Coastline Management Manual

New South Wales Government

COASTLINE MANAGEMENT MANUAL

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FOREWORD

The Coastline Hazard Policy is but one of a range of Government policies and initiatives relating to the coastal zone. Many of these are outlined in the *NSW Coast: Government Policy.* Decisions regarding the management of coastline hazards must be considered in relation to all these policies and initiatives.

Specifically, the Coastline Hazard Policy introduces a range of planning and structural measures which provide for:

- the establishment of a statewide management system which requires balanced management of the coastline;

- the control the potential for losses in new development through the application of effective planning controls designed to ensure that the development is compatible with the hazards;

- a reduction in the impact of hazards on existing developed areas through the construction of protective works and/or the voluntary purchase of property at equitable prices; and

- the construction of beach improvement works to protect or enhance the recreational amenity of the State's most heavily used beaches and their associated sand dune systems.

In applying the Coastline Hazard Policy, all planning, development and building proposals should be treated on their merits. Social, economic, aesthetic, recreational, and ecological factors need to be considered, as well as coastline hazards. In this way, appropriate development of coastal areas will not be unnecessarily prevented, but potentially inappropriate development will either be excluded from hazardous areas or conditioned to render it compatible with the hazards and its environment.

As part of the implementation of the Policy, this Manual has been prepared to assist those responsible for management of the coastline to reach balanced, merit based decisions. The Manual sets down a management system through which local councils can better manage the coastline in accordance with the Government's requirements and provides information concerning coastal processes, hazards and hazard management measures to those involved with development proposed in proximity to the coastline and to those whose property is threatened by coastal hazards.

Under the Policy, legislation will be introduced to permit rates to be reduced for land that cannot be developed because of its hazard exposure. The Government will also legislate to provide exculpation from liability to councils for decisions and advice provided on the basis of the coastline management principles set down in this Manual.

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SECTION 1 INTRODUCTION

1.1 THE PROBLEM

The coastline of New South Wales is a major element in the geographic, recreational, commercial and ecological fabric of the State. It is an area of unparalleled beauty, characterised by small pocket beaches bounded by rocky headlands in the south, and sweeping beaches of golden sand in the north. Coastal areas are major destinations for local, national and international tourists. More than 80% of the State's population lives and works along the eastern seaboard.

The coastline is under constant attack from the natural forces of wind and waves. In response to these processes, the coastline is ever changing: beaches and sand dunes erode and are rebuilt in response to wave action; sand dunes can migrate inland in response to wind attack; many sections of the coastline are receding and moving inland at significant rates. Man's activities in the coastal zone can exacerbate these processes.

The coastline can be a hazardous area to develop. Coastal properties may be at risk from beach erosion, shoreline recession, coastal inundation, sand drift and other hazards.

There are increasing pressures to develop coastal areas for tourism, residential, commercial, and recreational purposes. Not only is the pressure for coastal developments continuing, but the nature of such developments is changing. Modest weekend cottages are giving way to substantial brick homes and there is a growing trend towards the development of major coastal resorts that provide total holiday packages.

Coastline hazards are not a minor problem. Beach erosion accompanying storms of the early 1970's caused the loss of 20 houses and other assets valued at many millions of dollars along the central and north coasts. In addition, coastal communities suffered significant social and commercial disruption.

Studies in 1985 indicated that in New South Wales property worth $500 million could be exposed to coastline hazards during the next 30 to 50 years. The potential damage value, already greatly in excess of the 1985 figure because of property value increases, may escalate rapidly if appropriate planning and development control measures are not instituted. Moreover, the detrimental impacts of coastline hazards could be intensified if the global climate changes postulated to accompany the greenhouse effect eventuate.

New South Wales can ill afford the social and financial disruption associated with placing this level of development at unnecessary risk.

1.2 GOVERNMENT INITIATIVES

The coastline of New South Wales is used by various groups in society for a variety of different purposes. Aesthetic, recreational and ecological attributes are important factors in coastal amenity and use, as is the growing role of the tourist industry in economic and employment issues.

While management of the coastal area is primarily the responsibility of local councils, a number of Government agencies are responsible for policies relating to the coast and its environs.

In 1973, concern with the development and use of coastal lands led the New South Wales Government to introduce the Coastal Lands Protection Scheme. Under this scheme, 13,000ha of environmentally important coastal lands have been put into public ownership and in addition some 14,500ha of private coastal land is now subject to strict planning controls.

In 1975, the Government established the Beach Improvement Program. Under this program, funds were provided to assist councils to protect and enhance heavily used recreational beaches and their associated sand dune systems. Over the past 14 years, some $20 million has been spent on such work at popular beaches adjacent to centres of urban population.

In 1979 two legislative initiatives relevant to coastal management were enacted.

- The Coastal Protection Act established the Coastal Council as an advisory body to the Minister for Planning and Environment on coastal management issues and as a means of facilitating coordination of government agencies with functions in the coastal area. It also provided a means by which the Minister for Public Works could, if deemed necessary, exercise a concurrence role in respect of coastal development decisions.

- The Environmental Planning and Assessment Act established a broad framework for statutory planning and environmental assessment in NSW. The procedures suggested in this manual are designed to be consistent with the requirements of this Act.

In 1988 the Government adopted the Coastline Hazard Policy. The objective of the policy is to reduce the impact of coastal hazards on individual owners and occupiers of coastal lands, thus reducing public and private losses and to ensure that future development is compatible with the hazards. The Policy will be implemented through the Coastline Hazard Program (incorporating the former Beach Improvement Program) and by the production of this Manual, which will assist in the task of managing the coastline.

In 1990, the Government released the *NSW Coast: Government Policy* addressing a range of issues including coastline hazard management.

1.3 THE NEED FOR AN INTEGRATED PLANNING APPROACH

Works can be built to protect existing developments at risk. However, it has been recognised for some time that future increases in coastal damage can only be contained by ensuring that new developments take coastline hazards into account. In particular, it is essential that the type, location and construction of new developments are consistent with the risk and impact of the hazards. This can be achieved through various management options including effective land use zoning, the imposition of building conditions, dune management and the construction of appropriate protective works as part of the development.

A wide range of issues, interests and constraints affect planning and management of the coastline, of which coastline hazards is but one. Decisions relating to the management of coastline hazards should be made with reference to all relevant Government policies and other factors that affect coastal amenity and use. Social, economic, aesthetic, recreational and ecological factors all need to be considered.

The interrelated and sometimes conflicting nature of many of these issues, together with the different options for hazard management, indicate the need for an integrated approach to environmental planning and hazard management on the coastline.

Such an approach has not been successfully undertaken in the past because:

- Firstly, our understanding of the underlying coastal processes was inadequate. This has improved significantly in the last two decades, and the impact of coastline hazards can now be predicted more reliably;

- Secondly, major coastline hazard events occur on a sporadic basis. Decision makers and the community alike tend to forget the accompanying disruption and devastation in the "normal" periods between major events. It is relevant to note that the period from about the mid-seventies until 1990 has been characterised by a low intensity and frequency of storm activity along the New South Wales coast;

- Thirdly, the necessity of multi-disciplinary land use planning in the coastal zone has only become apparent in the last two decades. This has been brought about by the variety of competing and conflicting uses and users of coastal areas; and

- Finally, prior to the introduction of the present Policy, little financial assistance was provided by the State to local councils in the specialised area of coastline management.

Figure 1.1 Storm Waves, Narrabeen Beach Sydney, 1976 (Courtesy of Dr. A. Short).

1.4 GOVERNMENT SPECIALIST ADVICE

The integration of engineering and planning factors into coastline management plans is a complex process. Under its Coastline Hazard Policy, the State Government will make available specialist advice from various Departments and Authorities to assist councils in this matter. In particular, the principal relevant Authorities and their areas of speciality are:

- the Public Works Department, which provides advice on coastal processes, hazards and coastal engineering;

- the Department of Planning, which provides advice on land use planning and environmental assessment; and

- the Soil Conservation Service, which provides advice on coastal management issues such as the rehabilitation and maintenance of the sand dune system.

1.5 OBJECTIVE OF THE MANUAL

This Manual has been prepared to assist local councils in developing balanced plans of management for the coastline. It is also aimed at providing information to assist present and potential users and occupiers of the coastline understand the nature of coastline hazards and the options available for their management. The body of the Manual outlines the management system which is advocated in the Coastline Hazard Policy and which is the central issue in meeting the objective of the legislation proposed to provide councils with exculpation from liability. This section also provides a summary of the management options available to deal with coastline hazards and their relevance in two broad scenarios, namely in areas of "low" and "high" development.

Appendix A sets out the Policy as adopted by the Government.

Appendices B and C provide some background material on coastal processes and the hazards which may arise as a result. These appendices are not intended to be comprehensive or unduly rigorous. On occasions strict interpretations may have been sacrificed for simplicity of presentation. It is not intended that the material in these sections be a substitute for the carrying out of appropriate investigations or for the seeking of expert advice.

Appendix D provides details of a range of options which may be considered in developing the appropriate management strategy for an area of coast. No such list will be exhaustive nor can every possible circumstance be discussed. More often than not a combination of options will provide the optimum solution. The Manual should be considered the starting point for thinking about solutions to coastline hazard problems rather than a document that will provide an answer in each case.

SECTION 2 THE COASTLINE HAZARD POLICY

2.1 POLICY OBJECTIVES

The primary objective of the Government's Coastline Hazard Policy is to reduce the impact of coastline hazards on individual owners and occupiers of coastal lands, and to reduce private and public losses resulting from such hazards. Hazards peculiar to the coastline must be recognised in the design of new developments, in the planning of changed land use patterns and in the protection of present developments at risk. In this way there will be a reduction in the future call on State, Council and private funds to:

- protect development;
- secure persons and property; and
- provide, maintain and replace infrastructure.

There will also be a reduction in the risk to volunteer and emergency personnel in emergency situations.

In formulating this Policy, the New South Wales Government had regard to two important facts:

- the coastline of New South Wales is a priceless asset at local, state and national levels which should be managed with care and protected; and

- coastal land is a valuable resource, the development of which should not be unnecessarily restricted because of undue concern over hazards.

Important features of the Coastline Hazard Policy are:

- that balanced long term coastline management plans be developed by local councils, which in addition to hazard considerations, also address social, economic, aesthetic, recreational and ecological issues; and

- the requirement that all development proposals be treated on their individual merits taking into account the above factors and policies outlined in the *NSW Coast: Government Policy.*

A statement of the policy is in Appendix A.

2.2 POLICY PROVISIONS

To achieve these objectives the policy provides for:

- the Coastline Hazard Management Program to be administered by the Minister for Public Works;

- the preparation of a manual to assist local councils in a better understanding of coastal processes, hazards and coastline management;

- financial assistance to local councils for the purpose of managing coastline hazards. This assistance is available to cover:

  (i) identification of hazards and preparation of coastline management plans;

  (ii) construction of protective works and measures to reduce the risk and impact of hazards in existing developed areas;

  (iii) construction of works to enhance and protect the amenity and beauty of the State's more heavily used recreational beaches; and

  (iv) specialist technical advice in respect of any of the foregoing activities.

- the application of effective (but not unreasonable) land use and development controls to contain the potential for losses in all new developing areas;

- the protection of councils and other public authorities and their staff against claims for damages resulting from the issuing of advice or the granting of approvals related to coastal developments, provided that such action was taken in accordance with government policy at the time and in line with the principles set out in the Manual;

- relief for owners of vacant land which cannot be developed because of coastline hazards from land tax, council rates and water and sewerage rates; and

- specialist technical assistance to local councils from the Public Works Department, the Soil Conservation Service and the Department of Planning.

2.3 POLICY APPLICATION

Management of the coastal zone is primarily the responsibility of local councils. This responsibility should be discharged through the preparation and implementation of plans of management in accordance with normal local planning and development controls.

Application of the policy can best be achieved through the development of a coastline management plan by the local council. Important steps in the formulation of such a plan include the formation of a Coastline Management Committee, the undertaking of Coastal Process and Hazard Definition Studies, and the undertaking of a Coastline Management Study.

This Manual, outlining guidelines and principles, will assist local councils in dealing with development proposals and in preparing and implementing plans of management. The Manual also provides guidance to those involved with development proposed in proximity to the coastline and to those whose property is threatened by coastal hazards.

All Government agencies are required to comply with the policy, and in so doing, give due regard to social, economic, aesthetic, recreational and ecological factors, as well as coastal process factors.

The State Government, through the Public Works Department, the Soil Conservation Service, the Department of Planning and other relevant authorities, will provide advice and assistance to local councils on technical matters relevant to the coastline.

2.4 THE MERIT APPROACH

The Policy requires that other planning factors, such as social, economic, recreational, aesthetic and ecological issues, be weighed along with hazard considerations and beach amenity requirements when making decisions regarding coastal developments.

In the short term, it is likely that application of the Policy will involve the assessment of development applications on an individual basis.

In the long term, the preparation and implementation of balanced coastline management plans will incorporate the merit approach in its fullest sense. Once this situation has been reached, the need for the detailed analysis of specific proposals will be significantly reduced as the management plan should accommodate most situations.

2.5 LEGAL RESPONSIBILITY AND INDEMNITY

With respect to liability in negligence for decisions made and advice furnished by councils and advisory bodies regarding hazardous coastal land, it is, and always has been the case that a council or other body acting reasonably and in good faith has the protection of common law.

Nevertheless, the Government proposes to introduce legislation providing exculpation from liability in respect of certain advice or actions concerning coastline hazards. It is likely that this will be given effect by amendment to the Coastal Protection Act by introducing a clause similar to Section 582A of the Local Government Act which deals with this issue in regard to flooding.

3.1 POLICY IMPLEMENTATION OBJECTIVES

Implementation of the Coastline Hazard Policy generally involves the formulation and execution of a coastline management plan. Such a plan should ensure that:

- all reasonable measures are taken to avoid hazard and potential damage to existing properties and recreational amenity at risk;
- future development, works and activities in the coastal zone do not cause any significant or unacceptable growth in hazard or damage potential by adverse interaction with coastal processes;
- the long term future protection and use of the coastline is provided for, as required by the *NSW Coast: Government Policy*;
- land subject to coastline hazards is identified and managed in a manner compatible with the type, nature and damage potential of these hazards;
- guidance is given to developers concerning issues and factors they should address when proposing development;
- hazardous lands are managed to maximise the social, economic, aesthetic, recreational and ecological benefits to both individuals and the community, as well as taking into account hazard considerations, and rights of private landowners;
- information on the nature of existing and possible future hazards is made available to the public;
- due regard is paid to community safety, health and welfare; and
- appropriate warning systems and contingency plans are available to minimise personal risk and to facilitate post-event recovery.

3.2 AN OUTLINE OF THE MANAGEMENT SYSTEM

The steps involved and issues to be considered in formulating a coastline management plan are depicted in Figure 3.1. In broad terms they include:

- establishing a coastline management committee (Section 3.3);
- identifying the type, nature and significance of the various coastal processes and hazards that affect the area of interest (Section 3.4);
- undertaking a coastline management study (Section 3.5), to identify;
    - land tenure and existing planning controls, and the adequacy of existing planning controls;
    - environmental features and the condition of dunal vegetation;
    - access, recreational use patterns and visual and aesthetic features; and
    - sensitivity of the site to climate change.
- as part of the management study, identifying management options having regard to social, economic, aesthetic, recreational and ecological issues in the coastal zone (Sections 3.5.1 to 3.5.7); and the potential impact of any assessed climate change on coastal hazards (Section 3.5.8);
- preparing a coastline management plan consisting of the best combination of options for dealing with the various social, economic, aesthetic, recreational, ecological and hazard issues and problems (Section 3.6); and
- developing a strategy to implement the plan (Section 3.7).

The development and implementation of a coastline management plan is the responsibility of local councils with the assistance of relevant Government agencies. Figure 3.1 provides a ready reference to the interrelationships between the various elements of the management system.

3.3 COASTLINE MANAGEMENT COMMITTEE

It is unlikely that any council will have a sufficiently high level of experience and expertise in all the diverse areas of consideration required for coastline management. Consequently, the experience of state authorities in the fields of coastal engineering, planning and dune management will be available to councils.

Given the complexity and range of issues involved in the development of a coastline management plan, the most appropriate means of coordinating and disseminating advice is through a "coastline management committee". Such committees would be formed by councils.

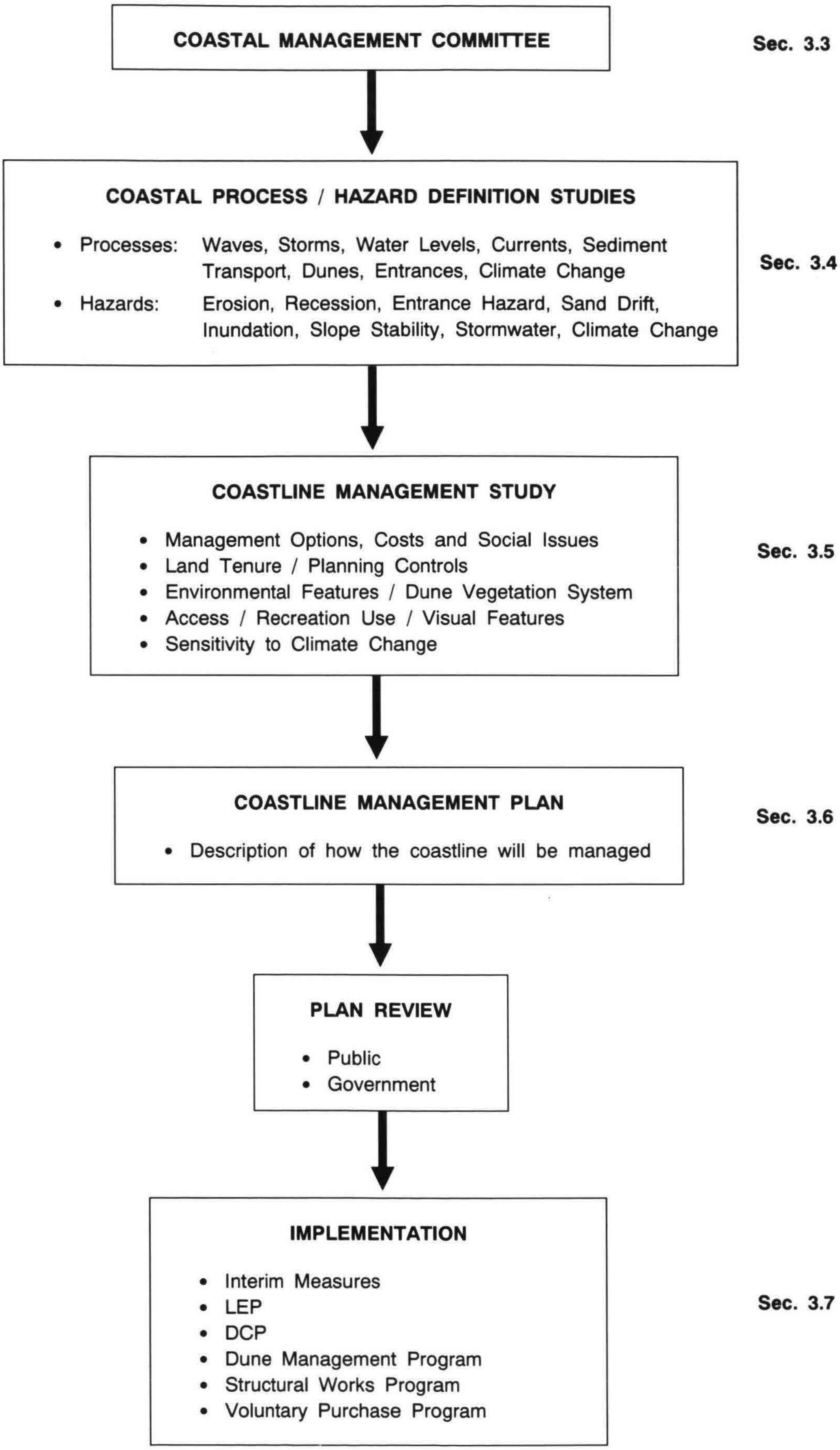

Figure 3.1 Elements of the Coastline Management System

The principal role of the committee should be to assist council in the development and implementation of a coastline management plan. In addition, the committee could also assist in:

- the direction and integration of any supporting studies made at various stages during the development of the plan;

- the formulation and application of interim development controls for use until the plan is completed, approved and implemented;

- the formulation and implementation of beach improvement and sand dune management programs;

- the determination of appropriate control conditions for developments; and

- the development of strategies for the implementation of management plans.

