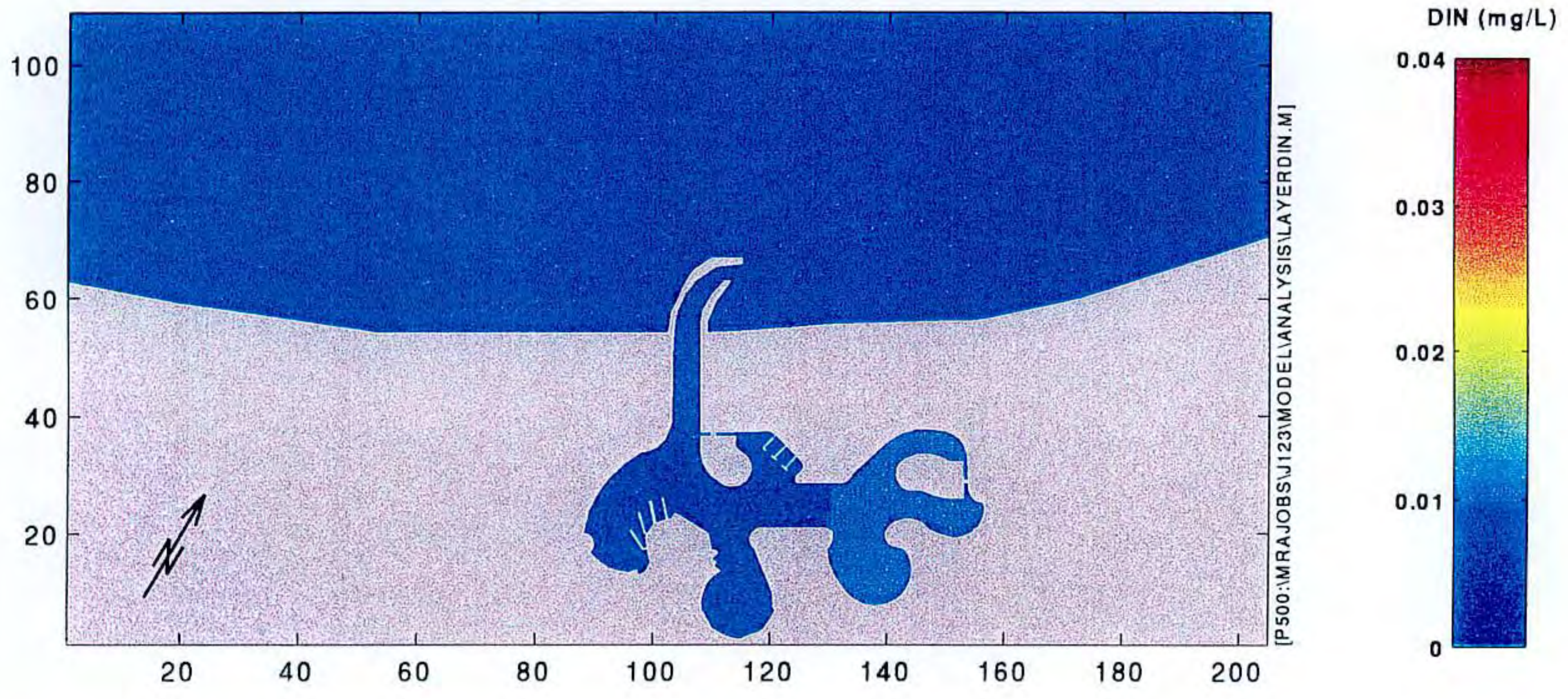


Figure 5.22 – Modelled DIN Levels after Winter Peak

TITLE: Coral Coast Resort – Winter Case

PLOT TYPE: Spatial Distribution of Phosphorus

TIME: 00:00 30/07/1998 **LAYER:** Surface

SCALE: 1:25000 **GRID RESOLUTION:** 20 m by 20 m

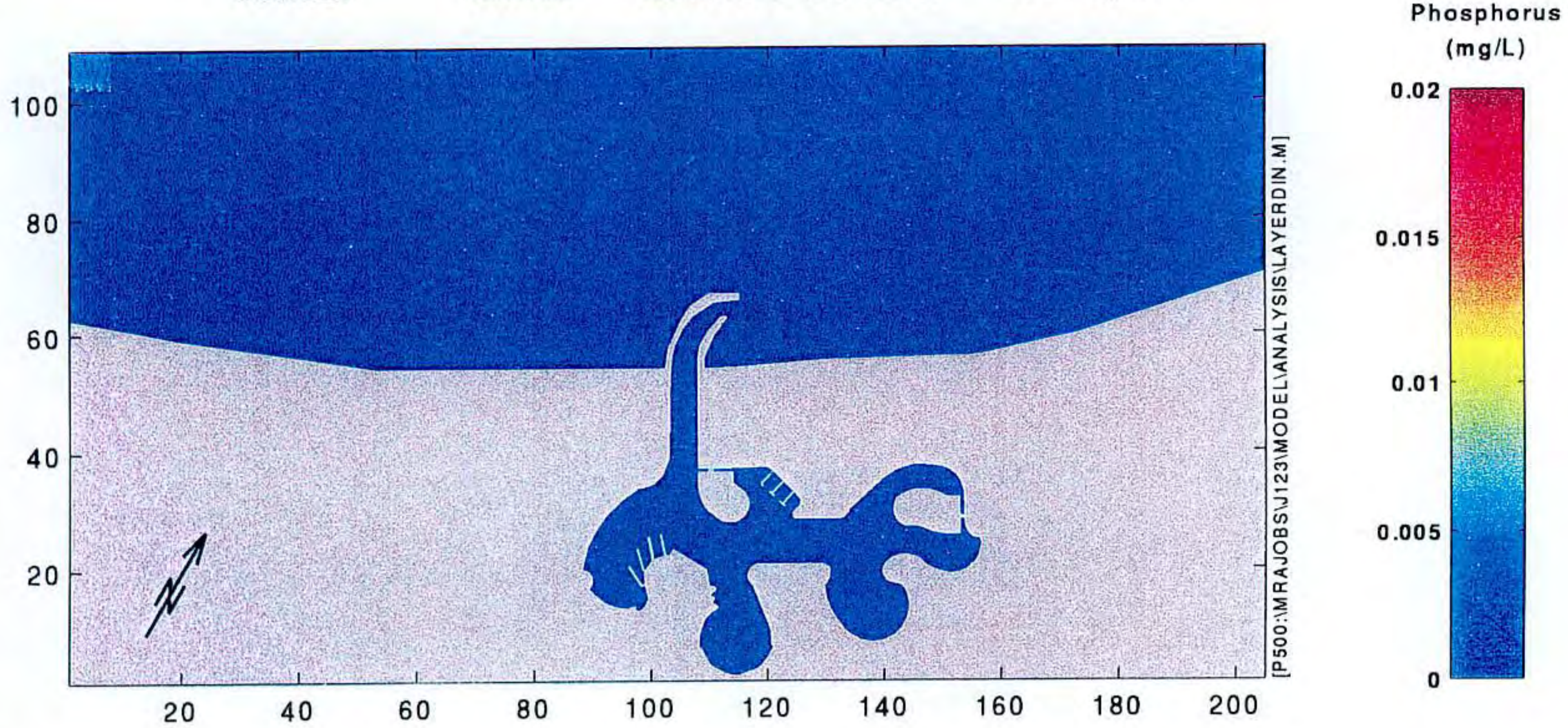


Figure 5.23 – Modelled Phosphorus Levels after Winter Peak

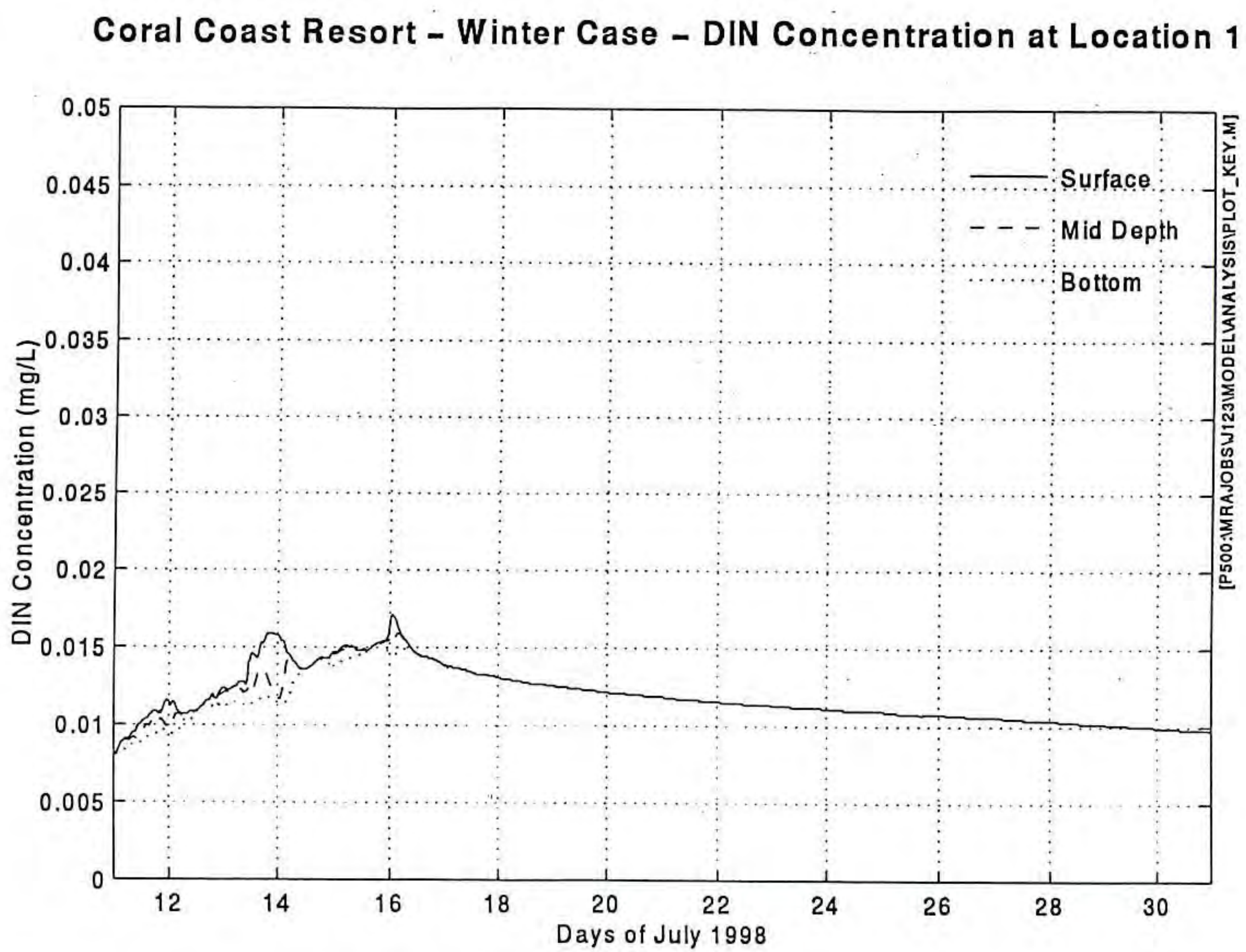


Figure 5.24 – Winter DIN Levels – Location 1

Figure 5.25 – Winter DIN Levels – Location 5

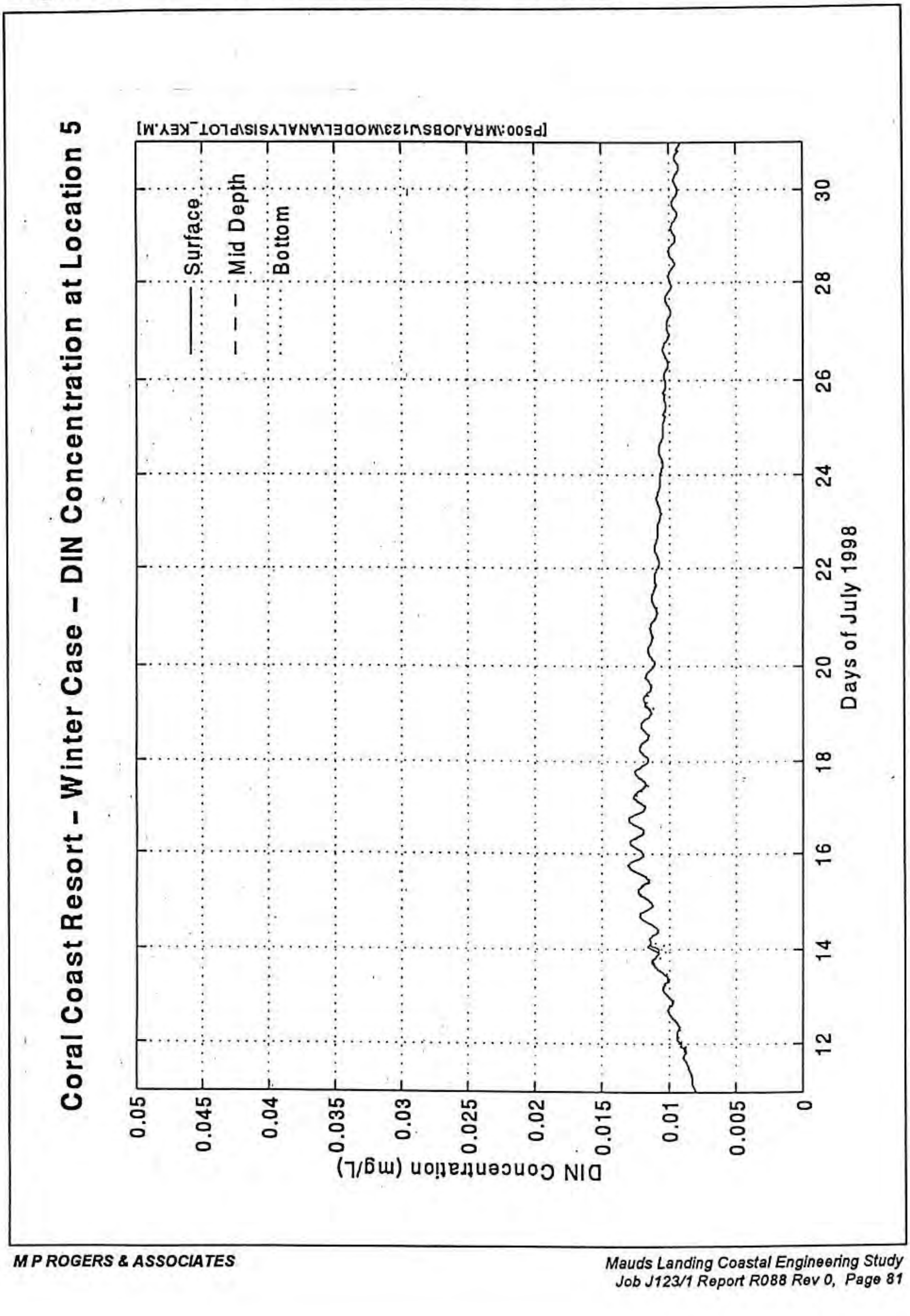


Figure 5.27 – Winter Phosphorus Levels – Location 1

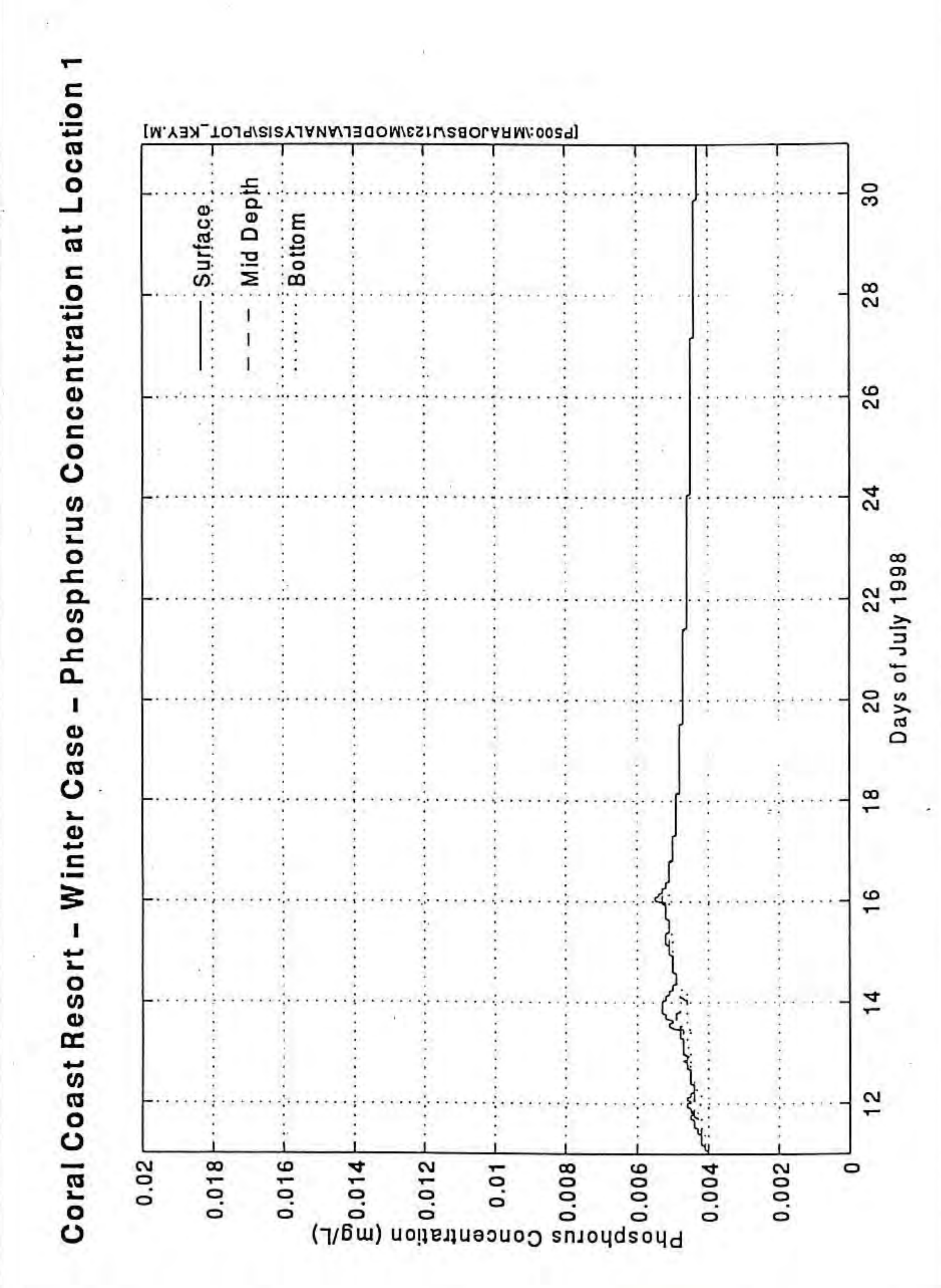
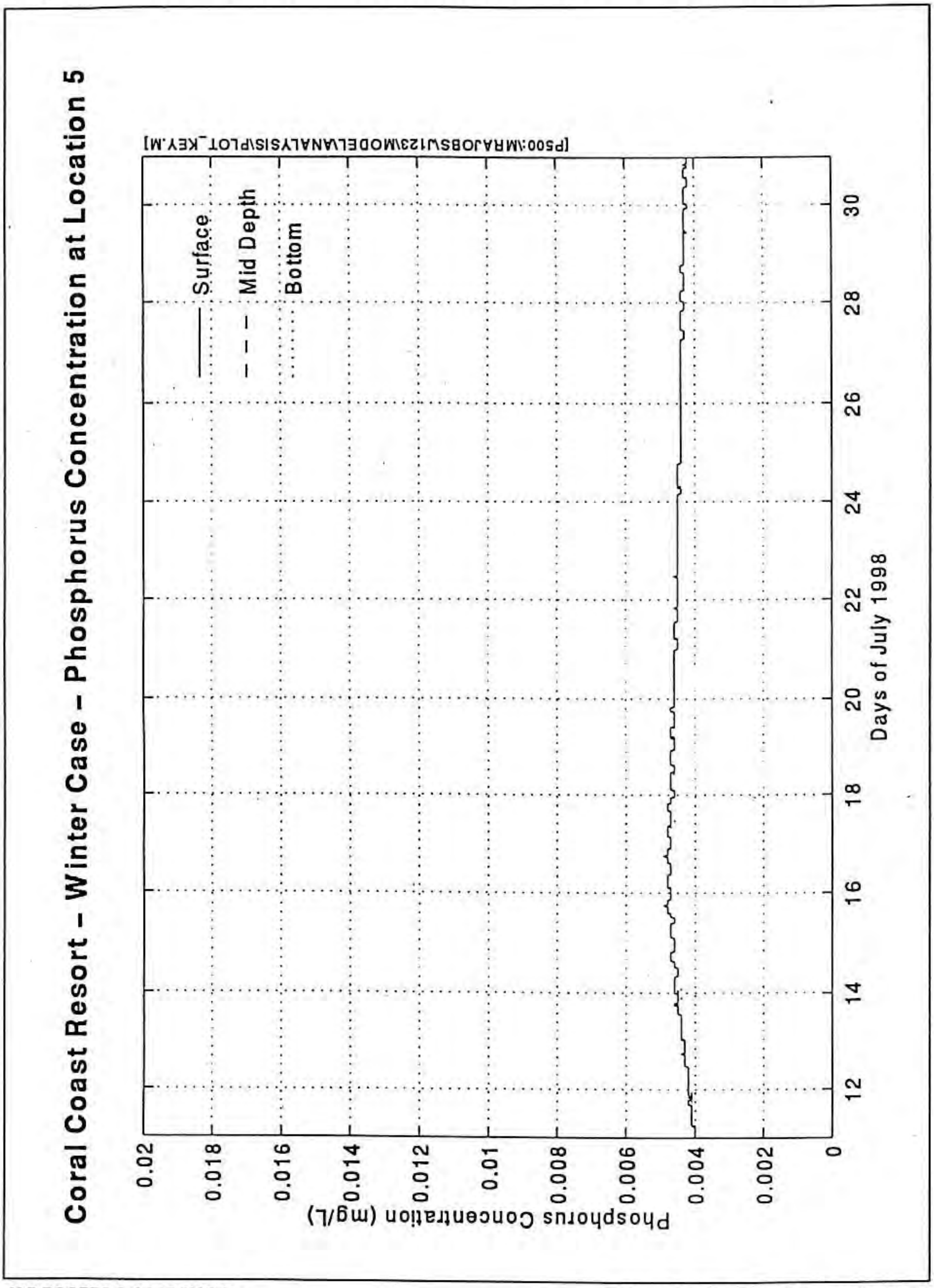


Figure 5.28 – Winter Phosphorus Levels – Location 5



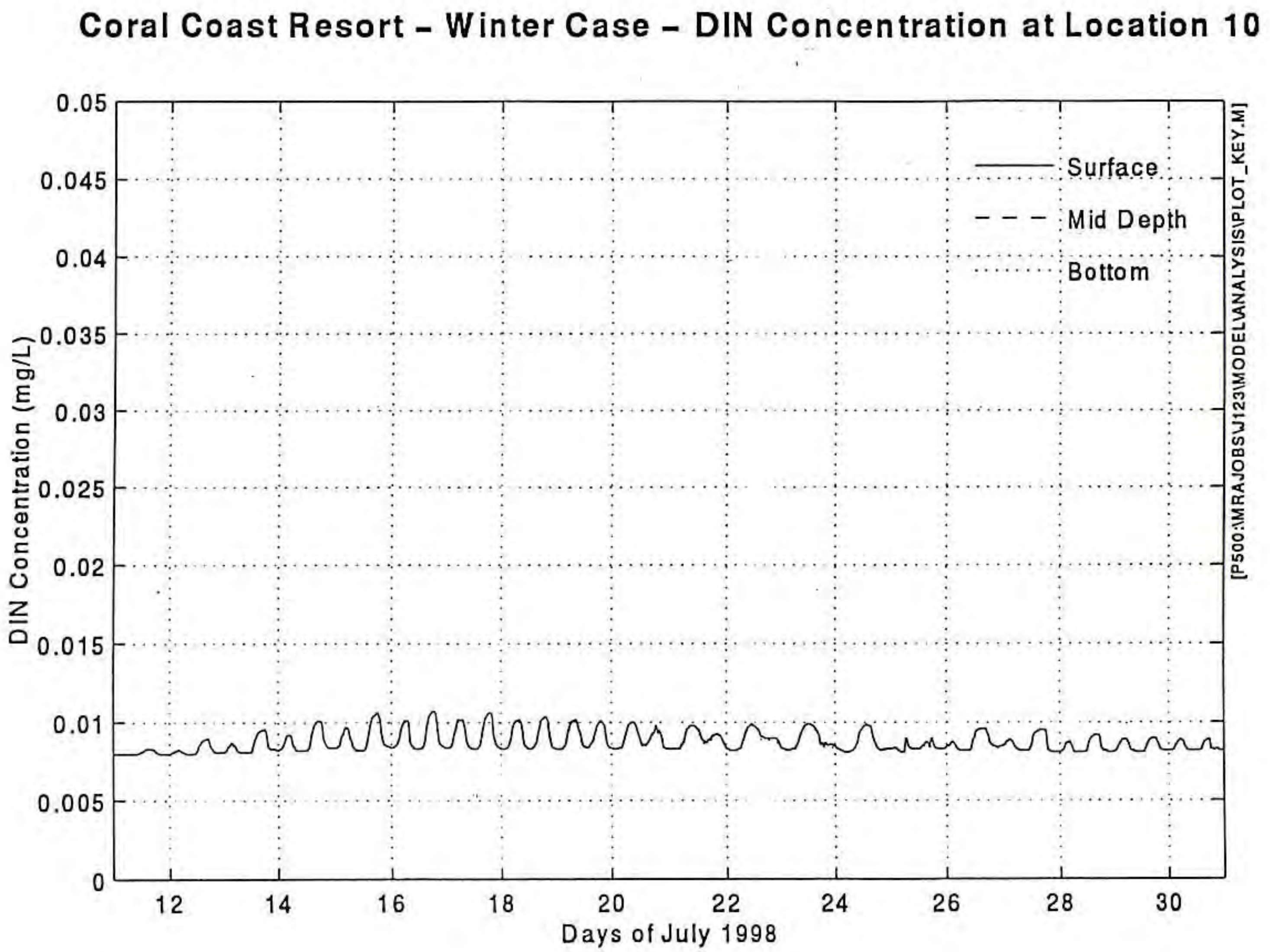
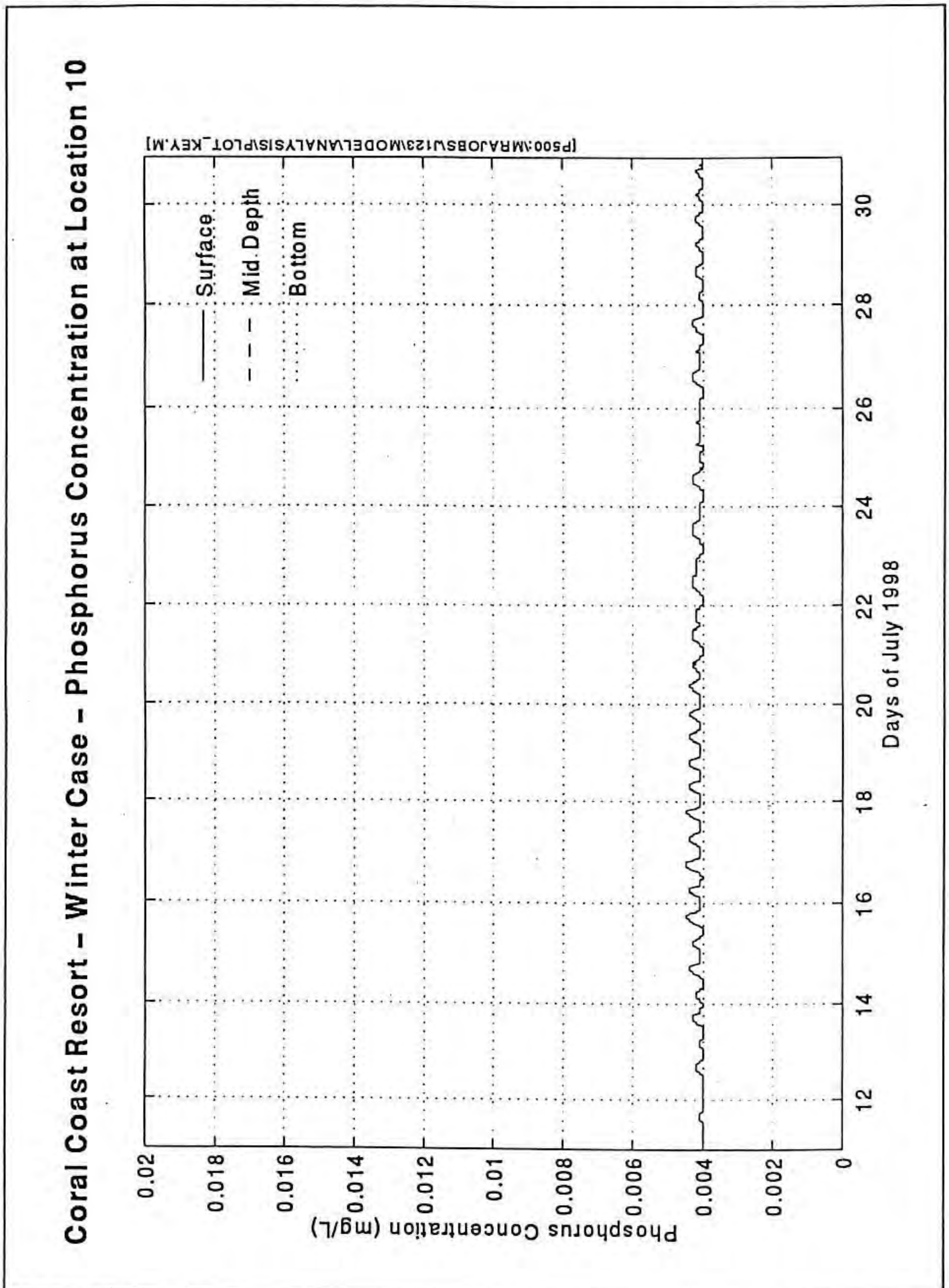


Figure 5.26 – Winter DIN Levels – Location 10

Figure 5.29 – Winter Phosphorus Levels – Location 10



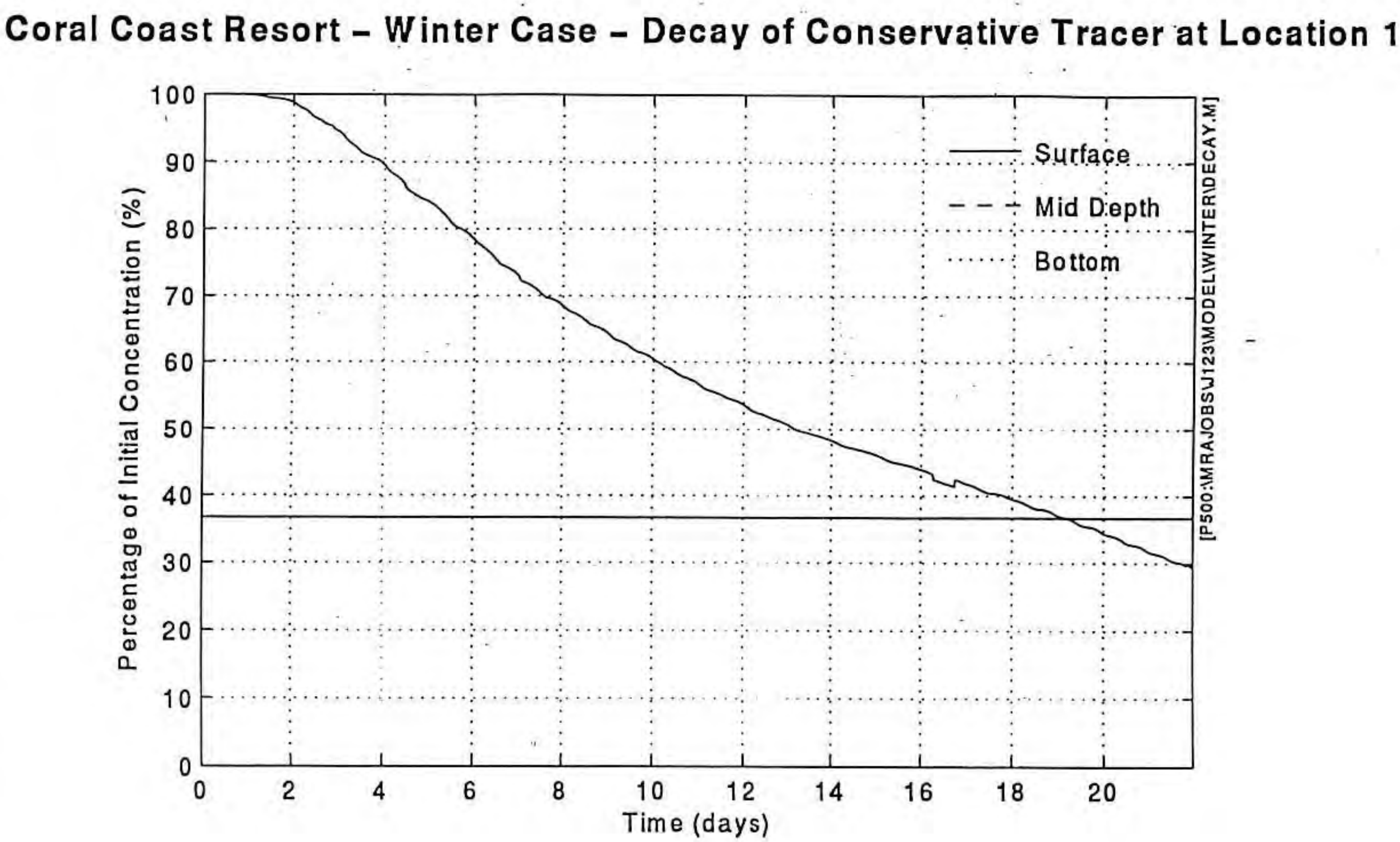


Figure 5.30 – Winter Decay Curve – Location 1

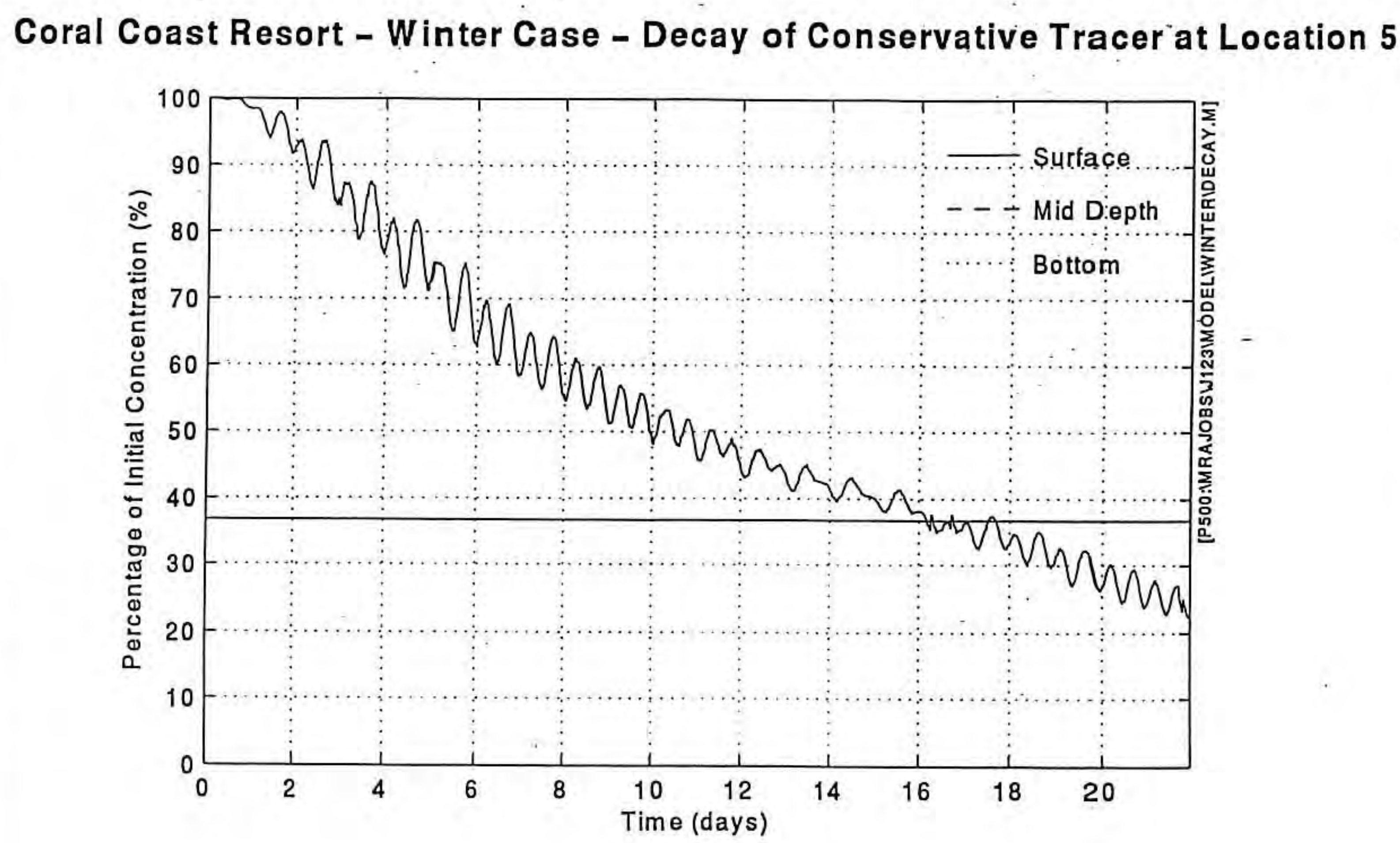


Figure 5.31 – Winter Decay Curve – Location 5

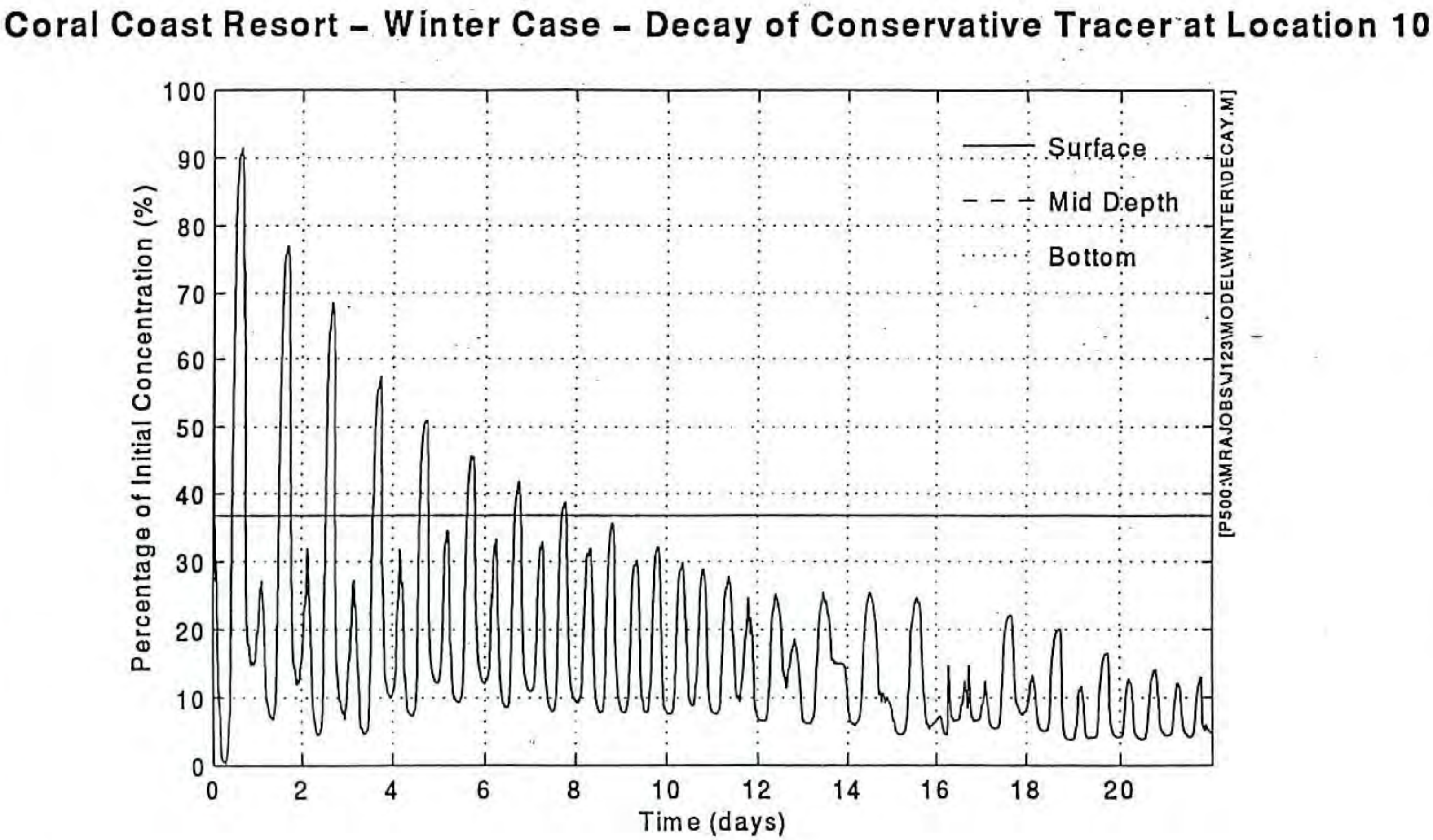
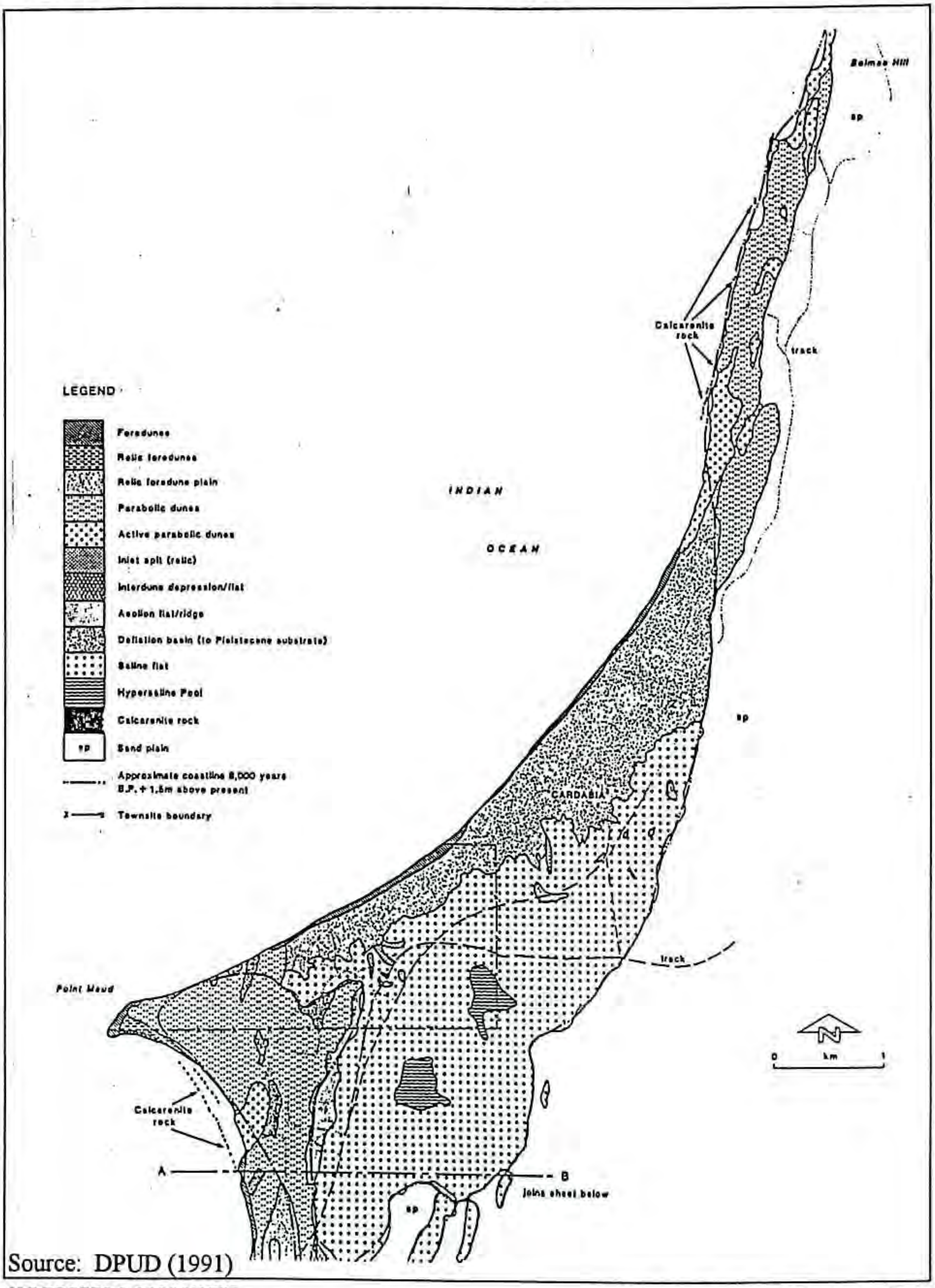


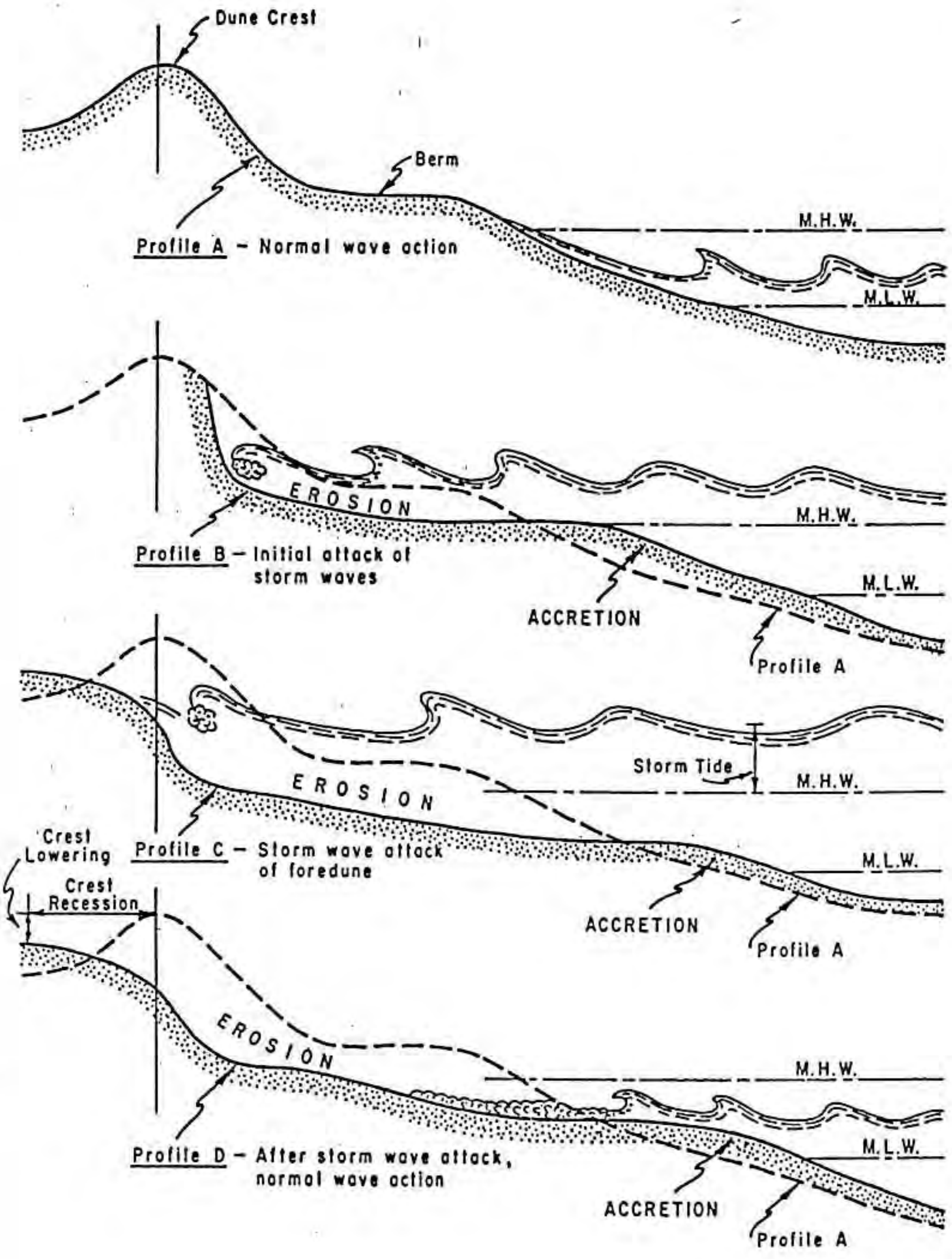
Figure 5.32 – Winter Decay Curve – Location 10

Figure 7.1 – Coastal Geomorphology



Source: DPUD (1991)

Figure 7.2 – Storm Wave Attack



Source: Shore Protection Manual (1984)

Figure 7.3 – Extreme Storm Erosion

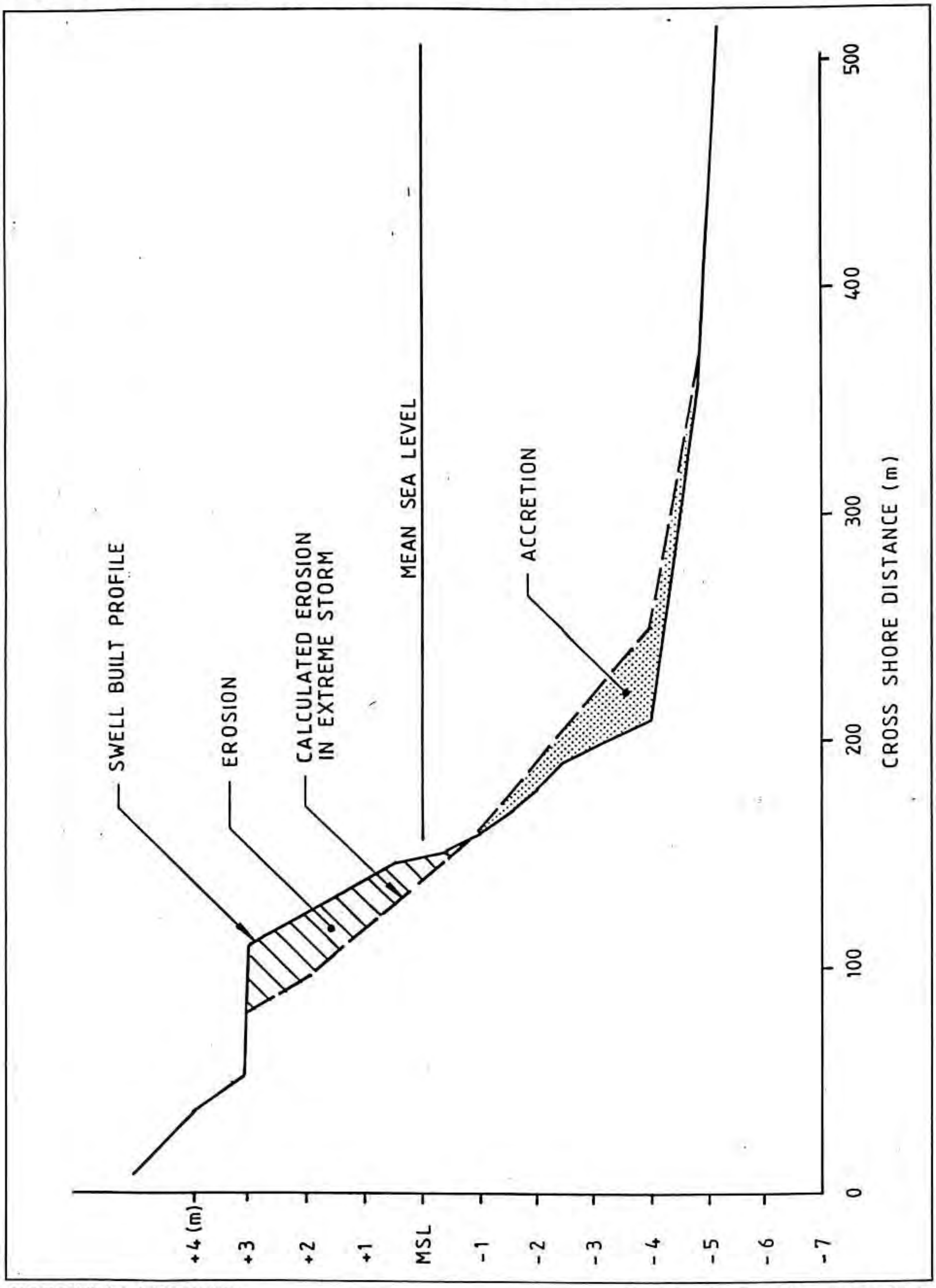


Figure 7.4 – Shoreline Movement Plan

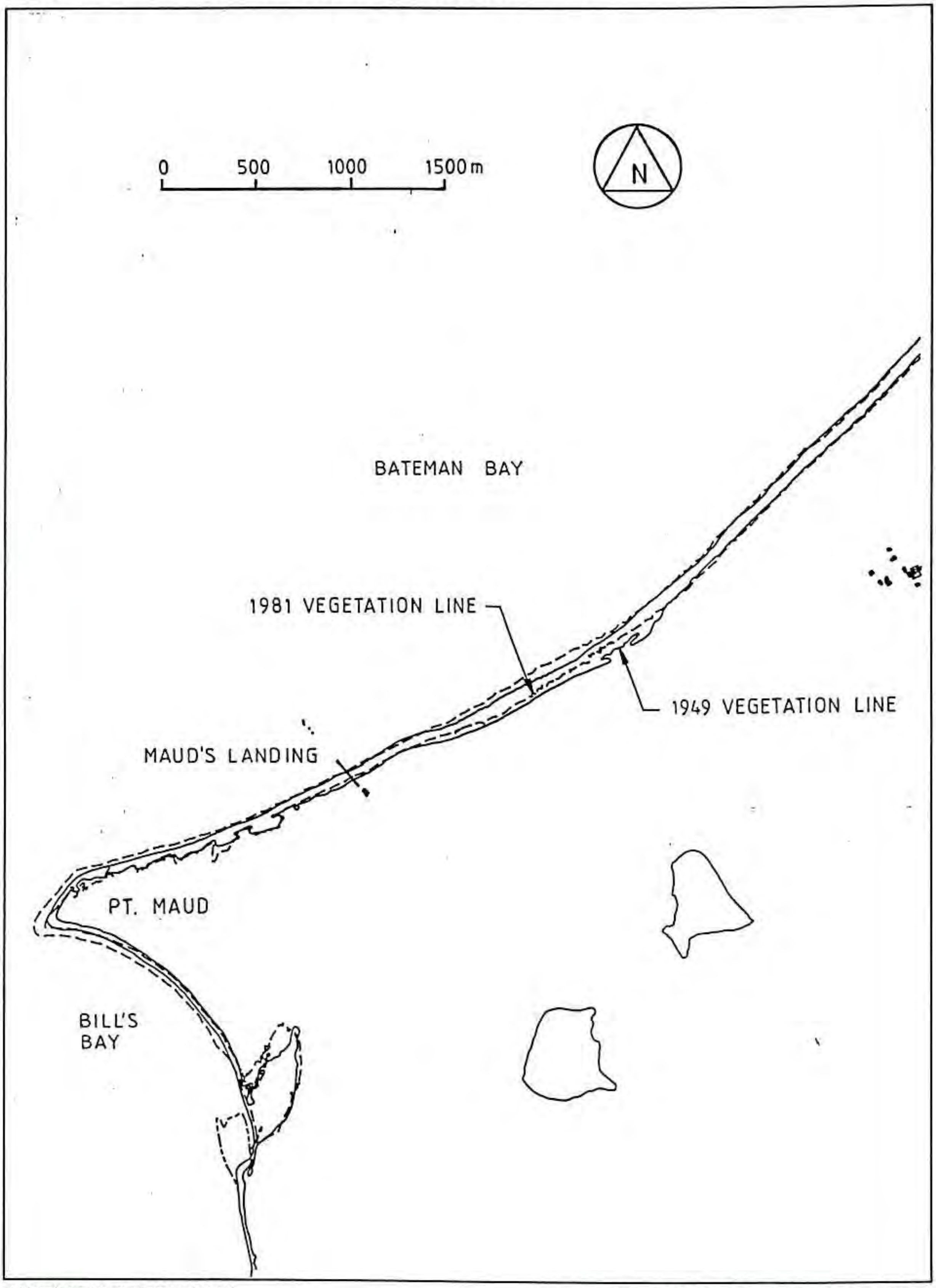
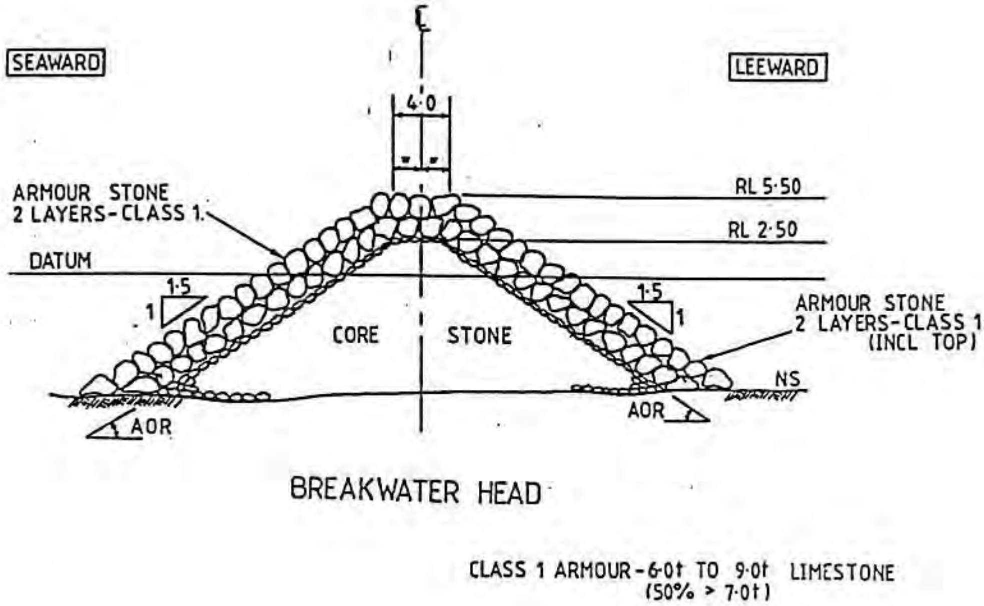
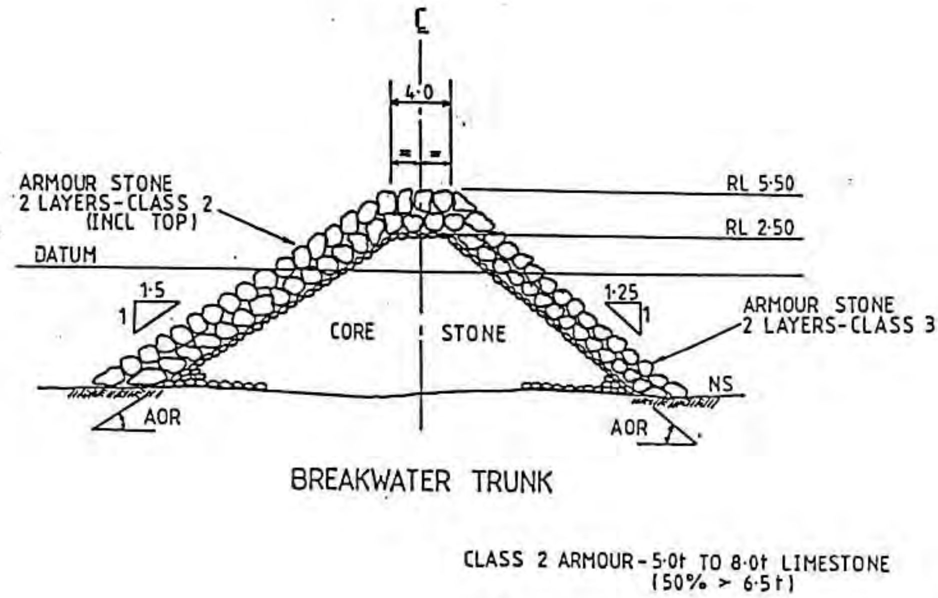


Figure 8.1 – Breakwater Cross Section





Source: Port & Harbour Consultants (1989)

Figure 8.2 – Typical Edge Treatment

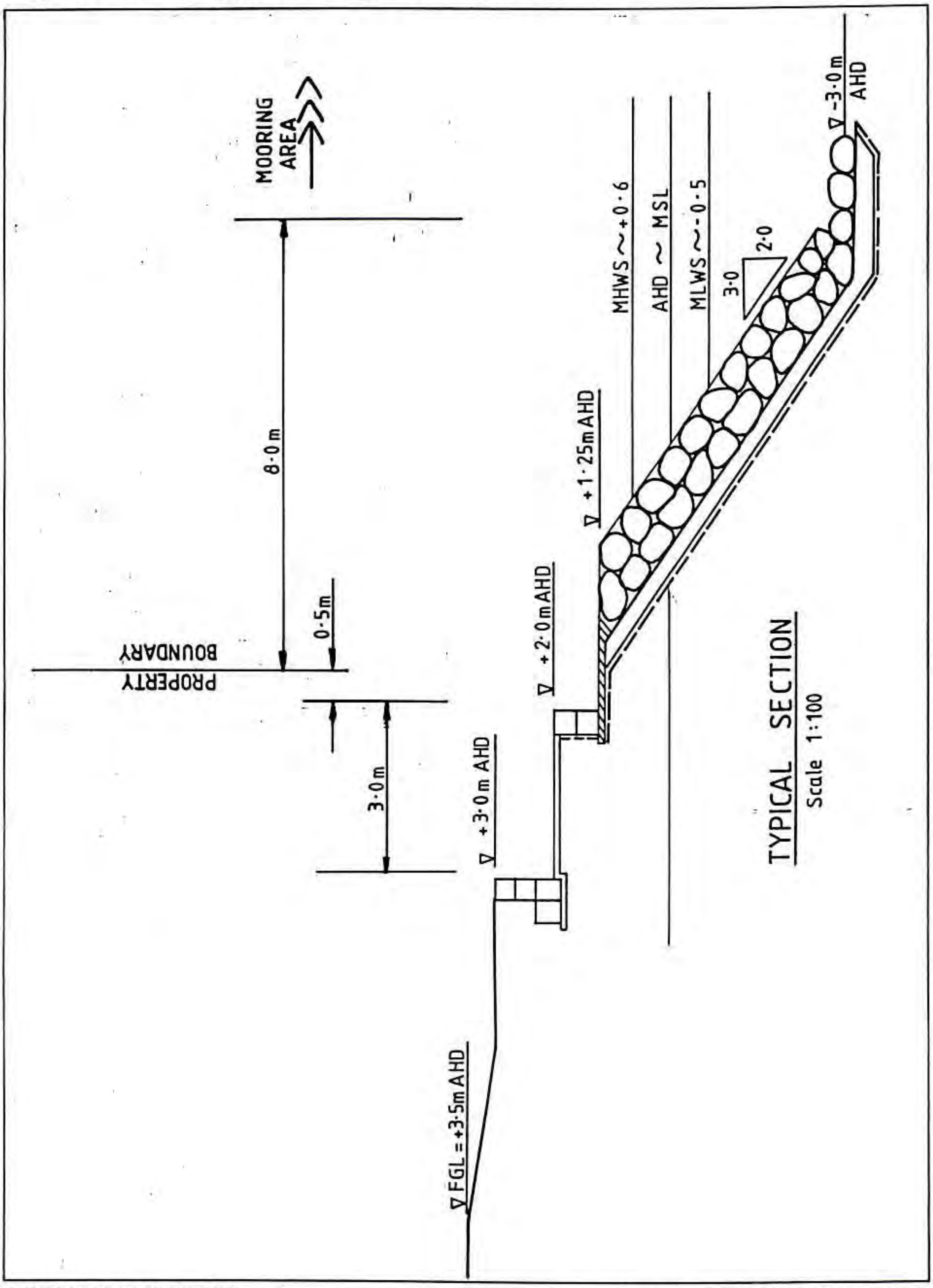
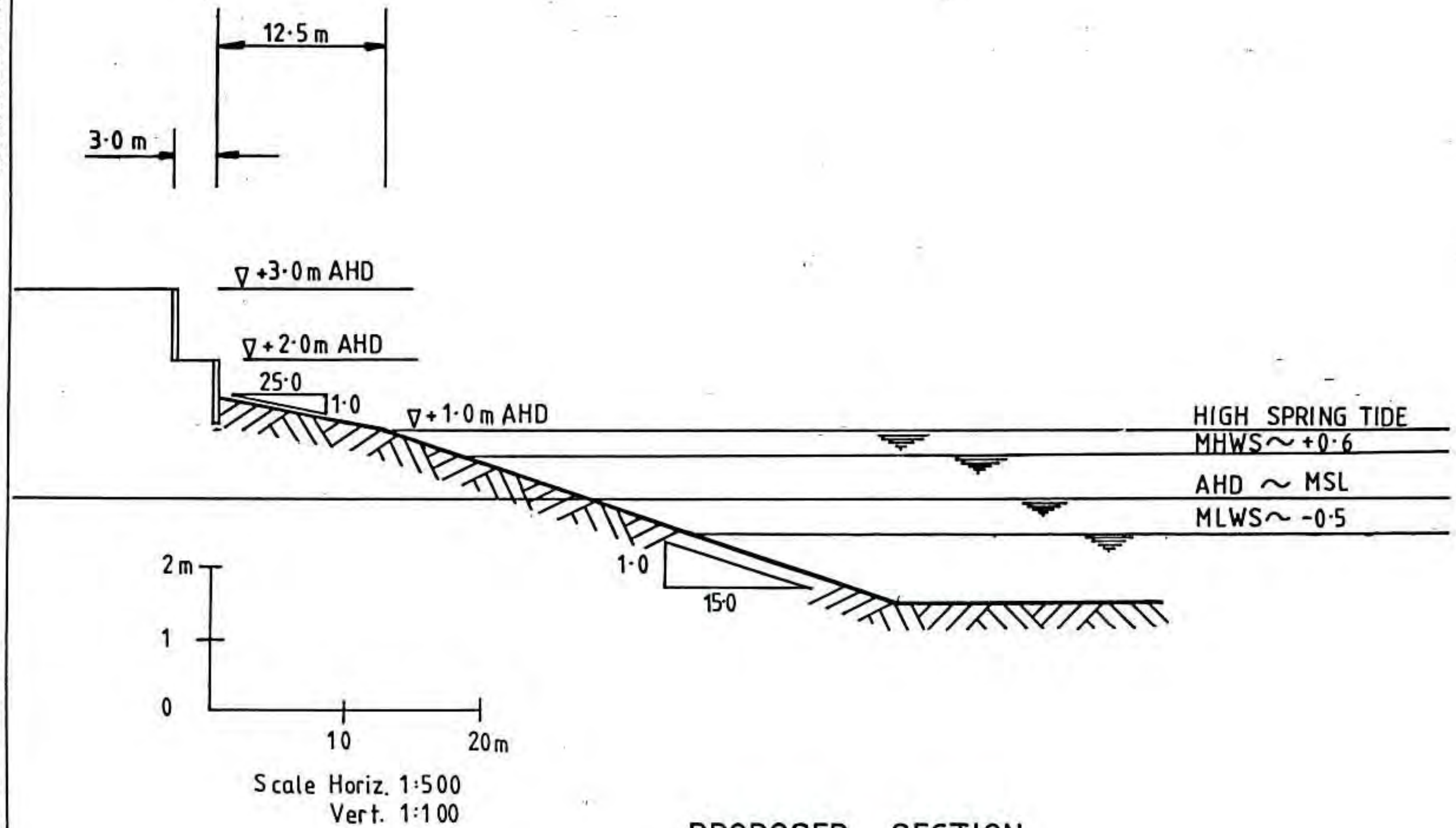


Figure 8.3 – Beach Edge Treatment



PROPOSED SECTION
SAND BEACH

12. Appendices

Appendix A	**Description of Delft3D Model**
Appendix B	**ATA Environmental – Nutrient Inflow Report**
Appendix C	**Modelled Nutrient Concentrations**
Appendix D	**Modelled Decay Curves**

Appendix A Description of Delft3D Model

Delft3D

Functional Specification

March, 2000

Contents

1 Introduction **1**

2 Hydrodynamic module **2**

2.1 Module description 2

2.2 Applications areas 3

2.3 Coupling with other modules 3

3 Water quality module **4**

3.1 Module description 4

3.2 Application areas 5

4 Sediment transport module **7**

4.1 Module description 7

4.1.1 Cohesive sediment 7
4.1.2 Non-Cohesive sediment 8
4.1.3 Limitations 8

4.2 Application areas 8

5 Particle tracking module **9**

5.1 Module description 9

5.2 Application areas 10

6 Ecological module **12**

6.1 Module description 12

6.2 Applications 13

7 Chemical module **15**

7.1 Module description 15

7.2 Application areas 15

8 Wave module **16**

8.1 Module description 16

8.2 Application areas 18

8.3 Coupling with other modules 18

9 Morphodynamic module 19

9.1 Module description 19

9.2 Numerical aspects 20

9.3 Application areas 21

10 Pre- processing and post-processing 22

10.1 Visualisation 22

10.2 Grid generation 23

10.3 Grid data manipulation 23

10.4 GRID aggregation 23

10.5 Tidal analysis 24

11 Hardware configuration 25

1 Introduction

The Delft3D system is a flexible, modular modelling system capable of simulating:

- Flows due to tide, wind, density gradients and waves induced currents;
- Propagation of directionally spreaded short waves over uneven bathymetries, including wave-current interaction;
- Advection and dispersion of effluents;
- Water quality phenomena;
- Initial and/or dynamic (time varying) 2D-morphological changes, including the effects of waves on sediment stirring and bed-load transport.

Delft3D can switch between the 2D vertically averaged and 3D mode simply by changing the number of layers. This feature enables to set up and investigate the model behaviour in 2D mode before going into full 3D simulations.

All features are embedded in a state-of-the-art Graphical User Interface based on the OSF/MOTIF and X-Windows (Unix workstations) or the MS Windows (Wintel-platforms) standards. An application (model) can be completely defined through this menu-driven, user-friendly, graphical interface.

Furthermore, the system is embedded in a project and scenario management tool to define, select, (de-) archive simulations by referring to project and/or scenario names instead of file names. Consequently, errors in specifying input data are largely prevented, thereby increasing the overall model integrity and user's productivity.

Delft3D is composed of a number of modules, each addressing a specific domain of interest, such as flow, near-field and far-field water quality, wave generation and propagation, morphology and sediment transport, together with pre-processing and post-processing modules. All modules are dynamically interfaced to exchange data and results where process formulations require.

In the following chapters these modules are described in more details.

For more information:
dr. G.K. Verboom
Product manager Delft3D
Tel.: ++ 31 15 2858787
Email: gerrit.verboom@wldelft.nl
Homepage: www.wldelft.nl

2 Hydrodynamic module

The hydrodynamic module, Delft3D-FLOW, is a multi-dimensional hydrodynamic simulation program that calculates non-steady flow and transport phenomena resulting from tidal and meteorological forcing on a curvilinear, boundary-fitted grid. In 3D simulations, the hydrodynamic module applies the so-called sigma co-ordinate transformation in the vertical, which results in a smooth representation of the bottom topography. It also results in a high computing efficiency because of the constant number of vertical layers over the whole computational domain.

2.1 Module description

The hydrodynamic module is based on the full Navier-Stokes equations with the shallow water approximation applied. The equations are solved with a highly accurate unconditionally stable solution procedure. The supported features are:

- Three co-ordinate systems, i.e. rectilinear, curvilinear and spherical in the horizontal directions and a sigma co-ordinate transformation in the vertical;
- Simulation of drying and flooding of intertidal flats (moving boundaries);
- Coriolis force and (optionally) tide generating forces;
- Density gradients due to a non-uniform temperature and salinity concentration distribution;
- Inclusion of density (pressure) gradients terms in the momentum equation (density driven flows);
- Turbulence model to account for the vertical turbulent viscosity and diffusivity based on the eddy viscosity concept;
- Selection from four turbulence closure models: k-epsilon, k-L, algebraic and constant coefficient;
- Shear stresses exerted by the turbulent flow on the bottom based on a quadratic Chézy or Manning's formula;
- Wind stresses on the water surface modelled by a quadratic friction law;
- Simulation of the thermal discharge, effluent discharge and the intake of cooling water at any location and any depth in the computational field (advection-diffusion module).
- Automatic conversion of the 2D bottom-stress coefficient into a 3D coefficient;
- Horizontal turbulent exchange coefficients composed of a 3D turbulence model and a 2D sub-grid turbulence model;
- The effect of the heat flux through the free surface;
- On-line analysis of model parameters in terms of Fourier amplitudes and phases enabling the generation of co-tidal maps;
- Space varying wind and barometric pressure, including the hydrostatic pressure correction at open boundaries (optional);
- Drogue tracks (optional);
- The influence of spiralling motion in the flow (i.e. in river bends). This phenomenon is especially important when sedimentation and erosion studies are performed;
- On-line visualisation of model parameters enabling the production of animations (in preparation).

2.2 Applications areas

Delft3D-FLOW can be applied to the following application areas:

- Salt intrusion in estuaries;
- Fresh water river discharges in bays;
- Thermal stratification in lakes and seas;
- Cooling water intakes and waste water outlets;
- Transport of dissolved material and pollutants;
- Storm surges;
- River flows;
- Wave driven flows.

2.3 Coupling with other modules

The results of the hydrodynamic module are used in all other modules of Delft3D. The results are dynamically exchanged between the modules through the use of a so-called communication file. Basic (conservative) water quality parameters like concentrations of dissolved material and pollutants, can be included in the computations. But, for more dedicated water quality simulations, the hydrodynamic module is coupled with the far-field water quality module (Delft3D-WAQ) and the near-field particle tracking module (Delft3D-PART). A coupling with the sediment transport module (Delft3D-SED) is available to simulate cohesive and non-cohesive sediment transport processes, e.g. in the case of erosion and sedimentation studies. For wave-current interaction a dynamic coupling is provided with the wave module (Delft3D-WAVE) and for morphodynamic simulations the hydrodynamic module is integrated with the wave module and a sedimentation and erosion module into a morphodynamic module (Delft3D-MOR).

To simulate a model defined on a curvilinear grid system, an orthogonal grid must be provided. To generate such a grid the program RGFGRID is provided, though the grid can be generated by any grid generator program as long as the grid is delivered in the prescribed (ASCII) file format. The generation of a curvilinear grid is an important and somewhat complex task. Along with the main model parameters, the grid will ultimately determine the accuracy of the final model results.

To prepare the bottom topography or other grid-related data, such as a non-constant initial condition file, the program QUICKIN is provided. This program interpolates the scattered, digitised chart data to depth-values at the grid points in the model. Many powerful interactive processing options to further adjust the topography are supported, e.g. manual adjustment of the values at individual points, selection of the domain of influence, group adjustments, and smoothing. The output of this program (ASCII-file) can be imported into other Delft3D modules.

Analysis and interpretation of a hydrodynamic simulation in terms of tidal quantities can be performed by the program TRIANA. TRIANA performs off-line tidal analyses of time-series of either water levels and or velocities. The results from these analyses can be subsequently compared with observation data supplied by the user.

3 Water quality module

The transport of substances in surface and ground water is commonly represented by the so-called advection-diffusion equation. The water quality module, Delft3D-WAQ, is based on this equation and it offers different computational methods to solve it numerically (in one, two or three dimensions) on an arbitrary irregular shaped grid, on a grid of rectangles, triangles or curvi-linear computational elements. In order to model waste loads and water quality processes the advection-diffusion equation is extended with an extensive water quality library of source/sink terms. The model is capable of describing any combination of constituents and is not limited with respect to the number and complexity of the water quality processes.

The water quality processes may be described by arbitrary linear or non-linear functions of the selected state variables and model parameters. For many water quality problems, these process formulations have been standardised in the form of a library, which smoothly interfaces with the water quality module. The library contains over 50 water quality processes routines covering 140 standard substances. A graphical user interface within the WAQ module enables the user to select substances and associated water quality processes.

3.1 Module description

In most practical cases Delft3D-WAQ models a physical system that consists of a surface or ground water body. Strictly speaking it models a body of a medium that is able to transport passive constituents. In this respect "passive" means that the influence of the concentration of the constituents on the transport coefficients may be neglected.

The transporting medium is characterised by its spatially and time dependent content (mass) of the modelled constituents. Some of these are transportable, some are non-transportable. An example of the latter is the material in the bottom sediment in a surface water model.
The concentration of the transportable constituents is computed by dividing the mass by the water volume. The mass is the state variable and the model is mass conserving by definition.

Waste disposals are specified either as mass units per time unit or as a combination of waste flow and concentration. They represent either point sources (urban, industrial, rivers) or diffuse sources (run-off, atmospheric deposition). The case of recirculating flows, as with cooling water studies, is also taken care of: the water that was let in, will have the same quality at the outlet.

The hydrodynamic characteristics of the transporting medium are expressed in terms of the volume and the flux of the transporting medium ("flow"). The combination of water volumes and flows must be consistent, i.e. an increase of the water volume must be balanced by a difference between inflow and outflow. As part of Delft3D, the coupling module can derive a set of consistent hydrodynamic flows automatically from Delft3D-FLOW, but the methods involved can be applied equally well to third-party hydrodynamic models outside Delft3D.

In many cases the water quality processes in the model are determined by meteorological conditions, by other (modelled or non-modelled) constituents or by other (modelled or non-modelled) processes. Examples are wind, water temperature, acidity (pH), primary production and the benthic release of nutrients. These entities are referred to as "forcing functions". Water quality process formulations are often of an empirical or semi-empirical nature and contain "model parameters" that are subject to tuning or calibration. Because of this, Delft3D-WAQ allows complete freedom in selecting the set of water quality processes and the relevant forcing functions and model parameters may vary between individual applications. It therefore provides flexible input facilities for constants, spatially varying parameters, functions of time and functions of space and time.

The physical system is affected by two types of processes:
- Transport processes: these processes involve the movement of substances;
- Water quality processes: these processes involve a transformation of one or more substances.

The transport of substances in surface and ground water is commonly represented by the so-called advection diffusion equation, which includes two basic transport phenomena: advection and diffusion. Advection is determined by the velocity field and dispersion by the dispersion coefficient. These basic transport processes operate on all transportable substances in the same way. Delft3D-WAQ offers the possibility to model other transport phenomena as well which may differ between individual substances. Examples are the gravity induced settling of particles and the autonomous motion of fish. These additional transport processes must be expressed as an extra, substance dependant, velocity or dispersion coefficient.

Water quality processes are incorporated in the advection diffusion equation by adding an additional source in the mass balance. Examples of water quality processes are:
- Exchange of substances with the atmosphere (oxygen, volatile organic substances, temperature);
- Adsorption and desorption of toxicants and ortho-phosporous;
- Deposition of particles and adsorbed substances to the bed;
- Re-suspension of particles and adsorbed substances from the bed;
- The mortality of bacteria;
- Biochemical reactions like the decay of BOD and nitrification;
- Growth of algae (primary production);
- Predation (e.g. zooplankton on phytoplankton).

Special attention is paid to the treatment of the interaction with the bottom:
- All suspended sediment is modelled as cohesive sediment that can be transported with the water flow just like a dissolved substance;
- All particulate inorganic matter can be represented by three size fractions or components;
- All particulate organic matter is represented by separate components, namely detritus carbon, other organic carbon, diatoms, non-diatom algae (Green), adsorbed phosphorus and organic carbon from loads;
- The bottom sediment is modelled via two separate layers. Each layer is considered homogeneous (well mixed). The different layers can have different compositions. The density of a layer is variable depending on the sediment layer composition, which is also variable. The porosity within a given layer is constant (user defined);
- A third (deeper) layer exists (but is not explicitly modelled) which can supply sediment for upward sediment transport 'digging';
- Sedimentation and resuspension are modelled using the Krone-Partheniades approach (see the description of the sediment transport module Delft3D-SED).

3.2 Application areas

Delft3D-WAQ can be applied to the following application areas:

- Bacterial decay processes;
- Chemical processes;
- Nutrient cycling and eutrophication processes;
- Sedimentation and resuspension of particulates;
- Interaction between water and bottom (including diffusive and benthic mixing);
- Evaporation, re-aeration and other surface processes;
- Transport and chemical processes regarding heavy metals and organic micropollutants;
- Recirculation of cooling water.

These processes hold for such substances as:
- Chloride/salinity;
- Up to five different conservative substances;
- Up to five different first order decaying substances;
- Coliform bacteria (E.coli, faecal coliforms and total coliforms);
- Oxygen and BOD;
- Excess temperature;
- Dissolved nutrients and nutrients in organic material;
- Various fractions of inorganic phosphorus;
- Up to three fractions of suspended sediment (both in water phase and bottom);
- Up to three algae species (diatoms, greens, bluegreens);
- Heavy metals like cadmium, copper, zinc, mercury, nickel, lead, chromium;
- Organic micropollutants like PCB-153, HCB, lindane, fluoranthene and benzo(a)pyrene.

The processes always require input in the form of rate constants and/or simulation results from other substances. The input could come from:
- One of the other modelled substances;
- A user specified spatially distributed time function;
- A user specified time function for the whole area;
- A user specified spatially distributed constant;
- A user specified constant for the whole area;
- A process flux originating from one of the water quality processes from the library;
- Output from one of the other processes in the library;
- A default value from the database containing default values.

The pre-processor will report the origin of the input for each process. If information for a process is missing, so that the process can not be evaluated, it will detail what information is actually required in addition.

4 Sediment transport module

The sediment transport module, Delft3D-SED, can be applied to model the transport of cohesive and non-cohesive sediments, i.e. to study the spreading of dredged materials, to study sedimentation/erosion patterns, to carry out water quality and ecology studies where sediment is the dominant factor.

It is in fact a sub-module of the water quality module, that is all processes contained in the sediment transport module are also present in the water quality module. For a detailed description of the general aspects we refer to the description of the water quality module.

4.1 Module description

4.1.1 Cohesive sediment

This section describes the implementation of the physical processes in some detail. For cohesive sediment transport sedimentation, erosion, burial and digging are taken into account.

For sedimentation the following assumptions apply:

- Sedimentation takes place when the bottom shear stress drops below a critical value;
- There is no correlation between the sediment components (i.e. each of the particulate fractions can settle independently);
- Sedimentation always results in an increase of sediment in the uppermost sediment layer;
- The total shear stress is the linear sum of the shear stresses caused by water velocity and wind effects. Effects of shipping and fisheries can also be included.

The effects of 'hindered settling' (i.e. decrease in sedimentation velocity at very high suspended solids concentration) can be included.

For resuspension the assumptions are:

- The bottom sediments are homogenous within a layer. Therefore, the composition of the resuspending sediment is the same as that of the bottom sediment;
- The resuspension flux is limited based on the available amount of sediment in a sediment layer for the variable layer option. The resuspension is unlimited if the fixed layer option is used;
- As long as mass is available in the upper sediment layer, resuspension takes place from that layer only;
- Resuspension flux is zero if the water depth becomes too small.

Burial is the process in which sediment is transferred downward to an underlying layer. The sediment layer is assumed to be homogeneous, therefore the composition of the sediment being buried is the same as that of the (overlying) sediment layer.

Digging is the process in which sediment is transferred upward from an underlying layer. The sediment layers are homogeneous, therefore the composition of the sediment being transported upwards is the same as that of the (underlying) sediment layer. A third and deeper layer allows for an unlimited 'digging' flux to the second layer. The quality of this third layer must be defined by the user and is not modelled by Delft3D-SED.

4.1.2 Non-Cohesive sediment

For non-cohesive sediment (sand) the transport rate is calculated according to the transport formulae of Engelund-Hansen and Ackers-White. These (semi-)empirical relation describes the total transport (bed load and suspended load) in the situation of local equilibrium.

The implementation recognises two options: unlimited supply of sand via the boundaries and the presence or absence of bedrock.

4.1.3 Limitations

To apply the sediment transport module the following limitations must be observed:

- In the sedimentation process, there is no correlation between the cohesive and non-cohesive components, i.e. between sand and silt; each is treated independently;
- The effect of short waves must be taken into account through the hydrodynamic module or through a localised wave effect estimation (that is, the waves are considered to be in equilibrium with local circumstances);
- Delft3D-SED should only be used for short- or medium-term (days, weeks, months) modelling of erosion and sedimentation process as the changes on bottom topography and its effects on the flow are neglected. For long-term processes (years), whereby the flow changes induced by changing bottom topography is significant, the separate morphological and sediment module (Delft3D-MOR) should be used. This module has advanced on-line coupling capabilities with the hydrodynamic flow and wave modules.

4.2 Application areas

Delft3D-SED can be applied to the following application areas:

- Effects of dredging on the environment;
- Sedimentation and resuspension of sediment in general;
- Sand transport.

5 Particle tracking module

The particle tracking module, Delft3D-PART, is a 3-dimensional near-field water quality model. It estimates a dynamic concentration distribution by following the tracks of thousands of particles in time. The model is fit for a detailed description of concentration contours of instantaneous or continuous releases of salt, oil, temperature or other conservative or simple decaying substances. This section gives a brief introduction to the computer module and its applications.