Membership of a committee should involve a balance of community and technical interests, including elected members of council, council staff, local community representatives, planners from the Department of Planning, coastal engineers from the Public Works Department and officers from the Soil Conservation Service. Officers from other Government agencies/departments may be included on the committee if required or called upon for ad hoc assistance.

As the responsibility for planning matters lies with the council, the committee should report either to council or to an appropriate council committee. In certain cases, joint committees may need to be formed by neighbouring councils.

3.4 COASTAL PROCESS AND HAZARD STUDIES

3.4.1 Process Studies

The coastline of New South Wales is subject to a variety of interacting processes that affect water levels and beach profiles. These processes are described in detail in Appendix B.

A coastal process study is the formal starting point of any hazard management program, and involves a comprehensive technical assessment of the processes that affect the coastal area of interest. The scope of a coastal process study may be local or regional in extent. This will determine the degree of involvement and responsibility of a single council.

The first stage of such a study is usually the collection of a wide variety of data, together with the analysis of data already to hand. The continuing collection of statewide coastal data such as wave and wind statistics will remain a State Government responsibility.

3.4.2 Hazard Definition Studies

Coastal processes give rise to a variety of coastline hazards that can damage or destroy coastal developments and coastline amenity. One important outcome of a coastal process study will be the identification of the most important processes and their associated hazards. This will form the basis of the resulting hazard definition study.

The following seven hazards occur along the NSW coastline and are described in detail in Appendix C:

- beach erosion
- shoreline recession
- coastal entrance instability
- vegetation degradation and sand drift
- coastal inundation
- slope and cliff instability
- stormwater erosion

While the two major categories of the coastline are beaches and cliffs, for the purpose of discussing management options it has been convenient to adopt three classifications: **Sandy Beaches, Coastal Bluffs** and **Rocky Sea Cliffs**. Appendix C10 indicates the types of hazards that may affect these coastal classifications.

The hazard definition study will specifically identify hazards threatening a particular area of the coast and will quantify these hazards and their effects. For example, the landward limit of the active beach zone, the rate of recession, etc. Table 3.1 indicates the information to be supplied by hazard definition studies.

3.5 COASTLINE MANAGEMENT STUDY

3.5.1 Management Study

Having defined the type, nature and significance of coastline hazards of relevance to the area of interest, a coastline management study is next undertaken to identify options relevant to the environmental planning and management of the coastal area. The management study should consider all feasible management options.

The study should comprehensively assess the social, economic, aesthetic, recreational and ecological issues associated with land use along the coastline, in addition to coastline hazards, e.g. implications of existing land tenure and planning controls, the creation of new jobs, the preservation of areas of aesthetic or ecological significance, the protection or enhancement of recreational amenity, exploitation and management of tourism opportunities, etc.

Table 3.1
Information to be Supplied by the Hazard Definition Study

Hazard	Information Required (As appropriate)
Beach Erosion	Landward limit of active beach zone for design storm(s).
Shoreline Recession	Long term average rate of shoreline recession/accretion.
Entrance Instability	An assessment of the past behaviour of untrained and trained entrances and likely future problems under design storm and flood conditions.
Sand Drift	A survey of the extent and current state of sand dunes, including dune vegetation, existing and potential future problems, adequacy of current management practices.
Coastal Inundation	The superelevation of the sea surface for design storm conditions; the extent of coastal inundation.
Slope Instability	A general survey of likely slope stability problems along the coastline. Ideally, classification into "Problem", "Possible Problem" and "No Problem" areas.
Stormwater Erosion	A survey of current stormwater disposal practices and identification of existing or possible future problems.

It is recommended that having identified broad options the sensitivity of each be tested in respect to possible future climate change scenarios based on information available at the time of the study. (See Section 3.5.8).

3.5.2 Ownership Considerations and Extent of Study Area

Tenure will markedly affect the coastline planning, management and development options and opportunities open to Local Government. Key areas of concern include:

- compensation and liability issues for freehold lands;
- ownership of the bed of any tidal lands; (while the majority will be in Crown ownership, some areas adjacent to and contiguous with early freehold titles may be in private ownership);
- role of public lands, particularly Crown lands under the administration of the Department of Lands or Council trusteeship, in providing various public amenities; (Public uses include access, clubhouses, parking, infrastructure, picnic areas. These uses are often undertaken in a multiple use context while retaining natural ecosystems and providing coastline protection); and
- role of public lands, including both Crown areas and areas reserved and managed by the National Parks and Wildlife Service as nature reserves and national parks. (Such substantially natural lands provide ecologically important areas, visual buffers and extensive recreation sites while providing coastline protection).

To provide an information base for the coastline management plan and to delineate those areas to be subject to the plan, it is recommended that a map be compiled displaying tenure in key categories. These categories would include:

(i) National Park, Nature Reserve and State Recreation Area (under the administration and management of the National Parks and Wildlife Service);

(ii) Crown lands, reserved, dedicated, leased or otherwise vacant (under the administration and management of the Department of Lands and/or Council and/or private trustees);

(iii) Other publicly owned lands (e.g. council land, Public Works Department depots for port facilities); and

(iv) Freehold tenure.

It will be useful also to include on the tenure map (or as an overlay), the land use zones in the existing planning scheme to enable a review to be made of suitability of the existing zones.

By reference to the tenure map and with due consideration to coastal processes, social and economic issues, aesthetic and ecological factors and recreational amenity, the area subject to the coastline management study can be determined. It is recommended that this be a zone of variable width to include both marine and terrestrial areas about the shoreline.

While the marine area is not subject to a council's planning control it is important to consider all those waters and submerged lands where existing and proposed human activities may impact upon the shoreline and its immediate environments.

The terrestrial areas would generally include all marine-derived coastal dunes, headlands and associated waterbodies where existing and proposed human activities may impact upon the shoreline and its immediate environs. Terrestrial areas for consideration under the coastline management plan may be extended beyond the area of direct hazard to include all relevant Crown lands within which coastline related uses and recreational activities are undertaken or are proposed (e.g. day use parks, caravan parks and other accommodation centres, access and related infrastructure).

3.5.3 Aesthetic and Ecological Factors

The coastline can contain a wide variety of unique aesthetic and ecological elements.

From a scenic viewpoint, there may be spectacular vistas, areas of high relief and dramatic landforms, zones of varied, interesting and important vegetation, aboriginal sites, items of cultural significance, etc. It is essential that such aspects be identified and assessed as part of the management study.

With respect to coastal ecology, there may be special areas and fragile environments of native flora and fauna. An important part of the coastline management study will be an expert analysis of the ecology of the coastline, and if appropriate, its hinterland. The objectives of such an analysis are to:

- identify the major environmental elements contributing to the integrity of the area, such as land use, plant and animal communities, riverine, estuarine and coastal habitats, water quality, visual and aesthetic amenity;
- identify the major threats to these elements;
- propose measures to protect these elements; and
- assess the environmental implications of alternative development and hazard mitigation proposals.

In the preparation of any management plan, it is vital that the hazardous area is not considered in isolation, but as an integral component of a larger ecological system.

Particular consideration should be given to the environmental consequences of proposed measures and to the requirement of Section 112 of the Environmental Planning and Assessment Act, 1979, namely that an Environmental Impact Statement be prepared where significant adverse environmental effect is likely.

3.5.4 Recreational Amenity

Many of the State's beaches are heavily used for public recreation. Like many natural things, beaches are dynamic and everchanging in nature; certain elements of their composition can be very fragile.

The recreational amenity that beaches provide the community is dependent on many things including access, scenic vistas and the presence of a sandy foreshore. One fragile component of many such beaches is the store of sand held in sand dunes at the rear of the beach and protected by dunal vegetation. Ensuring the long term viability of such dune systems, through sound planning and physical management, is a vital element in beach protection.

Beach systems can be badly damaged by the very recreational patronage they attract, by unsympathetic development and through poorly planned or designed beach amenities, e.g. shops, toilet blocks, etc. To account for such concerns, it is necessary to address recreational demands and opportunities in the management study and to identify areas in need of planning or works assistance.

3.5.5 Dedication of Public Lands

Under the *NSW Coast: Government Policy,* the Government will ensure that:

- beaches remain in public ownership and that the public has access to them;
- claims to the private or exclusive use of beaches will not be permitted.
- legal title to all NSW beaches will be registered and beaches will be formally dedicated as Crown land, for public use".

Given that the beach is an active zone and can change position over time that area to be dedicated from within the existing Crown land resource may be substantial and will vary from embayment to embayment.

As part of a Coastline Management Plan it is suggested that recommendations be made to the Department of Lands specifying those areas of Crown land which should be dedicated for the multiple purposes of public recreation, access and environmental protection. The extent of such an area will depend on the Crown land resource available, the coastal behaviour identified within the Coastal Process and Hazard Definition Studies (Section 3.4) and the various issues regarding beach use and amenity (Section 3.5). Prior to any development or reservation/dedication of Crown Lands, a full land assessment will be required under the Crown Lands Act, 1989.

Given the dynamic nature of the beach and the varied history of land title in NSW, some areas below high water may already be held under freehold title. Wherever possible, title searches should be undertaken with the assistance of the Department of Lands and the Land Titles Office to determine the extent of private ownership.

It is recommended that all land that falls below high water, whatever the title, must be regarded as accessible to the public until such time as the beach is dedicated by the Crown and compensation paid to previous land owners under the land acquisition scheme. These matters will need to be addressed within the Coastline Management Plan.

3.5.6 Social Issues

The coastal zone is used by the community for a variety of different purposes. These include active and passive recreation, tourism, and as a place in which to live and work. The social issues associated with existing community uses and proposed future uses, (e.g. increased residential use, job creation), need to be carefully identified and assessed as part of the management study.

One important social issue is the disruption associated with the aftermath of a coastline hazard event. This may include financial loss, inconvenience, isolation, structural damage and any resulting psychological disturbances or physical ill health.

The social disruption caused by coastline hazards is a significant effect to be considered in emergency, contingency and recovery plans. Loss of life through coastline hazards has not been significant in Australia, but the risk is always present.

3.5.7 Economic Issues

Many existing and proposed coastal developments are of major economic importance to the local government area. They may create both temporary and permanent jobs, increase council revenue from rates, and attract considerable tourist expenditure to the area. Any increase or decrease in the local economy likely to accompany coastal development needs to be identified in the management study. The liability of council in respect of maintenance, future damage or damage prevention also needs to be considered.

The economics of any proposed hazard avoidance or mitigation options will need to be assessed in respect of existing development. This is usually done by conventional cost-benefit and cost-effectiveness procedures. An option may often be found to be "uneconomic" in straight cost–benefit terms. However, such analyses ignore human "costs", such as the anxiety and resultant ill health caused by living under threat of and experiencing coastline hazards.

An economic analysis will also need to consider the value of not developing an area and of maintaining a natural coastline. Few, if any, analyses in the past have assessed the value or benefits of a natural coastline open to free use by the whole community. These benefits include environmental and wildlife values, wilderness values, social health values and psychological values.

3.5.8 Climate Change : Planning Under Uncertainty

Having considered the range of management options which might be applied to an area, and before attempting to make a final selection of the most appropriate, the impact of likely variations in assumptions made and of possible climatic changes should be considered. The sea level rise that might accompany atmospheric changes is the most discussed but is only one of a number of uncertain factors that might affect the implementation of a particular management strategy. In respect of climate change there is no current engineering basis for the adoption of a particular scenario, but the effects of any chosen scenarios can be assessed.

The variations in possible scenarios that might be considered is largely a matter of sound planning judgement. The Government will continue to monitor the results of scientific research and will make available to councils the most up to date assessment of the position at any given time.

The preparation of a coastline management plan is made difficult by uncertainties in the estimates of coastal processes and their hazards and by uncertain future conditions, e.g. the magnitude of any postulated future sea level rise. Appendix D7 discusses "Planning under Uncertainty" and provides examples of "robust" planning decisions that remain viable when the actual outcome of uncertain factors is more extreme than assumed in planning studies.

3.6 COASTLINE MANAGEMENT PLAN

The primary objectives of a management plan are to ensure compatibility with hazards, to reduce the impact of hazards on individual owners and occupiers, to reduce private and public losses from hazard damage, to protect and enhance the recreational amenity of beaches, and to ensure an appropriate long term balance in the utilisation and conservation of the coastline.

The development of a coastline management plan requires that a number of diverse considerations be taken into account, including:

- implications of coastal planning policy and guidelines and local, regional and State planning instruments;

- the type and nature of coastline hazards, including risk and potential damage to coastal developments and amenity;

- aesthetic, recreational and ecological values of the particular section of the coastline under consideration;

- social factors, including the needs and desires of the community, the social disruption and other intangible costs of potential damage, and the physical and psychological effects of damage;

- long term considerations of climate change; and

- an economic analysis of proposed or existing development, including expected costs and benefits to both the public and private sectors, based on options to develop, redevelop or leave undeveloped an area of the coast.

Having identified all issues of relevance to the area of coastline being studied, having considered these issues in terms of management objectives, and having weighed up all management options, the findings of the coastline management study next need to be incorporated in a coastline management plan.

A coastline management plan describes how the coastline will be used and managed to achieve defined objectives. Such plans may include:

- a description of the objectives of the plan;

- a discussion of issues, problems, special features and values specific to the area of the plan;

- a schedule of specific management measures aimed at achieving the objectives; and

- a description of the means and timing of implementation of these measures.

In essence, there are three means of managing coastline hazards:

1. environmental planning measures to ensure development is not unnecessarily sited in hazardous locations;

2. development control plans and development conditions on individual projects and sites to ensure that developments and potential damage are compatible with hazard risk; and

3. the use of structural controls and dune management to protect against hazards.

These management methods are discussed in detail in Appendix D. Environmental planning measures are of use in seeking to avoid the growth in potential damage associated with future developments. Development conditions are of use in limiting the damage associated with new development in zoned areas and redevelopments. Structural controls are generally more relevant to existing properties at risk.

In addition to consideration of the impact of hazards on developments, a management plan must also take into account social, aesthetic, recreational and ecological issues. Environmental planning controls and development conditions will play the major role in achieving desired objectives with regard to these issues. However, structural and dune management works will also have a place in the protection of beaches and dunes. On occasions, works may also be required to provide security to delicate ecological features along the coastline, e.g. where such features are threatened by the instability of sand dunes.

A coastline management plan should have the knowledge and support of the whole community. It is advisable that councils actively involve representatives of the public, in the preparation and review of the plan. Irrespective of any statutory requirements, the plan should be exhibited and public comment should be sought and taken into account before the plan is finalised and adopted.

3.7 IMPLEMENTATION

Until a coastline management plan is formulated and adopted, it is desirable that a council adopt and implement measures to contain growth of any problems.

Once a coastline management plan has been adopted, the next step in the management system is its implementation. Council can use a variety of approaches to implement various elements of the plan. These include:

- the use of Development Control Plans to outline detailed planning policies and controls for the coastline and to impose conditions on new developments and redevelopments;
- the use of Local Environmental Plans to introduce appropriate land use zoning, identify consent uses, etc. and so control the likelihood of development being inappropriately sited and thus reduce the damage potential of new developments;
- the initiation of a dune management program to protect and where necessary rehabilitate sand dunes;
- provision of structural works to protect existing property at risk;
- voluntary purchase programs to remove existing properties at undue risk; and
- public awareness and education programs.

Certain components can be implemented quickly, such as development and building controls, hazard education, public awareness and dune management programs.

Local environmental plans offer one of the most effective methods of limiting the development of coastal land and avoiding the losses and problems caused by hazard events. Councils are encouraged to incorporate elements of their coastline management plan into a Local Environmental Plan (see Appendix D3).

It is unlikely that any management plan could be implemented immediately in its entirety. For example, availability of funding will determine when certain options can be implemented (e.g. structural measures, voluntary purchase of property). Consequently, a strategy needs to be developed to implement the plan over time. The strategy should include the staging of components that are dependent on availability of funds, the adoption of interim measures, protection priorities, etc.

If a council seeks Government financial assistance in the implementation of a coastline management plan, it will be required to provide amongst other things, advice on the procedures followed in seeking public comment, the nature of the submissions received and the actions taken to minimise adverse environmental impacts. A copy of the council's resolution in approving the plan will also be required.

City, Municipal and Shire Councils are usually the planning and consent authorities responsible for the management of coastal lands. However, State Government Departments and Authorities, the Commonwealth Government, the Land and Environment Court, property developers and the community all have roles in the management of the coastline. These roles and responsibilities are briefly discussed below.

4.1 LOCAL COUNCILS

Within the requirements laid down from time to time by the State Government, a council is responsible for the planning and management of land in its own area, including land subject to coastline hazards.

4.1.1 General Responsibilities

(a) Coastline Management Plan

As part of its normal planning responsibilities, any council with land subject to coastline hazards should plan and manage that land in accordance with its hazard susceptibility. This is most effectively done through the preparation of a coastline management plan. Whilst such plans have no formal status under the Environmental Planning and Assessment Act, they are a statement of council policy regarding the type, nature and management of the coastline. Implementation may be by way of incorporation of certain elements into a statutory plan, by the construction of protective works, by implementation of dune management measures, or by the application of development conditions. Coastline management plans are discussed in Section 3.6.

(b) Coastline Hazard Mitigation

Councils are responsible for the investigation, design, construction and maintenance of works and measures to mitigate coastline hazards. To this end, the State Government will provide financial assistance under a program administered by the Public Works Department. (See Section 4.7.1.).

(c) Hazard Awareness

In an attempt to reduce the social disruption and damage caused by coastline hazards, councils should promote hazard awareness in their community. This can be done by supplying information and advice to property owners, residents, visitors, potential purchasers and investors. Council, after discussion with the State Emergency Services, should also promote awareness of any warning systems or evacuation procedures deemed necessary. In recognition of the turnover in residents, such information should be provided on a regular basis.

(d) Beach Management

The beaches of the State are usually public reserves and provide important recreational amenity to the community. The care, control and management of these beaches is usually vested in the local council. It is a council responsibility to improve and maintain beaches and their amenity. Advice on beach and dune management is available from the Soil Conservation Service and from the Public Works Department. Financial assistance for beach improvement is available through programs administered by the Public Works Department and the Department of Sport and Recreation.

4.1.2 Responsibilities Under the Environmental Planning and Assessment Act

(a) General

The Environmental Planning and Assessment Act, 1979 provides the framework for regulating development and protecting the environment in New South Wales. It has the object of encouraging:

- the proper management, development and conservation of natural and man-made resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages, for the purpose of promoting the social and economic welfare of the community and a better environment;
- the promotion and coordination of orderly economic use and development of land;
- the protection, provision and coordination of communication and utility services;
- the provision of land for public purposes;
- the provision and coordination of community services and facilities; and
- the protection of the environment.

Where a local planning instrument prepared under the Environmental Planning and Assessment Act requires consent for a use and development of land, a proposal under the Coastline Hazards Policy would fall under Part IV of the Act, (see (d) Development Applications below). In other cases, Part V would apply (see (b) Environmental Impact Assessment below).

(b) Environmental Impact Assessment

The Coastline Hazard Policy is relevant to decisions made under Part V of the Environmental Planning and Assessment Act, which deals with environmental impacts. Councils are therefore encouraged to establish formal procedures to ensure that:

- a systematic environmental review of all proposed works is undertaken; and

- the objectives of the Coastline Hazard Policy are reflected in subsequent decisions.

Where a Council decides that a proposed activity is likely to significantly affect the environment, approval cannot be given and the activity cannot be carried out until an Environmental Impact Statement has been prepared, exhibited and considered.

(c) Planning Instruments

The Coastline Hazard Policy will be most effective where new Local Environmental Plans and Development Control Plans are prepared in accordance with the Policy. Councils are therefore encouraged to achieve this position for all coastal lands.

(d) Development Applications

Permissible developments and the need or otherwise for council consent are usually specified by a Local Environmental Plan. In some circumstances, land uses specified in a Local Environmental Plan may be expanded or restricted by various State Environmental Planning Policies and Regional Environmental Plans, or by Development Control Plans (see Appendix D2).

When considering development applications, councils must have regard to matters set out in Section 90 of the Environmental Planning and Assessment Act. These include the provisions of any environmental planning instrument or draft instrument, including a Draft State Policy or Regional Plan. Particular subsections of relevance are listed in Appendices D2 and D4.

In some cases development applications may not be required and the first approach to council is a building application. Section 313 of the Local Government Act requires a council to consider a range of issues and is wide enough to encompass all matters set out in Section 90 of the Environmental Planning and Assessment Act.

If a proposal involves beneficial use of extracted material (sand, rock etc.) and requires development consent it would be "designated development" and the development application must be accompanied by an Environmental Impact Statement.

(e) Section 149 Certificates

Schedule 2 of the Regulations of the Environmental Planning and Assessment Act lists prescribed matters to be included in a certificate issued pursuant to Section 149 (2) of the Act. Of particular relevance to coastline management are:

- item (f) which refers to the application of any development control plan to the land; and

- item (k) which refers to any council policy adopted by resolution which restricts development of land because it is subject to flooding, or tidal inundation or other hazard.

4.2 STATE GOVERNMENT

In broad terms the State's role in coastline hazard management involves:

- the definition of broad policies and objectives;

- the provision of specialised technical advice;

- the provision of financial assistance through a subsidised program of studies, mitigation works, management measures and beach improvement measures; and

- management of state owned coastal land..

The Public Works Department, the Soil Conservation Service, the Department of Planning and the State Emergency Service are the state authorities responsible for providing technical advice and information on coastal processes, hazards and hazard management to councils.

4.2.1 The Public Works Department

The Public Works Department is the State's authority on coastal engineering. Specifically, the Department:

- employs specialist coastal engineers with considerable experience in coastal studies;

- collects data necessary for coastal process and hazard studies; including wave heights, tidal information, beach erosion and recession data, etc.;

- carries out coastal process studies and/or directs the work of private consultants in this field;

- assists councils with the preparation of coastline management plans;

- advises and assists councils with the evaluation of significant development proposals; and

- administers and manages programs of financial assistance for coastline management and beach improvements.

4.2.2 The Soil Conservation Service

The Soil Conservation Service is the State's authority on soil and land resource management. The Service has a major role to play in the coastal zone of New South Wales because of its responsibilities under the Soil Conservation Act. The Service has extensive coastal dune management experience and expertise. Specifically the Service:

- provides the skills and staff to identify specific problems, and to design and manage remedial programs;

- carries out works to rehabilitate areas of degraded coastal land;

- advises and assists councils in the planning and implementation of beach dune management and stabilisation programs;

- provides specialised foreshore planting material from its coastal nurseries;

- develops public awareness of coastal dune management and active community participation in coastal programs through education, advisory and extension programs such as Dune Care; and

- provides a range of consultant services covering all the above activities.

Detailed information on dune management techniques is provided in the Soil Conservation Service's, "Coastal Dune Management" manual, (SCS, 1990.).

4.2.3 The Department of Planning

The Department of Planning is the State's authority on planning and environmental assessment matters and is responsible for administering the Environmental Planning and Assessment Act, including the provision of advice on matters relevant to land subject to coastline hazards. Specifically the Department:

- employs planners and specialists with particular expertise in coastal environmental planning and natural resource management;

- formulates coastal planning policy and prepares guidelines and advice to councils and the community;

- issues State Environmental Planning Policies, Regional Environmental Plans and circulars to councils on planning issues, as well as preparing s117 Directions for issue by the Minister for Planning;

- performs a decision making role and applies planning controls on certain coastal development;

- carries out environmental protection and oversees the impact assessment process;

- administers the Heritage Act as it relates to protection of coastal heritage items;

- conducts studies of the coast relating to environmental and development issues;

- has a servicing role for the NSW Coastal Committee; and

- assists Councils with the preparation of coastline management plans.

4.2.4 The Department of Lands

The NSW Department of Lands has a key role to play in coastline management. This stems from the Department's statutory functions as owner, administrator and manager of public lands. Key facets of Departmental involvement include the following:

- ownership of the bed of all estuaries, embayments and ocean to the limit of State internal waters. (The only exceptions are the major ports of Port Kembla, Port Botany, Sydney Harbour, Port Newcastle and areas under the National Parks and Wildlife Act such as the marine extension to Bouddi National Park);

- ownership of the vast majority of coastal foreshore lands that remain in public ownership;

- land assessment of Crown lands to determine their most appropriate use;

- land management through Local Government and/or community involvement via Trusts, including the preparation of plans of management; and

- the assessment of potential for "off-budget" funding of management programs via the selected development under lease of marinas, resorts, caravan parks and other occupancies.

4.2.5 The State Emergency Service

The State Emergency Service is the State's authority on emergency and natural hazard contingency planning. The Service has specific responsibilities under the State Emergency Services and Civil Defence Act 1972, for the establishment of procedures to disseminate hazard warnings and for the preparation of evacuation plans.

4.2.6 The National Parks and Wildlife Service

The National Parks and Wildlife Service is the controlling authority for National Parks, State Recreation Areas and certain other reserves. These areas represent a significant proportion of coastal lands.

The Service carries out a range of management practices in respect of these areas including the preparation of plans of management. Authorities responsible for management and planning of areas adjacent to National Parks etc. should liaise with the Service in respect of potential impacts on those areas. Similarly, in carrying out its management functions, the Service should take account of the aspirations of those responsible for adjacent lands.

The Service also has responsibilities in respect to Aboriginal sites and wildlife outside of National Parks. The significance of Aboriginal sites needs to be recognised when considering works on the coastline. Development applications for coastal wetlands (SEPP 14) and littoral rainforests (SEPP 26) must be referred to the Director of the Service.

The Service possesses a body of knowledge and expertise which may be useful to those managing coastal lands.

4.2.7 The Minister for Public Works

The Minister for Public Works is responsible for the administration of Part III of the Coastal Protection Act, 1979. The Minister, under that part of the Act, may direct that, prior to approval by a consent authority, development applications of a certain class or within a certain area must be referred for his concurrence. Should concurrence not be given, the authority must refuse consent. Should the Minister apply conditions to his concurrence, the authority must apply these conditions to any consent granted.

It is proposed that only applications involving issues of State or Regional significance will require referral to the Minister for his concurrence.

A regulation has been made under the Coastal Protection Act which applies to those areas of the coastal zone which are not in a Local Government Area and which are not subject to an Environmental Plan. In essence, this regulation applies to that area from the shoreline to the three nautical mile limit. This regulation requires that the Minister's concurrence be granted before an authority's consent is given to a proposed development or before any person carries out any development or activity. Such activities include dredging, aggregate extraction, and the dumping of unwanted material or dredge spoil.

In implementing these provisions, the Minister must have regard to the likely effect of the development on coastal processes and the coastline, and the effect of these processes on the development.

4.2.8 The Department of Minerals and Energy

The Department is responsible for the administration of exploration and mining activities in the State under the Mining Act, 1973, and the Coal Mining Act, 1973.

Of these, the ones most likely to have impacts on the coastline are mining for heavy mineral sands and the offshore mining of heavy mineral sands and marine aggregate.

Under the conditions of exploration and mining titles the Department requires the proponent to undertake rehabilitation during and following exploration and mining activities. These take the form of Mining Rehabilitation and Environmental Management Plans which detail the proposed mining, monitoring and rehabilitation procedures to be implemented prior to, during and after mining. These are subject to annual review by the relevant government authorities.

Complementary to the Management Plan is the Department's Rehabilitation Policy which outlines principles to be applied, methods to be used, and standards to be achieved in the rehabilitation of land to a permanent and stable landform compatible with the surrounding land use.

The Department requires the lodgement of a security bond to be used in the rehabilitation of a site in the event of default by the mining company.

The Department is heavily involved in the rehabilitation of derelict mined land and carries out investigations to enable full assessment of environmental problems.

In addition, the Department, through the NSW Geological Survey, collects and interprets data on the geology of the State. The Department is also able to provide advice on coastal and marine geology and sedimentology and coastal geomorphology.

4.2.9 The State Pollution Control Commission

The SPCC is responsible for ensuring that all practical measures are taken to protect the environment and for coordinating the activities of public authorities in respect of those measures. Works likely to affect the storage, treatment or disposal of pollutants require a pollution control approval, and all discharges will need to be licensed by the SPCC.

Detailed information on approvals and licensing is provided in the Commission's "Pollution Control Approval and Licensing of Developments or Works", (SPCC, 1989).

4.2.10 The Coastal Committee of NSW

The Coastal Protection Act, 1979, established the Coastal Council of NSW. The Council comprised representatives of a range of Government agencies, persons with expertise in coastal management and a representative of local government. The functions of the Council are to advise the Minister for Planning on matters relating to coastal management and to coordinate the activities of the agencies with functions in the coastal area.

The Government wishes to expand the representation of local government and provide representation of the environmental movement on the Council. This requires amendment of the Act.

To give effect to its wishes more quickly, the Coastal Committee of NSW was established under Section 22 of the Environmental Planning and Assessment Act. The composition of this Committee reflects the Government's proposal for the Council and includes three representatives of local government and a representative of the Nature Conservation Council.

There is no barrier to a particular local government council seeking and receiving advice on coastal management issues from the Committee nor to a council seeking its assistance in issues of coordination between agencies.

4.2.11 Universities

The various Universities in NSW have been active in the collection of data and the carrying out of research on coastal processes along the NSW coast. The results of the research are widely published in Australia and overseas. The data can usually be made available for analysis in the context of a particular coastal investigation. The two organisations responsible for the bulk of the the work in this area are the Coastal Studies Unit of the University of Sydney, and the Water Research Laboratory of the University of NSW The nature and extent of the work carried out can be obtained from publications such as Annual Reports.

4.2.12 Other Government Authorities

All government authorities concerned with the use and development of lands subject to coastline hazards must:

- Comply with the provisions of:
  - the NSW Coast: Government Policy;
  - the Government's Coastline Hazard Policy; and
  - local planning instruments, development control plans, and council coastline management plans.
- Take into account:
  - the nature and consequences of coastline hazards;
  - the impact of a proposed use or development on coastline hazards; and
  - the impact that hazards may have on the proposed use or development.
- Have regard for the need to:
  - avoid causing any increase in the risk to life and limb or increase in the hazard to other property;
  - avoid any unwarranted increase in potential damage to public property and services; and
  - ensure that where necessary, Government services can be available during coastline hazard events, and that appropriate Government facilities can be used for emergency purposes.

The advice of the Public Works Department should be sought with respect to coastline hazards, the Department of Planning in relation to planning and environmental considerations, the Soil Conservation Service in relation to coastal dune management and the State Emergency Service with respect to emergency procedures.

The principles and guidelines described in this manual should be used in decision making.

4.3 COMMONWEALTH GOVERNMENT

The Commonwealth Government is responsible for the collection and forecasting of meteorological data and the administration of certain Acts which control activities in the coastal area.

The Bureau of Meteorology collects atmospheric pressure and wind data and prepares synoptic weather maps which may be used in the investigation of design parameters for coastal works. The Bureau also issues weather forecasts which include cyclone and storm warnings for coastal waters.

An Act administered by the Commonwealth controls the dumping of material at sea. Commonwealth Authorities may also be involved in the construction of works and facilities in the coastal zone.

Various Commonwealth Government Committees investigate aspects of Coastal Management from time to time. To date no assistance, either of a management or financial nature, has been made available by the Commonwealth to State or Local Governments.

4.4 LAND AND ENVIRONMENT COURT

The Land and Environment Court is the arbiter between councils, objectors and applicants in disputes over building and development applications. In these matters the Court will have access to the State's specialist technical advice through expert witnesses.

When based on "duty of care" considerations, claims by victims of coastline hazard events would be dealt with in the Supreme Court. Here again, the State will be a source of engineering and planning advice as well as coastal data.

4.5 DEVELOPERS

Developers of land likely to be subject to coastline hazards are required to satisfy consent authorities that any development will not affect or be affected by coastline processes, or that appropriate measures are included for the mitigation and management of coastline hazards.

Developers are responsible for the carrying out of any investigations that may be required. The Public Works Department and/or the Department of Planning will provide advice to the local council on the extent of data available, the additional data required, and the nature and scope of investigation considered appropriate to satisfy the consent authority.

4.6 THE COMMUNITY

The State's coastline is a priceless community asset. Many sections of the community have a legitimate interest in the management of the coastline, whether or not they are directly affected by coastline hazards and whether or not they live nearby or are potential visitors.

Any proposals for coastline management should therefore allow the community access to information and provide for community participation and comment.

The ultimate responsibility to make a final determination based on the issues and submissions remains with the planning or consent authority.

4.7 FINANCE AND CONDITIONS FOR GOVERNMENT GRANTS

4.7.1 Finance

The State Government will make financial assistance available to councils under the Coastline Hazard Program. The level of assistance is 50% of the cost of projects and works.

Projects which are eligible for assistance fall into the following categories:

- studies to investigate the type, nature and magnitude of coastline hazards;

- preparation of management plans within the context of social, economic, ecological, land capability etc. issues;

- works and measures which put into effect plans of management (these may include structural works, dune management measures, or the voluntary purchase of property). The total amount eligible for assistance will include the cost of any necessary design, environmental assessment and supervision of construction; and

- works to maintain and improve the recreational amenity of the State's beaches.

In respect of proposed studies in particular, the views and comments of various state agencies should be sought at the earliest possible stage to ensure the most satisfactory progress towards a final proposal.

Projects which councils wish to have considered for financial assistance should be submitted in the first instance to the appropriate Regional Office of the Public Works Department. Offers of grants will be made by the Minister on the basis of available funds and statewide priorities.

In respect of projects involving structural works, councils will be responsible for certifying that all necessary environmental assessment and review processes have been undertaken.

Government assistance is not available for works made necessary by any new development. Under these circumstance, the developer and/or the consent authority are responsible for the cost of any hazard management measures.

Various state agencies have their own practices with respect to charges for recovery of costs of advice and services provided. This Policy does not infer the waiving of charges by individual agencies. Any such costs incurred by a council would be eligible for financial assistance as part of the total cost of an approved project.

4.7.2 Conditions for Grants

General conditions relating to grants made available to councils under the Coastline Hazard Program will typically be as follows:

1. Proposals associated with the preparation of hazard definition or coastline management studies should clearly identify:
   - the full extent of investigations proposed; and
   - how investigations are to be managed, e.g. the composition of the coastal management committee, the relationship between committee and council, etc.
2. Proposals for implementing works and measures will need to:
   - demonstrate that the project is technically and economically viable;
   - detail cash flow requirements;
   - demonstrate that due regard has been given to environmental factors; and
   - demonstrate that public consultation (where appropriate) has occurred and advise of any modifications/actions arising from this consultation.
3. Investigations and studies must be undertaken in accordance with approved briefs.
4. Works must be completed in accordance with approved plans.
5. Works must be commenced within a specified period.
6. Prior approval is required to vary the conditions of the grant, e.g. additions or extensions to studies, investigations, works, activities (such as public awareness campaigns), etc.
7. Where appropriate, works must be designed on the basis of technical standards acceptable to the Public Works Department the Soil Conservation Service, or other relevant agencies.
8. During the progress of the works, council must provide regular itemised Certificates of Expenditures (in approved format) at intervals nominated for that grant. Progress payments, particularly in the early stages of the project, may be made on the basis of valuations made by the Department or the Service.
9. Councils will be expected to observe cash flow/rate of expenditure requirements.
10. Councils will be expected to complete work within the approved estimated cost, and the grant amount will be based on that approved cost.
11. Councils' costs chargeable against approved subsidised programs are as follows:
    - those costs incurred directly in the execution of the project, including payments to consultants and contractors, labour costs, costs of plant, land and materials;
    - engineering costs involved in survey, design and supervision of the project;
    - statutory overheads (Workers Compensation Insurance, Payroll Tax, Leave Loadings, etc.) for all labour and staff chargeable against particular projects; and
    - an amount agreed as a contribution to general administrative costs.

When implementing voluntary purchase schemes, specific conditions apply. The Public Works Department will provide details of these conditions.

4.7.3 Income Generation for Management Works on Crown Land

One of the key issues facing coastal land managers is the availability and sustainability of funds to undertake works. Sources of funds include the re-investment of revenue obtained from developments on Crown Lands. This source is discussed in detail below.

The Crowns Lands Act, 1989, places the Department of Lands, in association with Local

Government, in an excellent position to generate funds by way of joint venture projects with the private sector, (e.g. tourist resorts, marinas, caravan parks, kiosks, extraction royalties), and the reinvestment of these funds in land management works via the Department's Public Reserves Management Fund. This places the Department in a lead position as the State's major multiple land use agency and helps provide Local Government with the means to implement coastal management plans.

Section 106 of the Crown Lands Act, 1989, provides the statutory basis for the allocation of any revenue gained by a Trust such as Local Government. Briefly, any revenue (by sale, lease or licence) by a Reserve Trust shall be allocated according to directions from the Minister. Directions by the Minister may include:

- the acquisition of other lands;

- the funding of management works in other reserved lands;

- payment to Consolidated Revenue (Treasury); and

- payment to the Public Reserves Management Fund; and

- management of lands under the care of the Trust.

Such Ministerial directions could be by way of a plan of management adopted under the Crown Lands Act, 1989, and supplementary financial plans.

Coastline management plans prepared by Local Government may be appropriate for adoption under the Crown Lands Act, 1989 as they affect and specify tenure and management arrangements for Crown Lands.. Liaison with the Department of Lands is recommended with a view to establishing appropriate administrative arrangements for plan adoption, to compiling financial plans for the allocation of revenue and to identify any further opportunities for joint venture developments.

5.1 COASTLINE HAZARDS

This section discusses the appropriateness in various circumstances of the range of management options, detailed in Appendix D, for addressing coastline hazards. Seven hazards have been identified along the New South Wales coastline. These hazards, described in detail in Appendix C, are:

- Beach Erosion
- Shoreline Recession
- Coastal Entrance Instability
- Vegetation Degradation and Sand Drift
- Coastal Inundation
- Slope and Cliff Instability
- Stormwater Erosion.

5.2 HAZARD MANAGEMENT OPTIONS

Options for managing coastline hazards maybe conveniently grouped into four categories:

- Environmental Planning;
- Development Control Conditions;
- Dune Management; and,
- Construction of Protective Works.

Environmental planning options are described in Appendix D3 and are an effective means of avoiding or limiting risk to future coastal developments. The object of land use controls is to ensure that the type of development and potential damage is consistent with the hazard.

Development control conditions are described in Appendix D4. Such conditions are imposed through development and building approvals and are a means of reducing hazard on a site specific basis. Development conditions are especially relevant to limiting the growth in damage associated with new developments and redevelopments.

Dune management options are described in Appendix D5. Dune management activities are designed to maintain the integrity of the dune system as nature's last line of defence against wind and wave attack. Dune stability is based primarily on maintaining the dunes' protective mantle of fragile vegetation. The role of dune vegetation as a coastal "process" is described in Appendix B8. Dune vegetation is also briefly discussed in relation to Windborne Sediment Transport (Appendix B9), and Sand Drift Hazard (Appendix C5). Dune management is often referred to as a "soft" protection option, as opposed to the "hard" protection afforded by other protective works.

Works to protect hazardous areas of the shoreline are described in some detail in Appendix D6. The aim of such works is to eliminate or to reduce hazards to an acceptable level.

Hazard management generally draws on a mix of all types of options, which are incorporated into a coastline management plan.

Within each of the four categories there is a range of options which may be applied to management of hazards along the New South Wales coastline. These options are listed in Table 5.1. The broad advantages and disadvantages of each are briefly described in this section. Additional details are given in Appendix D.