5.1 Module description

Delft3D-PART simulates transport processes and simple chemical reactions of substances. The present release also allows for red tide modelling. The module allows the simulation of detailed shapes of patches of wasted material.

Delft3D-PART can operate in various modes:

- Standard mode: 3D or 2.5DH mode: Delft3D-PART is coupled to Delft3D-FLOW in 2D or 3D mode (one layer model or multi-layer model), and extended with an analytical vertical velocity profile for bottom shear and wind;
- Temperature model: Delft3D-PART in 2.5DH mode with two layers. Exchange between the layers is done with a finite volume method in order to account for stratification. Buoyancy of plumes of heat is included with a simple approximation of horizontal dispersion;
- Red Tide model: Delft3D-PART in 3D mode, with transport and growth kinetics of red tides and nutrients, including light effects and settling (special license required);
- Oil spill module: simulation of oil spills with floating and dispersed oil fractions (special license required).

The physical components in the system are:

- The water system: a lake, estuary, harbour or river, possibly with open boundaries to other water systems. Tidal variations are included;
- Outfalls due to human activities;
- Chemical substances like rhodamine dyes, salt, oil or a demand of oxygen due to fast chemical reactions;
- Physical quantities like temperature and density;
- Wind fields;
- Stratification of the water column in two layers;
- Red Tides, nutrients and sun light;
- Settling velocities.

In terms of physical processes or phenomena Delft3D-PART can represent:

- The dynamics of patches close to an outfall location;
- Simple first-order decay processes like the decay of several fractions of oil;
- Vertical dispersion for well-mixed systems;
- Limited vertical dispersion due to stratification. Stratification may occur near outfall locations due to a waste of heat or a waste of salt;

- Horizontal dispersion due to turbulence. According to turbulence theory this dispersion increases in time;
- Horizontal dispersion that decreases in time due to buoyancy-driven currents near an outfall of heat or salt;
- The effects of time-varying wind fields on the patches;
- The effects of bottom-friction on the patches;
- The existence of a plume at the outfall (rather than a point-source) by starting the simulation from a circular plume with an estimated or field-measured radius.
- The transport and growth of red tides, steered by nutrients and light;
- Settling of particles;
- Floating of oil at the water surface, and dispersion of oil induced by wind waves (depending on wind speed and oil characteristics). Evaporation of floating oil is modelled as well.
- The model may be started from a known initial distribution of material, e.g. a remote sensing image of an oil spill.

Delft3D-PART can simulate up to 400,000 particles with a maximum of 8 substances. This requires about 64 Mbyte internal (hard core) computer memory. A computer simulation requires for most applications less one hour, and takes most often less 200 Mbyte of disk space. Post-processing is done with the general postprocessing program GPP. Graphical maps can also be generated with advanced methods like point spread functions. Visualisation is off-line. The coupling between the hydrodynamic module, Delft3D-FLOW, and Delft3D-PART is fluent, but is off-line.

5.2 Application areas

Delft3D-PART can be applied to the following applications. Note that in all applications a dynamic two- or three-dimensional flow calculation (including an accurate description of tidal variations) with a water quantity model has been done first.

- Study of outfall of Coliform Bacteria in an estuary.
- Study of the initial stages of dispersion in the vicinity of outfalls. Dye measurements were performed in order to calibrate and verify the simulation results. Important quantities from the field experiment are concentrations of dye, recovery rates and wind data. The module is calibrated on dispersion coefficient parameters and a wind drag coefficient.
- Outfall of a pipe-discharge in the sea from an oil terminal. At the outfall location oil-residues are wasted. The residues contain a high salt- and H_2S concentration and heavy metals. An oxygen demand is modelled because H_2S is immediately oxidised. Heavy metals are modelled as conservative substances. The oil is an assembly of different fractions that decay according to first order kinetics. Since a high salt load is wasted, a stratified system is modelled. The thickness of the bottom layer is estimated for two different prototypes of the pipe, using a near-field model. The two situations have a significant difference in concentration distributions. The model simulates a period of about 4 days.
- Outfall of heat for a power station in an estuary with natural areas, oyster beds and recreation areas. Since a high thermal load is wasted, a stratified system is modelled. The thickness of the top layer is estimated from near-field theory for two different

outlet situations (at two different depth contours). Density currents due to buoyancy effects are modelled as time-dependent dispersion.

- Red Tide simulations in an estuary. Nutrient concentration have been obtained from a water quality simulation based on the finite volume method (WAQ-module). The effects of light are incorporated in the model. In this application algae growth may continue during night time.
- Oil spill modelling. Hindcast of an oil spill model, starting from an initial distribution of oil that was obtained from photography from an aeroplane.

6 Ecological module

The far-field water quality module Delft3D-WAQ models algae using an approach based on Monod kinetics and is routinely included in the process library. The Delft3D-ECO module contains the more sophisticated algae model BLOOM II (Los, 1991) that is based on an optimisation technique.

6.1 Module description

Delft3D-ECO distributes the available resources (nutrients and light) in an optimal way among the different types of algae. A large number of groups and/or species of algae and even different phenotypes within one species can be considered. In the same way, algae living in the water column (phytoplankton) and algae and water plants living on the sediment (benthic species) can be included with their specific ecophysiological characteristics. With BLOOM II, apart from the calculation of biomass concentrations, the dynamics of algae communities including competition for light and nutrients, adaptation to environmental conditions and species composition can be simulated. The same water quality processes are available in Delft3D-ECO as are in Delft3D-WAQ. As it is a superset of Delft3D-WAQ, Delft3D-ECO includes all processes considered by Delft3D-WAQ and more.

Delft3D-ECO can be used to calculate eutrification phenomena, including:

- The competition between several groups of algae species;
- Adaptation of algae to changes in the environment, in terms of stochiometry and growth characteristics, (This can be of particular importance if the simulation of possible development of nuisance algae is an aim of the modelling.);
- Steep gradients in algae biomass due to temporal or spatial variations;
- Phytoplankton blooms;
- Chlorophyll concentrations;
- Species composition;
- Limiting factors for algae growth;
- Oxygen kinetics, including daily cycles;
- Nutrient concentrations.

Algae blooms usually consist of various species of phytoplankton belonging to different taxonomic or functional groups such as diatoms, microflagellates and dinoflagellates. They have different requirements for resources (nutrients; light) and they have different ecological properties. Some species are considered to be objectionable for various reasons. Among these are *Phaeocystis*, which causes foam on the beaches and various species of dinoflagellates, which among others may cause diurethic shell fish poisoning. To deal with these phenomena it is necessary to distinguish different types of phytoplankton in the algae model.

Delft3D-ECO is based upon the principle of competition between different species, or groups of species. The basic variables of this module are called types. A type represents the physiological state of a species under strong conditions of limitation. Usually a distinction is made between three different types: an N-type for nitrogen limitation, a P-type for phosphorus limitation and an E-type for light energy limitation. Usually for each (group of) species the three different types are modelled.

The solution algorithm of the model considers all potentially limiting factors and first selects the one, which is most likely to become limiting. It then selects the best adapted type for the prevailing conditions. The suitability of a type (its fitness) is determined by the ratio of its requirement and its growth rate. This means that a type can become dominant either because it needs a comparatively small amount of a limiting resource (it is efficient) or because it grows rapidly (it is opportunistic). Then the algorithm considers the next potentially limiting factor and again selects the best adapted phytoplankton type. This procedure is repeated until it is impossible to select a new pair of a type and limiting factor without violating (= over-exhausting) some limiting factor. Thus the model seeks the optimum solution consisting of n types and n limiting factors. The optimal distribution of biomass over the types cannot always be reached within one time step due to growth and mortality limitations.

As they represent different stages of the same species, the transition of one type to another is a rapid process with a characteristic time step in the order of a day. Transitions between different species is a much slower process as it depends on mortality and net growth rates.

It is interesting that the principle just described, by which each phytoplankton type maximises its own benefit, effectively means that the total net production of the phytoplankton community is maximised.

6.2 Applications

The BLOOM model has been extensively used to model the Southern North Sea and has been calibrated to 20 years of data in the Dutch coastal zone. Furthermore the model results have been validated for a wide range of both freshwater and marine systems. The following (groups of) algae or macrophyte species have been modelled using the BLOOM module for salt waters:

- Diatoms;
- Flagellates;
- Dinoflagellates;
- *Phaeocystis;*
- Ulva (on the bottom);
- Ulva (floating).

For Ulva two life forms are distinguished: Ulva that is rooted in the sediment and Ulva that floats on the water after it has been cut loose by strong winds or currents. The process of cutting loose has been incorporated in the model.

Up to now 6 types of algae or macrofytes have been modelled and calibrated. As in BLOOM the properties of the algae are adjusted to the light climate and nutrient availability, the user does not need to adjust the parameters for this by calibration. The default parameter values obtained by calibration of one model can therefore be applied in a wide range of other model applications. For this reason, if one needs to model an area that resembles a water system that has been modelled with BLOOM II before, choosing the model that has proven successful under those conditions can be particularly helpful.

7 Chemical module

In the chemical module, Delft3D-CHEM, the water quality module (Delft3D-WAQ) is coupled to the chemical equilibrium model CHARON. CHARON calculates the distribution of elements over a pre-specified set of chemical species. The model is based on two principles: the conservation of mass and the minimisation of the Gibbs free energy. Delft3D-CHEM enables the user to perform a CHARON calculation in a Delft3D-WAQ environment. In this way a powerful tool is created to assess both common water quality and more complicated chemical reactions in one model.

7.1 Module description

A simple example of the CHARON possibilities is the occurrence of inorganic carbon, which in water exists in different forms, like CO_2, HCO_3^-, and $CO_3^{=}$. Besides speciation in the water phase, CHARON is also able to calculate speciation between water and solid phases, which can occur by means of adsorption (e.g. heavy metals, and phosphorous) and/or precipitation (e.g. $CaCO_3$, Iron oxides and sulphides, but also sulphides of heavy metals).

CHARON has been used for a variety of problems, such as modelling the behaviour of phosphorous in eutrophication studies, modelling the behaviour of heavy metals, both in fresh surface waters, in estuarine and salt water conditions, as well as in ground waters.

Currently, the coupling in Delft3D-CHEM is limited to speciation and adsorption in the water column. Solid phases could be modelled but are not handled correctly with respect to sedimentation and erosion processes in Delft3D-WAQ. Consequently, only a small part of CHARON's capabilities are exploited in Delft3D-CHEM at the moment. Presently work is being done to expand the possibilities of Delft3D-CHEM.

The hydrodynamic conditions as calculated by the hydrodynamic module (Delft3D-FLOW) are coupled to Delft3D-CHEM and provide the advective transport of constituents.

Delft3D-CHEM is used in conjunction with the water quality module (Delft3D-WAQ) and runs on the same computational grid. There is dynamic interaction between the two modules so that constituents calculated in one module are automatically incorporated in the calculations of the other module.

7.2 Application areas

DELFT3D-CHEM may be applied to areas where hydrolysis-, redox- and/or solid phase reactions of substances of interest play a role.

DELFT3D-CHEM is a general module that is not devoted to a particular system. In principle, various complicated processes can be prescribed by editing a separate input file which contains information about the species to be modelled. However, construction of such a file requires an experienced chemist. The input processor contains most of the chemical substances used in standard applications.

8 Wave module

To simulate the evolution of random, short-crested wind-generated waves in coastal waters (which may include estuaries, tidal inlets, barrier islands with tidal flats, channels etc.) the wave module Delft3D-WAVE can be used. This wave module computes wave propagation, wave generation by wind, non-linear wave-wave interactions and dissipation, for a given bottom topography, wind field, water level and current field in waters of deep, intermediate and finite depth.

8.1 Module description

At present two wave models (both of the phase-averaged type) are available in the wave module of Delft3D. They are the second-generation HISWA wave model (Holthuijsen et al., 1989) and - its successor - the third-generation SWAN wave model (Ris, 1997; Booij et al., 1999).

The HISWA wave model is presently the **standard** wave model for the wave module of Delft3D. A limited version of the SWAN model is presently optionally available in an experimental version of Delft3D. (We would like to stress out here that the SWAN model is still undergoing further enhancements. It is therefore that also the implementation of SWAN in Delft3D is still under development and that presently not all features of SWAN are available under Delft3D. It is expected that the SWAN model will be fully operational under Delft3D (including userinterface etc.) at the end of 1999.)

HISWA
The HISWA wave model is a ***second generation stationary*** wave model (see Holthuijsen et al., 1989). The model has been developed at Delft University of Technology, Delft (the Netherlands). It has been operational in Delft3D for many years and is - at present - the default option. HISWA is computationally very efficient and the results are fairly reasonable in many practical applications.

HISWA accounts for the following physics:
- Wave generation by wind;
- Wave refraction over a bottom of variable depth and/or a spatially varying ambient current;
- Dissipation by wave breaking (Battjes-Janssen type dissipation) and/or bottom friction;
- Wave blocking by flow;
- Shoaling;
- Current driving process determined directly from radiation stress gradients or by a (more robust) formulation based on energy dissipation;
- Directional wave spreading;
- Two way wave current interaction, i.e. the effect of waves on current via forcing, enhanced turbulence and enhanced bed shear stress and the effect of flow on waves, via set up, current refraction and enhanced bottom friction.

The solution technique applied marches forward row by row over the grid beginning at the incident wave boundary where the wave characteristics can be defined. The propagation of energy is modelled using energy balance equation adapted to include terms for wave growth by wind action or dissipation due to bottom friction/wave breaking. The time variation is implemented in a quasi-stationary manner whereby sequences of conditions (input waves, water level and flow field) can be specified within a single run.

Non-stationary situations are simulated with the HISWA model as quasi-stationary with repeated model runs. This implies that as e.g. the flow computations progresses in time, a (stationary) wave computation is performed at time level *t*. Such stationary wave computations are considered to be acceptable since the travel time of the waves from the seaward boundary to the coast is mostly relatively small compared to the time scale of variations in incoming wave field, the wind or tidal induced variations in depth and currents.

Although the HISWA model performs fairly well in many complex field situations for which it has been developed, it has a number of limitations. The most important limitations are that a) wave propagation is limited to a directional sector of less than 180°, b) the computational grid has to be oriented in the mean wave direction, which is operationally inconvenient, c) the frequency spectrum is parameterized and d) the modification and addition of physical processes is rather difficult due to the highly parameterized formulations that are used. These limitations are to a large extent overcome by the new wave model SWAN.

SWAN

The SWAN model, which is an acronym for Simulating WAves Nearshore, is a ***spectral third-generation*** wave model (see e.g. Holthuijsen et al. 1993; Ris, 1997). The SWAN model is the successor of the stationary second-generation HISWA model (Holthuijsen et al., 1989) and has the great advantage, compared to HISWA, that the physics are explicitly represented with state-of-the-art formulations and that the model is unconditionally stable (fully implicit schemes). Moreover, the SWAN model can perform computations on a curvilinear grid (better coupling with the flow-module of Delft3D) and it can - for instance - generate output in terms of one- and two-dimensional wave spectra. In addition, the wave forces, as computed by SWAN on the basis of the gradient of the radiation stress tensor (instead of the dissipation rate as in HISWA), can be used as driving force to compute the wave-induced currents and set-up in the flow module.

The SWAN model is based on the discrete spectral action balance equation and is fully spectral (in all directions and frequencies). This latter implies that short-crested random wave fields propagating simultaneously from widely different directions can be accommodated. SWAN computes the evolution of random, short-crested waves in coastal regions with deep, intermediate and shallow water and ambient currents. The SWAN model accounts for (refractive) propagation - as the HISWA model - and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. To avoid excessive computing time and to achieve a robust model in practical applications, fully implicit propagation schemes have been applied. It should be noted here, however, that although an efficient numerical technique has been implemented in SWAN the computing time for a typical computation is about 20 times longer (or even more) than that of the HISWA model. This should be considered if many wave computations are to be performed (i.e. for instance for morphological studies). The SWAN model has successfully been validated and verified in several laboratory and (complex) field cases (see e.g. Ris, 1997). It is noted that the SWAN model (as the HISWA model) does not account for diffraction effects.

The SWAN model was developed at Delft University of Technology (the Netherlands) and it is undergoing further enhancements. It is specified as the new standard for nearshore wave modelling and coastal protection studies Therefore, WL | DELFT HYDRAULICS is integrating the SWAN model into Delft3D and is applying SWAN (as a stand-alone model) in its consultancy projects. The SWAN model has been released under *public domain*.

8.2 Application areas

The wave module can be used for harbour and offshore installation design and for coastal development and management related projects. It can also be used as a wave hindcast model. Typical areas for the application of the wave module lie in the range between 2 by 2 km to 50 by 50 km.

The wave module can optionally be coupled with the other modules of Delft3D. By this an efficient and a direct coupling is obtained between e.g. the flow module (wave driven currents) and the sediment transport module (stirring by wave breaking).

8.3 Coupling with other modules

The wave computations are carried out in Delft3D on a rectangular grid for the HISWA and SWAN model (and optionally on a curvilinear grid for the SWAN model) to be specified by the user. The Delft3D system will then automatically transfer all the relevant information to and from (2-way coupling) the hydrodynamic module Delft3D-FLOW, which simulates the flow on a curvilinear grid.

9 Morphodynamic module

The morphological module, Delft3D-MOR, integrates the effects of waves, currents, sediment transport on morphological development, related to sediment sizes ranging from silt to gravel. It is designed to simulate the morphodynamic behaviour of rivers, estuaries and coasts on time-scales of days to years.

The typical problems to be studied using this system involve complex interactions between waves, currents, sediment transport and bathymetry. To allow such interactions, the individual modules within Delft3D all interact through a well-defined common interface; a flexible steering module controls the calling sequence of the individual modules.

The computational modules within Delft3D are identical to their stand-alone counterparts and each offer the full range of physical processes. In this way, WL | DELFT HYDRAULICS combined experience of over thirty years in computer modelling is built into this system.

A morphological simulation in Delft3D is defined as a tree structure of processes and sub-processes down to elementary processes which contain calls to the computational modules. The user is free to build up processes of increasing complexity, from a single call to the flow model to morphodynamic simulations spanning years, with varying boundary conditions.
This module simulates the processes on a curvilinear grid system used in the hydrodynamic module, which allows a very efficient and accurate representation of complex areas.

9.1 Module description

Delft3D-MOR contains or is able to utilise the following components:

Steering module
Allows the user to link model inputs for the module components. The morphological process can be specified as a hierarchical tree structure of processes. Time intervals for the elementary processes are defined. Processes may be executed a fixed number of times, for a given time span or as long as a certain condition is not satisfied. A variety of options are available to specify the time progress.

Waves
The wave module (Delft3D-WAVE) is built around the stationary short-crested wave model HISWA (Holthuijsen et al., 1989). This model computes the effects of refraction, shoaling, wave dissipation by bottom friction and breaking and wave blocking for a discrete directional wave spectrum, over a two-dimensional bathymetry. Within the module the user can specify several HISWA computations in one run, with varying boundary conditions, and for each boundary condition various nested runs can be executed. Flow and water level information can be used from a flow run, and the results can be passed on to the flow module.

At present, a project is carried out to implement the SWAN model (which is the successor of the HISWA model, see Holthuijsen et al., 1993; Ris, 1997) in the wave module. The SWAN model is fully spectral (in all directions and frequencies) and computes the evolution of random, short-crested waves in coastal regions with shallow water and ambient currents. The SWAN model accounts for (refractive) propagation - as the HISWA model - and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. It is noted that the SWAN model (as the HISWA model) does not account for diffraction effects.

Hydrodynamics
The hydrodynamic module (Delft3D-FLOW) used by Delft3D-MOR is based on the shallow water equations, including effects of tides, wind, density currents, waves, and turbulence models up to k-eps. The module includes a transport solver for salinity, temperature and conservative substances. The effects of salinity and temperature on the density and on the momentum balance are taken into account automatically.

The module uses a curvilinear grid in the horizontal plane. The vertical grid sizes are proportional to the local water depth.

For efficient morphological computations a one-layer, depth-averaged approach is used. The effects of spiral flow, i.e. in river bends, are computed by a secondary flow module which takes into account the advection of spiral flow intensity and the effect of the secondary flow on the primary current.

Wave effects in the model include radiation stress gradients associated with wave dissipation, wave-induced mass flux and enhanced bed shear stress, computed by a choice of formulations.

Sediment transport
The sediment transport module computes the bed-load and suspended-load sediment transport field over the curvilinear model grid, for a given period of time.

The bed-load transport is computed as a local function of wave and flow properties and the bed characteristics. The equilibrium suspended load is also computed as a local function of these parameters. The module then recognises two modes of transport: total transport (equilibrium) mode, or suspended load mode. In the first, the total transport is simply the addition of bed-load and equilibrium suspended-load transport. In the second mode, the entrainment, deposition, advection and diffusion of the suspended sediment is computed by a transport solver. Here, a quasi-3D approach is followed, where the vertical profiles of sediment concentration and velocity are given by shape functions.

The bed-load and equilibrium suspended-load transport can be modelled by a range of formulations, among which are Engelund-Hansen, Meyer-Peter-Muller, Bijker, Bailard and Van Rijn for sand, and a separate formulation for silt transport.

Effects of the bed slope on magnitude and direction of transport, and effects of un-erodible layers can be taken into account for all formulations.

Bottom change
The bottom update module contains several explicit schemes of Lax-Wendroff type for updating the bathymetry based on the sediment transport field. Options are available for fixed or automatic time-stepping, fixed (non-erodible) layers, various boundary conditions, and dredging.

9.2 Numerical aspects

All modules except the wave module operate on the same rectangular or curvilinear, orthogonal grid. Fully implicit ADI or AOI schemes are applied in the hydrodynamic module for the momentum and continuity equations. The solver has robust drying and flooding procedures for both 2D and 3D cases. In the transport solver a Forrester filter can be applied which guarantees positive concentrations throughout.

The same transport solver is applied for suspended sediment computations.

The wave model HISWA operates on rectangular grids, and uses an implicit scheme in propagation direction, combined with a forward marching technique. The wave module takes care of all transformations and interpolations between these rectangular grids and the curvilinear flow and transport grid. The wave model SWAN can perform computations directly on a curvilinear grid.

The bottom update model uses an explicit scheme of Lax-Wendroff type. This leads to a Courant type stability criterion. However, cheap intermediate "continuity correction" steps keep the computational effort at a reasonable level.

9.3 Application areas

Delft3D-MOR is designed to simulate wave propagation, currents, sediment transport and morphological developments in coastal, river and estuarine areas.

Coastal areas including beaches, channels, sand bars, harbour moles, offshore breakwaters, groynes and other structures. The coastal areas may be intersected by tidal inlets or rivers; parts of it may be drying and flooding.

Rivers including bars, river bends (spiral flow effect), bifurcations, non-erodible layers, dredging operations and having arbitrary cross-sections (with overbank flow). Various structures may be represented. Special features for 2-D river applications are presently being developed and validated, such as a bottom-vanes and graded-sediment.

Estuarine areas including estuaries, tidal inlets and river deltas influenced by tidal currents, river discharges and density currents. Sediment can be sandy or silty. The areas may include tidal flats, channels and man-made structures, e.g. docks, jetties and land reclamations.

10 Pre- processing and post-processing

In this chapter several pre- and postprocessing programs available in Delft3D are described in some details. These programs concern visualisation, grid generation, manipulation of grid related data and data analysis and manipulation.

10.1 Visualisation

The general post-processor (GPP) module of Delft3D allows uniform access to all kinds of data files to select and visualise simulation results and measurement data. More specifically the program allows to:

- Select the map and/or time histories you want to visualise;
- Select the lay-out and composition of the plot figure to be produced;
- Select the type of output medium, i.e. screen for inspection, plotter or printer for hard copy output.

The type of presentation depends on the character of the data set:

- *vector plots* for flow velocities, bottom shear stress and other vector quantities, with automatic or user-defined scaling of x-axis, y-axis and vector scale;
- *time history plots*, from a single run, from various runs in the same plot or simulation results in combination with measurement data. Depending on the data files, these can be typical hydrodynamic quantities, such as water levels, velocity magnitude and direction, but also water quality parameters like salinity, temperature and E.coli concentration. The scaling can be determined automatically or set by the user;
- *contour and isoline plots* of scalar quantities like the depth, water levels or algae growth rates. Again the user can choose automatic scaling or set the contour classes manually;
- *vertical profiles* for quantities defined on a three-dimensional grid;
- *geometric plots* of the grid itself, tidal flats, land boundaries;
- *mass balances and limiting factors* for displaying the details of water quality models.

Datasets can be plotted in any (sensible) combination, as long as there is a common co-ordinate system. Layouts may contain more than one viewport, allowing several independent plots on one page. It is noted that the overview above is by no means complete but it gives a general idea about the possibilities.

The program has been designed to be general enough to handle different kinds of underlying geometries and data files of widely varying formats.

The program is capable of producing high quality colour plots. It is also able to produce a plot file in various standard formats. At the same time a print-out of the results in ASCII format can be made, enabling the data to be imported in other post-processing programs.

10.2 Grid generation

RGFGRID is a program to generate orthogonal, curvilinear grids of variable grid size, that are to be used in combination with the hydrodynamic module Delft3D-FLOW. The grid-generator includes a graphical interface and an orthogonalisation module, providing easy control of the grid generation process.

RGFGRID supports the following features:
- Graphical user interface;
- Display of grid features as orthogonality, smoothness, aspect ration etc.;
- Several user functions have been implemented to provide easy control over the grid shape;
- Keyboard and mouse driven events are supported;
- Iterative way of working, each cycle providing more definition in the grid shape.

10.3 Grid data manipulation

To create, visualise and modify grid based data, such as bathymetries, and other grid related data the program QUICKIN is provided. QUICKIN is used in combination with the modules of Delft3D.

QUICKIN support the following features:
- Graphical user interface;
- Several interpolation options;
- Suitable for different ratios of grid-density vs. sample-density;
- Various display possibilities: isolines, dots, perspective, etc.;
- Implementation of various user functions to provide easy control over the final bathymetry;
- Sample data from different sources can be interpolated in sequence, thus, starting with the best quality data available, an optimal bathymetry can be created.

10.4 GRID aggregation

The program DIDO enables the user to span coarser, irregularly shaped, grid segments for water quality modelling, starting from the fine grid of e.g. the grid used by the hydrodynamic model. For ecological modelling with large numbers of state variables, a coarser schematisation, following ecological and transport separation lines rather than grid lines, is often preferable. The fine grid of the hydrodynamic model serves as input, integer multiples of the input grid are used for the description of the coarse grid. The procedure is fully mass-conserving. Aggregation is only supported in a plane surface.

DIDO provides the following features
- Zoom in locally;
- Separate a working area from the remainder of the schematisation;
- Aggregate regularly (e.g. every 2 segments in the one and 3 in the other direction);
- Aggregate irregularly (by rubber band lines comparable to the bulls hide);
- Fine tune by point and click on single elements;
- Select a subset of the hydrodynamic area for water quality modelling;
- Display information of a selected segment;

- Save intermediate results on the fly;
- Resume unfinished work from saved files;
- Save the final result for water quality simulation.

The final result of DIDO will be used as input to the coupling program between the hydrodynamic module Delft3D-FLOW and the water quality module Delft3D-WAQ enabling the latter to run on a coarser grid using the fine grid hydrodynamic database. Water quality simulations are converted back to the fine grid in post-processing software. This gives spatial plots with the fine resolution (although aggregated areas will still show equal concentration values).

10.5 Tidal analysis

The program GETIJSYS (acronym for GETIJ SYSteem, Dutch for tidal system) system is used for the analysis of tidal recordings and the preparation of tidal predictions.

The main module GETIJSYS/ANALYSIS performs tidal analysis on time-series of water levels or currents. A variety of features is included, such as:

- The coupling of closely positioned astronomical components;
- The simultaneous analysis of successive records of different instruments;
- The discrimination of sub-series to account for gaps in measurement recordings;
- The appreciation of linear trends and an accuracy analysis.

In a tidal analysis of a time-series of one year with a 10 minutes interval, 100 or more tidal constituents can be prescribed simultaneously. The constituents are selected from the internal database that contains 234 constituents that may be important at locations world-wide.

The module GETIJSYS/FOURIER performs Fourier-analyses on any type of time-series. This feature can be used to investigate the series of residual levels or velocities which has been identified during the tidal analysis on remaining tidal components.

Using a set of tidal constants, such as computed in the analysis module, the GETIJSYS/PREDICT module predicts water levels or tidal currents as a function of time.

The module GETIJSYS/HILOW may provide the production of tide tables with the dates, times and heights of the High and Low Waters. Using a word-processor or desktop publishing software package, the basic tide tables can be processed further and combined with other relevant information like tidal stream data.

Whereas in the regular analysis part of the package the user pre-defines the constituents that will be considered, the program also features an option (GETIJSYS/ASCON) to compute the astronomic arguments and node amplitude factors for all 234 internally defined constituents.

The package is accompanied with an comprehensive Users' Manual, exemplifying the use of the program and its scientific backgrounds. A number of examples is added in the form of input and data files.

11 Hardware configuration

Delft3D and its accompanying programs is supported on the following platforms:

- UNIX workstations (HP, SUN and SG);
- WINTEL platform (W95 and Windows NT).

The minimal and preferred configuration are:

Configuration item	Minimal	Preferred
Processor speed	166 Mhz	333 Mhz or more
Internal memory	64 Mb	128 Mb
Swap space	1.5 * internal memory	2.5 * internal memory
Hard disk	2 Gb	10 Gb
Monitor	17 inch colour	19 inch colour
CD-ROM	standard	standard
Printer	PCL, HPCL	PostScript

For the UNIX workstations the following operating systems are supported:

Workstation	Supported operating systems
HP	HP-UX 10.2 or higher
SUN	SOLARIS 2.6 or higher
SG RS10000	IRIX 6.5 or higher

Other hardware platforms or operating systems can be supported on request.

Appendix B ATA Environmental – Nutrient Inflow Report

MAUDS LANDING NUTRIENT CALCULATIONS FOR STORMWATER AND GROUNDWATER DISCHARGES TO MARINA

20057_044_nd

1. Introduction

The following estimates of nutrient inputs to the Mauds Landing marina have been derived on the basis of information on rainfall and groundwater provided by Ewing Consulting Engineers Pty Ltd (Locke) and using the site layout depicted in Figure 1. Any variation in the plan may require a reconsideration of the estimates.

Information has also been drawn from the work of Rockwater Pty Ltd (1994) and Jeffery (1994) that was presented in the previous CER.

Additional information on nutrient applications to turf and on nutrient levels found in ground and surface waters have been obtained from work completed by Woodward-Clyde (1996) and Tan (1991).

1.1 Landscape Zones

The Mauds Landing site encompasses a total area of 250ha of which the area of development is approximately 100ha in total. As shown on Figure 1, the Mauds Landing site has been divided into three landscape zones each of varying sizes. They are:

- Total area Landscape Zone 1 — 5.6ha
- Total area Landscape Zone 2 Mixed — 44.0ha
- Total area Landscape Zone 3 (zero nutrients) — 200.4ha

Each of these Landscape Zones will be irrigated under different watering and fertiliser regimes as indicated below:

- Landscape Zone 1 – 15% of total area under spray irrigation with 2.0m/year for shrubs and vegetation, 5% of total area grassed under 3m/year of spray irrigation. 20kg/ha phosphorous addition for both areas.
- Landscape Zone 2 – 15% of total area trickle irrigation of shrubs and trees 1.0m/year, 5% of total area grassed under 3m/year of spray irrigation. 10kg/ha phosphorous addition.
- Landscape Zone 3 - Incorporates marina waterbody, beaches, roads, paved areas and native dryland landscaping with no irrigation or fertiliser addition.

2. Modelling Assumptions

A number of general assumptions have been utilised in the preparation of the calculations. These assumptions are:

1. That the landscaped areas are uniformly distributed within each zone;
2. No direct run-off to the marine environment will occur except in extreme storm events;
3. All collected stormwater is piped piped to infiltration basins that will be located a minimum of 60m from the high water mark;

4. Stormwater basins have been designed for maximum 24-hour rainfall event of 140mm. For larger events, overflow from infiltration areas may discharge to the marine environment. These overflows will contain negligible nutrients due to the very high levels of dilution and the basins having been designed to trap nutrients; and
5. All areas of the resort will be connected to deep sewer.

2.1 Nutrient and Reticulated Water Inputs

Landscape plantings will primarily consist of native species. Grass will be restricted to five percent of the areas of Zones 1 and 2. Limited grass in Zone 3 with some small areas of grass in caravan park and public recreation areas.

In Zone 1, reticulation of landscape plantings and grass will occur using spray irrigation. In this zone irrigation of trees and shrubs will be at a higher rate to achieve a more lush appearance around the resort. It has been assumed that irrigation will occur at an application rate of 2m of applied water/year for vegetation and 3m/year for grassed areas. Jeffery indicated in his report for the previous CER that 3m/year would be an adequate irrigation rate for grassed areas at Mauds Landing.

In Zone 2, reticulation of landscape plantings will occur using either a trickle or drip irrigation system to match the quantity of water applied with plant needs. Irrigation systems for grassed areas will also be controlled to optimise water use.

To reduce iron concentrations, all irrigation will occur using aerated groundwater. No other water treatment will be carried out. The groundwater is sourced from the Birdrong Formation Aquifer and analyses show that the groundwater has the following properties:

- TDS 2475 mg/l
- pH 7.5
- $NO_3^=$ < 0.03 mg/l
- Total P Below detection

Jeffery reported that water from the Birdrong Aquifer used for irrigation of turf at the existing Coral Bay townsite contained approximately 5mg/l of ammonium ion (NH_4^+). This was confirmed through visual observation of turf health and measurements of nitrogen in plant foliage. Irrigation on the site was estimated to be 5m of applied water per year but there was no evidence of nitrogen leaching through the root zone of the soil. This translates to a nitrogen application rate of 250kg/ha. Jeffery reported that no other fertiliser was added and that although the foliage indicated a slight phosphorous deficiency, the saltene turf was extremely healthy.

Jeffery's findings suggest that the applied water contains all the nitrogen necessary for healthy plant growth.

As native plant species are proposed there will be minimal requirements for phosphorous addition as native plants are adapted to low nutrient levels.
Jeffery indicated that the soils in the vicinity of the Mauds Landing site have a low to moderate phosphorus retention index (PRI) of 2-8, depending on location. He

indicated the need for some phosphorous addition for plant health. Studies on turf irrigation indicate that in low PRI areas phosphorous addition should be limited to less than 5kg/ha because of the low ability of soils to retain phosphorous this could be extended to say 20kg/ha for the soil types in the Mauds Landing area. For the purpose of this analysis the following assumptions have been used:

- Irrigation of turf areas is 3m of applied irrigation per year in Zones 1 and 2;
- In Zone 1, irrigation of vegetation will be at the rate of 2m/year;
- In Zone 2, irrigation of vegetation will be at the rate of 1m/year;
- No nitrogenous fertilisers will be added due to the presence of 5mg/l of available nitrogen in the water supply;
- Phosphorous will be applied at 20kg/ha in Zone 1; and
- Phosphorous will be added at 10kg/ha in Zone 2

2.2 Nutrient Uptake

It is assumed that a high percentage of the applied fertiliser is taken up through one or more of the following processes:

- uptake by plants;
- binding to the soil; and
- loss through volatilization (nitrogen only).

Any residual is assumed to remain in the soil profile until it is leached to the groundwater table.

The following assumptions are made regarding uptake of nitrogen and phosphorous:

- **Zone 1**: Nitrogen uptake is 80% and phosphorous uptake is 80% being utililised in vegetation.

  Nitrogen uptake is 90% and phosphorous uptake is 90% being utililised in grasses.

- **Zone 2**: Nitrogen uptake is 90% and phosphorous uptake is 90% being utilised in vegetation.

  Nitrogen uptake is 90% and phosphorous uptake is 90% utilised in grasses.

These assumptions have been made in view of the following factors:

- Jeffrey's found in Coral Bay that even at 5m/year of irrigation for saltene turf, the applied nitrogen was fully utilised and there was no build up of nitrogen in the soil under turf.

- The irrigation systems will be designed and operated to optimise water application and nutrient use.

- The irrigation of vegetation in Zone 1 is at a higher rate using spray irrigation and therefore the uptake efficiency has been reduced from 90% to 80%.

2.3 Rainfall Data

Rainfall data for Cardabia Station has been used to estimate typical and maximal rainfall events. These are summarised below:

Winter rainfall (June-August)

Peak Winter Rainfall

280mm	1996/7
210mm	1992/3

Assuming 150mm peak in June (ie peak month)

Maximum daily event 40mm

Summer (October-April)

Approximate peak 140mm
Assume this represents daily maximum

Data for Exmouth is set out below:

Parameter	Summer	Autumn	Winter	Spring	Year
Ave rain (mm)	58.1	130.3	99.9	6.9	294.1
Highest Month	344.4 (feb)	362.8 (Mar)	243.1 (Jun)	106.2 (nov)	362.8
Highest day	208.8 (Dec)	208.8 (Mar)	135.9 (Jun)	16.0 (Oct)	208.8
Mean number of rain days	3.9	7.3	10.1	1.0	22.3

On the basis of the available data it appears that there are relatively few rain days through the years (approximately 22 per year). These are divided roughly as follows:

Summer/Autumn	10.5 days
Winter	10.5 days
Spring	1.0 day

On the basis of the available data it has been decided to model 'worst case' events:

- A summer storm event of 140mm in 24 hours that removes half of the annual residual nutrients and discharges them uniformly to the marina over a 48-hour period.
- A winter storm event of 140mm over three days that also removes half of the stored nutrients and discharges them to the marina over five days.

2.4 Soil Properties

Soils in the area are of marine origin and are primarily calcareous. On this basis they should have some ability to retain phosphorous with a PRI in the range of 2 for dune soils and up to 4-8 for swale soils. For conservatism, in this analysis, it has been assumed that phosphorous retention on the soils is zero.

Ewing Consulting Engineers advise that soils are porous and exhibit features common to Perth coastal sands. These features include:

- vertical transmissivity 25m/day
- horizontal transmissivity 250m/day

3. Nutrient Calculations

Based on the assumptions listed above, the amount of nitrogen and phosphorous applied through fertiliser and groundwater additions have been determined.

3.1 Nitrogen Application

Nitrogen application is directly proportional to the rate of water application.

Assuming water contains 5mg/L of NH_4, then nitrogen loads can be estimated as follows:

- For 1 hectare, 3m of applied irrigation represents 30000m^3 of water.
  At 5mg/L of NH_4, this represents 150kg of NH_4 per hectare. or 150 x 14/18 kg/ha of nitrogen = 116kg/ha of N
  (As Molecular Weight of N = 14 and H =1).
- Similarly for 2m of applied irrigation the load is 78kg/ha N and for 1m the load is 39kg/ha.

3.2 Phosphorous Application

The phosphorous application rates are as indicated:

- Phosphorous will be applied at 20kg/ha in Zone 1; and
- Phosphorous will be added at 10kg/ha in Zone 2

4. Nutrient Leaching

In view of the low rate of application of phosphorous and the controlled irrigation regime it could be expected that almost all of the nutrients would either be used by the plant or retained in the soil. For conservatism, a figure of 90% utilisation or soil absorption has been used for areas other than the vegetation in Zone 1 where a slightly lower uptake has been assumed due to the likelihood that more lush vegetation will be sought in this area.

This means that under landscaped areas the following quantities of phosphorous and nitrogen could be expected to have leached into the soil profile or remain unutilised on the soil surface.

The following figures apply to the nutrients in the soil in landscaped areas only.

	Turf Zones 1 and 2 (kg/ha)	Irrigated landscape Zone 1 (kg/ha)	Irrigated landscape Zone 2 (kg/ha)	Dryland Landscape
Applied N	116	78	39	0
Leached N	11.6	15.6	3.9	0
Applied P	20	20	10	0
Leached P	4	4	1	0

If we assume that the landscaped areas are evenly distributed through each zone of the development, then these figures can be transformed into the average annual burden of leached nutrients in the soil profile as follows (see attached table: Project Summary – Phase 1 for the breakdown of development characteristics):

Landscape Distribution

Development Type	Area (ha)	Irrigated Landscape Area (ha)		Total Irrigated Landscape Area (ha)
		Turf	Vegetation	
Zone 1	5.6	0.28	0.84	1.12
Zone 2	44	2.2	6.6	8.8
Zone 3 [1,2]	35.9	0	0	0

1. Excluding conservation areas and water areas
2. Only dryland native vegetation in this area

Annual Nutrient Loads Lost to Soil Profile

Development Type	Landscape Area (ha)		N applied (kg)		P applied (kg)		N lost (kg)		P lost (kg)	
	Turf	Veg	Turf	Veg	Tur f	Veg	Turf	Veg	Turf	Veg
Zone 1	0.28	0.84	32.5	65.5	5.6	16.8	3.25	13.1	.56	3.34
Zone 2	2.2	6.6								

Assuming the landscaped areas are distributed uniformly throughout each zone, we can calculate the annual applied load in each zone and derive an average annual load retained in the soil as follows:

Tourist Area:

Nitrogen
Annual applied load = 250 kg over 31ha = 8.1kg/ha
Annual load lost to soil profile = 50kg in 31ha = 1.6kg/ha

Phosphorous
Annual applied load = 33.4kg over 31ha = 1.1kg/ha
Annual load lost to soil profile = 6.68kg in 31ha = 0.2kg/ha

Residential Area:

Nitrogen
Annual applied load = 125kg over 31.9ha = 3.9kg/ha
Annual load lost to soil profile = 25kg in 31.9ha = 0.8kg/ha

Phosphorous
Annual applied load = 16.7kg over 31.9ha = 0.5kg/ha
Annual load lost to soil profile = 3.34kg in 31.9ha = 0.1kg/ha

5. Modelling

The amounts derived in section 4 (above) do not appear to be environmentally significant. However it is necessary to develop an argument regarding the fate of these unutilised nutrients in order to provide an input to the modelling of the marina circulation.

A 'worst case' assumption would be that the entire annual store of nitrogen and phosphorus is leached from the soil profile in a single storm event. This is highly conservative as the soils have some ability to retain phosphorus and natural processes will tend to remove nitrogen from the soil, particularly in such a warm climate.

5.1 Summer Rainfall Event

Ewing Consulting Engineers (1994) indicated that in a summer storm event 140mm of rainfall would possibly occur within a 24-hour period. An event of this magnitude would involve a total of 88060m^3 of incident rainfall over the total catchment. Ewing estimated a runoff coefficient of 0.42 for the catchment. This would result in a total of 36980m^3 of run-off and 51080m^3 of infiltration from a total catchment area of 62.9ha.

The following figure shows that this can be broken down to the tourist and residential sub-catchments of 31.0ha and 31.9ha as follows:

Catchment	Infiltration (m^3)	Run-off (m^3)	Total (m^3)
Tourist	25175	18230	43405
Residential	25905	18750	44655
Total	51080	36980	88060

Assuming that the nutrient burden in the soil has been totally leached into this volume of water then the following concentrations of nutrients would occur in the water:

Development Area	Area (ha)	Nutrient in soil (kg/ha)		Total Nutrient (kg/ha)		Total Water (m^3)	Nutrient conc'n (mg/l)	
		N	P	N	P		N	P
Tourist	31	1.6	0.2	50	6.68	43405	1.15	0.15
Residential plus roads	31.9	0.8	0.1	25	3.34	44655	O.56	0.07

This analysis is highly conservative as an examination of the rainfall records for both Exmouth and Carnarvon shows that the average annual rainfall is within the range of 229mm to 294mm with rainfall being distributed reasonably uniformly through the nine months of the year (other than during the spring months) with approximately 20 rain days. On this basis it can be safely assumed that some portion of the nutrients stored in the soil would be leached into the marina during the course of the year. Other factors include nitrogen losses due to denitrification processes and phosphorous losses to due to soil absorption.

An examination of the rainfall data for Exmouth suggests that approximately two-thirds of the annual rainfall occurs in spring and summer during intense storm events (10 rain days in 6 months), while approximately one-third of the annual rainfall occurs in winter in less intense events (10 rain days in 3 months). In addition, the winter rainfall tends to occur following the wettest period of the year and would be during the time when the irrigation rates would be the lowest.

As a result, it appears reasonable to assume that at least one-half of the nutrient-store is removed during winter, leaving the maximum credible concentrations in the groundwater for a summer event as 50% of the figures presented in the above table.

The following figure indicates what the maximum concentration for summer would therefore be more likely to be.

Estimate Nutrient Concentrations in Summer Storm Event

Development Area	Conc'n (mg/l)	
	N	P
Tourist	0.58	0.08
Residential plus roads	O.28	0.04

Having calculated the concentration of nutrients in the groundwater entering the marina, it is then necessary to develop a model for the rate at which groundwater enters the marina following a storm event.

Ewing's analysis indicates that the soils are extremely porous with travel time from the infiltration basins to the marina in the order of seven hours during a major storm event. For such porous soils with infiltration basins close to the marina, the following assumptions could be applied:

Following a summer storm event:

50 % of the incident rainfall enters the marina on day 1; and
50 % of the rainfall enters the marina on day 2.

This would mean therefore that for every two days of the modelling-run the following would occur:

From the tourist areas:

21702.5m^3/day with N 0.58mg/l and P 0.08mg/l

From the residential area:

22327m^3 with N 0.28mg/l and P 0.04mg/l

5.2 Winter Rainfall Event

The analysis for a 'worst case' winter storm event is based on the assumption that 50% of the annual nutrient store has already been lost during a summer storm event.

The rainfall data for Cardabia Station indicates that on average, 150mm of rain falls during winter with the maximum winter storm event being 40mm within a 24-hour period. With this pattern of rainfall, it is more reasonable to assume that the remaining 50% of the nutrients are leached from the profile reasonably uniformly over the three months of winter rainfall. This would mean the average concentration of nutrients would be virtually identical to the nutrient concentrations and the total volume of water presented for the summer storm event (total of 150mm of winter rain versus 140mm during a summer storm event and within the same catchment area) but the rate of entry into the marina would much lower.

Possible assumptions include:

1. That the volume of water enters the marina uniformly over the over 90 days of winter; or

2. That there are 10 rain days over winter and that for each day of rain, the rainfall infiltrates the soil profile steadily over a two-day period. This would result in 20 days of inflow over the course of the 90-day winter period or two days of inflow every nine days.

   The total volume of water flowing into the marina over the 90-day winter period would be virtually identical to the summer event but instead of entering the marina within two days in the modelling period, the 'worst case' would be that two rainfall events occur nine days apart in the model-run with each event consisting of two days of inflow where a tenth of the total volume of incident rainfall for a 150mm event entered the marina.

My recommendation is to use inflows based on assumption 2 with the same concentrations as predicted for summer.

This would mean that the model should include a two times two-day periods of inflow nine days apart, where on each day the inflow characteristics are as follows:

From the tourist areas:

Inflow = 2170m^3/day with N 0.58mg/l and P 0.08mg/l

From the residential area:

Inflow = 2232m^3 with N 0.28mg/l and P 0.04mg/l

These numbers should be compared with surface run-off measurements recorded in urbanised catchments in Perth that have indicated that the total N is in the range of 0.2 –0.3 mg/l during winter storm events and in the range of 1.2 –1.3mg/l during autumn storm events. At the same time, total P in the same catchments is in the range of 0.05-0.06mg/l during winter and 0.18-0.44mg/l during autumn.

REFERENCES

Ewing Consulting Engineers, unpublished, *Coral Coast Resort – Mauds Landing, Report on Engineering Considerations*, prepared for Coral Coast Marina Development Pty Ltd, December 1994.

Jeffery R.C., unpublished, *Report on the Chemical and Physical Properties of Soils from Mauds Landing, Coral Bay and Cardabia Station*, prepared for Coral Coast Marina Development Pty Ltd, November 1994.

Rockwater Pty Ltd, unpublished, *Evaluation of Groundwater Conditions near Mauds Landing in the Coral Bay Area for the Public Environmental Review*, prepared for Coral Coast Marina Development Pty Ltd.

Tan H, 1991, *Nutrients in Perth Surface Drainage Catchments Characterised by Applicable Attributes*

Woodward-Clyde, 1996, *Turf Irrigation and Nutrient Study*, for Horticultural Research and Development Corporation and Royal Australian Institute of Parks and Recreation

APPENDIX 1 - Development Characteristics

PROJECT SUMMARY – PHASE I

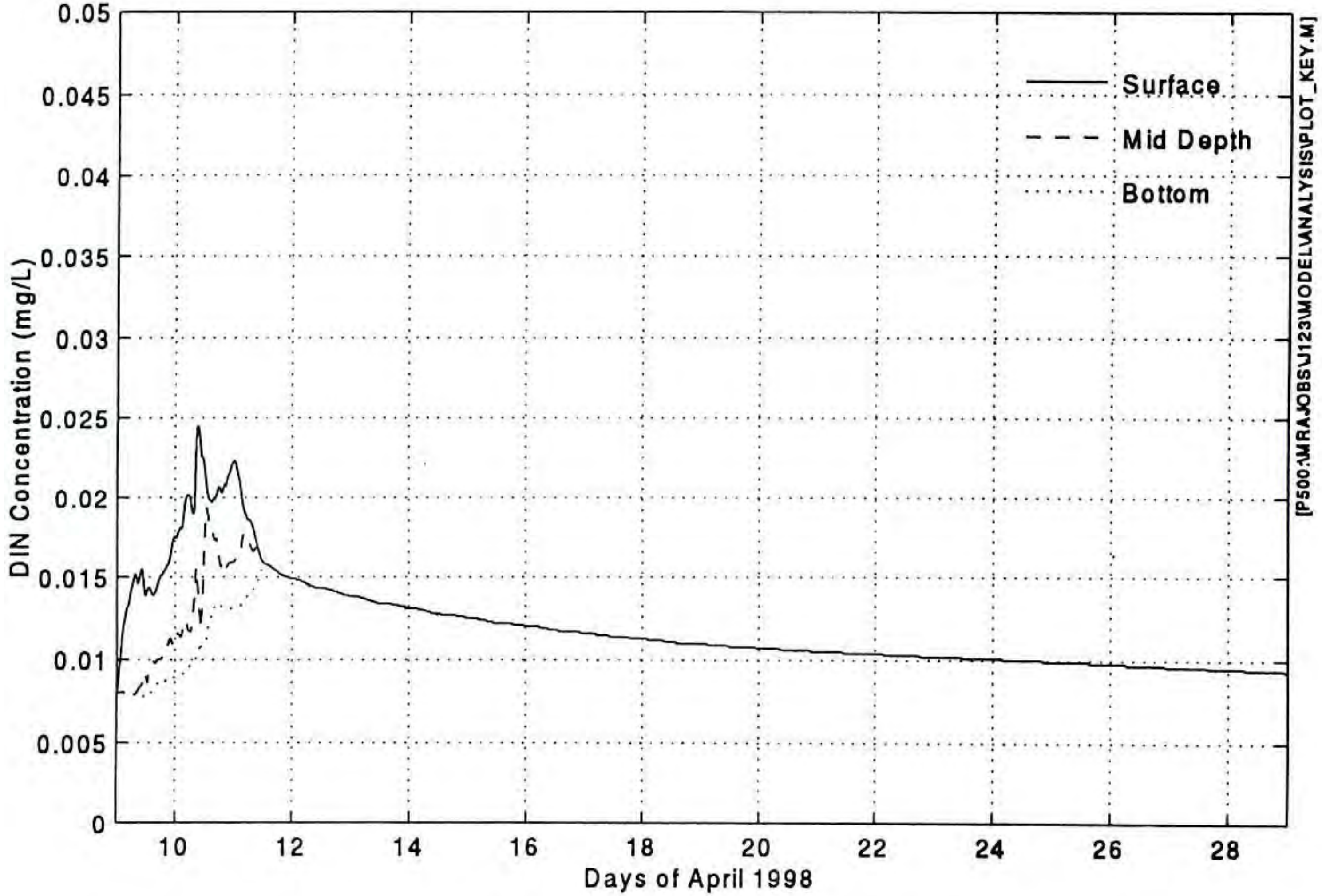
SITE AREA	AREA (ha)
Mauds Landing Townsite	250
External Services Area	62

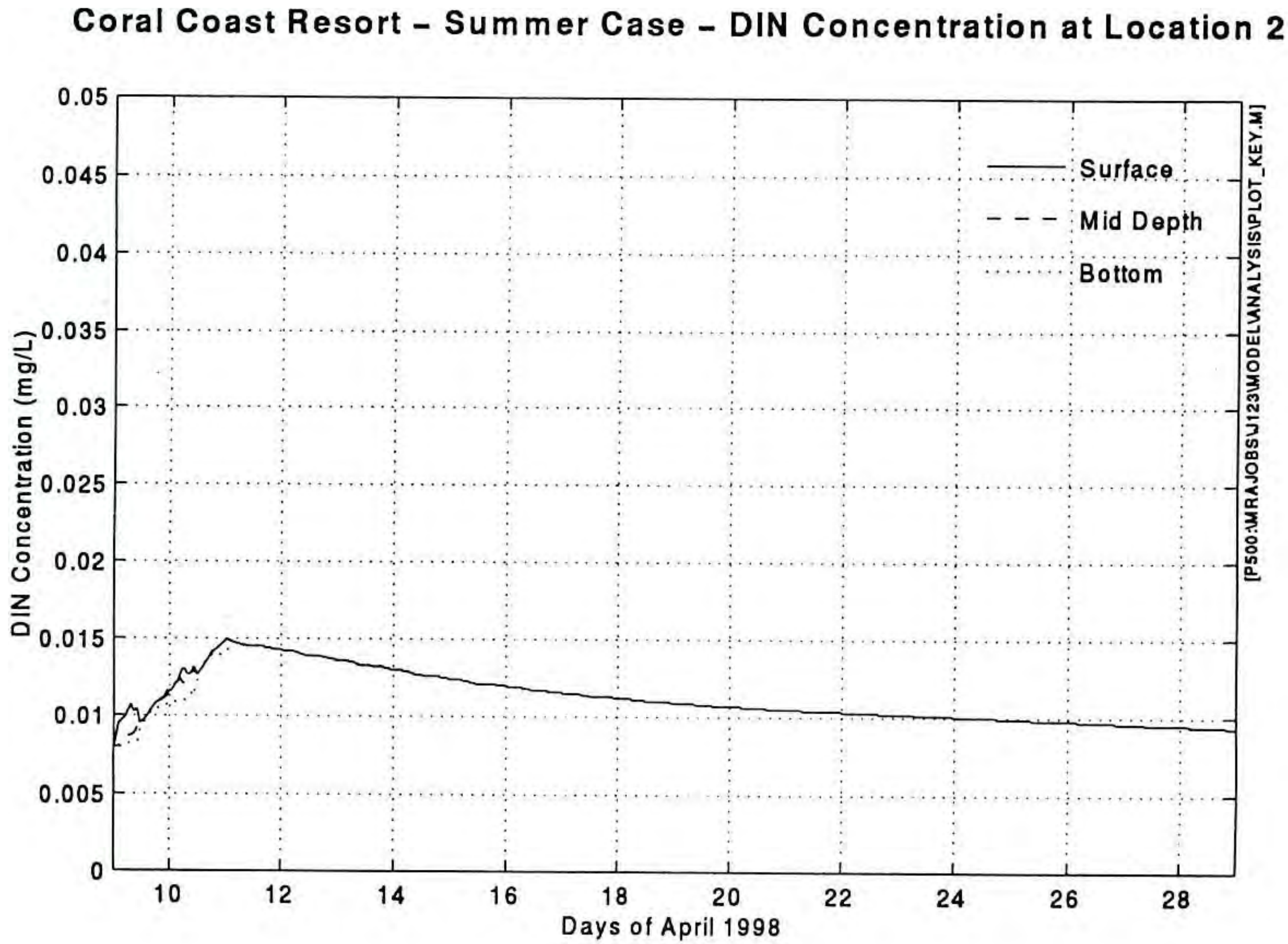
RESORT LAND USE	AREA (ha)	%	Landscape Zone	Description of Proposal when Fully Implemented
Dune Conservation & Non-developed Areas	118.0	47.2	3	Areas reserved under Council TPS or not to be developed under Structure Plan
Marina Waterbody	46.5	18.6	3	Inland boating and swimming waterbody
Marina Beaches	3.5	1.4	3	Public beaches to inland swimming areas
Marina Village & Serviced Apartments	4.0	1.6	1	120 serviced resort accommodation, retail, food, beverage, entertainment, visitor centres
Caravan & Chalet Park	4.0	1.6	2	100 bays, 20 chalets & assoc facilities
Serviced Apartments	3.5	1.4	2	130 serviced resort accommodation
Backpackers Hostel	1.0	0.4	2	60 beds and assoc facilities
Timeshare	3.6	1.4	2	100 resort timeshare units
Tourist Villas & Townhouses	6.7	2.7	2	180 resort villas and townhouses, assoc facil.
Auto / Coach Services	0.9	0.3	2	Service stn, minor repairs, coach facilities
Sports & Community Centre	1.6	0.6	1	Public sporting and community facilities
Major open spaces	6.5	2.6	2	Principal open space areas
Northern "Arroya"	8.0	3.2	3	Roads & dry "river bed" drainage swale
Village & Boat Parking	3.2	1.3	3	Central parking and boat launching parking
Staff Residential Lots	1.7	0.7	2	40 Managed Freehold Lots – 420m2+
Staff Group Housing	3.5	1.4	2	130 Managed Villa & "Duplex" units
Permanent Residential Lots	12.6	5.1	2	200 Freehold Lots – 420m2+ to 700m2+
Roads & Minor Open Spaces	20.7	8.3	3	Road reserves and minor open space areas
High Level Water Storage	0.5	0.2	3	Water storage & treatment area Mauds Hill
TOTAL	250.0	100.0		

Total Tourist 31 ha
Total Residential, roads, parking and marine service area 31.9 Ha
Total phase 1 land development area 62.9 ha

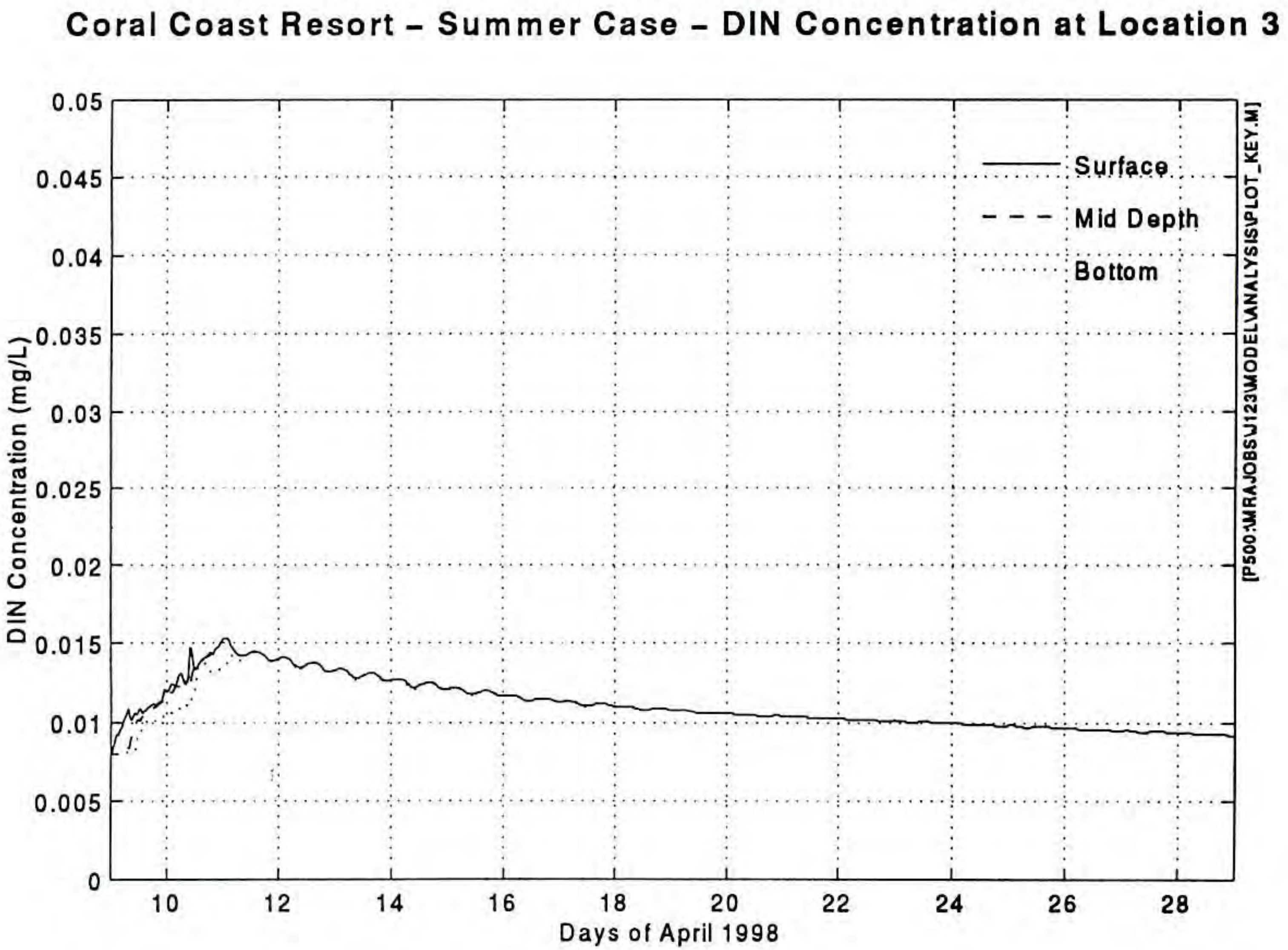
Appendix C Modelled Nutrient Concentrations

Coral Coast Resort – Summer Case – DIN Concentration at Location 1

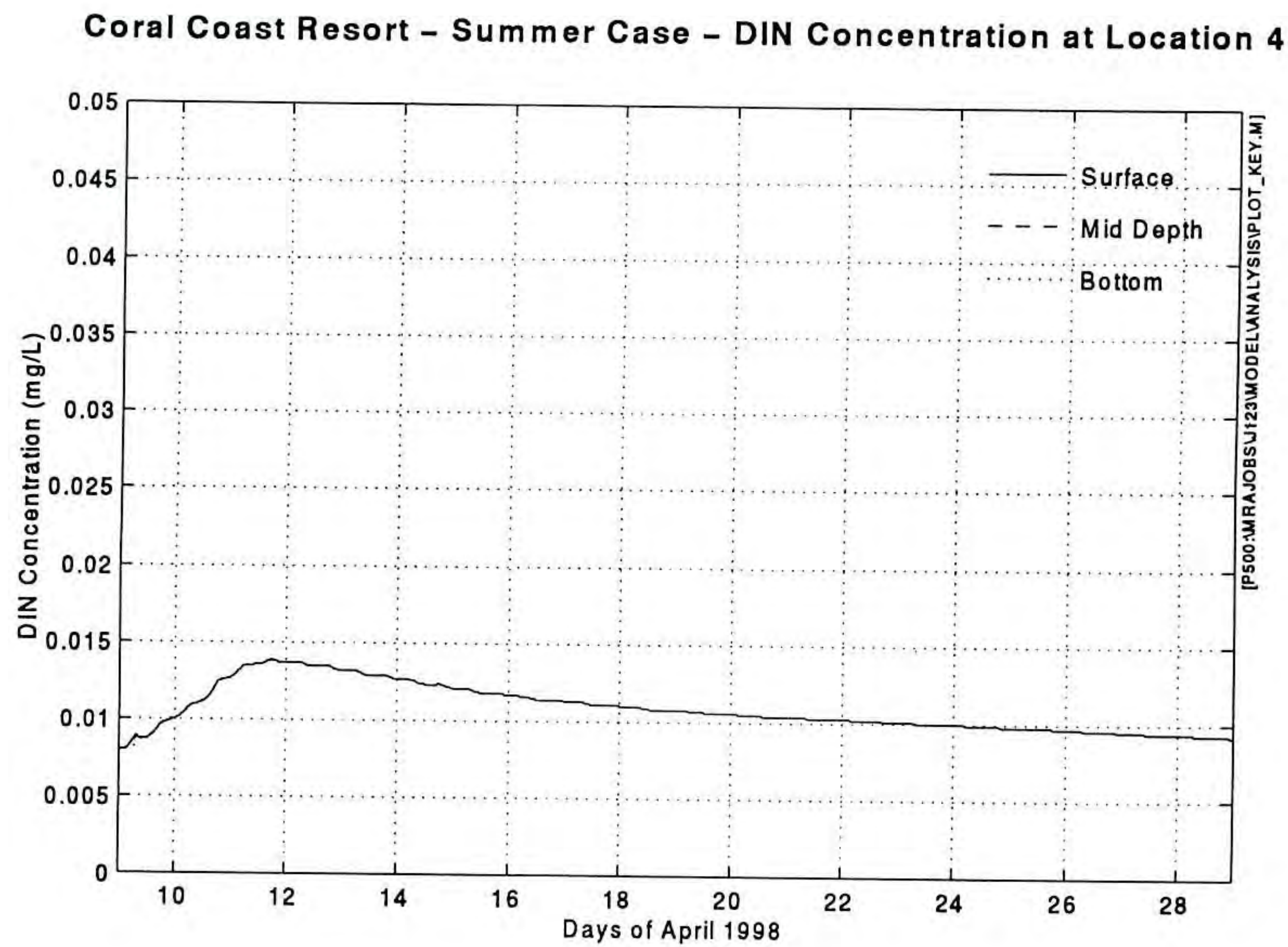




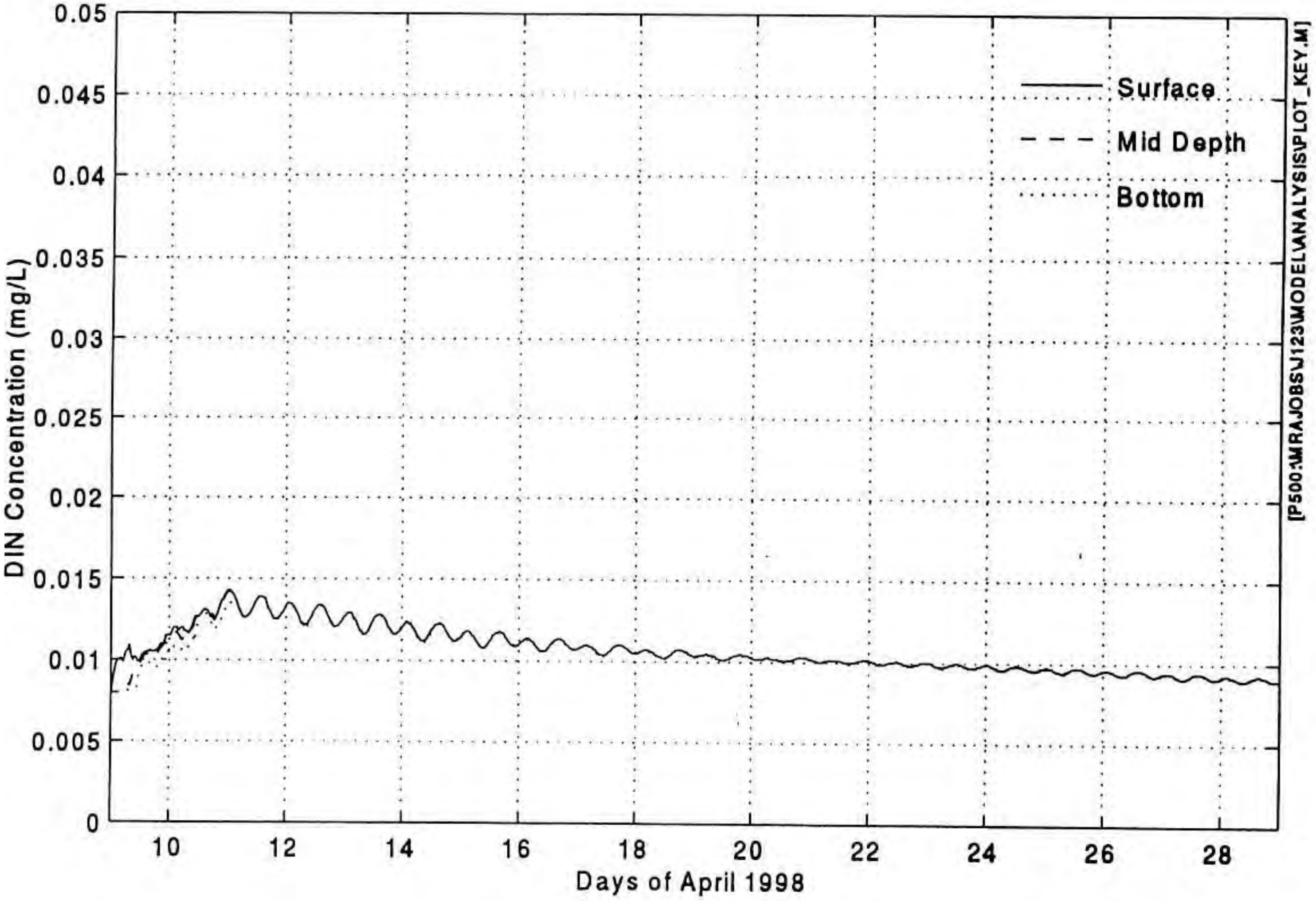
Coral Coast Resort - Summer Case - DIN Concentration at Location 2
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

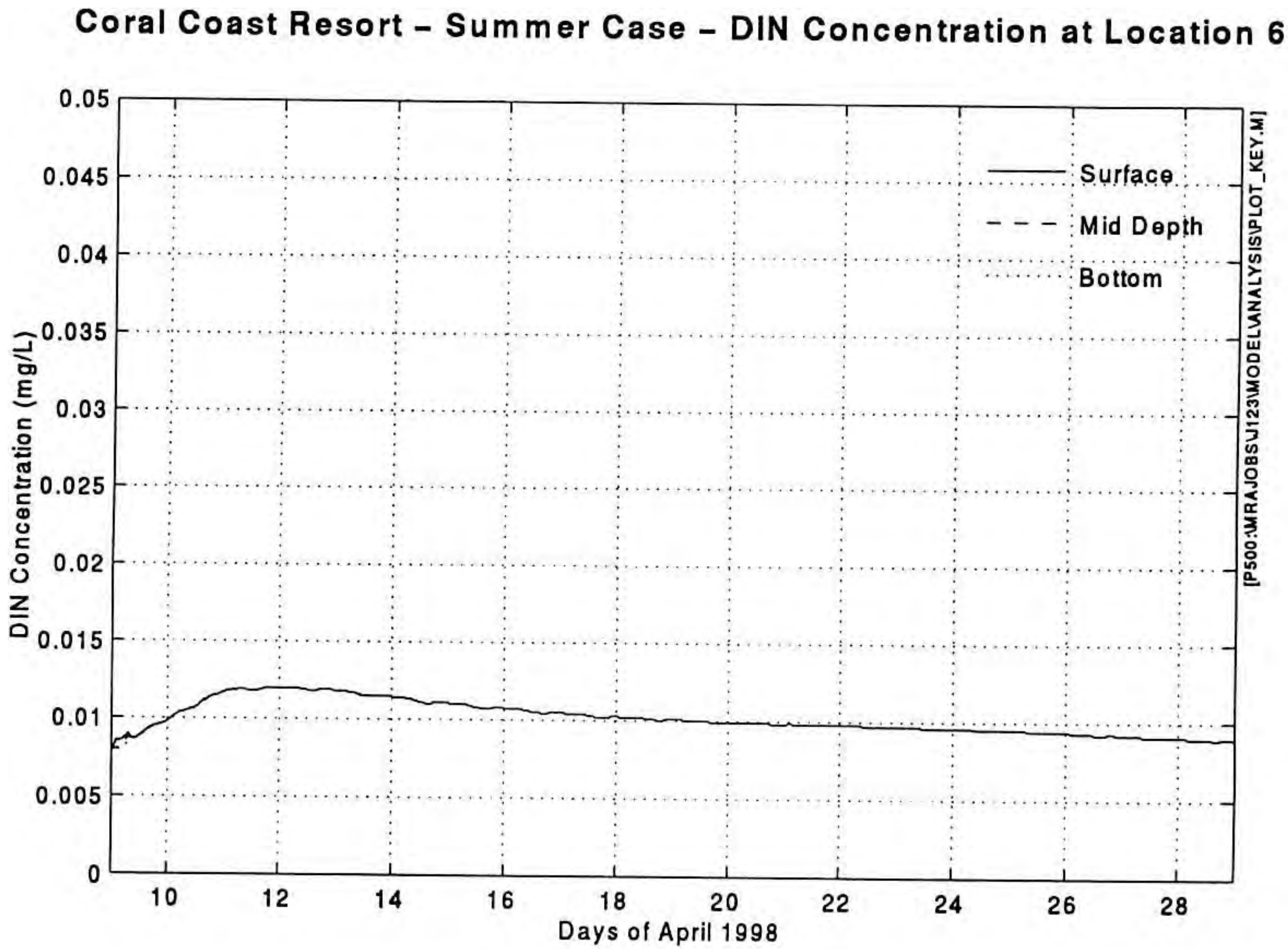


Coral Coast Resort – Summer Case – DIN Concentration at Location 3
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

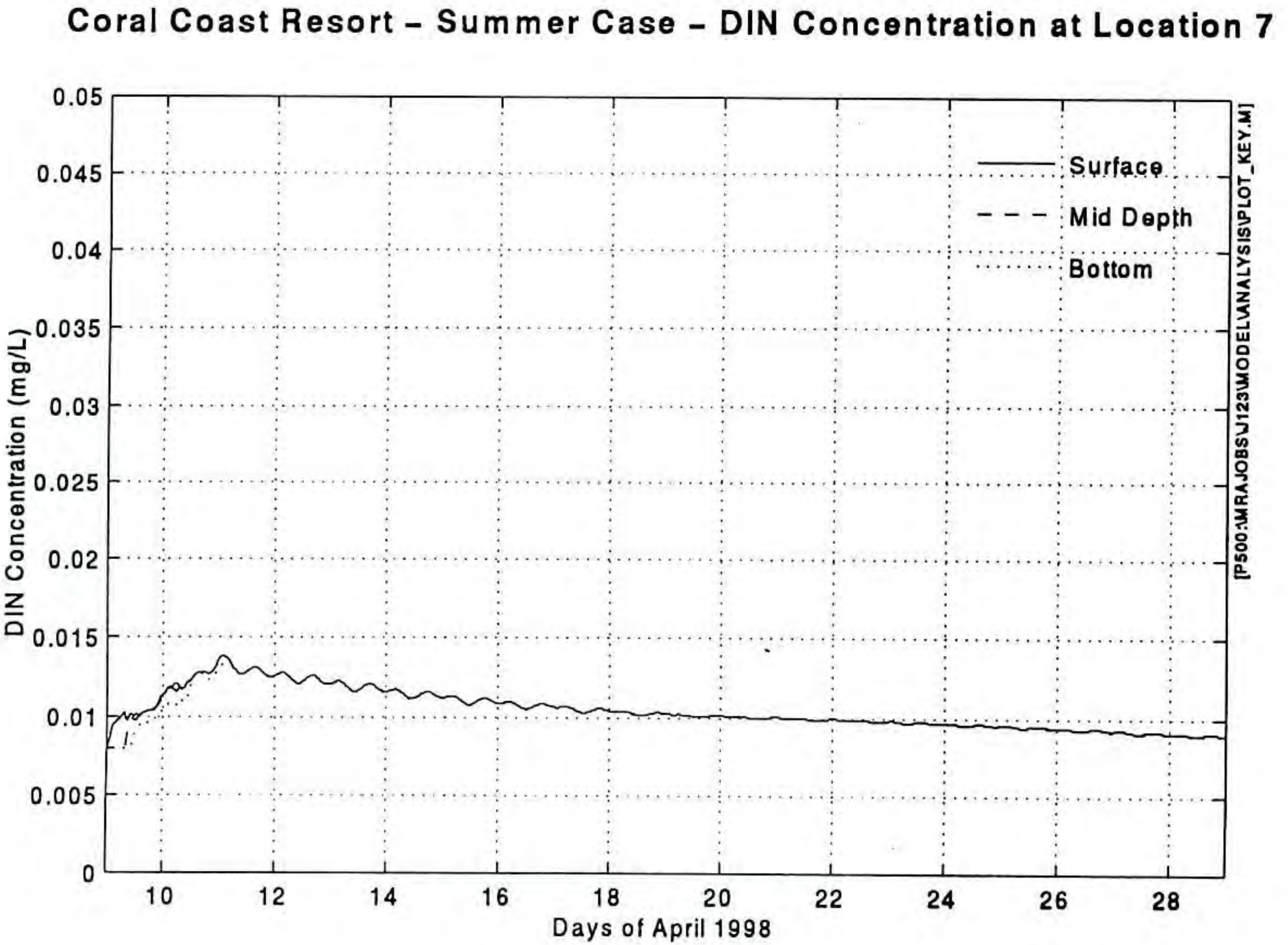

Coral Coast Resort - Summer Case - DIN Concentration at Location 4
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

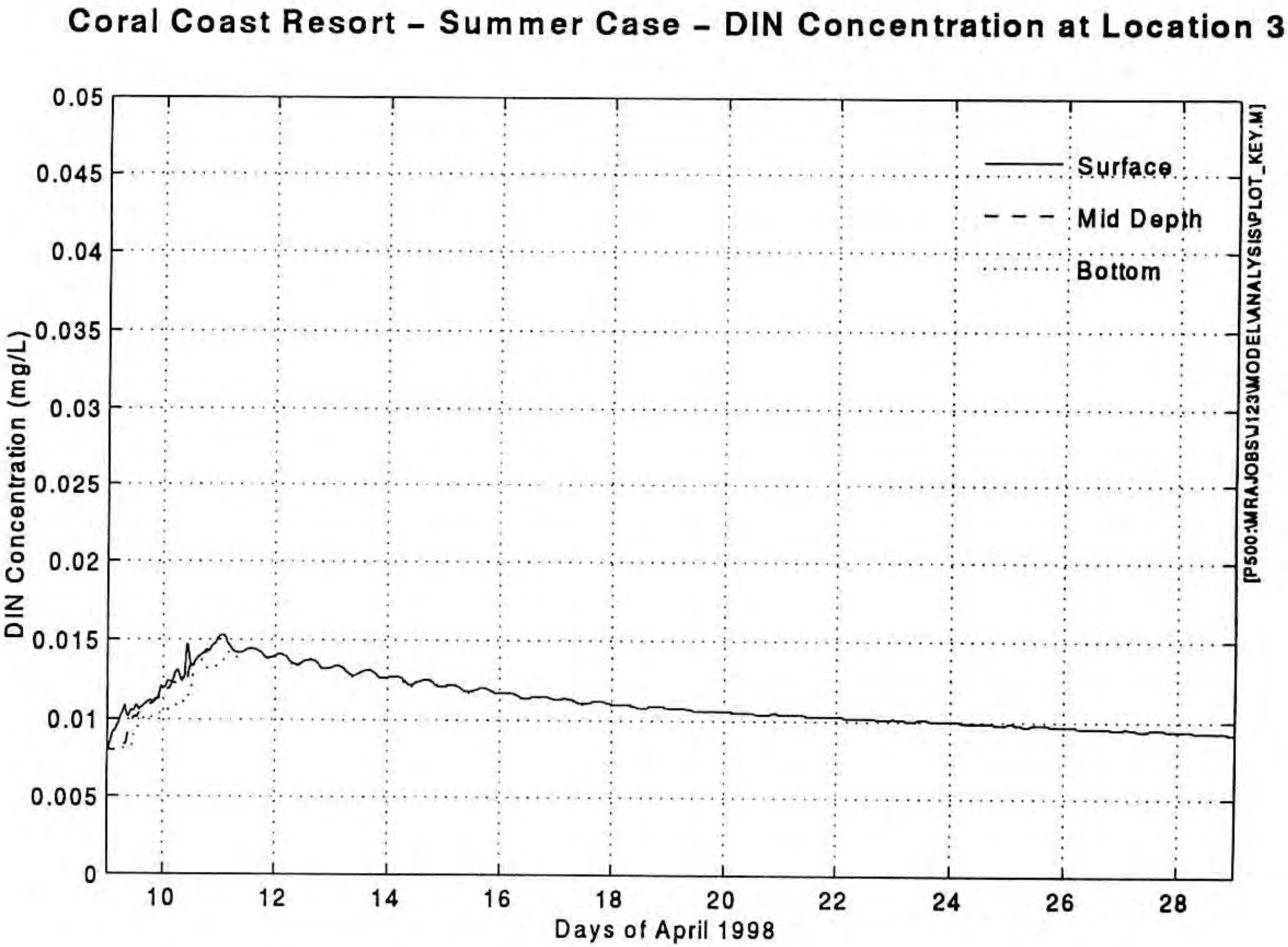
Coral Coast Resort – Summer Case – DIN Concentration at Location 5

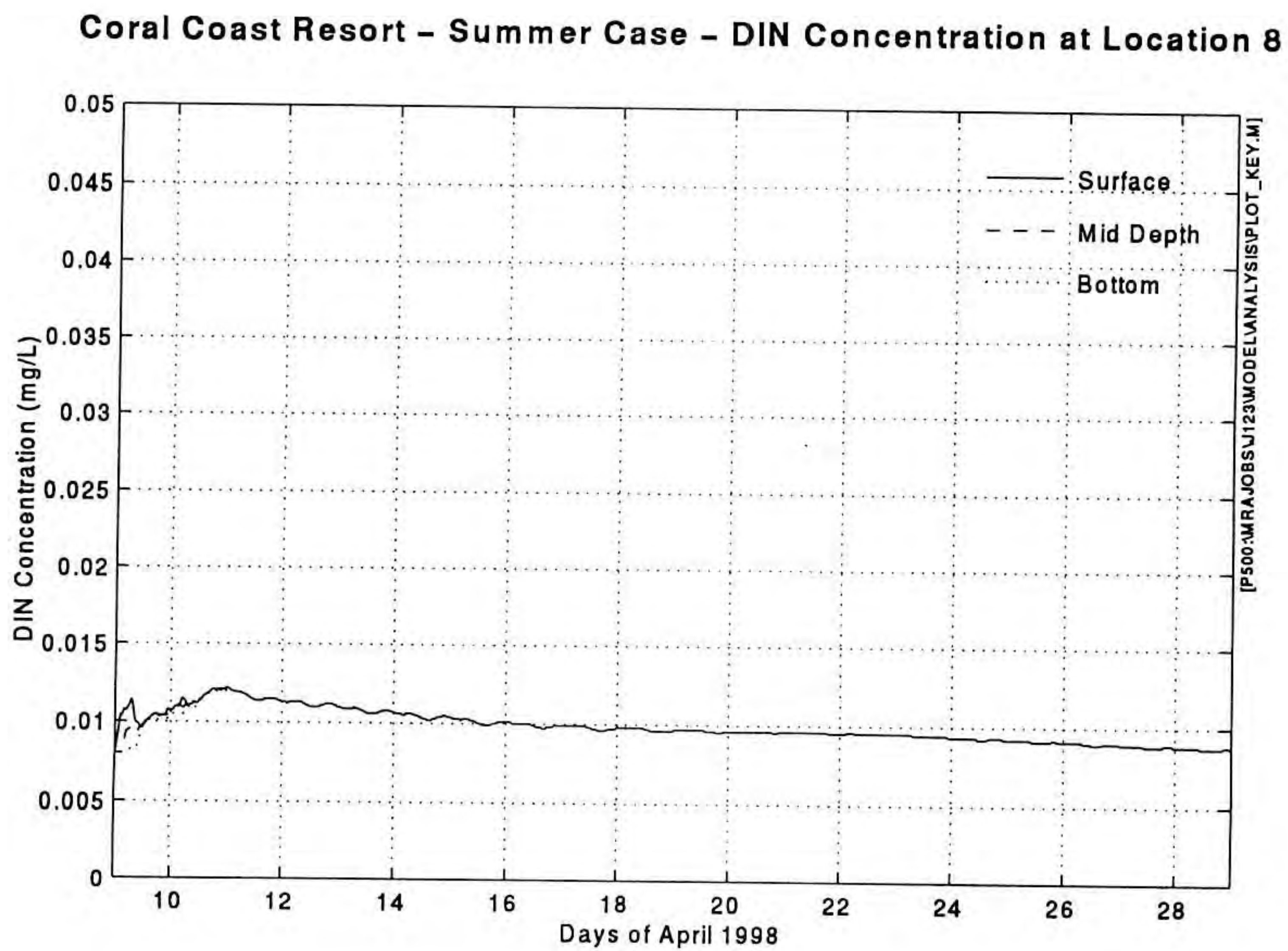




Coral Coast Resort - Summer Case - DIN Concentration at Location 6
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