Table 5.1
Hazard Management Options

Category	Management Option
Environmental Planning	Buffer Zones Restrictive Zoning Planned Retreat Voluntary Purchase
Development Control Conditions	Building Setback Building Types Dune Protection Flood Mitigation Foundation Design Emergency Access Relocatable Buildings Planned Retreat
Dune Management	Dune Management Planning Community Involvement Dune Reconstruction Dune Revegetation Dune Protection Dune Maintenance
Protective Works	Seawalls Training Walls Groynes Beach Nourishment Offshore Breakwaters Artificial Headlands Configuration Dredging

5.2.1 Environmental Planning

Environmental planning options provide measures to ensure protection of coastal land and restriction of development in hazardous sites, as well as encouragement of development in areas not subject to hazards so that hazards are avoided or minimised. Measures are detailed in Appendix D3, and include:

- Buffer Zones
- Restrictive Zoning
- Planned Retreat
- Voluntary Purchase

The underlying principle with these options is to recognise the environmental processes operating on the coast and "design with nature", ie to ensure development is sited so that hazards are avoided.

Alternatively, where this is difficult to achieve because of existing development constraints, the principle involves enacting policies to ensure development is carefully designed in or withdrawn from hazardous sites, in an equitable manner, so that hazards are minimised or avoided.

(a) Buffer Zone

The concept of a buffer zone is based on the philosophy that the coastal processes should be accommodated rather than prevented. The most basic form of accommodation is to avoid siting structures within areas affected by the various hazards. This requires the reservation or zoning of an appropriately managed area between the beach and development within which natural fluctuations can be accommodated. An appropriate buffer zone allows both for maintenance of natural beach amenity and also for the impact of natural processes without demands on the public purse for protection of structures.

When areas along the coastline are zoned to facilitate protection of existing vegetation communities, vegetated dunal systems or stabilised recreation areas, these areas provide an effective separation of developed areas from hazardous sites. The width of a buffer zone should take account of the natural foredune, and a buffer zone is most effective when it is sufficiently wide to allow for both the present fluctuations of the beach position with erosion and build-up, as well as likely future fluctuations.

Where high recession rates are experienced either the buffer zones should be wide enough to accommodate ultimate landward recession, or development landward of the buffer should be planned for only a limited time period in that position. Alternatively, other types of protective measures may have to be considered. Otherwise, the area of land from which development is excluded may be excessive.

Buffer zones have the advantage of providing for public foreshore access and protection while at the same time holding development back from hazardous sites and avoiding building damage. They facilitate the carrying out off effective dune management measures to further protect landward development from coastal hazards.

(b) Restrictive Zoning

Restrictive zoning can be effective as a means of "damage control" to deal with coastal areas where previous zoning has granted rights for development in hazardous sites, i.e. where previous zoning decisions have not properly taken coastal hazards into account, or where high recession rates have eroded earlier buffer zones.

Figure 5.1 Buffer Zone, Maroubra Beach, Sydney.

Such zonings can limit the amount of new development in hazardous areas and avoid increase of a hazard problem by new or increased intensity of development and keep hazard problem areas from becoming exacerbated by increased levels and densities of development. Provisions can include: requirements for development consent to be obtained to allow special conditions to be applied; establishment of building setback lines (See Development Control Conditions, Section 5.2.2.); limits on the number, size, scale and design of structures; etc.

Excessive restriction may generate compensation claims and care is needed in striking the right balance. A related approach is the application of a freeze on development (See Appendix D3) and requirements for an engineer's report on building and redevelopment proposals in areas of risk.

(c) Planned Retreat

Coastal land can be planned to permit development that has a limited life and this approach allows use and occupation of the coastal site until coastline hazards threaten or damage property. This permits a flexible approach in the future if hazards become more severe, for example in response to climate change, or in cases where there is moderate to high coastal recession.

At the time development is approved, a specified period can be identified before consent lapses. Alternatively, approval may specify that consent only remains valid while a beach erosion scarp does not encroach within a set distance from a development. At this stage, consent lapses and the structure must be moved back, relocated or demolished. (See Planned Retreat, Appendix D3)

Local planning instruments (LEP's and DCP's) can be used to outline policies for planned retreat of development on hazardous coastline and can be coupled with other conditions on development and buildings to further limit potential damage to structures.

(d) Voluntary Purchase

Both the State and some Local Government bodies have adopted schemes to bring certain coastal properties, threatened by hazards, into public ownership. Following purchase, structures are usually removed and dune management techniques implemented to provide a stable coastal reserve at the site.

These schemes can include purchase of properties voluntarily offered for sale at equitable prices. This provides a cost-effective way of avoiding future damage to development subject to hazards. Voluntary purchase is also a means of removing anomalous developments from a rezoned area.

The costs of such schemes escalate as the level of development increases. Realistically, only small numbers of properties may be able to be acquired over a number of years due to constraints on available funding.

Other financial schemes may involve lease-back following purchase (see Appendix D4, Financial Measures,). These schemes may be coupled with other coastal management options, such as restrictive zoning, to increase their effectiveness.

5.2.2 Development Control Conditions

Development control conditions are described in Appendix D4 and comprise a mix of development and site specific measures aimed at ensuring that the siting, scale and type of damage potential are consistent with the hazards. They are a particularly appropriate means of limiting the damage potential of new developments and redevelopments.

Development control conditions are applied by council through the consent process associated Development Applications and Building Applications.

(a) Building Setback

Building can be restricted to areas on the landward side of properties in order to maintain their distance from potentially eroding dunes and bluffs. They can similarly be restricted to areas landward of setback lines established in planning instruments.

When consent for redevelopment is sought, building setbacks from original positions may also be achieved, to reduce the potential for hazard damage. Emergency access through new developments or redevelopments may be required to facilitate the provision of emergency protection of existing buildings at risk from erosion/recession hazards.

Where rates of coastal recession are high, provision of building setback lines will produce only temporary relief from the hazards. If refusal of consent is untenable, it may be appropriate to combine setback with other conditions such as foundation design conditions, lapse of consent when the hazards draw near, dune reconstruction and/or maintenance etc.

(b) Building Types

The scale and bulk of buildings may be limited by development control conditions to maintain the damage potential of hazards at low levels, as well as for other planning purposes such as avoiding overshadowing of beaches.

(c) Dune Protection

Dune protection should be a condition of any coastal development on or behind sandy beaches. If the dunes are damaged during the development process, or by the day-to-day use of the facility, future management costs will increase. It is essential that the integrity of the foredune system be maintained during and following any development. A range of dune management options is outlined in Section 5.2.3. The Soil Conservation Service will provide advice on relevant conditions to be applied for developments adjacent to the coastal dune system.

(d) Flood Mitigation

Flood mitigation measures include minimum floor levels, the use of suitable building materials and flood proofing. The use of such measures for buildings on land subject to coastal inundation is essential.

(e) Foundation Design

Appropriate foundation design for all types of coastline development is a fundamental means of limiting damage to buildings and structures. On sandy beaches subject to erosion/recession, this may involve the use of piles of a specified length to ensure that the building remains standing if the sand beneath it is eroded away. Where recession is high this represents only an interim solution as piled structures on the beach are not socially acceptable. On a coastal bluff subject to slumping, it may involve drainage control works.

(f) Emergency Access

Access through new developments or redevelopments may be required to facilitate the provision of emergency protection to existing buildings at risk of erosion/recession hazards (e.g. for the dumping of rock protection).

(g) Relocatable Buildings

Requirements can be applied for buildings to be relocatable. This can facilitate a temporary occupation of a beachfront site and allow for hazards to be avoided by movement of the structure to landward when appropriate. There are different approaches that can be employed depending on the type and purpose of the structure. For example, a surf club building could be built in a demountable style that allows removal and reconstruction as part of a strategy of planned retreat (see section 5.2.1 (c)). Relocatable buildings can be substantial and comfortable to live in but be designed and constructed for relocation if and when the risk of erosion or recession becomes too great. Foundation design conditions, such as piles, can be applied in conjunction with relocatability conditions to ensure that the structure can survive an unexpectedly large storm prior to relocation.

(h) Planned Retreat

A council may allow a building to be constructed and used until such time as the risk of erosion/recession hazard is deemed too great. At this time the building owner must cease occupation and either remove the building (if it is a relocatable building), demolish the building or abandon the building. Council would specify the required fate of the building.

5.2.3 Dune Management

Dune management is the combination of activities that aim to sustain the role and value of beach dunes. Management for a stable dune system involves the control of windblown sand when it encounters the foredune. The elevated foredune interacting with zoned vegetation is recognised as one of the basic requirements for coastal stability. (see Appendix B8).

The basic principle in dune management is to maintain a satisfactory vegetative cover on the foredune. This prevents sand blowing inland where it is lost from the coastal system. Management of coastal dunes involves the application of land capability principles, organisation of recreational activity and rehabilitation of disturbed dunes.

Dune management options are described briefly below, and in more detail in Appendix D5. Detailed information on dune management techniques is provided in the Soil Conservation Service's "Coastal Dune Management" manual.

(a) Dune Management Planning

Before any management or rehabilitation program is undertaken, certain information must be obtained so that a suitable program can be developed. Investigation of the land resource, land use patterns and planning of management programs should be undertaken well before any actual works commence. A detailed treatment of dune management planning is provided in the following reference: "Coastal Dunes of New South Wales, Status and Management", D.M. Chapman, University of Sydney Coastal Studies Unit Technical Report No. 89/3.

(b) Community Involvement

Measures designed to influence peoples' awareness of, their attitude to, and their physical impact on the beach system are an integral part of a successful dune management program.

The dilemma facing the coastal manager is that although dunes are an extremely fragile landform not well adapted to community pressure, they are a popular resource. Australians are largely coastal dwellers and traditional beach users. This beach usage has been intensified in recent years as traditional beach activities have been added to by newer recreational, residential, and tourist development.

To be most successful, dune management programs require the community to be aware of, and actively or passively support, dune management works.

(c) Dune Reconstruction

Any revegetation program implemented on coastal dunes requires a suitable landform for the planting of grasses, shrubs and trees. A suitable landform is essentially an area of sand with no major hummocks or undulations which will interrupt wind flow and cause the wind to concentrate, making vegetation establishment difficult or even impossible.

Preparing such landforms generally involves the reforming of dunes. This may involve filling of small blowouts, or on a larger scale, the reconstruction of hundreds of metres of dune.

(d) Dune Revegetation

The major objective of any dune revegetation program should be to provide sufficient plant cover to protect against wind erosion. Species native to the coastal dune system have adapted to survive the hostile environment of drifting sand, strong winds, salt spray and infertile soils, and provide long term stability to the system.

A successful revegetation program will also provide other benefits to the coastal system including increased protection for landward areas and amenities, improved habitat for native fauna, particularly birds, and enhanced beach amenity.

(e) Dune Protection

The provision of dune protection is necessary where land use pressures will, in the absence of protection measures, cause damage to the dune landform or vegetation. A combination of dune fencing, formalised accessways and signposting is normally used to protect the dune system. An active community awareness program will complement these measures.

Fences preserve both revegetated and naturally vegetated areas by protecting them from uncontrolled pedestrian and vehicle traffic. Formalised accessways allow pedestrians and vehicles access to dunes in a manner which protects both the dune and adjoining vegetation; they are fenced to direct and confine the movement of the traffic; and the dune surface is generally protected by materials such as board and chain mats to prevent sand blowing from the accessway and to provide traction for traffic.

(f) Dune Maintenance

Both rehabilitated and natural dune areas require long term maintenance (maintenance in perpetuity), to ensure that vegetation and structures such as fences and accessways retain their function, and to protect the initial investment of funds in management works.

Figure 5.2 Dune Stabilisation, Newport Beach, Sydney.

Figure 5.3
Seawall and Promenade, North Steyne, Sydney.

Deterioration of rehabilitation works may be caused naturally by the action of the wind, waves and moving sand. Vandalism may increase the rate of deterioration of works.

Maintenance of dune management works includes the following aspects:

- continuation of public awareness campaigns;
- repairs to fences, accessways and signs;
- replanting of areas where plants have failed to establish or have died because of disease, insect attack, fire or moisture stress;
- planting of secondary and tertiary vegetation in suitable areas;
- control of weeds such as bitou bush and lantana;
- application of fertiliser when required; and
- fire control.

Consistent and adequate maintenance of rehabilitation works will contribute to the aesthetic appeal and amenity of the beach area. Regular maintenance will also reduce the need for major restoration at a later date, thereby reducing the cost of subsequent works.

5.2.4 Protective Works

Protective works are described in detail in Appendix D6.

In general, protective works tend to be expensive. However, they often provide the only socially and economically acceptable means of reducing hazards to existing properties at risk. Unless carefully designed and constructed, structural works, by reason of their location within the active beach zone, may have a number of unforeseen detrimental effects on amenity.

(a) Seawalls

A properly designed and constructed seawall will protect properties and areas of the foreshore from the impacts of beach erosion and coastline recession hazards. However, the recreational use and scenic appeal of the beach may be reduced by seawalls, especially if their presence facilitates the loss of sand in front of the wall and/or delays beach rebuilding after storms.

(b) Training Walls

Properly designed and constructed training walls can stabilise a coastal entrance, improve navigation and help mitigate estuarine flooding. However, training walls can markedly alter patterns of erosion and deposition, both within the estuary and on the coastline either side of the entrance. They can also have a marked effect on the tidal range of the estuary and thereby estuarine ecology.

(c) Groynes

Groynes can provide coastal protection and increase amenity by building a wider beach. However, erosion tends to occur along the section of beach downdrift of the groyne field. This can be minimised by initially filling the groyne embayments with sand as part of a beach nourishment program.

(d) Beach Nourishment

Like groynes, beach nourishment provides coastal protection and increases beach amenity by building a wider beach. However, unlike groynes, nourishment does not promote erosion in downdrift locations of the beach. In fact, beach nourishment programs have few if any detrimental effects (this is part of their attraction) provided that an adequate supply of suitable sand is available and that it can be obtained without undue consequences. One potential drawback of beach nourishment is that further nourishments may be needed in the future.

(e) Offshore Breakwaters

Offshore breakwaters reduce the intensity of wave action in inshore waters and thereby reduce coastal erosion. They have not been commonly used along the New South Wales coast. They are costly to construct because of the prevailing wave climate and their use is generally limited to the protection of sheltered areas not exposed to open coast wave conditions.

(f) Artificial Headlands

Artificial headlands act as large groynes that extend into deep water to restrict longshore transport. On the open coast, they require large, expensive structures. Consequently, their use has been restricted to areas with less severe wave climates.

(g) Configuration Dredging

Configuration dredging is dredging to a pattern such that wave refraction limits the effects of wave action on a stretch of coastline. Its usefulness on the open coast is restricted by the variety of wave directions possible and the scale and cost of works required. It may have application in more sheltered waters but could only be considered where the coastline processes were well understood.

5.3 SELECTION OF MANAGEMENT OPTIONS

The intention of this section is to provide an indication of the more likely management options which may be appropriate in a range of circumstances. The approach used is to adopt the two broad categories of "low" and "high" development and to indicate the application of management options in addressing the hazards in each case.

A "high" level of development refers to a coastline characterised by intense urban use (e.g. residential, commercial) supported by substantial urban infrastructure (roads, water supply, sewerage, etc.). Surfers Paradise and Collaroy are examples of high levels of coastline development.

A "low" level of development is taken to mean a coastline characterised by rural or other non-urban uses. An important characteristic is also that land holdings are large single ownerships rather than urban sized allotments.

In fact there is a continuum between one extreme and the other. The subdivision into the two categories is convenient for discussion purposes and is intended as a starting point for consideration of options. Each situation on the coastline is unique and in the final analysis needs to be considered individually.

Figure 5.4 Groyne Structure, Kirra Beach Qld.

The above classifications are largely synonymous with "**damage potential**". Obviously a coastline with a high level of development has a high damage potential. Whether or not this damage potential is realised depends upon the extent of the hazards and the presence and effectiveness of any protective works.

It must be stressed that each situation along the coastline is unique and that individual solutions will emerge for each, depending on the particular degree of hazard and the economic, social and ecological conditions applying. Nevertheless it is considered that there are specific characteristics of each situation similar to those for the "high" and "low" development cases which can be used to broadly group options.

The discussion that follows might be considered as two case studies of a very general nature which provide some guidance in the selection of options for consideration in specific situations.

5.3.1 Low Development

Areas in the category of "low" existing development will usually, but not always, be outside the urban areas with existing land use zonings being non-urban, rural, open space or similar. The obvious characteristic will be little if any physical development and thus a low level of asset value. An important social consideration will be that landholdings will tend to be large single ownerships, even if subdivision has taken place. Where there is little or no existing development the conservation of ecological values is more likely to be a significant consideration.

(a) Environmental Planning

Where there is little or no development already existing the opportunity presents itself to manage the area by avoiding the potential coastline hazards. It is likely therefore that environmental planning will provide the most appropriate management strategies. While avoidance of the hazards is the most likely approach, should there be reasons for planning some forms of development within hazardous areas, other options are available to manage the coastline hazards.

Options available within the general category of environmental planning include restrictive land use zonings, planned retreat and voluntary purchase. This latter option would usually be associated with other options to cater for whatever development may exist or to provide for some specific purpose. These options were discussed in detail in Section 5.2.1.

The way in which land use zoning can be used to manage individual hazards is discussed below:

(i) Beach Erosion

Beach erosion, that is the short term fluctuation of the beach, without any shoreline recession can readily be managed by planning options. The extent of the hazard can be defined to within reasonable limits and is not progressive. The concept of creating land use zones encompassing the hazard area and precluding most development is an appropriate option.

(ii) Shoreline Recession

The progressive nature of shoreline recession puts a qualification on planning options as a means of managing the hazard. In broad terms, unless any zone encompasses the ultimate extent of the recession, the hazard area will at some future time extend beyond the zone.

Any zone which seeks to provide long term protection is likely to unnecessarily prevent development of land in the short term. A less conservative approach is likely to lead to property becoming threatened sooner than is acceptable. The accuracy of prediction of future recession is not high and as yet no techniques exist for predicting the ultimate shoreline location.

However, the concept of planned retreat does lend itself to accommodating the progressive nature of the hazard.

It is often the case that an area adjacent to the shoreline is to be zoned open space or environmental protection for reasons not related to the coastline hazards, (for example to conserve habitats or to provide for public recreation). The widths of such zones may be such as to contain any future shoreline movement and thus no further consideration of the hazard is necessary. However, it should be recognised, however, that these zones will become narrower as time progresses.

(iii) Coastal Entrances

The hazard presented by the wandering of coastal entrances can be managed by environmental planning options where there is little or no existing development. The only technical concern may be the difficulty of precisely defining the limits of movement.

Introducing land use zones to accommodate entrance movement is not likely to affect large areas of land. Where isolated structures do exist, voluntary purchase may often be more appropriate than protective works.

(iv) Sand Drift

When dealing with areas of low development the most appropriate option for dealing with sand drift will be to implement appropriate dune management techniques to ensure that a well vegetated, stable dune system can be maintained. In order to do so, an adequate width must be provided for in land use zones etc. to allow for a self-sustaining vegetative system.

Voluntary purchase may well be an attractive way of dealing with isolated property threatened by extensive transgressive dunes.

(v) Coastal Inundation

The extent of land affected by inundation can usually be readily defined. Land use zoning and voluntary purchase of isolated, badly affected properties are appropriate options in a low development area. The zones required will often be an extension of those defined for beach erosion or shoreline recession, except where a dune system might be breached and the area affected may be more significant. Inundation alone may be insufficient reason to preclude development and other options exist to ensure compatibility with this hazard.

(vi) Slope and Cliff Instability

Buffer zones, restrictive zonings, and voluntary purchase will be appropriate where there is little development in areas subject to slope, bluff or cliff instability. It is particularly important to allow for the stability of dunes behind eroded beaches when considering zoning boundaries for other hazards.

(vii) Stormwater Erosion

Problems encountered from stormwater erosion in the low development case are likely to be encompassed within environmental planning options adopted to deal with other hazards. Voluntary purchase of badly affected structures may be considered.

It should be noted that in planning development near the coastline, even though the development itself may not be threatened, its impact on stormwater flows may be significant. The increased peak flows often resulting can have detrimental impacts on beaches.

(b) Development Control Conditions

Development control conditions are usually placed on development of an individual property at the time of granting development consent or building approval. In some cases, the types of controls which may be applied are outlined in a Development Control Plan (DCP).

In order to be applicable the property would need to be zoned in such a way as to allow development in an area subject to hazard. Given that areas of low development zonings are more likely to preclude development in a hazardous area, the use of development control conditions will be the exception rather than the rule.

There are cases where, for sound reason, zonings will permit development of some type in hazard prone areas and the application of development control conditions would then be appropriate. An example might be surf life saving facilities, tourist facilities or some other development where the purpose of the development dictates close proximity to the coastline. In such cases it is desirable that the extent and nature of the zoning is not unduly restrictive, to allow the greatest degree of flexibility in the application of development controls.

The options available in this category were discussed in section 5.2.2. The following sections outline the application of development control conditions to manage individual hazards in the context of low existing development scenarios.

(i) Beach Erosion

Whilst in areas of low development, zonings will usually restrict development of areas prone to threat from beach erosion, there may be cases either where the purpose of a structure dictates its location within a hazard zone, or a small part of a larger property falls within a hazard zone. Building setback lines and design conditions may then be appropriate options.

Where a small part of a property lies within the active beach zone setback lines can be used to exclude structures from the active area. Otherwise conditions such as foundation design and floor levels can be applied.

(ii) Shoreline Recession

Development control conditions related to building design and location are not particularly suited in the long-term where shoreline recession is one of the hazards. Difficulties with determining the extent of zonings discussed earlier apply also to the location of setback lines. Design conditions aimed at ensuring the integrity of a building may be effective so far as the safety of the structure is concerned, but a possible consequence is that, as time passes, the building's location may become socially unacceptable.

The use of conditions requiring buildings to be relocatable may be effective if used in conjunction with an overall policy of planned retreat. Specification of piled foundations may assist by ensuring that the building remains undamaged during a storm.

(iii) Coastal Entrances

Whilst development near mobile entrances is likely to be the exception rather than the rule in the low development situation, the application of development control conditions would have a place. Setbacks could be used to limit the location of development on large properties bordering on an entrance. Foundation design conditions could be applied as a safety measure where the extent of movement of the entrance is uncertain.

(iv) Sand Drift

Where other hazards do not dictate the exclusion of development, conditions relating to the maintenance of vegetation on a dune system might be appropriate. In the low development situation, land near the coast might be set aside for recreation (e.g. a golf course). Conditions requiring maintenance of the dune system or restriction of access would be appropriate measures to consider. In a rural situation grazing on fragile dune systems should be prevented.

(v) Coastal Inundation

Where minor coastal inundation is the only coastal hazard, development might be considered in such an area subject to the application of conditions relating to floor levels. Wave height and runup should be considered in setting levels. Possible damage to foundations from scour and floating debris should also be considered.

(vi) Slope and Cliff Instability

Whilst development in areas subject to slope, bluff and cliff instability is likely to be avoided in the "low" development areas, development control conditions may have a place in some circumstances. Building setback and foundation design aimed at overcoming the hazard are the conditions likely to be considered.

(vii) Stormwater Erosion

Stormwater erosion by itself is unlikely to be sufficient to preclude development and development conditions may be applied to render a particular development safe. Where new development is being considered conditions may be applied to regulate the discharge of stormwater.

(c) Dune Management

The objective of sound dune management is to sustain the role and value of the dunes as part of the coastal system. This role is multifaceted and includes the control of wind blown sand, the assurance of a buffer against short-term erosion, and the enhancement of the beach and coastal amenity. The basic principle is to maintain a satisfactory vegetative cover; this involves the application of land capability principles, organisation of recreational activity and rehabilitation of disturbed dunes.

In the "low" development situation there is usually ample scope for, and significant benefits to be derived from, the other applications of dune management principles.

The implications of dune management in respect of the various hazards are outlined in the following sections.

(i) Beach Erosion

The extent of the zone affected by short-term erosion is related to the volume of sand on the beach berm, incipient dune and foredune. If a good vegetative cover exists on the foredune a volumetric buffer against erosion is retained and the process of colonisation and building of the incipient dune is facilitated. In assessing the extent of the short-term erosion hazard, the existence of a well vegetated dune will reduce the width affected.

(ii) Shoreline Recession

One of the mechanisms for the loss of material from an area of coastline is by wind blown loss of sand. While this is not usually the major loss mechanism, it is significant in many cases. A well managed dune system will prevent this loss and thereby reduce the rate of shoreline recession.

(iii) Coastal Entrances

The existence or otherwise of a well maintained dune system is in itself not a major factor in limiting the movement of a coastal entrance. However, a mobile entrance may create instability on the surrounding area and managing these areas will assist in preventing further damage and also wind blown losses.

(iv) Sand Drift

Dune management and the maintenance of a satisfactory vegetative cover is the major management option for the control of sand drift.

(v) Coastal Inundation

The existence of a stable dune of appropriate height can be of major importance in the prevention of inundation of low lying coastal areas. The crest level of the dune should be determined by the likely elevated ocean water level and the wave runup level. It may be necessary to reform the dune to achieve the right crest level and thereafter manage the dune to ensure it remains stable.

(vi) Stormwater Erosion

Dune management does not have a significant direct impact on the management of stormwater erosion, except to the extent of limiting the instability that may be caused, and as part of rehabilitation if other options are used to relocate or control the discharge.

(d) Protective Works

For the "low" development situation, major protective works are likely to be low on the list of options considered, environmental planning and voluntary purchase being the more likely options.

Minor works to cater for some low level hazards might be considered, for example to protect one or two existing houses from stormwater erosion. The role of such works would be similar to the role performed in the case of the high development scenario and will be discussed in that section.

However, an option which should not be overlooked, however, is the case of protective works to allow a major development in an area now undeveloped or with little existing developments. It is always an option to allow development in an area prone to coastline hazards and to provide engineering works to protect or make the development secure.

If such an option is being considered there are some important aspects to take into account. Such a proposal should not be considered only in the context of development of a single property but at least in the context of a whole beach compartment or in the context of regional planning. The physical impacts of the necessary protective works on adjoining areas should be assessed and the proposal judged on its merits taking account of the physical impacts, social implications, economic benefits and costs and ecological implications.

Should this approach be considered as a management option for an area it is important that the land use zoning (both in extent and in description) allow a flexible approach to the use of protective works, setting of design conditions and accommodating public aspirations such as foreshore access.

5.3.2 High Development

As the name implies areas in the category of "high" existing development will be characterised by a more intense usage of the coastline and a high potential for damage by coastline hazards. The best known example in Australia of highly developed coastline is perhaps the Surfers Paradise area of Queensland's Gold Coast, with Collaroy Beach providing a Sydney example. Even in these areas of apparently full development, there is continuing pressure for redevelopment and a need for a management strategy as the framework for decision making.

Figure 5.5 Severe Beach Erosion, 1974 Storms, Bilgola Beach, Sydney.

Figure 5.6
Oceanic
Inundation,
East Coast
USA.

While many areas of the coastline are not as intensely developed as those cited above, the more favoured management options are likely to be similar. Protective works, dune management and development control conditions are likely to emerge as the favoured options rather than environmental planning, although land use planning will have a role in laying a framework for implementing the outcomes of management studies.

Areas typified in the discussion of the "high" development situation will include those in urban areas with a significant proportion of the properties developed and may include areas with little physical development but with property which is subdivided and with most blocks in individual ownership.

In the "high" development situation, more so than in the low development situation, a mixture of works options combined with dune management, development control conditions, land use zoning and voluntary purchase may produce the optimum solution. While these options are generally discussed separately in this section, the advantages of combining options should not be overlooked.

In the following sections each of the broad categories of management options as they apply to the range of coastline hazards are discussed in the context of there being a relatively high level of existing development.

(a) Protective Works

Protective works are likely to be amongst the favoured options for "high" development areas. There are a number of types of works, their common objectives being to "remove" the hazard which is threatening the properties. In achieving this objective, works are likely to have impacts elsewhere and this must be carefully considered in assessing a works option.

The various protective works options are discussed in the following sections in the context of the range of coastline hazards.

(i) Beach Erosion

Many structures have been built in the past within the active beach zone where they come under threat from beach erosion. While voluntary purchase and the application of development control conditions to infill development and redevelopment may play a role, protective works are likely to be amongst the more favoured options.

Of the range of protective works available, beach nourishment and terminal revetments (or seawalls) are the most likely solutions. Dune management should be considered in combination with these options.

Beach nourishment will depend on the existence of an acceptable source of material. Terminal revetments will be effective and may be combined with nourishment to lower the cost or to produce a socially acceptable result.

(ii) Shoreline Recession

The most effective option where long term shoreline recession is taking place will depend (apart from cost) on the mechanisms causing the recession.

Seawalls will usually prove effective but may have an impact on adjacent areas, and may result in a short or long term reduction of beach amenity.

Beach nourishment also will usually be effective, and environmentally most acceptable, but depends on there being an economically viable and environmentally acceptable (as well as technically satisfactory) source of material. Nourishment by its nature is an option which will need to be repeated periodically.

Where there is high longshore transport or losses into an entrance, groynes and training walls may be effective. These measures may be combined with initial nourishment to minimise the impact on adjacent areas or to produce a more acceptable beach environment. Dune management will be needed in combination with these options.

Where wind blown sand losses are a major contributor to recession, major dune stabilisation works may be effective.

(iii) Coastal Entrances

Mobile entrances can often be restrained by training walls. Often low cost, carefully designed works can be effective for all but major entrances. None of the other works options are applicable to the management of this hazard.

(iv) Sand Drift

The most appropriate solution to sand drift problems will be by implementing dune management practices. These are discussed in section (b) below.

(v) Coastal Inundation

Coastal inundation can refer to two types of phenomenon. Properties immediately fronting the coast can be affected by wave runup. Others in low lying areas adjacent to the coast can be inundated as a result of elevated ocean water levels and overtopping of dunes by wave runup. The works options applicable are seawalls and reconstruction of dunes. Seawalls are most usually used (in a secondary role, as they are usually constructed for protection from erosion) to counter wave runup. Dune reconstruction and stabilisation of existing dunes can be an effective counter to both forms of inundation. An effective drainage system may be required in each case as it may not be economical to provide absolute protection from wave runup.

(vi) Slope and Cliff Instability

Protective works are not usually constructed primarily to counter the hazard of slope, bluff or cliff instability. However, revetments may be constructed to protect the toe of a potentially

Figure 5.7 Migrating Dune, Wairo Beach, South Coast, NSW.

Figure 5.8
Beach Berm Scour due to Stormwater Discharge, Soldiers Beach, Central Coast, NSW.

unstable slope and retaining walls may be used to assist in maintaining otherwise unstable slopes. Works constructed primarily to combat other hazards may of course have a secondary benefit in countering slope instability.

(vii) Stormwater Erosion

Works of two types may be used to offset the impacts of stormwater erosion. Training structures or small revetments may either redirect or contain stormwater flows or provide protection from the increased wave attack brought about by stormwater discharges lowering the beach berm. Works aimed at relocating stormwater outlets to more stable positions or dissipating the energy, and thus the effect on the beach berm, are preferred if possible.

(b) Dune Management

The application of dune management techniques to the management of coastline hazards in the "high" development scenario where space permits, is critical because of the greater value of hinddune development and the higher population pressures placed on the dune system.

On a highly developed coastline, development often encroaches onto the foredune, thus restricting the capability of the dune and its vegetation to fulfill normal functions and processes. Under these circumstances the dune system will require more active management.

The application of dune management to the various hazards is discussed below.

(i) Beach Erosion

Where space is available to form a dune or a dune already exists, the benefit is the presence of a buffer of sand to afford some additional protection during storm erosion of the beach. The dune vegetation does little to stop the erosion but windborne sediment trapped by dune plants ensures that an additional volume of sand is available to meet the storm demand.

Where a terminal revetment is constructed it may be possible to cover the structure with sand and to vegetate the area to reduce the visual impact of the structure. Where beach nourishment is adopted as the management option it is desirable to provide for the formation of a dune.

(ii) Shoreline Recession

Dune management will be an appropriate strategy only where wind blown sand losses are in large part responsible for the recession. While it may not always be possible because of space limitations, dune management can be used to prevent wind blown sand losses and thus reduce the rate of recession. Where space limitations preclude the maintenance of dune vegetation other steps such as the construction of dune forming fences, may be advantageous to prevent losses. Such fences require regular maintenance to ensure adequate function.

(iii) Coastal Entrances

Where protective works such as training walls are used to stabilise coastal entrances, a range of dune management techniques may need to be implemented. Both construction works and subsequent use of the area may impact on adjoining dune systems with resultant movement of sand. Many large dune rehabilitation programs have been associated with coastal entrances.

(iv) Sand Drift

Dune management will be the most effective means of controlling sand drift. Should lack of space prevent the maintenance of dune vegetation, solutions such as the construction of dune forming sand fences can be considered. Where promenades or roads lie immediately at the back of a beach the only option may be to return wind blown sand to the beach periodically.

(v) Coastal Inundation

Dune management will be one of the favoured options to control coastal inundation and wave runup. In some cases it may only be possible to provide a dune in conjunction with other options such as beach nourishment when a dune can be designed as part of the project.

(vi) Stormwater Erosion

See "low" development, Section 5.3.1 (c)(vi)

(c) Development Control Conditions

Development control conditions are likely to play a significant part in management plans for the more highly developed areas. The extent of the hazards may influence the extent to which this is so. Development control conditions are likely to be particularly important in cases where infill development and redevelopment is occurring and also as interim measures pending decisions on, or implementation of, other options such as protective works.

The measures likely to be more appropriate for the various types of hazards are discussed below.

(i) Beach Erosion

Building setback, foundation conditions and floor levels may be effective options in dealing with beach erosion where long term coastal recession is not a major factor. Many properties extend into the active beach zone while being deep enough to allow building outside that zone. Building setback lines can be used to control the location of structures in this case. Foundation design and floor level controls can be used to ensure the integrity of a building and may be particularly useful as an interim measure where protective works are proposed in the future or as a safeguard against underestimation of the extent of the hazard.

(ii) Shoreline Recession

Building setback and design conditions are not likely to be appropriate where long term recession of the shoreline is occurring. Setback lines simply defer the problem to the future and ensuring the integrity of buildings may lead to building locations which in the future will be socially unacceptable and provide difficulty in servicing. The use of relocatable buildings and the use of conditions to ensure effective relocatability may be used as part of an overall policy of planned retreat and to a lesser extent for isolated development applications.

Specification of piled foundations, while not necessarily a satisfactory long term solution, will ensure a building is not damaged during a storm and thus allow longer term action to be assessed or implemented in a context other than that of impending destruction.

(iii) Coastal Entrances

Development control conditions requiring adequate foundations and setting of floor levels may be an appropriate option for management of the hazard of mobile entrances. The choice between this and protective works to stabilise the entrance may depend on economics and may be influenced by the size of the entrance, extent of movement and impacts elsewhere of proposed works.

(iv) Sand Drift

Development conditions are unlikely to be effective against major transgressive dunes but conditions requiring the maintenance of a dune system and controlling access should be considered as a means to limit wind blown sand, to preserve a natural barrier, and to manage inundation.

(v) Coastal Inundation

Where low lying areas near the coast suffer inundation the setting of minimum floor levels is a management option. The maintenance of an effective dune barrier is also an appropriate option and conditions may be imposed requiring dunes to be maintained at certain levels and to be adequately vegetated. Foundation designs, floor levels and protection from debris are issues which may be addressed where wave runup is a threat, although protective works may be more effective in this case.

(vi) Slope and Cliff Instability

Foundation design conditions are an option to be considered to manage the hazard of slope, bluff or cliff instability. Controls on the management of stormwater on the property may be useful. Where there is room on a property to construct a building which is outside the active beach zone, subsequent slumping of the escarpment or slip circle failure can be guarded against with appropriate foundation design.

(vii) Stormwater Erosion

Foundation design can be used to protect property near stormwater discharge points in the same way as for mobile entrances. Conditions controlling the concentration of stormwater on newly developing areas could be considered.

(d) Environmental Planning

This option is not likely to be prominent in developing management plans for highly developed areas, except that planning instruments may provide the statutory framework for implementing plans of management. The balance between environmental planning and the other options will depend greatly on the level of existing developments.

There may be cases where other planning motives such as creation of open space, recreation areas or provision of access might complement the creation of buffer zones and be implemented through statutory planning instruments and judicious voluntary purchase.

The application of environmental planning options to each of the hazards is discussed below.

(i) Beach Erosion

Where the hazard zone can be well defined and is fixed in plan (i.e. there is no long term recession) environmental planning and voluntary purchase might be used to create buffer zones or to impose restrictions to limit future expansion of property at risk. This option is more likely to be appropriate towards the lower end of the "high" development range.

Land use zones might be used to define areas over which restrictions apply, or development control conditions might be imposed, but the details of these are more usually contained in a Development Control Plan.

(ii) Shoreline Recession

The progressive nature of shoreline recession leaves little scope for the use of environmental planning as such in the management of this hazard. Restrictions on redevelopment may limit the amount of development placed at risk when the potential hazard is actually realised.

Voluntary purchase might be considered to acquire some properties but is unlikely to be economical on a large scale. A policy of planned retreat may be appropriate in some cases to allow use of property until the potential hazard is actually realised.

(iii) Coastal Entrances

Even on a highly developed coastline the immediate vicinity of a mobile entrance may not be intensely developed. In such a case voluntary purchase and land use planning may be an option.

(iv) Sand drift

Where development already exists land use planning is not likely to be effective. Voluntary purchase of isolated properties might be attractive. If a natural dune exists between existing development and the coastline, zoning to protect the dune may be successful.

(v) Coastal Inundation

Voluntary purchase of the more adversely affected properties might be considered. Other environmental planning options will not usually apply where there is existing development except as a means of implementing and delineating the extent of areas where floor level restrictions might be applied. Once again these latter restrictions would more usually be incorporated in a Development Control Plan.

(vi) Slope and Cliff Instability

Planning options other than voluntary purchase are not likely to be effective, except as a means of limiting the spread of structures in locations which are subject to slope, bluff or cliff instability.

(vii) Stormwater Erosion

This hazard is usually too localised in effect to be addressed directly by planning measures. However, control of stormwater should be considered in future planning decisions. Voluntary purchase could be considered in extreme cases but is likely to be less economical than protective works.

GLOSSARY

GLOSSARY

Accreted Profile — The profile (cross-section) of a sandy beach that develops in the "calm" periods between major storm events. During such periods, swell waves move sediment from the offshore bar back onto the beach to rebuild the beach berm.

Artificial Headlands — Man–made offshore structures connected to the shoreline to provide coastal protection or to restrict longshore transport.

Barometric Setup — The increase in mean sea level caused by a drop in barometric pressure.

Bathymetry — The measurement of depths of water; also information derived from such measurements.

Beach Berm — That area of shoreline lying between the swash zone and the dune system.

Beach Erosion — The offshore movement of sand from the sub–aerial beach during storms.

Beach Nourishment — The supply of sediment by mechanical means to supplement sand on an existing beach or to build up an eroded beach.

Blowout — The removal of sand from a dune by wind drift after protective dune vegetation has been lost. Unless repaired promptly, the area of blowout will increase in size and could lead to the development of a migrating sand dune and its associated problems.

Bore — A broken swell wave travelling shorewards across the surf zone.

Breaker Index — The ratio between the height of a wave and the water depth in which the wave breaks.

Breaker Zone — That area of coastal waters where shoaling effects cause swell waves to break. This typically occurs in the shallower waters over an offshore bar.

Breaking Waves — As waves increase in height through the shoaling process, the crest of the wave tends to speed up relative to the rest of the wave. Waves break when the speed of the crest exceeds the speed of advance of wave as a whole. Waves can break in three modes: spilling, surging and plunging.

Breakwater — Structure protecting a shoreline, harbour, anchorage or basin from ocean waves.

Buffer Zone
An appropriately managed and unalienated zone of unconsolidated land between beach and development, within which coastline fluctuations and hazards can be accommodated in order to minimise damage to the development.