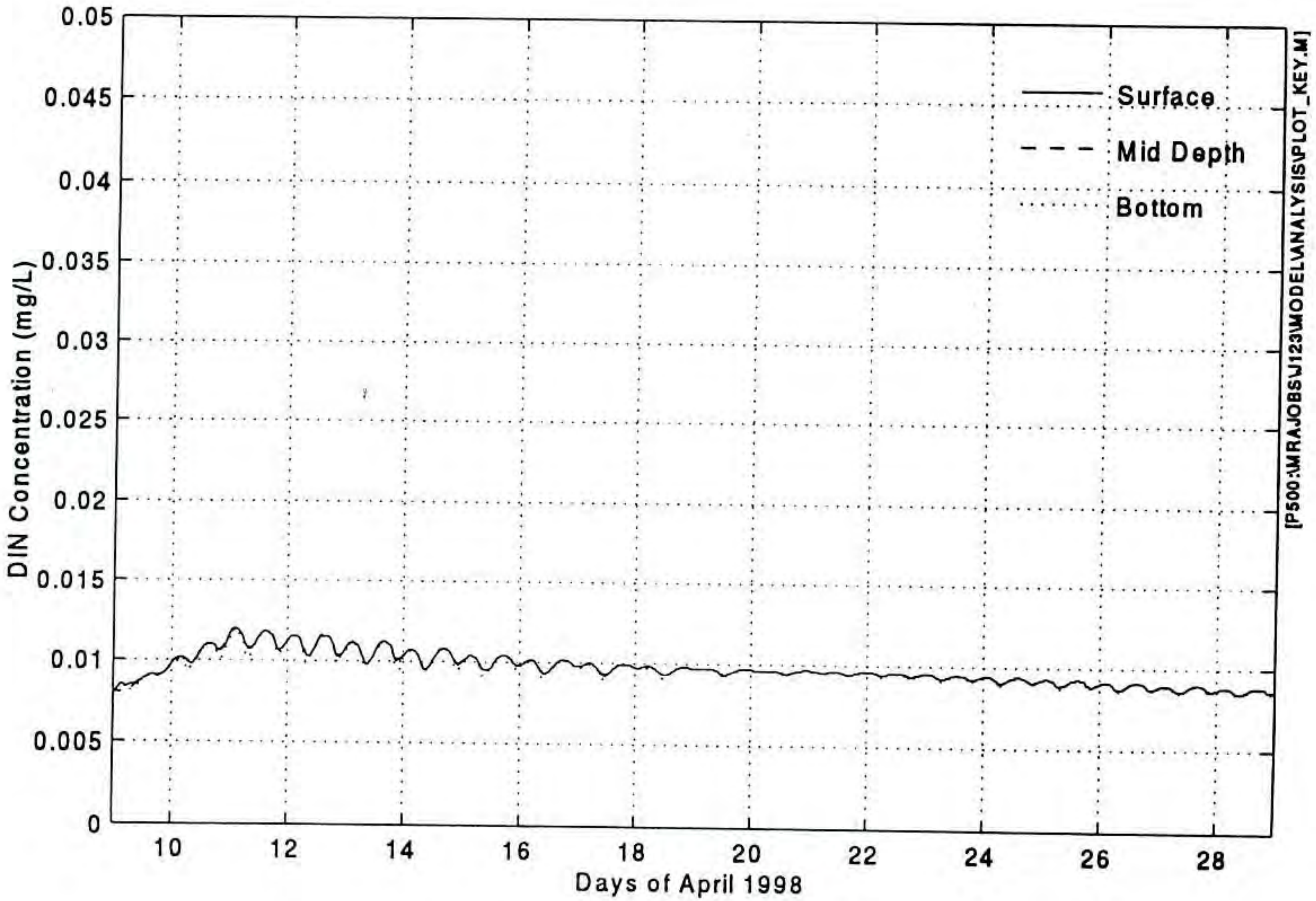

Coral Coast Resort - Summer Case - DIN Concentration at Location 7
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
DIN Concentration (mg/L)
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]


Coral Coast Resort - Summer Case - DIN Concentration at Location 3
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

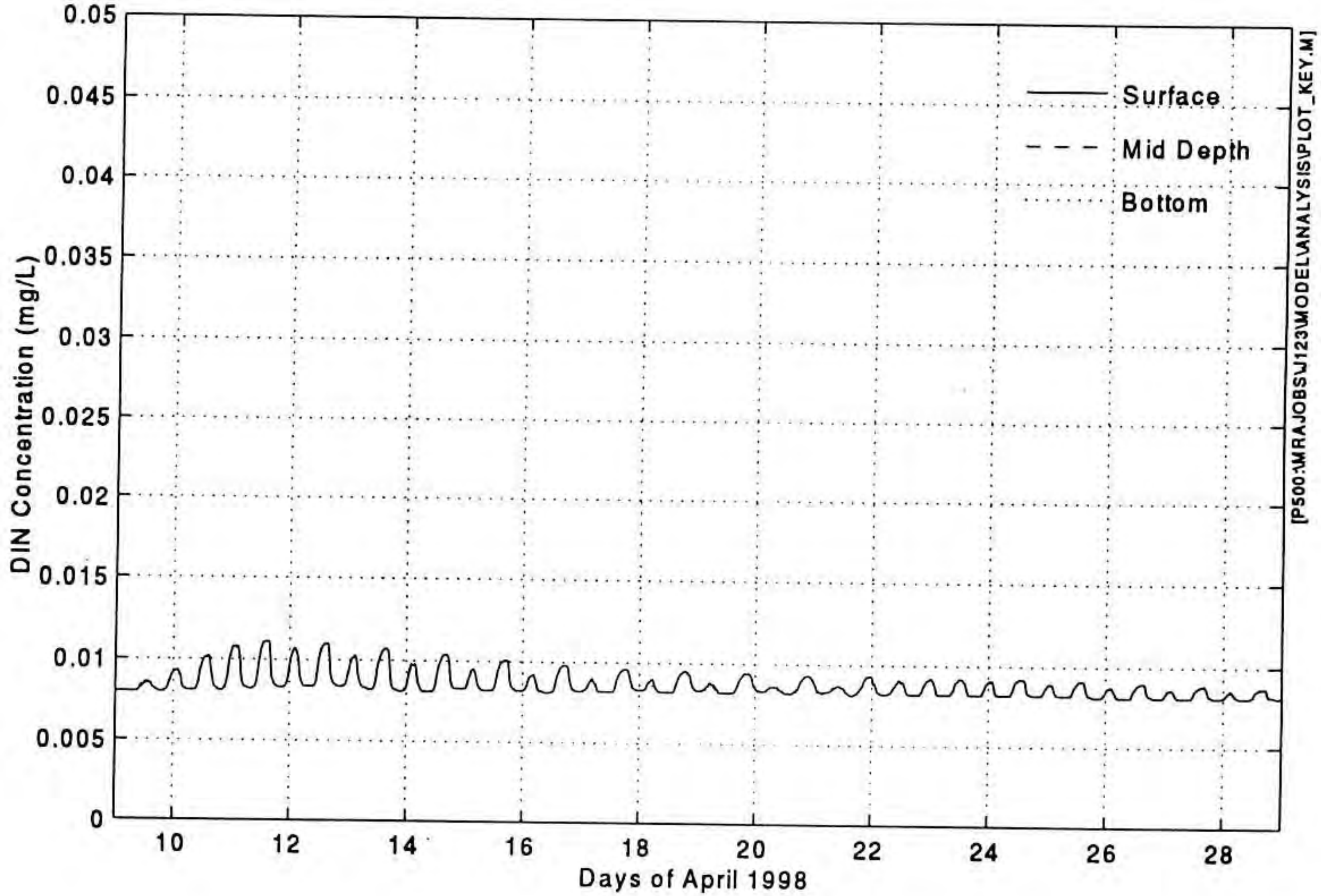


Coral Coast Resort - Summer Case - DIN Concentration at Location 8
DIN Concentration (mg/L)
Days of April 1998
Surface
Mid Depth
Bottom
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

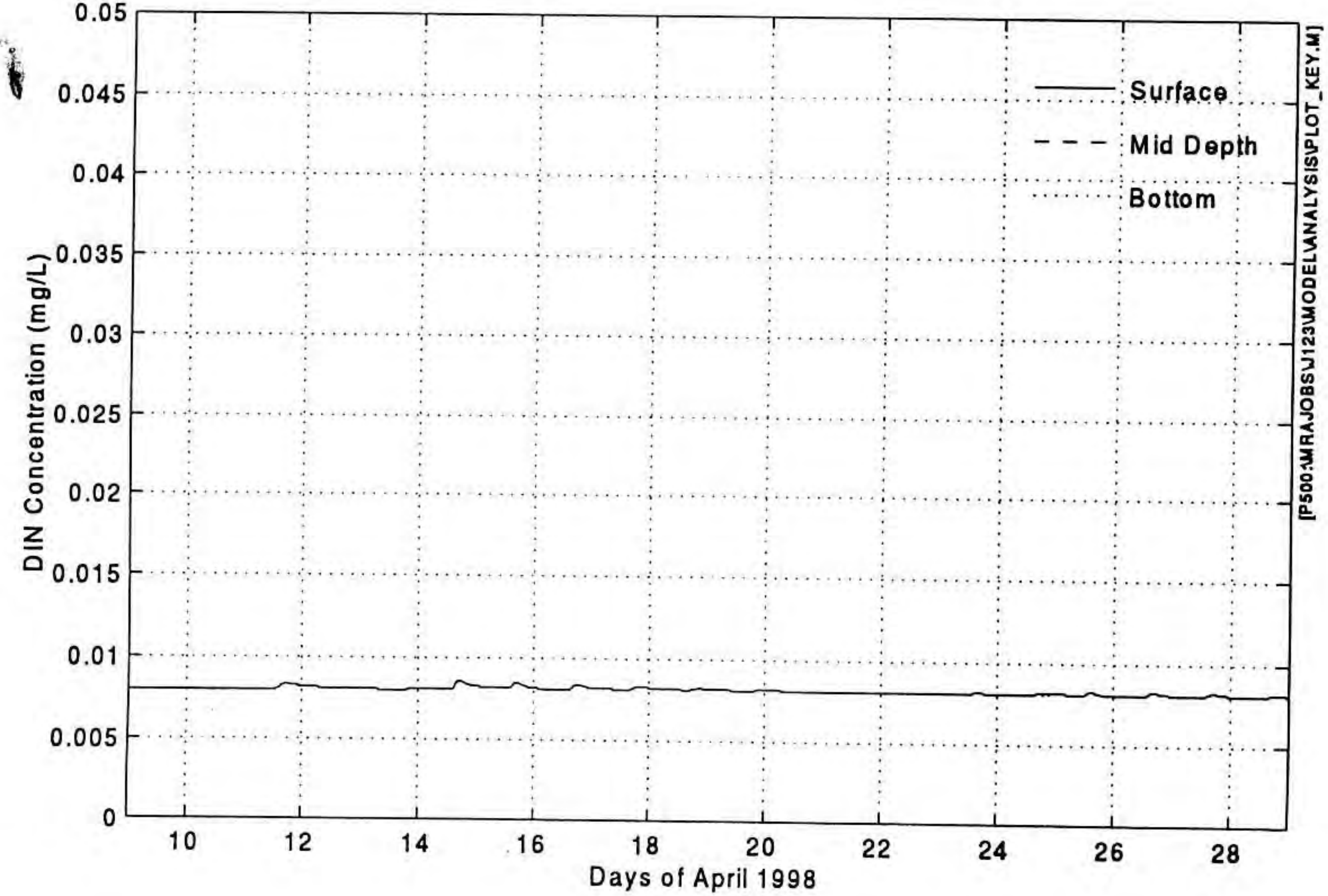
Coral Coast Resort - Summer Case - DIN Concentration at Location 9

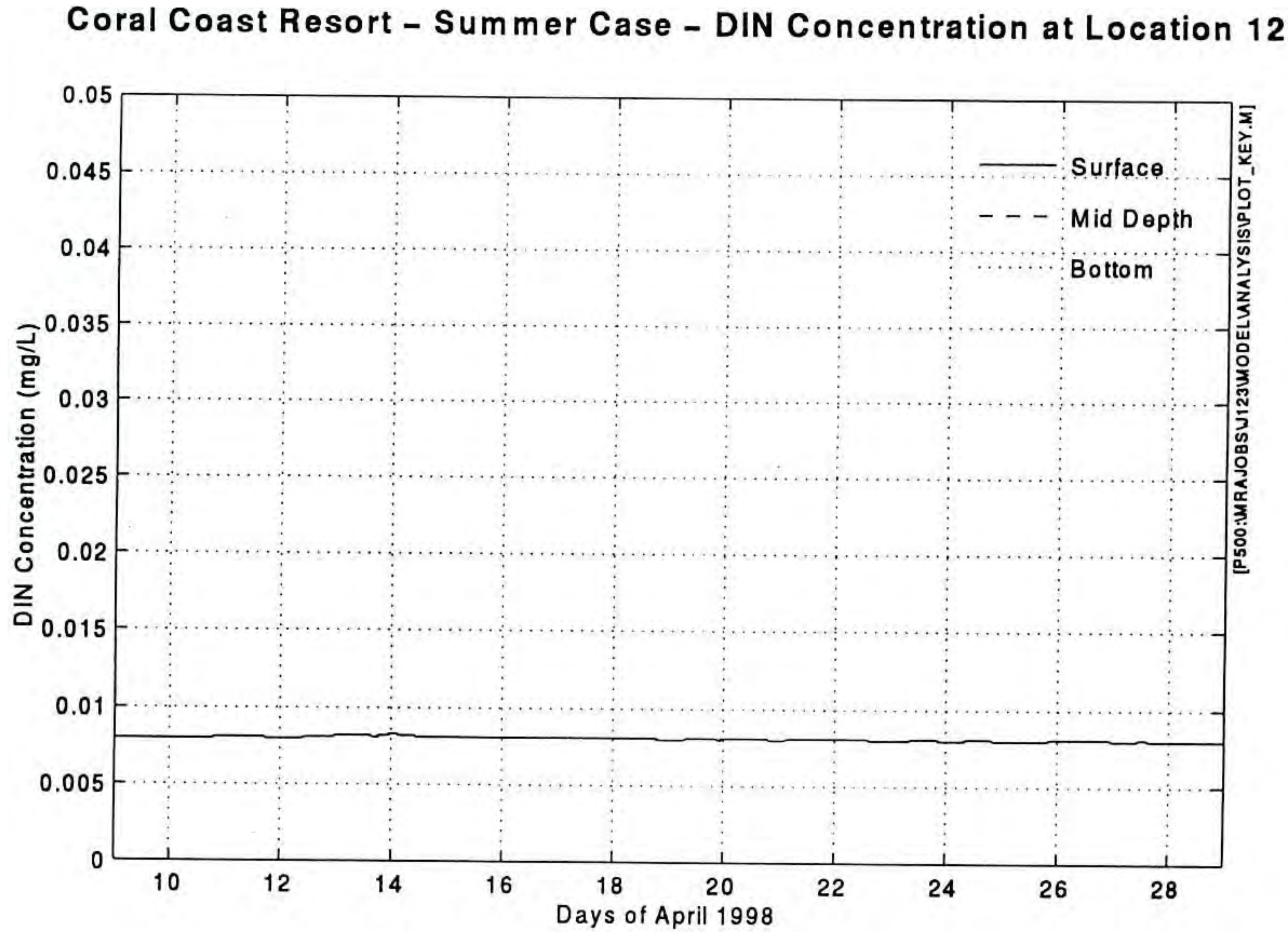


Coral Coast Resort - Summer Case - DIN Concentration at Location 10

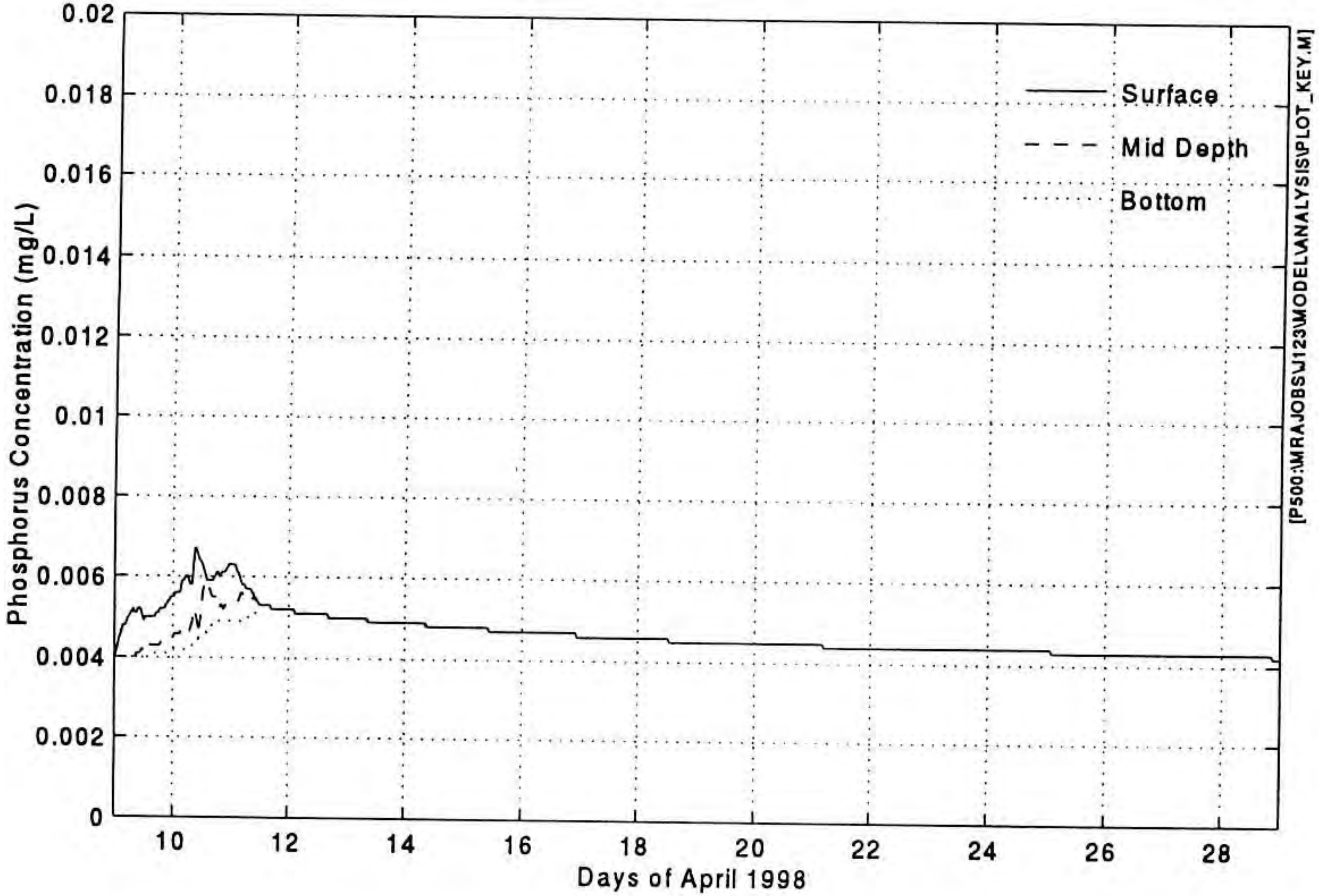


Coral Coast Resort - Summer Case - DIN Concentration at Location 11

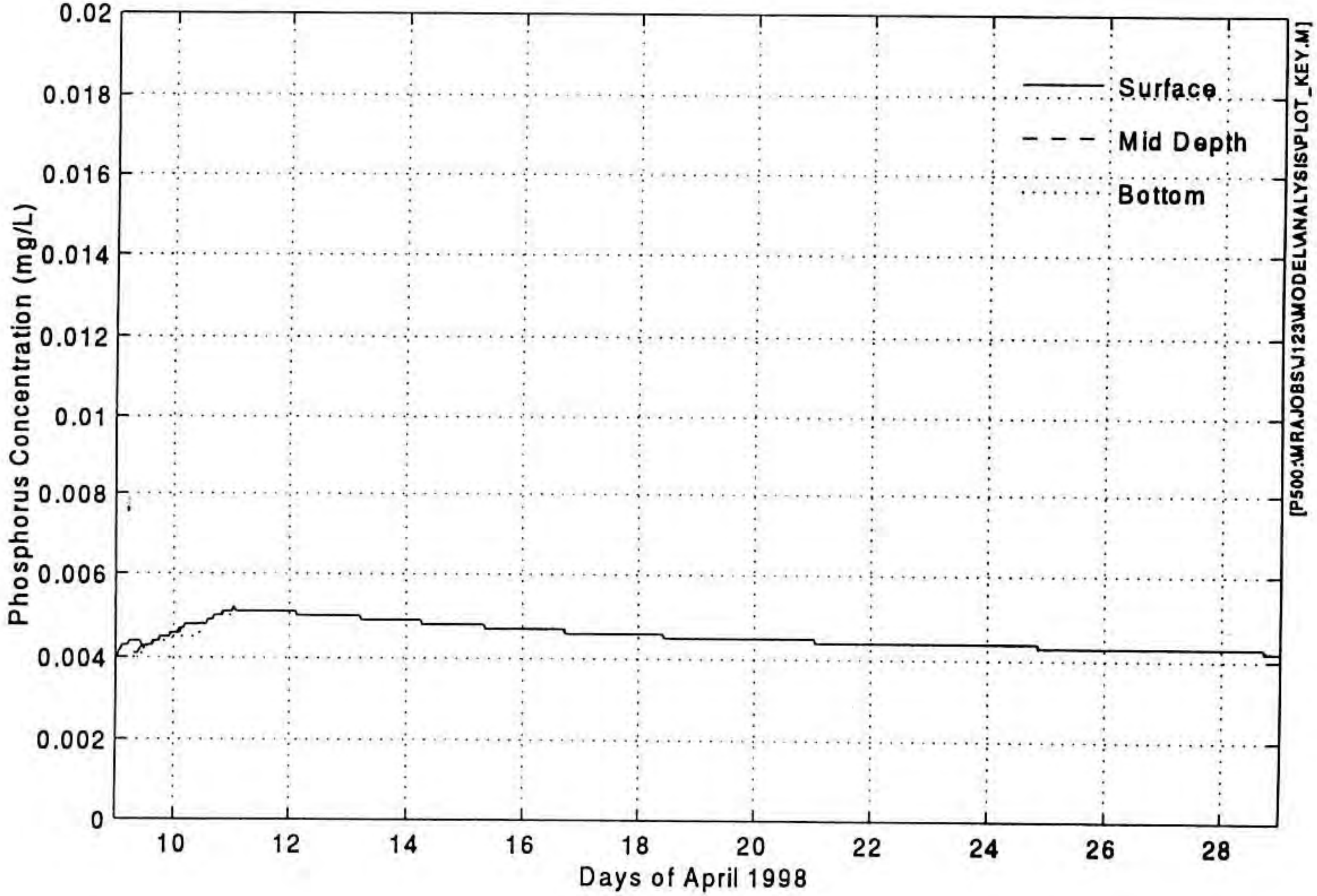


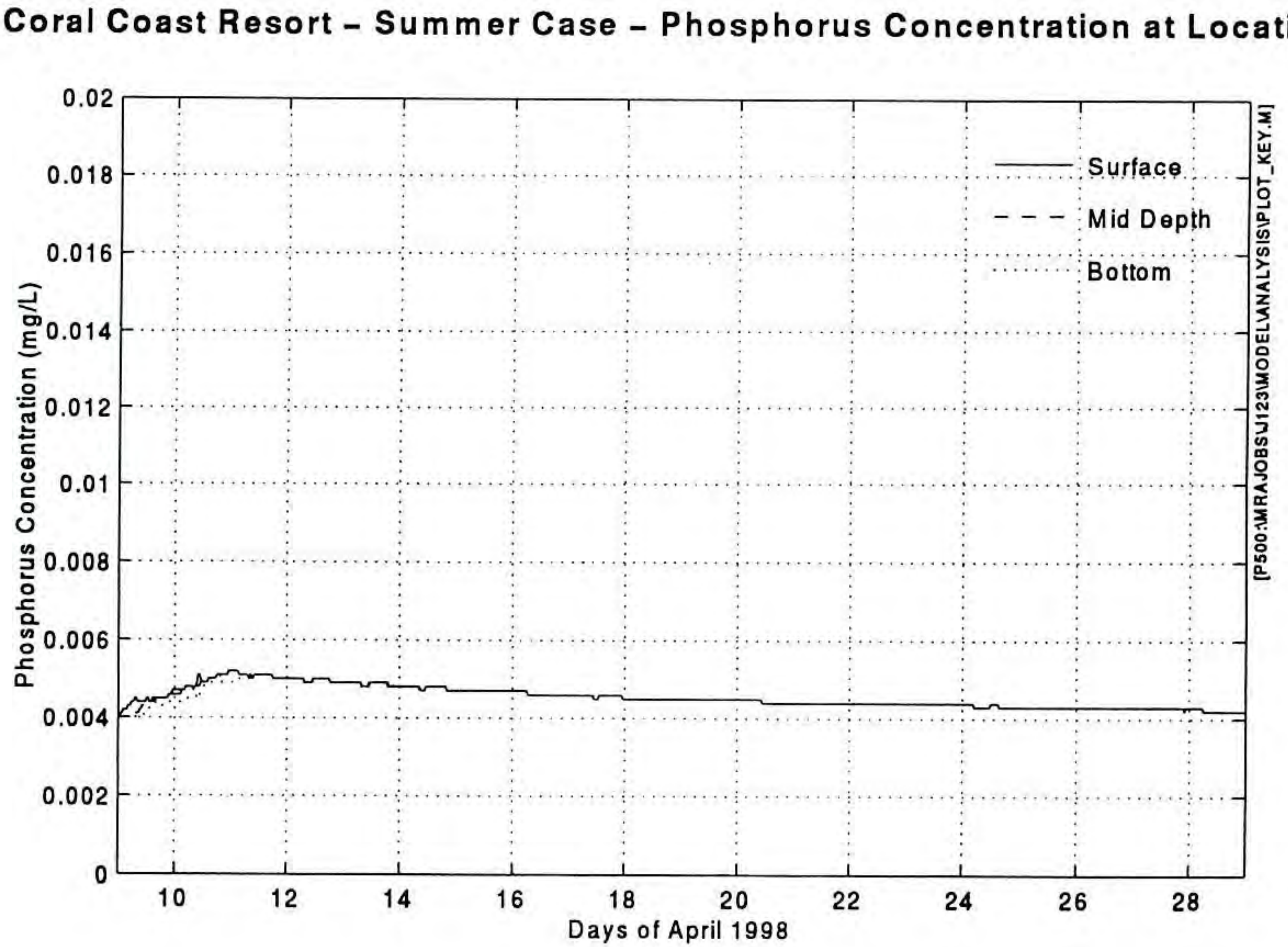

Coral Coast Resort - Summer Case - DIN Concentration at Location 12
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 1

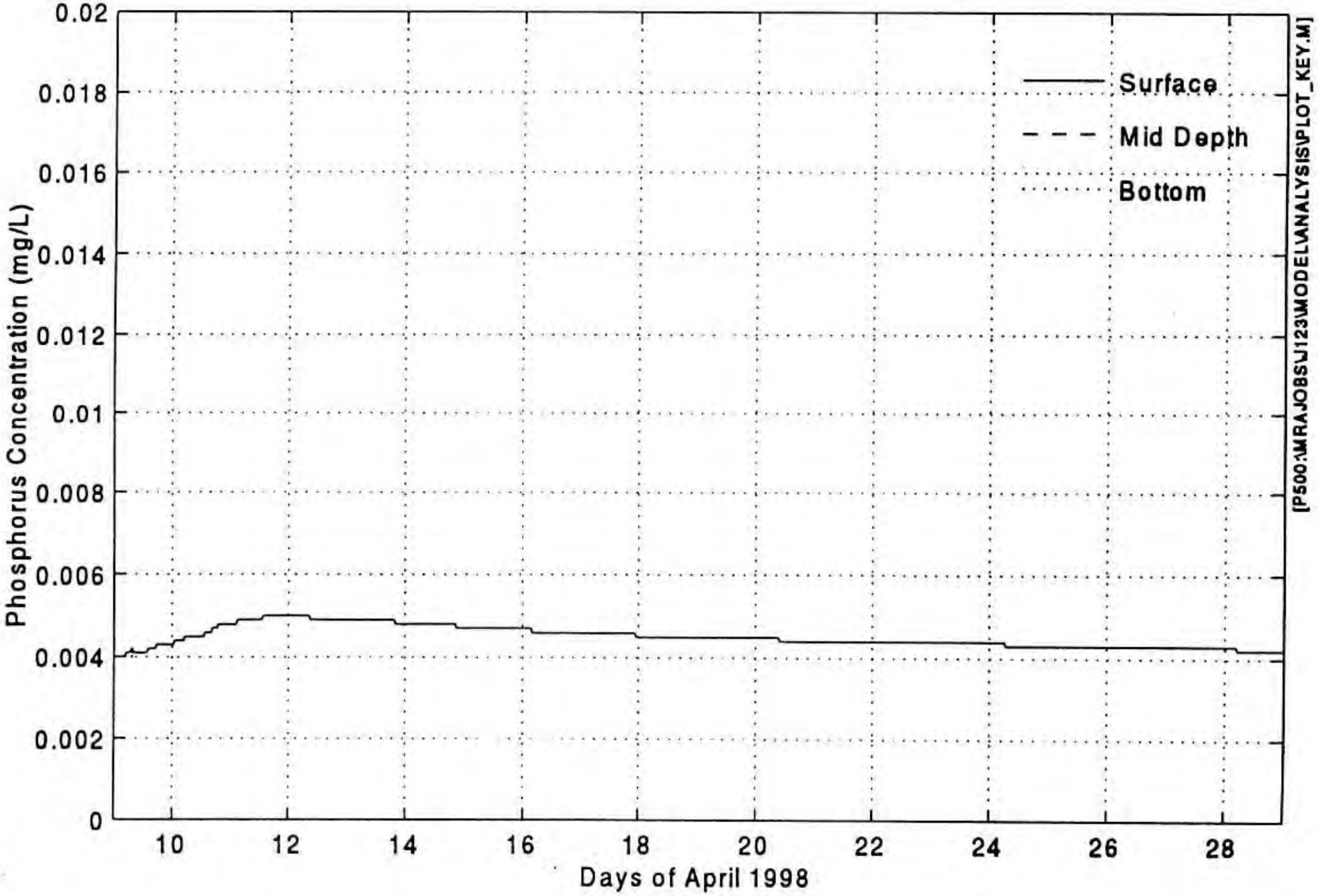


Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 2

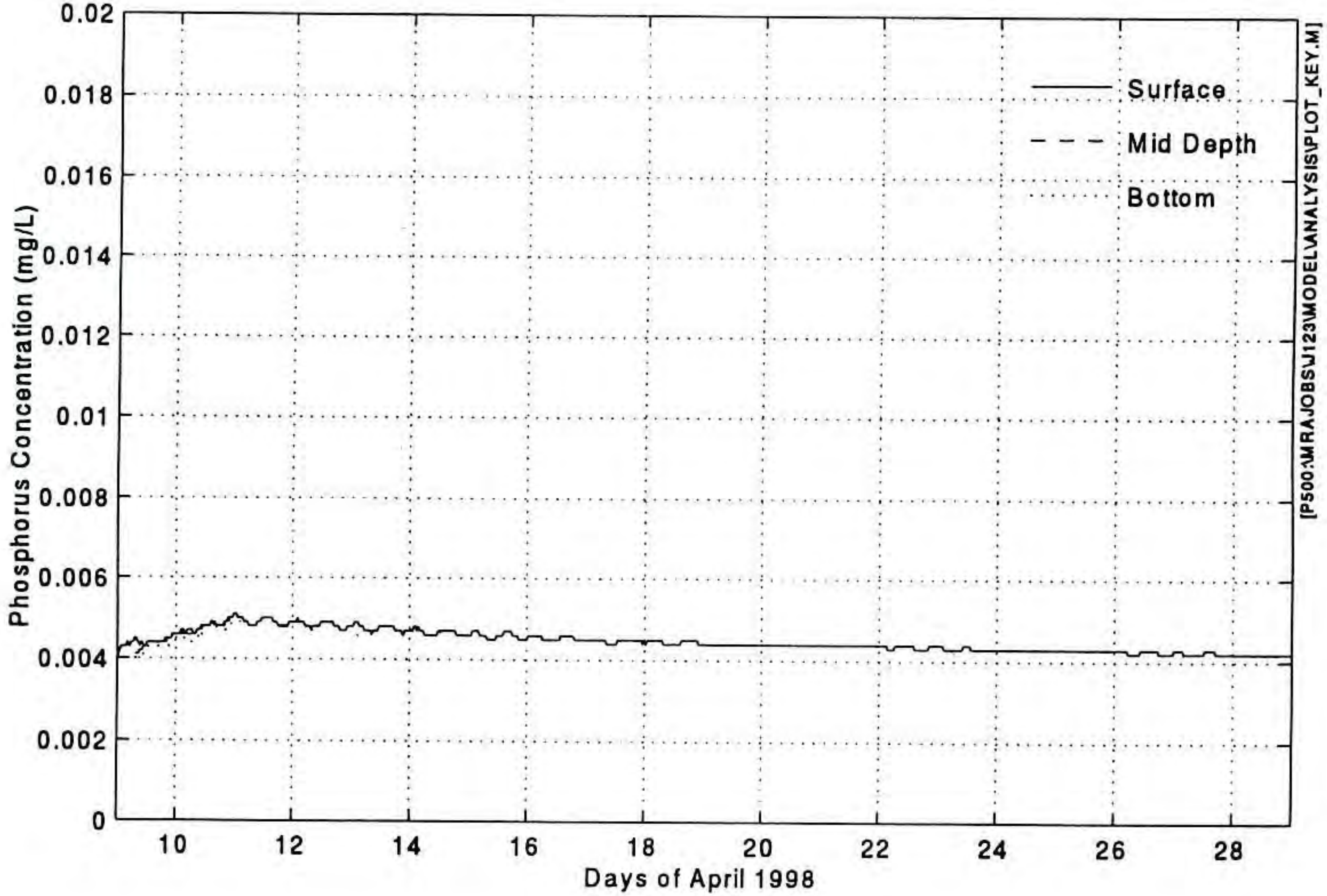



Coral Coast Resort - Summer Case - Phosphorus Concentration at Location 3
Phosphorus Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

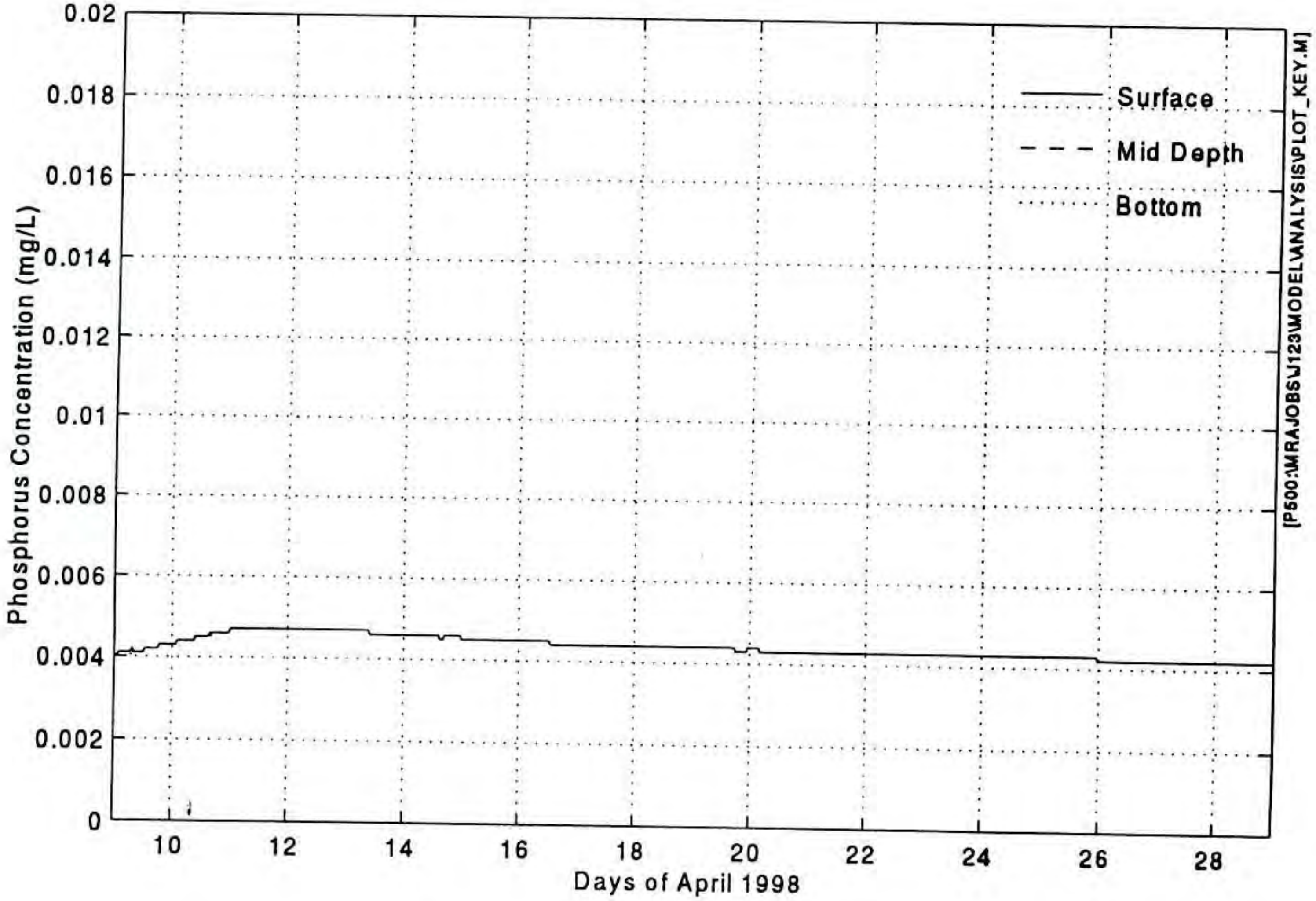
Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 4



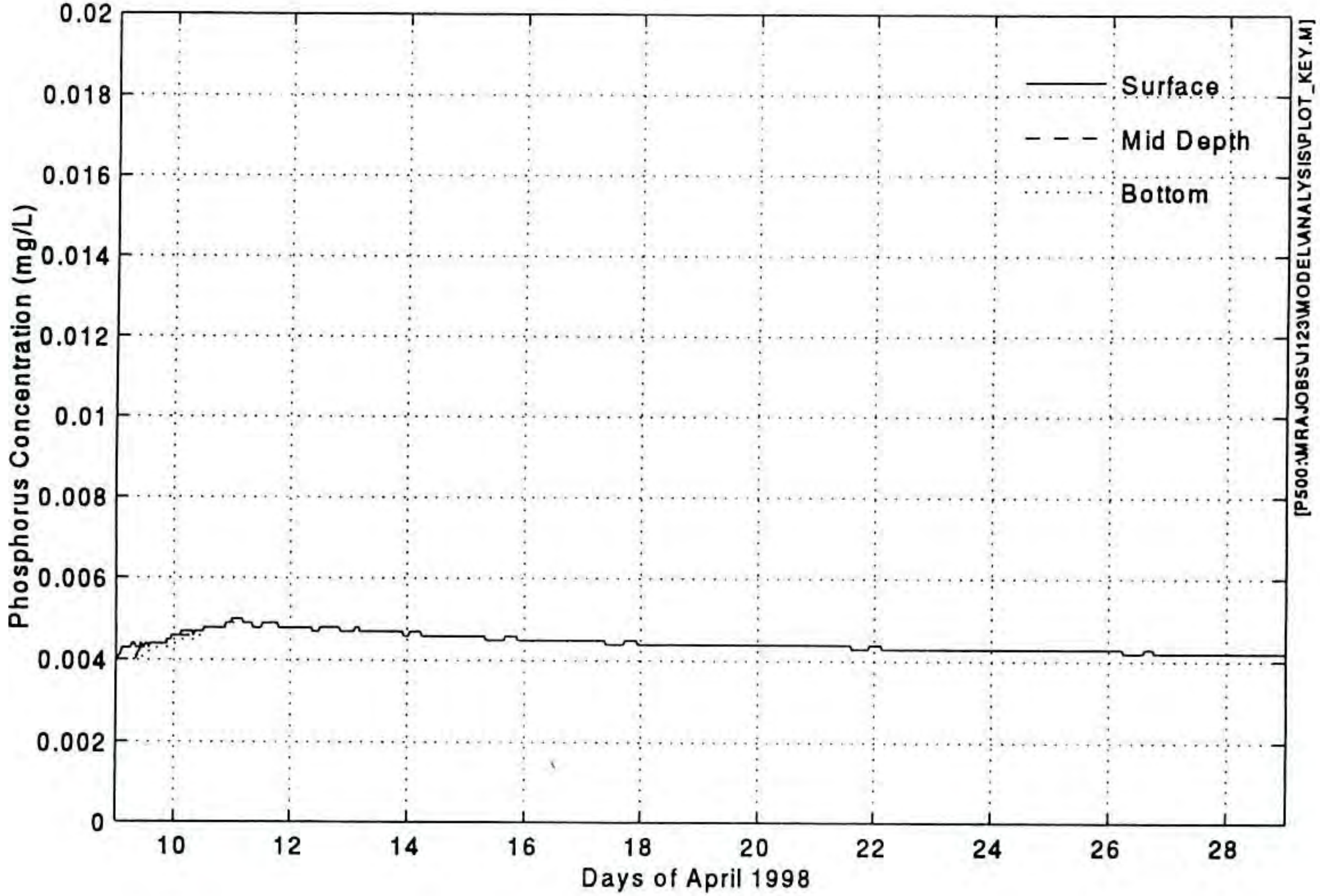
Coral Coast Resort - Summer Case - Phosphorus Concentration at Location 5



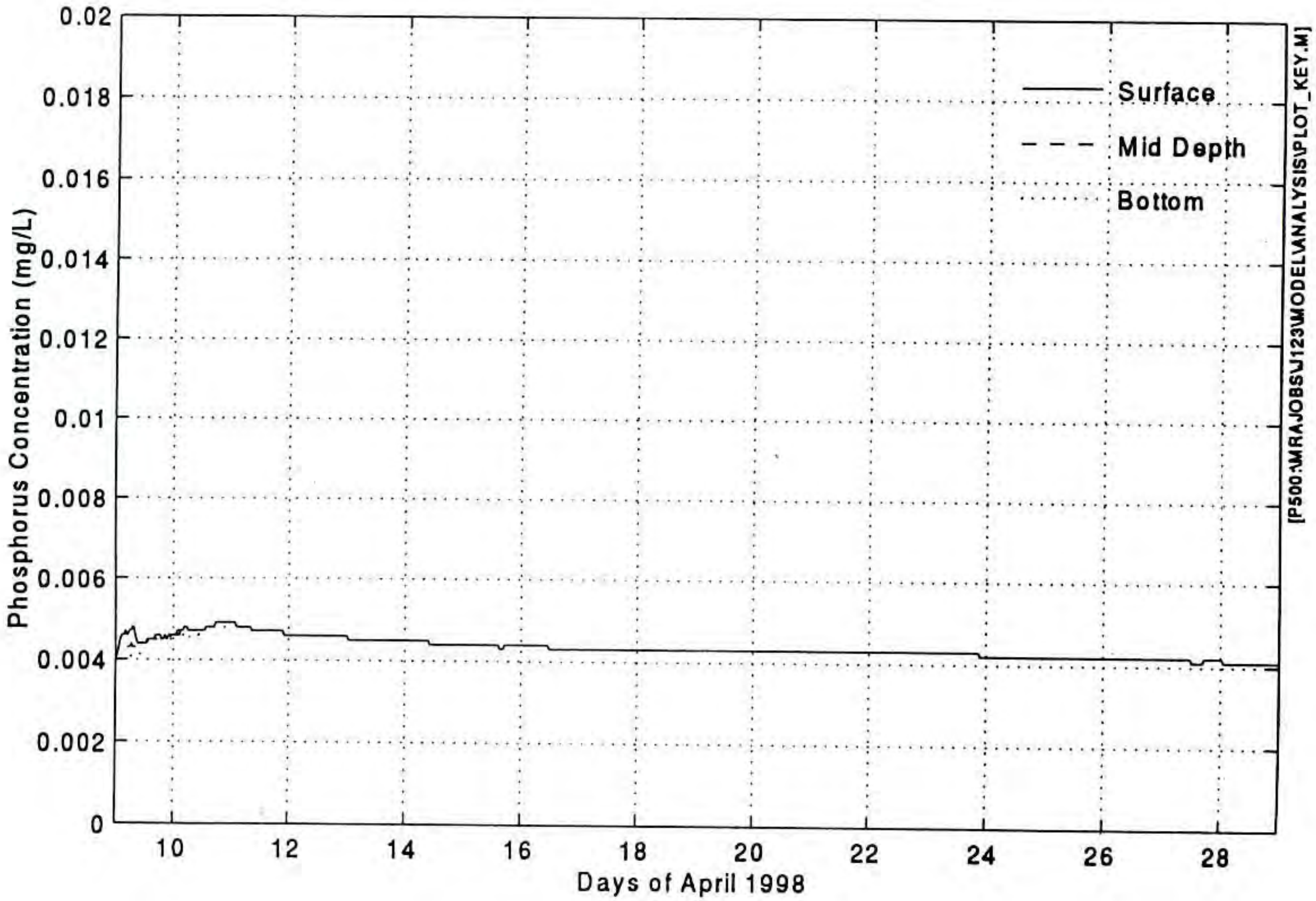
Coral Coast Resort - Summer Case - Phosphorus Concentration at Location 6

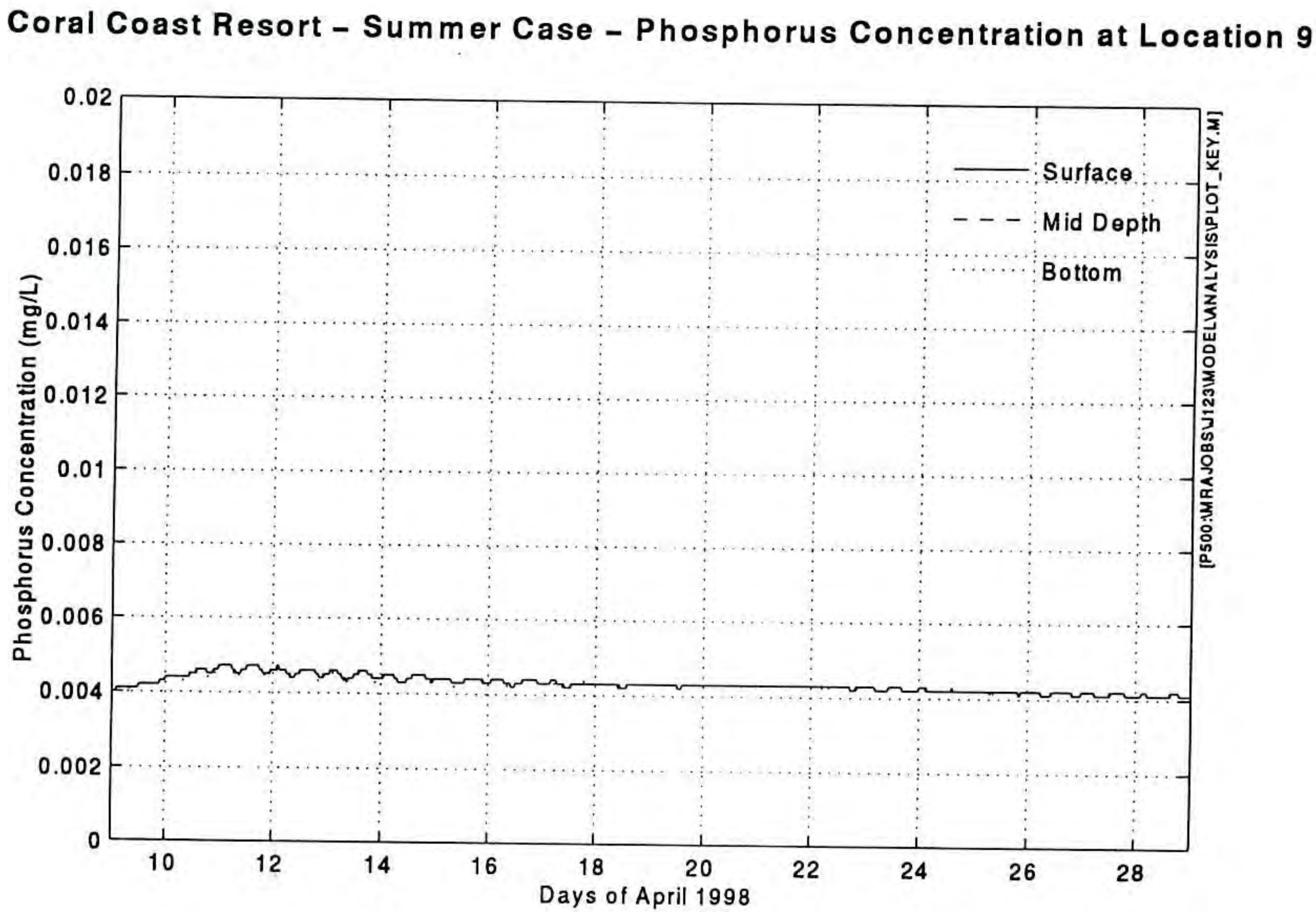


Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 7

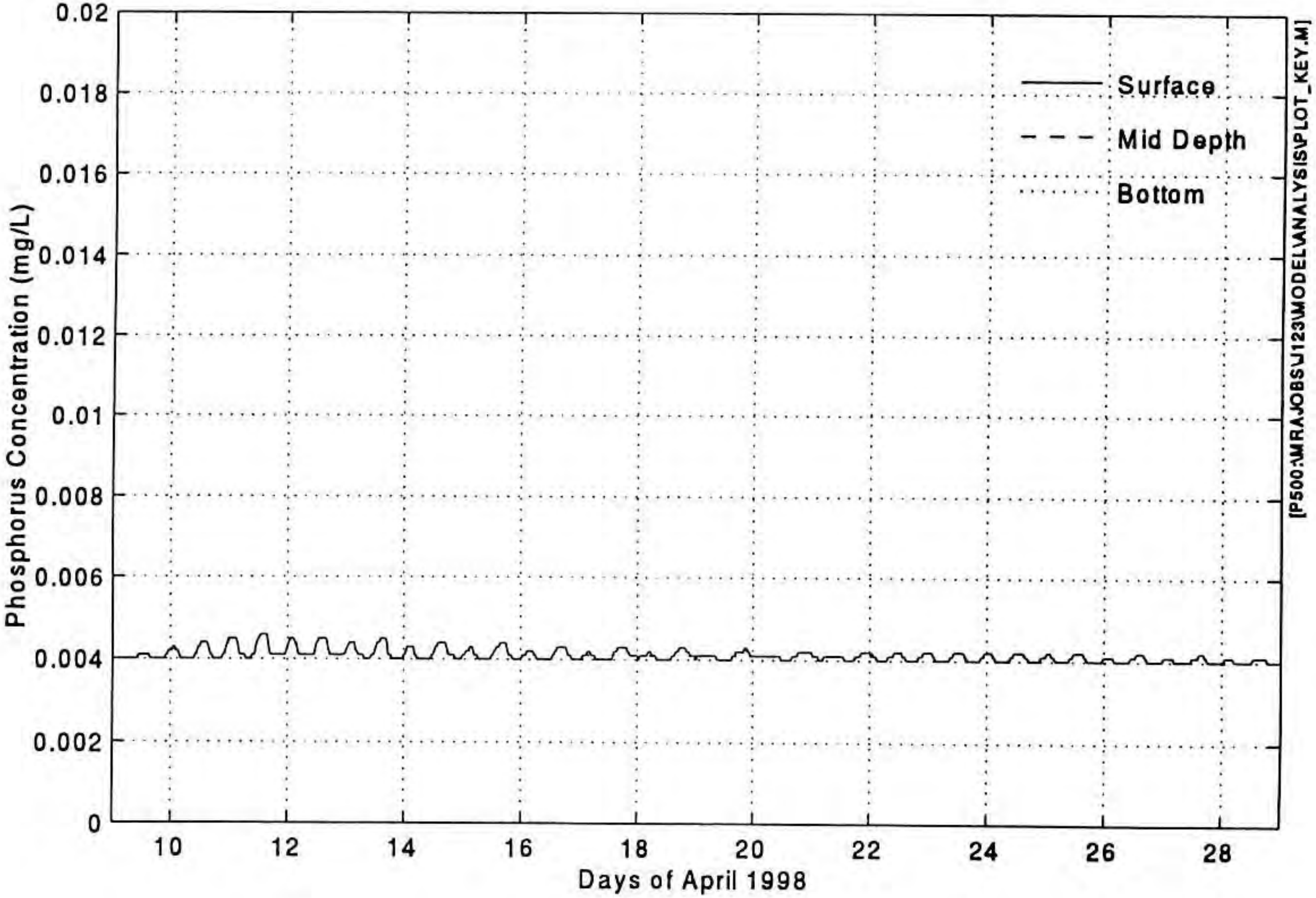


Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 8

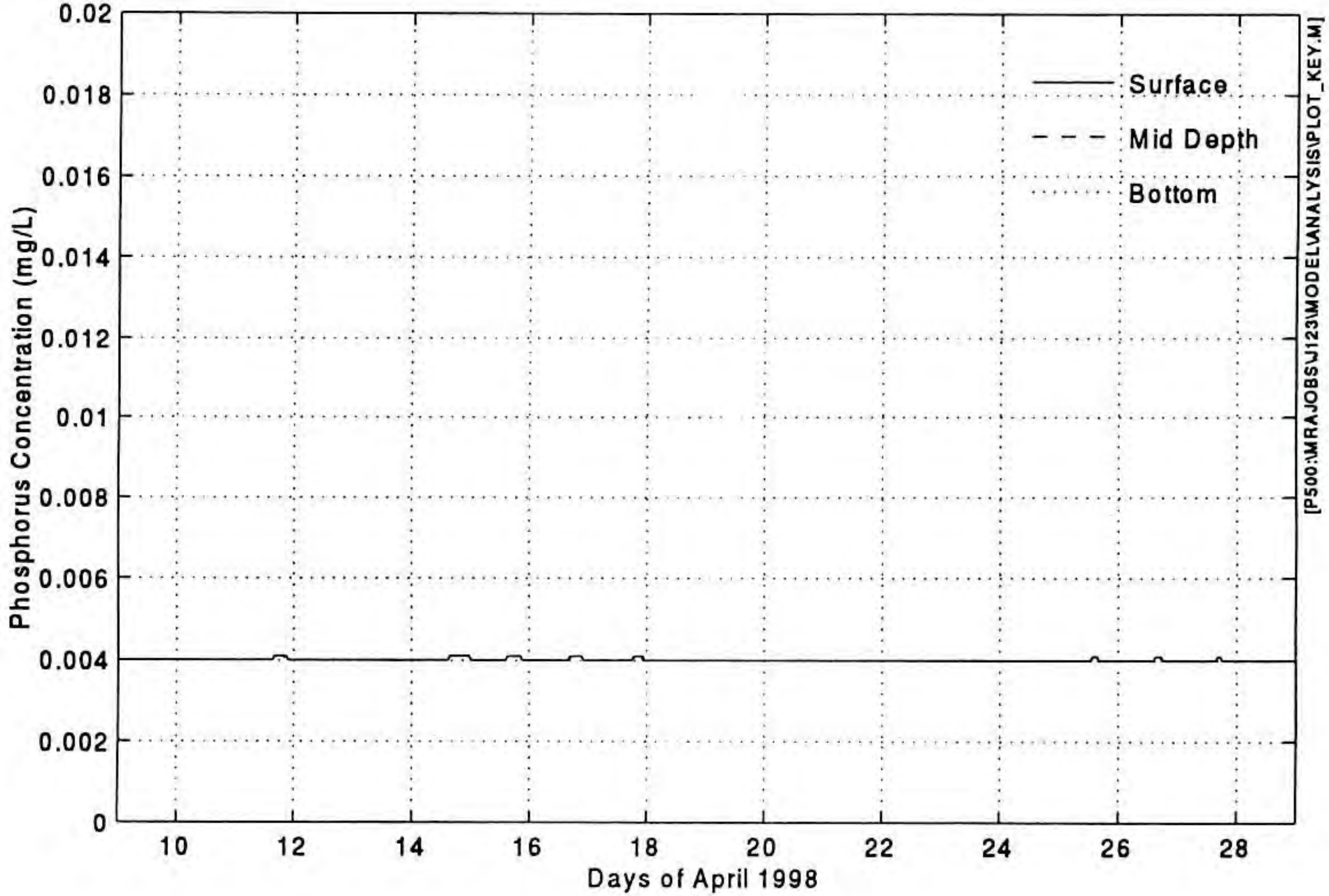



Coral Coast Resort - Summer Case - Phosphorus Concentration at Location 9
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Phosphorus Concentration (mg/L)
10
12
14
16
18
20
22
24
26
28
Days of April 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

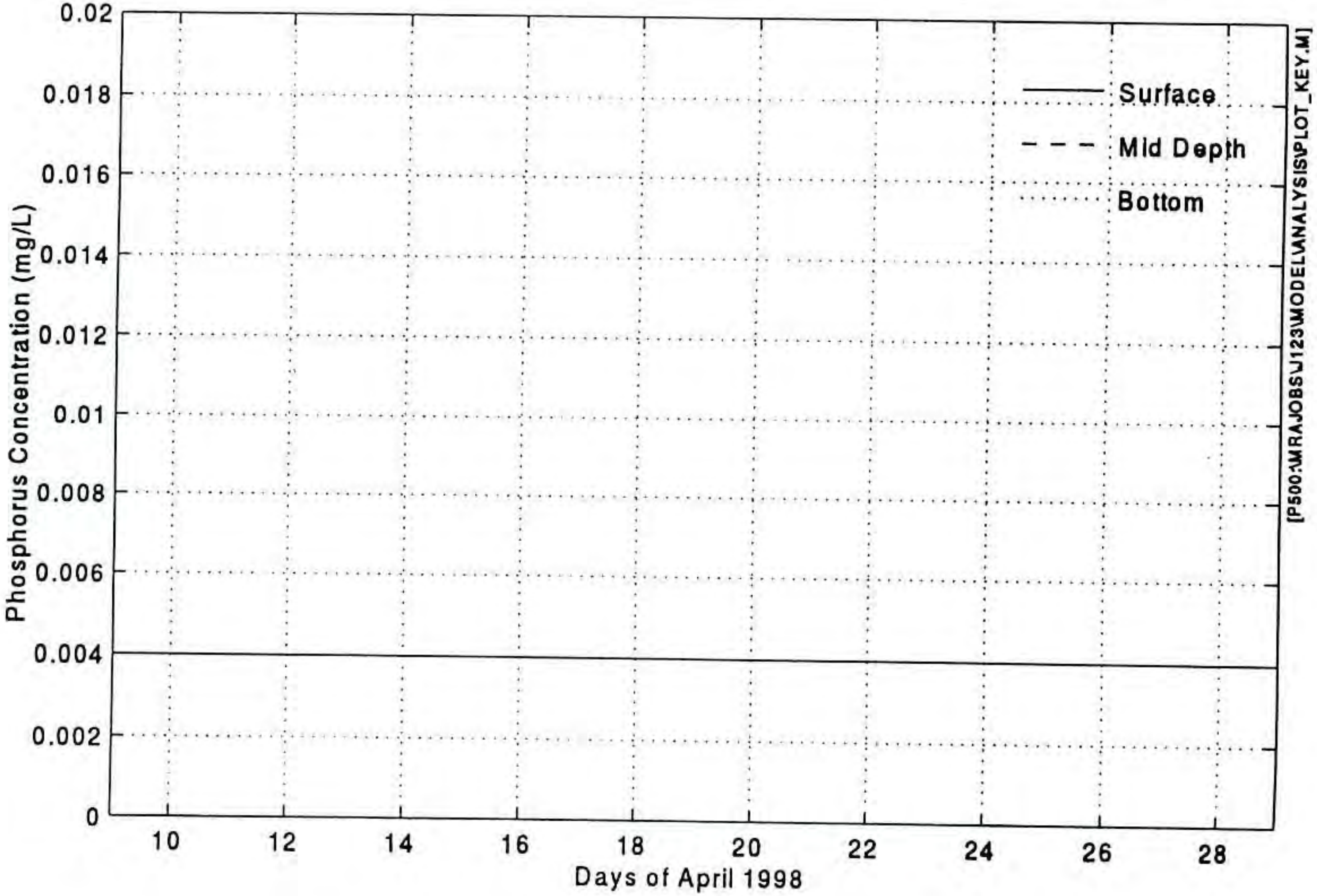
Coral Coast Resort - Summer Case - Phosphorus Concentration at Location 10



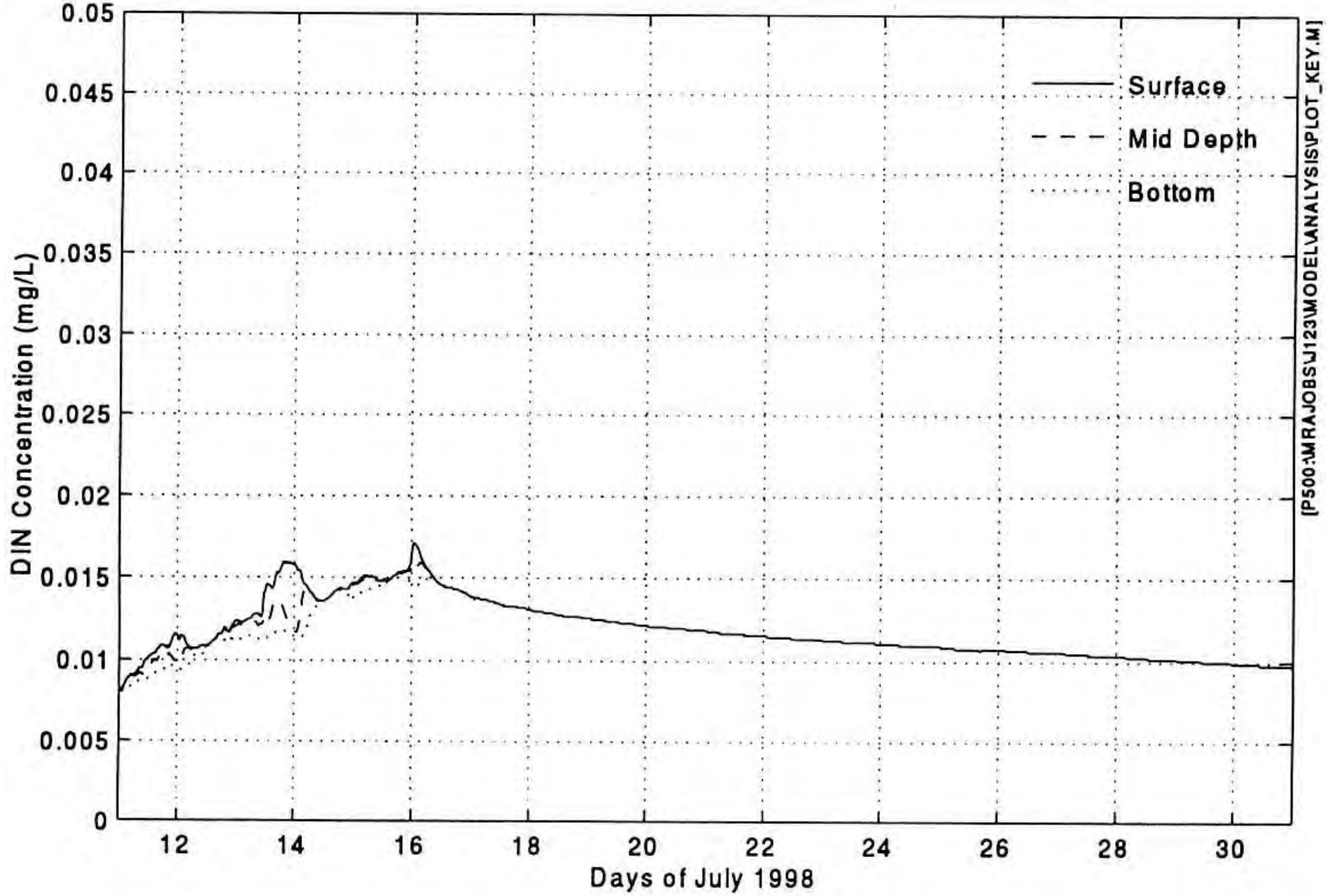
Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 11



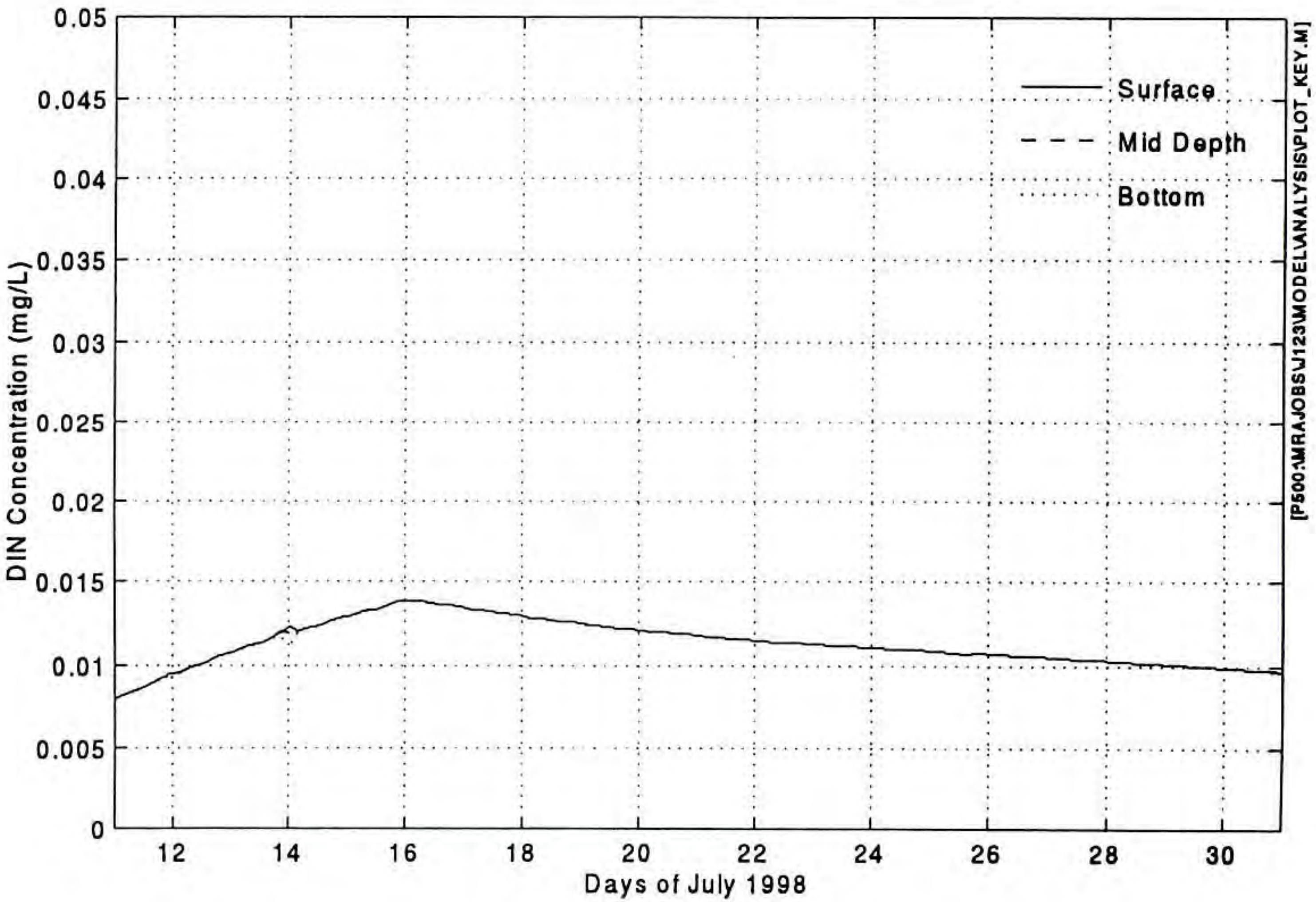
Coral Coast Resort – Summer Case – Phosphorus Concentration at Location 12

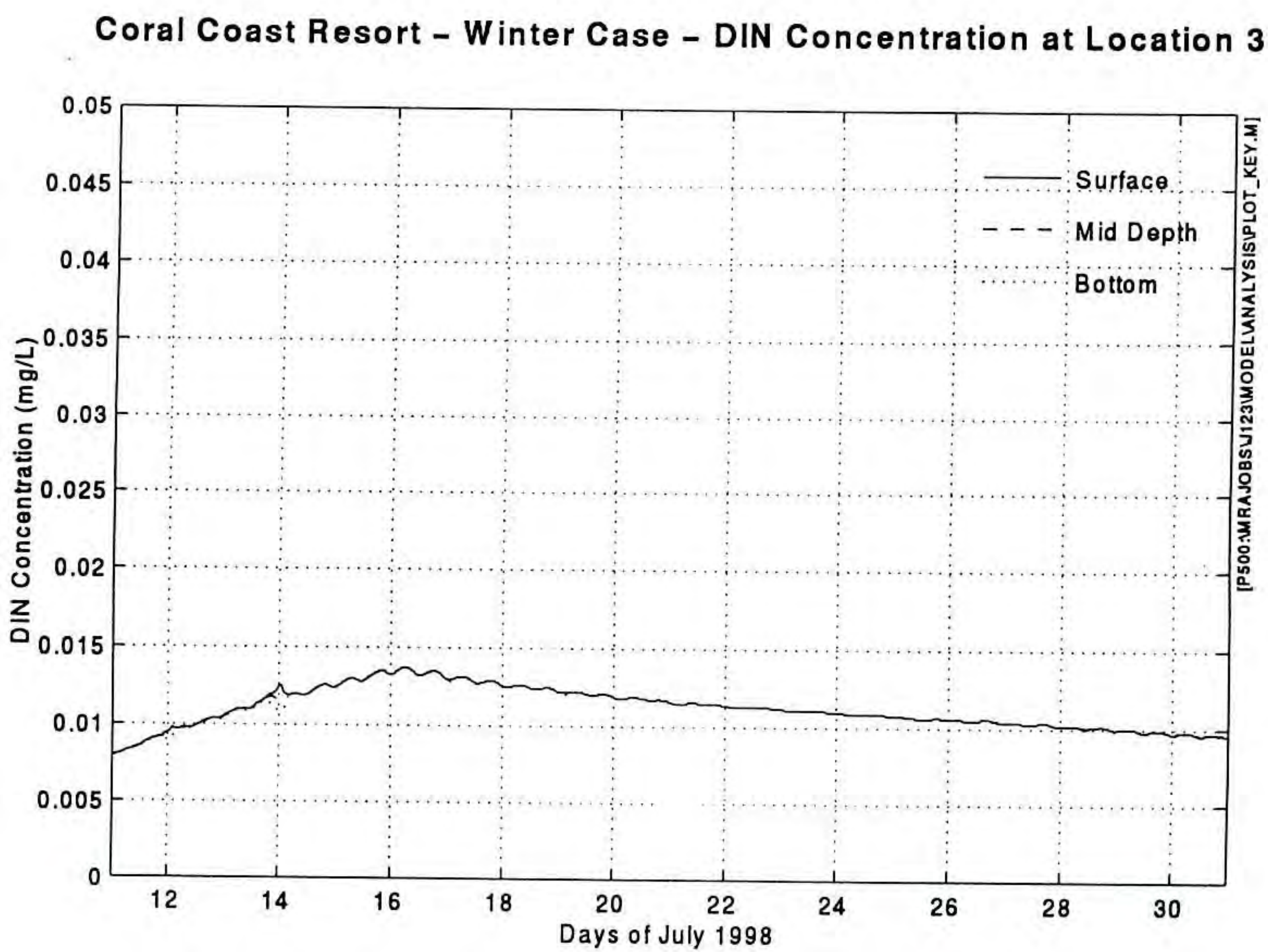


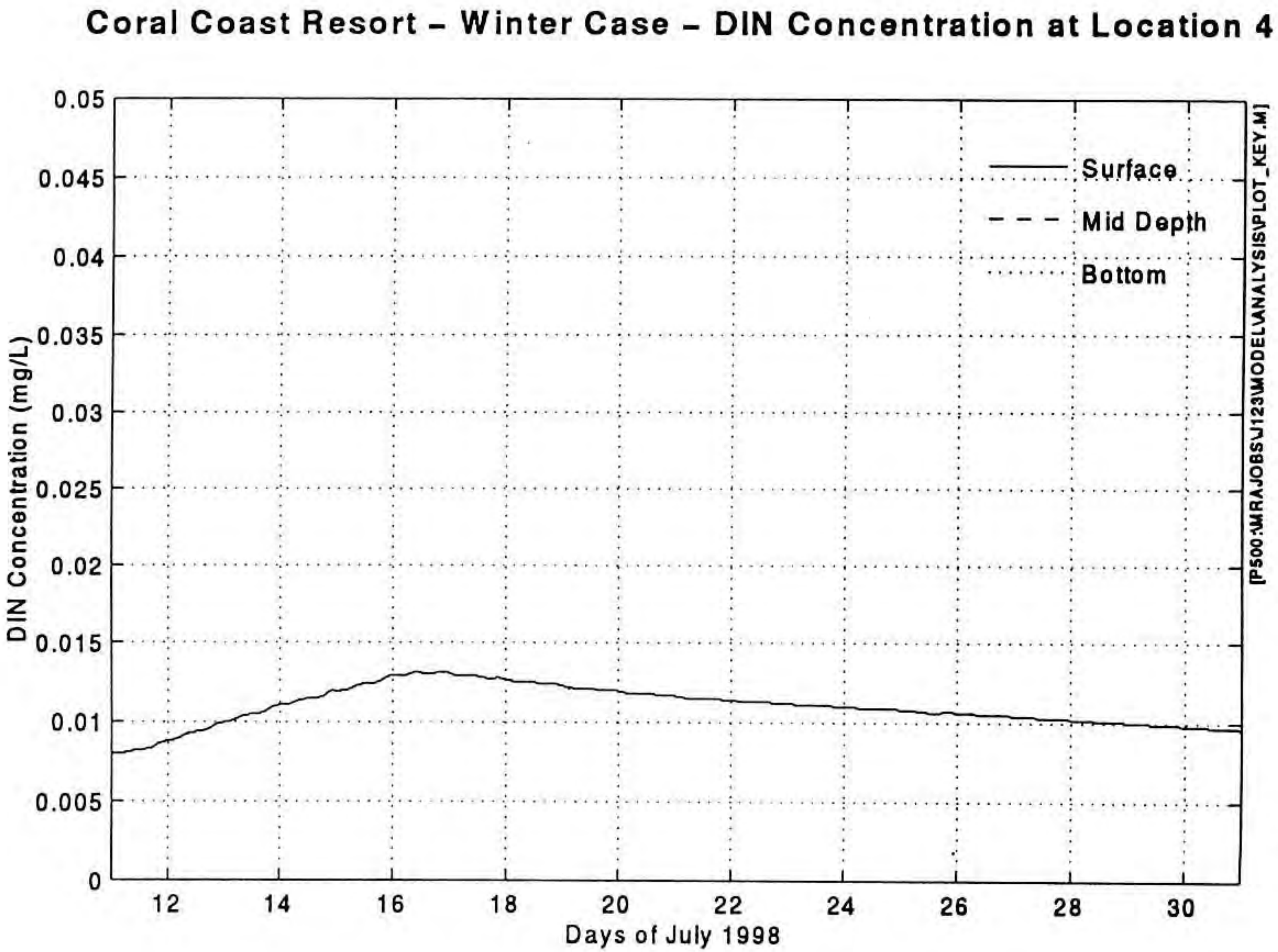
Coral Coast Resort - Winter Case - DIN Concentration at Location 1



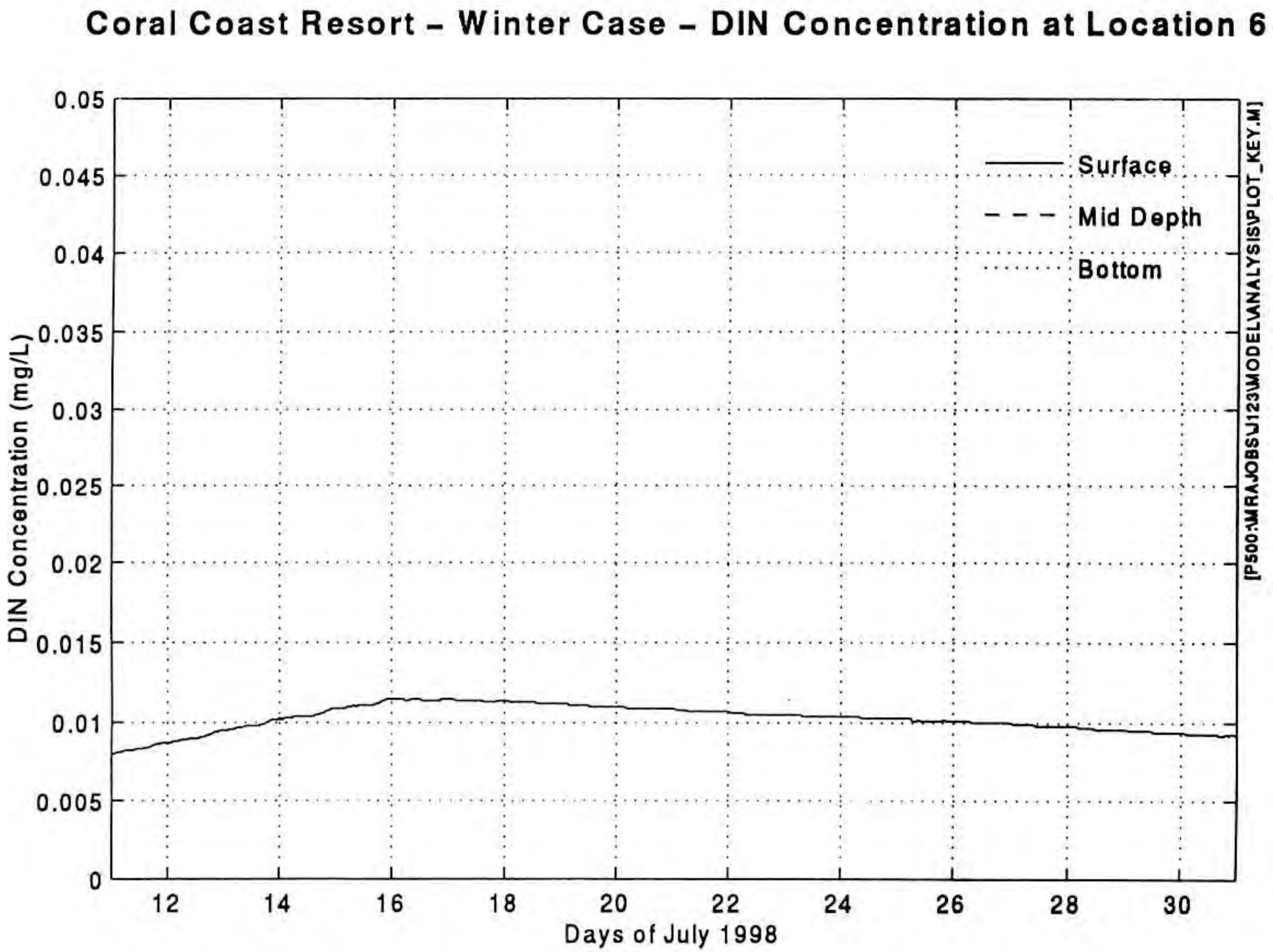
Coral Coast Resort - Winter Case - DIN Concentration at Location 2

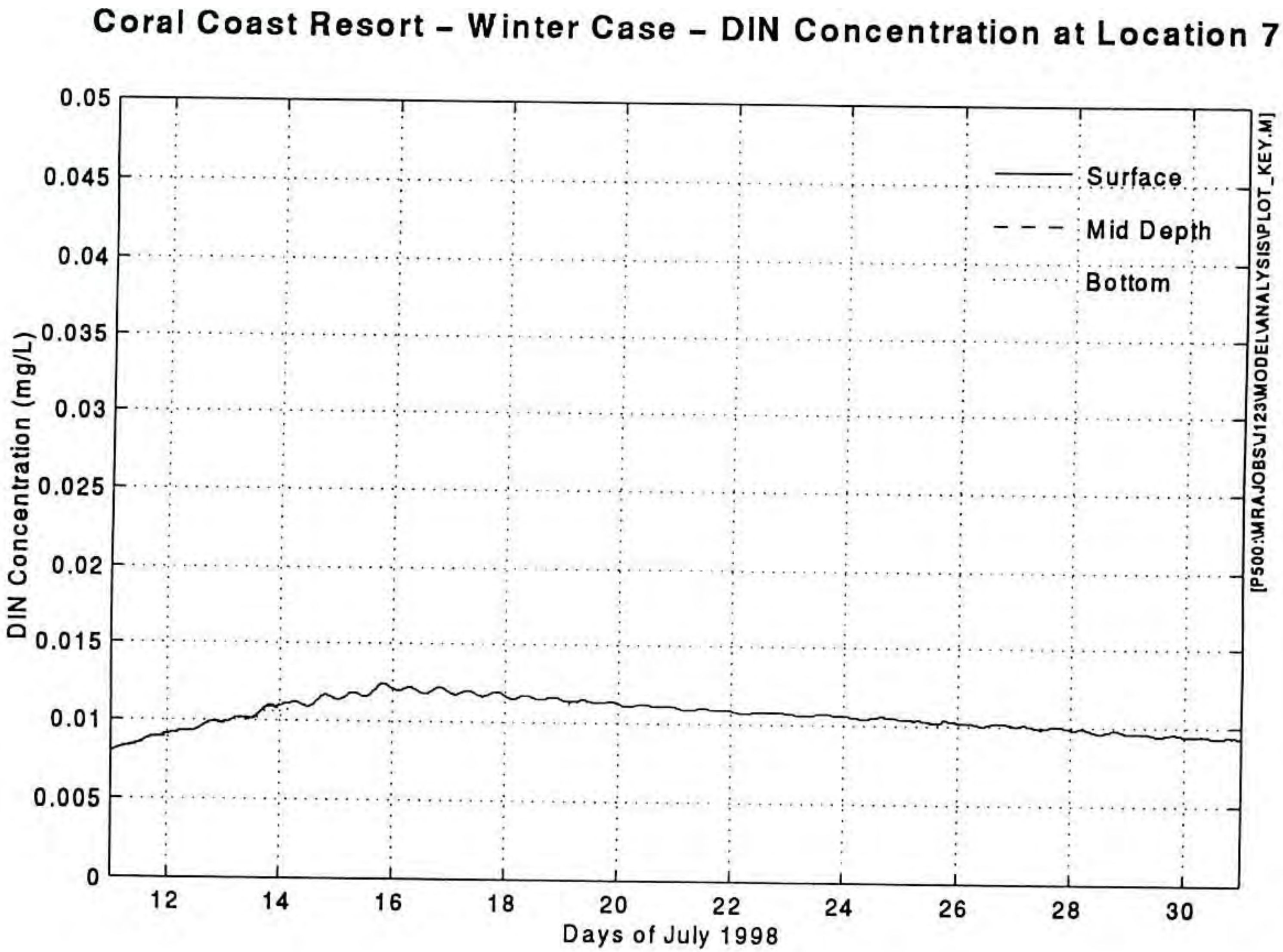



Coral Coast Resort – Winter Case – DIN Concentration at Location 3
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