Coastal Structures
Those structures on the coastline designed to protect and rebuild the coastline and/or enhance coastal amenity and use.

Coastline Hazards
Detrimental impacts of coastal processes on the use, capability and amenity of the coastline. This manual identifies seven coastline hazards:

- Beach erosion
- Shoreline recession
- Entrance Instability
- Sand drift
- Coastal inundation
- Slope and cliff instability
- Stormwater erosion

Damage Potential
The susceptibility of coastline development to damage by coastline hazards.

Design Wave Height
The wave height adopted for the purposes of designing coastal structures such as breakwaters and seawalls. It is chosen to ensure that the structures are not at undue risk of wave damage.

Diffraction
The "spreading" of waves into the lee of obstacles such as breakwaters by the transfer of wave energy along wave crests. Diffracted waves are lower in height than the incident waves.

Dune Field
The system of incipient dunes, foredunes and hinddunes that is formed on sandy beaches to the rear of the beach berm.

Dune Maintenance
The management technique by which dunes, dune vegetation and dune protective structures are kept in good "working order"; activities may include weed/pest/fire control, replanting, fertilising, repair of fences and accessways, and publicity.

Dune Management
The general term describing all activities associated with the restoration and/or maintenance of the role and values of beach dune systems; dune management activities and techniques include planning, dune reconstruction, revegetation, dune protection, dune maintenance, and community involvement.

Dune Protection
The management technique by which the dune system is protected from damage by recreational and development activities; dune protection activities generally include the use of fences, accessways and signposts to restrict and control access to dune systems.

Entrance Instability — Refers to the tendency of entrances to estuaries and coastal lakes to migrate along the shore, close up, reopen, form new entrances, etc. in response to wave and current action and freshwater flows.

Ebb Tide — The outflow of coastal waters from bays and estuaries caused by the falling tide.

Fetch (Fetch Length) — The horizontal distance over which a wind blows in generating waves.

Flood Tide — The inflow of coastal waters into bays and estuaries caused by the rising tide.

Forbland — Area characterised by low, herbaceous or slightly woody plants, annual or sometimes perennial (not grasses).

Foredune — The larger and more mature dune lying between the incipient dune and the hinddune area. Foredune vegetation is characterised by grasses and shrubs. Foredunes provide an essential reserve of sand to meet erosion demand during storm conditions. During storm events, the foredune can be eroded back to produce a pronounced dune scarp.

Greenhouse Effect — A term used to describe the likely global warming predicted to accompany the increasing levels of carbon dioxide and other "greenhouse" gases in the atmosphere.

Groynes — Low walls built perpendicular to a shoreline to trap longshore sediment. Typically, sediment buildup on the updrift side of a groyne is offset by erosion on the downdrift side.

Groyne Field — A system of regularly spaced groynes along a section of shoreline.

Hinddunes — Sand dunes located to the rear of the foredune. Characterized by mature vegetation including trees and shrubs.

Incipient Dune — The most seaward and immature dune of the dune system. Vegetation characterised by grasses. On an accreting coastline, the incipient dune will develop into a foredune.

Littoral Zone — Area of the coastline in which sediment movement by wave, current and wind action is prevalent. The littoral zone extends from the onshore dune system to the seaward limit of the offshore zone and possibly beyond.

Longshore Currents — Currents flowing parallel to the shore within the inshore and nearshore zones. Longshore currents are typically caused by waves approaching the beach at an angle. The "feeder" currents to rip cells are another example of longshore currents.

Mass Transport	The net shorewards current associated with the movement of waves through the nearshore and inshore zones. Sediment transport from the offshore bar by this current is responsible for the rebuilding of storm eroded beaches during inter-storm periods.
Nearshore Zone	Coastal waters between the offshore bar and the 60m depth contour. Swell waves in the nearshore zone are unbroken, but their behaviour is influenced by the presence of the seabed. (This definition is adopted for simplicity in this Manual and is based on wave motion considerations rather than sedimentology).
Offshore Bar	Also known as a longshore bar. Submerged sandbar formed offshore by the processes of beach erosion and accretion. Typically, swell waves break on the offshore bar.
Offshore Breakwater	Offshore structure built parallel to the beach to protect the beach and/or reduce wave action in inshore waters.
Offshore Zone	Coastal waters to the seaward of the nearshore zone. Swell waves in the offshore zone are unbroken and their behaviour is not influenced by the presence of the seabed. (See note to "Nearshore Zone").
Onshore/Offshore Transport	The process whereby sediment is moved onshore and offshore by wave, current and wind action.
Plunging Waves	The wave crest breaks suddenly and with tremendous force by curling over a near vertical wave face.
Pocket Beaches	Small beach systems typically bounded by rocky headlands. Because of the presence of the headlands and the small size of these beaches, longshore currents are relatively insignificant in the overall sediment budget.
Reflected Wave	That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.
Refraction	The tendency of wave crests to become parallel to bottom contours as waves move into shallower waters. This effect is caused by the shoaling process which slows down waves in shallower waters.
Revetment	(Refer to Seawall)
Rip Currents	Concentrated currents flowing back to sea perpendicular to the shoreline. Rip currents are caused by wave action piling up water on the beach. Feeder currents running parallel to the shore (longshore currents) deliver water to the rip current.

Sand Bypassing — A procedure whereby sand deposited on the updrift side of a training wall or similar structure is mechanically delivered to the downdrift side. This facilitates the natural longshore movement of the sediment.

Sand Creep Diagram — Representation in the form of a compass rose of the rate and direction of sand drift.

Sand Drift — The movement of sand by wind. In the context of coastlines, "sand drift" is generally used to describe sand movement resulting from natural or man-induced degradation of dune vegetation, resulting in either nuisance or major drift. Sand drift can damage buildings, roads, railways and adjoining natural features such as littoral rainforest or wetlands; sand drift can be a major coastline hazard.

Sand Drift Control — The repair and maintenance of sand dunes to minimize sand drift. The protection and fostering of dune vegetation is an important element of such programs.

Sand Drift Vector — The net direction and net volume flux of sand drift at a particular location.

Sand Dunes — Mounds or hills of sand lying to landward of the beach berm. Sand dunes are usually classified as an incipient dune, a foredune or hinddunes. During storm conditions, incipient and foredunes may be severely eroded by waves. During the intervals between storms, dunes are rebuilt by wave and wind effects. Dune vegetation is essential to prevent sand drift and associated problems.

Scarp — Also known as the Dune Scarp and Backbeach Erosion Escarpment. The landward limit of erosion in the dune system caused by storm waves. At the end of a storm the scarp may be nearly vertical; as it dries out, the scarp slumps to a typical slope of 1V:1.5H.

Seawalls — Walls built parallel to the shoreline to limit shoreline recession.

Sea Waves — Waves in coastal waters resulting from the interaction of different wave trains and locally generated wind waves. Typically, sea waves are of short wavelength and of disordered appearance.

Sediment Budget — An accounting of the rate of sediment supply from all sources (credits) and the rate of sediment loss to all sinks (debits) from an area of coastline to obtain the net sediment supply/loss.

Sediment Sink — A mode of sediment loss from the coastline, including longshore transport out of area, dredging, deposition in estuaries, windblown sand, etc.

Sediment Source	A mode of sediment supply to the coastline, including longshore transport into the area, beach nourishment, fluvial sediments from rivers, etc.
Semi-Diurnal Tides	Tides with a period, or time interval between two successive high or low waters, of about 12.5 hours. Tides along the New South Wales coast are semi-diurnal.
Shoaling	The influence of the seabed on wave behaviour. Such effects only become significant in water depths of 60m or less. Manifested as a reduction in wave speed, a shortening in wave length and an increase in wave height.
Shelf Wave	Long period waves of low height that travel along the continental shelf and may modify coastal water levels off New South Wales by up to 0.2m. Shelf waves are generated by the pressure gradients associated with atmospheric disturbances in Bass Strait.
Shoreline Recession	A net long term landward movement of the shoreline caused by a net loss in the sediment budget.
Shadow Area	Areas behind breakwaters and headlands in the lee of incident waves. Waves move into shadow areas by the process of diffraction.
Significant Wave Height	The average height of the highest one third of waves recorded in a given monitoring period. Also referred to as $H_{1/3}$ or H_S.
Slope Readjustment	The slumping of a backbeach erosion escarpment from its near vertical post-storm profile to a slope of about 1V:3H.
Slipface	Area at the rear of a blownout dune where drifting sand from the blowout is deposited. The slipface is typically at the angle of repose of the sand.
Spilling Waves	The wave crest breaks gradually as the wave travels to the shore. Characterised by the appearance of white water at the crest.
Storm Profile	The profile (cross-section) of a sandy beach that develops in response to storm wave attack. Considerable volumes of sediment from the beach berm, the incipient dune and the foredune can be eroded and deposited offshore. The landward limit of the storm profile is typically defined by a backbeach erosion escarpment (dune scarp).
Storm Surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of two components: the increase in water level caused by the reduction in barometric pressure (barometric setup) and the increase in water level caused by the action of wind blowing over the sea surface (wind setup).

Storm Bar — An offshore bar formed by sediments eroded from the beach during storm conditions.

Strandline — Line immediately above high water characterised by deposition of drift material.

Surf Beat — Periodic rise and fall in coastal water levels caused by two or more different wave trains arriving at the shoreline.

Surf Zone — Coastal waters between the breaker zone and the swash zone characterised by broken swell waves moving shorewards in the form of bores.

Surging Waves — The wave does not "break" but maintains its basic shape as it moves towards the shore, where it surges up the beach. Very little white water is evident before surging waves reach the shore.

Swash Zone — That area of the shoreline characterised by wave uprush and retreat.

Swell Profile — Another term for accreted profile.

Swell Waves — Wind waves remote from the area of generation (fetch) having a uniform and orderly appearance characterised by regularly spaced wave crests.

Swept Prism — The active area of the coastal system in which sediment may be mobilized by the forces of wind and wave action. On a sandy beach, it extends into the dune system and offshore to the limit of the nearshore zone.

Tidal Prism — The volume of water stored in an estuary or tidal lake between the high and low tide levels; the volume of water that moves into and out of the estuary over a tidal cycle.

Tides — The regular rise and fall of sea level in response to the gravitational attraction of the sun, moon and planets. Tides along the New South Wales coastline are semi-diurnal in nature, i.e. they have a period of about 12.5 hours.

Training Walls — Walls constructed at the entrances of estuaries and rivers to improve navigability.

Tsunami — Long period ocean waves generated by geological and tectonic disturbances below the sea. Incorrectly referred to as "tidal waves", Tsunami travel at speeds of up to 800 km/hr in the open ocean, where they are of low height. However, tsunami can rise to a height of 10m or more through the shoaling process as they approach land.

Vegetation Degradation — The process by which coastal vegetation is "degraded" or damaged; this reduces the effectiveness of vegetation in protecting coastal landforms and increases the potential for erosion of underlying soil materials by wind (resulting in sand drift), water or waves.

Wave Energy Rose — A representation in the form of a compass rose of the directions and frequency of incident wave energy arriving at the location of interest.

Wave Height — The vertical distance between a wave trough and a wave crest.

Wave Hindcasting — The estimation of wave climate from meteorological data (barometric pressure, wind) as opposed to wave measurement.

Wave Length — The distance between consecutive wave crests or wave troughs.

Wave Period — The time taken for consecutive wave crests or wave troughs to pass a given point.

Wave Rider Buoy — A floating device used to measure water level variations caused by waves. It is approximately 0.9m in diameter and is moored to the sea floor.

Wave runup — The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.

Wave Setup — The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.

Wave Train — A series of waves originating from the same fetch with more or less the same wave characteristics.

Wind Setup — The increase in mean sea level caused by the "piling up" of water on the coastline by the wind.

Wind Waves — The waves initially formed by the action of wind blowing over the sea surface. Wind waves are characterised by a range of heights, periods and wavelengths. As they leave the area of generation (fetch), wind waves develop a more ordered and uniform appearance and are referred to as swell or swell waves.

Windborne Sediment Transport — Sand transported by the wind. Sand can be moved by the processes of suspension (fine grains incorporated in the atmosphere), saltation (medium grains "hopping" along the surface) and traction (large grains rolled along the surface).

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APPENDIX A : NSW COASTLINE HAZARD POLICY

APPENDIX A

APPENDIX A NSW COASTLINE HAZARD POLICY

In June 1988 Cabinet adopted a Coastline Hazard Policy involving:

a) provision, under the proposed Coastline Hazard program, of financial and technical assistance to local government on the basis of 1:1 subsidy, (1 State : 1 Council);

b) production of a Manual to assist local government in dealing with coastline hazards and with new coastline development proposals;

c) amendment of the appropriate Act to provide Councils and other public authorities and their staff with immunity from liability in respect of advice provided or acts done in good faith in respect of coastline hazard matters, provided they follow the principles set down in the Manual; and

d) amendment of appropriate Acts to allow Councils and other authorities to provide rate relief in respect of vacant land which cannot be developed because of planning decisions made in response to coastal hazards caused by oceanic processes.

In more detail, the Policy adopted is set out below.

Preamble

The coastline of NSW is under constant attack from the natural forces of the wind and waves. Consequently, much development is under threat from the hazards of erosion and recession of the coastline, and from inundation by the ocean.

In many places, beaches are receding at a significant rate, with implications both for existing development and for the siting of future development. Recession of the coastline may also result in the loss, not only of beaches but of public reserves and facilities along with a uniquely Australian landscape.

The situation is being exacerbated by the "greenhouse" effect which, inter alia, involves an increase in average world temperature, a consequent expansion of water in the upper layers of the ocean and a world wide sea level rise which is already being recorded in Australia.

Construction of protective works is not necessarily the solution to coastal hazards, as in many cases these can cause loss of the beach amenity, and can have adverse impacts on other parts of the coastline. The answer, where existing development is at risk, lies in an understanding of the forces at work and the application of management measures appropriate to the situation. Elsewhere, pre-planning should aim at ensuring that any development will be compatible with the degree of hazard.

The Government is concerned that much coastline development has in the past occurred in ignorance of, or without regard to, its potential for damage or inundation by storm seas, or the less obvious, but inevitable effects of coastline recession. The Government therefore desires that the coastline be managed in an integrated fashion so that its natural and man-made values will be conserved for posterity, but with regard being had to the legitimate needs of society to enjoy, occupy and use coastal areas.

Policy Statement

The primary objective of the Coastline Hazard Policy is to reduce the impact of coastal hazards on individual owners and occupiers, and to reduce private and public losses resulting from natural coastal forces. Consequently, it is the policy of the NSW Government that:

- the impact of coastal forces on existing developed areas shall be reduced by works and measures and by the purchase of property on a voluntary basis, where appropriate;

- the potential for coastal damage in respect of any proposed coastline development shall be contained by the application of effective planning and development controls by local councils; and

- a merit approach to all development and building decisions which takes account of social, economic and ecological as well as oceanic process considerations, shall be followed by local councils and developers.

Implementation Strategy

1. The Government intends to lead by example. It therefore requires all government departments, authorities and instrumentalities to comply with the Policy, its spirit and this implementation strategy.

2. Authorities must have regard to social, economic and ecological considerations, as well as the potential impact of oceanic process on proposals and the impact of proposals on oceanic processes.

3. Management of the coastal zone is, primarily, the responsibility of local government, in accordance with its normal responsibilities for local planning and development control. This responsibility is to be discharged through the preparation and implementation of plans of management in the manner depicted hereunder.

4. The State Government will provide, through the Coastline Hazard Program, financial assistance for:

   — the development and implementation of management measures and works, to reduce potential damage from oceanic processes in existing developed areas;

   — construction of works for the conservation and improvement of beaches and public reserves; and

   — the provision of specialist technical advice on coastal hazards resulting from oceanic processes. The Coastline Hazard Program will be administered by the Minister for Public Works.

APPENDIX B

APPENDIX B : COASTLINE PROCESSES

APPENDIX B1 INTERACTION OF COASTLINE PROCESSES

1 INTRODUCTION

Coastal lands are exposed to never ending attack by the sea, the atmosphere and coastal rivers. The waves, increased water levels and winds associated with storms, together with coastal currents and rivers debouching into coastal waters, reshape beaches and shift beach sediments offshore, onshore and alongshore. At best, a restless equilibrium is achieved with sandy beaches waxing and waning in response to the above forces.

The coastal fringe of New South Wales is an attractive area in which to live, work and play. Over 80% of the State's population live along the seaboard. However, improperly sited, poorly designed or inadequately protected coastal developments are exposed to a variety of coastline hazards. Beach erosion, coastal inundation and wind blown sand can damage or destroy coastal developments and reduce beach amenity.

In order to better manage coastline hazards, it is necessary to understand the various processes that cause them. This suite of appendices describes coastal processes of relevance to the New South Wales coastline:

- Storms
- Elevated Water Levels
- Waves
- Currents
- Waterborne Sediment Transport
- Dune Vegetation
- Windborne Sediment Transport
- Rainfall and Runoff
- Coastal Entrances
- Climate Change
- Human Activities

Before describing these processes, Appendix B2 presents a brief description of the geology of the coastline and continental shelf of New South Wales, and the coastline terminology used in this report.

For reasons of convenience, coastal processes have been largely described on an individual basis in these appendices. However, it is essential to appreciate that they do not operate in isolation, but interact with each other, often in quite complex ways. The purpose of this appendix is to briefly highlight these interactions.

2 INTERACTIONS BETWEEN PROCESSES

Figure B1.1 shows the major processes or manifestations of processes that affect coastal areas. There are five major categories:

Astronomical Processes – as manifested in the tidal rise and fall of water levels.

Meteorological Processes – winds, storms, rainfall and climate change.

Hydraulic Processes – water movement, as manifested in waves,changing water levels and currents.

Sediment Transport Processes – sediment movement by water and wind.

Human Activities – the use of the coastal zone for different purposes by various groups of the community.

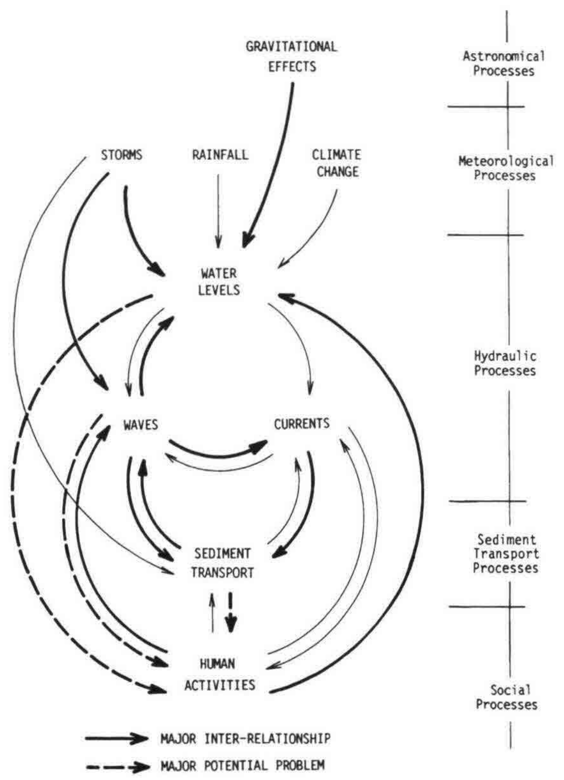

Figure B1.1 Interaction Between Coastal Processes

The first four groups of processes are of a physical nature. They have been studied for many years, and although complex, are now reasonably well understood.

The final group of processes, Human Activities, reflect the many and varied uses of coastal areas by the community and are subject to the economic, political and environmental whims and pressures of our society.

3 EXAMPLES OF INTERACTIONS

Figure B1.1 also shows interactions between the various coastal processes. Significant interactions are shown more prominently. Major potential impacts detrimental to human activities are also highlighted. Three examples serve to illustrate the highly interrelated nature of coastal processes:

First, consider the processes affecting coastal water levels. Water levels are increased by storms (storm surge), rainfall (flood levels in estuaries), the gravitational effects of the planets and moon (tides), climate change (the Greenhouse Effect) and waves (wave setup).

Second, consider wave behaviour. This is the result of storms (generation of waves by wind), currents (refraction of waves), water levels (wave depth on breaking), offshore bathymetry (sediment movement) and human activities (e.g. dredging or breakwaters).

Finally, consider the detrimental impact of coastal processes on human activities. Waves can destroy our coastal structures; elevated water levels can flood coastal developments and erosive sediment transport can wreak havoc on coastal structures and beaches.

In describing the various coastal processes in the following appendices, reference is made to these interrelationships. However, this is necessarily brief and the complex nature of their interactions should be borne in mind when reading Appendix B.

APPENDIX B2 BACKGROUND INFORMATION

1 INTRODUCTION

The present coastline of NSW and its features have been shaped by geological processes over the ages. This appendix briefly describes the four major geological units of the coastline, the relief of coastal and continental shelf areas, and the resulting three representative coastline types of the New South Wales coast. The variation of coastal water levels over the last 250,000 years is also presented. For much of this time, the "beaches" of New South Wales were located around the edge of the continental shelf, some 20 to 60km seawards of their present position. Finally, the coastline terminology adopted in this report is presented.

The overview presented in this section is largely a summary of information presented in Chapman (1982) prepared for the Coastal Council of NSW.

2 GEOLOGICAL FRAMEWORK

The coastline and continental shelf of NSW were formed during the last 500 million years by three major geological events. First, the underlying rocks of the coastal area were laid down over the period 500 to 350 million years ago. Next, two major sedimentary basins were formed along the central and northern regions of the coast during the period 250 to 120 million years ago. Finally, tectonic events between 120 to 60 million years ago gave rise to the major features of the existing coastal and continental configuration (see Chapman et al., 1982 for further details). Over the last 60 million years, the coastal and continental features have weathered in response to climate and sea level changes.

Figure B2.1 shows the four principal geologic units of the New South Wales coastline. These

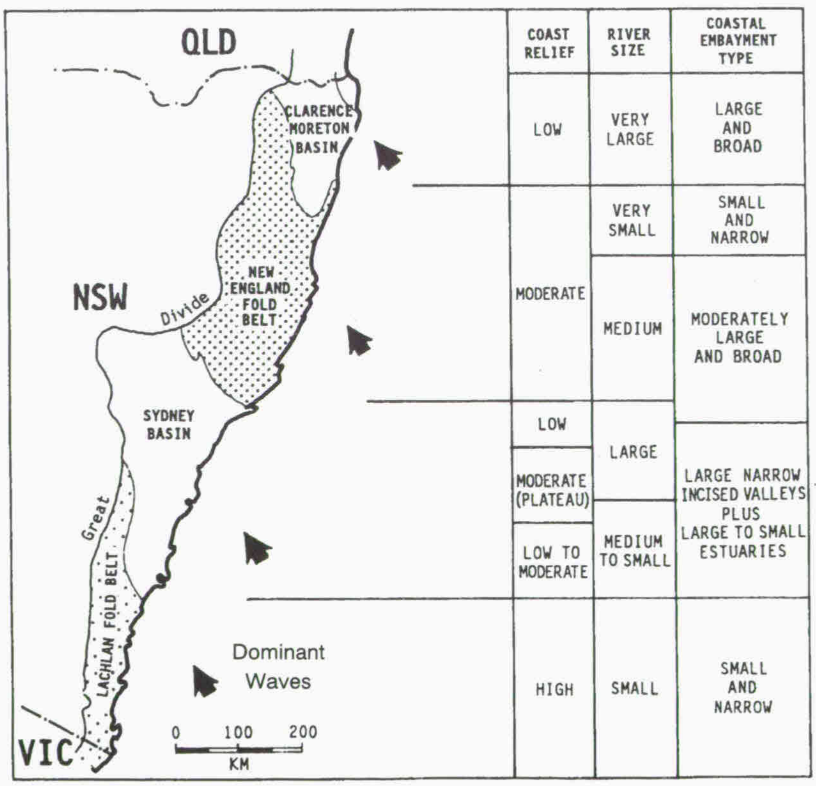

Figure B2.1
Main Geological Units of the New South Wales Seaboard (after Chapman et. al., 1982)

comprise two fold belt structures and two sedimentary basins:

- the Lachlan Fold Belt in the south;
- the New England Fold Belt along the central and north coast;
- the Sydney Basin along the central coast; and
- the Clarence-Moreton Basin in the north.

3 COASTAL FEATURES

Figure B2.1 also indicates how coastal relief, river size and embayment type are related to these four major geologic features. Coastal relief in the fold belt areas is high to moderate; relief in the basin areas is low to moderate. Rivers of the fold belt regions vary in size from very small to medium; rivers of the basin areas vary in size from small to very large. In the south (Lachlan Fold Belt) coastal embayments are generally small and narrow, and consist of "pocket beaches" flanked by rocky headlands that project seawards into deep water. In the north (Clarence-Moreton Basin) coastal embayment are generally large and broad with less prominent headlands. Along the central region of the coast (Sydney Basin and New England Fold Belt) embayments are variable in size and features. Figure B2.2 shows typical north and south coast embayments.

Figure B2.2 Coastal Embayments, North and South Coasts, New South Wales

4 COASTLINE TYPES

There are a variety of ways in which the coastline can be classified, the appropriate one depending to a large extent on the purpose for which the classification is being made. In this manual a classification has been adopted which allows convenient discussion of the relative importance, and means of management of the various coastline hazards identified. This classification divides the coast into three types:

- Sandy Beaches
- Coastal Bluffs
- Rocky Sea Cliffs

Figure B2.3 shows photographs of each type.

Sandy beaches are typified by the rapid fluctuation, (erosion and accretion), of the beach in response

Figure B2.3 The Three Coastline Types of New South Wales: Sandy Beaches, Coastal Bluffs and Sea Cliffs to changing wave conditions which may be overlaid by longer term recession or progradation. Coastal bluffs are typically relatively steep slopes of cohesive soils, often overlying rock platforms. They may suffer relatively rapid erosion with no corresponding accretion and suffer from stability problems induced by a variety of processes. Rocky sea cliffs are near vertical cliffs of rock characterised by slow erosion but by sudden collapse. The timing and extent of the collapse is determined by the internal structure rather than by the erosive process.

5 THE CONTINENTAL SHELF

The continental shelf is a major physical feature that modifies coastal processes. Figure B2.4 shows the profile of the continental shelf at five locations along the New South Wales coast. At a depth of 100 to 150m, the shelf falls away into the continental abyss, which reaches a depth of some 4,000m. The shelf varies in width from about 20 to 60km, being generally narrower and steeper in the south.

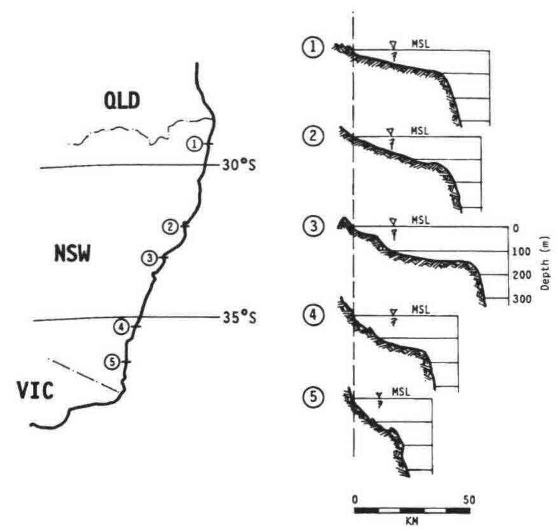

Figure B2.4 Profiles of the Continental Shelf, New South Wales

In discussing the processes that shape and affect the NSW coastline, it is the inner shelf areas that are of most significance. Storm waves generated hundreds or thousands of kilometres out to sea travel across the ocean and the outer shelf region without "feeling bottom". Bottom effects only begin to significantly modify wave behaviour when waves enter inner shelf areas about 60m deep (see Appendix B5). Large scale and complex currents are generated over the continental shelf ("Shelf Currents"). These are described in Appendix B6 and represent the only coastal process of relevance to this manual in which the whole shelf area is of significance.

6 PAST SEA LEVEL CHANGES

Figure B2.5 shows the estimated variation in coastal water levels along the New South Wales over the last 250,000 years (Chapman et al., 1982). For some two thirds of this time, sea level has been in the range 20m to 70m below present level. The highest it has risen is 5m above present level; the lowest it has fallen is 140m below it's present level.

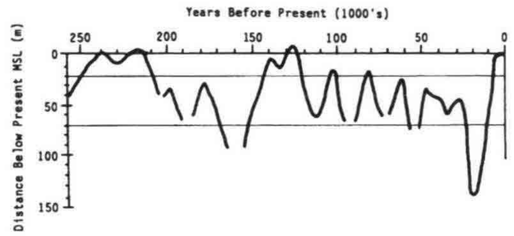

Figure B2.5 Variation in Mean Sea Level over the Last 250,000 Years

The above sea level variations are attributed solely to the effects of temperature changes in the earth's atmosphere, which are reflected in the expansion and contraction of water in the oceans and the formation and melting of glaciers. The coastline of New South Wales has been tectonically stable over this period of time. Subsidence of the coastline has been estimated at only 0.01 mm/year or less (Chapman, et al., 1982).

The most recent rise in sea level has been both rapid and extreme. Over the period 17,000 to 6,000 years BP, ocean levels rose by some 140m to the present level, i.e. 17,000 years ago waves were breaking around the edge of the continental shelf.

7 COASTAL ZONE TERMINOLOGY

Figure B2.6 shows a typical cross-section of a "sandy beach" coastline. It consists of four major zones: the offshore zone, the nearshore zone, the inshore zone and the onshore zone. Taken together, the last three zones constitute the Coastal Zone of this manual.

Offshore Zone

The Offshore Zone is sufficiently deep that wave behaviour is not modified by the presence of the sea bottom. The landward limit of the Offshore Zone lies on the continental shelf around the 60m depth contour. The behaviour of large swell waves begins to be significantly influenced by bottom effects at about this depth.

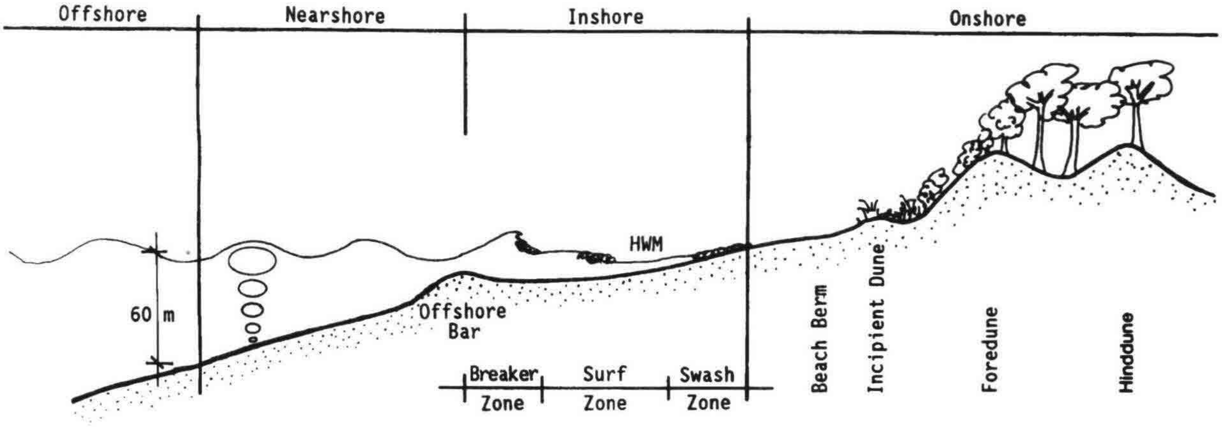

Figure B2.6 Coastal Zone Terminology

Nearshore Zone

Within the Nearshore Zone, the sea bottom influences wave behaviour through shoaling and refraction effects, but large swell waves remain unbroken. The seaward limit of the Nearshore Zone is marked by the 60m depth contour; the landward limit is marked by the Offshore Bar on which waves break.

Inshore Zone

The Inshore Zone extends from the Offshore Bar to the upper limit of the swash zone. It is characterized by breaking waves and broken wave behaviour.

The Inshore Zone is divided into three further zones: the Breaker Zone, the Surf Zone and the Swash Zone. Waves break in the Breaker Zone; they move towards the beach as a "surge" or a "bore" in the Surf Zone; they wash up and down the beach in the Swash Zone.

Onshore Zone

The onshore zone is the land portion of the coastline. It runs inland from the swash zone and may consist of a beach berm and dunefield (Figure B2.6), a coastal bluff or sea cliffs.

A dunefield can be sub-divided into incipient dunes, foredunes and hindunes. During storm wave attack, sand from the beach berm, the incipient dune and the foredune is often carried offshore. This sand is returned to the shore and the beach is rebuilt during calm weather conditions (Short and Hesp, 1982 and Hesp, 1984).

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APPENDIX B3 STORMS

1 INTRODUCTION

A storm is a major meteorological disturbance generally caused by low atmospheric pressures. Storms are of a temporary nature and are characterised by strong winds, raging seas and possibly heavy rain. An intense storm close to the coast can severely erode the shoreline and damage coastal developments. Even storms located a long distance offshore can generate heavy ocean swells which reach and attack the coast.

Storms can wreak damage along the entire length of the New South Wales coastline. The photograph of Figure B3.1 shows the type and extent of damage associated with major storm events.

2 THE IMPACT OF STORMS ON THE COAST

Storm winds cause direct damage to coastal developments, e.g. unroofing buildings, uprooting trees, bringing down power lines and even causing the collapse of buildings. This direct wind damage can extend many kilometres inland.

The windborne sediment transport associated with strong storm winds accelerates the migration of coastal sand dunes and the smothering of coastal developments (see Appendix B9).

Storms are responsible for the generation of large and potentially destructive waves (see Appendix B5).

The significant increase in coastal water levels caused by storm induced wind and wave setup intensifies wave damage to beaches and coastal structures and coastal flooding problems (see Appendix B4).

The elevated water levels and large waves associated with storms are a major cause of beach erosion (see Appendix B7).

3 STORM TYPES

Storms along the NSW coast have been classified into the six types listed below. Figure B3.2 shows characteristic synoptic patterns (PWD, 1985) of the first four storm types, which are the more important

Figure B3.1
Storm Damage to Beaches and Coastal Structures, New South Wales.

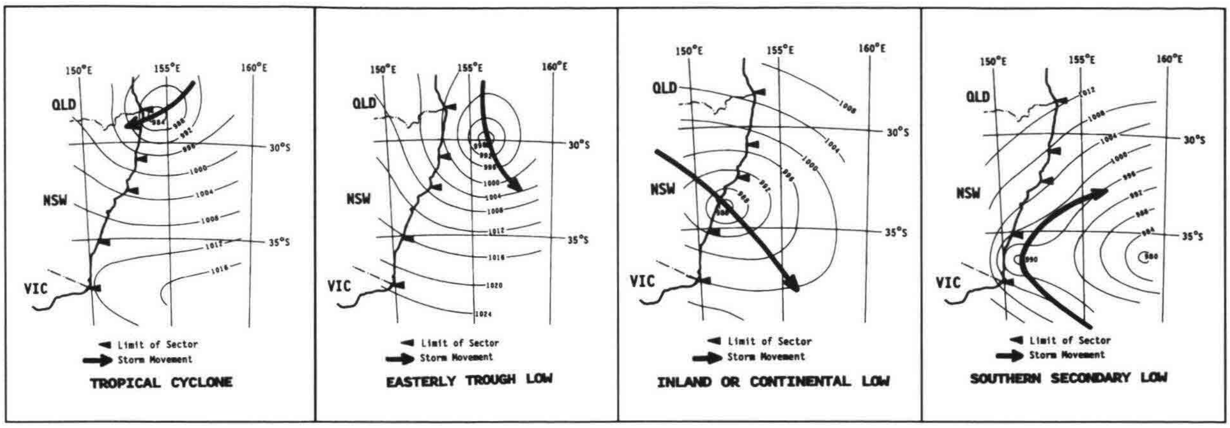

Figure B3.2 Typical Synoptic Patterns of Different Storm Types Affecting the New South Wales Coast

with regard to coastal processes in NSW:

- Tropical Cyclone
- Easterly Trough Low
- Continental Low
- Southern Secondary Low
- Inland Trough Low
- Anti-Cyclone Intensification

4 COASTAL SECTORS

The coastline of NSW has been divided into four sectors on the basis of storm types generally experienced in each sector. These sectors are shown in Figure B3.3 and correspond approximately to Bureau of Meteorology forecasting districts.

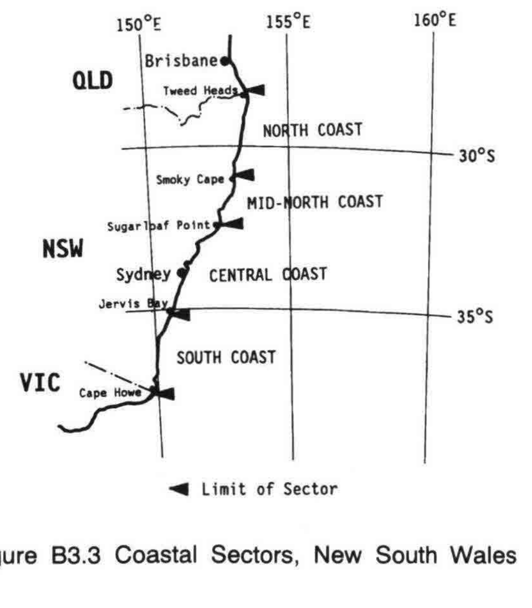

Figure B3.3 Coastal Sectors, New South Wales

5 STORM LOCATION AND SEASONALITY

The occurrence of the six storm types in each of the four coastal sectors is shown in Figure B3.4. These results are based on an analysis of 50 years of storm data (PWD, 1985). Tropical cyclones are experienced mainly in the North Coast sector. The majority of storm events on the North and Mid-North Coasts are due to locally formed Easterly Trough Lows and Tropical Cyclones. Southern Secondary Lows predominate in Central and South Coast sectors.

The various storm types generally display a distinct seasonality, i.e. certain types of storm are more likely to occur during a particular period of the year. Details are shown in Table B3.1. The seasonal occurrence of all storm types for each of the four coastal sectors is shown in Figure B3.5.

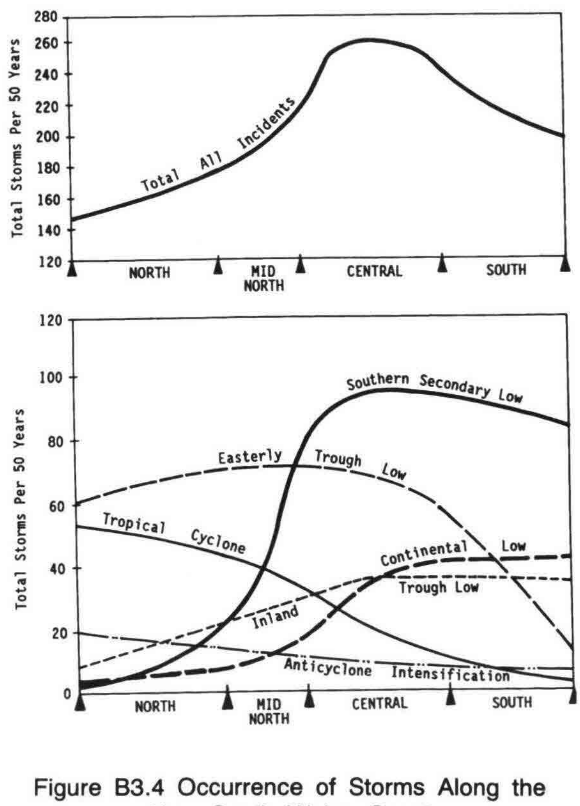

Figure B3.4 Occurrence of Storms Along the New South Wales Coast

Table B3.1
Likely Season of Storm Occurrence

Storm Type	Likely Season of Occurrence
Tropical Cyclone	Summer
Easterly Trough Low	Autumn & Winter
Inland Trough Low	Summer & Autumn
Continental Low	Winter & Spring
Southern Secondary Low	Autumn, Winter & Spring
Anti–cyclone Intensification	Summer & Autumn

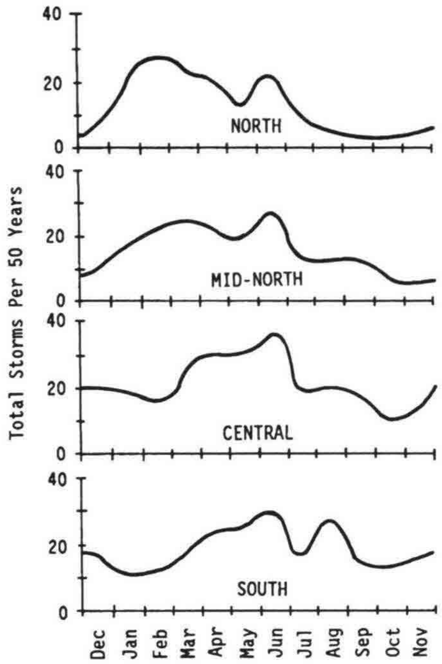

Figure B3.5 Seasonal Variation in Storm Occurrence, NSW Coastal Sectors

6 STORM SEVERITY

The central pressure of the storm is a good indicator of its severity and the likely strength of the winds it generates. However, the impact of a storm on the coast depends upon its location, movement and the extent and duration of strong winds. The resulting wind speed, storm surge level and wave height can all be used as measures of storm severity. A classification of storm severity based on significant wave height is given above (PWD, 1985, 1986b).