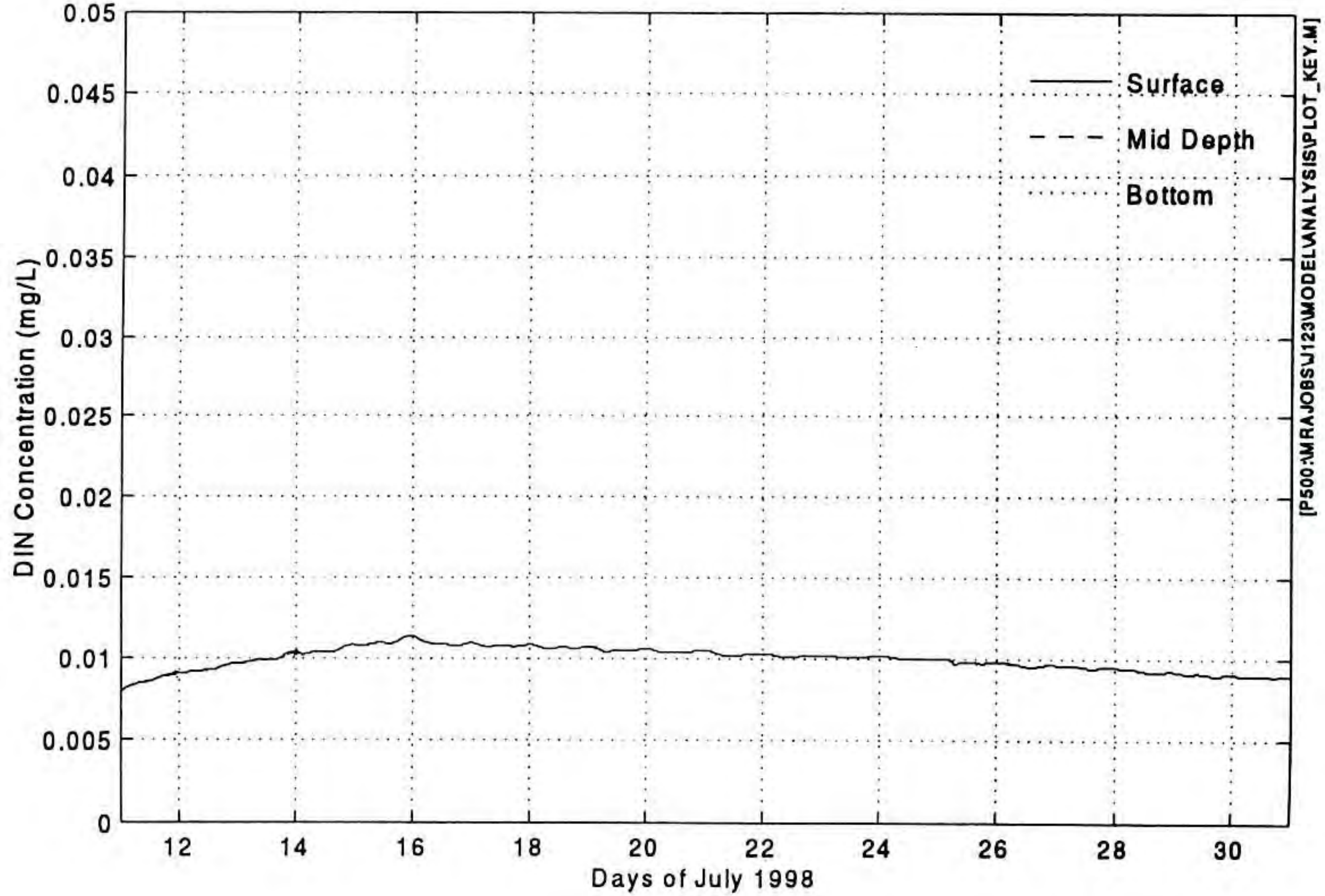


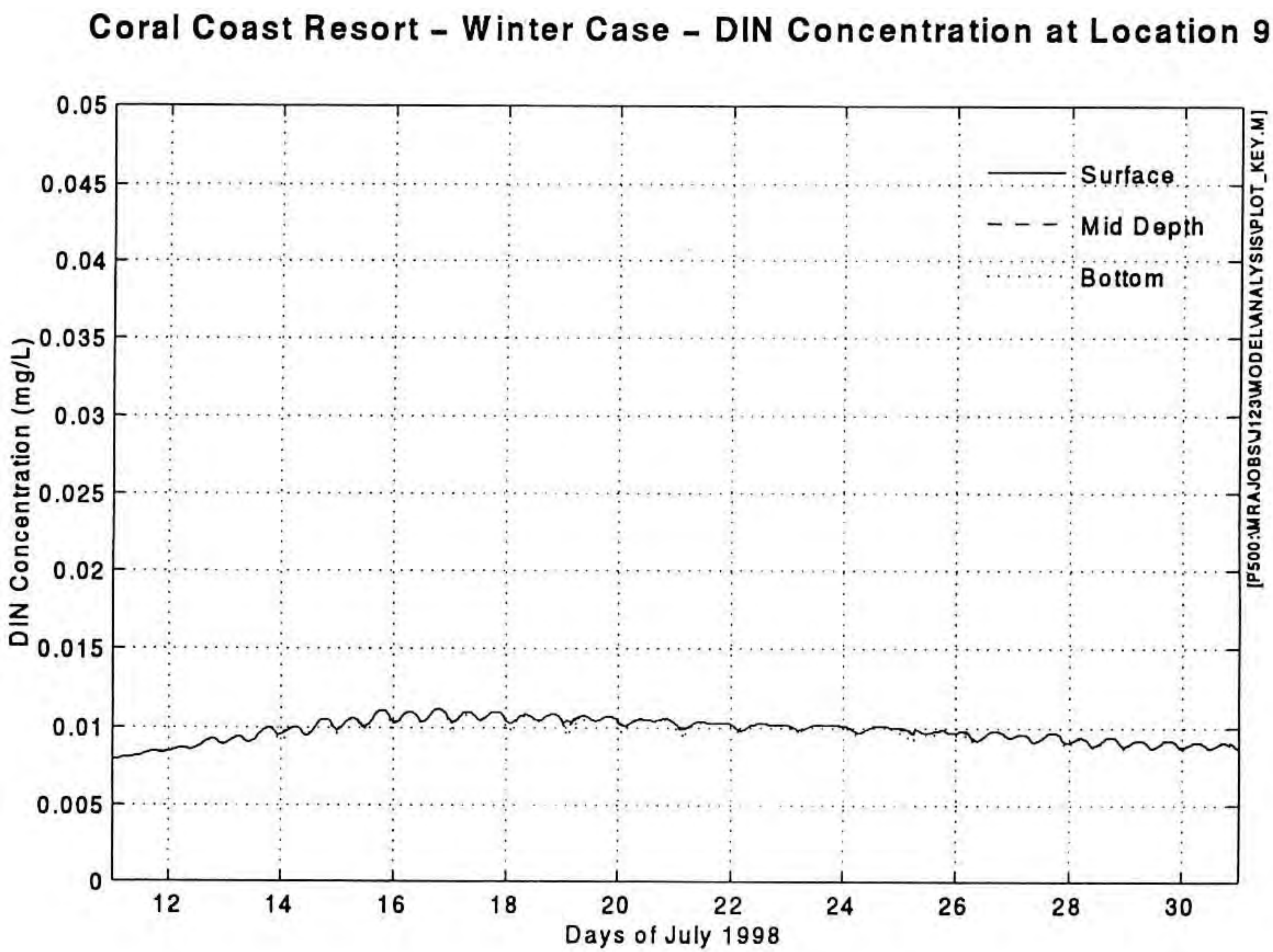
Coral Coast Resort - Winter Case - DIN Concentration at Location 4
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]


Coral Coast Resort - Winter Case - DIN Concentration at Location 6
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]


Coral Coast Resort - Winter Case - DIN Concentration at Location 7
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

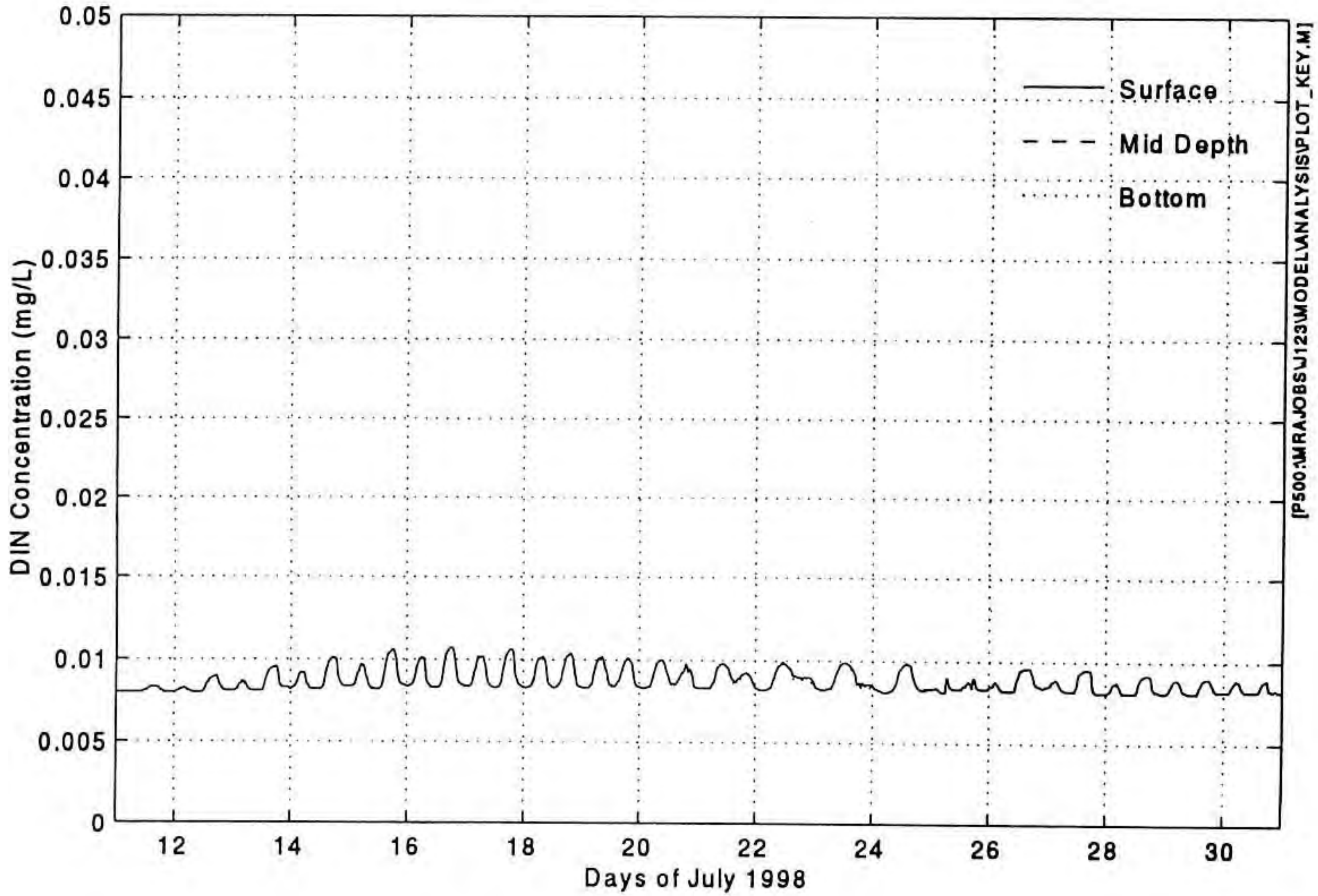
Coral Coast Resort – Winter Case – DIN Concentration at Location 8

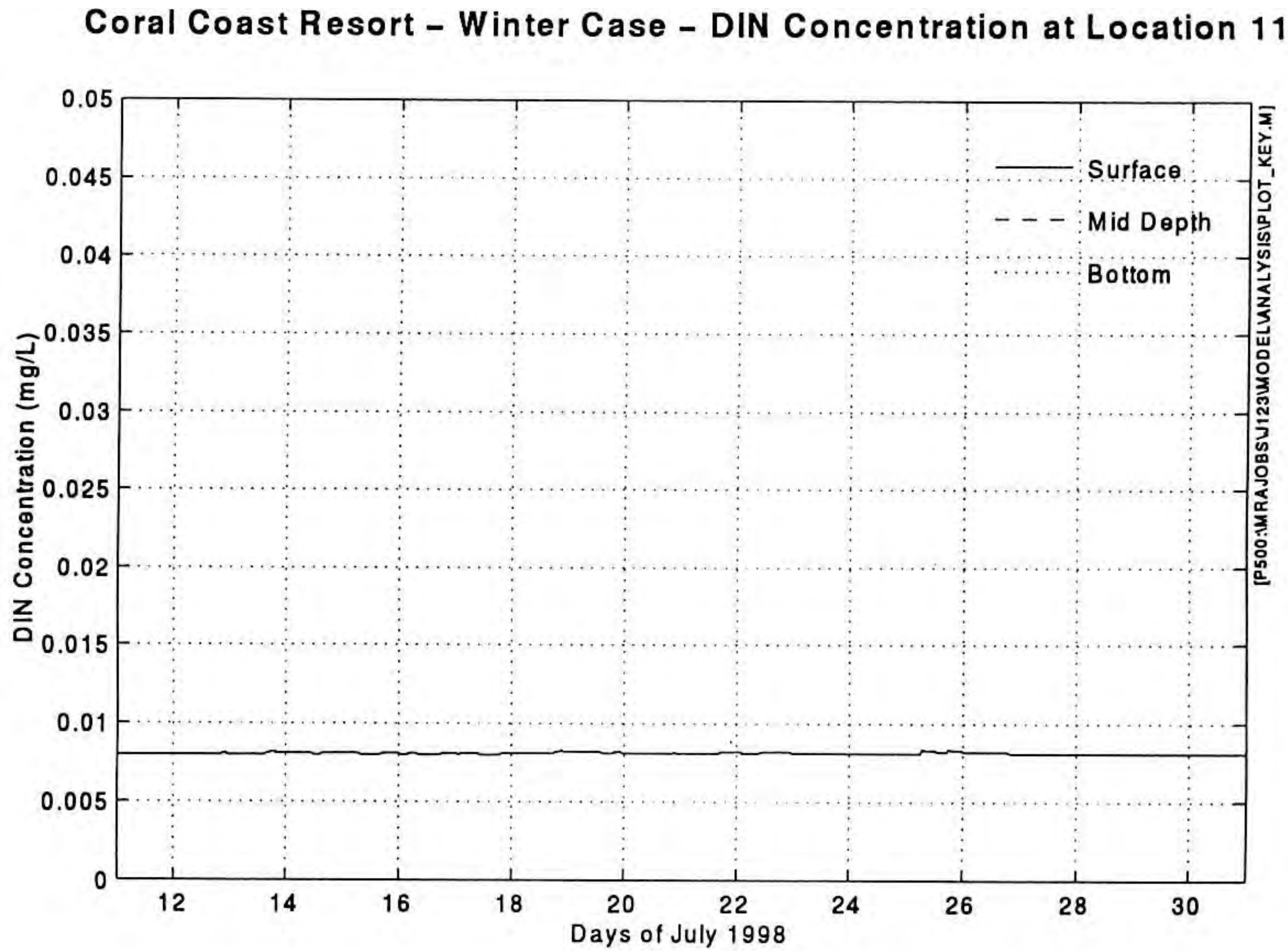




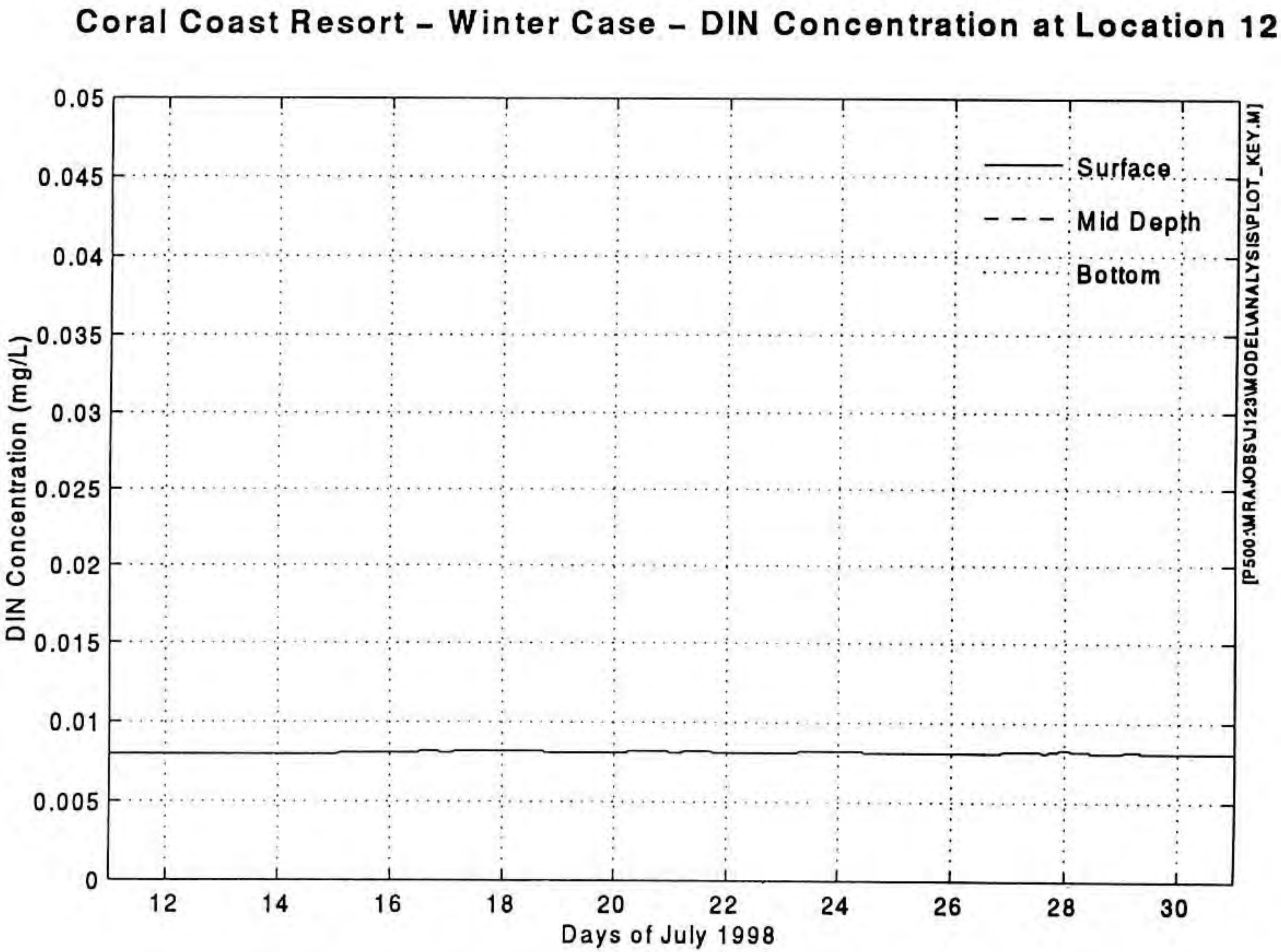
Coral Coast Resort - Winter Case - DIN Concentration at Location 9
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

Coral Coast Resort - Winter Case - DIN Concentration at Location 10



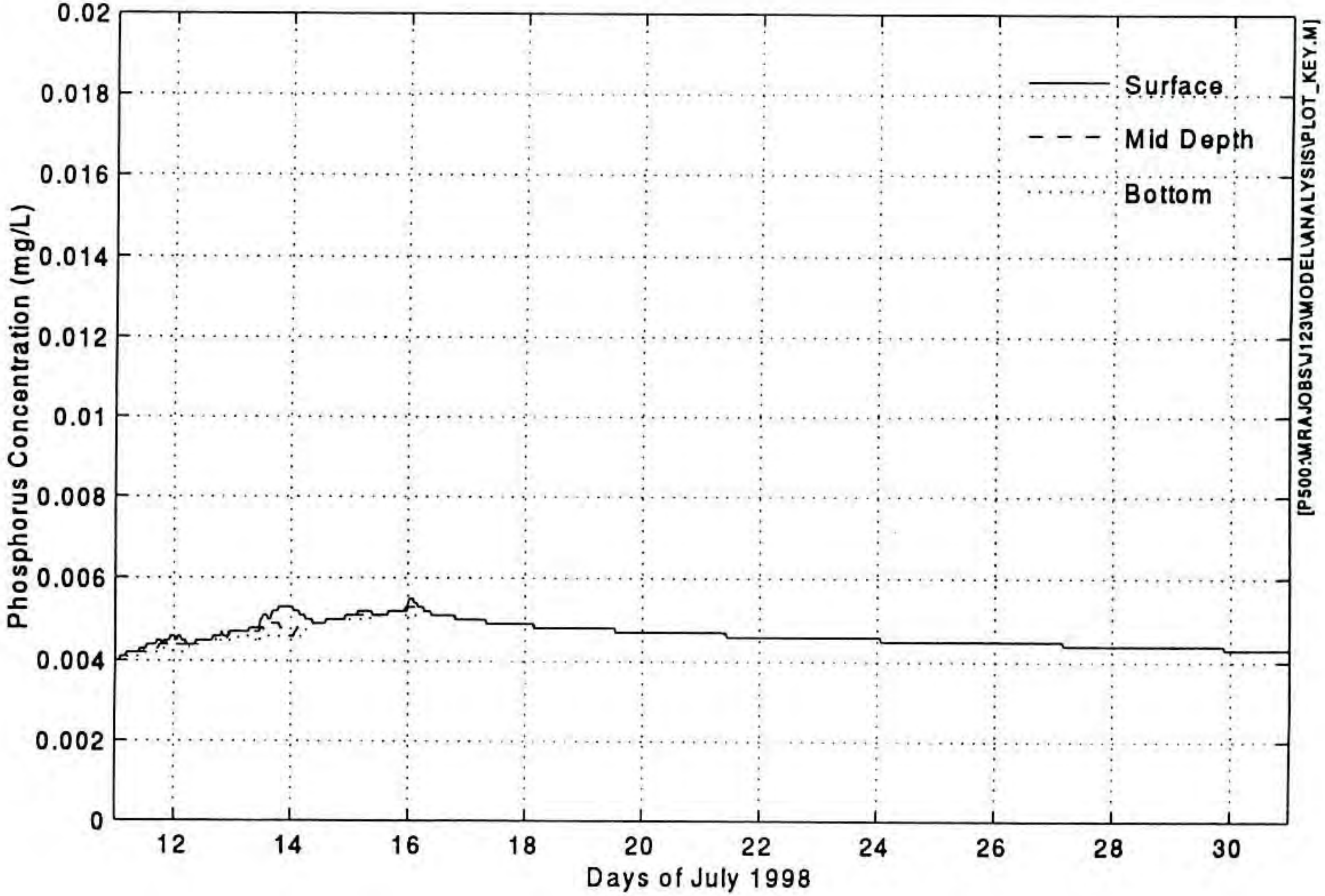

Coral Coast Resort - Winter Case - DIN Concentration at Location 11
DIN Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

M P ROGERS & ASSOCIATES

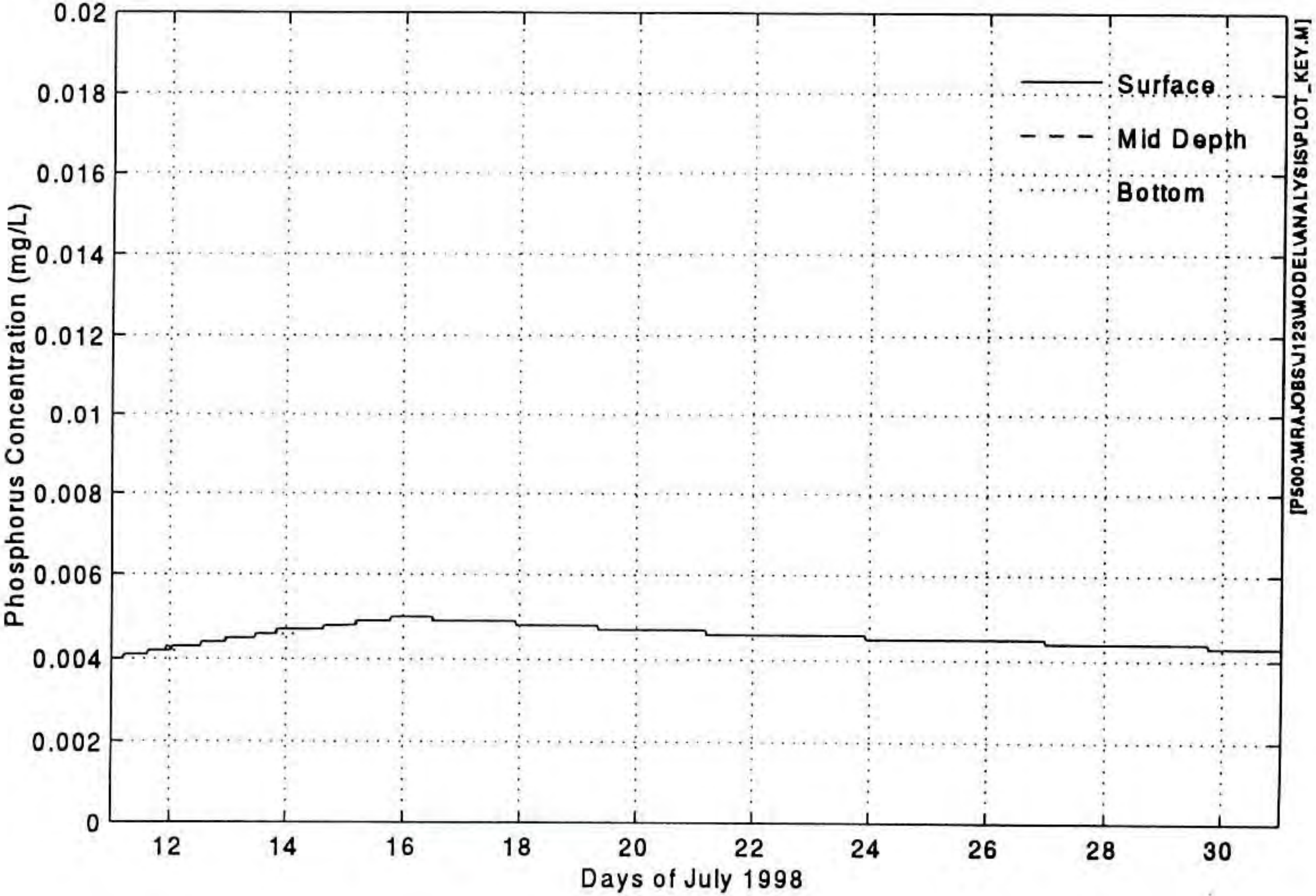


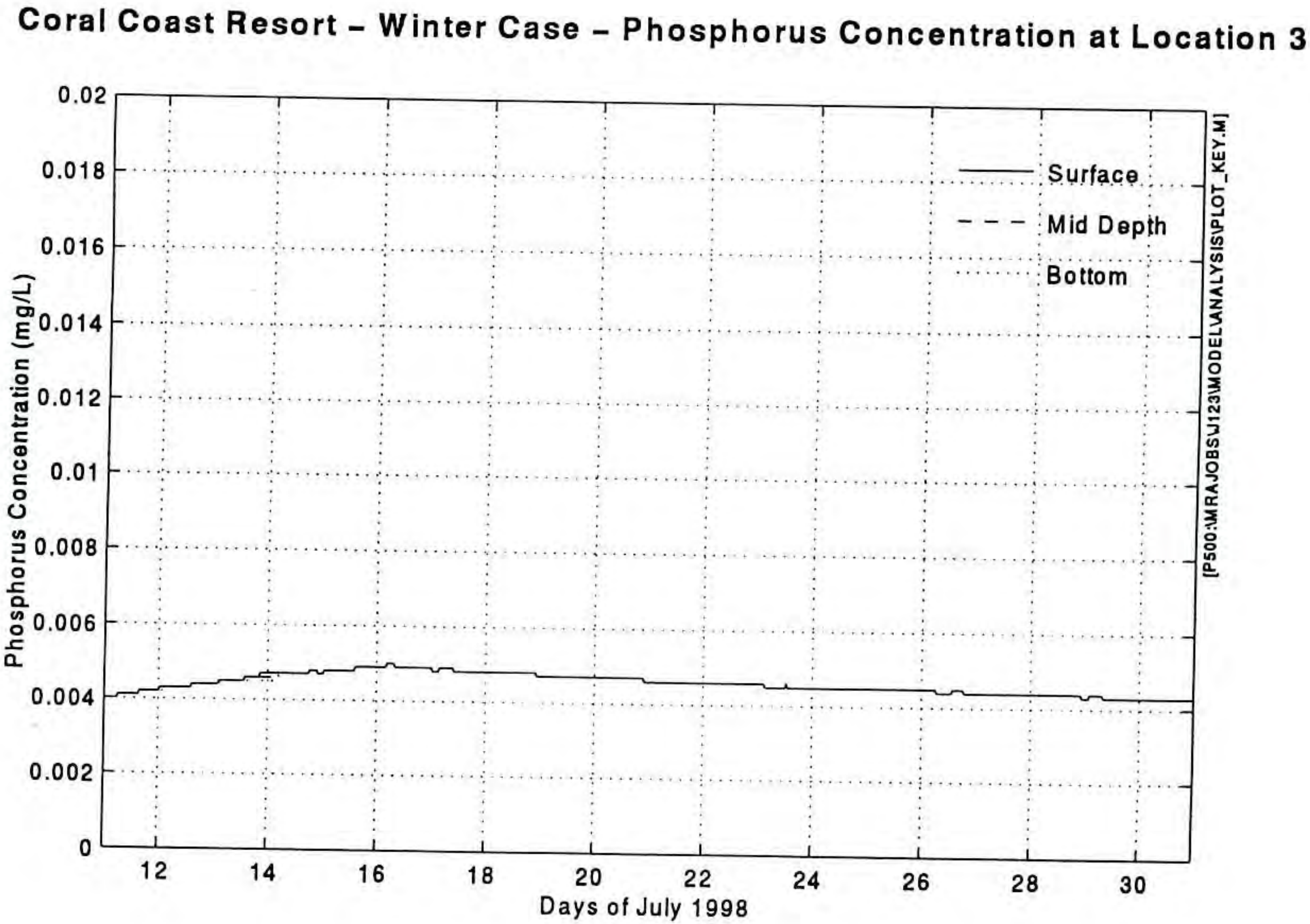
Mauds Landing Coastal Engineering Study
Job J123/1 Report R088 Rev 0

Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 1

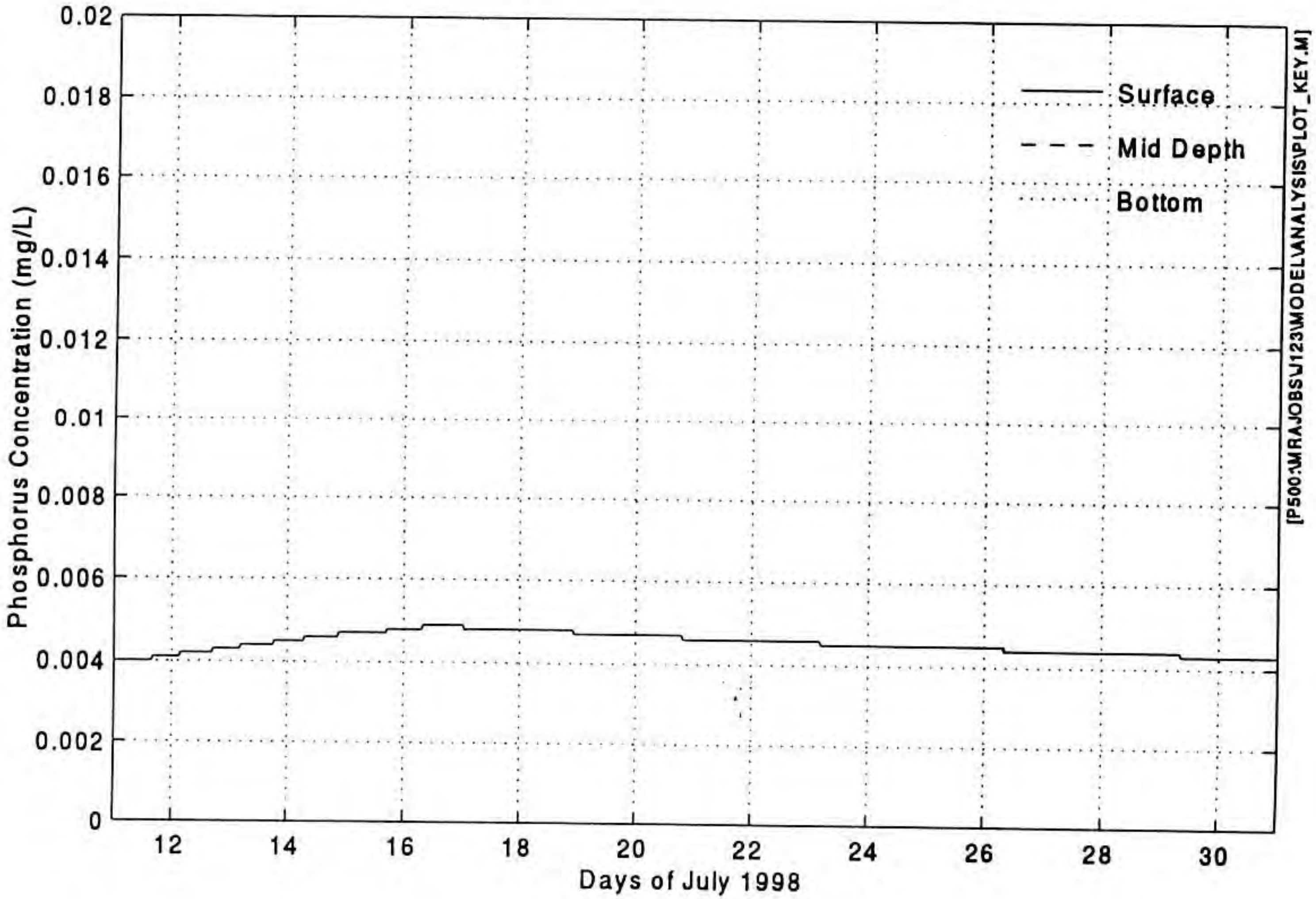


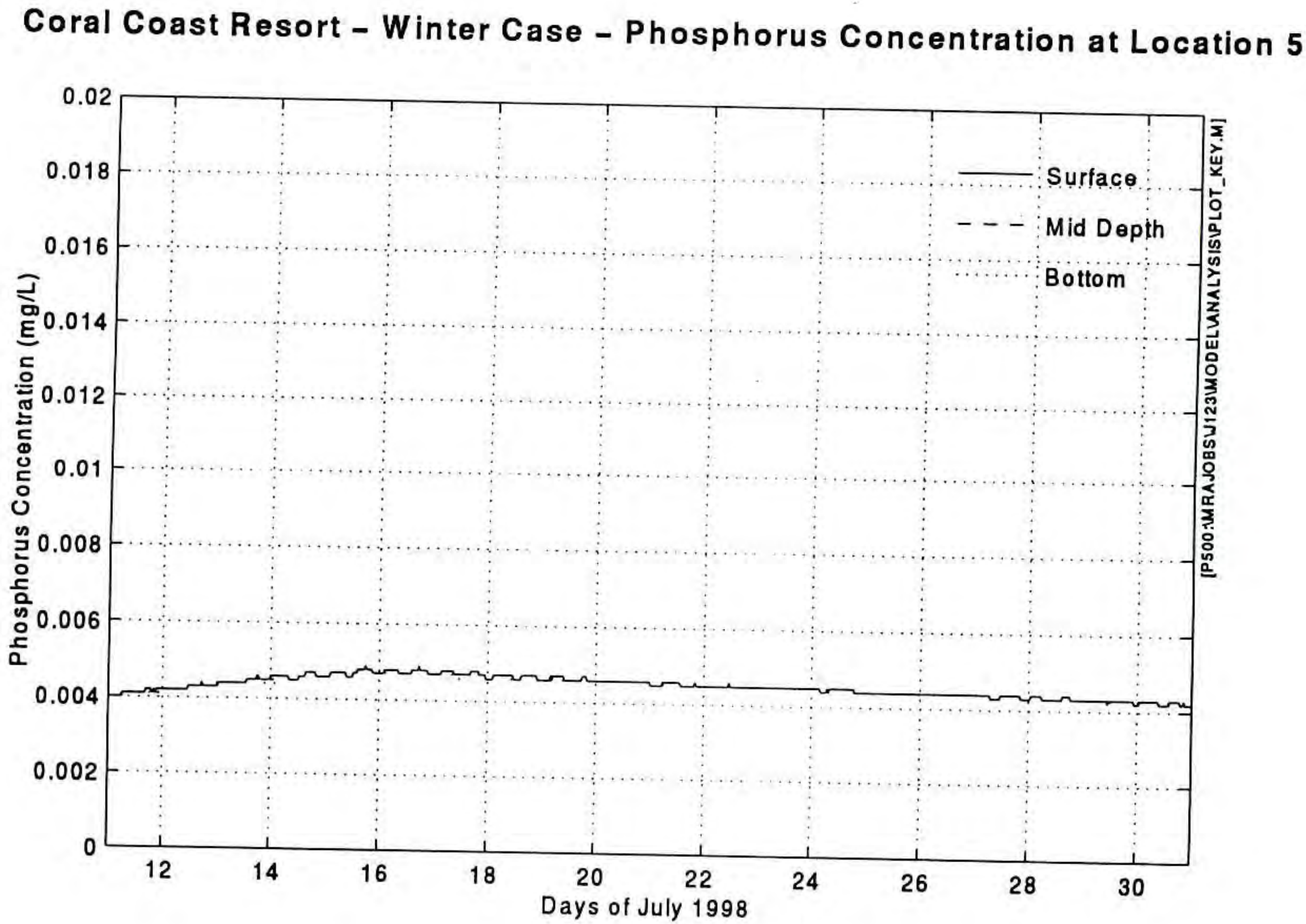
Coral Coast Resort - Winter Case - Phosphorus Concentration at Location 2

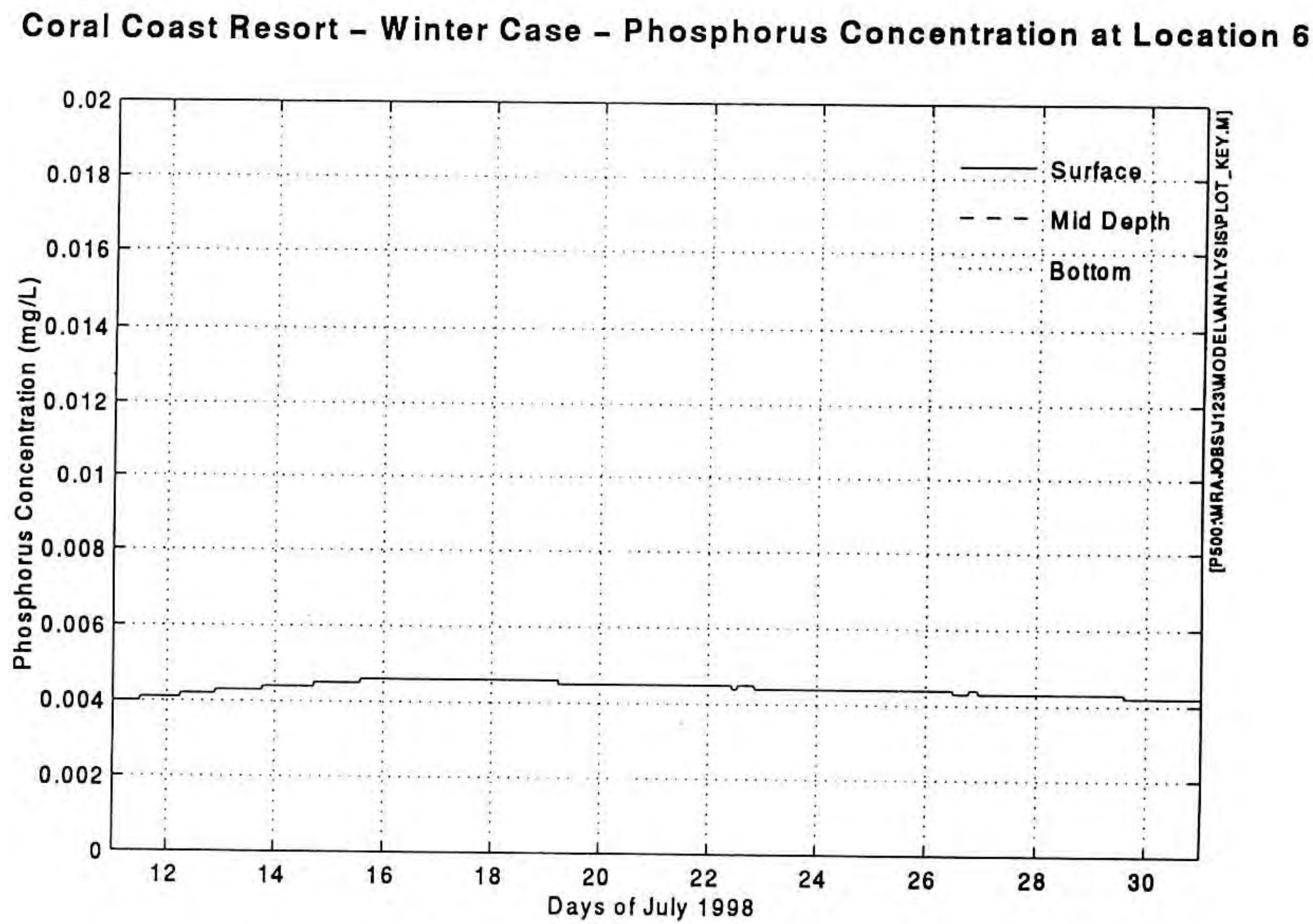



Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 3
Phosphorus Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

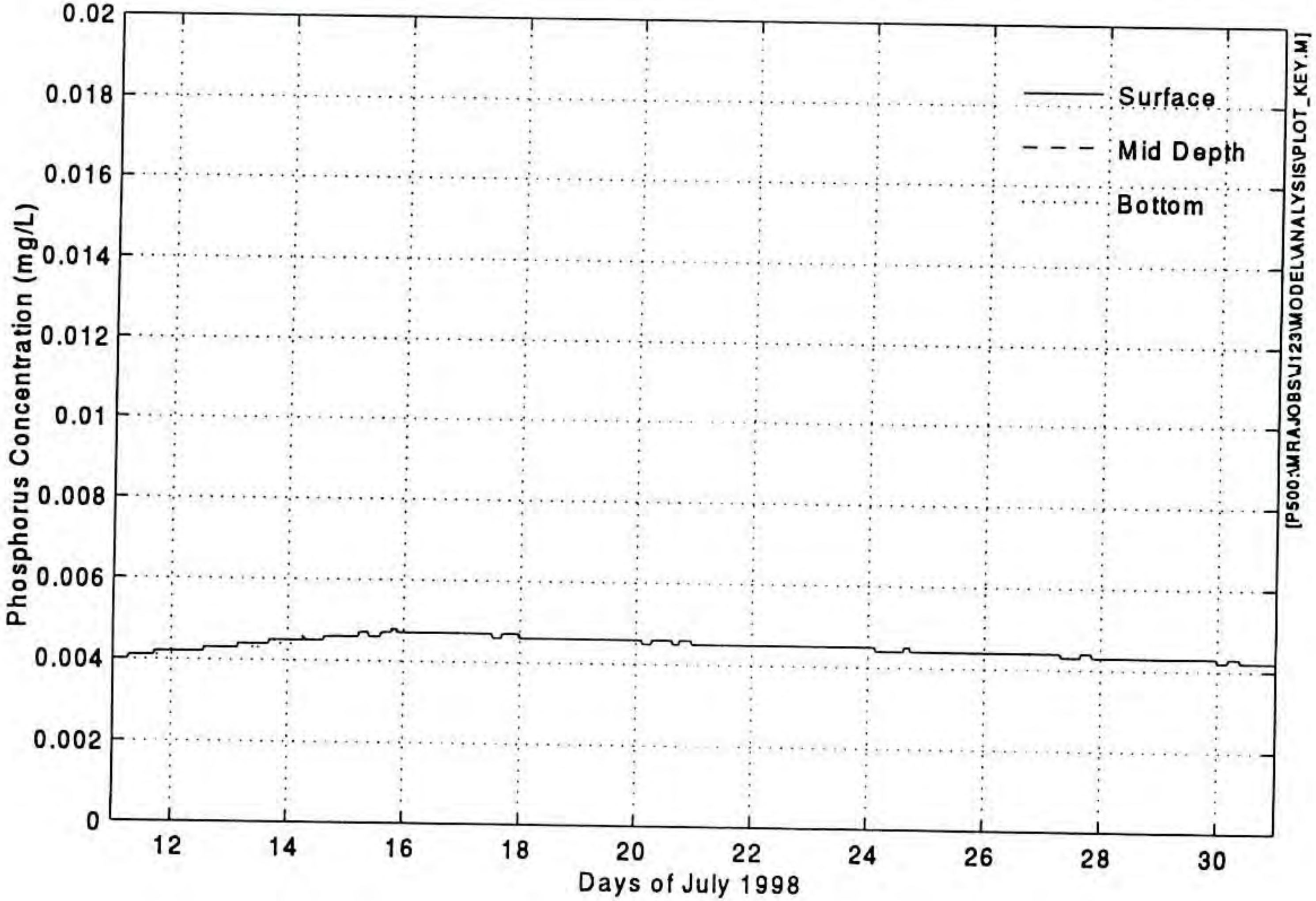
Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 4



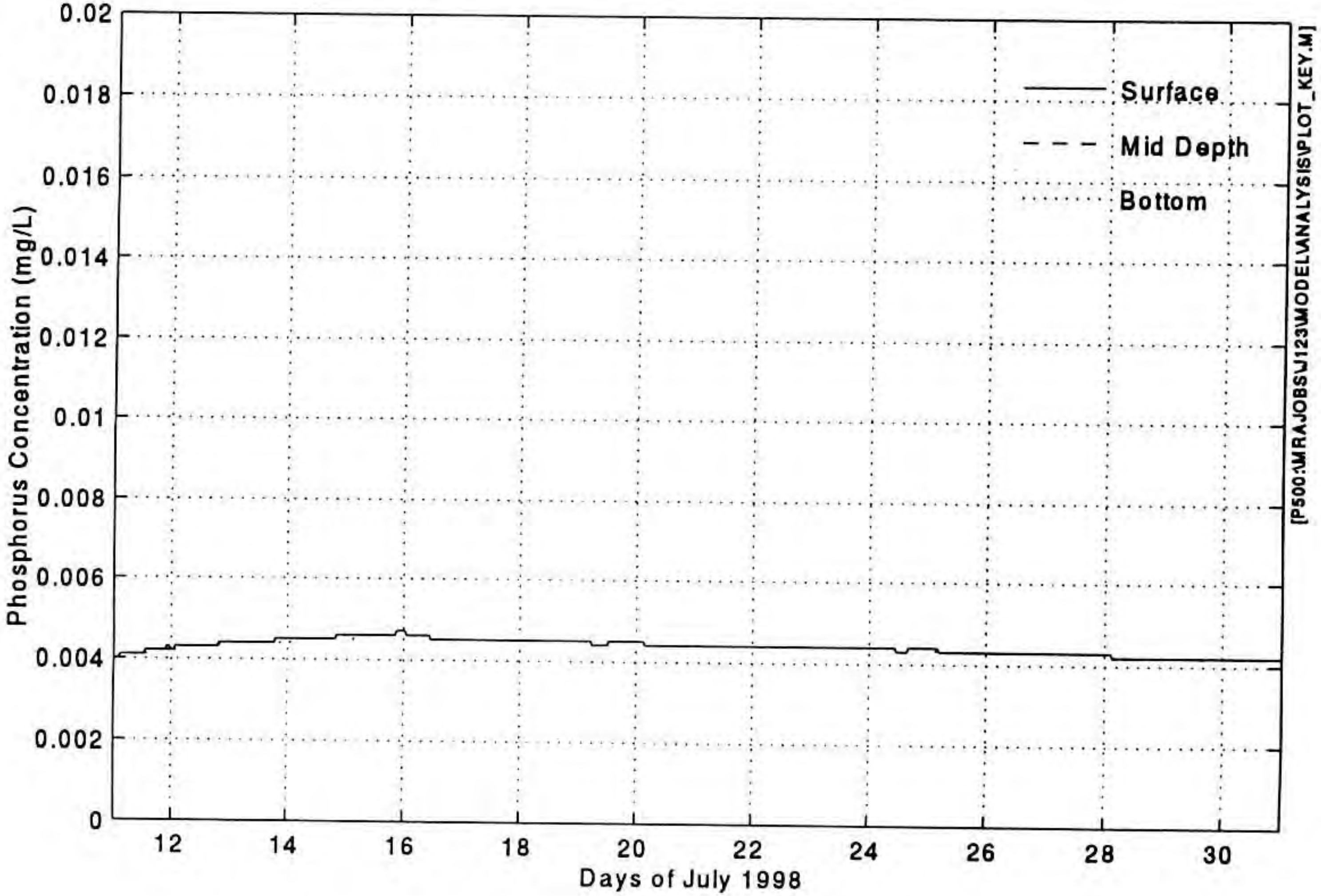

Coral Coast Resort - Winter Case - Phosphorus Concentration at Location 5
Phosphorus Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRAJOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]


Coral Coast Resort - Winter Case - Phosphorus Concentration at Location 6
Phosphorus Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
12
14
16
18
20
22
24
26
28
30
Days of July 1998
Surface
Mid Depth
Bottom
[P500:\MRA\JOBS\J123\MODEL\ANALYSIS\PLOT_KEY.M]

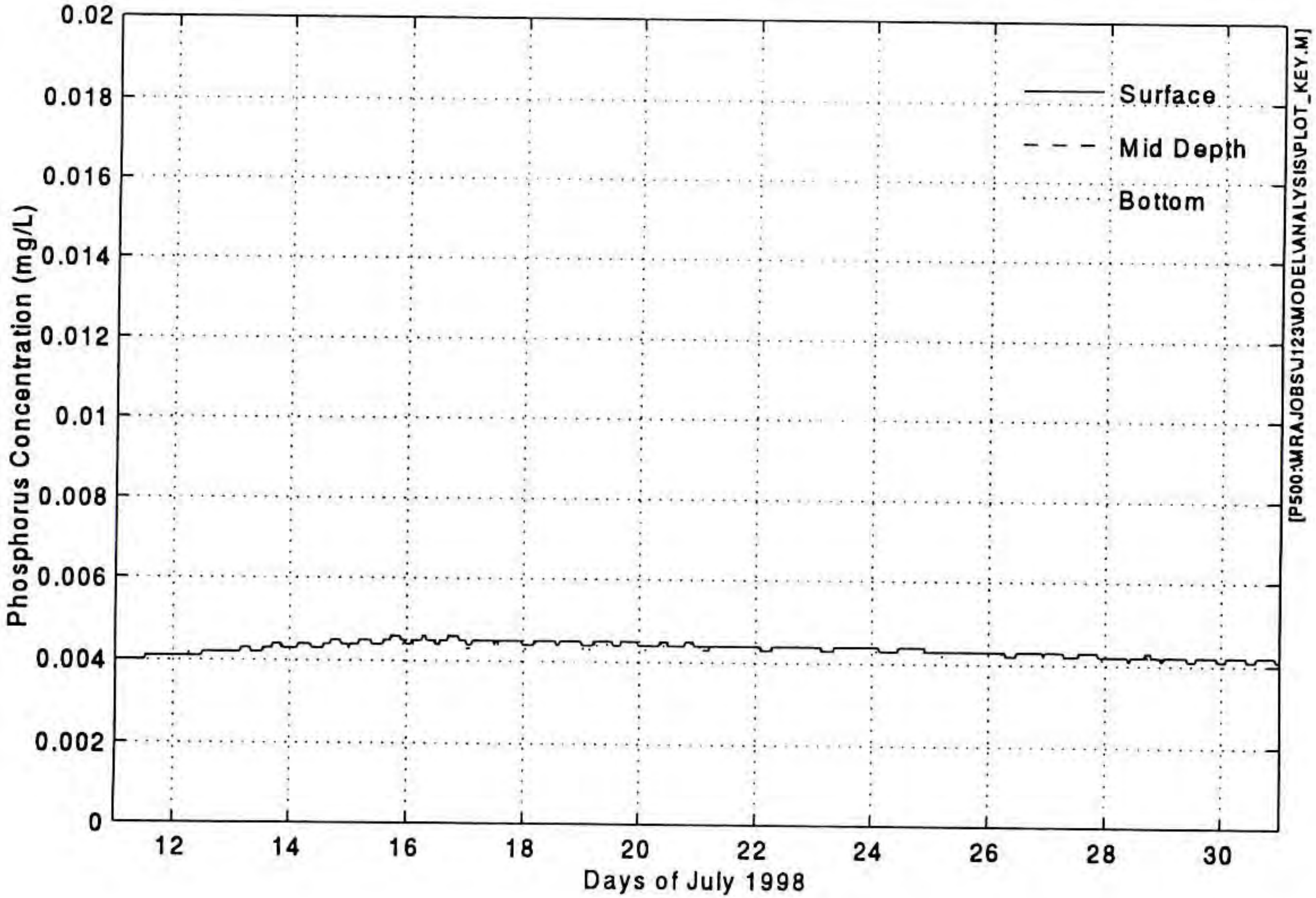
Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 7



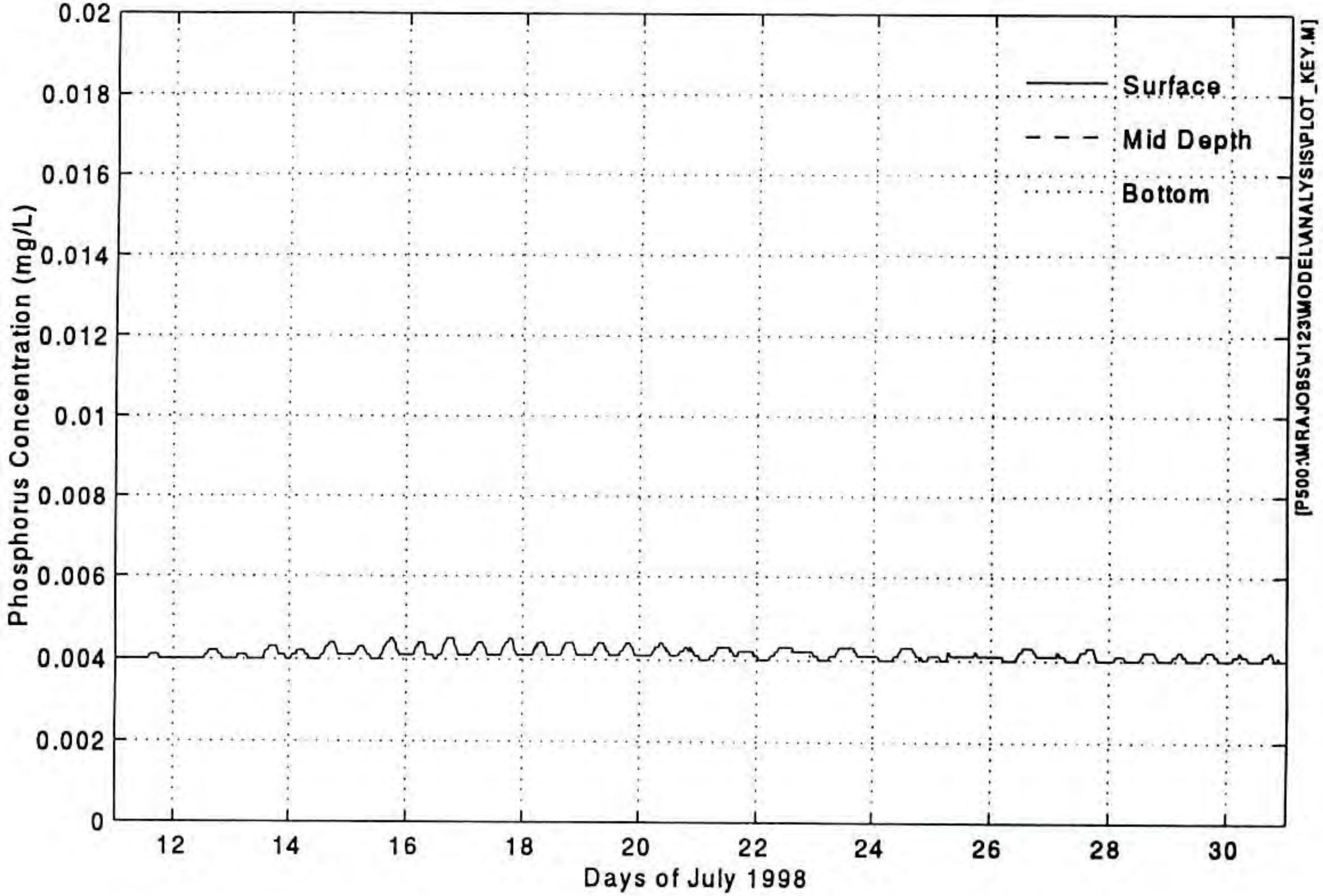
Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 8



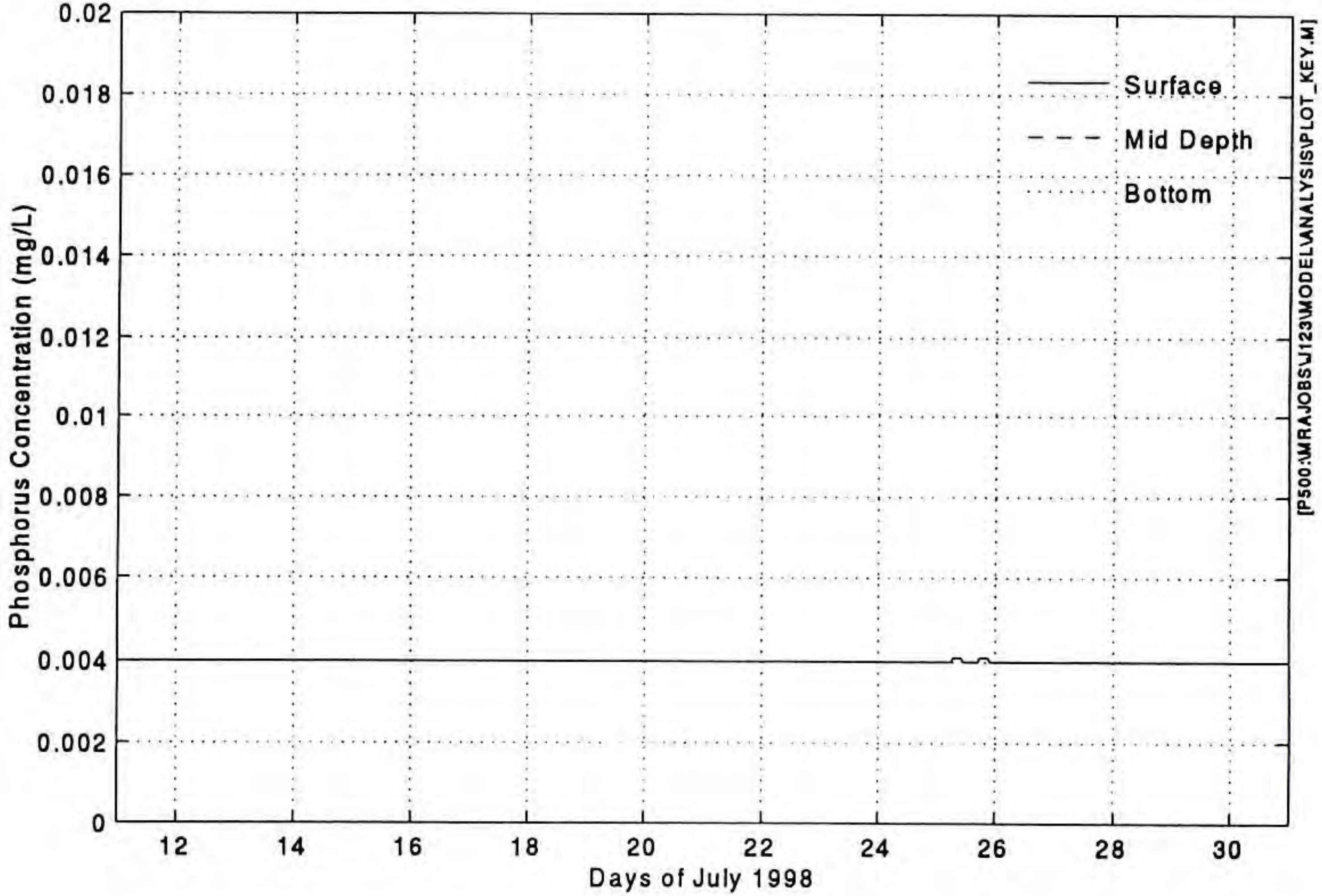
Coral Coast Resort - Winter Case - Phosphorus Concentration at Location 9



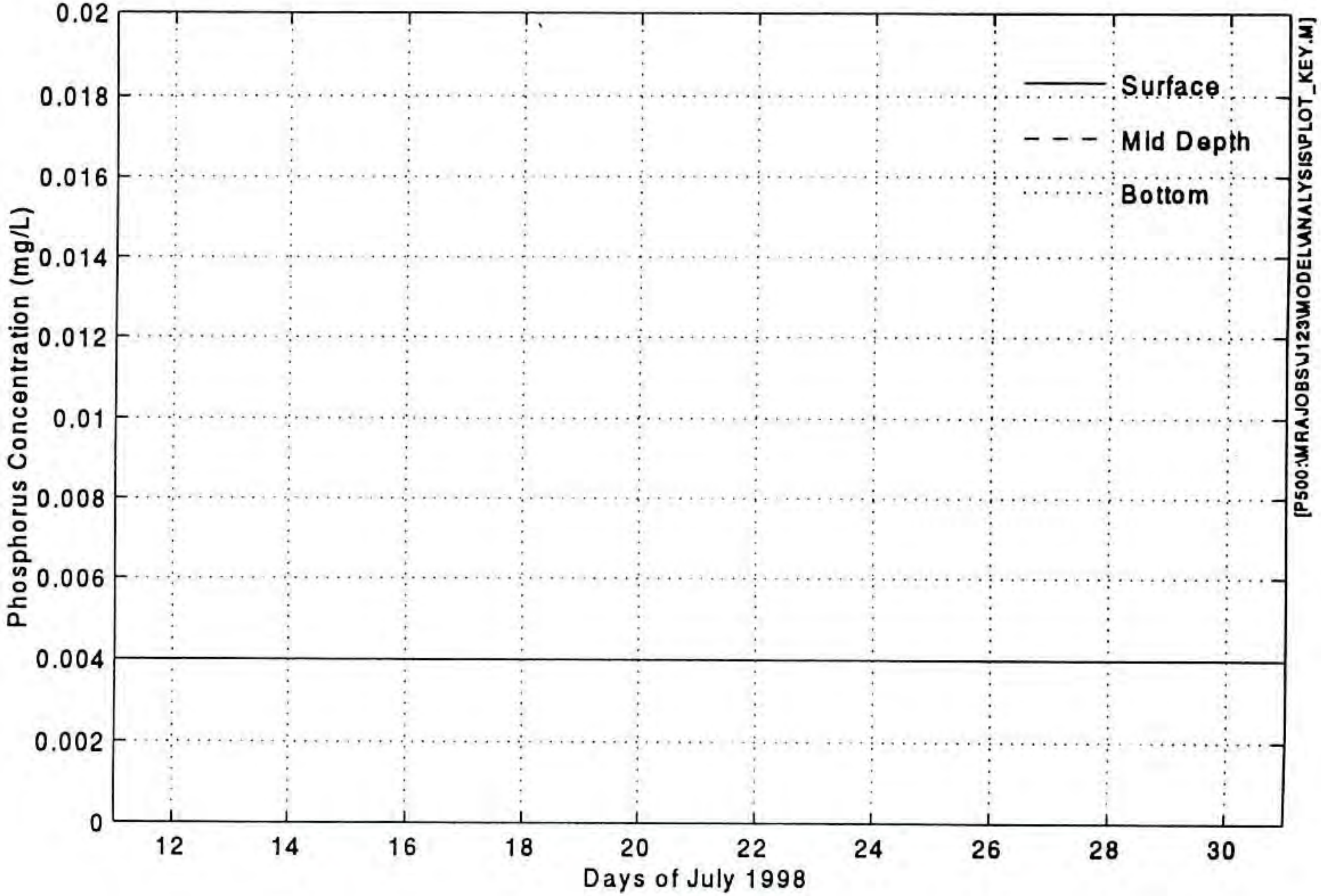
Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 10



Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 11

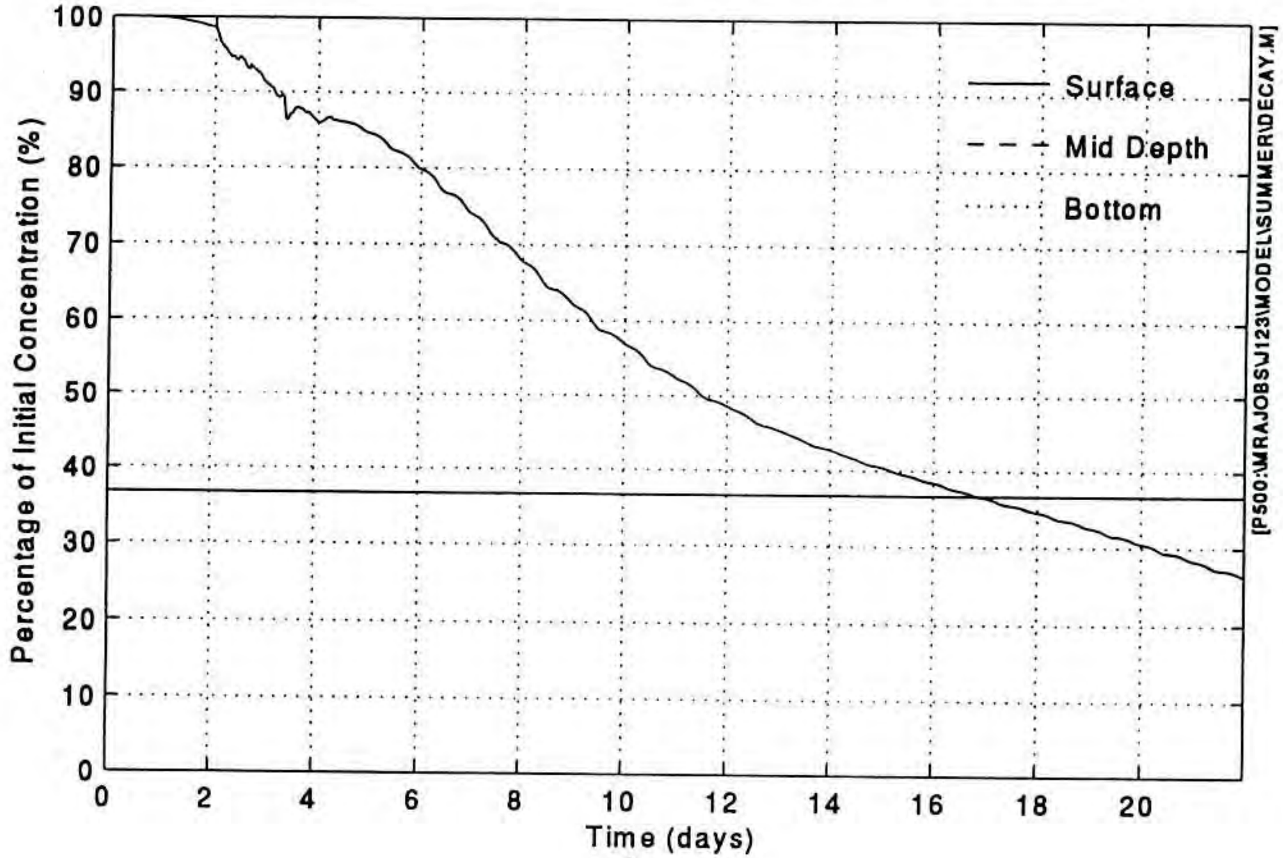


Coral Coast Resort – Winter Case – Phosphorus Concentration at Location 12

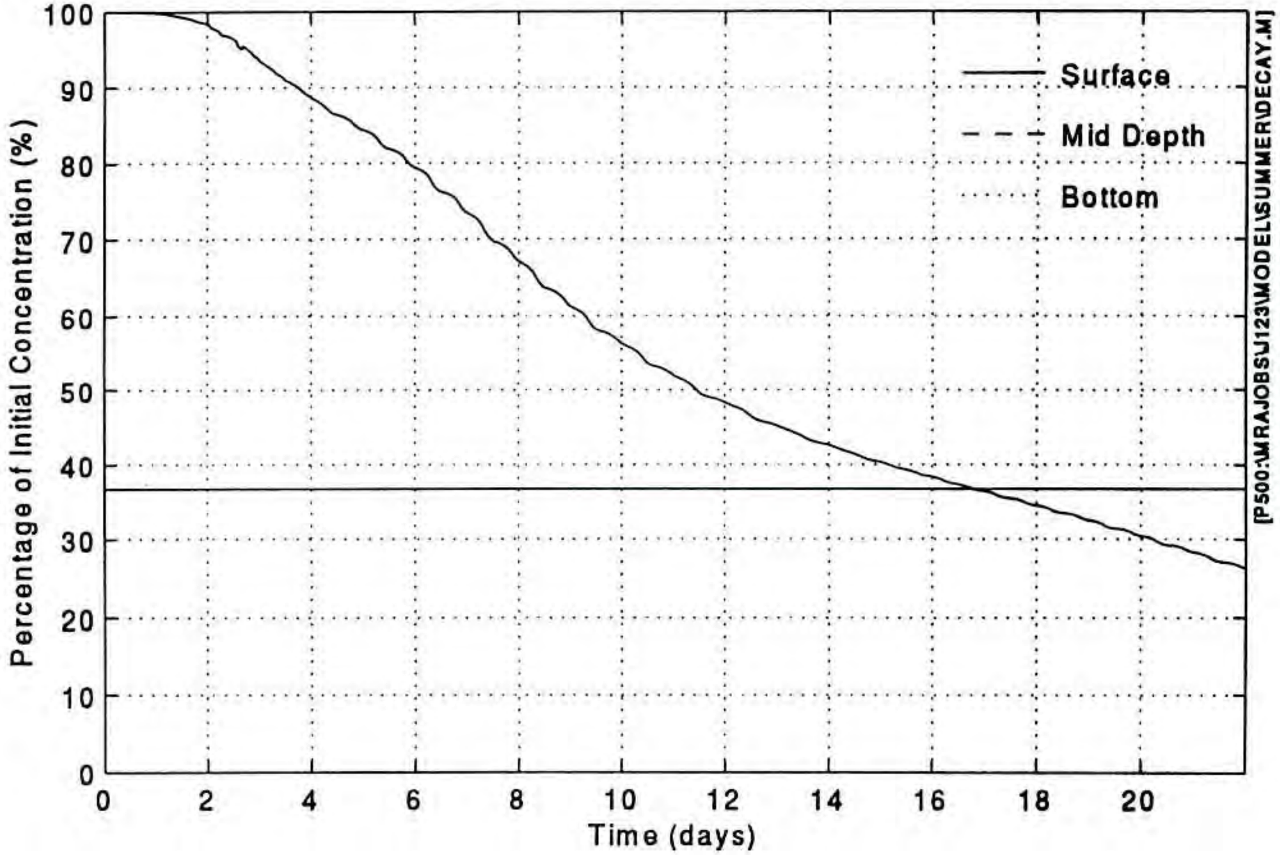


Appendix D Modelled Decay Curves

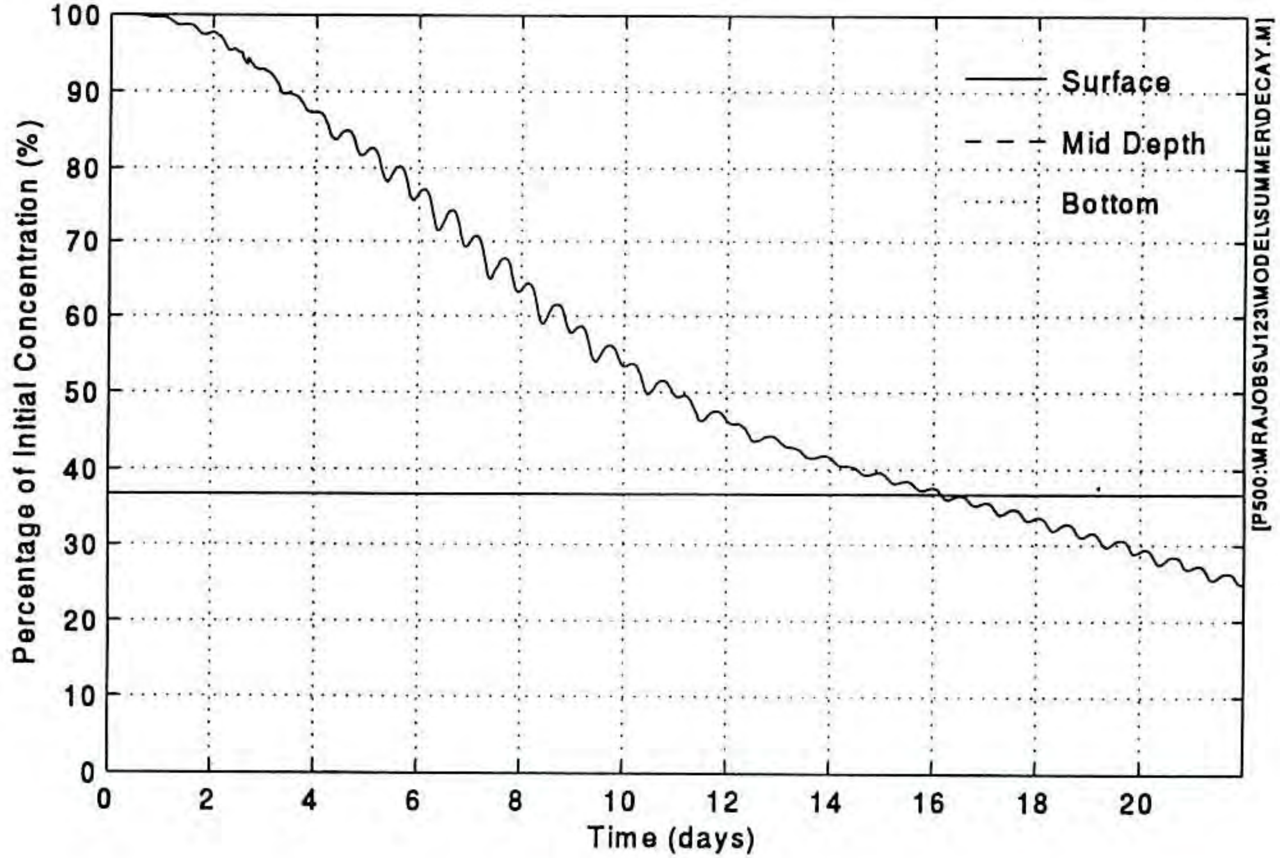
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 1



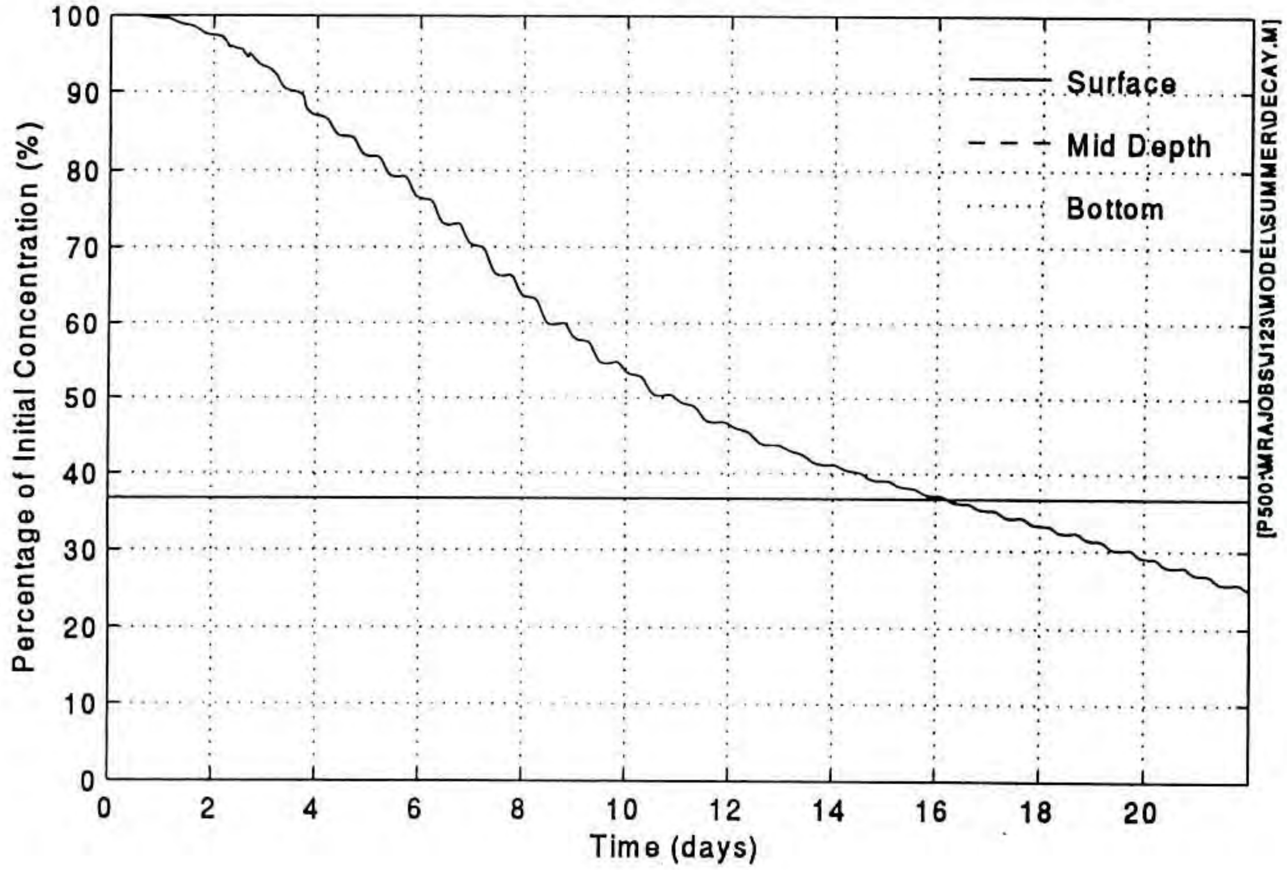
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 2



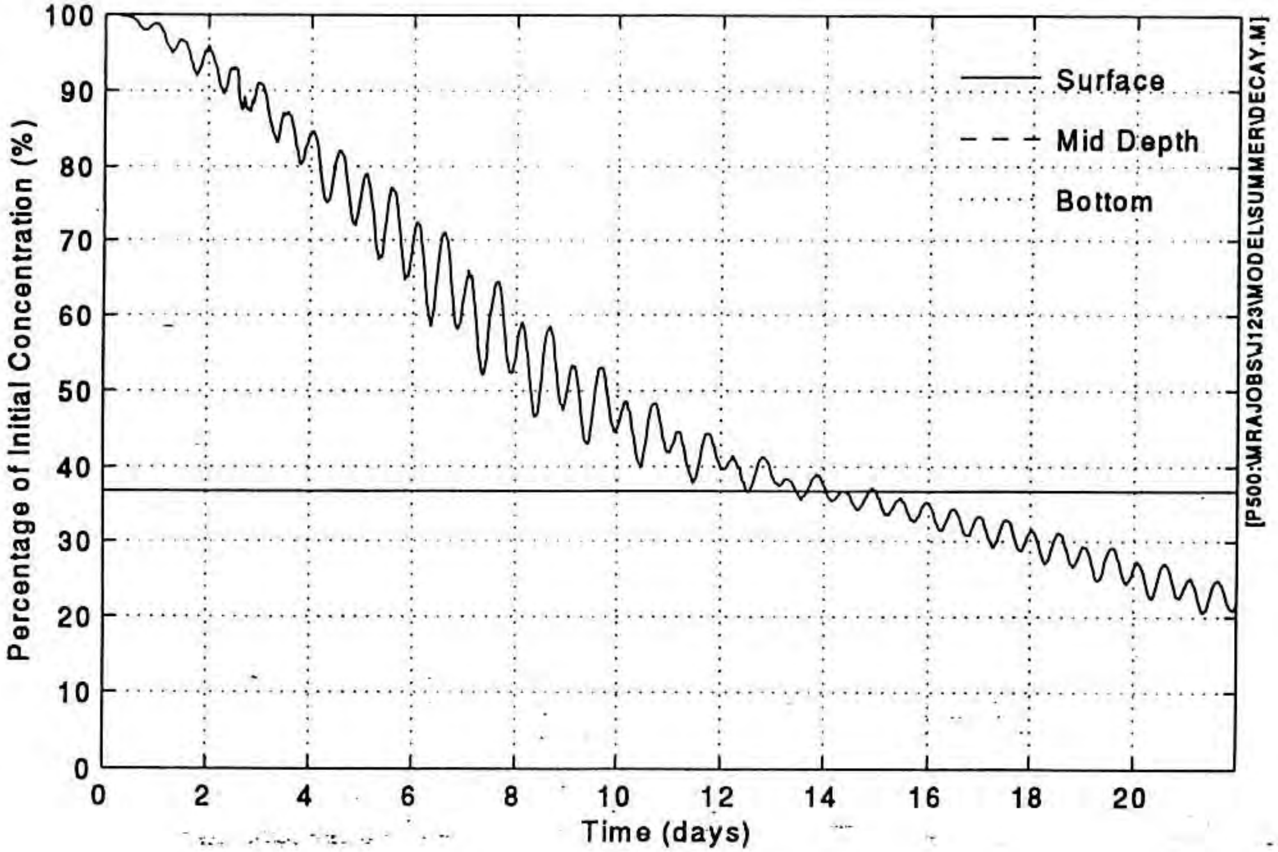
Coral Coast Resort – Summer Case – Decay of Conservative Tracer at Location 3



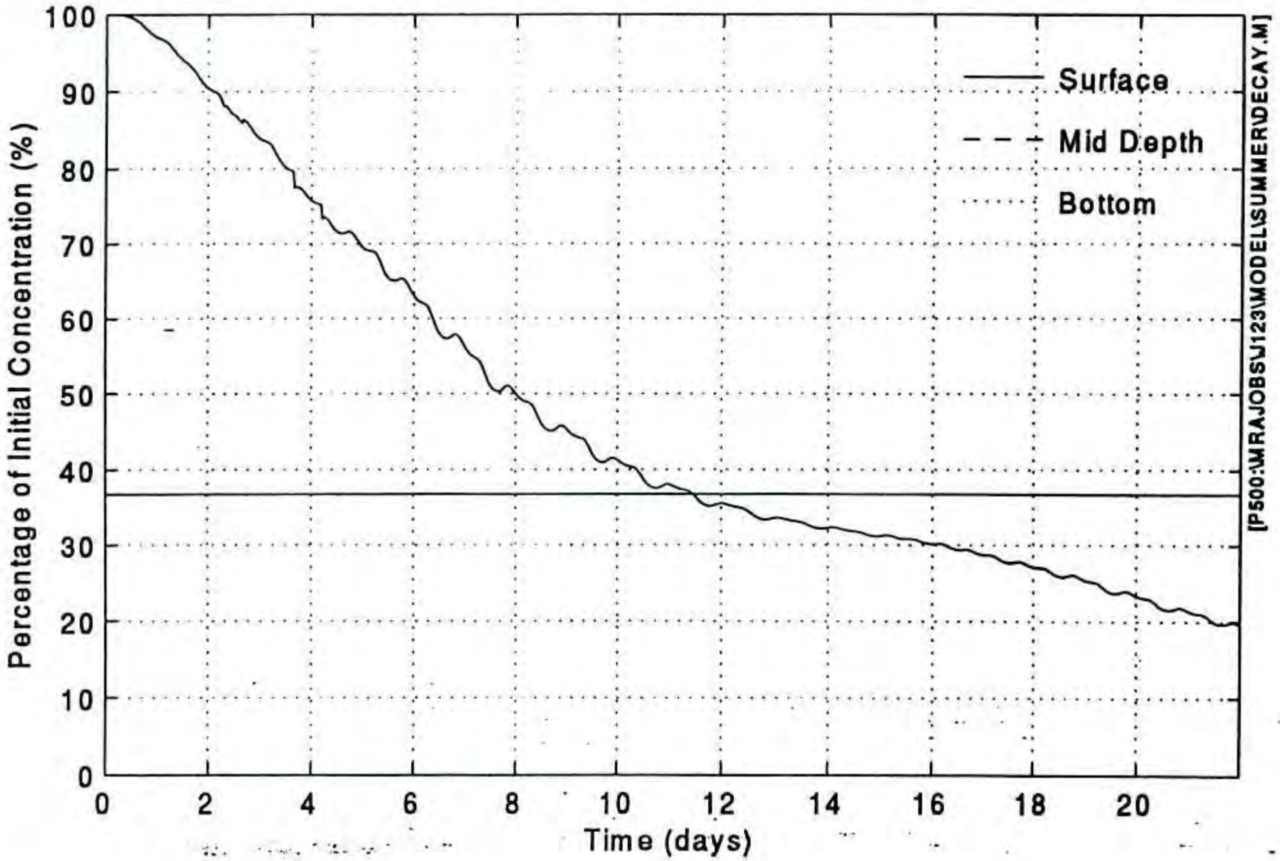
Coral Coast Resort – Summer Case – Decay of Conservative Tracer at Location 4



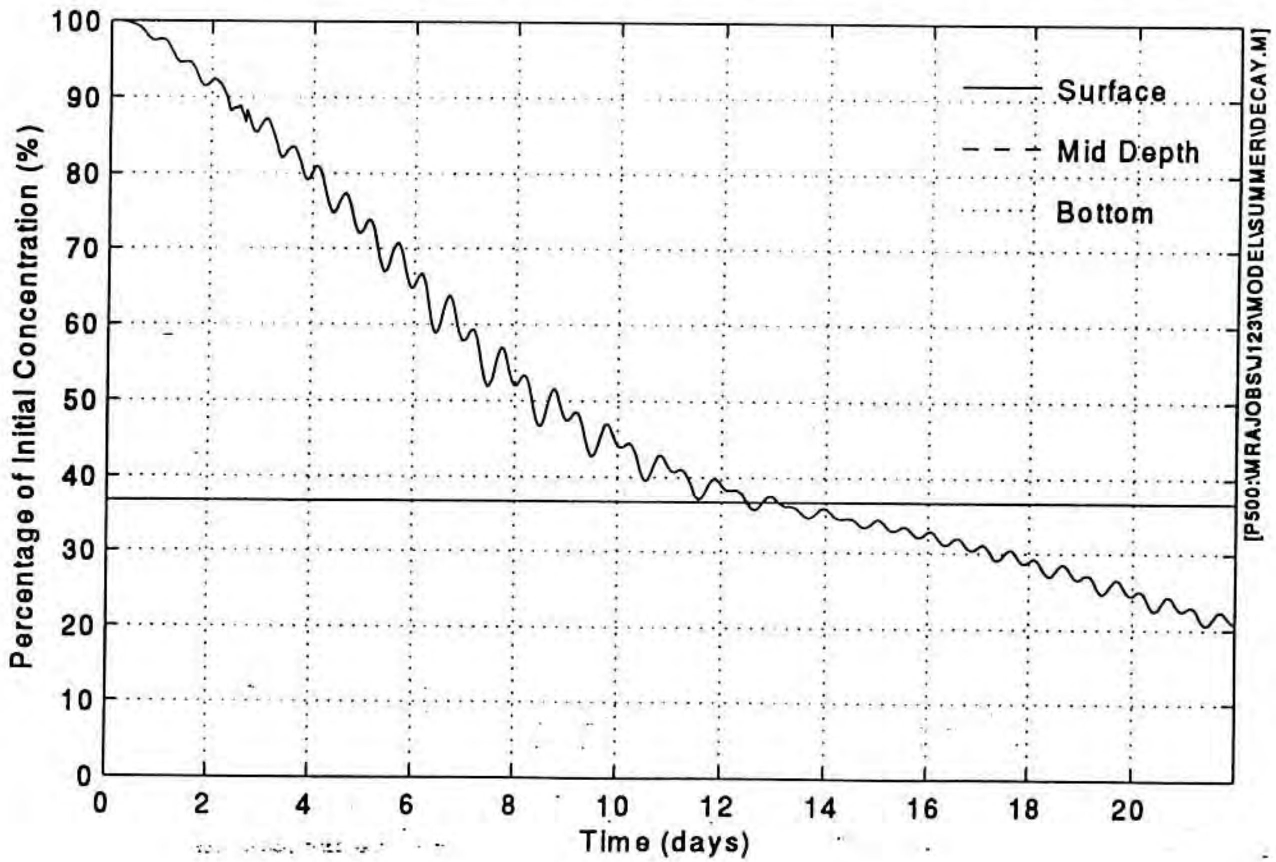
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 5



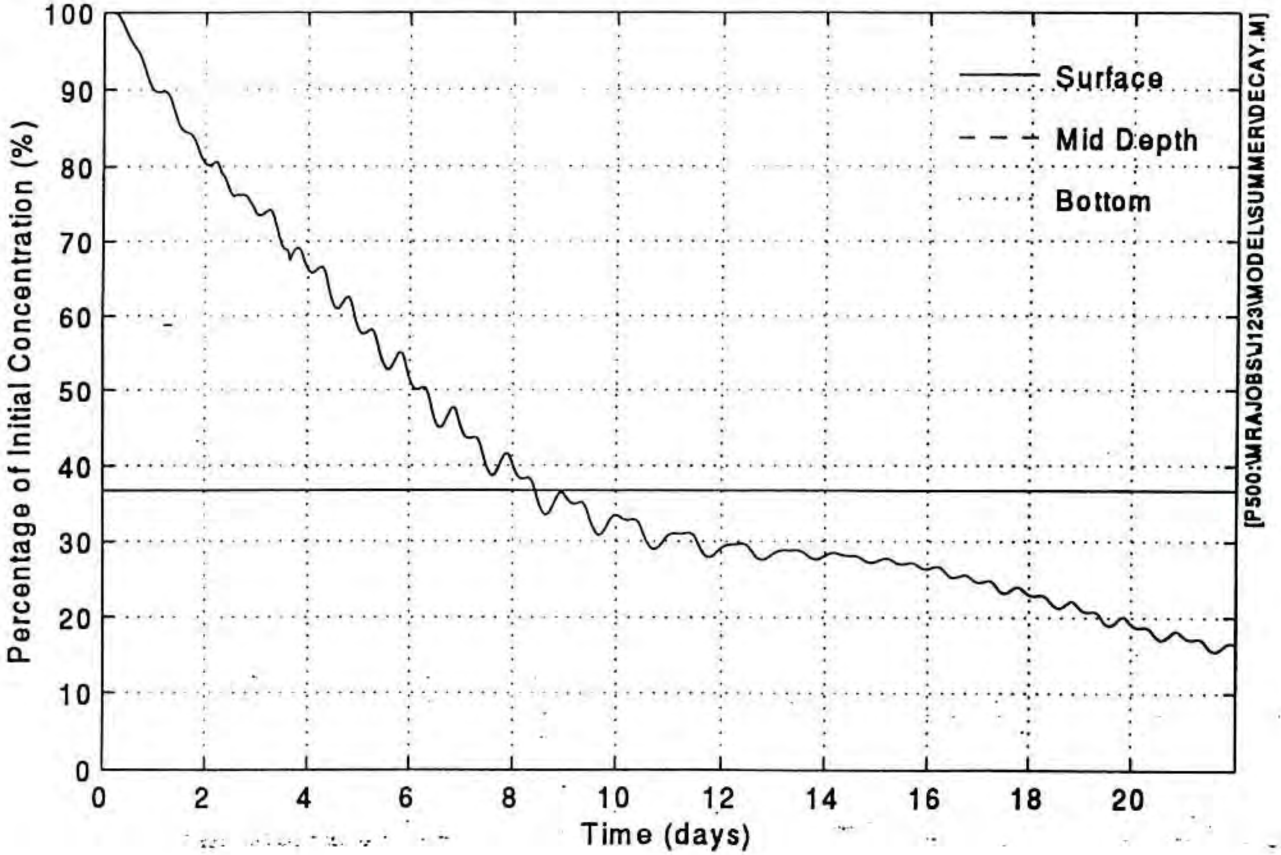
Coral Coast Resort – Summer Case – Decay of Conservative Tracer at Location 6



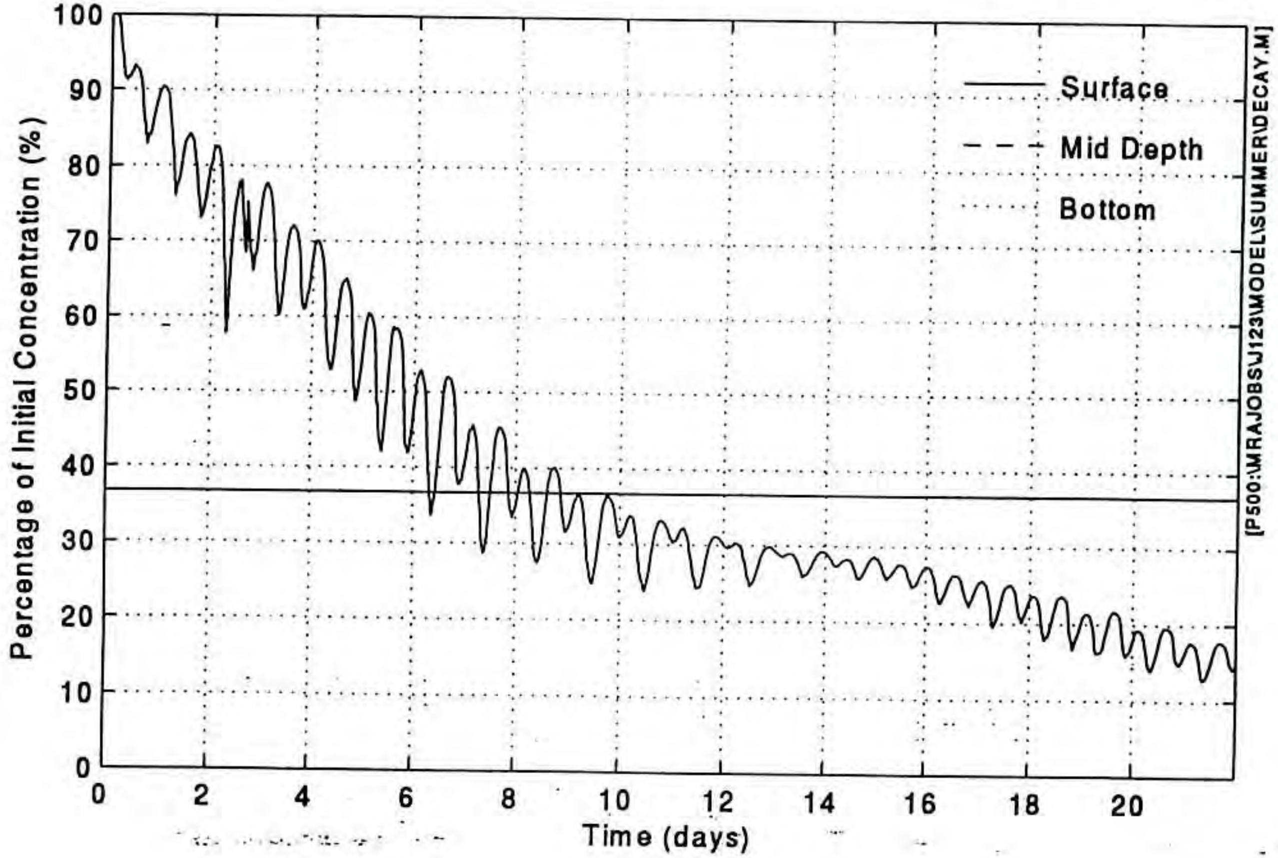
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 7



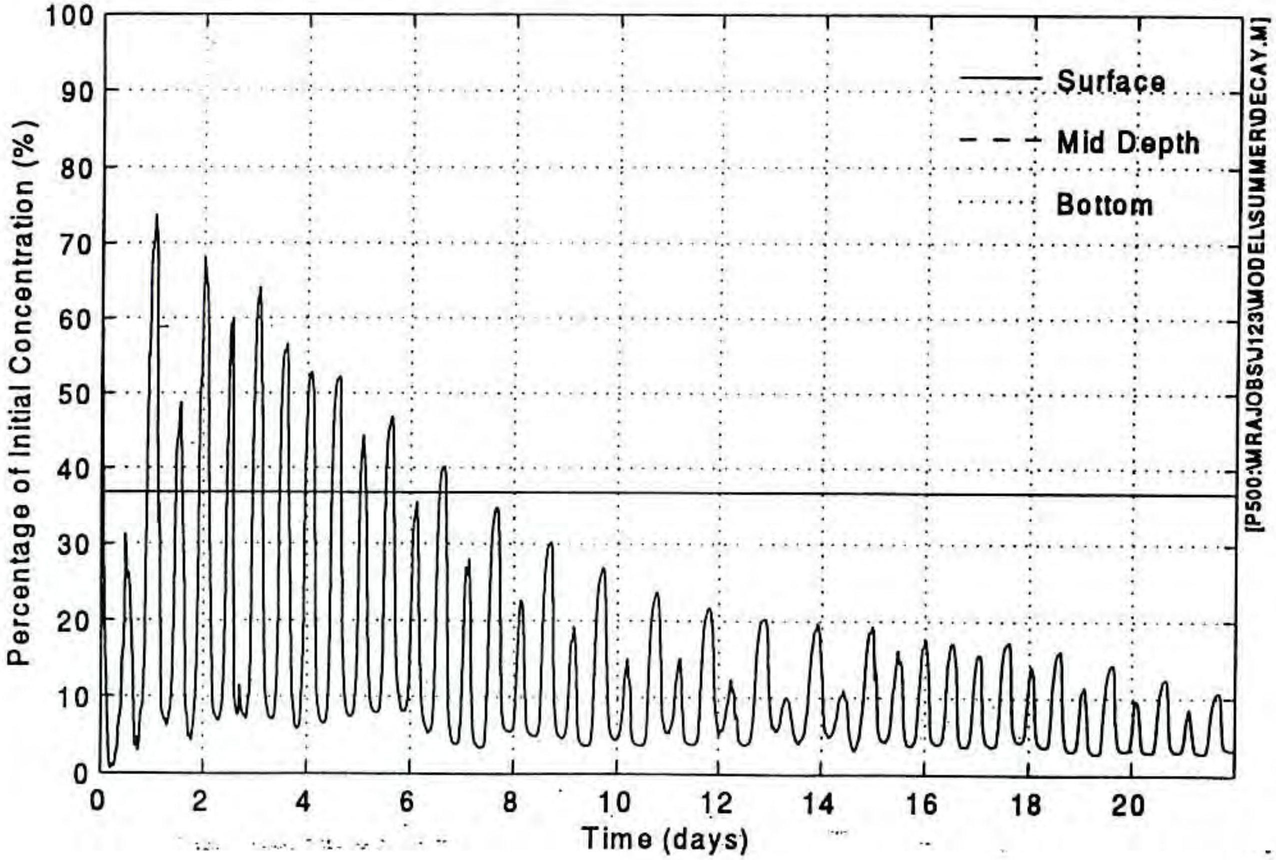
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 8



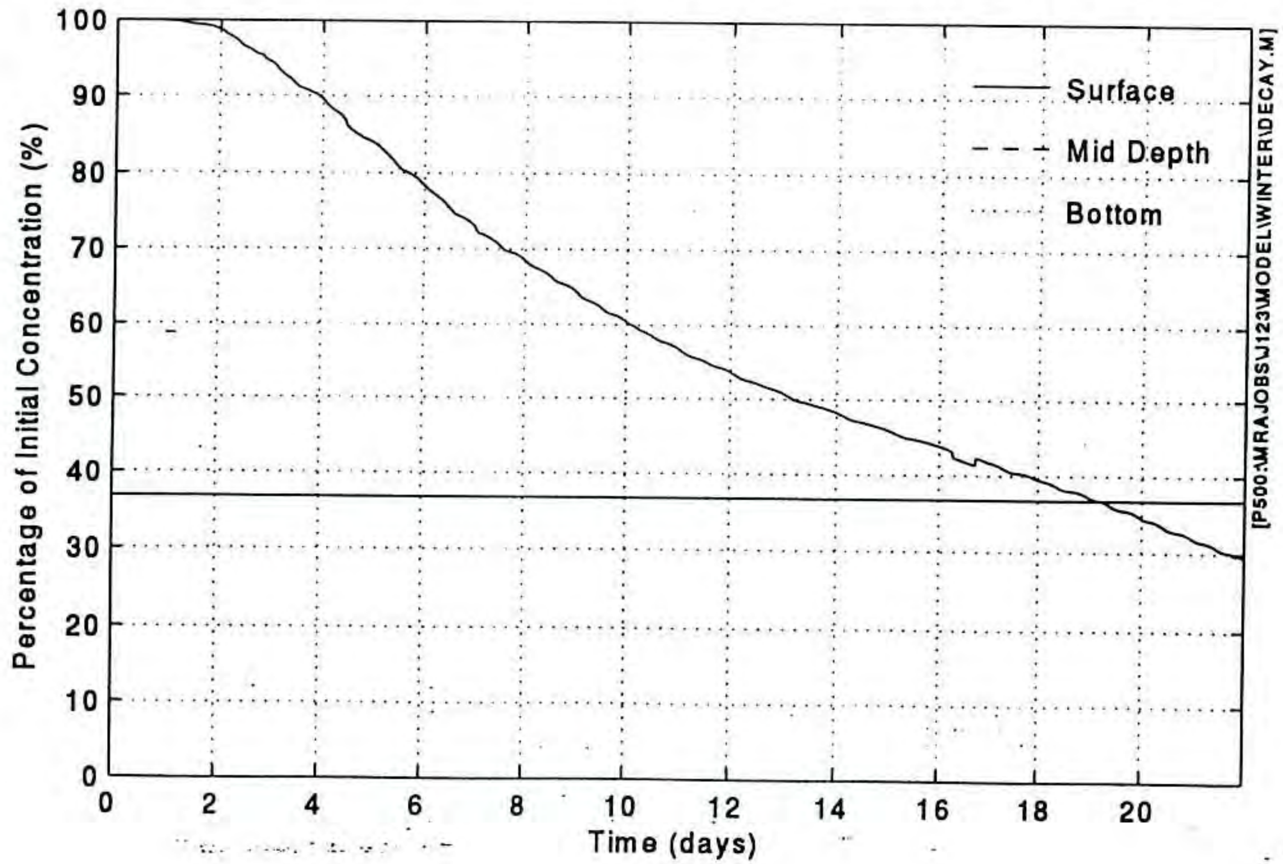
Coral Coast Resort - Summer Case - Decay of Conservative Tracer at Location 9



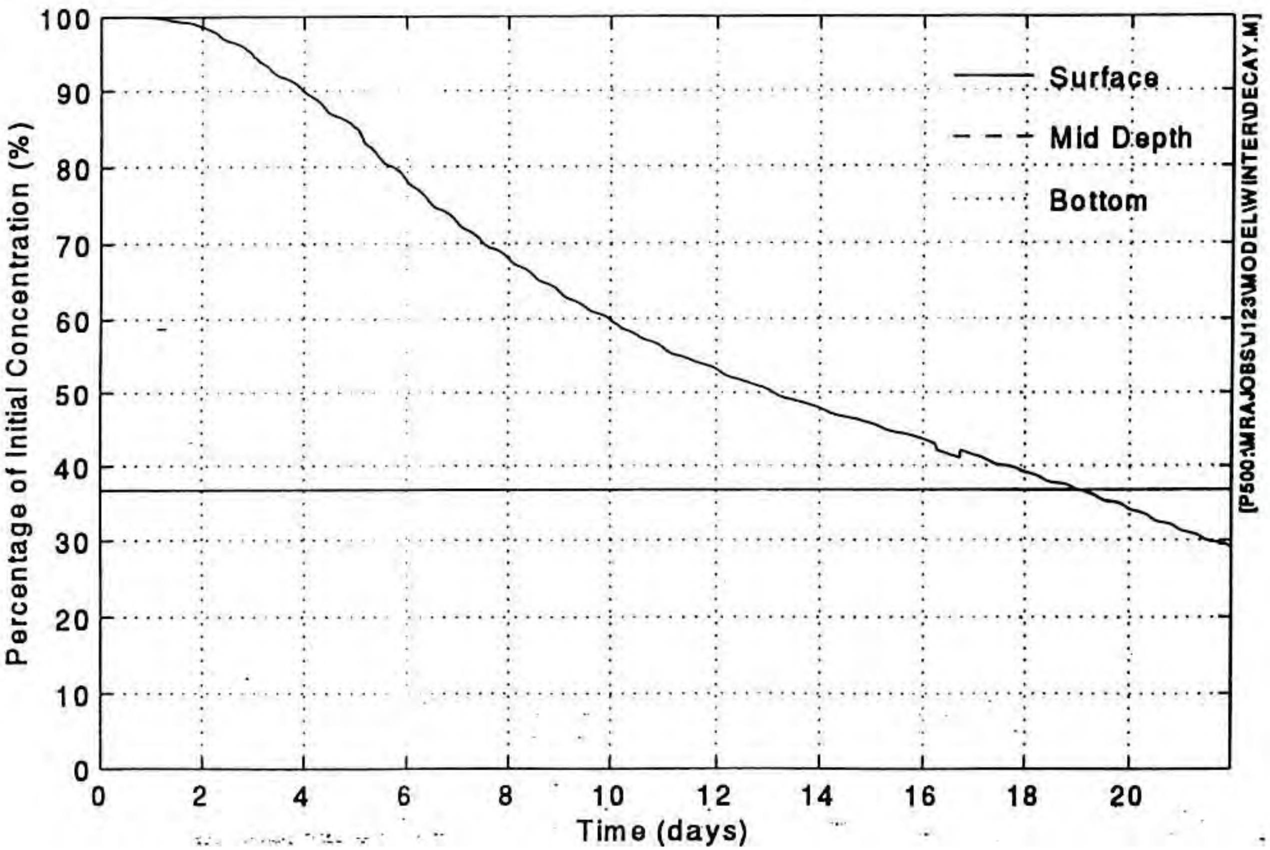
Coral Coast Resort – Summer Case – Decay of Conservative Tracer at Location 10



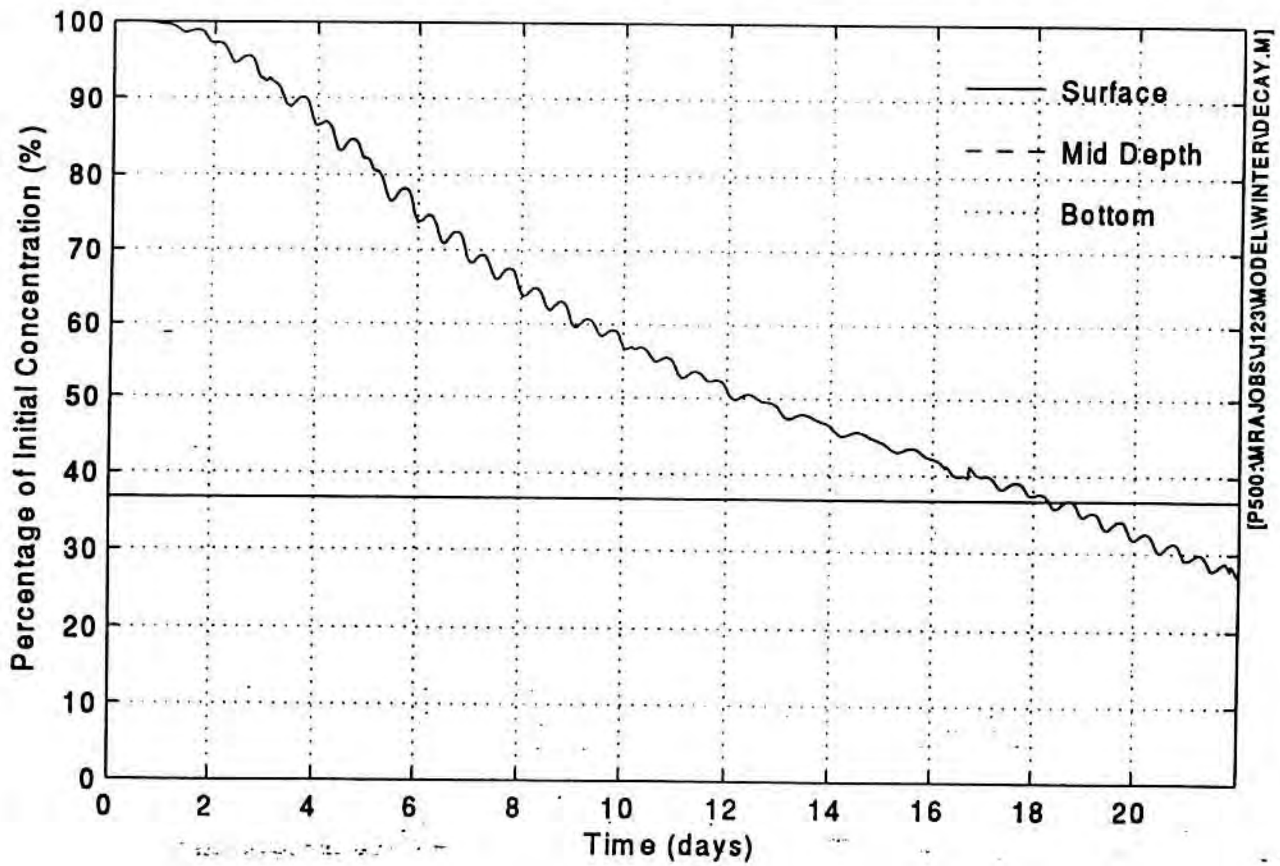
Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 1



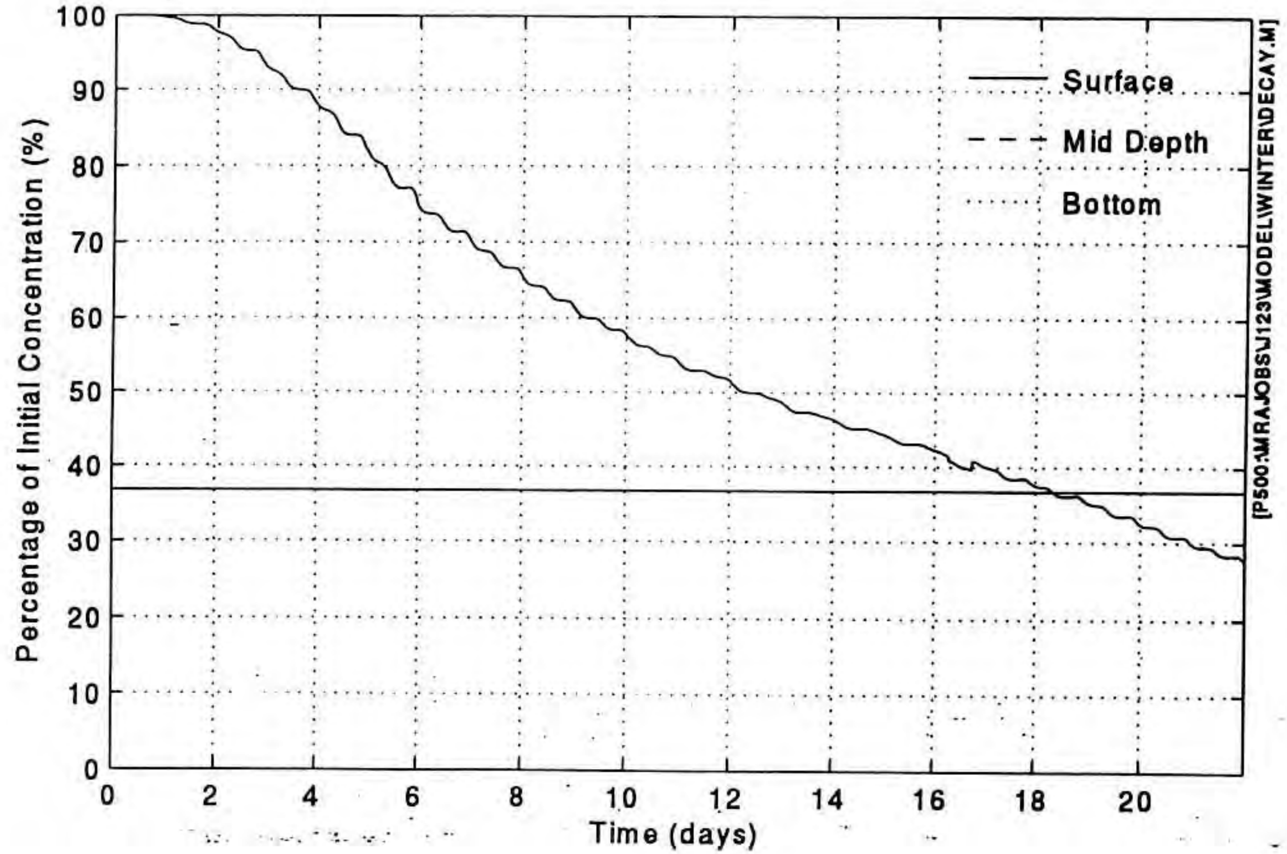
Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 2



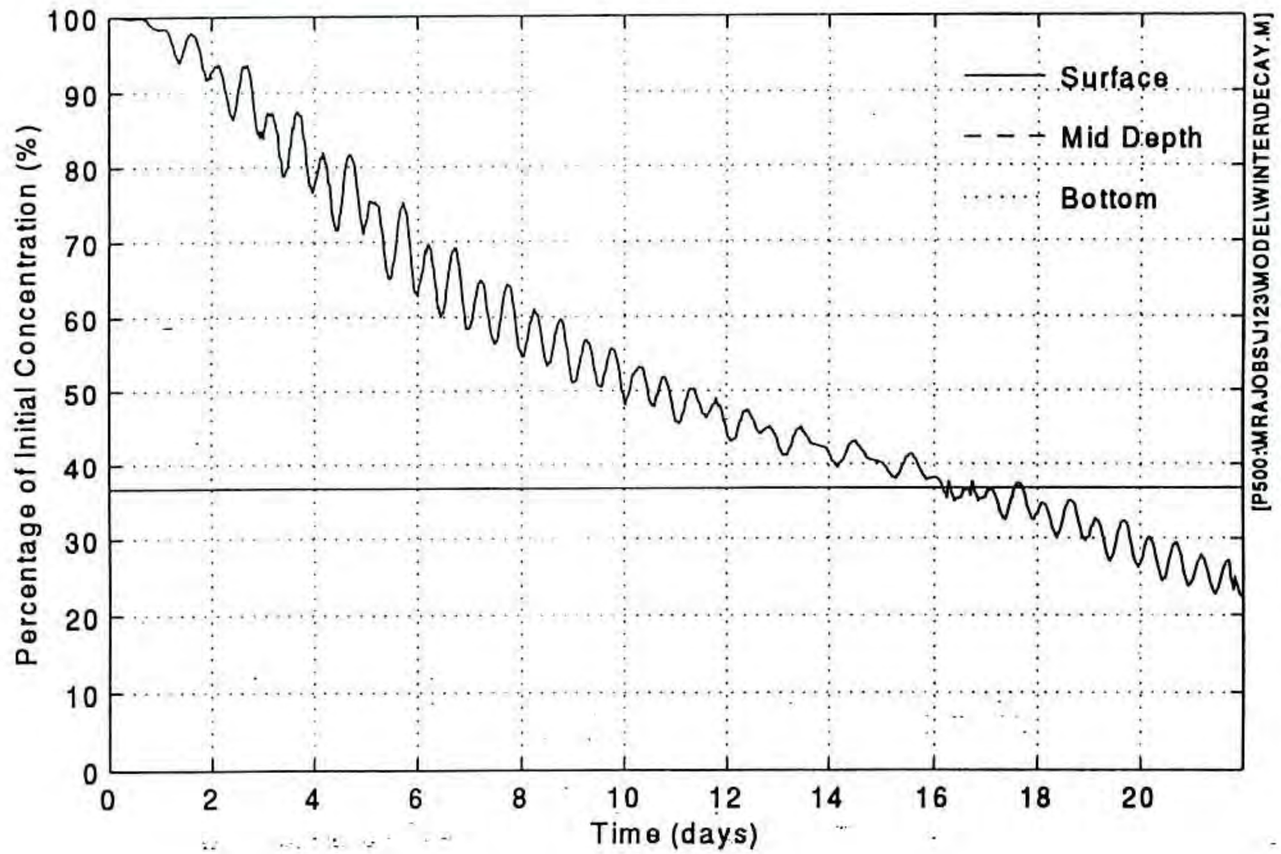
Coral Coast Resort - Winter Case - Decay of Conservative Tracer at Location 3



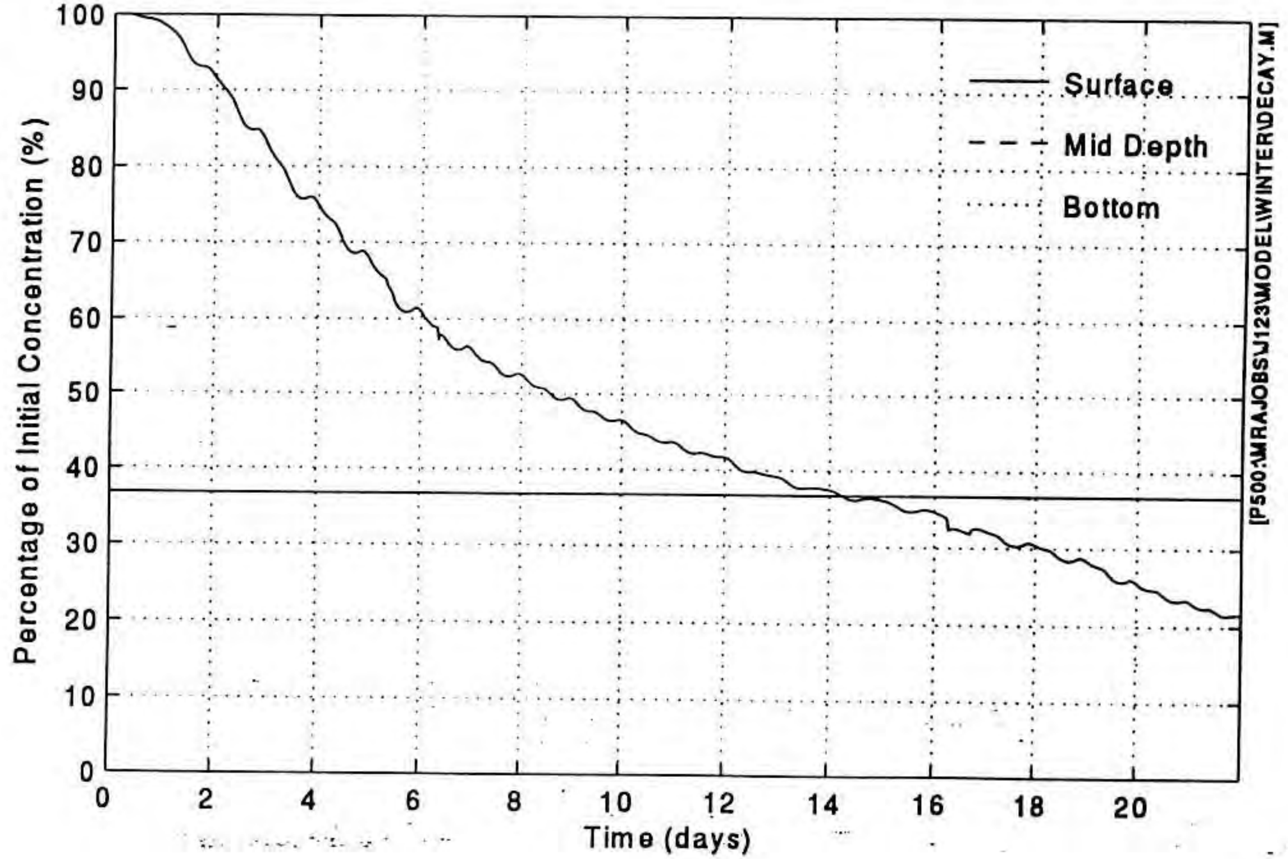
Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 4



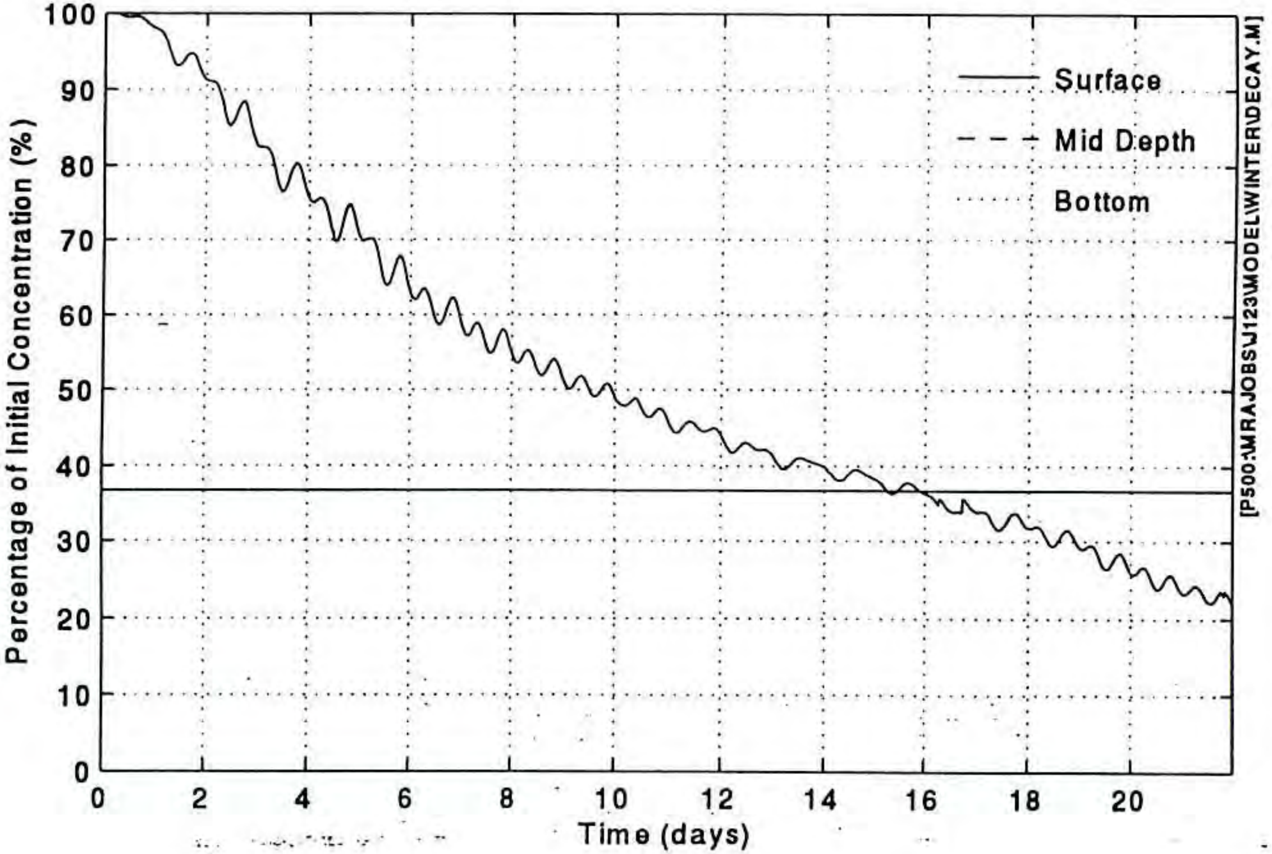
Coral Coast Resort - Winter Case - Decay of Conservative Tracer at Location 5



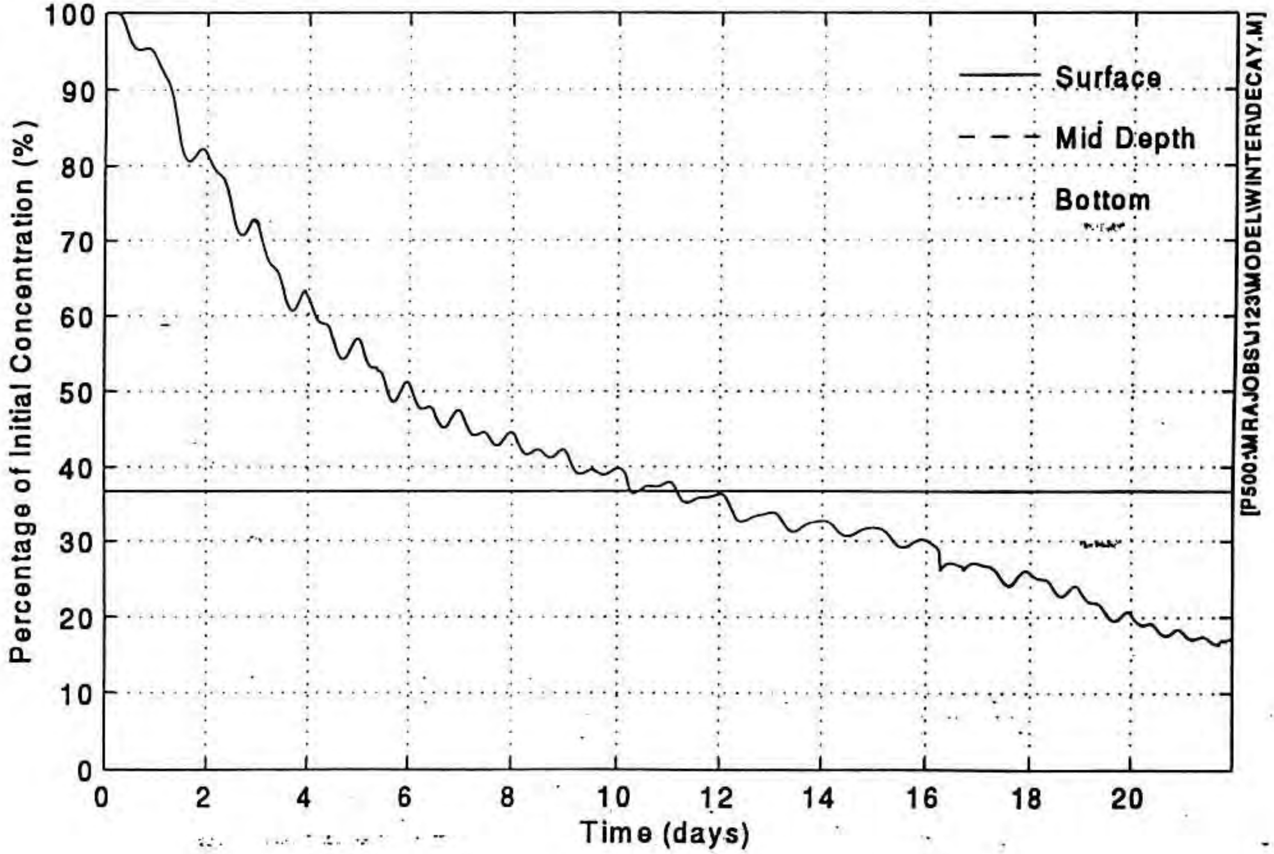
Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 6



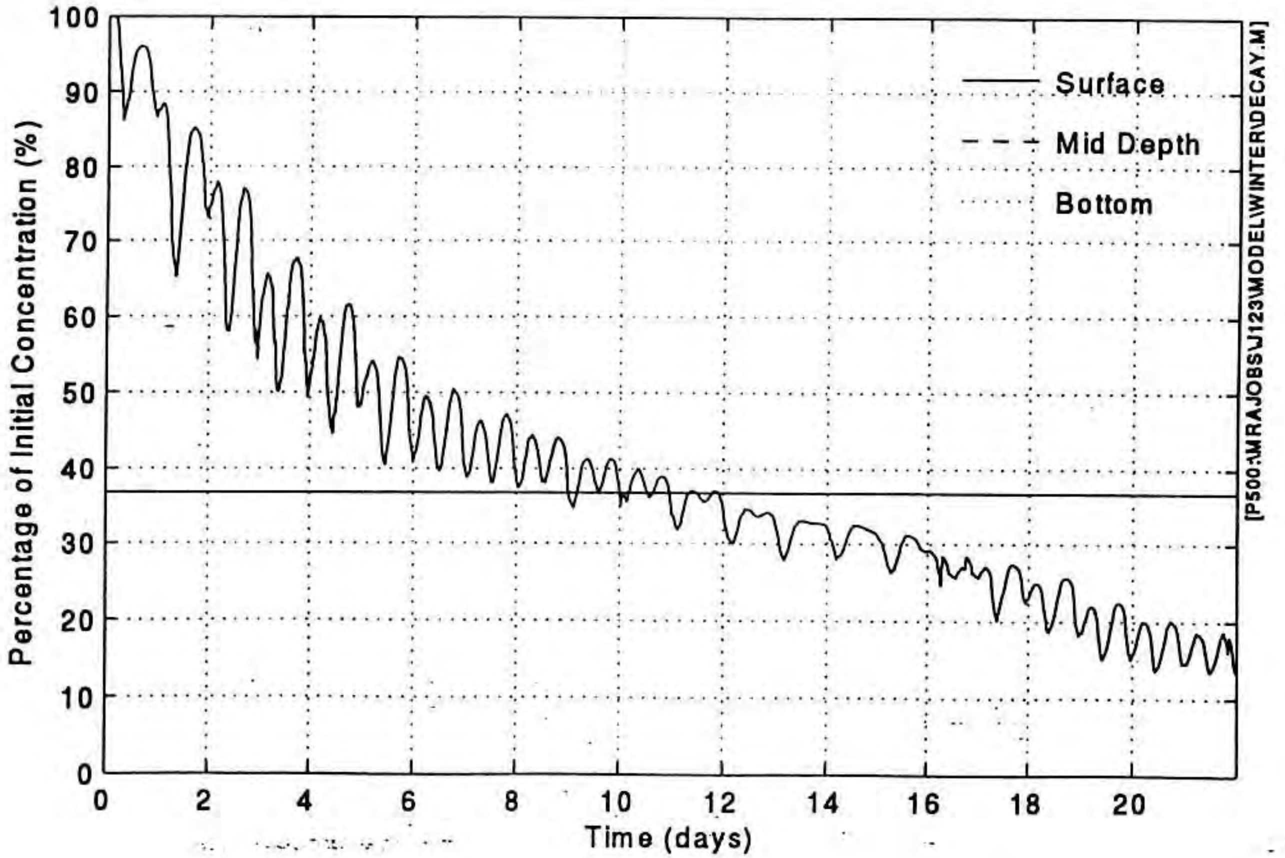
Coral Coast Resort - Winter Case - Decay of Conservative Tracer at Location 7



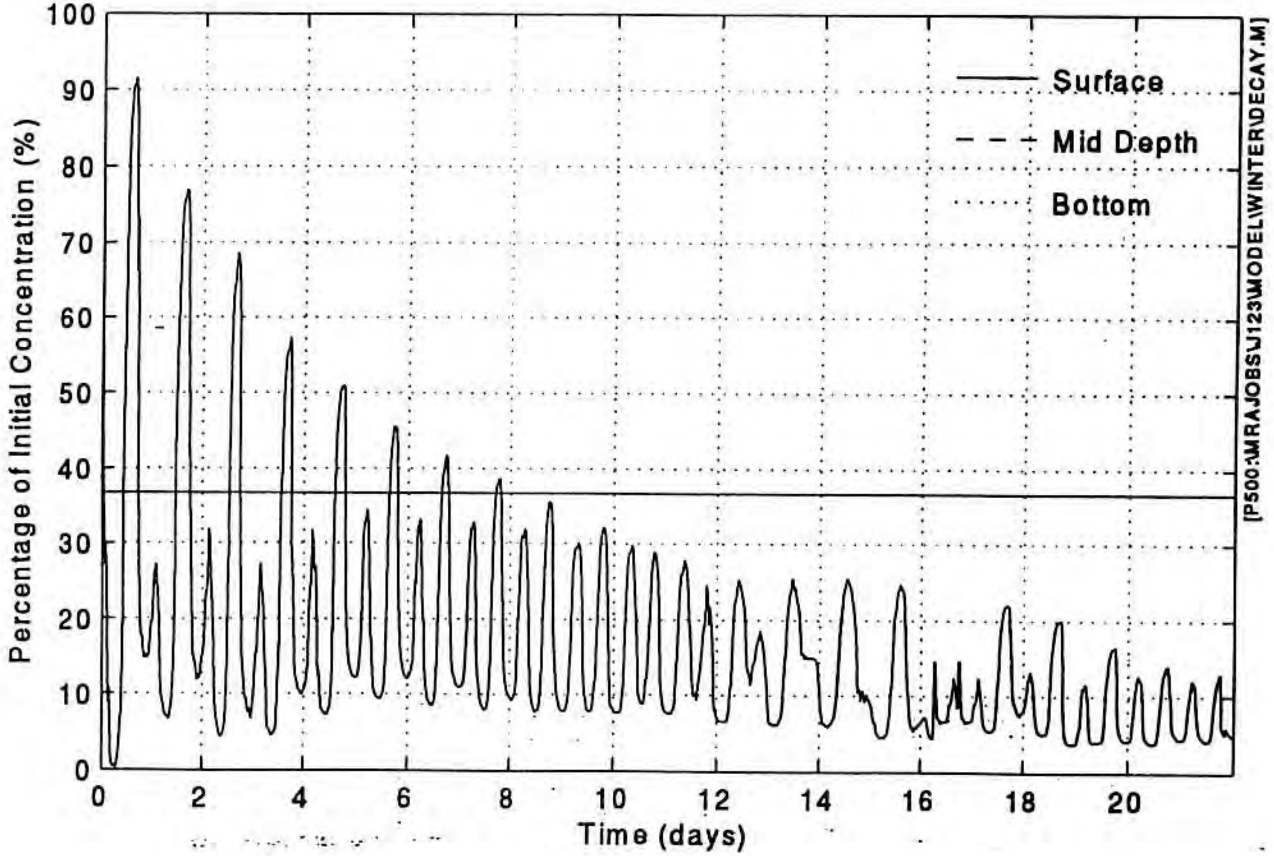
Coral Coast Resort - Winter Case - Decay of Conservative Tracer at Location 8



Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 9



Coral Coast Resort – Winter Case – Decay of Conservative Tracer at Location 10



APPENDIX 4

MAUDS LANDING BIOLOGICAL, MARINE WATER AND SEDIMENT QUALITY SURVEY, MAY 2000

CORAL COAST MARINA
DEVELOPMENT PTY LTD

MAUDS LANDING BIOLOGICAL, MARINE WATER AND SEDIMENT QUALITY SURVEY MAY 2000

FINAL REPORT

OCTOBER 2000

REPORT NO: 2000/147

DISCLAIMER

This document is published in accordance with and subject to an agreement between ATA Environmental **("ATA")** and the client for whom it has been prepared, Coral Coast Marina Development Pty Ltd **("Client")** and is restricted to those issues that have been raised by the client in its engagement of ATA and prepared using the standard of skill and care ordinarily exercised by Environmental Scientists in the preparation of such Documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by ATA and the Client without first obtaining the prior written consent of ATA, does so entirely at their own risk and ATA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this Document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

ATA Environmental has implemented a comprehensive range of quality control measures on all aspects of the company's operation and has Quality Assurance certification to ISO 9001.

An internal quality review process has been applied to each project task undertaken by us. Each document is carefully reviewed by core members of the consultancy team and signed off at Director level prior to issue to the client. Draft documents are submitted to the client for comment and acceptance prior to final production.

Document No:	20057_062a_pc	
Report No:	2000/147	
Report Status:	Final	
Checked by:	D. Neilson	Date: 16 October, 2000
Approved by:	H. van der Wiele	Date: 16 October, 2000

TABLE OF CONTENTS

1. INTRODUCTION 1

2. BIOLOCIAL SURVEY 2

2.1 Introduction 2
2.2 Methodology 2
2.3 Results 2
2.3.1 Shoreline Reef Platforms 2
2.3.2 Sandy Beaches 2
2.3.3 Sub-Tidal Limestone Pavement 3
2.3.4 Shallow Sub-Tidal Sand Platforms 3
2.3.5 Sand Basins 3
2.3.6 Coral Reef Communities 3
2.3.7 Seaward Reef Platform 4
2.4 Discussion 4

3. MARINE WATER AND SEDIMENT SAMPLING AND ANALYSIS 5

3.1 Sample Locations and Parameters 5
3.2 Sampling Methodology 6
3.3 Analysis of Samples 6
3.4 Assessment Criteria 6
3.4.1 Marine Waters Assessment Criteria 6
3.4.2 Sediment Assessment Criteria 7
3.4.3 Explanation of Environmental Quality Objectives 9

4. MARINE WATER AND SEDIMENT SURVEY RESULTS 10

4.1 Marine Waters 10
4.2 Marine Sediments 11
4.3. Discussion 13

5. ASSESSMENT CRITERIA FOR FUTURE MONITORING 14

5.1 Overview 14
5.2 Water Quality Criteria 14
5.3 Sediment Quality Criteria 14

6. CONCLUSIONS 17

REFERENCES 18

LIST OF FIGURES

Figure 1 Study Area and Habitat Sampling Locations

Figure 2 Marine Habitats of the Mauds Landing, Coral Bay Area

LIST OF APPENDICES

Appendix 1 Marine Habitat Survey of the Mauds Landing Region

Appendix 2 Chain of Custody Records

Appendix 3 Laboratory Certificates

1. INTRODUCTION

The Ningaloo Marine Park is generally considered to be in a pristine condition, yet there is little available data on the marine water and sediment quality. The best data is available from the results of a Department of Environmental Protection (DEP) survey in 1994-95 which was focussed on Coral Bay and the Surrounding Bill's Bay (DEP, 1995).

The DEP undertook an assessment of water and sediment quality in Bills Bay and Mauds Landing in response to concerns from the local community regarding nutrient enrichment and possible microbiological contamination (DEP 1995). The report concluded that the elevated concentrations of inorganic nitrogen and faecal coliforms in the groundwater along the shoreline of Bills Bay and adjacent marine waters, was likely sourced from groundwaters contaminated by sewage. This had the effect of increasing nutrient concentrations in nearshore waters increasing phytoplankton biomass, light attenuation through the water profile, and macro algae within the bay.

The results of heavy metal and organotin analyses indicated elevated levels of arsenic, chromium, iron, manganese and zinc relative to other sites at Mauds Landing, and extremely high levels of tributyltin (TBT) close to mooring locations within Bills Bay. DEP (1995) noted that TBT was an issue as the extreme toxicity of this chemical was hazardous to a range of marine flora and fauna.

Biological information on the marine habitats of the Maud's Landing region is already available from a habitat map BBG (1995) extending from Monks Head (2km south of Coral Bay) to approximately 12km north of Point Maud and from CALM regional habitat mapping (CALM, unpublished data).

There are some differences in habitat type and distribution between the above two sources. For this reason, and to confirm the distribution of habitats and describe the major biota in each habitat, a brief survey of marine habitats was conducted for the Maud's Landing project in May 2000. This survey also provided the opportunity to undertake marine water and sediment sampling to provide additional data on water and sediment quality parameters in the region.

This document outlines the results of the May 2000 field survey.

2. BIOLOCIAL SURVEY

2.1 Introduction

A brief survey of marine habitats was conducted for the Maud's Landing project in May 2000 to confirm the distribution of habitats and describe the major biota in each habitat. The survey extended from Monks Head in the south to Bruboodjoo Point in the north. The area surveyed extended to the 20m depth outside the barrier reef, but most emphasis was placed on the shallower waters inside the reef.

The objectives of the survey were to:

i) confirm the identity and distribution of the major habitat types;
ii) describe the major groups of biota for each habitat; and
iii) assess, if possible, the condition or 'health' of the areas surveyed.

2.2 Methodology

Surveys were conducted along a series of transects extending from the coast and running east-west across the lagoons to the outer edge of the barrier reef to approximately the 20m contour (Figure 1). Habitat types, major biota groups, and condition of the biota were assessed along these transects and related to aerial photographs of the area. A GPS was used for position fixing.

2.3 Results

Seafloor characteristics, major biota groups and other comments for the survey transects are shown in Appendix 1.

Comparison of the information in Appendix 1, together with aerial photographs and the BBG (1995) habitat map, suggests that the CALM habitat map could be refined to more accurately reflect the distribution of habitats in the area. Accordingly, a habitat map which incorporates information from all of the above sources is shown in Figure 2. The characteristics and distribution of each of the habitats is discussed below.

2.3.1 Shoreline Reef Platforms

These occur along much of the shoreline south of Coral Bay and from about 4km north of Maud's Landing. The platforms are colonised by algae at lower tidal levels and by a variety of invertebrate molluscs, worms, crustaceans and echinoderms, as well as fish during high tides.

2.3.2 Sandy Beaches

Sandy beaches occupy the remainder of the shoreline, principally about 7km north of Point Maud as well as areas around Bills Bay and to the south. The biota of the sandy beaches is not as diverse or abundant as some other habitats. The obvious components include ghost crabs, amphipods and other small crustaceans in algal and seagrass wrack, and burrowing bi-valves and other molluscs at lower tidal levels. The beaches also provide nesting sites for turtles.

2.3.3 Sub-Tidal Limestone Pavement

Exposed limestone pavement is colonised by macroalgae and occurs as a distinct habitat. This habitat is most common in a broad bank parallel to the shoreline commencing approximately 8km north of Point Maud and extending northwards. A veneer of sand of varying thickness, can cover part of this habitat, particularly depressions in the pavement. Occasionally, sparse seagrass (Amphibolis) occurs in this habitat and corals, usually small and scattered, occur on the higher pavement.

2.3.4 Shallow Sub-Tidal Sand Platforms

This habitat occurs in the shallow waters (<5m) to the south of Bills Bay where sand sheets cover the underlying limestone pavement, and throughout much of Bateman Bay, and the lagoon to the north. Generally, a layer of sand of various thickness overlies limestone pavement or old reef structures. The habitat is largely devoid of surface biota such as algae or seagrass, and most of the fauna consists of burrowing in fauna including starfish. High numbers of large starfish buried under the sand occur in some areas. Occasionally limestone pavement protrudes through the sand layer and is colonised by macroalgae.

2.3.5 Sand Basins

Much of the deeper (>5m) lagoon area in Bateman Bay and to the north consists of a sandy seafloor, probably overlying limestone pavement at the same depth. Much of this seafloor is devoid of vegetation but seagrasses (*Posidonia coriacea* and to a lesser extent *Halophila ovalis*) do occur in some areas. Mostly the seagrasses occur at low density. *Posidonia coriacea* generally occurs in small clumps and occupies a low proportion (1.5%) of the seafloor at those sites. However, an area where the *Posidonia coriacea* was more extensive, and formed a meadow was observed to the north of Bateman Bay. The exact limit of the seagrass distribution was difficult to determine because of the low density and small patch size of the seagrass.

Fauna in this habitat is principally infauna, and again burrowing starfish were observed at high density at some sites.

2.3.6 Coral Reef Communities

Coral reef communities occur extensively along the coastline. They include the outer barrier reef as well as lagoonal areas, and range from intertidal to subtidal.

The most extensive areas of coral occur in the lagoon forming Bills Bay and the areas to the south. Lagoonal coral communities are limited north of Point Maud and Cardabia Passage, with some areas of coral occurring along the inner edge of the barrier reef and other isolated patches elsewhere in the lagoon. Coral growth along the outer edge of the barrier reef, at the site visited for this survey, was extremely limited, although reef fish and other biota farming this community were abundant.

Coral growth in the Bill's Bay area has been subjected to severe damage in recent years. An outbreak of the coral eating snail. *Drupella* in the 1980s caused extensive damage throughout the region. Subsequently, deoxygenation following spawning of corals in 1989 caused heavy mortality of corals and associated fauna in the Coral Bay area. During this survey, the coral communities generally appeared healthy with new recruitment of corals in areas where damage had previously occurred. Damage to corals by *Drupella* was evident, but not at the scale seen in previous years.

2.3.7 Seaward Reef Platform

The seaward reef platform occurs outside the barrier reef and was largely beyond the scope of this survey. It appears to consist of a sloping limestone pavement seafloor, with sand patches forming in the depressions in the pavement.

2.4 Discussion

Habitat mapping is useful in identifying high priority environmental areas. The habitats which have the highest environmental importance are:

i) the coral reef communities;
ii) the limestone pavement with macroalgae; and
iii) seagrass.

The coral reef communities are the most environmentally significant. They have extremely high productivity, very high biodiversity and make this region unique. The most important area is to the south (and west) of Pt Maud including Bill's Bay and the areas further south. Other coral areas occur to the north along the barrier reef, and as some isolated patches in the lagoon to the north of Point Maud.

Limestone pavement with macroalgae is an important habitat for primary productivity and biodiversity. The largest area of this habitat occurs 1.2km west of Point Maud.

Seagrass is the least important of these three habitats within this area. The seagrass generally occurs sporadically and at low density (1% to 5% of seafloor cover).

Most of the sandy seafloor in the area is devoid of seagrass.

Much of the lagoon area enclosed by the barrier north of Point Maud has a sandy seafloor. This is an area of low primary productivity and low biodiversity. It has a low environmental priority.

3. MARINE WATER AND SEDIMENT SAMPLING AND ANALYSIS

The Department of Environmental Protection survey in 1994-95 that focussed on Coral Bay and the Surrounding Bill's Bay (DEP, 1995) identified that nutrients, some metals and TBT were elevated in sediments adjacent to the Coral Bay settlement and the old Mauds Landing jetty.

A field survey for the Coral Coast Resort project was conducted in May 2000 to collect additional data on water and sediment quality parameters in the region. The following section details the sampling and analysis methodology used during this field survey.

3.1 Sample Locations and Parameters

The locations of the sample sites are shown in Figure 1. The water and sediment quality parameters that were recorded at each site are shown in Table 1. The balance of samples collected have been retained for analysis should the project proceed.

TABLE 1
SAMPLE PARAMETERS AND SITES

Sample Type	Parameter	Sample Sites
Marine Water	Metals: Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc Total Petroleum Hydrocarbons (TPH) Polycyclic Aromatic Hydrocarbons (PAH)	ML2, ML3, ML7B, ML9S, ML17, ML20, ML25
	Nutrients: Ammonium Nitrogen Nitrate Nitrogen Nitrite Nitrogen Total Kjeldahl Nitrogen Filterable Reactive Phosphorus	ML2, ML3, ML5, ML7B, ML7S, ML9B, ML9S, ML11B, ML11S, ML12, ML14, ML15B, ML15S, ML16B, ML16S, ML17, ML20, ML24B, ML24S, ML25
Marine Sediments	Metals: Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc Polycyclic Aromatic Hydrocarbons (PAH)	ML2, ML3, ML7, ML17, ML25
	Nutrients: Ammonium Nitrogen Nitrate Nitrogen Nitrite Nitrogen Total Kjeldahl Nirtogen Reactive Phosphorus Total Phosphorus Organochlorine Pesticides Organotins (including TBT)	

3.2 Sampling Methodology

The collection and assessment of sediment samples was conducted in accordance with Australian Standard 5667.12 Water Quality – Sampling, Part 12: *Guidance on Sampling of Bottom Sediments* where appropriate. All diving operations were supervised to ensure the maximum level of safety and to conform to the required Australian Standards and WorkSafe conditions.

The collection of water quality samples and measurement of water quality parameters is in accordance with Australian Standard AS/NZ55667.1:1998 Part 1: *Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples* and AS/NZ55667.9:1998 Part 9: *Guidance on Sampling from Marine Waters.*

Once the sample containers were filled, each container was capped and placed in the sample esky containing ice and transported to the laboratory for analysis. Chlorophyll 'a' samples were filtered *in-situ* and the filter placed in a darkened container and stored on ice. Containers were unambiguously marked in a clear and durable manner to permit clear identification of all samples in the laboratory.

3.3 Analysis of Samples

Samples were analysed by a NATA (National Association of Testing Authorities) certified laboratory and in accordance with the relevant analysis protocols.

The analytical results for the sediment and water quality sampling sites are presented in Section 3. The Chain of Custody forms and laboratory certificates are included in Appendices 2 and 3.

3.4 Assessment Criteria

3.4.1 Marine Waters Assessment Criteria

The water quality parameters were selected from the list of Environmental Quality Criteria provided in the Southern Metropolitan Coastal Waters Study (DEP, 1996), and based on known potential contaminants likely to occur as a result of development at Mauds Landing. Relevant criteria and guidelines provided within the draft Western Australian Water Quality Guidelines for Fresh and Marine Waters (EPA, 1993) are applied where no criteria is provided in the 1996 report.

The criteria to be used for assessment of these parameters are the relevant Environmental Quality Criteria for the Maintenance of Ecosystem Integrity in Multiple Use Zones (EQO 2, Class I and Class II) (DEP, 1996). Relevant criteria and guidelines provided within the draft Western Australian Water Quality Guidelines for Fresh and Marine Waters (EPA, 1993) are applied where no criteria is provided in the 1996 report.

TABLE 2
SUMMARY OF MARINE WATERS QUALITY CRITERIA

Sample Description	Units	EQO 2, Class I[1]	EQO 2, Class II[2]	EPA Marine Water[3]
Metals				
Arsenic	ug/L	No discernible change	50	50
Cadmium	ug/L		2.0	2
Chromium	ug/L		50.0	50
Copper	ug/L		5.0	5
Lead	ug/L		5.0	5
Mercury	ug/L		0.1	0.1
Nickel	ug/L		15.0	15
Zinc	ug/L		20.0	20
Organic Toxicants				
Pesticides		No discernible change		
Aldrin	ug/L		0.002	0.002
Dieldrin	ug/L		0.002	0.002
Chlordane	ug/L		0.004	0.004
DDE	ug/L		0.014	0.014
DDT	ug/L		0.0005	0.0005
Total Heptachlor	ug/L		0.0003	0.0003
Chlorpyrifos	ug/L		0.001	0.001
Lindane	ug/L		0.003	0.003
Demeton-S-methyl	ug/L		0.1	0.1
TOTAL	ug/L		NR	NR
Total TPH	ug/L		10.0	10
Total PAH	ug/L		3.0	NR
Other				
pH	(-)	No discernible change	NR	<0.2 unit change
Conductivity	(mS/cm)		NR	<10% change seasonal mean
Nitrate	μg/L		NR	10 – 60
Nitrite	μg/L		NR	NR
Ammonia	μg/L		NR	<5
TKN	μg/L		NR	NR
Total N	μg/L		NR	NR
Filterable Reactive Phosphorus	μg/L		NR	1-10
Total P	μg/L		NR	NR
Chlorophyll-a	μg/L		NR	0.8
Phaeophytins	μg/L		NR	NR

NR No recommendation at this time.
1 Taken from Maintenance of Ecosystem Integrity (EQO 2, Class I) (DEP,1996)
2 Taken from Maintenance of Ecosystem Integrity (EQO 2, Class II) (DEP,1996)
3 Taken from Draft WA Water Quality Guidelines for Marine and Fresh Waters (EPA, 1993)

3.4.2 Sediment Assessment Criteria

The parameters monitored in the sediments were selected from the list of Environmental Quality Criteria in Southern Metropolitan Coastal Waters Study (DEP, 1996).

These criteria are summarised in Table 3.

TABLE 3
SUMMARY OF SEDIMENT QUALITY CRITERIA

Analyte	Units	Criteria 1[a]	Criteria 2[b]	Criteria 3[c]	Criteria 4[d]	Criteria 5[e]
Metals[1]						
Arsenic	mg/kg	No discernible change	8.2	0.2-30	20	30
Cadmium	mg/kg		1.2	0.04-2	3	5
Chromium	mg/kg		81	0.5-110	50	250
Copper	mg/kg		34	1-190	60	100
Lead	mg/kg		46.7	<2-200	300	150
Mercury	mg/kg		0.15	0.001-0.1	1	2
Nickel	mg/kg		20.9	2-400	60	100
Zinc	mg/kg		150	2-180	200	500
Organic Toxicants[1]						
Polycyclic Aromatic Hydrocarbons	mg/kg	No discernible change	4.022	0.95-5	NR	NR
Total DDT	mg/kg		0.0016	<0.001-0.97	NR	0.5
Dieldrin	mg/kg		NR	<0.005-<0.05	0.2	0.5
Individual Organochlorine Pesticides	mg/kg		NR	NR	NR	0.5
Total Organochlorine Pesticides	mg/kg		NR	NR	NR	1
Polychlorinated Biphenyls	µg/kg		22.7	20-100	100	100
Tributyl Tin	µg/kg		10	NR	NR	NR
Nutrients						
Ammonium Nitrogen	-	No discernible change	NR	NR	NR	NR
Nitrate Nitrogen	-		NR	NR	NR	NR
Nitrite Nitrogen	-		NR	NR	NR	NR
Total Kjeldahl Nitrogen	-		NR	NR	NR	NR
Reactive Filterable Phosphorus	-		NR	NR	NR	NR
Total Phosphorous	-		NR	NR	NR	NR

NR No recommendation at this time.
a Taken from Maintenance of Ecosystem Integrity – Multiple Use Zones (EQO 2, Class I) (DEP, 1996).
b Taken from Maintenance of Ecosystem Integrity – Industrial Buffer Zones (EQO 2, Class II) (DEP, 1996).
c Taken from Background (A) values (ANZECC/NHMRC, 1992).
d Taken from Environmental Investigation (B) values (ANZECC/NHMRC, 1992).
e Taken from Dutch 'B' criteria.

The assessment criteria do not specify any criteria for assessing the levels of the nutrients. However, the Draft Sediment Quality Guidelines (ANZECC & ARMCANZ, 1999) note that it is important to monitor the amount of nutrients as they represent a threat to benthic communities. The level of nutrients in the marine sediments of Perth coastal waters (DEP, 1996), and those recorded at Coral Bay during the earlier DEP survey (DEP, 1995), are used to provide a comparison.

Parameters for which no guideline levels are provided will be assessed by examining concentration trends.

3.4.3 Explanation of Environmental Quality Objectives

In a recent review of marine waters along the Perth southern metropolitan coastline, the Department of Environmental Protection (DEP, 1996) has suggested a range of Environmental Quality Objectives (EQO) for various parts of the marine environment. The EQO specify limits for metals, hydrocarbons, pesticides and other substances which should not be exceeded.

The level of these limits depends on the use and value of each particular marine area. The various EQO and their applications are:

- EQO 1 – Maintenance of Biodiversity
- EQO 2 – Maintenance of Ecosystem Integrity
  Class I – Conservation Zone
  Class II – Multiple Use Zone
  Class III – Industrial Buffer Zone
- EQO 3 – Maintenance of Aquatic Life (including molluscs) for Human Consumption
- EQO 4 – Maintenance of Recreational Values
- EQO 5 – Maintenance of Aesthetic Values

Designated exclusion zones are where some or all of the EQO do not apply also exist.

Criteria for EQO 1 and EQO 2 Class 1, that there be no change from the natural state, would be appropriate for areas of Bateman Bay beyond an initial mixing zone at the entrance channel to the marina. In relation to nutrients, and in consideration of the natural variation on nutrient levels, it is considered that this requirement is met at all times. The DEP (1996) also note that a concentration-based approach to nutrient management in isolation is inappropriate for marine ecosystems because of the confounding influence of nutrient uptake. Notwithstanding nutrient levels can be indicative of existing sources and, when considered in relation to spatial distributions, can indicate contributing sources. Implementation of the monitoring component in the Specific Area Marine Management Plan (SAMMP) for the Maud Specific Management Area (MSMA) will include consideration of spatial and temporal variation on nutrient levels of the nearshore marine area.

4. MARINE WATER AND SEDIMENT SURVEY RESULTS

4.1 Marine Waters

The results of analyses of marine waters are shown in Tables 4A to 4C.

The concentrations of metals, Total Petroleum Hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (total) are all substantially below the criteria required for high protection of marine environments (Table 3.5.4 of DEP, 1996).

Nitrogen concentrations (nitrate and total) and phosphate concentrations (total phosphorus and reactive phosphorus) are extremely low and similar to that observed at Coral Bay (DEP, 1995) previously.

TABLE 4A
MARINE WATER QUALITY (µg/L)

Sample Site	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	TPH (as n-alkanes)
ML2	1	<0.05	<1	0.8	1.6	<0.1	1.2	1.6	<10
ML3	1	0.05	<1	0.2	0	<0.1	0.4	0.5	<10
ML7B	3	<0.05	<1	0.3	<0.1	<0.1	0.4	0.28	<10
ML9S	5	0.1	<1	0.1	0.3	<0.1	0.2	<0.02	<10
ML17	1	<0.05	<1	0.2	0.4	<0.0001	0.3	0.15	<10
ML20	1	<0.05	<1	<0.1	0.4	<0.0001	<0.1	<0.02	<10
ML25	1	<0.05	<1	<0.1	0.4	<0.0001	0.4	0.1	<10
ASSESSMENT CRITERIA									
EQO2	50	2	50	5	5	0.1	5	0	10

TABLE 4B
MARINE WATER QUALITY (µg/L)

Sample Site	Naphthalene	2-methylnaphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene	Benz[b]fluoranthene	Benz[k]fluoranthene	Benz[a]pyrene	Indeno[1,2,3-c,d]pyrene	Dibenz[a,h]anthracene	Benz[g,h,I]perylene	Total PAH's
ML2	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04
ML3	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09
ML7B	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
ML9S	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
ML17	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
ML20	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
ML25	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ASSESSMENT CRITERIA																		
EQO2	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3.0

TABLE 4C
MARINE WATER QUALITY (mg/L)

Sample Site	Ammonium Nitrogen	Nitrate Nitrogen	Nitrite Nitrogen	Total Kjeldahl Nitrogen	Total Phosphorus	Filterable Reactive Phosphorus	Chlorophyll a (µg/L)	Phaeophytins (µg/L)
ML2	<0.01	0.03	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML3	<0.01	0.01	<0.005	<0.02	<0.01	0.006	<0.02	<0.04
ML5	<0.01	0.02	<0.005	0.03	<0.01	0.006	<0.02	<0.04
ML7B	<0.01	0.007	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML7S	<0.01	0.01	<0.005	<0.02	<0.01	0.006	<0.02	<0.04
ML9B	<0.01	0.01	<0.005	<0.02	<0.01	0.006	<0.02	<0.04
ML9S	<0.01	0.008	<0.005	0.03	<0.01	<0.005	<0.02	<0.04
ML11B	<0.01	0.008	<0.005	0.04	<0.01	<0.005	0.03	<0.04
ML11S	<0.01	0.008	<0.005	0.03	<0.01	<0.005	<0.02	<0.04
ML12	<0.01	0.01	<0.005	0.03	<0.01	<0.005	<0.02	<0.04
ML14	<0.01	0.007	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML15B	<0.01	0.01	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML15S	<0.01	0.008	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML16B	<0.01	0.007	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML16S	<0.01	0.02	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML17	<0.01	0.01	<0.005	<0.02	0.01	<0.005	<0.02	<0.04
ML20	<0.01	0.01	<0.005	0.02	<0.01	<0.005	<0.02	<0.04
ML24B	<0.01	0.009	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML24S	<0.01	0.008	<0.005	<0.02	<0.01	<0.005	<0.02	<0.04
ML25	<0.01	0.005	<0.005	<0.02	<0.01	<0.005	0.02	<0.04
ASSESSMENT CRITERIA								
EPA	<0.005	0.01 – 0.06	NR	NR	NR	0.001-0.01	<1	NR

4.2 Marine Sediments

Total phosphorus and total nitrogen concentrations (Table 5) in the sediments were low and characteristic of the coarser carbonate, uncontaminated sediments of the coastal area offshore from Perth (DEP, 1996).

Metal concentrations were also generally low and less than the DEP (1996) criteria for high protection marine areas. Arsenic, cadmium, copper, lead, mercury, nickel and zinc were extremely low, and equivalent or lower than the previously recorded values at Coral Bay (DEP, 1995). Chromium concentrations were also low, but a few were higher than those previously observed at Coral Bay (DEP, 1995).

Organochlorine pesticides, PCBs, tributyltin (TBT) and polycyclic aromatic hydrocarbon concentrations were also at extremely low levels.

TABLE 5
MARINE SEDIMENTS

	ML2	ML3	ML7	ML17	ML20
Nutrients (mg/kg)					
Ammonium Nitrogen	<1	<1	<1	<1	<1
Nitrate Nitrogen	0.23	0.14	0.20	0.10	0.16
Nitrite Nitrogen	0.10	0.08	0.11	0.05	0.08
Total Kjeldahl Nitrogen	140	150	130	170	75
Reactive Filterable Phosphorus	0.7	1.2	5.9	4.7	2.4
Total Phosphorus	320	260	610	360	610
Metals (mg/kg)					
Arsenic	3	<1	<1	<1	<1
Cadmium	0.1	0.1	0.1	0.1	0.1
Chromium	11	5	3	30	29
Copper	<0.5	<0.5	<0.5	<0.5	<0.5
Lead	<0.5	<0.5	<0.5	<0.5	<0.5
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	1.0	0.5	1.5	1.0	1.5
Organochlorine Pesticides & PCB's (mg/kg)					
Aldrin	<0.001	<0.001	<0.001	<0.001	<0.001
Chlordane	<0.001	<0.001	<0.001	<0.001	<0.001
Chlorpyritos	<0.001	<0.001	<0.001	<0.001	<0.001
Dieldrin	<0.001	<0.001	<0.001	<0.001	<0.001
DDD	<0.001	<0.001	<0.001	<0.001	<0.001
DDE	<0.001	<0.001	<0.001	<0.001	<0.001
DDT	<0.001	<0.001	<0.001	<0.001	<0.001
Heptachlor	<0.001	<0.001	<0.001	<0.001	<0.001
HCB	<0.001	<0.001	<0.001	<0.001	<0.001
Linolene	<0.001	<0.001	<0.001	<0.001	<0.001
PCBs	<0.02	<0.02	<0.02	<0.02	<0.02
Organotin (μg/kg)					
Monobutyltin	<1	<1	<1	<1	<1
Dibutyltin	<1	<1	<1	<1	<1
Tributyltin	<1	<1	<1	<1	<1
PAHs (mg/kg)					
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
2-methylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[a]anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01
Benz[b]fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benz[k]fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benz[a]pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno[1,2,3-c,d]pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenz[a,h]anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Benz[g,h,I]perylene	<0.01	<0.01	<0.01	<0.01	<0.01
Total PAH's	<0.01	<0.01	<0.01	<0.01	<0.01

4.3. Discussion

The DEP (1995) recorded concentrations of some parameters, particularly heavy metals and tributyltin, that were elevated in Bills Bay and other nearby sites. During this survey, the concentrations of these parameters were less than the concentrations detected by the DEP and were as expected for a near pristine environment.

5. ASSESSMENT CRITERIA FOR FUTURE MONITORING

5.1 Overview

The proponent has committed to continue the marine water and sediment monitoring programs for a period of at least five years following structural completion of the development, followed by a review.

Concentration of water and sediment quality results will be compared to the following assessment criteria:

Criteria 1	From commencement of development until 5 Years after development in the Development Impact Area. Derived from baseline monitoring results.
Criteria 2	After 5 Years in the Development Impact Area, and from commencement of development until 5 Years after development in the Specific Management Area. Derived from EQO 2, Class II criteria.

5.2 Water Quality Criteria

Water quality criteria for the different monitoring locations are contained in Table 4. The background values observed during the baseline monitoring and the DEP (1995) survey have used provide specific criteria for the EQO I criteria from the Southern Metropolitan Coastal Waters Study (DEP, 1996). The water quality assessment criteria proposed for the duration of the monitoring programs are summarised in Table 6.

5.3 Sediment Quality Criteria

Sediment quality criteria for the different monitoring locations are contained in Table 5. The background values observed during the baseline monitoring and the DEP (1995) survey have used provide specific criteria for the EQO I criteria from the Southern Metropolitan Coastal Waters Study (DEP, 1996). The sediment assessment criteria proposed for the duration of the monitoring programs are summarised in Table 7.

TABLE 6
SUMMARY OF MARINE WATER QUALITY BACKGROUND VALUES AND ASSESSMENT CRITERIA

Analyte	Units	Sept/Oct 1994[a]		May 2000		Proposed Criteria 1	Criteria 2[b]	EPA Marine Water[c]
		Range	Average	Range	Average			
Metals								
Arsenic	ug/L	-	-	1-5	1.86 (n=7)	5.0	50	50
Cadmium	ug/L	-	-	0.05-0.1	0.08 (n=7)	0.1	2.0	2
Chromium	ug/L	-	-	<1	<1 (n=7)	1.0	50.0	50
Copper	ug/L	-	-	0.1-0.8	0.32 (n=7)	0.8	5.0	5
Lead	ug/L	-	-	<0.1-1.6	0.52 (n=7)	1.6	5.0	5
Mercury	ug/L	-	-	<0.0001-<0.1	(n=7)	<0.1	0.1	0.1
Nickel	ug/L	-	-	0.2-1.2	0.48 (n=7)	12	15.0	15
Zinc	ug/L	-	-	0.1-1.6	0.53 (n=7)	16	20.0	20
Organic Toxicants								
Total TPH	ug/L	-	-	<10	<10 (n=7)	<10	10.0	10
Total PAH	ug/L	-	-	<0.01-0.09	0.04 (n=7)	0.09	3.0	NR
Other								
Nitrate	µg/L	4-9	4.9 (n=27)	5-30	10 (n=20)	30	NR	10 – 60
Nitrite	µg/L			<5	<5 (n=20)	<5	NR	NR
Ammonia	µg/L	3-12	7.5 (n=27)	<10	<10 (n=20)	12	NR	<5
TKN	µg/L	23-73	40 (n=27)	<20-40	<20 (n=20)	73	NR	NR
Filterable Reactive Phosphorus	µg/L	9-28	17 (n=27)	<5-6	1.2 (n=20)	10	NR	1-10
Total P	µg/L	13-32	20 (n=27)	<10-10	<10 (n=20)	32	NR	NR
Chlorophyll-a	µg/L	0.07-0.28	0.15 (n=27)	<0.02-0.03	0.0025 (n=20)	0.28	NR	0.8
Phaeophytins	µg/L	-	-	<0.04	<0.04 (n=20)	<0.04	NR	NR

Notes:

a From DEP (1995)

b Taken from Maintenance of Ecosystem Integrity (EQO 2, Class II) (DEP,1996)

c From Draft WA Water Quality Guidelines for Marine and Fresh Waters (EPA, 1993). Included for comparison only.

TABLE 7
SUMMARY OF SEDIMENT QUALITY BACKGROUND VALUES AND ASSESSMENT CRITERIA

Analyte	Units	Sept/Oct 1994[1]		May 2000		Proposed Criteria 1	Criteria 2[b]	Criteria 3[c]	Criteria 4[d]	Criteria 5[e]
		Range	Average	Range	Average					
Metals										
Arsenic	mg/kg	-	-	<1-3	0.6	3.0	8.2	0.2-30	20	30
Cadmium	mg/kg	-	-	0.1	0.1	0.1	1.2	0.04-2	3	5
Chromium	mg/kg	-	-	3-30	15.6	30	81	0.5-110	50	250
Copper	mg/kg	-	-	<0.5	<0.5	<0.5	34	1-190	60	100
Lead	mg/kg	-	-	<0.5	<0.5	<0.5	46.7	<2-200	300	150
Mercury	mg/kg	-	-	<0.01	<0.01	<0.01	0.15	0.001-0.1	1	2
Nickel	mg/kg	-	-	<0.5	<0.5	<0.5	20.9	2-400	60	100
Zinc	mg/kg	-	-	0.5-1.5	1.1	1.5	150	2-180	200	500
Organic Toxicants										
PAHs	mg/kg	-	-	<0.01	<0.01	<0.01	4.022	0.95-5	NR	NR
Total DDT	mg/kg	-	-	<0.001	<0.001	<0.001	0.0016	<0.001-0.97	NR	0.5
Dieldrin	mg/kg	-	-	<0.001	<0.001	<0.001	NR	<0.005-<0.05	0.2	0.5
Individual Organochlorine Pesticides	mg/kg	-	-	<0.001	<0.001	<0.001	NR	NR	NR	0.5
Total Organochlorine Pesticides	mg/kg	-	-	<0.001	<0.001	<0.001	NR	NR	NR	1
PCB's	µg/kg	-	-	<20	<20	<20	22.7	20-100	100	100
Tributyl Tin	µg/kg	-	-	<1	<1	<1	10	NR	NR	NR
Other										
Ammonium-N	mg/kg	-	-	<1	<1	<1	NR	NR	NR	NR
Nitrate-N	mg/kg	-	-	0.1-0.23	0.17	0.23	NR	NR	NR	NR
Nitrite-N	mg/kg	-	-	0.05-0.11	0.08	0.11	NR	NR	NR	NR
TKN	mg/kg	100-500	260	75-170	133	500	NR	NR	NR	NR
Reactive Filterable Phosphorus	mg/kg	-	-	0.7-5.9	2.9	5.9	NR	NR	NR	NR
Total Phosphorous	mg/kg	60-540	230	260-610	432	610	NR	NR	NR	NR

NR No recommendation at this time.
a From DEP (1995)
b Taken from Maintenance of Ecosystem Integrity – Industrial Buffer Zones (EQO 2, Class II) (DEP, 1996).
c Taken from Background (A) values (ANZECC/NHMRC, 1992). Included for comparison only.
d Taken from Environmental Investigation (B) values (ANZECC/NHMRC, 1992). Included for comparison only.
e Taken from Dutch 'B' criteria. Included for comparison only.

6. CONCLUSIONS

The water and sediment quality survey provides data for the Mauds Landing region. The results of the May survey show that concentrations of nutrients in marine waters and sediments are extremely low.

Concentrations of potential contaminants (metals, hydrocarbons, PCBs, pesticides) are also extremely low. TBT concentrations, which are contained in some antifouling paints were again very low. The concentrations of all these potential contaminants were below the criteria suggested by the DEP for high protection of marine environments, and reflect an environment that is relatively pristine.

REFERENCES

ANZECC (1992) Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites. Australian and New Zealand Environment and Conservation Council and National Health and Medical Research Council, January 1992.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (1999) Draft Sediment Quality Guidelines. In: Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1. July 1999.

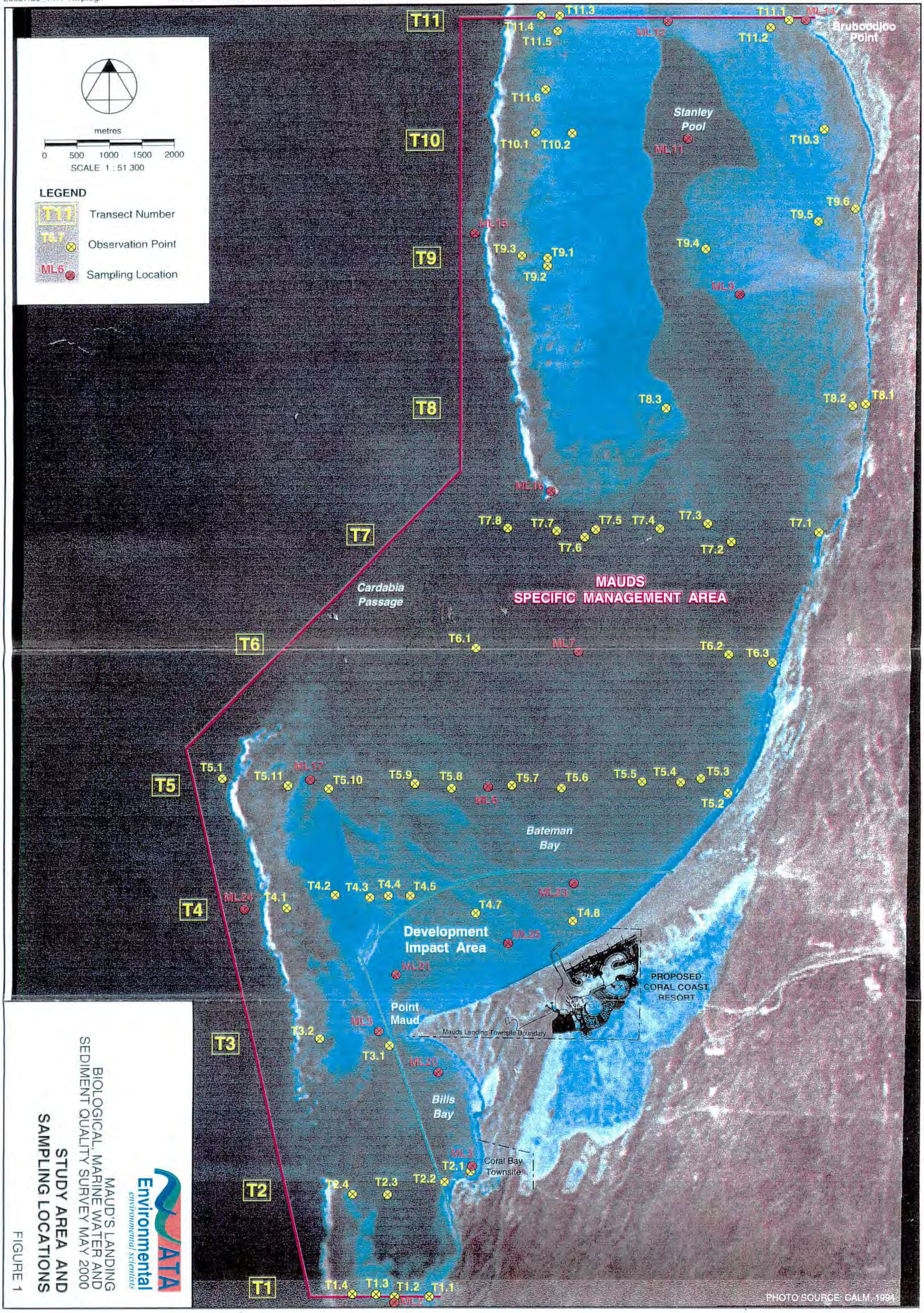
Assink, J W and van der Brink, W J (1986) Contaminated soil, First International TNO Conference on Contaminated Soil 11-15 November 1985, p399 – 405. The Netherlands Martinus Nijhoff Publishers, The Netherlands 1986.

Department of Environmental Protection (1995). Survey of Water Quality, Groundwater, Sediments and Benthic Habitats at Coral Bay, Western Australia. Technical Series No 80, Department of Environmental Protection November 1995.

Department of Environmental Protection (1996). Southern Metropolitan Coastal Waters Study (1991 - 1994). Report No. 17. Perth, Western Australia.

FIGURES

20057/20_147F1wrp.dgn DRAWN: HVW/GLM 3-11-00 CHECKED: HVW 3-11-00 PRINTED: Fri 03 Nov 00



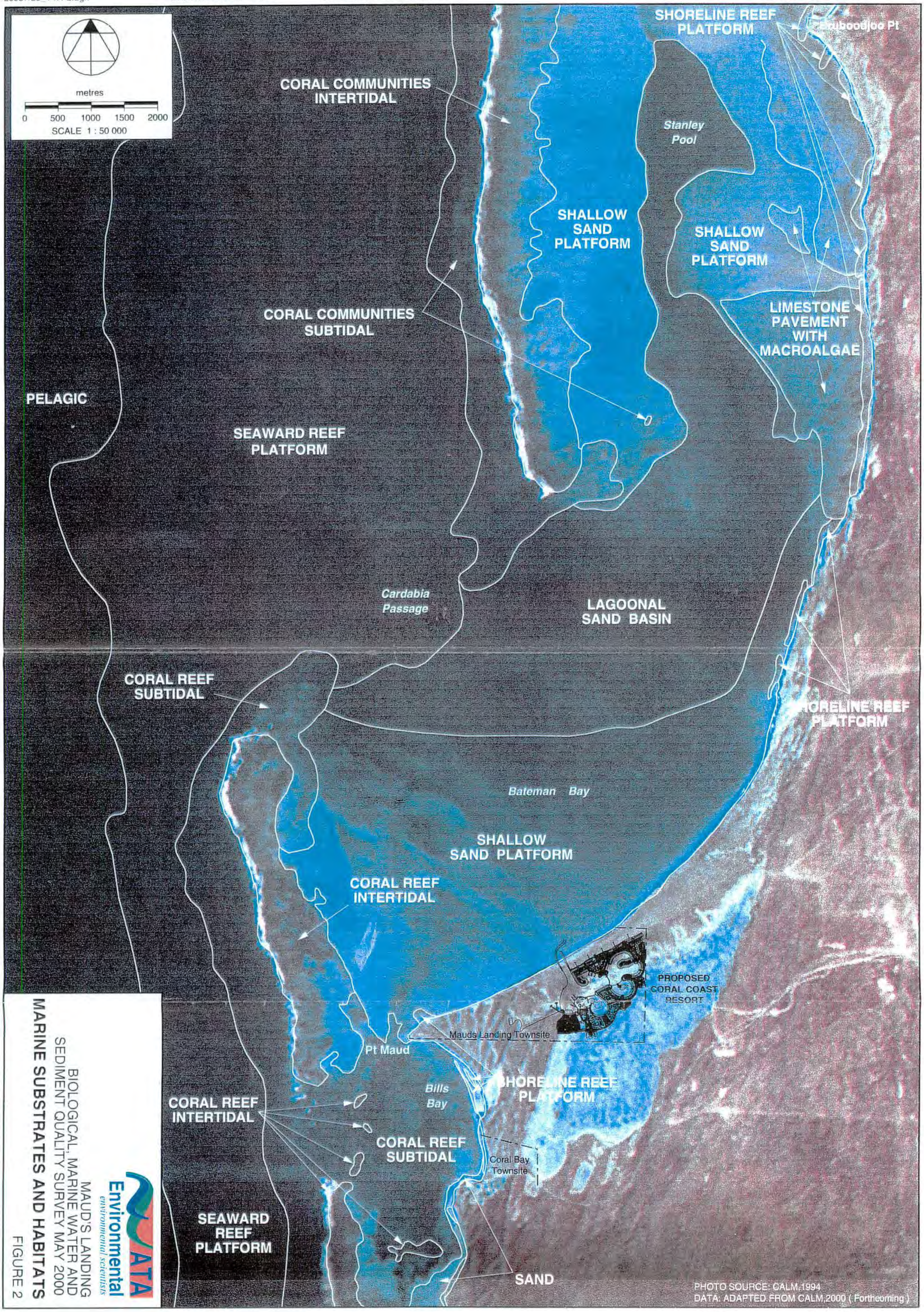
ATA Environmental
environmental scientists

MAUD'S LANDING
BIOLOGICAL, MARINE WATER AND
SEDIMENT QUALITY SURVEY MAY 2000

STUDY AREA AND SAMPLING LOCATIONS

FIGURE 1

20057/20_147F2.dgn DRAWN: GLM 30-10-00 CHECKED: HVW 30-10-00 PRINTED: Tue 31 Oct 00



ATA Environmental
environmental scientists

MAUD'S LANDING
BIOLOGICAL, MARINE WATER AND
SEDIMENT QUALITY SURVEY MAY 2000

MARINE SUBSTRATES AND HABITATS

FIGURE 2

APPENDICES

APPENDIX 1

LABORATORY RESULTS

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.

LABORATORY REPORT

ARL LAB No: 10835-68
DATE: 18 August 2000

CLIENT: ATA Environmental
21 Howard Street
PERTH WA 6000

ATTENTION: Ms Deanne Neilson

SAMPLE DESCRIPTION: Twenty one water samples and thirteen sediment samples as received for analysis.

DATE RECEIVED: 26 May 2000

JOB NUMBER: 20057

JOB NAME: Coral Bay

RESULTS:

WATERS

Lab No	10849	10850	10852	10855
Sample Marks	ML2	ML3	ML7B	ML9S
			µg/l	
Arsenic	1	1	3	5
Cadmium	<0.05	0.05	<0.05	0.10
Chromium	<1	<1	<1	<1
Copper	0.8	0.2	0.3	0.1
Lead	1.6	0.3	<0.1	0.3
Mercury	<0.1	<0.1	<0.1	<0.1
Nickel	1.2	0.4	0.4	0.2
Zinc	1.6	0.50	0.28	<0.02
Total Petroleum Hydrocarbons (as n-alkanes)	<10	<10	<10	<10

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.
A.C.N. 050 159 898 A.B.N. 91 050 159 898

55 Wittenoom Street, East Perth, Western Australia 6004
Telephone: (08) 9221 1415 Facsimile: (08) 9325 2398
Email: arlwa@wanet.com.au
NATA Registration No. 2377

Lab No	10864	10865	10868
Sample Marks	ML17	ML220	ML25
		ug/l	
Arsenic	1	1	1
Cadmium	<0.05	<0.05	<0.05
Chromium	<1	<1	<1
Copper	0.2	<0.1	<0.1
Lead	0.4	0.4	1.4
Mercury	<0.0001	<0.0001	<0.0001
Nickel	0.3	<0.1	0.4
Zinc	0.15	<0.02	0.10
Total Petroleum Hydrocarbons (as n-alkanes)	<10	<10	<10

PAH

Lab No	10849	10850	10852	10855
Sample Marks	ML2	ML3	ML7B	ML9S
			µg/l	
Naphthalene	0.04	0.09	0.02	0.03
2-Methyl-naphthalene	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	<0.01	<0.01	<0.01	<0.01
Acenaphthene	<0.01	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01	<0.01
Phenanthrene	<0.01	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01
Pyrene	<0.01	<0.01	<0.01	<0.01
Benz(*a*)anthracene	<0.01	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01	<0.01
Benzo(*b*)fluoranthene	<0.01	<0.01	<0.01	<0.01
Benzo(*k*)fluoranthene	<0.01	<0.01	<0.01	<0.01
Benzo(*a*)pyrene	<0.01	<0.01	<0.01	<0.01
Indeno(*1,2,3-c,d*)pyrene	<0.01	<0.01	<0.01	<0.01
Dibenz(*a,h*)anthracene	<0.01	<0.01	<0.01	<0.01
Benzo(*ghi*)perylene	<0.01	<0.01	<0.01	<0.01

Ms Deanne Neilson
ATA Environmental
ARL LAB No: 10835-68
18 August 2000

Lab No	10864	10865	10868
Sample Marks	ML17	ML20	ML25
		μg/l	
Naphthalene	0.03	0.02	<0.01
2-Methyl-naphthalene	<0.01	<0.01	<0.01
Acenaphthylene	<0.01	<0.01	<0.01
Acenaphthene	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01
Phenanthrene	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01
Pyrene	<0.01	<0.01	<0.01
Benz(*a*)anthracene	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01
Benzo(*b*)fluoranthene	<0.01	<0.01	<0.01
Benzo(*k*)fluoranthene	<0.01	<0.01	<0.01
Benzo(*a*)pyrene	<0.01	<0.01	<0.01
Indeno(*1,2,3-c,d*)pyrene	<0.01	<0.01	<0.01
Dibenz(*a,h*)anthracene	<0.01	<0.01	<0.01
Benzo(*ghi*)perylene	<0.01	<0.01	<0.01

Lab No	Sample Marks	Ammonia-N	Nitrate-N	Nitrite-N	Total Kjeldahl Nitrogen
				mg/l	
10849	ML2	<0.01	0.03	<0.005	0.05
10850	ML3	<0.01	0.01	<0.005	<0.02
10851	ML5	<0.01	0.02	<0.005	<0.02
10852	ML7B	<0.01	0.007	<0.005	0.03
10853	ML7S	<0.01	0.01	<0.005	<0.02
10854	ML9B	<0.01	0.01	<0.005	<0.02
10855	ML9S	<0.01	0.008	<0.005	<0.02
10856	ML11B	<0.01	0.008	<0.005	0.03
10857	ML11S	<0.01	0.008	<0.005	0.04
10858	ML12	<0.01	0.01	<0.005	0.03
10859	ML14	<0.01	0.007	<0.005	0.03
10860	ML15B	<0.01	0.010	<0.005	<0.02

Ms Deanne Neilson
ATA Environmental
ARL LAB No: 10835-68
18 August 2000

Lab No	Sample Marks	Ammonia-N	Nitrate-N	Nitrite-N	Total Kjeldahl Nitrogen
				mg/l	
10861	ML15S	<0.01	0.008	<0.005	<0.02
10862	ML16B	<0.01	0.007	<0.005	<0.02
10863	ML16S	<0.01	0.02	<0.005	<0.02
10864	ML17	<0.01	0.01	<0.005	<0.02
10865	ML20	<0.01	0.01	<0.005	0.02
10866	ML24B	<0.01	0.009	<0.005	<0.02
10867	ML24S	<0.01	0.008	<0.005	<0.02
10868	ML25	<0.01	0.005	<0.005	<0.02

Lab No	Sample Marks	Total Phosphorus	Filterable Reactive Phosphorous
		mg/l	
10849	ML2	<0.01	<0.005
10850	ML3	<0.01	0.006
10851	ML5	<0.01	0.006
10852	ML7B	<0.01	<0.005
10853	ML7S	<0.01	0.006
10854	ML9B	<0.01	0.006
10855	ML9S	<0.01	<0.005
10856	ML11B	<0.01	<0.005
10857	ML11S	<0.01	<0.005
10858	ML12	<0.01	<0.005
10859	ML14	<0.01	<0.005
10860	ML15B	<0.01	<0.005
10861	ML15S	<0.01	<0.005
10862	ML16B	<0.01	<0.005
10863	ML16S	<0.01	<0.005
10864	ML17	0.01	<0.005
10865	ML20	<0.01	<0.005
10866	ML24B	<0.01	<0.005
10867	ML24S	<0.01	<0.005
10868	ML25	<0.01	<0.005

Ms Deanne Neilson
ATA Environmental
ARL LAB No: 10835-68
18 August 2000

SEDIMENTS

Lab No	10835	10836	10844	10847	10848
Sample Marks	ML2	ML3	ML7	ML17	ML25
			mg/kg		
Ammonia-N	<1	<1	<1	<1	<1
Nitrate-N	0.23	0.14	0.20	0.10	0.16
Nitrite-N	0.10	0.08	0.11	0.05	0.08
Reactive Phosphorus	0.7	1.2	5.9	4.7	2.4
			mg/kg (Dry Basis)		
Total Kjeldahl Nitrogen	140	150	130	170	75
Total Phosphorus	320	260	610	360	610
Arsenic	3	<1	<1	<1	1
Cadmium	0.1	0.1	0.1	0.1	0.1
Chromium	11	5	3	30	29
Copper	<0.5	<0.5	<0.5	<0.5	<0.5
Lead	<0.5	<0.5	<0.5	<0.5	<0.5
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	1.0	0.5	1.5	1.0	1.5
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
2-Methyl-naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Benz(*a*)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(*b*)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(*k*)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(*a*)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno(*1,2,3-c,d*)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenz(*a,h*)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(*ghi*)perylene	<0.01	<0.01	<0.01	<0.01	<0.01

Ms Deanne Neilson
ATA Environmental
ARL LAB No: 10835-68
18 August 2000

Organochlorine Pesticides

Lab No	Sample Marks
10835	ML2
10836	ML3
10844	ML7
10847	ML17
10848	ML20

No organochlorine pesticides or polychlorinated biphenyls were detected in the five sediment samples.

Limits of Detection:

	mg/kg (Dry Basis)
Aldrin	0.001
Chlordane	0.001
Chlorpyrifos	0.001
Dieldrin	0.001
DDD	0.001
DDE	0.001
DDT	0.001
Heptachlor	0.001
HCB	0.001
Lindane	0.001
PCBs	0.02

Organotins

Lab No	Sample Marks	Tributyl Tin	Dibutyl Tin µg/kg	Monobutyl Tin
10835	ML2	<1	<1	<1
10836	ML3	<1	<1	<1
10844	ML7	<1	<1	<1
10847	ML17	<1	<1	<1
10848	ML20	<1	<1	<1

Kim Rodgers
Laboratory Manager

SGS Australia Pty Ltd A.C.N. 000 964 278

80 Railway Parade, Queens Park, Western Australia 6107
Phone (08) 9458 9666 Fax (08) 9358 2228

Water Quality Report

Report Number : 00005617
Job Number : JW001783

Report Comprising:	This Cover Page Pages 1 to 4	Date Received: Date Reported:	29/05/00 29/06/00
		No. of Samples:	20

To:

Analytical Reference Laboratory

Please note assay results for the above samples, as received.

Samples were analysed in accordance with the following test methods (MOAP):

63.1 Chlorophyll a and Phaeophytins

SGS Australia Pty Ltd A.C.N. 000 964 278

80 Railway Parade, Queens Park, Western Australia 6107
Phone (08) 9458 9666 Fax (08) 9356 2228

29/06/00

Water Quality Report

Report Number : 00005617
Job Number : JW001783

Samples Received : 29/05/00

Lab No.	Sample Description	Date Sampled
W0006416	ML2	23/05/00
W0006417	ML3	23/05/00
W0006418	ML5	23/05/00
W0006419	ML7B	25/05/00
W0006420	ML7S	25/05/00
W0006421	ML9 (4L)	24/05/00

	W0006416	W0006417	W0006418	W0006419	W0006420	W0006421
Chlorophyll A (µg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phaeophytins (µg/L)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

All units in mg/L (equivalent to g/m³) unless otherwise stated.

ISO 9002

Certified ....
..../..../....

SGS Australia Pty Ltd A.C.N. 000 964 278

80 Railway Parade, Queens Park, Western Australia 6107
Phone (08) 9458 9666 Fax (08) 9356 2228

29/06/00

Water Quality Report

Report Number : 00005617
Job Number : JW001783

Samples Received : 29/05/00

Lab No.	Sample Description	Date Sampled
W0006422	ML9 (7)	24/05/00
W0006423	ML11B	23/05/00
W0006424	ML11S	23/05/00
W0006425	ML12	23/05/00
W0006426	ML14	23/05/00
W0006427	ML15B	24/05/00

	W0006422	W0006423	W0006424	W0006425	W0006426	W0006427
Chlorophyll A (µg/L)	<0.02	0.03	<0.02	<0.02	<0.02	<0.02
Phaeophytins (µg/L)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

All units in mg/L (equivalent to g/m³) unless otherwise stated.

ISO 9002

NATA

Certified ...[signature]...
..7/V..k../.2000

SGS Australia Pty Ltd A.C.N. 000 964 278

80 Railway Parade, Queens Park, Western Australia 6107
Phone (08) 9458 9666 Fax (08) 9358 2228

29/06/00

Water Quality Report

Report Number : 00005617
Job Number : JW001783

Samples Received : 29/05/00

Lab No.	Sample Description	Date Sampled
W0006428	ML15S	24/05/00
W0006429	ML16B	24/05/00
W0006430	ML16S	25/05/00
W0006431	ML17	25/05/00
W0006432	ML20	25/05/00
W0006433	ML24B	25/05/00

	W0006428	W0006429	W0006430	W0006431	W0006432	W0006433
Chlorophyll A (µg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phaeophytins (µg/L)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

All units in mg/L (equivalent to g/m³) unless otherwise stated.

Certified ....
29.6.2000

SGS Australia Pty Ltd A.C.N. 000 964 278

80 Railway Parade, Queens Park, Western Australia 6107
Phone (08) 9458 9666 Fax (08) 9358 2228

29/06/00

Water Quality Report

Report Number : 00005617
Job Number : JW001783

Samples Received : 29/05/00

Lab No.	Sample Description	Date Sampled
W0006434	ML24S	25/05/00
W0006435	ML25	25/05/00

	W0006434	W0006435
Chlorophyll A (μg/L)	<0.02	0.02
Phaeophytins (μg/L)	<0.04	<0.04

All units in mg/L (equivalent to g/m³) unless otherwise stated.

ISO 9002

NATA

Certified ....

PRO MICRO pty. ltd.
Incorporated in Western Australia
ACN 009 120 549
Industrial and Environmental Microbiology

31 Green Road
Hillarys WA 6025
Tel: 61-8-9401 5699
Fax: 61-8-9401 5900
A/h: 61-8-9295 1767
Mobile: 041 429 5176
email: promicro@cygnus.uwa.edu.au
NATA Accreditation No 2561

MICROBIOLOGICAL WATER REPORT

ATTENTION DAVID WILLIAMS
ANALYTICAL REFERENCE LABORATORIES
55 WITTENOOM STREET
EAST PERTH WA 6004

Date Samples Collected:25/5/00
Date Received in Lab: 29/5/00
Order No:
Sample Tested as Received: YES

Sample Site: Sample ID - ML20

Source:

Laboratory No: P0007757

General Water Appearance:

		Method
Faecal (Thermotolerant) Coliforms/100mL	0	ProMicro Manual Method PM 4.3
Escherichia coli /100mL	0	ProMicro Manual Method PM 4.3

Analyst: S. Grove

Authorised Signatory:
Date Reported: 31/5/2000

water2

NATA

APPENDIX 2

LABORATORY ANALYSIS AND CHAIN OF CUSTODY RECORDS

Alan Tingay & Associates
environmental scientists

ALAN TINGAY & ASSOCIATES
environmental scientists
21 Howard Street
PERTH WA 6000
Telephone: 08 9481 3434
Facsimile: 08 9481 3435

LABORATORY ANALYSIS & CHAIN OF CUSTODY RECORD

To:	A.R.L.	Date:	26-May-00
Attention:	Kim Rodgers	Job No.:	20057
Address:	55 Wittenoom Street	Job Name:	Coral Bay
	EAST PERTH WA 6004		***Sample Type***
Telephone:	(08) 9221 1415	Soil ☐	Groundwater ☐
Facsimile:	(08) 9325 2398		Other: Sediment

PLEASE QUOTE JOB NUMBER AND DATE ON ALL CORRESPONDENCE

Sample ID	Date Sampled	Container	Analyses	
				Storgae
ML2	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML3	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML5	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML9	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML11	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML12	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML14	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML15	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML16	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML17	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML20	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML24	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓
ML25	23.5.00 - 25.5.00	1L G. 1L P, 1PC		✓

Sent by: D. Neilson	**Date: 26.5.00**	**Delivered by:**
Received by:	**Date:**	**Results required by:**

environmental scientists

PERTH WA 6000
Telephone: 08 9481 3434
Facsimile: 08 9481 3435

LABORATORY ANALYSIS & CHAIN OF CUSTODY RECORD

To:	A.R.L.	Date:	26-May-00
Attention:	Kim Rodgers	Job No.:	20057
Address:	55 Wittenoom Street EAST PERTH WA 6004	Job Name:	Coral Bay
Telephone:	(08) 9221 1415		
Facsimile:	(08) 9325 2398		

Sample Type

Soil ☐ Groundwater ☐

Other: Filters

PLEASE QUOTE JOB NUMBER AND DATE ON ALL CORRESPONDENCE

Sample ID	Date Sampled	Container	Analyses: Chlorophyll-a (≤0.05 ug/L LOD	Storgae
ML2	23.5.00 - 25.5.00		✓	✓
ML3	23.5.00 - 25.5.00		✓	✓
ML5	23.5.00 - 25.5.00		✓	✓
ML7B	23.5.00 - 25.5.00		✓	✓
ML7S	23.5.00 - 25.5.00		✓	✓
ML9	23.5.00 - 25.5.00		✓	✓
ML9	23.5.00 - 25.5.00		✓	✓
ML11B	23.5.00 - 25.5.00		✓	✓
ML11S	23.5.00 - 25.5.00		✓	✓
ML12	23.5.00 - 25.5.00		✓	✓
ML14	23.5.00 - 25.5.00		✓	✓
ML15B	23.5.00 - 25.5.00		✓	✓
ML15S	23.5.00 - 25.5.00		✓	✓
ML16B	23.5.00 - 25.5.00		✓	✓
ML16S	23.5.00 - 25.5.00		✓	✓
ML17	23.5.00 - 25.5.00		✓	✓
ML20	23.5.00 - 25.5.00		✓	✓
ML24B	23.5.00 - 25.5.00		✓	✓
ML24S	23.5.00 - 25.5.00		✓	✓
ML25	23.5.00 - 25.5.00		✓	✓

Sent by: D. Neilson **Date: 26.5.00** **Delivered by:**

Received by: **Date:** **Results required by:**

Alan Tingay
& Associates
environmental scientists

ALAN TINGAY & ASSOCIATES
environmental scientists
21 Howard Street
PERTH WA 6000
Telephone: 08 9481 3434
Facsimile: 08 9481 3435

LABORATORY ANALYSIS & CHAIN OF CUSTODY RECORD

To: A.R.L.
Attention: Kim Rodgers
Address: 55 Wittenoom Street
EAST PERTH WA 6004
Telephone: (08) 9221 1415
Facsimile: (08) 9325 2398

FAXED

Date: 26-May-00
Job No.: 20057
Job Name: Coral Bay

Sample Type
Soil ☐ Groundwater ☐
Other: Marine Water

PLEASE QUOTE JOB NUMBER AND DATE ON ALL CORRESPONDENCE

Sample ID	Date Sampled	Container	Analyses: Faecal Coliforms	E. coli	Storage									
ML2	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML3	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML7B	23.5.00 - 25.5.00	1L P			✓									
ML9B	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML9S	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML11B	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML11S	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML12	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML14	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML15B	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML15S	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML16B	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML16S	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML17	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML20	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML24B	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML24S	23.5.00 - 25.5.00	1L G, 500mL G, 1L P			✓									
ML20	25.5.00	micro	✓	✓										
ML25	25.5.00	micro	✓	✓										
MLM	25.5.00	micro	✓	✓										

Sent by: D. Neilson **Date: 26.5.00** **Delivered by:**
Received by: **Date:** **Results required by:**

Alan Tingay
& Associates

ALAN TINGAY & ASSOCIATES
environmental scientists
21 Howard Street

ALAN TINGAY & ASSOCIATES
environmental scientists
21 Howard Street
PERTH WA 6000
Telephone: 08 9481 3434
Facsimile: 08 9481 3435

LABORATORY ANALYSIS & CHAIN OF CUSTODY RECORD

To: A.R.L.
Attention: Kim Rodgers
Address: 55 Wittenoom Street
EAST PERTH WA 6004
Telephone: (08) 9221 1415
Facsimile: (08) 9325 2398

Date: 19-Jun-00
Job No.: 20057
Job Name: Coral Bay
Sample Type
Soil ☐ Groundwater ☐
Other: Marine Water

PLEASE QUOTE JOB NUMBER AND DATE ON ALL CORRESPONDENCE

Sample ID	Date Sampled	Container	Nutrients	TPH	Metals	TBT	PAH
ML2	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML3	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML5	23.5.00 - 25.5.00		✓				
ML7B	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML7S	23.5.00 - 25.5.00		✓				
ML9B	23.5.00 - 25.5.00		✓				
ML9S	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML11B	23.5.00 - 25.5.00		✓				
ML11S	23.5.00 - 25.5.00		✓				
ML12	23.5.00 - 25.5.00		✓				
ML14	23.5.00 - 25.5.00		✓				
ML15B	23.5.00 - 25.5.00		✓				
ML15S	23.5.00 - 25.5.00		✓				
ML16B	23.5.00 - 25.5.00		✓				
ML16S	23.5.00 - 25.5.00		✓				
ML17	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML20	23.5.00 - 25.5.00		✓	✓	✓	✓	✓
ML24B	23.5.00 - 25.5.00		✓				
ML24S	23.5.00 - 25.5.00		✓				
ML25	23.5.00 - 25.5.00		✓	✓	✓	✓	✓

Metals = As, Cd, Cr, Cu, Pb, Hg, Ni, Zn

Nutrients = TKN, NO_2, NO_3, NH_3, TP, Filterable Reactive P

Sent by: D. Neilson **Date: 19.6.00** **Delivered by: In storage**

Received by: **Date:** **Results required by:**

Alan Tingay & Associates

environmental scientists

ALAN TINGAY & ASSOCIATES

environmental scientists

21 Howard Street
PERTH WA 6000
Telephone: 08 9481 3434
Facsimile: 08 9481 3435

LABORATORY ANALYSIS & CHAIN OF CUSTODY RECORD

To:	A.R.L.	Date:	19-Jun-00
Attention:	Kim Rodgers	Job No.:	20057
Address:	55 Wittenoom Street	Job Name:	Coral Bay
	EAST PERTH WA 6004		***Sample Type***
Telephone:	(08) 9221 1415	Soil ☐	Groundwater ☐
Facsimile:	(08) 9325 2398		Other: Sediment

PLEASE QUOTE JOB NUMBER AND DATE ON ALL CORRESPONDENCE

Sample ID	Date Sampled	Container	Nutrients	OC's/PCB's	Metals	TBT	PAH
			Analyses				
ML2	23.5.00 - 25.5.00	1L G, 1L P, 1PC	✓	✓	✓	✓	✓
ML3	23.5.00 - 25.5.00	1L G, 1L P, 1PC	✓	✓	✓	✓	✓
ML5	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML7	23.5.00 - 25.5.00	1L G, 1L P, 1PC	✓	✓	✓	✓	✓
ML9	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML11	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML12	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML14	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML15	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML16	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML17	23.5.00 - 25.5.00	1L G, 1L P, 1PC	✓	✓	✓	✓	✓
ML20	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML24	23.5.00 - 25.5.00	1L G, 1L P, 1PC					
ML25	23.5.00 - 25.5.00	1L G, 1L P, 1PC	✓	✓	✓	✓	✓

Sent by: D. Neilson	**Date: 19.6.00**	**Delivered by: In storage**
Received by:	**Date:**	**Results required by:**

APPENDIX 5

INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN

CORAL COAST MARINA DEVELOPMENTS PTY LTD

INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN FOR THE PROPOSED CORAL COAST RESORT

DRAFT REPORT

OCTOBER 2000

REPORT NO: 2000/148

in consultation with
Department of Conservation and Land Management

DISCLAIMER

This document is published in accordance with and subject to an agreement between ATA Environmental **("ATA")** and the client for whom it has been prepared Coral Coast Marina Development Pty Ltd **("Client")** and is restricted to those issues that have been raised by the client in its engagement of ATA and prepared using the standard of skill and care ordinarily exercised by Environmental Scientists in the preparation of such Documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by ATA and the Client without first obtaining the prior written consent of ATA, does so entirely at their own risk and ATA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this Document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

ATA Environmental has implemented a comprehensive range of quality control measures on all aspects of the company's operation and has Quality Assurance certification to ISO 9001.

An internal quality review process has been applied to each project task undertaken by us. Each document is carefully reviewed by core members of the consultancy team and signed off at Director level prior to issue to the client. Draft documents are submitted to the client for comment and acceptance prior to final production.

Document No:	20057_024_MEMP_hvw	
Report No:	2000/148	
Report Status:	Draft	
Checked by:	B. Van der Wiele	Date: 18 October 2000
Approved by:	H. Van der Wiele	Date: 18 October 2000

TABLE OF CONTENTS

OBJECTIVE 1

ACKNOWLEDGMENT 1

1. INTRODUCTION 2

2. OBJECTIVES 7

2.1 Objectives for the Ningaloo Marine Park 7
2.1.1 State Waters 7
2.1.2 Commonwealth Waters 8
2.2 Objectives for the SAMMP 8

3. MANAGEMENT STRUCTURE AND RESPONSIBILITY 10

3.1 Legislative Framework 10
3.2 Management Structure 10
3.3 Zoning within the Ningaloo Marine Park 13
3.4 Management Support in the MSMA 14

4. DESCRIPTION OF THE MSMA 16

4.1 Development Impact Area (DIA) 16
4.2 Maud Specific Management Area (MSMA) 16

5. ECOLOGICAL AND SOCIAL VALUES 17

6. MANAGEMENT OF PRESSURES WITHIN THE MSMA 21

7. DESCRIPTION & MANAGEMENT OF ECOLOGICAL AND SOCIAL VALUES ... 23

7.1 Best Practice in Performance Reporting 23
7.2 Ecological Values 24
7.2.1 Geomorphology 24
7.2.2 Intertidal reef platforms and communities 26
7.2.3 Water quality 27
7.2.4 Seagrasses 29
7.2.5 Macroalgal Communities 30
7.2.6 Seabirds 31
7.2.7 Corals and other invertebrate communities 34
7.2.8 Finfish 35
7.2.9 Turtles 37
7.2.10 Cetaceans 38

7.3. Social Values ... 39
7.3.1 Indigenous and maritime heritage ... 39
7.3.2 Commercial and Recreational Fishing ... 40
7.3.4 Coastal Use ... 42
7.3.5 Seascapes ... 43
7.3.6 Water sports ... 43
7.3.7 Marine nature-based tourism ... 44
7.3.8 Petroleum drilling & mineral development ... 46
7.3.9 Scientific research ... 47
7.3.10 Education ... 48

8. IMPLEMENTATION OF THE SAMMP FOR THE MSMA ... 50

REFERENCES ... 51

FIGURES

APPENDICES

LIST OF FIGURES

1. Location of Ningaloo Marine Park
2. Proposed Boundaries of the MSMA
3. Relationship between the MSMA and CALM's Marine Management Plan for Ningaloo Marine Park
4. Major Benthic Habitats

LIST OF APPENDICES

1. Proposed Assessment Criteria for Water Quality and Sediment Monitoring
2. Summarised Occurrence and Activity Data Relating to Large Finfish, Marine Mammals and Turtles

OBJECTIVE

Within the five years following the structural completion of the Coral Coast Marina Development, the marine flora and fauna, their support habitats and water quality within the Development Impact Area and Specific Management Area adjacent to the development will be in the same or better condition than in the year of initial implementation.

Implementation of the project will provide support for the Department of Conservation and Land Management and involved agencies in the management of Ningaloo National Park in their maintenance of the area, will support viable and ecologically sustainable fishing, recreation and nature-based tourism and the marine park will be considered to be an important asset by visitors and the local community.

ACKNOWLEDGMENT

MRPA and CALM have adopted and further developed *ANZECC Best Practice in Performance Reporting in Natural Resource Management* techniques and strategies in the development of Marine Management Plans for Marine Parks in Western Australia.

This model has been adopted in the preparation of this SAMMP. The assistance and direction given by CALM in the preparation of this document is acknowledged.

1. INTRODUCTION

The Western Australian coastline is over 13,000 kilometres in length and ranges from the warm, tropical waters off the Kimberley coast to the cool, temperate waters of the Great Australian Bight.

Three major biogeographic zones occur: a *tropical* zone north of North West Cape, a *temperate* zone east of Cape Leeuwin and a *biological overlap* zone in between.

A unique feature of the coastal waters of Western Australia is the presence of a southward, shelf-edge flow of tropical water, the Leeuwin Current, which flows down the Western Australian coastline. The current flows year round, but is stronger and closer to shore during autumn and winter. The Leeuwin Current has a major influence on the biogeography of the State's marine flora and fauna and is responsible for the occurrence of tropical biota at latitudes where these species are not typically found.

Other major influences on tropical and northern temperate waters are the regular occurrence of severe tropical storms (ie. cyclones), particularly off the northwest coastline, together with the high wave energy of the west coasts. Tidal influences are significant in northern areas.

The Ningaloo Marine Tract (NRT) extends from Gnarraloo Bay to Point Murat, a distance of about 280km (Simpson & Masini 1986). It comprises one of the five major coral reef assemblages that are recognised on the west coast, with the others being:

- the patch and fringing reefs off the Kimberley coast;
- shelf edge atolls on the north west coast;
- fringing and patch reefs off the Pilbara coast; and
- temperate coral reefs of the Houtman Abrolhos Islands.

Ningaloo Reef is the largest existing fringing reef system in Australia and occurs off an arid central west coast landscape. The aridity of this region allows reef development in close proximity to the coast due to the lack of terrestrial run-off that minimises water turbidity (Hatcher 1988).

The NRT, together with the reefs of the Pilbara coast, are scientifically important as they are the only major reef structures in Australia in an arid climate thereby providing opportunities for direct comparison with reefs of the Great Barrier Reef.

Oceanographic conditions vary markedly from the open ocean to the west of the Ningaloo Reef to the sheltered coastal waters east of the reef. The position and extent of the reef has a dominant influence on the nearshore currents and waves. The highest ocean water levels would be caused by storm surge when severe cyclones pass through the area. Studies completed by Steedman Science and Engineering (1989) indicated that the peak storm surge during a 100-year period cyclone would be approximately 1.9m. This would be in addition to the astronomical tides described.

Point Maud is considered to be in the transitional zone between the small, primarily diurnal tides (one tidal cycle per day) of the southwest coast, and the large semi-diurnal tides (two tidal cycles per day) of the North West Shelf (Simpson & Masini 1986; Hearn & Parker 1988).

Mean offshore water temperatures range from 22°C (July) to 26°C (January) (ANPWS 1990). Within the lagoon more extreme temporal and spatial variations are likely to occur. Detailed measurements for the lagoon (waters lying between the shore and the outer reef) off Mauds Landing are not available, however May *et al.* (1989) reported lagoonal water temperatures within Ningaloo Marine Park had seasonal averages ranging from 23°C in winter to 30°C in summer.

Simpson and Masini (1986) recorded mean temperatures over the Ningaloo Reef Tract from 22.1°C (October) to 26.1°C (May) and suggested that areas of limited flushing may experience more extreme temperatures with winter minima approaching ambient air temperatures (18-20°C). It was considered that quiescent lagoonal waters might exhibit pronounced diurnal temperature variations consistent with insular heating and night time cooling.

Regionally the Leeuwin Current, a southward flow of warm, relatively low-salinity water dominates offshore water circulation. This current is at its strongest from March to July and broadly follows the edge of the outer continental shelf and slope to the inner shelf. The Leeuwin Current is coupled with a northward undercurrent and is greatly attenuated by wind stress in summer (Holloway & Nye 1985; Hearne & Parker 1988).

Along the inshore shelf, there is a seasonal wind-driven northward flowing counter current to the Leeuwin Current (Taylor & Pearce 1999). This northward flowing current is known as the Ningaloo Current and occurs from September to mid-April when it is driven by southeasterly winds. Inter-annual variations in the southeasterly winds and in the Leeuwin Current produce year-to-year variations in the Ningaloo Current.

Behind the outer reef circulation within the lagoon are more complex driven by the varying and interacting influences of wind, wave and tidal forces. These can be considerably modified by the local morphology of the coast and reef, particularly the location and size of passages through the reef system.

The above natural characteristics and influences in the NMT produce a diversity of marine ecosystems and habitats, resulting in high biological diversity.

CALM (2000 forthcoming) note that much of the marine biodiversity of the State is poorly described, particularly along the west and south coasts where many endemic species are likely to occur. They further note that the conservation of Western Australia's marine biodiversity is not only important from an intrinsic point of view but also as the fundamental basis of major recreational, tourism, fishing and, potentially, pharmaceutical industries.

The Ningaloo Marine Park was established in 1988 and a 10-year Management Plan describing objectives for park management produced (CALM 1989). This Management Plan is currently under review. The location of the Ningaloo Marine Park is indicated in Figure 1.

The Marine Park Reserves Selection Working Group (CALM 1994) reviewed the existing reserves in Western Australia and made recommendations regarding new and additional areas for marine conservation, including the southern extension of the State portion of the Ningaloo Marine Park as far as Gnaraloo Bay.

Coral Coast Marina Development Pty Ltd (CCMD) propose to develop a serviced resort village providing a broad range of short-stay and holiday accommodation consistent with both West Australian Government requirements and the Gascoyne Coast Regional Strategy (1996). Based on 80% average peak occupancy, it is estimated that at full development the total population will be approximately 2025 persons. It is anticipated that peak occupancy will occur gradually over a ten year period following the commencement of construction.

The proposed resort is to be supported by incidental recreational, tourist and commercial services consistent with the needs of visitors to the location, and in recognition of the need for environmental protection. This will include, amongst others, the provision of deep sewerage and wastewater treatment at an inland site, a services area and a managed landfill site. The proposed inland marina will include boat launching and servicing facilities such as fuelling.

The site of the development is outside the sensitive sanctuary zone of Bills Bay. Reasonable depth water and habitats comprising principally of sand and pavement occurs immediately offshore of the proposed site. Access to Cardabia Passage is available to ecotourism-based and other boat users without traversing the unique coral communities of Bills Bay.

The Resort Concept Plan has been developed in consideration of the need to maintain high standards of water quality both within the inland marina and the nearshore marine environment. The ability to manage impacts of the development and resulting greater visitation/utilisation of Ningaloo Marine Park is recognised as critical to the successful implementation of this proposal.

This indicative Specific Area Marine Management Plan (SAMMP) for the Mauds area is complementary to and provides additional information within the context of the CALM Marine Management Plan currently under development for Ningaloo Marine Park. The SAMMP will provide a detailed description of the ecological and social values of the area, management objectives, strategies and targets. The goal of the plan is to facilitate the conservation of marine biodiversity of the area and to ensure that the existing and future pressures on this heavily impacted portion of the Ningaloo Marine Park are documented, and management undertaken in a sustainable framework. The plan also provides mechanisms for the local community to actively participate in the on-going planning and management of the Park.

The SAMMP will define two areas for specific management within the broader Ningaloo Marine Park. The areas defined and the possible impacts include:

- The Development Impact Area (DIA) comprises an area of approximately $9km^2$, including the sensitive Bills Bay area, and including an area adjacent to the development site that will likely be impacted directly by the effects of the construction and operation of the resort, including greater visitation. It is anticipated that there will be some short-term reduction in water quality within the DIA during the period of the construction and for a period of up to five years post construction. This SAMMP presents a series of environmental indicators that, properly monitored, will track the condition of the likely impact area and will provide a framework against which they can be reported.

- The Maud Specific Management Area (MSMA) comprises an area of approximately $111km^2$ and is described as the marine waters and land extending to 40m above the HWM, inclusive of the DIA and coincident with the Maud Sanctuary Zone, otherwise extending seaward to the 18m contour and north to a point due west of Bruboodjoo Point and westward to 40m above the HWM. It is anticipated that within this area, indirect impacts, principally a consequence of the greater selective pressure on certain target species and coincident damage (anchor, boat impacts), may occur.

The proposed boundaries of the MSMA and DIA are indicated in Figure 2.

This document presents the Indicative Mauds SAMMP consistent with the Ningaloo Marine Park Management Plan and the objectives of the Department of Conservation and Land Management in management of the area. The SAMMP will be finalised prior to the implementation of the project, should environmental approvals be given, and will be complementary to the revised CALM Marine Management Plan of which it will become a component. The SAMMP will provide a detailed description of the ecological and social values of the area surrounding the proposed development (including the existing Bills Bay area), management objectives, strategies and targets to be determined through a monitoring program to be implemented. Included in the SAMMP are descriptions and considerations in the management of:

- **Ecological Values** such as geomorphology, barrier reef, lagoonal systems, water quality, coral, seagrass and macroalgal communities, seabirds, invertebrate communities, finfish, dugong and other cetaceans, sharks and rays including whale sharks and manta rays, and marine turtles; and

- **Social Values** including: indigenous and maritime heritage, recreational fishing, coastal use, preservation of seascapes, water sports, marine nature-based tourism, petroleum drilling and mineral development, scientific research and education.

The SAMMP describes the management plan for a small, though heavily impacted portion of the Ningaloo Marine Park. It cannot be viewed in isolation, but as an integral part of a suite of complementary management practices that occur within and adjacent to both the DIA, elsewhere within the Ningaloo Marine Park, and more broadly across all Western Australian waters.

The SAMMP has been couched in terms of providing support for CALM and Fisheries WA consistent with the management objectives of the Ningaloo Marine Park. It acknowledges that many marine species, including important ecotourism target species such as whales, other cetaceans and whale sharks, are not permanently resident in the marine park and move in and out of the park during different stages of their lifecycles.

Deleterious impacts on the water quality in the Marine Park have previously been identified and the potential exists for further impacts as a consequence of the implementation of this proposal, if approved. Accordingly there will be a heavy emphasis on water quality and habitat monitoring to detect these changes as an aid to the implementation of timely management responses.

Statutory management and regulation of activities will remain with State Agencies such as CALM, Fisheries WA and the Department of Transport. Implementation of this SAMMP will provide support and resources for these regulatory agencies, to achieve the conservation and sustainable management objectives outlined in both this and the umbrella Marine Management Plan.

2. OBJECTIVES

The principle thrust of the Government's 1998 policy document in relation to marine conservation will be *"...to have one comprehensive reserve system under the Conservation and Land Management Act"*. The specific objectives of the marine conservation reserve system, as stated in *New Horizons - The Way Ahead In Marine Conservation And Management*, (Government of Western Australia 1998) are:

- to preserve representative as well as special ecosystems in the marine environment; and
- to put a formal management framework in place to ensure the various uses of marine conservation reserves are managed in an equitable, integrated and sustainable manner.

A component of the formal management framework is the development of an SAMMP where specific pressures have been identified as impacting on, or have the potential to impact on a specific area within the Marine Park.

2.1 Objectives for the Ningaloo Marine Park

2.1.1 State Waters

CALM (1988) defined the following objectives for the Ningaloo Marine Park:

1. To manage State and Commonwealth areas as one Park.
2. To integrate management and development of the Park with adjacent areas of land to achieve maximum effectiveness and optimum allocation of management resources.
3. To manage adjoining coastal land so that access to the Park is achieved with minimum disruption to the rights of adjoining landholders.
4. To conserve native species, habitats and natural processes.
5. To provide recreational opportunities and facilities which maximise the quality of experience sought by visitors.
6. To promote an appreciation and understanding of the marine environment and sites of cultural significance in the Park, through information, interpretation and education.
7. To manage recreational and commercial fishing without adversely affecting fish populations.
8. To provide for tourism, to the extent consistent with maintenance of resources.

9. To ensure that all development and activities are consistent with the maintenance of species populations, habitats, natural features, and cultural and scenic values.

10. To conduct research programs aimed at understanding how impacts of use and natural processes affect the maintenance and management of the Park.

2.1.2 Commonwealth Waters

A draft Management Plan for Ningaloo Marine Park (Commonwealth Waters) has recently been produced, (Commonwealth of Australia 2000). The draft Plan specifies the management goals and strategies or Ningaloo Marine Park (Commonwealth Waters). The goals relate to the strategic objectives of the Marine Park which are:

Conservation

- To maintain the marine biodiversity of the Marine Park.
- To maintain key ecological processes and life support systems.

Recreation

- To provide for and manage recreational and cultural uses to the extent compatible with the conservation objectives or the Marine Park.

Science and Education

- To promote education, nature appreciation and scientific research on the biological, geophysical and cultural values of the Marine Park.

National System

- To manage the area as part of a comprehensive, adequate and representative system of marine protected areas to contribute to the long-term ecological viability of marine and estuarine systems.

2.2 Objectives for the SAMMP

The following operational objective has been proposed for the MSMA:

Within the five years following the structural completion of the Coral Coast Marina Development, the marine flora and fauna, their support habitats and water quality within the Development Impact Area and MSMA adjacent to the development will be in the same or better condition than in the year of initial implementation.

Implementation of the project will provide support for the departments of CALM, Fisheries WA and other involved agencies in the management of Ningaloo National Park. This will support viable and ecologically sustainable fishing, recreation and nature-based tourism. Accordingly the marine park will be considered to be an important asset by visitors and the local community.

Within the above policy and legislative context, the strategic objectives for the indicative SAMMP management area are:

Conservation

- Provide a body or research as an aid in the management of the marine biodiversity of the specific area.
- Liase with regulatory agencies with a view to maintaining key ecological processes and life support systems (ie. ecosystem structure and function) both within the specific area and generally.

Recreational Uses

- Within an equitable and ecologically sustainable framework, provide a body of research as an aid to the management of a diverse range of recreational activities within the park.

Commercial Uses

- To support, and where appropriate, assist in the management of commercial activities, including ecotourism, both within the specific area and generally within an equitable and ecologically sustainable framework.

- To identify impacts on the DIA as a consequence of the implementation of this Coral Coast Marina development.

Science & Education

- To promote education, nature appreciation and scientific research.

The strategic objectives of the SAMMP are reliant on management achieved through the implementation of regulatory instruments by government agencies. The relationship of the SAMMP within CALM's Marine Management Plan for Ningaloo Marine Park is indicated in Figure 3 and is further discussed in section 3 below.

3. MANAGEMENT STRUCTURE AND RESPONSIBILITY

3.1 Legislative Framework

Ningaloo Marine Park consists of Ningaloo Marine Park (State Waters) and Ningaloo Marine Park (Commonwealth Waters), declared under Western Australian and Commonwealth legislation respectively, but managed as far as possible as a single unit by Environment Australia, the Western Australian Department of CALM and Fisheries WA. The day-to-day management of the Commonwealth waters is carried out by CALM, with Fisheries WA responsible for all matters relating to fishing.

The Ningaloo Marine Park lies within State territorial waters. Waters seaward of this limit and extending to the 200 nautical mile limit fall under the jurisdiction of the Commonwealth Government.

Marine parks are reserves declared under the *CALM Act* for the purposes of: "... *allowing only that level of recreational and commercial activity which is consistent with the proper conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature of archaeological, historic or scientific interest*".

Marine parks are vested in the MPRA and CALM is responsible for their management in accordance with the *CALM Act*. Fisheries WA is responsible for the management and regulation of recreational and commercial fishing, aquaculture and pearling in CALM Act marine conservation reserves in accordance with the *Fish Resources Management Act 1994* (*FRM Act 1994*). The *Wildlife Conservation Act* provides legislative protection for flora and fauna across the state's lands and waters. The *Marine Act 1983 and Navigable Waters Regulations* regulate boating in state waters and apply within marine parks. The Department of Transport administers these Acts. In addition, the Environmental Protection Authority assesses any development that may have a significant impact on the environment in or adjacent to a marine park, in accordance with the *Environmental Protection Act 1986*. The Department of Environmental Protection is responsible for controlling pollution to marine waters.

3.2 Management Structure

The Ningaloo Marine Park was first gazetted in 1987 and encompasses both Commonwealth and State waters and the respective parts have been declared under Commonwealth and State legislation. The Commonwealth component comprises that outer portion of the Park that lies seaward of the State territorial waters. A draft Management Plan for Commonwealth waters comprising the Ningaloo Marine Park has recently been released for public comments (Commonwealth of Australia 2000). Both the Commonwealth and State components are to be managed as a single unit by the State through CALM. Other land adjacent to the Marine Park includes the Cape Range National Park, two coastal reserves jointly managed with the Shire of Exmouth, Crown land leased for pastoral use, Commonwealth Defence Department land, and two small townsite areas.

The Ningaloo Marine Park, the Cape Range National Park and the coastal reserves is managed as one integrated unit, but each unit has its own management plan. A management plan for Cape Range National Park was approved by the Minister for Conservation and Land Management on 1 December 1987.

The Ningaloo Marine Park is gazetted as a Class A reserve.

The terms Development Impact Area and Maud Specific Management Area are not described in the context of CALM's Management Plans for either the Marine Park or Cape Range National Park. The development of specific management plans is recognised as a management tool for issues or areas requiring specific management attention within the umbrella of marine management plans.

The Ningaloo Marine Park also includes:

a) the airspace above such waters or land;

b) in the case of waters, the seabed or other land beneath such waters and the subsoil below the seabed or other land to a depth of 200m; and

c) land to 40m above HWM.

In the case of land other than waters, the subsoil below such land is to a depth of 200m (*CALM Act 1984*).

CALM is responsible for the overall management of marine parks under the marine reserve provisions of the *CALM Act*. CALM also collaborates with other agencies and authorities (i.e. MPRA, NPNCA, LGA's) that have responsibilities within marine reserves and in the surrounding waters and coastal areas to ensure the various regulatory and management practices are complementary. In some cases Memoranda of Understanding (MOUs) are developed to facilitate co-operation and promote operational efficiency. An MOU currently exists for the Ningaloo Marine Park.

The agencies with statutory responsibilities in marine conservation reserves in Western Australia are listed in Table 1.

TABLE 1
AUTHORITIES AND AGENCIES WITH RESPONSIBILITIES IN THE NINGALOO MARINE PARK *

Marine Parks and Reserves Authority	• Vesting body for the marine park. • Provides policy advice to the Minister for the Environment. • Audits management plan implementation by CALM.
Marine Parks and Reserves Scientific Advisory Committee	• Provides scientific advice to the Minister for the Environment. • Provides scientific advice to the MPRA.
Department of Conservation and Land Management.	• Manage marine conservation reserves vested in the Marine Parks and Reserves Authority. This includes the: a) preparation of management plans; b) implementation of the management plan; c) co-ordination with other agencies; d) implementation of education and monitoring programs; e) wildlife research and management;

	f) management of nature-based tourism; and g) lead role in enforcement (non-fisheries issues). • Ensures integrated management of marine conservation reserves with adjoining mainland and island conservation reserves.
Fisheries Western Australia	• Manages and regulates commercial and recreational fishing, aquaculture and pearling in marine conservation reserves. • Lead role in enforcement of fisheries legislation within the marine park
Department of Transport (DoT)	• Responsible for all boating regulations including licensing, safety standards, marker buoys, moorings and jetties (NB Mooring controls can be delegated to other agencies). • Chairs and supports the State Co-ordinating Committee which provides the mechanism to coordinate the management of marine pollution incidents.
Department of Environmental Protection	• Assists the Environmental Protection Authority in the process of assessing proposals that may significantly affect the marine environment, including marine conservation reserves. • Administers pollution control legislation.
Environmental Protection Authority	• Assesses reports and makes recommendations on proposals that may significantly affect the marine environment, including marine conservation reserves.
WA Maritime Museum	• Protection of pre-1900 shipwrecks and artifacts under the *Marine Archaeology Act 1973*. Shipwrecks over 75 years old are declared and protected under the Commonwealth *Historic Shipwrecks Act 1976*.
Department of Minerals and Energy	• Administers acts that control mineral and petroleum exploration and development.
Other	• Other government agencies (e.g. Resources Development, Commerce and Trade) also have a broad interest in the marine environment.

* from CALM 2000 (forthcoming)

Gordon (1999) reviewed legislation relevant to the management of marine parks at a local, regional and national scale.

At a national level, the conservation of marine biodiversity, maintenance of ecological processes and the sustainable use of marine resources are addressed by the Intergovernmental Agreement on the Environment. This is implemented through actions developed under national strategies such as: the *National Strategy for Ecologically Sustainable Development (*Commonwealth of Australia 1992*)*, the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996a), *Australia's Oceans Policy (*Commonwealth of Australia 1998*)*, and the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA 1998).

The Ningaloo Marine Park is an element of the National Representative System of Marine Protected Areas (NRSMPA). The NRSMPA is being developed cooperatively by the Commonwealth, State and Northern Territory governments responsible for the conservation, protection and management of the marine environment (ANZECC TFPMA 1998a).

3.3 Zoning within the Ningaloo Marine Park

A zoning scheme has been implemented within the Ningaloo Marine Park to separate conflicting uses and provide for specific activities such as nature-based tourism, scientific study, education and nature appreciation. CALM (in preparation) notes that the partial or total restriction of extractive activities in representative habitats is a key strategy in the long-term maintenance of marine biodiversity values of the park.

The southern portion of the MSMA overlies the Mauds Sanctuary Zone that plays a key role in the protection of the representative areas of important lagoonal coral. The Mauds Sanctuary Zone is located directly offshore of the Coral Bay townsite.
Zones are formally established as classified areas under Section 62 of the *CALM Act*.

The *CALM Act* provides for four different management zones in marine parks. These are (CALM in preparation):

Sanctuary Zones

Sanctuary zones provide for the maintenance of environmental values and are managed for nature conservation by excluding human activities that are likely to adversely affect the environment. They are used to provide the highest level of protection for vulnerable or specially protected species and to protect representative habitats from human disturbance so that marine life can be seen and studied in an undisturbed state. Specified passive recreational activities consistent with maintaining environmental values may be permitted, but extractive activities including fishing and traditional fishing and hunting are not. Commercial tourism operations (such as for nature-based tours) will be considered where they do not conflict with other uses and will be regulated under the *CALM Act*.

Recreation Zones

Recreation zones provide for conservation and recreation, including recreational fishing where this is compatible with conservation values. Commercial fishing and aquaculture are not permitted in these zones.

General Use Zones

General use zones are those areas of the marine park not included in sanctuary, special use or recreation zones. Conservation of natural values is still the priority of general use zones, but activities such as sustainable commercial and recreational fishing, aquaculture, pearling and petroleum exploration and production are permitted provided they do not compromise the ecological values.

Special Purpose Zone

Special purpose zones are managed for a particular priority use or issue such as a seasonal event (eg. wildlife breeding, whale watching) or a particular type of commercial venture.

3.4 Management Support in the MSMA

As described in section 1, CCMD has made a number of undertakings in relation to providing funding and other resources in support of regulatory agencies in the management of the management of the NMT. A draft Natural Resources Management Agreement (NRMA) has formed the basis for the provision of support.

The NRMA outlines the respective interest and commitments of the proponent, CCMD and the Department of Conservation and Land Management (CALM) and Fisheries WA in the ongoing protection of the environment and fish stocks at Mauds Landing and in adjacent marine waters including Ningaloo Reef system and the Ningaloo Marine Park.

The details of the agreement include:

- $200,000/annum for environmental monitoring and management;
- prior to the completion of Phase 1 the allocation of $50,000 for the compilation of existing data and a 12 month baseline fisheries management survey for the Coral Bay area;
- at completion of Phase 1, allocate $150,000/annum to environmental and natural resource management;
- provide opportunities for CALM and Fisheries WA to gain revenue through the visitor entry fees, a portion of boat launching and marina usage fees and the sale of merchandise from the interpretive centre;
- allocate $1,000,000 to the construction of the Coral Coast Environmental and Interpretive Centre as a field and interpretation centre (incorporating an underwater viewing area and an office for CALM and Fisheries WA);
- allocate a maximum of $250,000 for equipping the Coral Coast Environmental and Interpretive Centre; and
- construct a limestone substrate and allocate $200,000 for the propagation of a coral reef.

CCMD and CALM and Fisheries WA, in common will work diligently towards determining the most appropriate option(s) for funding the ongoing management of the environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo reef system and Ningaloo Marine Park. Additional commitments will include:

- prior to commencement of works, the preparation of a Foreshore Management Plan (ie. provision and maintenance of access and facilities the terrestrial component of Ningaloo Marine Park), a Nutrient and Irrigation Management Plan, a Shallow Groundwater Management Plan, a Shoreline Movement Monitoring Plan, a Turtle Management Plan and Turtle Nesting Surveillance Programme, a Coral Community Monitoring Programme, a Water Quality and Sediment

Monitoring Programme and a Fish Resource Management and Research Programme;

- employment of an environmental manager;

- in conjunction with CALM and Fisheries WA, discuss with the Shire of Carnarvon the option of implementing a Specified Area Rate to contribute to environmental management; and

- work with CALM and Fisheries WA to provide housing for CALM and Fisheries WA staff at normal commercial rentals.

The finalised SAMMP for the MSMA is an important component of this commitment to the determination of the impacts of the implementation of the Coral Coast Resort and maintenance of ecological processes and biodiversity of Ningaloo Reef generally.

4. DESCRIPTION OF THE MSMA

This SAMMP for the MSMA will identify two areas for specific management within the broader Ningaloo Marine Park. The areas defined and the possible impacts include:

4.1 Development Impact Area (DIA)

The DIA comprises an area of approximately 9km^2, including the sensitive Bills Bay area and an area adjacent to the development site that will likely be impacted directly by the effects of the construction and operation of the resort, including greater visitation.

It is anticipated that there will be some short-term reduction in water quality within the DIA during the period of the construction and for a period of up to five years post-construction. This SAMMP presents a series of environmental indicators that, properly monitored, will track the condition of the likely impact area and will provide a framework against which they can be reported.

The area comprising the DIA is defined as marine waters and land extending to 40m above High Water Mark (HWM) within 2600m of the HWM at the Coral Coast Resort channel entry and extending from a point 200m west of Point Maud southward to Pardy Point.

4.2 Maud Specific Management Area (MSMA)

The proposed MSMA to which this plan refers, is an area of approximately 111km^2 and includes the DIA, the entire Mauds Sanctuary Zone and extends northward to Bruboodjoo Point. It is anticipated that within this area, indirect impacts, principally a consequence of the greater selective pressure on certain target species and coincidental damage (anchor, boat impacts), may occur.

The area comprising the MSMA is defined as the marine waters and land extending to 40m above the HWM, inclusive of the DIA and coincident with the Maud Sanctuary Zone, otherwise extending seaward to the 18m contour and north to a point due west of Bruboodjoo Point and westward to 40m above the HWM.

The proposed MSMA is indicated in Figure 2.

5. ECOLOGICAL AND SOCIAL VALUES

CALM 2000 (forthcoming) defines **ecological values** as the intrinsic physical, chemical, geological and biological characteristics of an area, and that their value is measured in relation to their local, regional, national and global biodiversity significance and their role in maintaining the structure and function of ecosystems.

Social values are those cultural, aesthetic, recreational and economic characteristics for which the area is significant or well known.

As human activity in the relatively pristine marine environment of the NMT and specifically the MSMA is increasing, the recreational, commercial and tourism uses need to be managed to ensure compatibility with, and to minimize impact on, the areas conservation values. The ecological and social values of the MSMA are listed below.

Summary of Ecological Values

The Ningaloo Reef is a fringing barrier coral reef enclosing a shallow lagoon on the western side of the Cape Range Peninsula some 1200km north of Perth (Figure 1). The reef stretches some 260km south from North-West Cape and is the only extensive coral reef in the world fringing the west coast of a continent (Taylor & Pearce 1999). The distance of the reef offshore averages 2.5km varying from about 200m through to 7km.

Coral reefs are high profile marine habitats, of high value for tourism and biodiversity values (Ward *et al.* 1998). In many locations coral reefs are also important for recreational fisheries.

Australia is recognised as having both the largest area of coral reefs, and those that can be considered remaining in good condition Commonwealth of Australia (1996). Because of the problems in controlling trade in other jurisdictions all hard corals (*Scleractinia*) are listed on Appendix 2 of the Convention on International Trade in Endangered Species (CITES).

Coral reefs are subject to many different natural and anthropogenic disturbances that may affect reef condition both spatially and temporally. These include changes in sea level, temperature, light attenuation through the water column, and various pollutants including nutrients. Wilkinson and Buddemeier (1994) have described the possible relationship between coral condition and global climate change and how the condition of coral reefs can be used as an indicator of these changes.

Disturbances to coral reef systems range from trivial, such as those caused to individual corals by fish bites, to significant regional and global scale episodes caused by such vectors as major tropical storms, *El Nino* events, large scale sedimentation and major predation episodes (Simpson *et al.* 1993). The degree of impact to coral reef ecosystems caused by disturbance depends upon the magnitude and frequency of the event and the time necessary for recovery.

The Ningaloo Marine Park supports about 33 species of sea bird, 13 of which are residents, while the other 20 migrate through the area or are occasional visitors (CALM records). A number are protected under JAMBA and CAMBA.

The Ningaloo Reef Tract also has a diverse and abundant shark and ray population, with aggregations of small grey reef sharks and black tipped whites having been observed in Bills Bay over many years (Norman 1999).

The largest of the tropical sharks, the whale shark, (*Rhiniodon typus*), tiger shark, (*Gaeocerdo cuvier*), and the hammerhead shark, (*Sphyrna* spp.), are also present offshore.

The Ningaloo Marine Tract also supports a diverse and abundant ray population including the giant manta ray. Manta rays are most often encountered immediately outside the Ningaloo Reef and appear to be more common in autumn. Other rays occur throughout the Ningaloo Reef Tract from deep offshore waters to shallow near shore waters.

Marine reptiles utilising the waters adjacent to Mauds Landing may include four species of turtle and several species of sea snake.

Aerial surveys of the Ningaloo Marine Park suggest that an estimated population of approximately 4300 turtles (all species) is resident within the Park (Preen *et al.* 1997). Turtle densities are extremely high at Ningaloo and exceed the highest densities recorded on the Great Barrier Reef and most of the areas in Torres Strait.

Point Cloates is considered to be the northern extent of the subtropical fish distribution (Allen & Swainston 1988).

The fish fauna that is found in the Ningaloo Marine Tract is composed of a mixture of warm-temperate, subtropical and tropical species. According to Hutchins (1994) there are 307 fish species found within lagoonal areas and on the reef to a depth of approximately 20m. Pelagic fish beyond the reefs are not included, but would certainly increase significantly species numbers. Most of the species recorded are tropical (91%) with subtropical species making up a further seven percent.

In summary, relevant ecological values include:

- **Geomorphology**: A complex seabed and coastal topography consisting of a barrier reef, subtidal and intertidal coral reefs, protected inshore lagoons and deeper basins, beaches and headlands.
- **Intertidal reef platforms and communities**: A range of intertidal reef platforms occur in the park that are principally highly protected.
- **Water quality**: With the exception of some local deterioration near Coral Bay and near the former Mauds Jetty, the waters of the MSMA are in pristine condition. Maintenance of a high standard of water quality is essential to the maintenance of a healthy marine ecosystem.

- **Seagrasses**: Seagrasses in the MSMA are limited to patches of *Posidonia coriacea, Amphibolis antartica* and more widely dispersed areas of *Halophila ovalis*. Notwithstanding the abundance, these seagrass communities may be important as food for dugong.

- **Macroalgal communities**: As for seagrasses, subtidal macroalgal communities are not extensive within the DIA, however well developed macroalgal communities occur elsewhere within the MSMA, especially along the back reefs. These communities are important primary producers providing food for animals such as green turtles and as refuge areas for diverse fish and invertebrate assemblages.

- **Seabirds**: There are 13 types of resident seabirds recorded in the Mauds area. While none of these seabirds are known to breed on Point Maud, the area is an important roosting site. The importance of the beach at the tip of Point Maud has been recognised and was gazetted in 1992 as a No Vehicle Access, Bird Roosting Sanctuary under the *Offroad Areas Act*.

- **Invertebrate communities**: A diverse marine invertebrate community is present occurring in all marine and intertidal habitats near Mauds Landing. Coral communities in the Bills Bay area are outstanding and can be readily accessed from the beach.

- **Finfish**: A rich finfish fauna, which includes principally tropical fish, is present. In the Mauds Landing area, fish numbers are greatest on the shallow energetic areas of the outer Ningaloo Reef. Large numbers of fish are also found in association with the shallow, coral environments of the Ningaloo Reef backreef.

- **Turtles:** Green turtles feed on macroalgae and are by far the most common turtle on Ningaloo Reef. Loggerhead turtles are carnivorous feeding mainly on molluscs and crustaceans. They may utilise the mussel beds 3km northeast of Mauds Landing, and are known to breed in Bateman Bay. Hawksbill turtles feed mainly on sponges and are more often location in deeper water, seaward of Ningaloo Reef.

- **Cetaceans:** Marine wildlife includes six species of toothed whales, while eight species of baleen whales have been recorded in deeper water offshore. Five of the eight species of baleen whales are listed as *rare or likely to become extinct* under the *Wildlife Conservation Act*.

Benthic habitats identified within the proposed MSMA are presented in Figure 4.

Summary of Social Values

Recreational fishing is a popular activity in the area and it is likely to significantly increase should the Coral Coast Resort proceed. Recreational fishers employ a variety of methods including line, spear and on occasion net fishing within specified areas.

- **Indigenous heritage**: A historical link with indigenous Australian Aboriginal culture extending back 25000 years can be demonstrated within the region.

- **Maritime heritage**: The landing of the schooner 'Maud' in 1884 is the earliest recorded European activity in the MSMA.

- **Coastal use**: Recreational use of headlands, dunes and long white beaches for walking, swimming, surfing and fishing are a major value of the MSMA.

- **Seascapes**: Panoramic vistas of turquoise lagoon waters, the barrier reefs, beaches, and the blue open ocean beyond the reef line are major attractions of the MSMA.

- **Recreational fishing**: Excellent recreational fishing opportunities for local and visiting fishers targeting a number of finfish species.

- **Water sports**: The near pristine nature and diversity of the natural environment provides opportunities for swimming, boating, snorkeling and freediving, and scuba diving.

- **Marine nature-based tourism**: Natural values and accessibility of unique ecotourism target species ensure significant tourism activities. Target species include whales, whale sharks, manta rays and turtles.

- **Petroleum drilling and mineral development**: Offshore potential for hydrocarbons continue to be assessed near the NMT.

- **Scientific research**: The mix and ready access of ecotourism target species, high fish species diversity, range of corals and ongoing focus into tropical species ensures that the MSMA will become a major centre of research effort.

- **Education**: Easy access and the close proximity of the MSMA to Coral Bay and the proposed Coral Coast Resort provide opportunities for community education about the marine environment.

6. MANAGEMENT OF PRESSURES WITHIN THE MSMA

CALM 2000 (forthcoming) notes that an important step in maintaining the ecological and social values of a marine park is to undertake a risk assessment that considers the range of existing and potential pressures (cf. threats) on the park's key values and their associated ecological and social implications. Risk can be assessed by considering the factors in Table 2.

TABLE 2
RANGE OF POTENTIAL PRESSURES IN A MARINE PARK AND RESULTANT IMPLICATIONS

PRESSURE	RESULTANT IMPLICATION
Temporal scale	Pressures that continue over a longer time frame are often of greater concern than short-lived pressures.
Spatial scale	Pressures that affect a large area are often of greater concern than localised pressures.
Trophic level and conservation status of the species affected	Pressures that impact on lower trophic levels (i.e. primary producers) are of greater concern than those at higher trophic levels (i.e. secondary consumers) as a result of potential cascading effects on the whole ecosystem.
Probability of occurrence	The greater the likelihood of the occurrence, the greater the concern.
Consequences of the event	The ecological or socio-economic implications and the manageability of the pressure

modified from CALM 2000 (forthcoming)

In considering the existing uses and nature of the Ningaloo Marine Park generally and the MSMA specifically, only a limited knowledge of factors such as fishing pressure and the response of ecotourism species to continued pressure are not well known. Further, the short-term and long-term cumulative ecological effects of these activities on the environment are less well understood.

The pressures on the park's values are either a primary (direct) or secondary (indirect) impact of user activities.

Impacts resulting from the implementation of the Coral Coast Resort have been assessed and a range of management strategies focusing on the design, location, provision of infrastructure and management programs identified in the project design. As a result, planning for the resort incorporates all service utilities including deep sewerage, wastewater treatment and a managed solid waste landfill. CCMD have also made a commitment to design utilities such as sewage and power so that they can be upgraded to accommodate the requirements of Coral Bay.

Resort nearshore and marina waterway water quality management strategies are linked to the control of construction impacts (eg. de-watering, dredge management), the provision of services at an inland location (WWTP and landfill), management of nutrient inputs to private gardens and public open spaces and to the direction of potentially contaminated stormwater inland and away from the marina/ocean. No sensitive coral communities occur immediately offshore from Mauds Landing.

Indirect impacts will be managed through the implementation of monitoring and resulting management strategies developed in collaboration with government regulatory agencies. The resort and marina waterways themselves will provide a range of features such as protected swimming beaches, constructed snorkelling reef, interpretative centre and entertainment that will provide an alternative to traditional recreational use of the Ningaloo Marine Park.

As a result, strategies in the SAMMP for the MSMA will focus primarily on mitigating the effects of human activities. These can be direct effects such as damage to coral habitats by indiscriminate mooring and anchoring or through localised over-fishing. These impacts have the potential to increase with the advent of greater numbers of visitors utilising the MSMA and NMT generally.

The Ningaloo Marine Park is in a largely pristine condition, with human activities since European colonisation having left the bulk of the marine environment largely unaffected. However there have been localised disturbances that have impacted on water quality, with some potential direct impacts on biota such as coral damage due to boat activities and localised nutrient enrichment of Bills Bay. Natural disturbances such as the predation of corals by the marine snail *Drupella cornus* and coral and fish deaths due to a massive synchronised spawning of corals in association with flood tides and onshore winds, and resulting anoxic conditions have also been recorded.

However, regardless of the implementation of the Coral Coast Resort, the projected rise in use of the MSMA in the next decade and resulting pressures on the conservation values of the area will increase significantly and conflicts between users are likely to emerge.

This SAMMP for the MSMA identifies a number of pro-active strategies involving education and extension programs and active participation of MSMA users and the local community in the on-going management of the area. With better control of direct impacts through the provision of improved infrastructure to Coral Bay, the control of boat mooring and traffic, these will be important strategies in ensuring management objectives are met and user conflicts minimised.

7. DESCRIPTION & MANAGEMENT OF ECOLOGICAL AND SOCIAL VALUES

7.1 Best Practice in Performance Reporting

The format of this section is based on the best practice principles outlined in the report entitled Best Practice in Performance Reporting in Natural Resource Management (ANZECC 1997), and those adopted by CALM in its development of Marine Management Plans for Marine Parks in Western Australia.

The Marine Parks Reserve Authority (MPRA) has adopted this model so as to facilitate better conservation and management outcomes and a more objective and effective approach to auditing CALM management plans. It is similarly applicable to assess the performance of developments that will have impacts within any portion of the Marine Park.

For the remainder of this section, performance against which the management of ecological and social values are measured is presented in terms of:

- management objectives;
- management strategies;
- performance measures;
- management targets; and
- key performance indicators.

A brief description of the status of the values in the MSMA is also provided. A brief explanation of these terms is presented in Table 3.

TABLE 3
AN EXPLANATION OF THE TERMS USED IN THE DESCRIPTION OF ECOLOGICAL AND SOCIAL VALUES USED IN THIS SAMMP FOR THE MSMA

Value	Present objective in management of the value. It is against this objective that the measure of acceptability or otherwise of the value will be made.

Background	The current state of the environment will be described and an overview of pressures given.
Existing and potential uses and/or pressures	A summary of existing and potential uses and/or pressures will be presented.
Current major pressure	Current pressures, if any, will be described.
Management objective	Management objectives identify **what** the primary aims of management are and reflect the statutory responsibilities of the *CALM Act.*. Where a significant pressure/s on an ecological value has been identified, the management objective addresses the specific pressure/s. When there is not an obvious existing pressure or threat, the management objective provides broader direction to management in relation to protecting the value from the most likely future threats.
Strategies	Management strategies provide specific direction on **how** the management objective/s for each value might be achieved. All strategies outlined in this plan have been defined as either high **(H)**, medium **(M)** or low **(L)** priority to provide an indication of their relative importance. The **(H)** strategies considered to be critical to achieving the long-term objectives of the marine park are also designated as *key management strategies* **(H – KMS)**.

Performance measure	1. Performance measures against direct and indirect impacts are **indicators of management effectiveness** in achieving the MSMA's objectives and targets. Where possible they are quantitative, representative, simple and cost-effective.	**Desired trend**	Desired trend (negative or positive) in assessing performance measure is indicated.
Short-term target	Management targets represent the **end points of management**. Targets where possible are measurable, time bound and expressed spatially. Ecological targets are set as either the 'natural state' or some acceptable departure from the 'natural state'. The short-term target provides a benchmark for management to achieve within a specified time period and, in most cases, is a step to achieving the long-term target.		
Long-term target	The long-term target provides a specific benchmark to assess the success or otherwise of management action within the life of the management plan.		

Targets identified are indicative and will be further developed and finalised to the satisfaction of CALM.

Key performance indicators (KPIs) are a **measure of the overall effectiveness** or otherwise of management in relation to the strategic objectives of the MSMA. CALM 2000 (forthcoming) note that KPIs relate specifically to the management targets for key ecological and social values and reflect the highest conservation (from biodiversity and ecosystem integrity perspective) and management (social) priorities of the MPRA, CALM and the community.

7.2 Ecological Values.

CALM 2000 (forthcoming) describes ecological values as the physical, geological, chemical and biological characteristics of an area. Ecological values are significant in terms of their biodiversity (ie. representative, rare or unique) and ecosystem integrity role. Where social values (for example recreational fishing) are dependent on ecological values (maintenance of fish stocks), ecological values also have a social significance.

7.2.1 Geomorphology

Ecological value	**Geomorphology:** *A complex seabed and coastal topography consisting of barrier, sub-tidal and inter-tidal reefs, protected inshore lagoons and deeper basins, beaches and headlands.*

Background	The marine and coastal geomorphology and geology of the coast from North West Cape to Gnarraloo Bay is described in some detail in Wilson *et al.* (1994). The coast is formed mostly of Pleistocene (1.5 million to 10000 years ago) limestone and Holocene (since the end of the last Ice Age, about 10000 years ago) sands. These overlie the margin of a Miocene (from 26 to 7 millions years ago) limestone anticline (broad, raised stratified rock crest) (Wilson *et al.* 1994). The major marine geomorphological features are a gently sloping submarine shelf underlain by Pleistocene limestone with a veneer of marine sediments and interrupting this shelf, a fringing barrier reef system. The shelf in this region, known as the Dirk Hartog Shelf, is relatively narrow and within 40km of the coast just south of North West Cape (Wilson *et al.* 1994). The shelf rises abruptly to the outer barrier reef, which consists of limestone and coral (DCE 1984). The Ningaloo Reef comprises a partially dissected basement of Pleistocene marine or Aeolian sediments, or Tertiary limestone covered by dead or living coral, the reef flat is on average several hundred metres wide (May *et al.* 1989).

	In the vicinity of the proposed development area the reef is discontinuous and there is a break or 'passage' directly offshore. Just north and south of Point Maud the reef is only one to two kilometres offshore (DCE 1984), and plays a fundamental role in coastal processes. Sediments in the lagoon are generally coarse calcareous sand with finer calcareous sand or silt in deeper basins and gutters (May *et al.* 1989). These longshore drainage channels skirt the shoreward edge of the reef and may be up to 12m deep (May *et al.* 1983). The underlying limestone may occasionally be exposed as bare pavement where the sand veneer has been swept away. The sandy beach in the southern portion of Bateman Bay is believed to be stable and in balance with the incoming, persistent, low amplitude swell waves. The measured beach profiles are typically swell-built and there is expected to be little longshore transport of sediment under these usual conditions. The swell is believed to slowly feed the beach system with sediment produced in the nearby reefs. The largest movements of sand are believed to occur under the action of severe tropical cyclones. The complex geomorphology of the area supports a wide diversity of habitats and ecological niches which, in turn, contribute to the high marine biodiversity of the area. The most significant pressure on the geomorphology is increasing recreational use of coastal landforms and coastal development. Coastal facilities such as groynes and marinas have the potential to significantly affect sedimentation patterns resulting in major changes to beaches. Uncontrolled recreational use of fragile coastal dunes and headlands can also lead to considerable erosion of these features. Management of the MSMA, including the adjoining coastal land reserves, needs to be integrated with a focus on protecting sensitive areas from inappropriate use. This may be achieved by the provision of coastal facilities (i.e. boardwalks and roads) or through excluding access to specific areas. Given the robust nature of much of the subtidal geomorphology and the nature of existing activities in the area, there are no current major pressures on this component of the ecosystem.
Existing and potential uses and/or pressures	1. Recreational use of coastal landforms. 2. Coastal development (eg. groynes, marinas and boat launching ramps). 3. Commercial and recreational fishing activities. 4. Navigation: • installation of markers; and • removal of hazards.
Current major pressure	None, however breakwaters will need to be constructed to protect entrance channel for either Coral Coast Resort or North Bills Bay boat launching facility.
Management objectives	1. To ensure the structural complexity of the MSMA's geomorphology is not significantly reduced by human activities. 2. To ensure coastal landforms within the MSMA are not degraded by recreational access and use.
Strategies	1. Ensure effective management of coastal recreational through liaison with coastal land and Coral Coast Resort managers to control access and use of beaches and headlands adjacent to the park (CALM, CCMD, LGAs. Cardabia Station). **(M)** 2. Control recreational use of coastal features within the Mauds Landing townsite within the MSMA where these activities are likely to result in degradation of coastal landforms (CCMD). **(M)** 3. Liase with CALM for the control of recreational use of coastal features within the reserve adjoining the MSMA where these activities are likely to result in degradation of coastal landforms (CALM). **(M)** 4. Restate relevant management objectives and targets of the MSMA in induction and other educational materials produced for the Coral Coast Resort in relation to the geomorphology (CCMD, CALM, LGA). **(M)** 5. Develop short-term management targets as required (CALM). **(M)** 6. Educate park users about the ecological importance of the park's geomorphology (CCMD, CALM). **(L)**

Performance measures	1. Area of seabed disturbance (ha.) 2. Area of coastal degradation (ha.)	**Desired trend/s**	1. Negative 2. Negative
Short-term targets	To be developed prior to the operations phase of Coral Coast Resort.		
Long-term targets	1. That the structural complexity of the geomorphology of the park is not significantly altered by human activities from 2000 levels. 2. That the coastal landforms within the park are not significantly altered by human activities from 2000 levels.		

7.2.2 Intertidal reef platforms and communities

Ecological value	**Intertidal reef platforms and communities:** *A diverse range of intertidal reef platforms occur in the park ranging from highly protected backreefs to reefs fully exposed to the action of swell waves.*

Background	Intertidal reef platforms are a major feature adjacent to the coastline of the area. The Ningaloo Reef comprises a partially dissected basement of Pleistocene marine or Aeolian sediments, or Tertiary limestone covered by dead or living coral, the reef flat is on average several hundred metres wide (May *et al.* 1989). These areas contribute significantly to the variety of habitats and therefore the biological diversity of the MSMA. The intrinsic biological attributes and accessibility of shoreline intertidal reefs often attract limited commercial and significant recreational (eg. collecting, fishing,) activities beyond the sanctuary zone within the MSMA. There remain significant opportunities for education and scientific research within the entire area. The Ningaloo Reef backreef is generally very shallow with live corals often being exposed on extremely low tides. Shoreline reef platforms comprising a combination of igneous, metamorphic and sedimentary substrate types occur in on the eastern margin of the MSMA and are generally bare or covered in algal turf. Reef-walking and recreational fishing can impact on the flora and fauna on these reef platforms through trampling. Similarly commercial and recreational collecting activities have the potential to deplete local populations. These pressures are generally greatest on shoreline intertidal platforms due to the ease of access. Backreef tidal platforms are generally due to the presence of coral communities and are often difficult to access.
Existing and potential uses and/or pressures	1. Recreational and commercial fishing 2. Physical disturbance (eg. trampling) 3. Tourism 4. Scientific research
Current major pressures	1. Recreational and commercial fishing 2. Physical disturbance (eg. trampling)
Management objectives	No pressures within the Sanctuary zone. Ensure the species diversity and abundance of marine flora and fauna on the intertidal reef platforms in the MSMA outside the sanctuary zone are not significantly impacted by shell or specimen collecting, fishing and reef-walking activities.
Strategies	1. Provide support for the enforcement of zoning requirements. **(H - KMS)** 2. Initiate research programs to characterise the flora and fauna of selected intertidal reef platforms within the MSMA in relation to establishing management targets (CCMD,CALM, FWA). **(H - KMS)** 3. Assess the nature, level and potential impacts of human activities on intertidal reef platforms within the MSMA (CCMD,CALM). **(H)** 4. Educate park users about the potential detrimental effects of indiscriminate specimen collecting and reef-walking (CCMD,CALM). **(H)**

Performance measures	1. Diversity 2. Abundance (non-targeted species) 3. Abundance (targeted species)	**Desired trend**	1. Constant or positive 2. Constant or positive 3. Constant or positive
Short-term targets	To be developed prior to implementation of the Coral Coast Resort.		
Long-term targets	1. That the diversity of flora and fauna on intertidal reef platforms of the park are not reduced from baseline levels (to be determined) as a result of human activities. 2. That the abundance of protected flora and fauna on intertidal reef platforms does not differ between the Maud Sanctuary Zone and otherwise in the MSMA.		

7.2.3 Water quality

Ecological value	**Water quality**: *The waters of MSMA are representative of the general water quality within Ningaloo Marine Park, are largely pristine and are recognized as essential to the maintenance of a healthy marine ecosystem.*

Background	The waters of Ningaloo Marine Park are largely pristine with some deterioration noted in respect to nutrient enrichment (inorganic nitrogen), elevated microbiological levels and TBT levels in Bills Bay adjacent to the Coral Bay settlement. Some elevation of arsenic and metals levels off Mauds Landing possibly occur as a result of residual contamination from historical activities. The waters within the Ningaloo Marine Park are, by world standards, nutrient-poor as a result of both low riverine inputs and the absence of significant up welling of nutrient rich waters from the deeper oceans. A low standing crop of phytoplankton and high water clarity results. The DEP undertook an assessment of water and sediment quality in Bills Bay and Mauds Landing in response to concerns from the local community regarding nutrient enrichment and possible microbiological contamination (DEP 1995). The report concluded that the elevated concentrations of inorganic nitrogen and faecal coliforms in the groundwater along the shoreline of Bills Bay and adjacent marine waters, was likely sourced from groundwaters contaminated by sewage. This had the effect of increasing nutrient concentrations in nearshore waters thereby increasing phytoplankton biomass, reducing light attenuation through the water profile and increasing macroalgae within the bay. The results of heavy metal and organotin analyses indicated elevated levels of arsenic, chromium, iron, manganese and zinc relative to other sites at Mauds Landing, and extremely high levels of tributyltin (TBT) close to mooring locations within Bills Bay. Nitrogen is one of the main plant nutrients and in marine systems it is often described as 'limiting' in its absence. Nitrogen singularly controls the viability and growth of plant species. Abundant and bioavailable nitrogen, combined with other favourable conditions, can lead to an increase in local plant production and in extreme cases, eutrophication. Sediments often serve as a reservoir for nutrients that regularly recharge overlying waters and trigger perennial growth in aquatic vegetation. Nutrient enrichment of waters by human activities such as: • sewage discharge; • contaminated groundwater inputs; and • surface runoff, can stimulate phytoplankton blooms as well as promoting excessive growth of nuisance algae. Accidental and deliberate spills from: • boats; • hull antifouling treatments; • industrial discharges; and • contaminated surface drainage and groundwater flows, are possible sources of toxic contaminants, pathogenic organisms and litter.

	Sewage discharge from vessels has the potential to increase nutrient levels and to cause health problems for direct contact recreational activities. The Department of Transport has reviewed discharge of vessel sewage and recently released a position paper for Western Australia consisting of a three-zone discharge scheme (Department of Transport 1999). Implementation of this draft by government will result in a review of practices within the MSMA. Whilst the management of shipping and potential impacts of oil pollution following a shipping disaster is outside the scope of this SAMP, the preparation for management in the event of such an incident will be undertaken in association with CALM. Concentration of water and sediment quality results will both be compared to regional baseline levels and to 'trigger levels' in documents such as the *Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Nutrient data will be interpreted in consideration of biological indicators to obtain a more complete picture of general health. Indicated water quality will be considered on both a temporal and spatial basis.
Existing and potential uses and/or pressures	1. Nutrient inputs from: • sewage discharge from vessels; • septic tanks and leach drains via groundwater flows; and • urban stormwater runoff. 2. Toxicant inputs from: • accidental spillages of fuel and oils from boating activity; • hull antifouling of commercial and recreational boats; • urban stormwater runoff; and • oil spills from passing shipping. 3. Pathogen inputs from: • sewage discharge from vessels; • urban stormwater runoff; and • septic tanks and leach drains via groundwater flows. 4. Litter from: • commercial and recreational boating/fishing activities; and • urban stormwater runoff.
Current major pressures	1. Nutrients continue to leach into southern Bills Bay from septic tanks and leach drains at the Coral Bay townsite. 2. Fuelling of commercial vessels continues from small containers.
Management objective	To ensure the water quality of the MSMA is not significantly impacted by the input of contaminants.
Strategies	1. Make available alternative wastewater treatment facilities for Coral Bay. (CCMD in consultation with Govt.) **(H - KMS).** 2. Develop an appropriate understanding of the circulation and mixing of the MSMA waters (CCMD, CALM). **(H - KMS)** 3. Establish baseline water and sediment quality monitoring programs in relation to nutrient enrichment and metal contamination (CCMD, CALM). **(H - KMS)** 4. Map ecological and social values of the park that are particularly sensitive to oil spills and provide this information to the State Committee for Combating Oil Pollution (CALM. DoT). **(H)** 5. Inform users of the park about regulations on boat sewage disposal (CCMD, CALM, DoT). **(M)**

Performance measures	1. Nutrients: Chlorophyll *a* and inorganic nutrient (N) conc. In seawater. 2. Toxicants: conc. in seawater. 3. Pathogens: Faecal coliform conc. In seawater. (limited sites). 4. Litter: Mass (kg) of litter at selected monitoring sites.	**Desired trend**	1. Constant or negative 2. Constant or negative 3. Constant and/or negative 4. Negative

Short-term targets (KPI)	1. See Appendix 1. 2. As per: • WA Guidelines for Fresh and Marine Waters (or equivalent) (EPA 1993) • *Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC July 1999). • Environmental Quality Objectives identified in the Southern Metropolitan Coastal Waters Study (DEP 1996).
Long-term targets (KPI)	That the water quality of the MSMA meets agreed standards or guidelines for the maintenance of biodiversity, ecosystem integrity, direct and secondary contact recreation and seafood for human consumption.

7.2.4 Seagrasses

Ecological value	**Seagrasses**: *Maintenance of the species and extent of perennial seagrasses as an important habitat and nursery area for marine life.*

Background	Marine plants are highly susceptible to a range of pressures that may occur on both short and long time scales (Ward *et al.* 1998). These include local scale problems such as pollution and broad scale changes brought about by such effects as climate change. Seagrasses in the Mauds Landing area comprise *Posidonia coriacea, Amphibolis antartica* and *Halophila ovalis*. *A. antartica* was recorded at only a few sites to the north of Mauds Landing. *P. coriacea* occurs at low density (<1 to 10% seafloor cover) over parts of Bateman Bay, but was only recorded at higher densities in discrete patches. These are located at depths of 5-10m along 1.5km of shoreline, extending some 600m out to sea and commencing 4km north of Mauds Landing as well as the northern side of Cardabia Passage at depths of 16-18m. *Posidonia* is a temperate genus and the community near Mauds Landing comprises the most northerly meadows of *P. coriacea* presently identified. Leaves of species washed up on various local beaches would indicate that similar isolated communities occur on other areas of Ningaloo Reef. *Halophila ovalis* is a tropical species and is widespread throughout the Ningaloo Reef and Rowley Shelf region. Its representation near Mauds Landing is restricted to sparse and patchy occurrences, usually in shallow sediments overlying limestone. These areas include a small macroalgae-dominated area near Point Maud and limestone pavements northwest of Mauds Landing. *Halophila* is eaten by dugong (*Dugong dugon*) and is therefore ecologically important. The sparse occurrences of *H. ovalis* near Mauds Landing in association with its seasonal and itinerant nature, suggest that the communities occurring in the study area are of limited regional significance. Observation of seagrasses within the MSMA indicate that they are generally in good condition. There are no seagrasses within the mooring area at Bills Bay, although some localised damage may have occurred due to anchors being set in Bateman Bay. There is no evidence of heavy epiphytic growth on seagrasses at present. Development of the Coral Coast Resort has the potential to increase turbidity (during construction and to a limited extent during operation), and nutrient inputs could become higher. Excessive nutrient enrichment of waters results in increases in phytoplankton concentrations in the water and epiphyte (ie. algae) loads on seagrass leaves thereby reducing the amount of light reaching the leaves and causing the seagrasses to die of light starvation. Strategies for management of seagrasses may include infrastructure provision to regulatory agencies, education, surveillance, research and monitoring. The details of the monitoring program will be agreed with CALM and be consistent with and complement the Ningaloo Marine Park Monitoring Program (NMPMP) currently in progress. The techniques proposed for the MSMA will include gross measures of abundance supplemented by combinations of transect, quadrat and leaf-blade measurements as appropriate. Seagrass and macroalgae will be monitored annually and assessed using

	multivariate statistical analyses to summarise change where appropriate and will be presented as time-series data. Once agreed, the SAMMP will be implemented pre-construction and in consultation with relevant Government agencies.

Existing and potential uses and/or pressures	1. Mooring and anchoring 2. Nutrient inputs from point sources (eg. urban drains) 3. Propeller scour 4. Groundwater discharges (eg. nutrients and pesticides)
Current major pressure	None
Management objective	To ensure existing and future mooring and anchoring activities do not permanently damage seagrasses in the MSMA.
Strategies	1. Ensure all existing moorings within the MSMA are either removed or meet a specified environmentally acceptable standard within three years, and that all new moorings meet the specified environmentally acceptable standard (CCMD,CALM, DoT). **(H – KMS)** 2. Educate users of the important ecological role of seagrasses. and the potential impacts of human activities, particularly boat moorings and nutrient pollution, on these communities (CCMD,CALM). **(H - KMS)** 3. Assess proposals for new moorings. Moorings will not be permitted if they compromise vessel safety/navigation or if the installation and use of the mooring is likely to have significant impact on the ecological values (CALM, DoT). **(H)** 4. Monitor seagrass health within the MSMA (CCMD, CALM). **(H)**

Performance measures	Aboveground biomass (areal extent and density) of perennial seagrasses.	**Desired trend**	Constant or positive
Short-term target (KPI)	No permanent loss in the aboveground biomass of perennial seagrasses from 2000 levels in defined areas of highest existing risk.		
Long-term target (KPI)	No permanent loss in perennial seagrass aboveground biomass from 2000 levels as a result of human activities in the MSMA.		

7.2.5 Macroalgal Communities

Ecological value	**Macroalgal communities**: *Significant subtidal macroalgal communities with high floral diversity occur on reef and pavement substrates within the MSMA. These communities are important primary producers and refuge areas for diverse fish and invertebrate assemblages.*

Background	Marine plants are highly susceptible to a range of pressures that may occur on both short and long time scales (Ward *et al.* 1998). These include local scale problems such as pollution and broad scale changes brought about by such effects as climate change. Macroalgae are the dominant plant communities in terms of biomass and therefore are a key primary producer in the MSMA. The large fleshy algae provide food and shelter for a variety of marine organisms. Unlike perennial seagrass communities, most algal communities can quickly recover from human disturbance. Well-developed macroalgal communities also occur extensively along the Ningaloo Reef tract. The nearest backreef algal community to Mauds Landing occurs on the backreef immediately north of Mauds Entrance (Cardabia Passage), approximately 7km to the northwest. Although these communities are ecologically important, being highly productive and providing food for green turtles, (*Chelonia mydas*), limited examples occurring in the Mauds Landing area are not considered to be regionally significant. Small areas of sparse macroalgae occur near the western end of Point Maud. Sparse, stunted macroalgal-mixed coral filter feeder communities occur on the fringing shoreline platform located approximately 4km northeast of Mauds Landing. *Sargassum* is the dominant genera in each of these areas. The nearshore area of Bills Bay presently supports large amounts of *Sargassum* with individual plants having lengths of up to 2m in length. These plants are larger than otherwise occur in the

	area and may be a result of the nutrient enrichment suspected to be occurring from the Coral Bay settlement. Localised areas of low-profile pavements occur near Point Maud, and to the northeast of Mauds Landing. The area near Point Maud supports the shallow, mixed macroalgal and *Halophila* community Algae that detach from reefs often form drifts on the water's surface before accumulating on the seabed or shore as algal wrack. This wrack is ecologically significant in that it contains large numbers of invertebrates, which are prey for surf zone fishes and birds. The decomposition of the wrack also has ecological benefits by releasing nutrients and suspended organic particles into the water. There are currently no identified major pressures on the macroalgal communities within the park.
Existing and potential uses and/or pressures	1. Damage from boat anchoring 2. Nutrient enrichment resulting in prolific algal growth.
Current major pressure	Anecdotal information relating to macroalgal growth in Bills Bay possibly resulting from nutrient enrichment.
Management objective	To ensure macroalgal diversity and habitat in the park are not significantly impacted by human activities in the park.
Strategies	1. Educate park users about the ecological importance of macroalgal communities (CCMD, CALM). **(M)** 2. Initiate research programs to quantify the areal extent and floral and faunal diversity in major subtidal macroalgal habitats in the MSMA in relation to both developing management targets and to assess changes resulting from greater pressures (CCMD, CALM). **(M)**

Performance measures	1. Diversity 2. Areal extent of habitat (ha.)	**Desired trend**	1. Constant or positive 2. Constant or positive
Short-term target	To be developed prior to the operational phase of Coral Coast Resort.		
Long-term target	No reduction in macroalgal species diversity or macroalgal habitat below 2000 levels as a result of human activities in the MSMA.		

7.2.6 Shorebirds and Seabirds

Ecological value	**Shorebirds & Seabirds:** *More than 35 shorebirds and seabirds that are listed as Migratory Species under the EPBC Act and/or protected under JAMBA and CAMBA are known to occur in the Ningaloo area, and over 30 seabirds occur on islands and nearshore and offshore waters in the region.*
Background	Although no listed Migratory Species are known to breed at Point Maud, the area is an important roosting and loafing site for a variety of shorebirds and seabirds. Nine species listed as Migratory Species under the EPBC Act and/or protected by bilateral agreements have been recorded at Point Maud during surveys undertaken by CALM between 1990 and 2001. CALM (1997) notes that more than 30 species of seabirds are reported to occur on the coastal islands, mainland coastal and offshore waters of the Ningaloo area. Monitoring of birds at Point Maud by CALM has identified some current potential disturbances by dogs, walkers and vessels. Development of the Mauds Landing Townsite and resulting greater visitation will result in additional pressure on these bird populations. However the construction of the CCR will present a physical barrier to 4WD vehicles and quad-bikes that

	currently freely travel down Point Maud while travelling northward. The presence of the marina waterway may result in drivers and riders using an alternative inland route behind the CCR to gain access to northern beaches, and so lessen impacts on Point Maud. Data relating to the anticipated increase in visitation to the Coral Bay area following implementation of the proposal is presented in 4.3.2. Current landfill management practices are poor and include poor fencing, inadequate cover, excessive open face, wind blown litter and poor vermin control. It is proposed this landfill be replaced by a new and actively managed facility in the services area. Commonwealth of Australia (2000) has identified that education is a major strategy to achieve the management goals and thus a strategic objective of the NMP. The desired outcome of public education is to increase public awareness and understanding of conservation and management issues in the area and of the marine environment in general. This will include information on the importance of the protection of bird habitats, and litter management.
Existing and potential uses and/or pressures	1. Expansion of tourism activities at Point Maud 2. Entanglement in fishing gear 3. Entanglement with or ingestion of marine debris 4. Oil spills/pollution
Current major pressure	None
Impacts of the Action	It is CCMDs view that implementation of the proposed action will not impact on protected migratory birds and seabirds occurring within the project area, in nearby waters or passing through Commonwealth marine waters. The action will however result in both an increase in the number of people in the Coral Bay area generally, and result in a shift in the major concentration of people away from the more southerly Coral Bay to a location about 1.7km from the principal bird roosting areas. Greater visitation will also result in an increase in litter generated, greater fishing efforts with a resulting potential increase in entanglement of birds, and an increase in potential disturbance. Increased boat traffic also has the potential to increase oil and fuel spillage.
Management objective	To ensure that human activity does not significantly disturb seabird populations in the MSMA.
Evaluation	Solid wastes will be disposed of to a managed landfill that will be superior to that currently in use with a view to limiting vermin and bird access to litter. Physical activities and noise from the development site during construction and operation is unlikely to cause significant disturbance of shorebirds or seabirds, which largely occur at Point Maud, due to the distance separation and wind patterns. As the construction of the CCR will present a physical barrier to 4WD vehicles and quad-bikes these vehicles will be directed to use an alternative inland route and bypass bird roosting areas at Point Maud. The Point Maud area including the beach and dunes is proposed as a prohibited area for 4WDs and quad-bikes, and amendment to the currently prohibited area under the *Control of Vehicles (Off-road areas) Act 1978* will be sought. Bollards and signage will be provided to restrict access to the area. The importance of bird habitat protection and management of fishing waste (including discarded tackle and fishing line) will be included in literature and

	induction material produced for the CCR and adequate signage will be erected. Visitors will be encouraged to limit speeds and take due caution to avoid disturbance and potential injury of shorebirds and seabirds. Fuel spillage will be reduced by operation of a fuelling facility to replace current practices which include over the beach filling from small containers for all classes of vessels, including commercial. The ability to respond to hydrocarbon losses will be enhanced by appointment of a Marina Manager and the development and implementation of an Emergency Response Plan that will include a spill management protocol. Fox control measures implemented on site will reduce pressures on shorebird and seabird populations from introduced predators. Monitoring of species and abundance at Point Maud will be undertaken on a regular basis by CCMD and/or as a result of the permanent presence of a CALM officer at the site.
Strategy and Mitigation	1. Educate visitors and residents about the ecological significance of the MSMA's seabird populations and the potential detrimental impacts of human disturbance. (CCMD, CALM). **(H)** 2. Enter into a Natural Resources Management Agreement with CALM and FWA to: • Construct a world class interpretation and environment centre in keeping with the standards of the overall development, and prepare appropriate resources. (CCMD, CALM). **(H)** 3. Develop and implement an Emergency Response Plan, including but not limited to: • fuel spillage; • collision between vessels; • sewage and chemical spills; • loss of containment at bulk hydrocarbon storage facilities (including boat bunkering). (CCMD, DoT, Police, FRS, SES, CALM) **(H)** 4. Develop, construct and operate the first cell of a managed landfill site in the services area. The identified site will have sufficient capacity for 20 years disposal. (CCMD, Waste Management WA, LGA) **(H)** 5. Prohibit 4WD and quadbike access to the Point Maud area through the use of signage and bollards, and possible amendment to the declared area under the *Control of Vehicles (Off-road areas) Act 1978*. (CCMD, LGA) **(H)** 6. Undertake regular monitoring of seabirds at Point Maud (CCMD, CALM) **(M)**
Predicted Outcome	Mitigation measures and public education will reduce foreseen impacts resulting from addition pressures brought about by implementation of the proposed action. Listed migratory marine species such as the eight birds protected under bilateral agreements known from the NMP do not nest at Mauds Landing and adjacent waters (Controlling Provisions 20 and 20A) and mitigation measures described will negate additional pressures.
Performance measures	1. Species diversity 2. Abundance **Desired trend** 1. Constant or positive 2. Constant or positive
Short-term target	Maintain the species diversity and abundance of resident and transient birds within the MSMA.
Long-term target	Maintain the species diversity and abundance of resident and transient birds within the MSMA.

7.2.7 Corals and other invertebrate communities

Ecological value	**Invertebrate communities**: *Coral reefs are high profile marine habitats, of high value for tourism and biodiversity values. In many locations coral reefs are also important for recreational fisheries.*

Background	Marine invertebrates are those marine animals without a backbone. Invertebrates within the Ningaloo Marine Park include animals such as corals, rock lobster, squid, cuttlefish, sponges, bivalve and gastropod molluscs, jellyfishes and anemones. The Ningaloo Reef tract supports a very diverse range of marine invertebrates, the majority of which are tropical species. Wells (1980) reports that about 433 species of mollusc had been identified along Ningaloo Reef prior to 1978. The range of habitats available for molluscs and the position of Ningaloo Reef as a biogeographic cut-off zone would suggest that this is a conservative count and many more species probably occur. Molluscs are particularly abundant and the most investigated of the marine invertebrate groups. They occur in all marine and intertidal habitats present near Mauds Landing ranging from only occasionally inundated or splashed beach rock, to submerged sand plains and coral reefs. Molluscs on the intertidal platforms include the periwinkles, (Family Littorinoidea), and limpets, (Families Acmaeicae and Patellidae), in the upper intertidal zones and oysters, (*Saccostrea* spp.) at the midtide level. The platforms 4km north of Mauds Landing have particularly well developed *Saccostrea* communities hence the local name of "Three-Mile Oyster Reef". The deeper pavements support numerous browsing and carnivorous molluscs, such as cerithids and mitras and at times filter feeding bivalves. The most notable such community is the mussel bed (*Brachidontes* sp.) located 3km from Mauds Landing. Coral reefs provide a great range of habitats and support a varied molluscan fauna. These range from the large clams (*Tridacna maxima*), interspersed among the corals to tiny muricids within the dead coral branches. The most ecologically important of the molluscs on coral reefs near Mauds Landing is the coral eating gastropod *Drupella cornus*. This marine snail has occurred in large numbers on coral reefs throughout the Ningaloo Reef resulting in significant reductions in live-coral cover. The marine substrates closest to Mauds Landing are bare sands and molluscs are expected to be the dominant fauna of the submerged plains. Bivalves of the genus *Donax* are ubiquitous in lower intertidal beach sands and are expected to occur at Mauds Landing along with polychaete worms. Australia is recognised as having both the largest area of coral reefs, and those that can be considered remaining in good condition Commonwealth of Australia (1996). All hard corals (*Scleractinia*) are listed on Appendix 2 of the Convention on International Trade in Endangered Species (CITES), likely because of the problems in controlling trade in other jurisdictions. Coral reefs are subject to many different natural and anthropogenic disturbances that may affect reef condition both spatially and temporally. These include changes in sea level, temperature, light attenuation through the water column, and various pollutants including nutrients. Disturbances to coral reef systems range from trivial, such as those caused to individual corals by fish bites, to significant regional and global scale episodes caused by such vectors as major tropical storms, *El Nino* events, large scale sedimentation and major predation episodes (Simpson *et al.* 1993). The degree of impact to coral reef ecosystems caused by disturbance depends upon the magnitude and frequency of the event and the time necessary for recovery. A variety of natural disturbances to marine environments have been documented over recent decades as knowledge of marine environments has been gained. For Ningaloo, *Drupella cornus*, a predatory snail that feeds on corals, became extremely abundant in the early 1980's and devastated coral populations along the Ningaloo Reef (Osborne 1992). In 1989 a massive synchronised spawning of corals, in association with calm oceanic conditions, caused anoxic conditions to occur in Bills Bay (Simpson *et al.* 1993). Significant damage due to boat traffic has occurred to areas of lagoonal corals in Bills Bay and

	the informal 'boat track' southward toward Monck's Head. It is anticipated that methods relevant to corals will include interpretation of remote sensing data and the establishment and field sampling of a series of transects that will add to existing or provide baseline information on the condition of corals within the SAMMP as a basis for the identification of change. The monitoring will be modelled on the AIMS Long Term Monitoring survey techniques (manta tows and video techniques) and supplemented as necessary. The sites will be revisited annually, or as agreed with CALM, sufficient to detect change. Mapping the areal extent of coral reefs will be repeated five years from the initial survey. For reporting and interpretation, changes in coral reef flora and fauna species composition will be assessed using multivariate statistical analyses to summarise change, and time-series data will be presented.
Existing and potential uses and/or pressures	1. Anchor damage, prop-wash and impacts from boats on sensitive coral formations. 2. Activities that degrade critical habitats such as high turbidity stormwaters from unsealed parking areas following intense rainfall events. 3. Trophic interactions. 4. Diffuse and point source pollution such as nutrient discharges.
Current major pressures	1. Anchor damage, prop-wash and boating impacts 2. Smothering of corals and other invertebrates.
Management objective	1. To ensure the species diversity and abundance species are not significantly impacted by human activities in the MSMA.
Strategies	1. Identify opportunities to remove large boat traffic from the Mauds Sanctuary area (CALM, DoT). **(H - KMS)** 2. Undertake research programs to characterize invertebrate diversity and abundance in different zones in the park (CCMD,CALM). **(H - KMS)** 3. Identify invertebrate species which will be protected from recreational or commercial fishing in the park and provide the necessary legislative protection to achieve this (FWA, CCMD, CALM). **(H-KMS)**

Performance measure	1. Diversity 1. Abundance	**Desired trend**	1. Constant or positive 2. Constant or positive
Short-term target	Live coral density increases to pre-1989 levels within Bills Bay.		
Long-term target	1. Non-target invertebrate diversity and abundance in the park is maintained or increases over current levels (to be determined prior to the implementation phase of Coral Coast Resort). 2. Within the Maud Sanctuary Zone, invertebrate diversity and abundance is maintained or increases over current levels (to be determined prior to the implementation phase of Coral Coast Resort).		

7.2.8 Finfish

Ecological value	**Finfish**: *A rich finfish fauna which includes an interesting mix of tropical, and sub-tropical species.* (Commercial and recreational fish species are considered in Sections 6.2. 3 and 7.2.5).

Background	The Ningaloo Reef Tract supports extremely diverse populations of reef fishes including many tropical species that are at the southern limits of their range and subtropical species that do not extend further north. Surveys of species presence and abundance have been undertaken within the Ningaloo Reef Tract by Ayeling and Ayeling (1985) and Hutchins (1994). Point Cloates is considered to be the northern extent of the subtropical fishes distribution (Allen & Swainston 1988). The fish fauna that is found in the MSMA is composed of a mixture of warm-temperate, subtropical and tropical species. According to Hutchins (1994) there are 307 fish species found within lagoonal areas and on the reef to a depth of approximately 20m. Pelagic fish beyond the reefs are not included, but would certainly increase significantly species numbers. Most of the species recorded are tropical (91%), with subtropical species making up a further seven percent. One factor thought to be responsible for the high diversity of reef fishes occurring along the

	Ningaloo Reef is the proximity of the continental shelf and the influence of the Leeuwin Current. In the Mauds Landing area, fish numbers are greatest on the shallow energetic areas of the outer Ningaloo Reef. Large numbers of fish are also found in association with the shallow, coral environments of the Ningaloo Reef backreef, particularly at the diverse coral community 9km north of Mauds Landing. In these areas wrasse (Labridae) and the smaller reef fish such as damselfishes (Pomancentridae), gobies (Gobiidae) and cardinalfishes (Apogonidae) are the most common and diverse groups. The most common of the larger or more spectacular fishes include the parrotfishes (Scaridae), surgeonfishes (Acanthuridae) and butterflyfishes, (Chaetodontidae). The pavement habitats near Point Maud and north-east of Mauds Landing support a relatively impoverished fish fauna with turf algae eating fishes, such Parrotfishes and Surgeonfishes, being the most common. The bare sand substrates surrounding Mauds Landing have a very depauperate fish population with occasional schools of pelagic fishes such as trevally (Carangidae) and mullet (Mugilidae) being the most frequently encountered. The rich fish fauna is not only of intrinsic ecological value but it is also important in that it has significant tourism and recreation potential. Divers and snorkellers have the opportunity to view a wide diversity of subtropical and tropical species in an area which is readily accessible. CALM 2000 (forthcoming) notes that the management of finfish species that are taken for recreational and commercial purposes under the *FRM Act* also need to consider the viability of the populations of these species in the context of maintaining the values of the Marine Park. To overcome this potential problem, consideration is required as to the appropriateness of recreational and/or commercial extraction of these species. This decision may be based upon a number of factors including: species distribution, abundance, life history and an assessment of the ecological and social importance of the species within the context of the area. The major potential pressures on the diversity and abundance of non-target finfish in the Ningaloo Marine Tract are incidental extraction by commercial and recreational fishing activities (ie. by-catch), alteration or loss of critical habitats, and declines in water quality. Fisheries WA notes that catch effort and biological data is inadequate within the Ningaloo Marine Park and the Gascoyne Region generally (Fisheries WA 1999). Finfish are totally protected from extractive activity in Maud Sanctuary zones that comprise the southern extent of the MSMA. Strategies for the management of marine fauna include infrastructure provision, education, surveillance, research and monitoring. The details of the monitoring program will be agreed upon with CALM and be consistent with and complement the Ningaloo Marine Management Plan currently under review. The techniques proposed for these elements of the SAMMP will, together with CALM, Fisheries WA and local tourism operators include: protocols and strategies to manage manta ray tourism experiences with a view to identifying sustainable levels of interaction, triggers to identify unacceptable impacts and management procedures should this occur.
Existing and potential uses and/or pressures	1. Incidental recreational and commercial extraction. 2. Activities which degrade critical habitats 3. Trophic interactions
Current major pressures	None
Management objective	To ensure the species diversity and abundance of non-target finfish species are not significantly impacted by human activities in the park.
Strategies	1. Educate users of the importance of maintaining fish diversity and the potential impacts of human activities, on these populations. (CCMD, CALM). **(H - KMS)** 2. Undertake research programs to characterize finfish diversity and abundance in different zones in the park (CCMD, CALM). **(H - KMS)**

	3. Identify finfish species that will be protected from recreational or commercial fishing in the park and provide the necessary legislative protection to achieve this (FWA, CCMD, CALM). **(H-KMS)**

Performance measure	1. Diversity 2. Abundance	**Desired trend**	1. Constant or positive 2. Constant or positive
Short-term target	To be developed prior to the implementation phase of Coral Coast Resort.		
Long-term target	1. Non-target finfish diversity and abundance in the park is maintained or increases over current levels (to be determined). 2. In sanctuary zones, finfish diversity and abundance in the park is maintained or increases over current levels (to be determined).		

7.2.9 Turtles

Ecological value	**Turtles:** *Four species of sea turtles have been reported in the MSMA, with three known to breed in Bateman Bay.*

Background	Marine reptiles utilising the waters adjacent to Mauds Landing may include four species of turtle and several species of sea snake. Green (*Chelonia mydas*), hawksbill (*Eretnochelys imbricato*) and loggerhead (*Carretta carretta*) turtles are common occupants of the area. The leatherback turtle (*Dermochelys coriacea*), the largest of the turtle species, has the most widespread distributions of any turtle. Although not reported from Ningaloo Reef, the area is within its assumed distribution and occasional individuals are expected to occur (May *et al.* 1983). Green turtles feed on macroalgae and are by far the most common turtle on Ningaloo Reef. Loggerhead turtles are carnivorous, feeding mainly on molluscs and crustaceans. They may utilise the mussel beds 3km northeast of Mauds Landing. Hawksbill turtles feed mainly on sponges and are more often located in deeper water, seaward of Ningaloo Reef. Aerial surveys of the Ningaloo Marine Park suggest that an estimated population of approximately 4300 turtles (all species) is resident within the Park (Preen *et al.* 1997). Turtle densities are extremely high at Ningaloo and exceed the highest densities recorded on the Great Barrier Reef and most of the areas in Torres Strait. Turtles, including loggerheads, (*Caretta caretta*), are known to nest on beaches in Bateman Bay. Seventy-one turtle nests were recorded in Bateman Bay during the 1999-2000 season, Turtles are large and extremely long lived reptiles. They are slow to reach maturity and breed infrequently, returning to the same location for this purpose. Six of the world's seven turtle species occur in Australian waters, with the flatback turtle, (*Natator depressus*), being endemic. Turtles are seriously threatened worldwide. The major impacts on turtles while in Australian waters are; mortality of adults while in prawn nets, shark nets and gill nets, collisions with speed boats, subsistence hunting by indigenous communities, habitat degradation and predation on eggs by feral animals.
Existing and potential uses and/or pressures	1. Physical disturbance: • boat collisions and boat noise; • commercial whale-watching tours; and • during egg laying. 2. Entanglement (eg. in litter, ropes, discarded fishing gear)
Current major pressure	None
Management objective	To ensure turtles in the park are not significantly disturbed by human activities
Strategies	1. Maintain records of the incidence of entanglement, boat collisions and deaths of turtle species (CCMD, CALM, Community). **(M)** 2. Ensure turtle interaction activities do not impact wildlife, through education programs and liaison with charter operators (CCMD, CALM). **(L)**

Performance measure	1. Reported animal entanglements/year* 2. Reported animal-boat collisions/year* * as a proportion of fauna population	Desired trend	1. Negative 2. Negative
Short-term target	To be developed as a component of a turtle nesting and surveillance plan prior to construction commencing at Coral Coast Resort.		
Long-term target	No significant disturbance to turtles in the MSMA from human activities.		

7.2.10 Cetaceans

Ecological value	**Cetacean:** *Six species of toothed whales and eight species of baleen whales are recorded from the park area. However, the common dolphin, and humpback whales are the only cetaceans that are regularly seen in park waters. Dugong are also known to pass through the area.*

Background	Dugong (*Dugong dugon*) is the only fully herbivorous marine mammal in Australia. It is now extinct or near extinct in most of its former range that extended from East Africa to South-East Asia and the Western Pacific (Comm. of Aust. 1995). Northern Australia has the last significant population (estimated as 80,000 in 1995). The species is large, long lived and has a slow reproductive cycle. Major concerns in managing the species relate to overfishing by indigenous communities, mortalities in fishing nets, and loss of seagrass habitat. The dugong is listed by the IUCN as 'vulnerable to extinction', but not as yet listed under the *Environment Protection and Biodiversity Conservation Act 1999.* Six species of toothed whale have been recorded from the Ningaloo area, while eight species of baleen whale have been recorded in the deeper waters offshore. Five of the eight species of baleen whales are listed as *rare or likely to become extinct* under the *Wildlife Conservation Act* due to over-exploitation during the whaling era. The southern right, humpback and blue whales are also protected under the *Environment Protection and Biodiversity Conservation Act 1999.* The common dolphin and humpback whales are the only cetaceans that are regularly seen in the NMT waters. While the dolphins are probably resident in park waters, humpback whales are transitory visitors to these waters during their annual migration northward along the Western Australian coastline each autumn (April/May). The humpback whales return to NMT waters in spring (September/October) during their southern migration to summer feeding grounds in Antarctica. Species regularly encountered by tourism operators in the NMT or waters adjoining include common bottle-nose dolphins (*Tursiops truncates),* and Indo-Pacific humpback dolphins (*Sousa chinesis*), the humpback (*Megaptera novaeangliae*), minke (*Balanoptera Acutorostrata*), southern right (*Eubalaena australis*), and blue (*Balanoptera musculus*) whales together with a range of smaller toothed whales and dolphins. Humpback calves are occasionally observed entering Bateman Bay to rest in the calm waters off Mauds Landing (Doug Hunt, *pers comm.*). Killer whales, (*Orcinus orca*), have also been observed within Bateman Bay. Potential disturbance to cetacean populations in the MSMA waters are mainly from boat noise and collisions. The current incidence of entanglement of cetaceans in fishing gear or litter is considered to be low.
Existing and potential uses and/or pressures	1. Physical disturbance: • boat collisions and boat noise; and • commercial whale-watching tours. 2. Entanglement (eg. in litter, ropes, discarded fishing gear)
Current major pressure	None within the MSMA.
Management objective	To ensure cetaceans in the MSMA are not significantly disturbed by human activities
Strategies	1. Maintain records of the incidence of entanglement, boat collisions and strandings of cetacean and turtle species (CCMD, CALM, Community). **(M)**

	2. Ensure whale interaction activities do not impact wildlife, through education programs and liaison with charter operators (CCMD, CALM) **(L)**

Performance measure	1. Reported animal entanglements/year* 2. Reported animal-boat collisions/year* * as a proportion of fauna population	**Desired trend**	1. Negative 2. Negative
Short-term target	To be developed prior to the operational phase of Coral Coast Resort.		
Long-term target	No significant disturbance to cetaceans in the park from human activities.		

7.3. Social Values

Social values are defined here as the human uses of the area. These can include indigenous and maritime heritage, commercial and recreational usage, aesthetic and cultural values, science and education.

7.3.1 Indigenous and maritime heritage

Social value	**Indigenous and maritime heritage**: A historical link with indigenous culture and the maritime heritage of the area.

Background	**Indigenous heritage** Previous work indicates that Aboriginal people with a well-developed and diversified coastal economy lived in the Cape Range area intermittently from 25000 years ago to modern times. People of the Baiyungu linguistic unit within land traditionally occupy the area of the proposed development. The Baiyungu people inhabited an area roughly delineated by Point Cloates north of the site to Point Quobba in the south, and inland to Mia Mia. Evidence attesting to this habitatism includes: • archaeological material including marine shell, bone and occasional stone and glass artefacts is scattered very sparsely through the coastal dune system; • stone artefacts including a segment of sandy limestone thought to be part of a basal grinding stone and a partially silicified limestone flake; and • shell material includes large fragments of baler shell (*Melo* sp.) and several large bivalves (these are thought to have been used as carrying dishes. The significance of the marine environment to the Aboriginal people would seem to relate to food gathering and hunting. The coastal dunes in Bills Bay were used as burial sites and human skeletal remains have previously been exposed by dune blowouts. The Native Title claim over the proposed Coral Coast Resort at Mauds Landing has now progressed to advertising under section 29 of the *Aboriginal Heritage Act, 1972.* **Maritime heritage** The landing of the schooner 'Maud' in 1884 is the earliest recorded European activity in the region. In 1896 the townsite reserve was gazetted (No. 3699) to protect the site's existing jetty and government goods shed. In 1915 the town was officially name Mauds Landing (DPUD 1992). Only remnants of the pylons from the jetty remain today. Parts of the site behind the old jetty location have been utilised as a seasonal base by commercial fishermen in recent times, however these uses have not continued and there is only scant evidence of their earlier presence. Anecdotal evidence suggests a number of masts were formerly present within the Mauds area.
Requirements	Not applicable
Management objective	To involve local indigenous people in the management of the MSMA.

Strategy	Develop, in collaboration with the local indigenous population, an understanding of the significance of the area to Aboriginal people (CCMD, CALM, local Aboriginal groups). **(M)**

Performance measure	To be developed as required.	**Desired trend**	To be developed as required.
Short-term target	To be developed as required.		
Long-term target	To be developed as required.		

7.3.2 Commercial and Recreational Fishing

Social value	**Commercial and recreational fishing**: *Commercial fishing of a variety of finfish and minor commercial collecting activities for shells occurs generally outside the MSMA, although considerable recreational fishing occurs outside the Maud Sanctuary zone.*

Background	Commercial fishing of a variety of finfish and minor commercial collecting activities for shells occur generally outside the MSMA. A number of commercial fishing boats operate out of Bills Bay, fishing the pelagic and outer reef zones. Shell collecting activities have occasionally occurred within the NMT, however these activities are generally focussed in deeper waters. The MSMA is located in the Gascoyne fisheries management area and is renowned for its outstanding shore-based dingy and recreational fishery based on a diversity of fish. Recreational fishers participation rate increased to 30% of the States population (520 000) in 1996 (Paterson, quoted in Fisheries WA 1999). Fisheries WA (1999) note that with the development of coastal roads and boat refuges and residential developments such as marinas, waters previously protected from extensive fishing pressure due to isolation are now coming under increasing pressure. Current indicators (both scientific and social) show all major fish stocks are fully exploited. A variety of recreational fisheries management strategies have been implemented to control localised depletion of fish stocks within the Gascoyne. These have included: specific area controls at Ningaloo (1992), landing limits in Exmouth Gulf (1993), strict controls on the take of pink snapper in Shark Bay's inner gulfs (1997) and subsequent bag limits (1998), and the introduction of a management system for the charter and aquatic tour industry (1999) (Fisheries WA 1999). A major recreational catch survey was completed for the Gascoyne Region in March 1999. Although species such as golden trevally are most often caught, major concerns in relation to the sustainability of some of the lesser-caught bottom species such as spangled and red emperor, arise due to the relatively slow growth and recruitment rates of these species. Included in the fish fauna of the NMT are four fish species and molluscs (except oysters, cuttlefish, squid and octopus) which are completely protected in the area under the FRM Act, these being: • Queensland groper; • whale shark *(Rhiniodon typus)*; • potato cod; and • manta rays (*Manta birostris, Dasyatis thetidis*). With the exeption of whale sharks, these protected species may be present in the MSMA. Further limits on the number of fish caught and legal size have been proclaimed within the Ningaloo Marine Park. These include one per fisher per day limits on coral trout and coronation trout. Fisheries WA (1999) have also identified the following priority species for research within waters of the Gascoyne Region: • pink snapper (*Pagrus auratus*); • spangled emperor (*Lethrinus nebulosus*); • black snapper (*L laticaudis*);

	• red emperor (*Lutjanus sebae*); • baldchin groper (*Choerodon rubescens*; • Spanish mackerel (*Scomberomorus commerson*); • cods - estuary, rankin (*Epinephelus coides, E multinotatus*); • coral trout (*Plectropomus maculates*); • black spot tuskfish (*Choerodon schoenleinni*); and • mulloway (*Argyrosomus holoepidotus*). A proposal has been put to the Minister for Fisheries by Fisheries WA recommending that additional research be undertaken to provide information on species biology and stock structure of these priority species. No marine fish in Australia is listed as 'endangered' under the IUCN (International Union for the Conservation of Nature – World Conservation Union), although the whale shark is listed as 'intermediate'. Recreational fisheries management will be a significant focus within the SAMMP with monitoring requirements and priorities for fish management being developed in consultation with Fisheries WA. There is a clear need to develop a baseline for fish stocks form both within the MSMA and those areas being sources from facilities providing access to the NMT at Coral Bay. This will require: • baseline catch and effort data for the area; and • biological information for select species being collected. The level of protection afforded individual fish species is based on a number of factors including species distribution, abundance, life history and an assessment of the ecological and social importance of the species in the context of the area. Fisheries WA has the statutory responsibility for management of commercial fishing throughout the State, including the waters within marine parks. The primary role of marine park management in relation to commercial fishing, is to help maintain the natural values of the park on which the industry depends and, in liaison with Fisheries WA, ensure that commercial fishing activities in the park are socially and ecologically sustainable.
Requirements	1. High water quality. 2. Maintenance of key habitat. 3. Equitable access to fishing grounds within the park (in appropriate zones). 4. Maintenance of recreational and commercial fish stocks.
Management objective	1. To maintain the ecological values of the MSMA and larger NMT accessed from facilities at Coral Bay/ Mauds Landing that are significant to recreational and commercial fisheries. 2. To ensure that, in collaboration with the industry and FWA, commercial fishing activities in the park are managed in a manner that is consistent with maintaining the values of the MSMA and broader NMT. 3. Together with Fisheries WA, maintain quality recreational fishing opportunities in the MSMA and larger NMT accessed from facilities at Coral Bay/ Mauds Landing.
Strategies	1. Provide sufficient resources such that activities in the Maud Sanctuary zone can be adequately regulated (CCMD, CALM, Fisheries WA). **(H-KMS)** 2. Determine the effects of commercial and recreational fishing activity on the values of the MSMA and larger NMT accessed from facilities at Coral Bay/ Mauds Landing, and review management controls as required (FWA, CCMD, CALM). **(H-KMS)** 3. Ensure commercial and recreational fishers are aware of the zoning scheme within the Maud Sanctuary zone and elsewhere, and of any restrictions, which may apply to their operations (CCMD, FWA, CALM). **(H)** 4. Assist in the monitoring of commercial and recreational fishing catch/effort within MSMA and larger NMT accessed from facilities at Coral Bay/ Mauds Landing (CCMD, FWA) **(H).** 5. Assist in the formulation of performance measures and targets for key recreational species that will maintain the quality of recreational fishing in the park (FWA, RECFISHWEST, RFAC). **(H- KMS)**

Performance measure	To be developed prior to the operational phase of Coral Coast Resort.	**Desired trend**	To be developed

Short-term target	To be developed prior to the operational phase of Coral Coast Resort.
Long-term target	Commercial and Recreational fisheries within the MSMA and otherwise within the Ningaloo Marine Park are managed to a sustainable level.

7.3.4 Coastal Use

Social value	**Coastal Use:** *Recreational use of headlands, dunes and long white beaches for walking, swimming, surfing and fishing are a major value of the MSMA.*

Background	Recreational use of the Ningaloo Marine National Park and adjoining lands include: • use of headlands, dunes and beaches (for swimming, sunbathing, walking, beach fishing use of recreation vehicles and eco-tourism experiences such as turtle observation); • seascapes, including views of clear waters, reefs, breaking surf and clear oceans beyond the reef line; • recreational fishing targeting finfish from shore or by boat; • water sports, including swimming, snorkelling and SCUBA diving, and to a lesser extent windsurfing and sailing; and • marine nature-based tourism including boat trips to observe coral formations, interactions with whale sharks and manta rays, as well as turtle observation. As visitor numbers and therefore recreational usage of the coast increases, the issues of swimmer safety, impacts on corals, recreational fishing, off road vehicle use, litter and beach use will become increasingly important. Cary *et al.* (forthcoming) has undertaken a review of human usage in Ningaloo Marine Park as an aid to management. Data from the Coral Bay area is at present limited providing only a broad overview of activities and pressures. Tourism numbers and day visitation data is also limited, however peak occupancy at the existing Coral Bay townsite is considered to be about 2500 during busy school holiday periods. The number of legal accommodation units is 477, with overcrowding being common, particularly during the July school holidays (MfP 1996). Destruction of beach and dune vegetation by recreational vehicles can lead to erosion and deterioration in the amenity value of beaches, as well as leading to conflict between incompatible uses (eg. 4WD and quadbike use and sunbathing). Litter from recreational and commercial activities can significantly reduce amenity values.		
Requirements	1. Vehicle access. 2. Facilities eg roads, toilets and walkways. 3. Control of beach activities eg RV use and dogs. 4. Clean beaches.		
Management objective	1. To ensure the amenity value of beaches is not reduced by the inappropriate disposal of litter by park users. 2. To ensure RV use in the MSMA does not damage beach/dune vegetation or cause conflict with other users.		
Strategies	1. Increase awareness of park users of the ecological and social impacts arising from the inappropriate use of RVs on park beaches (CCMD, CALM). **(M)** 2. Liaise with coastal land managers to control vehicle access to park beaches where significant environmental or social impacts by RVs cannot be avoided (CALM, CCMD, LGA). **(M)** 3. Educate park users about the potential impacts of litter on the social values of the park (CCMD, CALM, FWA). **(L)**		
Performance measure	1. Amount (kg) of litter from local (known) sources on monitored beaches. 2. Number of complaints regarding RVs.	**Desired trend**	1. Negative 2. Negative
Short-term target (KPI)	1. To be developed prior to the operational phase of Coral Coast Resort.		

Long-term target (KPI)	1. Litter levels do not reduce the amenity values of park beaches. 2. No significant conflict over RV use of MSMA beaches.

7.3.5 Seascapes

Social value	**Seascapes**: *Panoramic vistas of turquoise lagoon waters, offshore barrier and subtidal reefs, beaches, breaking surf and the blue open ocean beyond the reef line are major attractions of the Ningaloo Reef.*

Background	The major marine habitats of the Mauds Landing region (Moncks Head to Bruboodjoo Point) have been mapped and described by CALM. Panoramic views of lagoon waters, offshore barrier and subtidal reefs, in clear waters, beaches, breaking surf and the blue open ocean beyond the reef line are major attractions of Coral Bay/ Mauds Landing area. These attributes can be viewed from the Coral Bay Road as it descends from the inland aeolian ridges, shoreline and from high vantage and lookout points along the coastal and Coral Bay. At present no permanent channel or navigation markers are in place within the MSMA although a preferred boat channel is marked with anchored floats. CALM 2000 (forthcoming) notes that inappropriate structures along the coastline, and in the surrounding waters have the potential to degrade these aesthetic values of natural vistas. As such, coastal developments and maritime infrastructure projects must be planned with careful consideration of this issue.		
Requirements	1. Generally uninterrupted coastal vistas 2. Sensitively designed and located offshore and coastal infrastructure		
Management objective	To identify designated seascapes of the MSMA and seek to minimise degradation of these seascapes proposed developments.		
Strategies	1. Identify and determine the key characteristics and spatial extent of the major seascapes of the park (CALM, LGA). **(H)** 2. Develop performance measures and management targets for designated seascapes (CALM, CCMD, LGA). **(M)**		
Performance measure	To be developed prior to the implementation of the operational phase of Coral Coast Resort.	**Desired trend**	To be developed.
Short-term target (KPI)	To be developed prior to the implementation of the operational phase of Coral Coast Resort.		
Long-term target (KPI)	No significant change in the designated seascapes of the MSMA from designated levels.		

7.3.6 Water sports

Social value	**Water sports**: *The natural environment of the MSMA provides opportunities for swimming, boating, windsurfing, snorkeling, scuba diving, free-diving and numerous other water sports.*

Background	Beaches, sheltered lagoons, offshore reefs and the open ocean environment provide a range of opportunities for water based activities within the MSMA. Swimming in South Bills Bay is very popular. Boating is also popular within the region. A marine traffic study was undertaken to quantify existing and potential marine traffic (including swimmers) as an aid to the evaluation of the most appropriate site for alternative boat entries to Bills Bay (Gascoyne Development Commission (GDC), unpublished data). The study combined community survey and counts. The Gascoyne Development Commission (unpublished data) also noted that the beach adjoining Bills Bay east of the boat mooring area, was the most popular for beachgoers at almost any given time of day, approximately doubling those south of Fletchers Hill. Over the survey, an average of 134 swimmers were recorded on the Bills Bay beach east of the boat mooring area at midday. Numbers reduced to an average of 98 at 2 pm, rising to an average of 107 at 4pm. Recreational use of the beach south of Fletchers Hill peaked at 4pm on the days

	surveyed averaging 68 swimmers. Opportunistic observations of boat traffic during the GDC survey indicated that 90 percent of boats used the in shore channel past Fletcher Hill to depart from, or return to Bills Bay, with the majority of these (84%) passing within 25m to 100m of the shore. This area is well known for its outstanding lagoonal corals and is most frequented by snorkellers wishing to view them. All respondents to the GDC survey swam or snorkelled in Coral Bay on a daily basis (GDC unpublished data).
Requirements	1. High water quality 2. Equity of access to appropriate areas within the MSMA. 3. Separation of incompatible recreational activities
Management objective	1. To ensure water sports are managed in a manner that is consistent with maintaining ecological values within the MSMA. 2. To maintain the ecological values of areas of the MSMA that are important to recreational water sports.
Strategies	1. Determine the nature, spatial patterns, compatibility and potential environmental impacts of all existing water sports in the park (CCMD, CALM). **(H)** 2. Use zoning and regulations to separate incompatible activities, as appropriate (CALM, DoT). **(M)** 3. In collaboration with user groups, develop *Codes of Conduct* to minimise environmental impacts of recreational activities, as appropriate (CALM, CCMD, DoT, Community). **(M)** 4. Resolve issues in relation to boat/ swimmer conflicts within the MSMA.

Performance measure	1. To be developed prior to the operational phase of Coral Coast Resort.	**Desired trend/s**	1. To be developed as required.
Short-term target	To be developed as required.		
Long-term target	To be developed as required.		

7.3.7 Marine nature-based tourism

Social value	**Marine nature-based tourism**: *Ecotourism experiences are much sought after within the MSMA and adjoining areas accessible from Coral Bay/Mauds Landing. Continuous accessibility of the resource and careful management of the target species will ensure maintenance of these significant tourism activities.*

Background	Marine tourism is a job-rich industry and, as such, has the potential to generate significant regional employment. Ningaloo Marine Park is a key tourist destination. Recorded visits to the Marine Park and the adjoining Cape Range National Park now exceed 80,000 per annum, having doubled in the last ten years (CALM unpublished data). Most visitors come to the area to experience the coral reef and other natural environments. The main activities undertaken by tourists to Ningaloo Marine Park are snorkelling and diving, recreational fishing, beach recreation and camping, coral and wildlife viewing and wildlife interaction tours. Recreational use of the Ningaloo Marine National Park and adjoining lands include the use of headlands, dunes and beaches (for swimming, sunbathing, walking, beach fishing use of recreation vehicles and eco-tourism experiences such as turtle observation). Marine nature-based tourism including boat trips to observe coral formations, interactions with whale sharks and manta rays, as well as turtle observation. A summary of occurrence and activity data relating to ecotourism target species is included as Appendix 2. Simpson (pers. com.) advised that there are 15 commercial vessels operating from Coral Bay. These include two licensed whale shark boats, nine charter vessels and three coral viewing vessels. Whale sharks congregate in the oceanic waters of Ningaloo Reef on a seasonal basis and as a consequence have been subject both to tourist and scientific interest (Taylor 1996; Davis *et al.* 1997; Taylor & Pearce 1999). The whale sharks move from offshore waters into the Ningaloo Marine Park where they congregate from March to May each year when corals undergo mass spawning. Pack numbers of whale sharks occur about two weeks after the coral spawning. It is believed that the release of massive amounts of coral larvae, and the synchronised spawning of other marine species, is utilised by the zooplankton as a food source. The zooplankton then undergo rapid population growth Marine mammals inhabiting the waters near Mauds Landing include dugong, (*Dugong dugon*), common bottle-nose dolphins (*Tursiops truncates*), Indo-Pacific humpback dolphin, (*Sousa chinesis*), and a number of different whale species. Humpback whales, (*Megaptera novaeangliae*), minke whales, (*Balaenoptera acutorostruta*), fin whales, (*B. physalis*), blue whales, (*B. musculus*), brides whales, (*B. edeni*) and killer whales, (*Orca orca*) occur in the offshore waters westward of Ningaloo Reef (May *et al.* 1983). Of these, humpback whales regularly pass along the reef during the northern and southern migrations, while the other species are less common. Marine reptiles utilising the waters adjacent to Mauds Landing may include four species of turtle and several species of sea snake. Turtle densities are extremely high at Ningaloo and exceed the highest densities recorded on the Great Barrier Reef and most of the areas in Torres Strait. Breeding of several species also occurs within Bateman Bay within the MSMA. The Ningaloo Reef Tract also supports a diverse and abundant ray population. These include the giant manta ray, (*Manta birostris*). During aerial surveys undertaken in 1989 and 1994, manta rays were common in the northern half (Point Cloates to North West Cape) of the Ningaloo Marine Park (Preen *et al.* 1997). Manta rays are most often encountered immediately outside the Ningaloo Reef and appear to be more common in autumn. Other rays occur throughout the Ningaloo Reef Tract from deep offshore waters to shallow near shore waters. CALM 2000 (forthcoming) note that the goal of marine park management in relation to marine tourism is to manage tourism activities in a manner that is consistent with maintaining the park's values, to maintain the values of the park on which the industry depends and assist in maintaining a viable nature-based industry in the park.
Requirements	1. Clean beaches. 2. High water quality. 3. Healthy benthic communities. 4. High aesthetic quality of the marine environment. 5. Provision of 'undisturbed' areas for nature appreciation.

	6. Equitable access to the natural values of the park. 7. Managed and responsive ecotourism industry.
Management objectives	1. To manage marine tourism in the MSMA and elsewhere accessible from the Coral Bay/Mauds Landing area in a manner that is consistent with maintaining the NMT's values. 2. To maintain the ecological values of the MSMA and elsewhere accessible from the Coral Bay/Mauds Landing area consistent with supporting the reasonable requirements of the tourism industry.
Strategies	1. Educate users of the potential impacts of human activities, on these ecotourism species (CCMD, CALM). **(H – KMS)** 2. License all commercial tourism operations within the park with appropriate conditions (CALM). **(H)** 3. Ensure equitable access for marine tourism within appropriate zones in the park (CALM). **(M)** 4. Develop *Codes of Practice* for commercial marine tourism operations in the park including: • Performance measures; • Desired trends; • Short-term and long-term management targets; and • Monitoring and reporting requirements (CALM, CCMD, WATC). **(M)**

Performance measure	To be developed within 5 years of the operational phase of Coral Coast Resort.	**Desired trend**	To be developed as required.
Short-term target	To be developed within 5 years of the operational phase of Coral Coast Resort.		
Long-term target	To be developed within 5 years of the operational phase of Coral Coast Resort.		

7.3.8 Petroleum drilling & mineral development

Social value	**Petroleum drilling & mineral development**: *A major petroleum accumulation has been located some 12 kilometres north of the northernmost extent of Commonwealth waters of the Ningaloo Marine Park. The area encompassing the MSMA is anticipated to be generally of low hydrocarbon prospectivity*

Background	Ningaloo Marine Park is situated in a region that is considered to be prospective or oil and gas production with offshore exploration drilling occurring to the north-west of the NMT. Petroleum exploration and production are not permitted in either the Commonwealth or State waters of Ningaloo Marine Park. There are two petroleum exploration permit areas that are adjacent to and form an incision into the boundaries of the Commonwealth waters of Ningaloo Marine Park (see Figure 1). These are exploration permit areas WA-24-P parts 2 and 3. A major petroleum accumulation has been located some 12 kilometres north of the northernmost extent of Commonwealth waters of the Ningaloo Marine Park (Commonwealth of Australia 2000). Petroleum and mining activities have the potential to cause negative impacts on the ecological and physical values of the Marine Park. Mineral and petroleum exploration and extraction is regulated under the *Petroleum Act 1967, Petroleum (Submerged Lands) Act 1982, Pipelines Act 1969* and the *Mining Act 1978* and administered by the Department of Minerals and Energy (DOME). In marine parks, drilling for exploration or production is not permitted in Sanctuary and Recreation zones or in Special Purpose zones where the Minister administering the *CALM Act 1984* declares that drilling or production is incompatible with the conservation purpose specified in the classified area notice. It is permitted in general use zones and some special purpose zones. Exploration and production in marine conservation reserves are subject to environmental impact assessment by the Environmental Protection Authority.
Requirements	Equitable access to areas of the park within appropriate zones subject to environmental assessment.

Management objective	To ensure that, in collaboration with the petroleum industry and DOME, petroleum industry activities in the park are managed in a manner that is consistent with maintaining the park's values.
Strategies	1. Provide formal advice to EPA and DOME in relation to the environmental assessment of proposed petroleum activities in the park (MPRA, CALM). **(M)** 2. Ensure the license conditions of approved petroleum industry projects include: • Appropriate environmental performance measures; • Desired trends; • Short-term and long-term management targets; and • Monitoring and reporting requirements (CALM, DOME, EPA). **(M)** 3. Ensure other uses of the park do not unnecessarily restrict future petroleum industry opportunities in appropriate zones in the park (CALM). **(M)**

Performance measure	To be developed as required.	**Desired trend**	To be developed as required.
Short-term target	To be developed as required.		
Long-term target	To be developed as required.		

7.3.9 Scientific research

Social value	**Scientific research**: *A highly diverse and ecologically important assemblage of tropical and sub-tropical marine plants and animals of particular scientific interest.*

Background	Commonwealth of Australia (2000) note that there are currently large gaps in the knowledge of the marine communities, species and ecosystem processes in Ningaloo Marine Park, particularly in the deeper waters. The Ningaloo Marine Park encompasses representative habitats of a large marine ecosystem from the shoreline to the edge of the continental slope. It includes the Ningaloo Reef structure itself, one of the longest fringing barrier reefs in the world, and extending between Gnarraloo Bay to Point Murat, a distance of about 280km (Simpson & Masini 1986). Ningaloo Reef comprises one of the five major coral reef assemblages that are recognised on the west coast of Australia. Further reef provides habitat for a diverse range of marine species including over 200 species of coral, 600 species of mollusc and 500 species of fish (Commonwealth of Australia 2000). One factor thought to be responsible for the high diversity of marine life occurring along the Ningaloo Reef is the proximity of the continental shelf and the influence of the Leeuwin Current. The continental shelf is closest to mainland Western Australia along the Ningaloo Reef and the south-flowing Leeuwin Current directly affects the reef communities. Accordingly, MSMA and the broader Ningaloo Marine Park provides opportunities for a wide variety of research programs investigating aspects of the coral reef, large marine fauna, ocean currents and cultural history. Improving knowledge of these aspects is recognised as being critical to improving management of the Marine Park. Most research activity takes place in the State waters and coastal environments. Commonwealth of Australia (2000) note that one of the key gaps in biological knowledge and research is an understanding of species and ecosystem processes of the deeper waters and seabed of the continental shelf and slope. Similarly, the biology of several of the large ecotourism target species such as the whale shark and manta ray is poorly understood, even though significant interaction is now taking place. CALM 2000 (forthcoming) notes that any increase in knowledge derived form research programs, is beneficial and, as such, all legitimate research projects will be encouraged.

	All research within the Ningaloo Marine Park (State) requires the appropriate research permit issued under the *CALM Act, Wildlife Conservation Act* or the *FRM Act 1994*. Similarly, under the *Environment Protection and Biodiversity Conservation Regulations*, carrying out research in the Commonwealth waters of Ningaloo Marine Park requires a permit from the Director of National Parks (Commonwealth).
Requirements	1. Access to representative sites free of major human influences for 'scientific reference' sites. 2. Access to representative sites covering the range of major human activities in the park for 'impact' sites. 3. Equitable access to the park for ecological and social research opportunities in appropriate zones.
Management objective	1. To promote ecological and social research in the park that enhances understanding of the functioning of these ecosystems and the short and long-term effects of human usage. 2. To allow for the measurement of the impacts associated with developments within the MSMA. 3. To ensure ecological and social research is ethical and ecologically sustainable.
Strategies	1. Identify and communicate high priority scientific and social research projects relevant to the management of the park to appropriate research organisations (CALM). **(H - KMS)** 2. Provide meaningful indicators of environmental quality within the MSMA as an input in the development of management strategies (CCMD). **(H)** 3. Facilitate scientific and social research in the park by research, academic and educational institutions by providing financial and logistical assistance (where possible) (CALM, CCMD, FWA). **(H)** 4. Develop and maintain a database of historical and current research in the park (CALM, CCMD). **(H)**

Performance measure	Number of current research projects relevant to priority information needs.	**Desired trend**	Positive
Short-term target	To be developed as required.		
Long-term target	To be developed as required.		

7.3.10 Education

Social value	**Education:** *A stimulating pristine natural environment provides opportunities for community education about the marine environment. Education is a major strategy to achieve the management goals for the MSMA and the Ningaloo Marine Park generally.*

Background	Commonwealth of Australia (2000) has identified that education is a major strategy to achieve the management goals and thus the strategic objectives of the Ningaloo Marine Park. The desired outcome of public education is to increase public awareness and understanding of conservation and management issues in the area and of the marine environment in general. An understanding of the issues and appreciation for their worth results in broader community ownership of the asset, leading to better protection of the ecological and social values. Other important and ongoing education programs will be required to minimise human impacts on the ecological values. A range of education and interpretation infrastructure (eg. walk/dive trails, interpretative centre) should be considered, where appropriate, with specific education strategies their are detailed for each specific ecological and social value. This will include the provision of information on the potential negative impacts of human activities on the values of the MSMA and Ningaloo Marine Park, and ways to minimise these impacts. Public education is to be provided through the production and distribution of printed material, signage, face-to-face contact, and educational displays and presentations.
Requirements	1. Access to sites free of major human influences. 2. Access to sites covering the range of major human activities in the MSMA and generally within the Ningaloo Marine Park. 3. Equitable access to the MSMA (in appropriate zones) for the full range of educational opportunities.

Management objective	To promote better public understanding of the areas natural values, uses and management issues and of the marine environment in general.
Strategies	1. Develop and distribute to the local community and visitors a range of education materials about the MSMA values and management (CALM, CCMD, FWA). **(H)** 2. Provide talks and briefings about the MSMA's values, uses and management to local and visiting groups (CALM, CCMD). **(H)** 3. Provide support, where possible, to institutions using the MSMA for educational purposes (CALM, CCMD). **(M)**

Performance measure	Survey of visitor knowledge regarding the marine park.	**Desired Trend**	Positive.
Short-term target	50% of visitors aware of the existence of the MSMA and the Ningaloo Marine Park generally, its values and of the restrictions applying to the area		
Long-term target	90% of visitors aware of the existence of the MSMA and the Ningaloo Marine Park generally, its values and of the restrictions applying to the area.		

8. IMPLEMENTATION OF THE SAMMP FOR THE MSMA

This management plan details a range of strategies relating to the control of particular human activities. The effectiveness of these strategies will be dependent on the extent to which the users of the park abide by these restrictions. The education program is recognised as critical to achieving a high level of compliance as in most cases users will abide with controls where they are clearly aware of what they are and why they have been implemented.

A research and monitoring program is a key strategy in that it develops an understanding of the natural and social environment of the park and monitors the state of the park's environment. This allows the early detection of detrimental changes and provides the trigger for management action to ameliorate potential impacts before they lead to undesirable changes in the park's values. The detection of human-induced changes requires an understanding of what is 'natural' as a benchmark. Much of this information does not exist within the proposed MSMA at this stage, nor more broadly in the Ningaloo Marine Park. Similarly the management responses to changes have yet to be determined.

Accordingly, such research and monitoring programs need to focus on establishing the natural state of key ecological values and processes.

Notwithstanding the best intentions of the majority of visitors and residents in the Coral Bay/.Mauds Landing area, there will always be a need to monitor the level of compliance and, where users continue to undertake illegal activities, take action to stop inappropriate behaviour. This can only be achieved through the permanent presence of officers from regulatory agencies who have appropriate resources and equipment.

The SAMMP has been couched in terms of providing support for CALM and Fisheries WA consistent with the management objectives of the Ningaloo Marine Park.

CALM and Fisheries WA have identified additional pressures on the Ningaloo Reef Tract that will result from the implementation of this proposal. To assist in managing these pressures, CCMD will enter into a binding agreement with CALM and Fisheries WA to provide additional resources for Ningaloo Marine Park. This will go toward the provision of a permanent regulatory staff presence, office space/research facility, and capital items.

REFERENCES

Allen, G.R. & Swainston, R. 1988, *The Marine Fishes of North-western Australia. A Field Guide for Anglers and Divers*. Western Australian Museum, Perth.

ANZECC & ARMCANZ (1994), *National Water Quality Management Policies and Principles – A Reference Document*. Department of Natural Resources and Environment, Melbourne.

ANZECC 1997, *Best Practice in Performance Reporting in Natural Resource Management*. Department of Natural Resources and Environment, Melbourne.

ANZECC TFMPA 1998a, *Guidelines for Establishing the National Representative System of Marine Protected Areas*. Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas, Environment Australia, Canberra.

ANZECC TFMPA 1998b, *Strategic Plan of Action for Establishing the National Representative System of Marine Protected Areas: public comment draft*. Environment Australia, Canberra.

ANZECC TFMPA 1999, *Strategic Plan of Action for the National Representative System of Marine Protected Areas: A Guide for Action by Australian Governments*. Environment Australia, Canberra.

ATA Environmental (2000a), *Baseline Establishment Marine Survey, Coral Coast Resort, June 2000*. ATA Environmental Report No. 2000/147

Ayeling, A.M. & Ayeling, A.L. 1987, *Ningaloo Marine Park: Preliminary Fish Density Assessment and Habitat Survey with Information on Coral Damage Due to Drupella Cornus Grazing*. A report prepared for the Department of Conservation and Land Management, Western Australia.

Cary, J.L., Grubba, T., Hogstrom, A., Milton, K., Williams, C. forthcoming, *Human Usage in Ningaloo Marine Park, Marine Management Support Field Programme* Report MMS/PILBARA/NMP – 20/2000. Marine Conservation Branch, CALM.

Commonwealth of Australia 1992, *National Strategy for Ecologically Sustainable Development*. Australian Government Publishing Service, Canberra.

Commonwealth of Australia 1996a, *The National Strategy for the Conservation of Australia's Biological Diversity*. Department of the Environment, Sport and Territories, Canberra.

Commonwealth of Australia 1996b, *The State of the Marine Environment Report for Australia*. Great Barrier Reef Marine Park Authority for Dept of Environment, Sport & Territories, Canberra.

Commonwealth of Australia 1998, *Australia's Oceans Policy*. Environment Australia, Canberra.

Commonwealth of Australia 2000, *Ningaloo Marine Park (Commonwealth Waters) Draft Management Plan*, Environment Australia, Canberra.

Conservation and Land Management (CALM) 1989, *Ningaloo Marine Park (State Waters) Management Plan 1989-1999, Management Plan No. 12*, Department of Conservation and Land Management, Perth, Western Australia.

Conservation and Land Management (CALM) 1994, *A Representative Marine Reserve System for Western Australia*. Report of the Marine Parks and Reserves Selection Working Group. Department of Conservation and Land Management, Perth.

Davis, D., Banks, S., Birtles, A., Valentine, P. & Cuthill, M. 1997, Whale sharks in Ningaloo Marine Park – Managing tourism in an Australian marine protected area. *Tourism Management* 18(5):259-271, Aug. 1997.

Department of Conservation & Environment (DCE) 1984, *Coral Bay Draft Coastal Management Plan*, Bulletin 174, Department of Conservation and Environment, Perth, Western Australia.

Department of Environmental Protection 1995, *Survey of Water Quality, Groundwater, Sediments and Benthic Habitats at Coral Bay, Western Australia*. Technical Series No 80, Department of Environmental Protection November 1995.

Department of Transport 1999, *Discharge of Sewage from Vessels into the Marine Environment – a Discussion Paper*. Department of Transport April 1999.

Environmental Protection Authority (EPA) 1993, *Western Australian Water Quality Guidelines for Fresh and Marine Waters*. Environmental Protection Authority (now the Department of Environmental Protection) Perth, Western Australia, Bulletin 711.

Fisheries WA (1999) *A Quality Future for Recreational Fishing in the Gascoyne (Proposal for Community Discussion)*, Fisheries Western Australia Fisheries management paper 124, Government of Western Australia

Forde, M. J. 1994, *Ecology of the Muricid gastropod Drupella cornus (Roding, 1798) and its significance as a corallivare on Ningaloo Reef, Western Australia*, Unpublished M.Sc. Thesis, University of Western Australia.

Government of Western Australia 1998, *New Horizons - the way ahead in marine conservation and management*. Department of Conservation and Land Management, Perth.

Grubba, T. L. & Cary, J. L. 2000, *Survey of the Monitoring Sites Established in 1989 After Coral Mortality in Bills Bay from the Coral Mass Spawning Event of March 1989*, CALM Field Program Report: Data Report MMS/NMP-23/200. (Marine Conservation Branch, CALM, Unpublished Report.

Hatcher, B.G. 1988, Coral reef primary productivity: a beggars banquet. *Trends in Ecological Evolution* 3:106-111.

Hearn, C.J. & Parker, I.N. 1988, Hydrodynamic Processes of the Ningaloo Coral Reef, Western Australia, *Proceedings of the 6th International Coral Reef Symposium, Australia*, 1988, Volume 2.

Holloway, P.E. & Nye, H.C. 1985, Leeuwin Current and wind distribution on the Australian North West Shelf, *Aust. J. Mar. Freshwat. Res.*, 36: 123-137.

Hutchins, B. 1994, A survey of the nearshore reef fish of Western Australia's west and south coasts – The Leeuwin Province, *Records of the Western Australian Museum*, Supplement No. 46.

May, R.F., Lenanton, R.C.J. & Berry, P.F. 1983, *Ningaloo Marine Park.* Report and Recommendations by the Marine Park Working Group, National Parks Authority.

May, R.F., Wilson, B.R., Fritz, S. & Mercer, G. 1989, *Ningaloo Marine Park Management Plan 1989-1999*, Department of Conservation and Land Management, Perth, Western Australia.

Ministry for Planning 1996, *Gascoyne Coast Regional Strategy*. Western Australian Planning Commission.

M.P. Rogers & Associates 2000, *Mauds Landing Coastal Engineering Study.* A report prepared for Coral Coast Marina Development Pty Ltd, September 2000, Report No. R088 Rev. 0.

Norman, B.M. 1999, *Aspects of the biology and ecotourism industry of the whale shark Rhincodon typus in north-western Australia*. Honours thesis, Murdoch University.

Osborne, S. & Williams, M.R. 1992, A preliminary summary of the effects of hand removal of *Drupella cornus* on Ningaloo Reef, pp.83-90, in Turner S.J., ed. *Drupella cornus: a synopsis*. Occasional Paper 3/92. Department of Conservation and Land Management, Perth.

Preen, A.R., Marsh, H., Lawler, I.R., Prince, R.I.T. & Shepherd, R. 1997, Distribution and abundance of dugongs, turtles, dolphins and other large vertebrate fauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, Western Australia, *Wildlife Research* 24(2):185-208, 1997.

Simpson, C.J., Cary, J.L. & Masini, R.J. 1993, Destruction of corals and other reef animals by coral spawn slicks on Ningaloo Reef, Western Australia. *Coral Reefs* 12(3-4):185-191, Nov. 1993.

Simpson, C. J. & Masini, R.J. 1986, *Tide and seawater temperature data from the Ningaloo Reef Tract, Western Australia, and the implications for coral mass spawning*, Bulletin 253, Department of Conservation and Environment, Perth, Western Australia.

State Planning Commission 1994, *Gascoyne Coast Regional Strategy – Draft for Public Comment*, Perth, Western Australia.

Steedman Science & Engineering, 1989, *Preliminary Extreme Wave and Storm Surge Study, Coral Bay*, Unpublished Report No. R440.

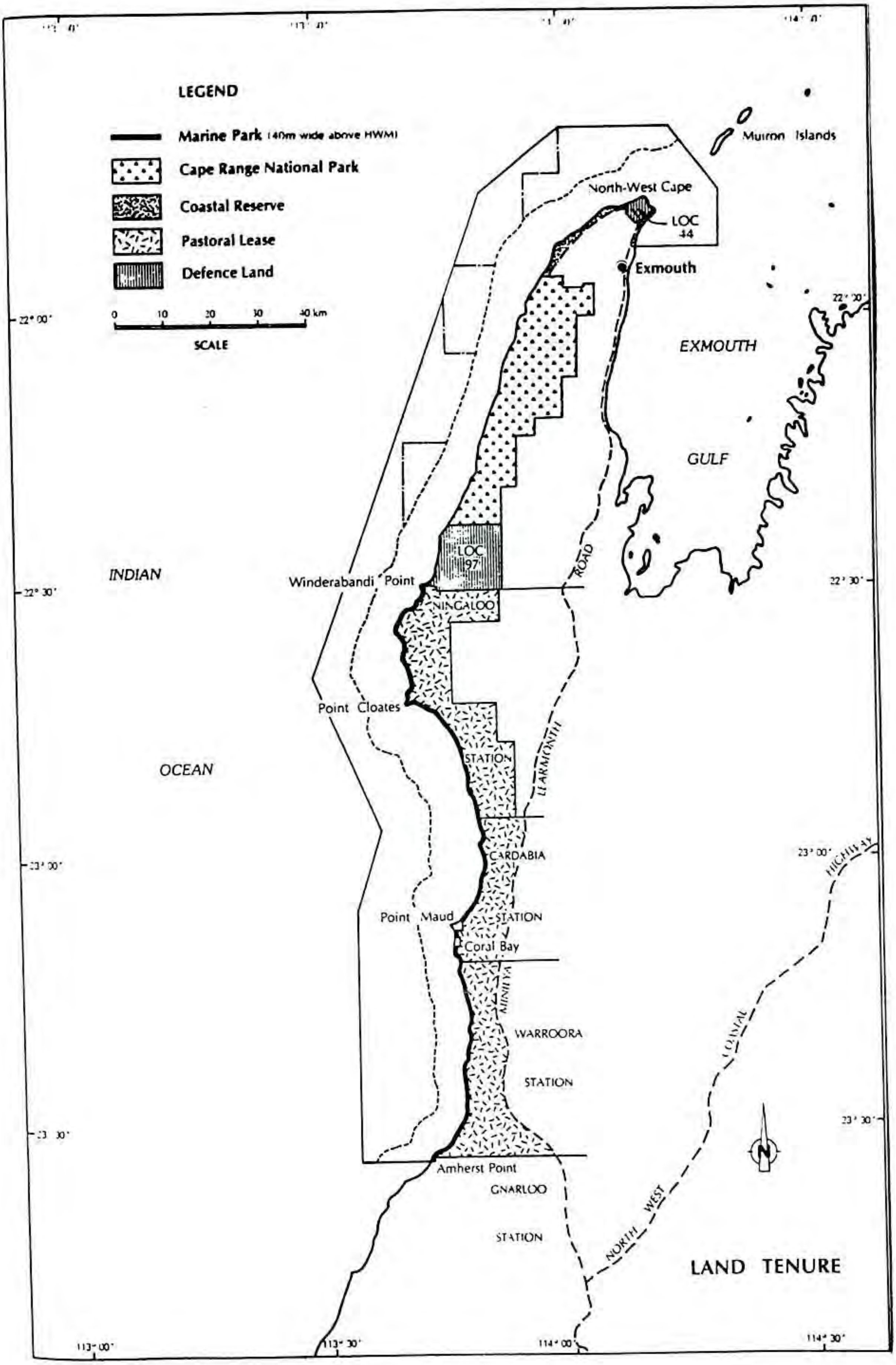
Taylor, G. 1996, *A Flora and Vegetation Survey and Assessment and Assessment of Conservation Values for Flora and Vegetation of the Area of the Proposed Coral Coast Marina*, Unpublished Report to Bowman Bishaw Gorham.

Taylor, J.G. & Pearse, A.F. 1999, Ningaloo Reef currents: implications for coral spawn dispersal, zooplankton and whale shark abundance. *Journal of the Royal Society of Western Australia* 82:57-65.

Ward T., Butler, E. & Hill, B. (1998) *Environmental Indicators for National State of the Environment Reporting – Estuaries and the Sea, Australia: State of the Environment (Environmental Indicator Reports)*, Department of Environment, Canberra.

Wells, F. 1980, The distribution of shallow-water marine prosobranch gastropod molluscs along the coastline of Western Australia, *Veliger* 22(3);232-247.

FIGURES



SOURCE: CALM, Ningaloo Marine Park, Management Plan No.12

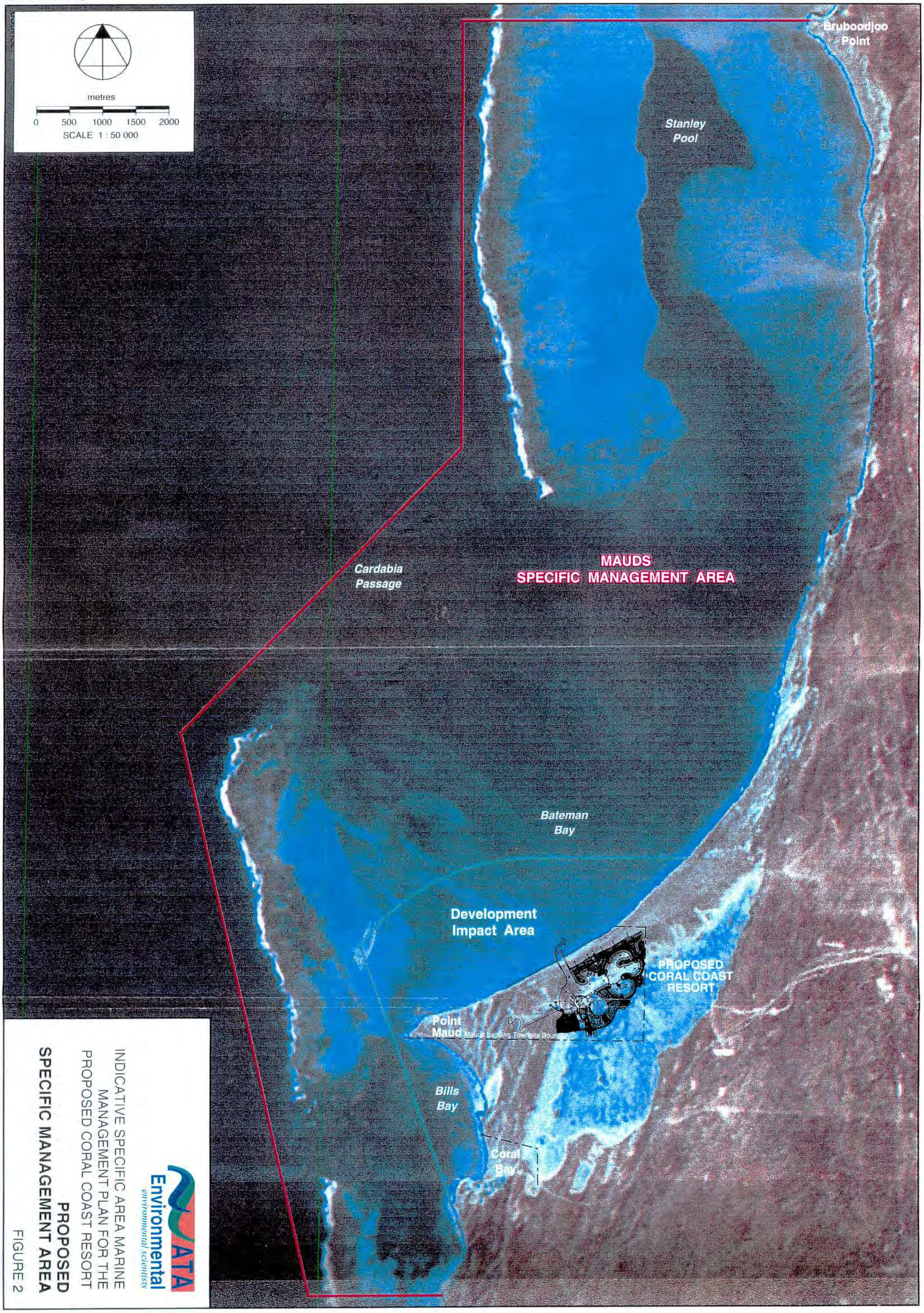
20057/20_148F1tpl DRAWN: GLM 30-10-00 CHECKED: HVW 30-10-00

ATA Environmental
environmental scientists

INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN
FOR THE PROPOSED CORAL COAST RESORT

LOCATION OF NINGALOO MARINE PARK

FIGURE 1

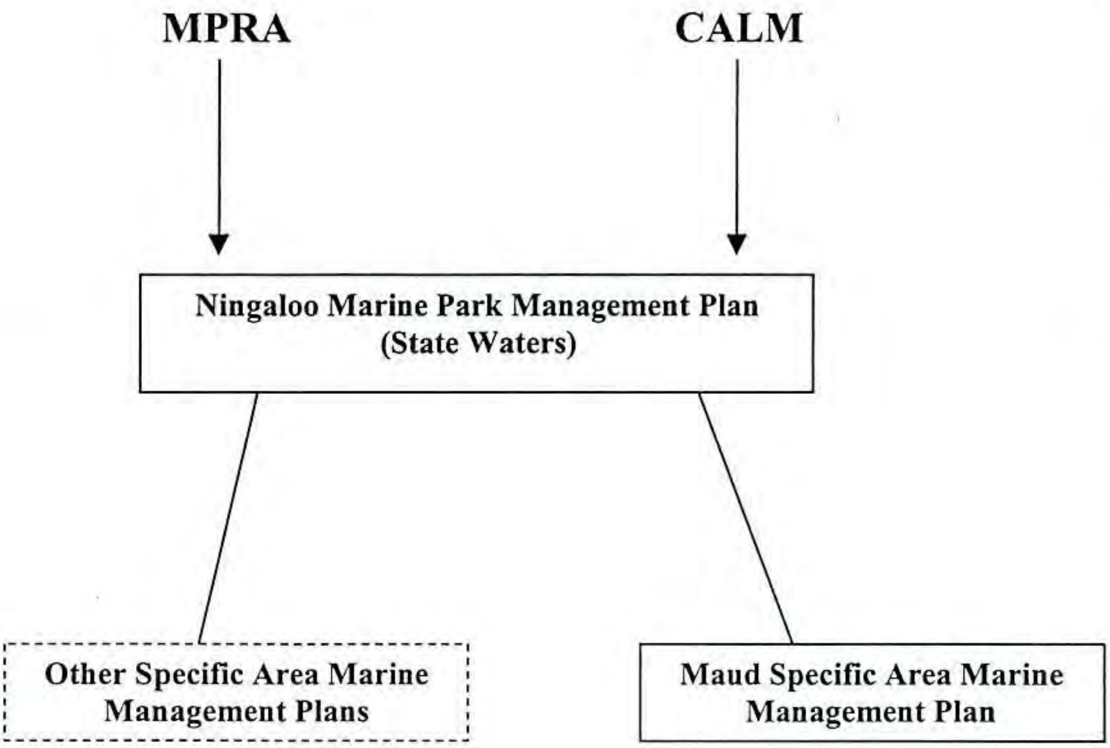


ATA Environmental
environmental scientists

INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN FOR THE PROPOSED CORAL COAST RESORT

PROPOSED SPECIFIC MANAGEMENT AREA

FIGURE 2



20057/20_148/f3tpl DRAWN: JS/GLM 30-10-00 CHECKED: HVW 30-10-00

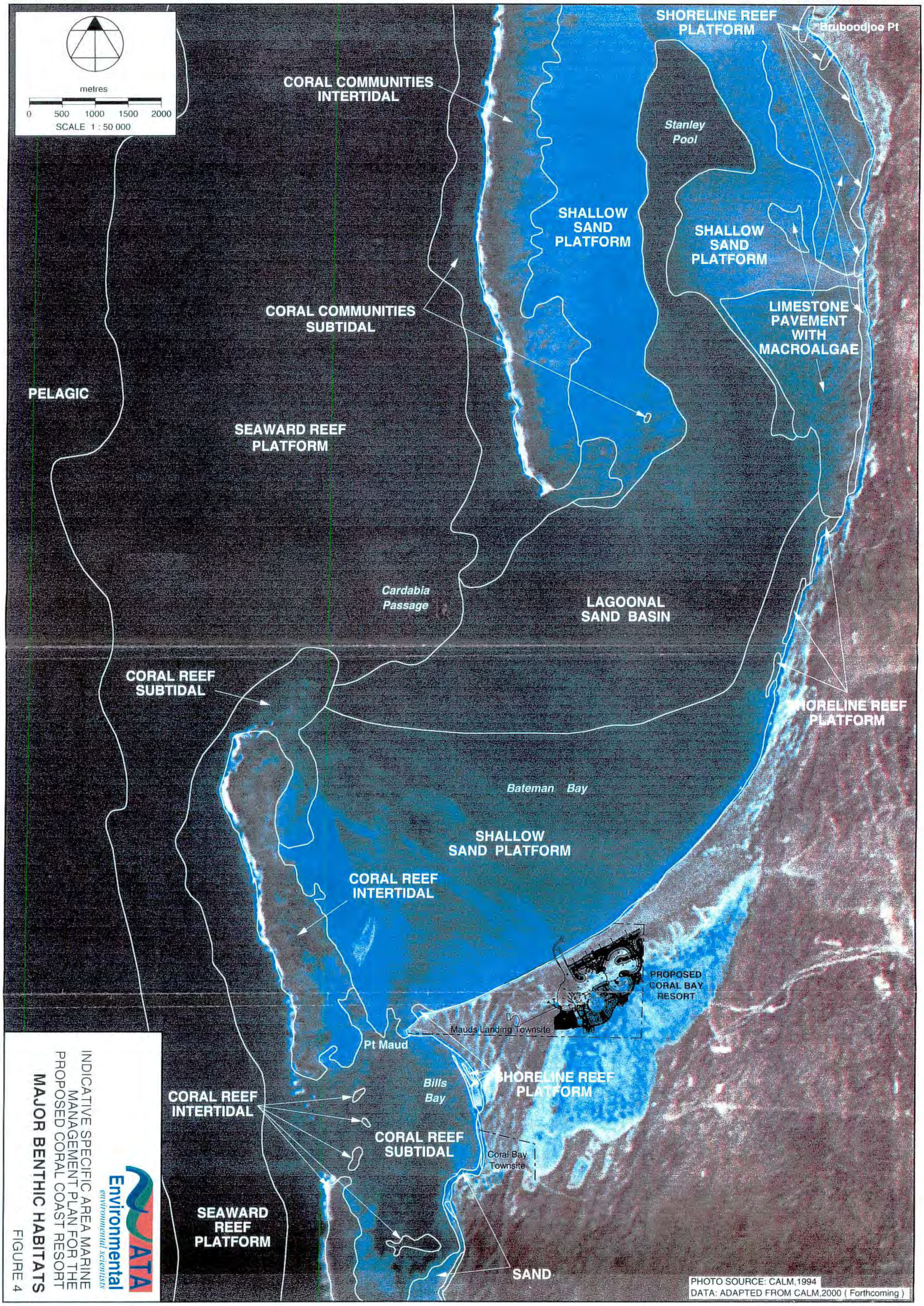
ATA Environmental
environmental scientists

INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN
FOR THE PROPOSED CORAL COAST RESORT

RELATIONSHIP BETWEEN THE MSMA & CALM'S MARINE MANAGEMENT PLAN FOR NINGALOO MARINE PARK

FIGURE 3

20057/20 148F4.dgn DRAWN: GLM 30-10-00 CHECKED: HVW 30-10-00 PRINTED: Mon 30 Oct 00



MAJOR BENTHIC HABITATS
INDICATIVE SPECIFIC AREA MARINE MANAGEMENT PLAN FOR THE PROPOSED CORAL COAST RESORT
FIGURE 4

APPENDICES

APPENDIX 1

PROPOSED ASSESSMENT CRITERIA FOR WATER QUALITY AND SEDIMENT MONITORING

APPENDIX 1
PROPOSED ASSESSMENT CRITERIA FOR WATER QUALITY AND SEDIMENT MONITORING

A1.1 Overview

CCMD has committed to establish and undertake a marine water and sediment monitoring programs for a period of at least five years following structural completion of the development, followed by a review.

Two impact areas have been defined and varying levels of potential impacts identified.

Within the DIA it is anticipated that there will be some short-term reduction in water quality within the period of construction and for a period of up to five years post-construction. This SAMMP presents a series of environmental indicators that, properly monitored, will track the condition of the likely impact area and will provide a framework against which they can be reported. Proposed Criteria 1 (from Tables A1.1 and A1.2, overleaf) identify water and sediment quality criteria to be applied within the DIA during this period. These fall within EQO II Class 2 values (Multiple Use Zone).

Following the period of initial construction and stabilisation of the marina water body, is it is anticipated that the balance of the DIA beyond an initial mixing zone, to be determined, will revert to water and sediment qualities representative of EQO II Class 1 values.

Within the MSMA it is anticipated that indirect impacts, principally a consequence of the greater selective pressure on certain target species and coincident damage (anchor, boat impacts) may occur. It is proposed that water and sediment quality within this area will not exceed background levels (i.e. EQO I or EQO II Class 1 values).

A1.2 Water Quality Criteria

Water quality criteria for the different monitoring locations are contained in Table 4 in ATA 2000. The background values observed during the baseline monitoring and the DEP (1995) survey have used provide specific criteria for the EQO I criteria from the Southern Metropolitan Coastal Waters Study (DEP 1996). The water quality assessment criteria proposed for the duration of the monitoring programs are summarised in TableA.1. These values will be adjusted as more results become available.

A1.3 Sediment Quality Criteria

Sediment quality criteria for the different monitoring locations are contained in Table 5 in ATA 2000. The background values observed during the baseline monitoring and the DEP (1995) survey have used provide specific criteria for the EQO I criteria from the Southern Metropolitan Coastal Waters Study (DEP 1996). The sediment assessment criteria proposed for the duration of the monitoring programs is summarised in Table A.2. These values will be adjusted as more results become available.

TABLE A.1
SUMMARY OF MARINE WATER QUALITY BACKGROUND VALUES AND ASSESSMENT CRITERIA

Analyte	Units	Sept/Oct 1994[a]		May 2000		Proposed Criteria 1	Criteria 2[b]	EPA Marine Water[c]
		Range	Average	Range	Average			
Metals								
Arsenic	ug/L	-	-	1-5	1.86 (n=7)	5.0	50	50
Cadmium	ug/L	-	-	0.05-0.1	0.08 (n=7)	0.1	2.0	2
Chromium	ug/L	-	-	<1	<1 (n=7)	1.0	50.0	50
Copper	ug/L	-	-	0.1-0.8	0.32 (n=7)	0.8	5.0	5
Lead	ug/L	-	-	<0.1-1.6	0.52 (n=7)	1.6	5.0	5
Mercury	ug/L	-	-	<0.0001-<0.1	(n=7)	<0.1	0.1	0.1
Nickel	ug/L	-	-	0.2-1.2	0.48 (n=7)	12	15.0	15
Zinc	ug/L	-	-	0.1-1.6	0.53 (n=7)	16	20.0	20
Organic Toxicants								
Total TPH	ug/L	-	-	<10	<10 (n=7)	<10	10.0	10
Total PAH	ug/L	-	-	<0.01-0.09	0.04 (n=7)	0.09	3.0	NR
Other								
Nitrate/Nitrite	μg/L	4-9	4.9 (n=27)	5-30	10 (n=20)	30	NR	10 – 60
Ammonia	μg/L	3-12	7.5 (n=27)	<10	<10 (n=20)	12	NR	<5
TKN	μg/L	23-73	40 (n=27)	<20-40	<20 (n=20)	73	NR	NR
Filterable Reactive Phosphorus	μg/L	9-28	17 (n=27)	<5-6	1.2 (n=20)	10	NR	1-10
Total P	μg/L	13-32	20 (n=27)	<10-10	<10 (n=20)	32	NR	NR
Chlorophyll-a	μg/L	0.07-0.28	0.15 (n=27)	<0.02-0.03	0.0025 (n=20)	0.28	NR	0.8
Phaeophytins	μg/L	-	-	<0.04	<0.04 (n=20)	<0.04	NR	NR

Notes:

a From DEP (1995)

b Taken from Maintenance of Ecosystem Integrity (EQO 2, Class II) (DEP,1996)

c From Draft WA Water Quality Guidelines for Marine and Fresh Waters (EPA, 1993). Included for comparison only.

d. These criterion guidelines are presented for discussion and will be reviewed in consultation with CALM and the DEP.

TABLE A.2
SUMMARY OF SEDIMENT QUALITY BACKGROUND VALUES AND ASSESSMENT CRITERIA

Analyte	Units	Sept/Oct 1994[a]		May 2000		Proposed Criteria 1	Criteria 2[b]	Criteria 3[c]	Criteria 4[d]	Criteria 5[e]
		Range	Average	Range	Average					
Metals										
Arsenic	mg/kg	-	-	<1-3	0.6	3.0	8.2	0.2-30	20	30
Cadmium	mg/kg	-	-	0.1	0.1	0.1	1.2	0.04-2	3	5
Chromium	mg/kg	-	-	3-30	15.6	30	81	0.5-110	50	250
Copper	mg/kg	-	-	<0.5	<0.5	<0.5	34	1-190	60	100
Lead	mg/kg	-	-	<0.5	<0.5	<0.5	46.7	<2-200	300	150
Mercury	mg/kg	-	-	<0.01	<0.01	<0.01	0.15	0.001-0.1	1	2
Nickel	mg/kg	-	-	<0.5	<0.5	<0.5	20.9	2-400	60	100
Zinc	mg/kg	-	-	0.5-1.5	1.1	1.5	150	2-180	200	500
Organic Toxicants										
PAHs	mg/kg	-	-	<0.01	<0.01	<0.01	4.022	0.95-5	NR	NR
Total DDT	mg/kg	-	-	<0.001	<0.001	<0.001	0.0016	<0.001-0.97	NR	0.5
Dieldrin	mg/kg	-	-	<0.001	<0.001	<0.001	NR	<0.005-<0.05	0.2	0.5
Individual Organochlorine Pesticides	mg/kg	-	-	<0.001	<0.001	<0.001	NR	NR	NR	0.5
Total Organochlorine Pesticides	mg/kg	-	-	<0.001	<0.001	<0.001	NR	NR	NR	1
PCB's	µg/kg	-	-	<20	<20	<20	22.7	20-100	100	100
Tributyl Tin	µg/kg	-	-	<1	<1	<1	10	NR	NR	NR
Other										
Ammonium-N	mg/kg	-	-	<1	<1	<1	NR	NR	NR	NR
Nitrate-N	mg/kg	-	-	0.1-0.23	0.17	0.23	NR	NR	NR	NR
TKN	mg/kg	100-500	260	75-170	133	500	NR	NR	NR	NR
Reactive Filterable Phosphorus	mg/kg	-	-	0.7-5.9	2.9	5.9	NR	NR	NR	NR
Total Phosphorous	mg/kg	60-540	230	260-610	432	610	NR	NR	NR	NR

NR No recommendation at this time.
a From DEP (1995)
b Taken from Maintenance of Ecosystem Integrity – Multiple Use Zone (EQO 2, Class II) (DEP 1996).
c Taken from Background (A) values (ANZECC/NHMRC 1992). Included for comparison only.
d Taken from Environmental Investigation (B) values (ANZECC/NHMRC 1992). Included for comparison only.
e Taken from Dutch 'B' criteria. Included for comparison only.

APPENDIX 2

SUMMARISED OCCURRENCE AND ACTIVITY DATA RELATING TO LARGE FINFISH, MARINE MAMMALS AND TURTLES

TABLE A2.1
SUMMARISED OCCURRENCE AND ACTIVITY DATA RELATING TO LARGE FINFISH, MARINE MAMMALS AND TURTLES

	Activity				Frequency			Location			***Comments***
	migration	feeding	breeding	Resting basking	Occasional	Frequent	resident	Open waters	Bateman Bay	Mauds Landing	
FINFISH Whale shark	x	x		x		x		x			Feeding and basking observed offshore.
Manta ray		x	x				x		x	x	Likely resident within the NRT. Considerable numbers within Bateman Bay, including Mauds.
Other sharks		x	x	x		x	x	x	x	x	Seasonal aggregations of some spp. in Bills Bay. Tiger sharks occasionally off Mauds during turtle reproduction.
MAMMALS Dugong		x		x	x				x	x	Likely transient through Bateman Bay and Mauds due to limited food availability
Whales	x	x		x	x			x	x		Baleen whale feeding and basking observed offshore. Southern right cows and calves occasionally enter Bateman Bay to rest. Toothed whales and porpoises enter Bateman Bay and have been observed off Mauds.
TURTLES Green	x	x	x				x		x	x	Most common, feeding on macroalgae.
Loggerhead		x	x				x		x	x	Carnivorous, feeding on molluscs and crustaceans
Leatherback	x	x					x		x		Occasional visitor
Hawksbill		x	x			x		x	x	x	Often present offshore. Feed mainly on sponges.

APPENDIX 6

BOAT SOURCE DATA AND ASSUMPTIONS

utilisation of accommodation and charters.

	CORAL BAY		MAUDS	
legal living units	477		1080	
ABS stats	2.54	per unit		
legal limit	1211.58	people	2743.20	
ave occupancy 01	1580	per night	1119.49 [1]	per night 2009
bed nights	576700	beds	408613.17	408613
people/legal living unit	3.312369		2.54	

FISHING CHARTER

demand	all year					
# boats	3					
places	47	places on boats				
boat utilisation	60	%				
Total fishing 'days'	9870	fishers	Totals CCR			
Total boats	1050	boat trips				
% of beds fishing (annually)	1.7	%	Gross	Net		Boat km
CB additional demand	3455	to 2009	6993	3539	fishers	1.1 additional boats @ 60% util.
at 60% boat utilisation	368	boat trips	744	376	boat trips	37646 additional km annually
at 90% boat utilisation	245	boat trips	496	251	boat trips	25098 additional km annually

notes
use 40% trips 90% capacity
60% trips 40% capacity
15 days not fishable (use 350 days)
[1] use lesser value of 1406 to allow for overflo
all day trip

SCUBA DIVING existing demand

demand	occurs all year					
# boats	4					
places	100	places on boats				
boat utilisation	66	%				
Total dives'	23100 [2]	dives	Totals CCR			
Total boats	1400	boat trips				
% of beds diving	4.0	%	Gross	Net		Boat km
additional demand	8085	to 2009	16367	8282	dives	1.4 additional boat @ 66% util.
at 66% boat utilisation	490	boat trips	992	502	boat trips	62744 additional km annually
at 90% boat utilisation	359	boat trips	727	368	boat trips	46012 additional km annually

notes
use all trips 66% capacity
two trips daily, each 50 capacity
15 days not diveable (use 350 days)
[2] dive groups not staying in area visit. Assum

SNORKELLING/ECOTOURISM EXPERIENCES

demand	all year					
# boats	4 [3]	boats				
places	90					
boat utilisation	66	%				
total snorkellers	20790 [4]	dives	Totals CCR			
total boats	1400	boat trips				
% of beds snorkelling (annua	3.6	%	Gross	Net		
additional demand	7277	to 2009	14730	7454	dives	1.4 additional boats @ 66% util.
at 66% boat utilisation	490	boat trips	992	502	boat trips	62744 additional km annually
at 90% boat utilisation	359	boat trips	727	368	boat trips	46012 additional km annually

notes
[3] one boat does 2 to 3 trips daily
[4] dives may include turtle, dugong or manta e
15 days not diveable (use 350 days)

HUMPBACK WHALE VIEWING

demand	Limited to migration, up to 12 weeks					
# boats	3 [5]	boats				
places	63					
boat utilisation	50	%				
total participants	2646	observers	Totals CCR			
total boats	252	boat trips				
% of beds viewing (annually)	0.5	%	Gross	Net		
additional demand	926	to 2009	1875	949	seats	1.1 additional boats @ 50% util.
at 50% boat utilisation	88	boat trips	179	90	boat trips	9035 additional km annually
at 80% boat utilisation	55	boat trips	112	56	boat trips	5647 additional km annually

notes
[5] five licences held locally

WHALE SHARK EXPERIENCES

demand	Limited To period following coral spawning, 10 weeks					
# boats	2					
places	32					
boat utilisation	80	%				
total participants	1792	snorkellers	Totals CCR			
total boats	140	boat trips				
% of beds viewing (annually)	0.3	%	Gross	Net		
additional demand	627	to 2009	1270	642	snorkellers	1.0 additional boats @ 80% util.
at 80% boat utilisation	49	boat trips	120	71	boat trips	7124 additional km annually
at 90% boat utilisation	44	boat trips	88	45	boat trips	4462 additional km annually

notes

BEACH TURTLE NESTING/ HATCHING EXPERIENCES

demand	Combined nesting and hatching 14 weeks					
operators	3					
# quadbikes/4WD places	24					
utilisation	95	%				
total participants	2234.4		Totals CCR			1.44
% of beds viewing (annually)	0.4	%	Gross	Net		
additional demand	782		1583	801	participants	
at 95% bike utilisation	8	quadbikes	17	9	additional quadbikes or 4WD places required daily	

notes
single participants on quadbikes or 8 in 4WD

ASSESSMENT OF BOAT NUMBERS AND km TRAVELLED

source, discussions with ecotorism operators

Item	PROPOSED CORAL COAST DEVELOPMENT Trailed	Pens	Totals	# trips/wee	Distance/yr	Source	CORAL BAY EXISTING Trailed	Moored	Distance/yr
Permanent residents	33	8	41	2	93938	M.P Rogers and Assoc, 2000	10		15860
Residential staff	27	7	34	1	76414	M.P Rogers and Assoc, 2000	10		8580
[1] short stay residential	44	0	44	4	98208	boat counts Coral Bay April/May 2001	63		140616
Visiting yachts	0	20	20	1	26000	M.P Rogers and Assoc, 2000	0		0
New Commercial boats	5	10	15	6	176280	discussions with ecotourism operators	0		0
CALM & Dept Fisheries	3	2	5	2	20280	M.P Rogers and Assoc, 2000	0		0
[2] Commercial Boats from Bills Bay	2	12	14	6		boat counts Coral Bay April/May 2001	2	16	271440
Overflow from Bills Bay	54		54	4		calculated			
SUM FOR CCR AND CORAL BAY 2009	168	59	227		491120	CORAL BAY 2001	85	16	436496

[1] assumes informal camps no longer needed, based on actual count data

[2] Not counted as existing boats relocated

ANNUAL DISTANCE TRAVELLED, CCR and Coral Bay, 2009 927616

% INCREASE DUE TO CCR 53

ASSUMPTIONS

source, boat counts Coral Bay April/May 2001

Percentage of Boats by Size

	% obs.	distance travelled km/day
cartoppers	25.71	10
<5.5	52.86	20
> 5.5	22.86	30
COMMERCIAL		100

(source, boat counts Coral Bay April/May 2001)

source, discussions with ecotourism operators

63.56

Proportion of Boats in Size Class by Group

BOATS BY GROUP	cartopper	<5.5	>5.5	COMMERCIAL
Residents	0.1	0.6	0.3	
Residential staff	0.2	0.5	0.3	
[1] short stay residential	0.25	0.5	0.25	
Visiting yachts			1	
New Commercial operators	0.2	0.3	0.5	
CALM & Dept Fisheries	0.2	0.2	0.6	
[2] Large Boats from Bills Bay			0.1	0.9

source, boat counts Coral Bay April/May 2001,
otherwise discussion with tourism operators

APPENDIX 7

DRAFT NATURAL RESOURCES MANAGEMENT AGREEMENT

NATURAL RESOURCES MANAGEMENT AGREEMENT

between

Coral Coast Marina Development Pty Ltd

and the

Executive Director of the

Department of Conservation and Land Management,
Western Australia

and the

Executive Director

Fisheries WA

In respect of the ongoing protection of the environment and ecological communities at Mauds Landing and in adjacent waters, including the Ningaloo reef system Ningaloo Marine Park

September 2000

NATURAL RESOURCES MANAGEMENT AGREEMENT

PREAMBLE

The Agreement outlines the respective interest and commitments of the proponent, Coral Coast Marina Development (CCMD) Pty Ltd (ACN 009 279 047) and the Department of Conservation and Land Management (CALM) AND Fisheries WA in the ongoing protection of the environment and fish stocks at Mauds Landing and in adjacent marine waters including Ningaloo Reef system and the Ningaloo Marine Park.

The Ningaloo Marine Park is vested in the Marine Parks and Reserves Authority and activities except for fishing are managed by CALM (see attached locality plan). The marine park includes the coastal strip 40 metres landward of high water mark, except within unallocated Crown Land containing Mauds Landing townsite where the marine park extends to high water mark only.

Fisheries WA under the Fish Resources Management Act (1994) manage fish resources throughout the State, including those within the waters of the Ningaloo Marine Park. Fish resources which occur from the three nautical mile limit of State territorial waters to the 200 nautical mile limit of the Australian Fishing Zone (AFZ), and are not specified in Commonwealth managed fisheries, are managed by the State under the terms of the Offshore Constitutional Settlement 1995. Under these arrangements all recreational fishing activity in the WA section of the AFZ is currently managed by Fisheries WA.

BACKGROUND

The proposed development of a commercial tourist accommodation and residential complex and marina at Mauds Landing is an important project to which the Government has a strong commitment. The development will enhance regional tourism and recreation opportunities, provide additional input to the regional economy, and has the potential to improve management of current tourism impacts in Bills Bay and Coral Bay itself.

In 1989 State Cabinet gave conditional endorsement to the development of a boat harbour, tourist facilities and residential subdivision at Mauds Landing. The successful tenderer for the project was CCMD. Cabinet support for the project was conditional to CCMD obtaining environmental and planning approvals and making satisfactory progress.

The major components of the proposal included a caravan/chalet park catering for 250—290 units, 250 serviced tourist accommodation units, 645 self contained tourist accommodation units, and 360 residential units. A marina and inland lagoon system linked to Bateman Bay with facilities for boat mooring and launching and a village centre were also envisaged.

The consequences of such a development could be significant. These consequences include not only opportunities for further tourism business development, the potential negative impact on waters and land immediately adjacent to the development, but also the likely impact on marine communities and fish stocks created by increasing visitor numbers, and increased boating and fishing activity.

Conversely, the environmental impacts of tourism and tourism infrastructure at Coral Bay townsite are already degrading the environment in Coral (Bills) Bay. Hence there is recognition that a 'no development' option at Mauds Landing is not desirable in the long-term – the Mauds Landing project is seen as an opportunity to manage the current degrading activity as well as the inevitable increase in the visitor numbers that this area will experience and contain future development in an ecologically sustainable manner. The project also represents a landmark opportunity to minimise the risks of environmental and ecological degradation often associated with coastal developments by providing resources and a planning framework to allow for the assessment and management of these impacts. An additional benefit will flow from the removal of many of the environmental stresses from Bills Bay.

Uncontrolled beach access will also potentially impact on coastal dune systems within Ningaloo Marine Park.

Key impacts on fish stocks include a zone of increased fishing exploitation that is likely to extend in a 20-kilometre area around the launching and mooring facilities. The marina will also create opportunities for larger, better-equipped commercial fishing tour and private boats to target pelagic and demersal fish populations in a part of the coastline that has historically experienced relatively low levels of fishing pressure.

This increase in fishing activity is likely to not only cover more fishing ground than in the past, but also extend over longer periods of time.

MANAGING ENVIRONMENTAL IMPACTS

A number of options exist to minimise the potential environmental impacts of the development. This is to be achieved at minimal additional cost to government. These mechanisms include:

1. Conducting baseline research on current use of the area, including recreational fishing activity and catches;
2. Establishing an ongoing scientific monitoring program to assess the environmental impact;
3. Increasing the management presence of both CALM and Fisheries WA;
4. Through interpretation and education increase public awareness of the potential consequences of recreation, including fishing on the environment and fish stocks at Mauds Landing and in adjacent marine waters including Ningaloo Reef system and Ningaloo Marine Park;
5. Providing alternatives to recreating on the natural reef by creating an artificial coral reef within the controlled environment of the marina;
6. Ministerial conditions and statutory requirements for managing environmental and fish resource impacts.

The terms "environment" and "environmental impact" used in this document encompass not only direct physical and hydrological issues, but also the terrestrial and aquatic biological communities and species affected by the development.

The Cabinet decision in April 1999 reiterated that the developer would be required to contribute resources towards environmental management, commensurate with the management burden the development would create. To this end, CCMD have devised a number of options aimed at providing the necessary funding.

The proposed Coral Coast Environmental and Interpretive Centre will play a key role in educating visitors about Ningaloo Reef and the potential impacts of recreating in fragile marine environments. Similarly, it is expected that impacts upon the reef could be minimised by constructing an artificial coral reef within the marina. The reef, which will be located proximal to the environment centre, will comprise an integral part of the overall interpretive experience.

CCMD's response to issues raised in public submissions to the initial PER recognised that a number of management plans were needed to minimise impacts, and that these would be completed prior to construction. Of particular interest to CALM are:

- a Foreshore Management Plan (ie. provision and maintenance of access and facilities the terrestrial component of Ningaloo Marine Park);
- a Nutrient and Irrigation Management Plan;
- a Shallow Groundwater Management Plan;
- a Shoreline Movement Monitoring Plan;
- a Turtle Management Plan and Turtle Nesting Surveillance Programme;
- a Coral Community Monitoring Programme; and
- a Water Quality and Sediment Monitoring Programme.

In addition Fisheries WA have identified the need for a Fish Resource Management and Research Programme, comprising the following elements:

- Collection and compilation of baseline fisheries management data for the Coral Bay area;
- An ongoing recreational fishery research catch and effort monitoring program;
- Biological and movement studies on the key exploited species;
- Mortality studies on key species;
- A recreational fishery field management and education program with a focus on the Mauds Landing / Coral Bay area;
- A community education programme.

Involvement of the local community, charter boat operations and volunteers will be encouraged where appropriate.

These issues will be addresses through the preparation of a fish resource management programme, consistent with the strategic objectives for recreational fisheries management in the Gascoyne Region prior to construction of the development.

This Schedule defines the respective roles and interests of CALM, Fisheries WA and CCMD.

SCOPE AND TERM

The agreement cannot restrict either CALM, Fisheries WA or CCMD in the performance of their functions or the execution of statutory powers, nor does it preclude any additional conditions required by the Minister for the Environment. Notwithstanding this, CALM, Fisheries WA and CCMD agree that identifying mechanisms for cooperation and liaison through the Schedule will benefit all parties. It may be reviewed at the instigation of any party and may be replaced by a revised agreement.

The Schedule will remain in place from the date of signature by its parties until any revised agreement document is signed, or until such time as a formal lease, incorporating the contents of this Agreement, is signed by all parties.

PURPOSE

The purpose of the schedule is to put in place an agreement on the commitments and obligations of both parties in relation to mechanisms to protect the environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo Reef system and Ningaloo Marine Park.

AIMS AND INTERESTS

Common aims –

CALM, Fisheries WA and CCCMD are aiming to manage in an ecologically sustainable manner human impacts on the natural environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo Reef system and Ningaloo Marine Park. This will be achieved by:

- establishing baseline environmental research and ongoing monitoring programmes;
- providing resources to CALM and Fisheries WA for management of the natural resources, commensurate with the management burden the development would create;
- constructing a world class interpretation and environment centre in keeping with the standards of the overall development; and
- establishing an artificial coral reef within the marina to reduce the impacts on the natural environment and provide opportunities for interpretation.

Individual aims and interests –

CCMD is committed to a high quality tourism development that minimises environmental impacts and maximises use of technology and design to reduce impacts and the use of non-renewable resources.

CCMD is committed to planning outcomes that are consistent with CALM and Fisheries WA management plans and achieve sustainable social, environmental and economic outcomes.

CALM is responsible for protecting and managing the natural environment, (excluding fish resources), of Ningaloo Marine Park, and is committed to enhancing the experience of visitors through the provision and maintenance of high quality facilities and services that allow visitors to understand and enjoy the features and attractions of the area.

Fisheries WA is responsible for protecting and managing the fish resources of the area including the waters of the Ningaloo Reef system and Ningaloo Marine Park. Fisheries WA is committed to providing key research, compliance and community education services which not only seek to ensure sustainable fish stocks, but also the maintenance of a high quality recreational fishing experience in the marine waters of the region.

OBLIGATIONS

Financing

In accordance with Section 6.5 of CCMD's Revised Structure Plan and Development Proposal (November 1999), CCMD will:

- during Phase 1, employ a full time environmental manager and provide \$200,000/annum for environmental monitoring and management;
- prior to the completion of Phase 1 allocate \$50,000 for the compilation of existing data and a 12 month baseline fisheries management survey for the Coral Bay area;
- at completion of Phase 1, allocate \$150,000/annum to environmental and natural resource management;
- provide opportunities for CALM and Fisheries WA to gain revenue through the visitor entry fees, a portion of boat launching and marina usage fees and the sale of merchandise from the interpretive centre;
- allocate \$1,000,000 to the construction of the Coral Coast Environmental and Interpretive Centre as a field and interpretation centre (incorporating an underwater viewing area and an office for CALM and Fisheries WA);
- allocate a maximum of \$250,000 for equipping the Coral Coast Environmental and Interpretive Centre; and
- construct a limestone substrate and allocate \$200,000 for the propagation of a coral reef.

CALM will:

- provide advice to CCMD in relation to a Foreshore Management Plan (ie. provision and maintenance of access and facilities for the terrestrial component of Ningaloo Marine Park), a Nutrient and Irrigation Management Plan, a Shallow Groundwater Management Plan, a Shoreline Movement Monitoring Plan, a Turtle Management Plan and Turtle Nesting Surveillance Programme, a Coral Community Monitoring Programme, a Water Quality and Sediment Monitoring Programme and any additional plans prescribed by the Minister for the Environment;
- in conjunction with Fisheries WA and CCMD, work diligently towards determining the most appropriate option(s) for funding ongoing natural resource management of Ningaloo Marine Park and adjacent areas;
- work diligently towards facilitating development leases within Ningaloo Marine Park for breakwater construction and entrance dredging, subject to the approval of the relevant authorities;
- in conjunction with Fisheries WA and CCMD, discuss with the Shire of Carnarvon the option of implementing a Specified Area Rate to contribute to natural resource management;
- share with Fisheries WA the legal costs in the preparation of a lease document;
- will work co-operatively with Fisheries WA to develop a joint approach for the utilisation of the revenue generated by this proposal to meet their overall service delivery costs in the Coral Bay area;
- contribute to the cost of equipping the Coral Coast Environmental and Interpretive Centre and the propagation of the artificial coral reef if the funding required exceeds \$250,000;
- prepare a management plan for Ningaloo Marine Park (including the waters adjacent to the proposed resort development) within three years; and

- co-ordinate and work with CCMD in ensuring that, where possible, sufficient tour operator licences for the Marine Park are held in reserve for the expected tourism requirements generated by the development.

Fisheries WA will:

- provide advice to CCMD in relation to the management of fish resources, the Gascoyne Regional Recreational Fisheries Management Strategy and any additional plans pertaining to the management of fish resources or prescribed by the Minister for the Environment;
- in conjunction with CALM and CCMD, work diligently towards determining the most appropriate option(s) for funding ongoing management of the environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo Reef system and Ningaloo Marine Park;
- in conjunction with CALM and CCMD, discuss with the Shire of Carnarvon the option of implementing a Specified Area Rate to contribute to natural resource management;
- share with CALM the legal costs in the preparation of a lease document;
- work co-operatively with CALM to develop a joint approach for the utilisation of the revenue generated by this proposal to meet their overall service delivery costs in the Coral Bay area;
- contribute to the cost of equipping the Coral Coast Environmental and Interpretive Centre and the interpretation of the artificial coral reef if the funding required exceeds $250,000;
- co-ordinate the management of the fishing tour industry in the area to ensure that fish stocks remain sustainable, and that the quality and diversity of recreational fishing opportunities in the area is maintained or enhanced.

CCMD will:

- construct the proposed $1,000,000 Coral Coast Environment Centre (incorporating an under water viewing area and an office for CALM and Fisheries Western Australia);
- allocate $250,000 for equipping the environment centre;
- in conjunction with CALM and Fisheries WA, work diligently towards determining the most appropriate option(s) for funding the ongoing management of the environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo reef system and Ningaloo Marine Park;
- prior to commencement of works, prepare a Foreshore Management Plan (ie. provision and maintenance of access and facilities the terrestrial component of Ningaloo Marine Park), a Nutrient and Irrigation Management Plan, a Shallow Groundwater Management Plan, a Shoreline Movement Monitoring Plan, a Turtle Management Plan and Turtle Nesting Surveillance Programme, a Coral Community Monitoring Programme, a Water Quality and Sediment Monitoring Programme and a Fish Resource Management and Research Programme;
- employ an environmental manager;
- in conjunction with CALM and Fisheries WA, discuss with the Shire of Carnarvon the option of implementing a Specified Area Rate to contribute to environmental management;
- construct a coral reef substrate within the marina, and provide funding for propagation of corals;
- ensure environmental best practice is used in all aspects of planning and site operation;

- contribute to funding of recreation facilities in the adjacent Ningaloo Marine Park deemed necessary to cater for the development's clientele;
- work with CALM and Fisheries WA to provide housing for CALM and Fisheries WA staff at normal commercial rentals;
- work diligently towards the signing of a lease document for the proposed Coral Coast Environmental and Interpretive Centre and staff accommodation;
- provide boat moorings for CALM and Fisheries WA; and
- CCMD, CALM and Fisheries WA will work together to monitor recreation use patterns that may affect the environment and fish stocks at Mauds Landing and in adjacent marine waters including the Ningaloo Reef system and Ningaloo Marine Park.

PRINCIPLES OF NEGOTIATION

The Parties will:

- commit to the management, protection and enhancement of the environment and fish stocks at Mauds Landing and in the adjacent marine waters including the Ningaloo Reef system and Ningaloo Marine Park;
- commit to the interpretation and research relevant to the management of natural resources in the Ningaloo Marine Park and surrounding waters;
- work together to ensure an outcome of mutual benefit to all parties;
- act in good faith in negotiating elements of the lease;
- raise any issues of concern and work towards satisfactory resolution of any disputes;
- provide reasonable notice to the other parties of any matters that may significantly affect the project;
- keep the other parties informed of matters that could be reasonably expected;
- seek to involve relevant scientific marine experts and organisations in monitoring and research activities, so as to widen the base of scientific input into environmental management; and
- work cooperatively for the purpose of achieving a successful development.

NATURAL RESOURCES MANAGEMENT AGREEMENT

BETWEEN

CORAL COAST MARINA DEVELOPMENT PTY LTD
AND

THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
AND

FISHERIES WA

This schedule represents the commitments of the undersigned parties in respect of the ongoing environmental protection and management of Ningaloo Marine Park and adjacent areas.

Signatures: *Seal:*

Executive Director

Department Of Conservation And Land Management

....
(Date)

Signatures: *Seal:*

Executive Director

Fisheries WA

....
(Date)

THE COMMON SEAL OF CORAL COAST MARINA DEVELOPMENT PTY LTD (ACN 009 279 047) was affixed by authority of the Board of Directors and in the presence of:

....
Director (Date)

....
Director/Secretary (Date)

APPENDIX 8

STRATEGY FOR THE MANAGEMENT OF TURTLES IN BATEMAN BAY AND ADJACENT COMMONWEALTH WATERS

CORAL COAST MARINA DEVELOPMENT
MARINE TURTLE MANAGEMENT STRATEGY

The Marine Turtle Management Strategy will consists of the following components:

- Feral Animals
- Light Pollution
- Beach Access
- Vessel Strikes
- Ecotourism
- Indigenous Hunting
- Public Education
- Turtle Management Officer

Feral Animals

Monitoring of turtle nesting and hatchling emergence north of the Maud's landing site has demonstrated significant predation of eggs by foxes (Peter Mack, pers. comm. 2001). Fox predation is believed to account for losses of up to 70% of turtle eggs (Bob Prince, CALM, pers comm., 2001).

Controlling fox populations would therefore have substantial impact on the number of hatchlings survival and the turtle population overall. The preferred method for fox control is through the use of approved baits. Alternatively, other less efficient methods such as use traps will be employed.

The use of baits for fox control will require negotiation and approval from agencies such as CALM and the Agricultural Protection Board. There is potential for some conflict between users of the area and the control of foxes in terms of the potential for non-target animals such as domestic pets being inadvertently killed. The program therefore will be designed in consultation with the relevant agencies.

Control measures will be concentrated near potential food sources such as refuse dumps within the Coral Coast Marina Development (CCMD) management area.

Complimentary fox control should also be undertaken along the length of the turtle nesting beaches at least during the turtle nesting season. The main nesting area is outside the boundaries of the development, occurring along the coast adjoining the Cardabia pastoral station managed by the Baiyungu Aboriginal Corporation. CCMD will liaise with CALM and the Baiyungu Aboriginal Corporation to encourage a comprehensive approach to fox control.

Visitors and residents of the area will be prohibited from bringing or keeping cats within the development area.

Light Pollution

Artificial lighting can attract and disorientate hatchlings and increase mortality. The development will be designed to ensure minimal fugitive light reaches the beaches. The development is located more than 2km south of the main nesting beaches although some nesting does occur along the beaches fronting the proposed development.

Lighting management at the development is proposed to include the following aspects:

- The development is located behind the dunes along the beach, which will restrict the light reaching the beaches.

- Orientation of the buildings and windows will be considered during detailed design. The design will aim the minimise the number of windows facing toward the north where the main nesting activity occurs and beaches fronting the development, and/or include elements to shield lighting from these areas.

- High intensity lighting and floodlights will not used within the development area. Lights throughout the resort area will be directional, low intensity and mounted low on supports or buildings.

- Lights and access paths will be positioned low with the light directed to provide sufficient illumination of the path for safety but with a limited light spillage above the vegetation and dunes.

- Lighting in the green-yellow to yellow region of the spectrum (560 to 600nm) will be used for outside lighting within the development and including lights associated with accommodation units. This range has been shown to be less attractive to Loggerhead and Green Turtle hatchlings (Lutz, 1997).

- Where necessary, shielding of lights within the development and accommodation units and motion-detector lights will be used.

- Residents will be informed on the impacts of lights on hatchlings and be encouraged to use low intensity lighting and window treatments to prevent light spill during the nesting and hatching season.

- The Environmental Code prepared for the development will include information for visitors to discourage the use of lighting and torches on the beaches at night during the nesting and hatching periods and provide guidelines for minimising impacts.

Beach Access

Development of the marina will interrupt movement of 4WD vehicles along the coast from Coral Bay. Access to beaches adjoining the site within the development area will be controlled by the use of appropriate structures and signage. Vehicles may however be able to deviate around the development area and access beaches to the north through Cardabia station.

Developers of the marina will liaise with the Baiyungu Aboriginal Corporation and CALM in relation to means to prohibit access, particularly during the nesting season between 1 November and 31 March, onto the beaches north of the marina development site. Access onto the beaches should be limited to quad bikes used by authorised operators such as CALM and Fisheries officers, and approved tour operators.

4WD vehicles would be permitted to access the beaches during between 1 November and 31 December only during daylight hours between 6am and 7pm. All vehicle access to the beaches would be prohibited during the main hatching period from 1 January to 31 March as the tyre tracks can present major obstacles for hatchlings as they migrate to the water.

Pedestrian access to the nesting beaches north of the Cardabia access track would also be prohibited during the breeding season between 1 November and 31 March unless as part of a coordinated tour or ecotourism activity.

Methods to prohibit access will be investigated during detailed design phases of the development. Control of access to these areas will be achieved through methods such as public education, signage, regular patrols of the beaches, creation of fomaliased parking areas and walk trails, and use of strategically placed bollards and fencing.

Vessel Strikes

The potential for injuries or deaths due to boat speed is considered relatively low. The greatest potential for impacts is by larger boats accessing areas outside the reef and which can reach greater speeds. All visitors and tour operators using boats from the development site will be required to comply with a Environmental Code of conduct prepared for the area. This will specify areas where boats are permitted and maximum boat speeds.

Limiting boat speeds will enable greater time for turtles to evade boats as they approach. The increased regulatory presence of CALM and Fisheries officers will enable enforcement of the Environmental Code.

Ecotourism

Tour operators such as whale watching tours and whale shark interactions within the area are largely controlled through licensing requirement of CALM. A code of conduct will however, be developed as part of CCMD, in liaison with CALM, for tour companies operating out of the development area. The code will outline guidelines for operation including access, vehicle speeds, and activities.

It is anticipated that the potential greatest impact will be during nesting and hatching season between November and March. Tour operators may undertake night searches to locate nesting turtles or watch hatchlings emerge. The use of vehicles and lights including torches, and general noise and disturbance during these activities may disrupt nesting and disorientate hatchlings. Activities and visitor groups will need to coordinated and managed appropriately to avoid significant disturbance of turtle nesting.

Developers of CCMD have no direct control or management responsibility of the neighbouring areas such as Cardabia station but will work in close liaison with the

Baiyungu Aboriginal Corporation in relation to ecotourism opportunities, access arrangements and night searches and interactions with turtles. The developers of CCMD will appoint a person dedicated to turtle management within the area who will, in consultation with CALM, liaise with tour organisers and visitor groups.

Indigenous Hunting

Developer of CCMD will liaise closely with the Baiyungu Aboriginal Corporation, the leaseholders of Cardabia station, to encourage only controlled gathering of turtle eggs and hunting of marine turtles.

Public Education

An Environmental Code will be prepared for the CCMD. The code will provide guidelines for various activities for visitors, residents and tour operators. The guidelines will range from topics such as boat usage and speed, use of 4WD vehicles, interactions with marine life and habitat including whales, dugongs, turtles, seagrass and coral, and beach usage. The code will include aspects such as litter disposal and pollution to prevent fauna such as turtles suffering injuries or being killed as a result of rubbish or marine debris.

Additional to the code, information will be made available to visitors and residents of the development regarding the environmental values and characteristics of the area and the issues and impacts associated with conserving these values. It is anticipated that the information will be disseminated though a variety of means such signage, information leaflets, visitor centre, short videos and staff at the development.

Turtle Management Officer

CCMD plans to appoint a dedicated person to oversee turtle management during the nesting season. The person will be present at the site between 1 November and 31 March each year.

Duties of the appointed person are proposed to include:

- ⇨ Coordinate fox control
- ⇨ Control beach access
- ⇨ Coordinate all searches for nesting turtles and emerging hatchlings
- ⇨ Liaise with visitors and tour operators
- ⇨ Identify opportunities for, and undertake, public education
- ⇨ Liaise with Baiyungu Aboriginal people
- ⇨ Locate all nests each morning
- ⇨ Record location, mark and provide protection for nests
- ⇨ Coordinate collection of tagging and monitoring data
- ⇨ Provide CALM with statistical data
- ⇨ Record incidences of turtle deaths, injuries or disturbance
- ⇨ Identify potential issues or impacts, and take action to notify relevant parties such as CALM and CCMD managers, as necessary.

The person appointed will be experienced in working with turtles or will undertake some training to recognise species and tracks and located nests.

Much of the activities to be undertaken by the appointed officer will be undertaken on beaches outside the boundary of the CCMD area. Close liaison and support of CALM and Baiyungu Aboriginal Corporation will be required in order for the officer to effectively perform the duties outlined above. CALM has previously indicated support in relation to the appointment of a turtle management officer (D. Myers, CALM, pers. comm., February 2001). The Baiyungu Aboriginal Corporation has indicated willingness for members of the Baiyungu community to be trained to undertake the turtle management role (see attached letter).

Protection of the turtle nests will involve identification of nest sites and recording of their location during the nesting season, which occur between about November and March each year. This will involve patrols of the beaches early each morning, before tracks disappear from wind or tidal action, to identify nests. Locations will also be marked at night during coordinated activities on the beach.

Each of the nests will be clearly marked and protected using material such as timber slats and/or plastic mesh. This will also assist in preventing turtles inadvertently destroying other nests as they excavate a body hole and egg chamber. Where turtles choose to lay eggs in locations that are closer to the development or disturbance, greater protection of the nests may be required. The nests will be monitored routinely until the eggs have hatched.

Volunteers can have an important role in monitoring populations and assisting conservation efforts. Residents of the development and members of the Baiyungu Aboriginal community may be enlisted to provide additional support to the nominated officer in monitoring nesting and hatching, and liaising with tour operators or leading ecotourism visits. The volunteers will need to be coordinated by the Turtle Management Officer with assistance from CALM.

References

Lutz, P.L. (1997). *The Biology of Sea Turtles.* CRC Press, Inc. United States of America.

APPENDIX 9

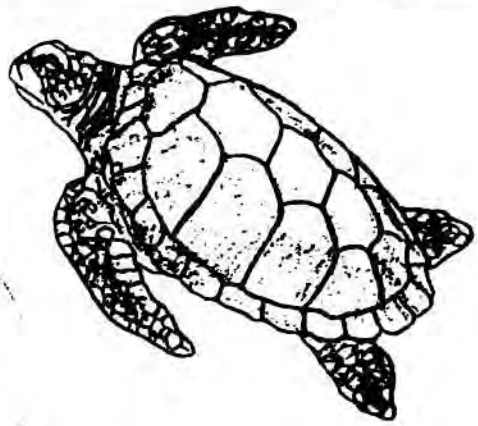
CORRESPONDENCE FOR THE BAIYUNGU PEOPLE PROVIDING AN UNDERTAKING TO ASSIST IN TURTLE AND CETACEAN MANAGEMENT

20057/FED

Baiyungu Aboriginal Corporation

Phone: (08) 9941 3814
Fax: (08) 9941 3814
email:

PO Box 180, Carnarvon, WA, 6701



ATA Environmental
21 Howard Street
PERTH WA 6000

RECE[illegible]ED

Attention: Mr Henk VanDer Wiele

Dear Sir

TURTLE MANAGEMENT - BATEMAN BAY

We wish to advise you that the Baiyungu people are the traditional owners of the land and sea in the Bateman Bay / Coral Bay area and the Baiyungu Aboriginal Corporation in lessee of Cardabia Pastoral Station.

The Gnulli Claimants, representing the Baiyungu People, and the Baiyungu Aboriginal Corporation have signed a Native Title Agreement with Coral Coast Marina Development Pty Ltd (CCMD) pertaining to development of the Coral Coast Resort at Mauds Landing.

This Agreement provides significant long term employment, training and business development opportunities for the Baiyungu People.

In particular, it includes development of cultural and environmental tourism opportunities based at Cardabia Pastoral Station.

Of significant interest to Environment Australia is that the Baiyungu People will be provided with the necessary support to manage visitors and control access along the Bateman Bay shore and to monitor and manage the turtle population in this area.

To date, turtle monitoring and management has been carried out solely through the voluntary efforts of Mr Peter Mack.

Through the resources to be provided by (CCMD), we will have young people trained by Mr Mack and CALM and employed in long term management of the turtle population, commencing in the near future, with the assistance of CALM, a program of baiting on Cardabia Station to reduce the threat by foxes and feral animals.

We believe that the development of Coral Coast Resort is essential to provide the proper resources for environmental management of our land and sea, which to date has been sadly neglected by under funded Government Agencies.

Yours Faithfully

Mary Franklin
For Baiyungu Aboriginal Corporation

3 April 2001

APPENDIX 10

CORAL COAST RESORT QUALITATIVE RISK ASSESSMENT

CORAL COAST RESORT QUALITATIVE RISK ASSESSMENT

Prepared for

Coral Coast Marina Development Pty Ltd

Det Norske Veritas

(DNV Project Number 21310103, August 2001)

Client:	Coral Coast Marina Development Pty Ltd	**Client Contract No:** 21310103
Title of Report:	Coral Coast Resort Qualitative Risk Assessment.	
Indexing Terms:	Coral Coast Resort, Risk Assessment	
Summary:	To determine the level of risk to human life and the environment at the proposed Coral Coast Resort.	
Work Carried Out By:	Stephanie de Grauw, Leonardo Santana & Stephen Robertson.	

DNV Project No.	**Prepared by:**	**Approved by:**
21310103	S.A. de Grauw	S.J. Robertson

Document Revision Record

Rev No	Issue Date	Reason for Issue	Prepared by	Approved by
0	02 Aug 01	Draft issued for comment.	SDG	SJR
1	09 Aug 01	Final issue.	SDG	SJR

Det Norske Veritas
Queensgate Centre
8 William Street
Fremantle WA 6160
Tel. +61 8 9239 7666
http://www.dnv.com/

CONTENTS

EXECUTIVE SUMMARY

1. INTRODUCTION 1
   - 1.1 Background 1
   - 1.2 Objectives 1
   - 1.3 Scope 1
   - 1.4 Abbreviations 1
2. METHODOLOGY 2
   - 2.1 Risk Management AS/NZS 4360:1999 2
   - 2.2 Relative Risk Ranking 2
   - 2.3 Site Visit 6
   - 2.4 Sources of Data and Associated Documentation 6
3. ASSUMPTIONS 8
   - 3.1 Proposed Health, Safety & Environmental Management Systems 8
4. RESULTS 10
5. DISCUSSION OF RESULTS 12
   - 5.1 Police and Traffic Control – Public Roads & Caravan Parks – Vehicle/Pedestrian Collisions 12
   - 5.2 Cyclones 12
     - 5.2.1 Damage to Buildings and Infrastructure 13
     - 5.2.2 Damage to Maritime 13
     - 5.2.3 Storm Surge (Ocean Flooding) 14
   - 5.3 Coral Bay Airstrip 14
     - 5.3.1 Obstacles/Collision 14
     - 5.3.2 Flooding 14
     - 5.3.3 Fire/Explosion, Fuel Contamination & Soil Contamination 15
   - 5.4 Public Accommodation (Hotels/Backpackers) - Fire/Explosion 15
   - 5.5 Staff Accommodation / Caravan Parks – Fire/Explosion 15
   - 5.6 Beaches / Boat Channels 16
     - 5.6.1 Collision Between Swimmers/Snorkellers and Marine Traffic 16
     - 5.6.2 Exposed Beach Moorings, Chains and Ropes 16
     - 5.6.3 Sharks 17
     - 5.6.4 Damage to the Coral Reef by Commercial, Recreational and Fishing Boats 17
   - 5.7 Sewage Effluent into Coral Bay – Health Effects & Environmental Impact 17
   - 5.8 Landfill – Ground and Water Pollution 18
6. CONCLUSION 19

7. REFERENCES 20

APPENDIX I: RISK RANKING TABLE

EXECUTIVE SUMMARY

Coral Bay is a small coastal town located approximately 140 kilometres south of Exmouth and adjoins the Ningaloo Marine Park. Coral Bay exists mainly to service commercial, recreation and tourism activities such as coral viewing, fishing, snorkelling, diving and whale watching.

Coral Coast Marina Development Pty Ltd (CCMD) proposes to construct a resort – Coral Coast Resort (CCR) at Mauds Landing north of the existing Coral Bay settlement. Det Norske Veritas (DNV) have been engaged by CCMD to undertake a Qualitative Risk Assessment of the proposed Coral Coast Resort to determine the level of risk to human life and the environment.

The hazardous events associated with the proposed Coral Coast Resort facilities have been identified and then ranked according to the risk to human life, and where applicable, the environment.

The significant hazards identified by the risk assessment are:

Human Life Hazards:	**Environmental Hazards:**
• Vehicle/pedestrian collisions on public roads.	• Cyclone damage to maritime.
• Obstacles/collision at the airstrip.	• Ground & water pollution due to landfill.
• Cyclone damage to buildings, infrastructure and maritime.	• Environmental impact due to sewage.
• Storm surge (ocean flooding).	• Storm surge (ocean flooding)
• Fire/explosion within public accommodation (hotels/backpackers).	
• Fire/explosion within staff accommodation / caravan parks.	
• Vehicle/pedestrian collisions in caravan parks.	
• Flooding of the airstrip.	
• Fire/explosion at the airstrip.	

The Risk Assessment has identified a number of areas of risk within the proposed Coral Coast Resort. It is recommended that the risks associated with the above mentioned hazards be reviewed by all relevant parties involved to ensure that the likelihood is reduced and procedures are put in place to reduce or control the consequences of such events.

CCMD's commitment to establish Health, Safety, Quality and Environmental Management systems for Coral Coast Resort, which can be certified to International standards, is supported as it demonstrates management commitment to a safe and environmentally sustainable development.

1. INTRODUCTION

1.1 Background

Coral Bay is a small coastal town located approximately 140 kilometres south of Exmouth and adjoins the Ningaloo Marine Park. Coral Bay exists mainly to service commercial, recreation and tourism activities such as coral viewing, fishing, snorkelling, diving and whale watching.

Coral Coast Marina Development Pty Ltd (CCMD) proposes to construct a resort – Coral Coast Resort (CCR) at Mauds Landing north of the existing Coral Bay settlement.

This document presents the Qualitative Risk Assessment of the proposed Coral Coast Resort.

1.2 Objectives

The objective of this study is to determine the level of risk to human life and the environment at the proposed Coral Coast Resort for identified hazardous scenarios, i.e:

- Airstrip operations.
- Severe weather conditions, e.g. cyclones, storm surge.
- Fire/explosion in public and staff accommodation and recreational activity areas.
- Traffic incidents.
- Tourist and other marine activities on the coral reef.
- Services, e.g. sewage, landfill, dangerous goods storage.

The level of risk will be determined qualitatively and where environmental hazards associated with the above hazards are identified, the level of risk for each hazard will be assessed.

1.3 Scope

The boundary of this study is the proposed Coral Coast Resort at Mauds Landing.

1.4 Abbreviations

AHD	Australian Height Datum
CALM	Conservation and Land Management
CASA	Commercial Air Safety Authority
CCMD	Coral Coast Marina Development Pty Ltd
CCR	Coral Coast Resort
DNV	Det Norske Veritas

2. METHODOLOGY

Public risk and safety was assessed using the Australian/New Zealand Standard AS/NZS 4360: 1999 "Risk Management". Terms and categorisations used in this document are the same as those in AS/NZS 4360.

2.1 Risk Management AS/NZS 4360:1999

The management of risk is defined by AS/NZS 4360 as an iterative process consisting of well defined steps which, when taken in sequence, support better decision making by contributing a greater insight into risks and their impacts. The risk management process can be applied to any situation where an undesired or unexpected outcome could be significant or where opportunities are identified.

In general, risk management may be seen as a multifaceted process with appropriate aspects best being carried out by a multidisciplinary team.

The elements of risk management considered during this project include:

- Identification of the risks for the proposed Coral Coast Resort facilities; what, why and how events can arise as a basis for further analysis.
- Analysis of the risks; analysis of risks in terms of likelihood and consequence in the context of existing and proposed controls.
- Assessment and prioritisation of the risks; risks are ranked to identify management priorities.

2.2 Relative Risk Ranking

Risk is usually considered as a function of likelihood (frequency of event) and consequence (severity).

Relative ranking is a qualitative evaluation of relative criticality. This should not be confused with issues relating to acceptability of risk. Evaluation of acceptability of risk is outside the scope of this report. Relative ranking assists with the prioritisation of activities to reduce potential adverse risk impacts.

The relative ranking of events identified in each subdivision was determined as the product of the likelihood and consequence.

The following categories have been adopted to allow the relative ranking of the identified risks to be determined.

TABLE 2.1: LIKELIHOOD CATEGORIES FOR RISK ASSESSMENT

CATEGORY		LIKELIHOOD
SCORE	RATING	
1	Rare	Event may occur but only under exceptional circumstances. Occurs once every 1,000 – 10,000 years
2	Unlikely	Event could occur at some time. Occurs once every 100 – 1,000 years.
3	Possible	Event should occur at some time. Occurs once every 10 – 100 years.
4	Likely	Event will probably occur in most circumstances. Event does occur, has a history, occurs once every 1 – 10 years.
5	Almost Certain	Event expected to occur in most circumstances. High frequency of occurrence – occurs more than once per year.

TABLE 2.2: CONSEQUENCE CATEGORIES FOR RISK ASSESSMENT

LEVEL		HUMAN LIFE	ENVIRONMENT
SCORE	RATING		
5	Catastrophic	Multiple fatalities or significant irreversible human health effects to >50 persons.	Catastrophic, long term environmental harm.
4	Major	Single fatality and/or severe irreversible disability or impairment to one or more persons.	Major release of pollutants. Significant, long term environmental harm.
3	Moderate	Irreversible disability or impairment to one or more persons.	Significant release of pollutants. Measurable environmental harm, with mid-term recovery.
2	Minor	Injuries requiring medical treatment. Reversible disability/impairment.	Transient release of pollutants. Minor/transient environmental harm. Required to inform EPA/other Environmental Regulators.
1	Insignificant	Low level short-term inconvenience or symptoms. No injuries or medical treatment.	Brief transient pollution with no environmental harm. Not required to inform EPA/other Environmental Regulators.

Consequences are divided into the categories of human life and environment; whichever may be applicable to the hazardous event.

When comparing the values in the risk matrix at the extremes, a value of "25" in the risk matrix (refer to Table 2.3) indicates a hazardous event that is expected to occur in most circumstances and that has potentially catastrophic consequences. A value of "1" in the risk matrix indicates a hazardous event that may occur but only under exceptional circumstances and has potentially insignificant consequences.

In other cases a value of "9" in the risk matrix indicates that the hazardous event should occur at some time but have moderate consequences. A value of "16" in the risk matrix indicates a hazardous event that will probably occur in most circumstances with potentially major consequences.

The hazards identified for the proposed Coral Coast Resort have been assessed for likelihood and consequence with consideration given to the identified controls that are included in the Coral Coast Resort proposal. This information has been tabulated in worksheets consisting of the hazard number, hazard description, possible consequences, the existing or proposed controls, comments, and the relative risk ranking results. These tables are documented in Appendix I.

It should be noted that the levels of consequence and frequency are broad and therefore the level of risk determined is broadly based. For example, the consequence level for multiple fatalities is the same for 2 or 100 fatalities.

A broad based risk assessment is appropriate at the early stages of a project so as to identify those hazardous events that warrant detailed analysis and risk reduction considerations.

TABLE 2.3: RISK RANKING MATRIX

LIKELIHOOD / CONSEQUENCE	RARE (1)	UNLIKELY (2)	POSSIBLE (3)	LIKELY (4)	ALMOST CERTAIN (5)
INSIGNIFICANT (1)	1	2	3	4	5
MINOR (2)	2	4	6	8	10
MODERATE (3)	3	6	9	12	15
MAJOR (4)	4	8	12	16	20
CATASTROPHIC (5)	5	10	15	20	25

2.3 Site Visit

In order to determine the extent of the hazardous events associated with the proposed Coral Coast Resort, DNV undertook site visits on 14 May to 16 May 2001, 30 and 31 July and 1 August 2001. The site visit consisted of interviewing key personnel, residents, inspection of various buildings, services and activities within Coral Bay and specifically:

- Exmouth Police Station
- CALM (Conservation and Land Management)
- Commercial/Recreational Vessel Operators
- Bayview Coral Bay Caravan Park and Peoples Park Caravan Village
- Bayview Backpackers
- Airstrip
- Landfill Site
- Service Station
- Filtration evaporation ponds
- Power Station
- Residential Housing Estate (Lot 46 and 52)
- Ningaloo Reef Resort Hotel
- Bills Bay
- Coral Bay Shopping Centre
- Mauds Landing
- Proposed Services Area

2.4 Sources of Data and Associated Documentation

The following information has been reviewed in the assessment:

- Structure Plan Coral Coast Resort Mauds Landing (Reference 1).
- Coral Coast Resort Public Environmental Review Documents (References 2 and 3).
- Saleeba Adams Architects risk issues associated with Category 5 cyclones (Reference 4).
- Pro Micro Pty Ltd Microbiological Water Report (Reference 5).
- Caravan Parks and Camping Grounds Regulations (Reference 6).
- MP Rogers and Associates Pty Ltd- Design Parameters and Management documentation (Reference 7).

- Ningaloo News articles (Reference 8).
- Gascoyne-Murchison Climatic Survey, Bureau of Meteorology (Reference 9).
- Extract from Gascoyne Coast Regional Strategy (Reference 10).
- Photographs of Coral Bay.
- AS/NZS 4360:1999 - Risk Management (Reference 11).

3. ASSUMPTIONS

In determining the level of risk for each identified hazard, the following assumptions were made.

- All commercial, community and domestic buildings within Coral Coast Resort will be designed to withstand Category 5 cyclones in the Region.
- The provision of infrastructure facilities will be staffed by appropriate personnel, for example, the police station will be staffed by police officers.
- The CCMD will provide volunteer-based emergency services, such as fire and emergency services, nursing station and first aid post, sea search and rescue.
- The construction of the marina facilities at Coral Coast Resort will result in the majority of boating activities being moved from Bills Bay to the marina.
- The construction of a boat launching facility in the North Bills Bay Sanctuary zone is unlikely due to environmental problems and the impact of breakwater construction.
- The Government will close Bills Bay to all boats except those operating as coral reef viewing boats.
- The inclusion of safe swimming and snorkelling facilities within the marina at Coral Coast Resort will reduce overcrowding at Coral Bay during periods of peak visitor demand.
- CCMD will relocate the existing airstrip and comply with CASA requirements including the nomination of a reporting officer for the relocated airstrip.
- The proposed services area will provide bulk storage for fuels and chemicals in accordance with the requirements of the WA Explosives and Dangerous Goods Regulations.
- A two-man police station will be provided at Coral Coast Resort for law enforcement. An environmental centre will also be provided to accommodate full-time CALM and Fisheries WA officers.
- A landfill site with a site area to provide a minimum 25 years capacity will be established in accordance with the requirements of the Shire and Waste Management WA.

3.1 Proposed Health, Safety & Environmental Management Systems

The derivation of the results is also based on the assumption that controls such as a Safety Management System, a Risk Based Assessment, and an Environmental Management Plan are implemented throughout the life of the Coral Coast Resort.

It is proposed that health, safety and environmental management plans for the Coral Coast Resort will comply with OHSAS 18001 and ISO 14001. This system will facilitate the management of the Occupational Health, Safety and Environmental risks associated with the business of Coral Coast Resort and include the organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the proposed Occupational Health, Safety and Environmental policy.

In order to eliminate, reduce, control and manage the identified risks and possible impacts the HSE management system to be developed will:

- Establish and maintain procedures for the ongoing identification of hazards and impacts, the assessment of risks, and the implementation of necessary control measures. These include design and construction, the operational activities of all personnel having access to the workplace including subcontractors and visitors, and facilities at Coral Coast Resort whether provided by CCMD or others.
- Establish and maintain a procedure for identifying and accessing the legal and other Occupational Health, Safety and Environmental requirements that are applicable to the HSE management system for Coral Coast Resort and keep this information up to date.
- Establish Occupational Health, Safety and Environmental objectives.
- Maintain an Occupational Health, Safety and Environmental programme(s) for achieving its objectives.
- Provide the structure and resources with roles, responsibilities and authorities of personnel who will manage, perform and verify activities having an effect on Occupational Health, Safety and the Environment.
- Provide training and awareness of all risks and impacts.
- Ensure that procedures are established for the dissemination of Health, Safety and Environmental information to employees and other interested parties.
- Establish and maintain procedures for controlling all documents and data required by the standards.
- Establish and maintain plans and procedures to identify the potential for and responses to incidents and emergency situations, and for preventing and mitigating the likely illness, injury or environmental impact that may be associated with them. For example, specific emergency and response plans will be established for incidents such as cyclones, fires, floods, and disconnection of services.
- Review plans and procedures after the occurrence of incidents or emergencies and periodically test procedures where practicable.
- Establish and maintain procedures to monitor and measure HSE performance on a regular basis.
- Provide procedures for the handling and investigation of incidents and accidents including corrective and preventive actions.
- Establish procedures for the identification, maintenance and disposition of HSE records and the results of audits and reviews.
- Develop an audit program and procedures for periodic HSE management system audits to be carried out.
- Review the HSE management system to ensure its continuing stability, adequacy and effectiveness and commitment to continual improvement at appropriate intervals.

4. RESULTS

The following tables summarise the risk ranking results for risk to human life and the environment for the proposed Coral Coast Resort. These results are taken from the detailed worksheets provided in Appendix I. Table 4.1 summarises the risk ranking results for human life and Table 4.2 summarises the risk ranking results for the environment.

TABLE 4.1: SUMMARY OF RISK RANKING RESULTS FOR HUMAN LIFE

HAZARD	Proposed Coral Coast Resort Risk Ranking
Police & Traffic Controls- Public Roads – Vehicle/Pedestrian Collisions	12
Airstrip – Obstacles/Collision	10
Cyclones – Damage to Maritime	9
Cyclones – Damage to Infrastructure	8
Cyclones – Damage to Buildings	8
Cyclones - Storm Surge (Ocean Flooding)	8
Public Accommodation (Hotels/Backpackers) - Fire/Explosion	8
Staff Accommodation/Caravan Parks - Fire/Explosion	8
Police & Traffic Controls - Caravan Park - Vehicle/Pedestrian Collisions	8
Airstrip - Flooding	8
Airstrip – Fire/Explosion	6
Airstrip - Fuel Contamination	5
Beaches / Boat Channels – Collision Between Swimmers/Snorkellers & Marine Traffic	4
Beaches / Boat Channels – Sharks	4
Sewage Effluent - Health Effects	3
Beaches / Boat Channels – Exposed beach Moorings, Chains & Ropes	2

TABLE 4.2: SUMMARY OF RISK RANKING RESULTS FOR ENVIRONMENT

HAZARD	Proposed Coral Coast Resort Risk Ranking
Cyclones – Damage to Maritime	9
Landfill - Ground & Water Pollution	8
Sewage Effluent – Environmental Impact	8
Cyclones - Storm Surge (Ocean Flooding)	6
Airstrip - Soil Contamination	4
Beaches / Boat Channels – Damage to Coral Reef by Commercial, Recreational & Fishing Boats	2

5. DISCUSSION OF RESULTS

The results of the Risk Ranking Tables are reviewed in this section in terms of the hazards associated with the proposed Coral Coast Resort, the proposed control measures and conclusions.

The population of Coral Bay during peak season and the 'off' season is important when determining the number of people exposed to the hazards for the proposed Coral Coast Resort. The daily population of Coral Bay at peak times during school holidays and Easter is approximately 2,500 people (Reference 10). It is estimated that this may be closer to 3,000 people in peak season with approximately 100 permanent residents. Based on an 80% average peak occupancy, Coral Coast Resort has an estimated total population at full development of approximately 2,025 persons, comprising of 1,330 tourists and 695 residents and staff.

5.1 Police and Traffic Control – Public Roads & Caravan Parks – Vehicle/Pedestrian Collisions

There is a potential hazard of vehicle and pedestrian collisions as pedestrians cross the roads within the proposed Coral Coast Resort to access the beach, shopping amenities or commercial operators, the consequences of which could be a single fatality and/or serious injury to one or more persons.

There is currently no police station in close proximity to Coral Bay and police officers from Exmouth visit Coral Bay approximately once per month for a day. In an emergency, the response time by Exmouth Police is approximately one and half-hours.

The proposed CCMD development, if requested by the Government, will provide a two-man police station, with accommodation and lock up, for law enforcement at Coral Coast Resort.

CCMD will provide a number of control measures on the public roads and within the caravan parks at the proposed Coral Coast Resort to reduce the number of vehicle and pedestrian collisions. These are:

- Designated pedestrian footpaths.
- The prohibition of two, three or four wheel motorcycles.
- Speed humps.
- Speed restrictions.
- A dual-use path system.
- A cyclist network.

With the above control measures in place, it is possible that a single fatality and/or serious injury to one or more persons from collision with a vehicle on a public road will occur at some time at the proposed Coral Coast Resort. It is unlikely that a single fatality and/or serious injury to one or more persons from collision with a vehicle in a caravan park will occur at the proposed Coral Coast Resort.

5.2 Cyclones

The North West Cape/Exmouth region is vulnerable to Category 4 and Category 5 cyclones which have winds in excess of 225 km/h. From 1910 to 1997, over 40 cyclones affected the Gascoyne coastline; of these, approximately 25 crossed the coast. Therefore, it can be estimated that on average one cyclone will affect the North West Cape/Exmouth region every 2 to 3 years.

Cyclones have occurred from December to May, although they are most frequent in February and March. The cyclone records show that in the period 1964 to 2000, seven cyclones were greater or equal to a Category 3 cyclone and approached the western side of Coral Bay. This equates to one severe cyclone on an adverse track approximately every 5 years.

In times of heavy rainfall, it is reported that Coral Bay is isolated and the roads to Carnarvon and other areas are cut off by flooding.

5.2.1 Damage to Buildings and Infrastructure

The consequences of a cyclone in the vicinity of the proposed Coral Coast Resort include a single fatality and/or serious injury to one or more persons, damage to roads, power supply, sewage treatment, water supply and vehicles, disintegration of buildings, flying debris, and shattered glass.

CCMD will provide a number of control measures to reduce the risk to human life and damage to buildings and infrastructure in the event of a cyclone at the proposed Coral Coast Resort. These are:

- An underground power supply.
- Assembly areas.
- Formal Emergency and Disaster Recovery plans and procedures.
- Buildings designed to withstand Category 5 cyclones.
- Trained Fire and Emergency services.
- Nursing Station and First Aid Post.

With the above control measures in place, it is unlikely that a single fatality and/or serious injury to one or more persons, damage to buildings or damage to infrastructure will occur at the proposed Coral Coast Resort.

5.2.2 Damage to Maritime

The consequences of a cyclone in the vicinity of the proposed Coral Coast Resort may cause damage to commercial, recreation and fishing boats as well as a single fatality and/or serious injury to one or more persons. Long-term environmental harm to the coral reef may also occur.

CCMD will provide a number of control measures to reduce the risk to human life and damage to maritime and the coral reef in the event of a cyclone. These are:

- Sea Search and Rescue teams.
- The construction of the inland marina with provision of marina facilities for secure anchorage of vessels and cyclone refuge.
- Formal boat ramps to allow boats to be taken out of the water and moved to the services area and tied down in the event of a cyclone.

With the above control measures in place, it is possible that a cyclone may damage maritime, damage the coral reef or cause a serious injury to one or more persons, i.e. the event should occur at some time.

5.2.3 Storm Surge (Ocean Flooding)

Storm surge is potentially a destructive aspect of a tropical cyclone, which is capable of inundating low lying coastal areas. It is experienced as an increase in the tide level and occurs from a combination of low pressure and high winds. In addition to the normal tidal variation, the height of the surge also depends on the cyclone's intensity, the shape of the coastline and sea-bed, the orientation of the coastline and the angle of the cyclone to the shore. The worst conditions arise when the surge peak coincides with high tide.

The consequences of storm surge includes severe flooding, damage to infrastructure, a single fatality and/or serious injury to one or more persons, release of pollutants and environmental harm.

CCMD will provide a number of control measures in the event of a storm surge at the proposed Coral Coast Resort. These are:

- The final finished floor levels will be 6.0m above AHD (Ocean side) and 3.65 m above AHD (lagoon side). This would be above the water levels caused by a cyclone of similar category to Vance (Category 5) in the region.
- A minimum ocean side storm surge development level of 4.7m AHD (Australian Height Datum).
- Design of resort structures and buildings will meet a 1-in-100 year return period storm event with contingencies.
- A new sewage treatment plant, which will alleviate any pollution into the bay.

With the above control measures in place, it is unlikely that severe flooding, damage to infrastructure, a single fatality and/or serious injury to one or more persons, release of pollutants and environmental harm will occur at the proposed Coral Coast Resort.

5.3 Coral Bay Airstrip

The hazardous events that were identified for the airstrip are obstacles/collision, flooding, fuel and soil contamination, and fire/explosion. These hazards will be discussed separately in the sections below.

5.3.1 Obstacles/Collision

The presence of obstacles on the airstrip or significant damage to the airstrip has the potential to damage an incoming or outgoing aircraft causing multiple fatalities.

The existing Coral Bay airstrip is classified as an authorised landing area. CCMD propose to extend or relocate the existing airstrip and take responsibility for insurance, management and maintenance to CASA standards. As a minimum, the front area of the airstrip would be fenced off to limit access to the site.

With the proposed control measures in place, it is unlikely that this event will occur.

5.3.2 Flooding

Flooding of the airstrip has the potential to damage an incoming or outgoing aircraft causing multiple fatalities.

The existing airstrip is situated on a salt pan and a flat terrain that does not allow for rapid evaporation or drainage of rainwater. Currently the pilot of the aircraft assesses the condition of the airstrip from the air before landing. There is no formal control reliance on contacting a specific individual at Coral Bay with regard to weather information provided by the Bureau of Meteorology.

CCMD propose to extend or relocate the existing airstrip and take responsibility for insurance, management and maintenance to CASA standards. If flooding of the airstrip occurs, the airstrip would be closed as per CASA requirements.

With the proposed control measures in place, it is unlikely that this event will occur.

5.3.3 Fire/Explosion, Fuel Contamination & Soil Contamination

Other hazardous events that may occur at the airstrip are fire/explosion, fuel contamination and soil contamination. The consequences of a fire/explosion or fuel contamination (hence an aircraft crash) include multiple fatalities or serious injury to one or more persons. Soil contamination may cause minor environmental harm.

CCMD will provide a number of control measures for the airstrip. These are:

- Extending or relocating the existing airstrip and take responsibility for insurance, management and maintenance to CASA standards.
- Providing approved storage and lock-up facilities for fuels.
- Aircraft fuel to be handled as per the oil company and CASA directives.
- Providing fire fighting and spillage clean-up equipment, signage, and bunding.

With the above control measures in place, it is unlikely that a fire/explosion or soil contamination will occur. It is rare that fuel contamination at the airstrip will occur, i.e. it may occur but only under exceptional circumstances.

5.4 Public Accommodation (Hotels/Backpackers) - Fire/Explosion

There is a risk of a fire/explosion within the public accommodation and recreational activity areas at the proposed Coral Coast Resort with the consequences of a single fatality and/or serious injury to one or more persons. Scenarios where this hazardous event could occur involve gas stoves, electricity, smoking, and general occupancy in these areas.

CCMD will provide a number of control measures for this event. These are:

- A services area with the provision for bulk storage of fuels and chemicals in bunded areas as per relevant Australian Standards and WA Legislation.
- Electrical power protection.
- Equipped and trained volunteer-based emergency services personnel to be provided to assist with fire scenarios.
- Buildings provided with smoke detectors and alarms.

With the above control measures in place, it is unlikely that the event of a fire/explosion within public accommodation and recreational activity areas will occur at the proposed Coral Coast Resort.

5.5 Staff Accommodation / Caravan Parks – Fire/Explosion

There is a risk of a fire/explosion within the staff accommodation/caravan parks at the proposed Coral Coast Resort with the consequences of a single fatality and/or serious injury to one or more persons. Scenarios where this hazardous event could occur involve fuel drums, gas cylinders, barbecues, bush fires, and general occupancy in these areas.

CCMD will provide a number of control measures for the event of a fire/explosion within staff accommodation/caravan parks at the proposed Coral Coast Resort. These are:

- A services area with the provision for bulk storage of fuels and chemicals in bunded areas as per relevant Australian Standards and WA Legislation.
- Equipped and trained volunteer-based emergency services personnel to be provided to assist with fire scenarios.
- Buildings provided with smoke detectors and alarms.

With the above control measures in place, it is unlikely that the event of a fire/explosion within staff accommodation/caravan parks will occur at the proposed Coral Coast Resort.

5.6 Beaches / Boat Channels

The hazardous events that have been determined for the Beach / Boat Channel areas are collisions between swimmers/snorkellers and marine traffic, injuries due to beach moorings, chains and ropes, shark attacks, and damage to the coral reef by commercial/recreational and fishing boats. These hazards will be discussed separately in the sections below.

5.6.1 Collision Between Swimmers/Snorkellers and Marine Traffic

The consequences of a collision between swimmers/snorkellers and marine traffic are a single fatality and/or serious injury to one or more persons.

CCMD will provide a number of control measures at the proposed Coral Coast Resort to reduce the risk associated with swimmers and marine traffic. These are:

- Funding to support a regulatory agency function.
- Construction of an inland marina.
- Inclusion of safe swimming and snorkelling facilities within the marina.

With the above control measures in place, it is rare that a collision between a swimmer/snorkeller and marine traffic will occur, i.e. the event may occur but only under exceptional circumstances.

5.6.2 Exposed Beach Moorings, Chains and Ropes

Beach moorings, chains and ropes can be exposed during low tides, which may pose a danger to people walking along beaches, the consequences of which being minor injuries requiring medical treatment.

CCMD will provide a number of control measures at the proposed Coral Coast Resort to reduce the risk associated with exposed beach moorings, chains and ropes. These are:

- Funding to support a regulatory agency function.
- Construction of an inland marina.
- Inclusion of safe swimming and snorkelling facilities within the marina.

With the above control measures in place, it is rare that a minor injury due to exposed beach moorings, chains and ropes will occur, i.e. the event may occur but only under exceptional circumstances.

5.6.3 Sharks

To date there has been no reported shark attacks in the Coral Bay area. If a shark attack was to occur, the consequences would include a single fatality and/or serious injury to one or more persons.

CCMD will provide the following control measures to prevent shark attacks at the proposed Coral Coast Resort. These include:

- A protected beach with shark nets.
- The construction of an inland marina.
- Inclusion of safe swimming and snorkelling facilities within the marina.
- Awareness programmes on times and where to swim.

With the above control measures in place, it is rare that shark attack will occur, i.e. the event may occur but only under exceptional circumstances.

5.6.4 Damage to the Coral Reef by Commercial, Recreational and Fishing Boats

Minor environmental damage to the coral reef may occur due to anchor drops, the dragging and dropping of objects, or the bottoms of boats dragging over the coral.

CCMD will provide a number of control measures at the proposed Coral Coast Resort to reduce the risk of damage to the coral reef caused by boats. These are:

- Funding to support a regulatory agency function to allow full-time control over the marina and boat launching activities.
- Construction of an inland marina which will be accessed by the existing channel.
- The development of a code of practice for all boats and fishermen.

With the above control measures in place, it is rare that damage to the coral reef by boating activities will occur, i.e. the event may occur but only under exceptional circumstances.

5.7 Sewage Effluent into Coral Bay – Health Effects & Environmental Impact

The overflowing or leaching of effluent into Coral Bay and the Mauds Landing areas may become a health hazard to the users of the beaches and surrounding areas. The health effects associated with sewage effluent polluting the bay include water borne diseases such as typhoid and cholera. Leaching into the bay may also impact on the marine environment due to elevated nutrient levels (phosphorous and nitrogen), causing long term environmental harm.

CCMD will provide a number of control measures to prevent sewage effluent polluting Coral Bay. These are:

- The construction of a sewage treatment plant approximately two kilometres inland of Coral Bay. The plant will provide deep sewage and wastewater treatment to service the Mauds Landing town site.
- A series of groundwater monitoring bores established prior to construction to commence the characterisation of the superficial groundwater quality.
- A shallow groundwater-monitoring program developed prior to construction to establish a baseline. This will continue for 5 years post operation followed by a review.
- The development of contingencies for failures in containment within the services and town site areas.

- A sewage pump-out facility in the marina, which includes the requirement of all boats with onboard sullage tanks, to discharge to the facility.

With the above control measures in place, it is unlikely that sewage effluent will overflow or leach into Coral Bay and the Mauds Landing areas, i.e. the event could occur at some time.

5.8 Landfill – Ground and Water Pollution

The consequences of ground and water pollution due to landfill are leaching and nutrient movement into Coral Bay causing long term environmental harm.

CCMD will provide a number of control measures to reduce the potential environmental damage to Coral Bay caused by landfill. These include:

- A new landfill site with a site area to provide an estimated minimum 25 years' capacity established according to the requirements of the Shire of Carnarvon and Waste Management WA.

With the above control measure in place, it is unlikely that ground and water pollution will occur due to landfill.

6. CONCLUSION

The review of the hazards associated with the proposed Coral Coast Resort facilities has established that risks exist and are addressed by preventative and mitigative risk reduction control measures incorporated in the proposal.

The Risk Assessment has identified a number of areas of risk within the proposed Coral Coast Resort. It is recommended that the risks associated with the above mentioned hazards be reviewed by all relevant parties involved to ensure the likelihood is reduced and procedures put in place to reduce or control the consequences of such events.

CCMD is committed to ensuring the proposed Coral Coast Resort meets international standards for health, safety and the environment and has engaged DNV to advise on management systems. The design philosophies which have been adopted for Coral Coast Resort are in accordance with good practice and management systems can be implemented which would ensure that Coral Coast Resort complies with international benchmarks, such as OHSAS 18001 and ISO 14001.

7. REFERENCES

1. *"Structure Plan Coral Coast Resort Mauds Landing, Executive Summary"*, October 2000.
2. *"Coral Coast Resort Public Environmental Review Document Volume 1"*, November 2000.
3. *"Coral Coast Resort Public Environmental Review Appendices Volume 11"*, November 2000.
4. *"Saleeba Adams Architects"*, 2 May 2001-05-31.
5. Pro Micro Pty Ltd, *"Microbiological Water Report"*, 26 February 2001-05-31.
6. Government of Western Australia, *"Caravan Parks and Camping Grounds Regulations 1997"*, WA, 1997.
7. MP Rogers and Associates Pty Ltd, *"Design Parameters and Management"*, 9 March 2001-05-31.
8. Ningaloo News articles, April and May 2001.
9. Bureau of Meteorology, Western Australia, *"Gascoyne - Murchison Climatic Survey"*, October 1998.
10. Extract from Gascoyne Coast Regional Strategy, March 1996.
11. Standards Association of Australia, *"AS/NZS 4360:1999 - Risk Management"*, NSW, 1999.

APPENDIX I
RISK RANKING TABLES

PROPOSED CORAL COAST RESORT

Area: Public Accommodation (Hotel/Backpackers)

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Fire/Explosion Hazard.	Single fatality and/or serious injury to one or more persons.	• A services area with the provision for bulk storage of fuels and chemicals in bunded areas as per relevant Australian Standards and WA Legislation. • Equipped and trained volunteer-based emergency services personnel to be provided to assist with fire scenarios. • Smoke detectors and alarms fitted to all accommodation and indoor recreational areas.	This will be consistent with housing in metropolitan areas.	2	Human Life 4	**8**

PROPOSED CORAL COAST RESORT

Area: Cyclones

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Damage to infrastructure.	Single fatality and/or serious injury to one or more persons. Damage roads, power supply, sewage treatment, water supply, vehicles etc.	• Power supply buried underground. • Assembly areas. • Formal Emergency and Disaster Recovery plans and procedures will be developed.	It is proposed that volunteer-based emergency services will be provided to the resort comprising of : • Fire and Emergency services. • Nursing Station and First Aid Post. • Sea Search and Rescue.	2	Human Life 4	**8**
2	Damage to buildings.	Single fatality and/or serious injury to one or more persons. Disintegration of buildings. Flying debris. Shattered glass increasing risk to occupants.	• Buildings designed to withstand Category 5 cyclones.		2	Human Life 4	**8**

PROPOSED CORAL COAST RESORT

Area: Cyclones

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
3	Damage to Maritime.	Serious injury to one or more persons. Measurable environmental harm, with mid-term recovery.	• Construction of an inland marina, designed for boats to moor in the area. This will provide cyclone refuge. • Formal boat ramps to allow boats to be taken out of the water and moved to the industrial area and tied down.	The experiences of Exmouth have been taken into consideration.	3 3	Human Life 3 Environment 3	**9** **9**

PROPOSED CORAL COAST RESORT

Area: Cyclones

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
4	Storm Surge (Ocean flooding).	Severe flooding, single fatality and/or serious injury to one or more persons. Damage to infrastructure. Significant release of pollutants. Measurable environmental harm.	• Power supply buried underground. • Assembly areas. • Formal Emergency and Disaster Recovery plans and procedures will be developed. • The new sewage treatment plant will alleviate any pollution into the bay.	The final finished floor levels will be 6.0m above AHD (Ocean side) and 3.65 m above AHD (lagoon side). This would be above the water levels caused by a direct hit on Coral Bay by a cyclone similar to Vance. Design of resort structures and buildings will meet a 1-in-100 year return period storm events with contingencies.	2 2	Human Life 4 Environment 3	**8** **6**

PROPOSED CORAL COAST RESORT

Area: Staff Accommodation / Caravan Parks

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Fire/Explosion	Single fatality and/or serious injury to one or more persons.	• Light Industrial area to be developed and will provide storage and bunded facilities for fuels and chemicals. • Well equipped and trained emergency services and facilities to be provided which can assist with fire hazard. • Smoke detectors and alarms fitted to all accommodation and indoor recreational areas.	This will be consistent with housing in metropolitan areas.	2	Human Life 4	**8**

PROPOSED CORAL COAST RESORT

Area: Police and Traffic Controls – Public Roads

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Vehicle/pedestrian collisions.	Single fatality and/or serious injury to one or more persons.	• CCMD will provide a two-man police station, accommodation and lockup.	Continuous law enforcement due to permanent police presence.	3	Human Life 4	**12**

PROPOSED CORAL COAST RESORT

Area: Police and Traffic Controls - Caravan Parks

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
2	Vehicle/pedestrian collisions.	Single fatality and/or serious injury to one or more persons.	• Designated pedestrian footpaths. • Prohibition of 2,3 or 4 wheel motorcycles. • Speed humps. • Speed Restrictions. • Dual-use path system. • Cyclist network.		2	Human Life 4	**8**

PROPOSED CORAL COAST RESORT

Area: Coral Bay Airstrip

Date: 14/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Obstacles on the airstrip, such as waste material, kangaroos, goats, and emus. Collision with obstacles.	Damage to aircraft and multiple passenger fatalities. Damage to the airstrip by wildlife and humans (vandalism).	• Relocation of the existing airstrip and provision of safe access to the homestead and controlled public access to the airstrip, however the airstrip will not be fenced. (Interim measure until a new airport is established.) • Air strip to be extended or relocated with advice from Connell Wagner and to the approval of the Baiyungu Aboriginal Corporation and Cardabia Pastoral Station. • CCMD will comply with CASA requirements including the function of reporting officer.	Alternatively, the strip could be nominated as a public airstrip, such as an ALA, registered airstrip or licensed airstrip. CCMD would assume responsibility for insurance, management and maintenance to CASA standards. Regional Airport Development of Transport Scheme (RADS) may have funding available to fence the relocated airstrip.	2	Human Life 5	**10**

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
			• Third parties will be allowed to use the Cardabia airstrip under practices to be established by BAC, CCMD and Connell Wagner, which will include safety, access, refuelling and cleanliness. • No structures or hangars will be permitted. • Subject to advise from Conell Wagner and Transport, the strip could be classified as a private strip, with a third party users agreeing to conditions of use to be set by BAC and CCMD.				

PROPOSED CORAL COAST RESORT

Area: Coral Bay Airstrip

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
2	Flooding.	Damage to aircraft and a single fatality and/or serious injury to one or more occupants.	• Air strip will be extended or relocated with advice from Connell Wagner and to the approval of the Baiyungu Aboriginal Corporation and Cardabia Pastoral Station. • Third parties will be allowed to use the Cardabia airstrip under practices to be established by BAC, CCMD and Connell Wagner, which will include safety, access, refuelling and cleanliness.	Should flooding occur the airstrip would be closed as per CASA requirements.	2	Human Life 4	**8**

PROPOSED CORAL COAST RESORT

Area: Coral Bay Airstrip

Date: 14/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
3	Fire/explosion	Serious injury to one or more persons. Damage to property.	• Fire equipment and signage to be provided.		2	Human Life 3	**6**
	Fuel Contamination	Jet fuel contamination may lead to an aircraft crash. Potential for multiple fatalities.	• Lock up facilities to be provided. • Aircraft fuel to be handled as per oil company & CASA's directives.		1	Human Life 5	**5**
	Soil Contamination	Minor environmental harm.	• Bunding and approved storage facilities to be provided (spill emergency kit).		2	Environment 2	**4**

PROPOSED CORAL COAST RESORT

Area: Beaches / Boat Channels

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Collision between swimmers/snorkellers and marine traffic.	Single fatality and/or serious injury to one or more persons.	• Funding to support regulatory agency function. • Construction of an inland marina. • Inclusion of a constructed artificial reef for swimming/snorkelling.	Opportunity for the relevant authorities, notably the Department of Conservation and Land Management (CALM) and Fisheries WA, to develop and institute more effective management controls as a consequence of a permanent on site presence.	1	Human Life 4	4

PROPOSED CORAL COAST RESORT

Area: Beaches / Boat Channels

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
2	Exposed beach moorings, chains, and ropes.	Minor injuries requiring medical treatment.	• Funding to support regulatory agency function. • Construction of an inland marina. • Inclusion of a constructed artificial reef for swimming/snorkelling.		1	Human Life 2	2

PROPOSED CORAL COAST RESORT

Area: Beaches / Boat Channels

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
3	Sharks.	Single fatality and/or serious injury to one or more persons.	• Construction of an inland marina. • Shark nets to be provided in the marina area.	Awareness program on times and where to swim.	1	Human Life 4	**4**

PROPOSED CORAL COAST RESORT

Area: Beaches / Boat Channels

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
4	Damage to coral reef by commercial, recreational and fishing boats.	Minor environmental damage to the coral reef due to anchor drops, dragging and dropping of objects. Vessel damaging coral.	• Construction of an inland marina. • CCMD to allow full-time CALM and Fisheries WA officers with control over the marina and boat launching and a boat for offshore patrols.	CCMD will develop a code of practice for all boats and fishermen.	1	Environment 2	**2**

PROPOSED CORAL COAST RESORT

Area: Sewage Effluent

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Health hazard, pollution of Coral bay due to overflow and leaching of effluent.	Water borne diseases affecting peoples health (Typhoid, cholera).	• A sewage treatment plant will be designed and installed in the services area, in consultation with the Water Corporation and Shire of Carnarvon. • Deep sewage and construction of a waste water treatment plant to service the Mauds Landing townsite.	Lined ponds are proposed and will be sized to allow for total evaporation of all treated effluents. The sewage treatment plant will be 2 km inland of Coral Bay.	1	Human Life 3	3

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
		Leaching into Bills bay, impact on the marine environment elevated nutrient levels (phosphorus, nitrogen). Significant, long term environmental harm.	• A series of groundwater monitoring bores will be established prior to construction commencing to characterise the superficial groundwater quality. • A shallow groundwater-monitoring program will be developed prior to construction and baseline established. • Shallow groundwater monitoring program will continue for 5 years post operation, followed by a review. • Development of contingencies for failures in containment within the services and townsite areas.	A sewage pumpout facility will be provided in the Marina and all boats with onboard sullage tanks will be required to discharge to the facility.	2	Environment 4	**8**

PROPOSED CORAL COAST RESORT

Area: Landfill

Date: 15/05/2001

Hazard No.	Hazard Description	Consequences	Existing/Proposed Controls	Comments	Likelihood Category	Consequence Category	Risk Ranking
1	Ground and water pollution.	Leaching and nutrient movement into Bills bay. Significant, long term environmental harm.	• A landfill site with a site area to provide a minimum 25 years capacity will be established to the requirements of the Shire of Carnarvon and Waste Management WA.		2	Environment 4	**8**