Table B3.2
Classification of Storm Severity

Storm Category	Storm Description	Significant Wave Height (m)
X	Extreme	>6
A	Severe	5.0-6.0
B	Moderate	3.5-5.0
C	Low	2.5-3.5

7 STORM FREQUENCY AND GROUPING

Minor to moderate storms occur frequently along the NSW coastline. Such storms do not have major impacts on the coast or coastal developments.

Severe storms of categories A and X, in which the significant wave height exceeds 5m, can be expected to occur on average four times per year somewhere along the NSW coast. The occurrence of major storms over the period 1880 to 1985 is shown in Figure B3.6. The past twenty five years have been relatively calm in comparison to the longer term storm record, even allowing for the major storms of 1967, 1974 and 1978.

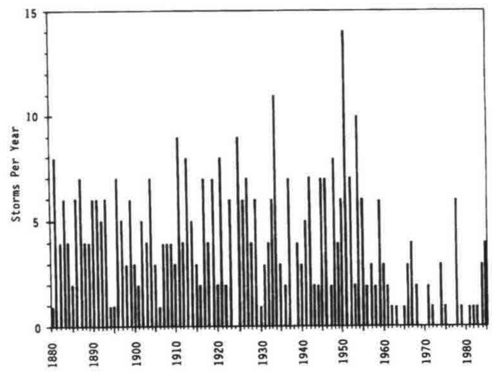

Figure B3.6 Occurrence of Major Storms, New South Wales Coastline, 1880-1985

Storms have a tendency to occur in groups. A useful measure of this grouping is the interval between successive storm events. On the central coast, some 40% of storms occur within 30 days of the previous storm and 60% occur within 60 days of the previous storm event.

There are a number of other factors which affect the impact of storms on the coastline, particularly with respect to their erosive capability. Storm duration, the incidence of high tides during and immediately after a storm are important examples. There is no single satisfactory measure of the damage potential of a storm or series of storms but the above sections provide some indication of the factors involved.

The erosive impact of storms on sandy beaches is discussed in Appendix C. Examples of long-term data sets illustrating beach fluctuations are those collected at Moruya and Narrabeen by members of the Coastal Studies unit, University of Sydney (Thom and Hall (in press)) and Hall, 1988).

8 THE DESIGN STORM EVENT

Typically, coastline hazard is assessed in terms of the likely impact of a design storm event. The selection of an appropriate design event is governed by many factors, including safety aspects, likely damage and social disruption, all of which depend upon the type and nature of the development. It should be noted that longer term coastal changes, such as shoreline recession and sea level rise, also affect the damage potential of the design storm event. Recession exposes additional development to storm hazard; elevated sea levels allow larger storm waves to attack the coast.

Typically, a design storm event is specified in terms of its "Annual Exceedance Probability" (AEP), e.g. the 5% storm event. There is a 5% chance of such a storm occurring in any year. On average five such storms would be expected to occur in a period of 100 years, i.e. the average recurrence interval of a storm of this severity is 20 years.

The coast can experience the design storm event at any time. Long periods of relative calm, as experienced in the past decade, can give a false sense of security.

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APPENDIX B4 ELEVATED WATER LEVELS

1 INTRODUCTION

Coastal water levels are influenced by a variety of astronomical, meteorological/oceanographical and tectonic factors, the most readily apparent being the tides. At times, these factors interact in a complex way to elevate water levels significantly above normal tide level. Storms, which develop low atmospheric pressure, strong onshore winds and large waves, are the most common cause of elevated water levels.

Elevated water levels are of concern because they intensify damage to the coastline and to coastal developments. Elevated water levels allow larger waves to cross offshore bars and break closer to the beach, which in turn increases beach erosion and the threat to coastal developments. Elevated water levels can inundate low lying areas of the coastline and around estuaries.

2 ASTRONOMICAL TIDES

The astronomical tide is caused by the gravitational effect of the moon, and to a lesser extent, the sun and other planets on the water mass of the oceans. Along the NSW coast, tides are semi-diurnal, i.e. two high tides and two low tides per day.

Tidal ranges vary significantly throughout each lunar month and from month to month. Very high and very low tides occur more frequently around Christmas and in the mid-winter months (King Tides). The tidal range is relatively constant along the open coast of New South Wales. The spring tide range is about 1.8 to 2.2m.

Detailed tidal predictions for the NSW coast are published annually by the Hydrographer of the Royal Australian Navy in the form of Tide Tables. The Maritime Service Board publishes summary tidal information.

3 METEOROLOGICAL/OCEANOGRAPHICAL PROCESSES

Three different meteorological processes can affect coastal water levels:

- storms
- meteorological oscillations
- climate change

Storms are local meteorological disturbances. The other two processes are semi-global or global in nature. Climate change, including the Greenhouse Effect, is discussed in some detail in Appendix B11.

Storms

The elevation of water level associated with a storm depends primarily on the following factors:

- the intensity, scale and direction and speed of movement of the storm;
- the bathymetry of the coastal area, including the presence or otherwise of offshore reefs and islands;
- the shape of the coastline, including the topography of the nearshore areas which may be inundated; and
- the prevailing astronomical tide.

A storm increases coastal water levels in four distinct ways: by "setup" due to barometric, wind and wave effects and by wave "runup". Figure B4.1 illustrates these components of elevated water levels. Table B4.1 shows typical values for New South Wales. The four components are all additive and their sum represents the superelevation of storm water level above prevailing astronomical tide level.

Table B4.1
Elevated Water Level Components Due to Storms

Component	Typical range (m)
Barometric setup	0.2 - 0.4
Wind setup	0.1 - 0.2
Wave setup	0.7 - 1.5
Wave runup	3.0 - 6.0
Total Setup plus runup	4.0 - 8.0

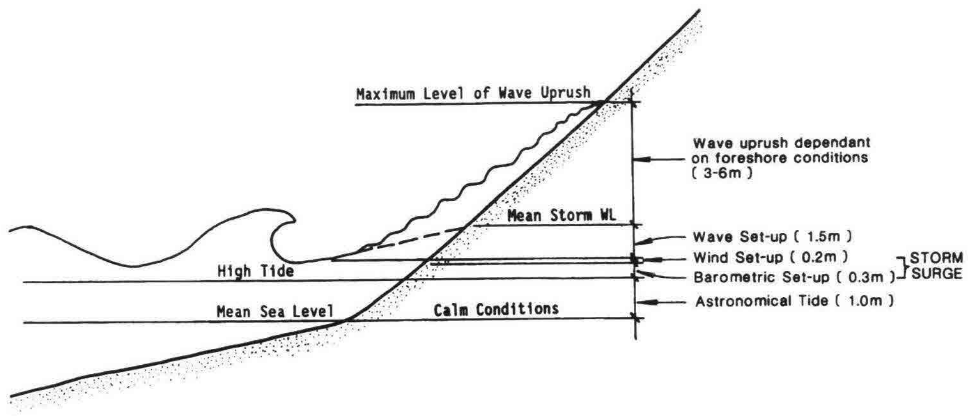

Figure B4.1 Elevated Water Levels During a Storm

Barometric setup

The reduced barometric pressures that generate storm winds also cause a local rise in ocean level (the inverse barometer effect). Providing low pressures persist for a sufficient length of time, the increase in water level amounts to about 0.10m for each 10hPa drop below normal barometric pressure (1,013hPa). In a severe storm with a central pressure of 980hPa, this amounts to about 0.3m.

Wind setup

Wind blowing onshore over the ocean's surface drives the surface waters before it and against the coastline. This results in elevated water levels in coastal areas, the degree of elevation being higher for extensive shallow areas and semi-enclosed bays.

Wind setup is much more severe in north Queensland waters because of the extensive shallow waters associated with the wide continental shelf and the presence of the Great Barrier Reef. Along the Mackay/Rockhampton coast, the continental shelf is 200 to 250km wide; along the New South Wales coast, the shelf is only 30 to 60km wide (see Appendix B2).

Storm Surge

The sum of barometric and wind setup is often referred to as storm surge. Along the New South Wales coast storm surge amounts to 0.3 to 0.6m.

Wave setup

The breaking action of waves results in an increase in water levels in the surf zone known as "wave setup". Wave setup is associated with the conversion of the wave's kinetic energy into potential energy (Battjes, 1974). The degree of setup depends upon the type, size and period of the waves at breaking and the slope of the beach.

On the New South Wales coast wave setup during severe storms can be in the order of 1.5m and often makes the largest contribution to the elevated water level.

Wave runup

Wave runup is an oscillatory phenomenon and refers to the vertical distance the uprush of water water from a breaking wave reaches above the combined level of the tide, storm surge and wave setup. A wave runup of more then 6m can occur. The magnitude of runup depends upon a variety of factors, particularly the slope and roughness of the runup surface. Runup on flat beaches is generally less than on steeper beaches; runup on smooth vertical sea walls is generally greater than on protective works with rough sloping faces.

Wave runup can result in the intermittent discharge of seawater into backbeach areas that may appear to be protected by beach barriers, such as sand dunes or seawalls.

Rainfall Runoff

Surface runoff from any rainfall accompanying a storm may cause an increase in water levels within estuaries and tidal inlets. Rainfall and runoff have no significant effect on coastal water levels.

Oceanographic Effects

Distant meteorological disturbances (say in Bass Strait) that are characterised by a sharp pressure gradient can generate a long low wave with a period of up to 10 days and a height of up to 0.2m. As this wave travels along the continental shelf, it becomes a "shelf wave" that is "trapped" by the shelf which acts as a wave guide. Shelf waves also modify coastal water levels.

Other effects which can result in tidal anomalies include variations in sea temperature and salinity and the influence of strong currents such as the Eastern Australian Current. (Davidson et al 1989).

Meteorological Oscillations

Major meteorological phenomena such as the El Niño Southern Oscillation (ENSO) affect water levels along the NSW coastline. ENSO results from interactions between the atmosphere and major ocean currents over the Pacific Ocean and appears to occur about every three to seven years. ENSO is thought to have a major impact on climate over the the eastern half of Australia, particularly with regard to the sequence of "dry" and "wet" years. The associated water level change along the New South Wales coast attributed to ENSO is ±0.1m. The relationship between ENSO induced rainfall and beach erosion is examined by Bryant (1983 and 1985).

Climate Change

A "eustatic" sea level change refers to a change in the mean water level of the oceans around the globe. A eustatic rise can occur through two mechanisms: the expansion of the surface waters of the ocean caused by a global warming and by the melting of land-based glacier ice that accompanies any such warming. In the initial period of any global warming, i.e. the first 50 to 100 years, the first effect will be the more significant.

The period 17,000 to 6,500 years B.P. saw the demise of the last ice age and the release of vast volumes of frozen water. The eustatic sea level rise associated with this event was approximately 140m. In response to this sea level rise, the shoreline of Australia retreated landwards from around the edge of the continental shelf to its present position (see Appendix B2). Ocean water levels appear to have remained relatively stable over the last 6000 years.

4 TECTONIC PROCESSES

The two tectonic processes that could potentially affect water levels along the NSW coast are subsidence or emergence of the crustal plate on which the coastline of New South Wales rides and the effects of tsunami generated by undersea landslides.

Crustal Movements

Tectonic uplift or sinking is often perceived as a change in MSL (as the land emerges from the sea, MSL is perceived to have fallen). Whilst such changes are occurring in North America and elsewhere, it is believed that they are not taking place along the NSW coast, or if they are occurring they are very small (less than 0.01mm/year - see Appendix A2).

Tsunami

Tsunami, which are caused by sea bed earthquakes, are incorrectly called "tidal waves". Australia is remote from the more active seismic areas of the world. Water level anomalies along the NSW coast due to tsunamis have occurred but are rare.

Studies of Fort Denison tide gauge records from 1867 onwards have identified a number of water level anomalies due to tsunami, the three largest of which occurred in 1868, 1877 and 1960 (PWD, 1985). Water level changes of 1.07m accompanied the 1868 and 1877 events. In 1960 a tsunami resulting from a severe earthquake in Chile caused the water level at Fort Denison to oscillate through a range of 0.84m over a 45 minute period. These rapid water level changes induced strong currents in Sydney Harbour and nearby ports and bays, causing considerable damage to boats and shoreline structures. The damage caused by this tsunami was exacerbated by the semi-enclosed nature of Sydney Harbour. The tsunami probably occurred without notice along the open coastline.

Tsunami occur on a random basis and are independent of all other effects causing elevated water levels. The simultaneous occurrence of elevated water levels due to a major storm event and a tsunami is most unlikely.

5 SURF BEATS

When swell waves from two different storm sources arrive simultaneously at a beach, the resultant waves tend to occur in consecutive groups of large and small waves (leading to the popular belief that every seventh wave is the largest). This has the effect of inducing periodic water level fluctuations in the amount of wave setup at the shoreline. Longer period water level fluctuations (2 to 3 minutes) are often referred to as "surf beat" and may have amplitudes of up to 0.5m.

6 TIDE MEASUREMENT

The Public Works Department and the Maritime Services Board have been measuring tidal data along the NSW coast for the last 100 years or so. Various instruments are used to collect the data which essentially is in the form of water level against time. There exists a substantial data base of tidal information which is presently being integrated into a state database. The recently formed NSW Committee on Tide and Mean Sea Levels coordinates tidal information for NSW (Wylie et al 1990).

7 DESIGN CONSIDERATIONS

Determination of appropriate design water levels for coastal developments requires first, an assessment of each component of elevated water level at the subject site and second, the combining of these components in a realistic and statistically meaningful way. Simple addition of the values for each element is not necessarily appropriate and will usually result in a conservative design value.

In considering the selection of appropriate design levels there is a further issue to be considered. Reference to Figure C9.2 shows not only a long-term trend of increasing sea level, (discussed in more detail in the context of climate change), but a considerable fluctuation in annual mean sea level with an apparent period of the order of a decade and with a magnitude of about 0.1 to 0.2m. This fluctuation is not entirely explained by the various factors discussed in the foregoing sections. The possibility of annual mean sea level varying from the long-term trendline should therefore be considered in any assessment of design levels.

Estimation of Water Level Components

Design values for water level components can be determined from measured values (if available), from analytical formulae or by numerical simulation.

Tidal data for New South Wales are available for many ports and extend over a considerable period of time, (PWD 1989). These data can be used to estimate tidal behaviour at unreferenced locations. At sites where tidal effects may be significantly modified by the local bathymetry, a "harmonic analysis" of measured tidal data may be required to better define likely tidal behaviour. This requires water level data collected at the site over a period of time, the length of which depends on the complexity of the tidal system and the accuracy sought.

Mathematical modelling is necessary to derive long-term storm statistics at specific sites. Computer simulation has been used for wind field modelling (Graham and Nunn, 1959) and for storm surge modelling (Sobey, Harper & Stark, 1977).

Wave setup may be calculated using simplified methods found in the Shore Protection Manual (CERC, 1984) or by using computer models where the offshore bathymetry is complex and natural wave spectra are being considered (Goda, 1975). Field measurements of wave setup are available at a limited number of locations (PWD, 1988; Nielsen, 1988; Davis and Nielsen, 1988).

Wave runup is a function of the beach profile, surface roughness and other shoreline features effecting breaking waves at the particular site. Physical model results are available in the Shore Protection Manual for simple beach profiles and wave conditions (CERC, 1984). Where runup levels are of significance, it may be necessary to undertake physical model studies.

Extreme Value Analysis

There is some difficulty in meaningfully combining storm surge statistics with tide height statistics to determine the extreme values of elevated water levels. Methods based on the application of conditional probabilities have been applied (Dexter, 1975; Haradasa et al, 1989), but inconsistencies remain. The mathematical simulation of the occurrence of a large number of random storms with coincident tides is another method of determining the likelihood of extreme water levels (McMonagle and Fidge, 1981).

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APPENDIX B5 WAVES

1 INTRODUCTION

Waves are one of the dominant phenomena that shape a coastline: they are largely responsible for beach erosion, longshore drift and elevated water levels. Waves transport energy from remote areas of the ocean to the coastline. When unleashed in the breaking process, this energy erodes beaches and can damage and destroy coastal structures such as seawalls, jetties and breakwaters.

2 WAVE GENERATION

Waves are generated by wind blowing over the ocean's surface. The area in which waves are generated is called the fetch. The size of waves generated in a fetch depends upon fetch dimensions and wind behaviour. For a given wind speed, wave height will increase with fetch length and wind duration.

Waves generated within the fetch area are called "wind waves" or "sea" and have a random appearance, i.e. there are no regular lines of wave crests. As waves travel outside the fetch area, they take on a more ordered appearance and are called "swell".

Swell can travel many hundreds of kilometres across the ocean from a fetch area. During this process, the waves "decay" by losing energy and height. The rate of decay is greatest for the small short period waves. Large waves of longer period can travel great distances with little decay.

Methods are available that allow the size of waves to be predicted from wind and fetch characteristics. Such methods are known as wave hindcasting, and although approximate, are often the only predictive means available in the absence of measured data (CERC, 1984).

3 WAVE CHARACTERISTICS

Figure B5.1 shows a simple waveform consisting of a crest and a trough. The wave train it represents is characterised by its wave height, wave length, wave period and the speed and direction of travel. The wave period is the time for successive crests (or troughs) to pass a given point.

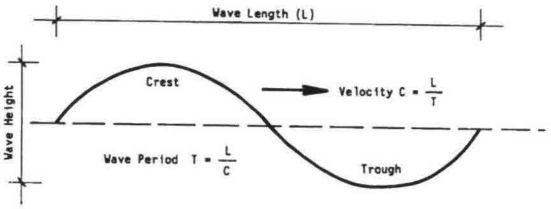

Figure B5.1 Characteristics of Waves

Wave energy is an indication of erosion and damage potential, the higher the energy, the greater the potential for beach erosion and damage to coastal structures. Wave energy is proportional to the square of the wave height multiplied by the wavelength. Thus, the higher the waves or the longer their wavelength, the greater their erosive and damage potential. For the same wavelength, doubling the wave height results in a fourfold increase in wave energy and erosive potential.

4 STATISTICAL REPRESENTATION

Wave behaviour in the ocean is far more complex than depicted in Figure B5.1. The area of interest may be subject to swell waves arriving from a number of different fetches and to locally generated wind waves. Waves arriving from different directions can generate a very confused sea surface which takes on a "choppy" appearance.

Observed wave behaviour is the result of interactions between all wave trains arriving at a location, as shown in Figure B5.2. Thus, wave behaviour is inevitably characterised by a range or "spectrum" of wave heights, periods, lengths and directions of travel. Consequently, it is appropriate to treat wave parameters in a statistical fashion.

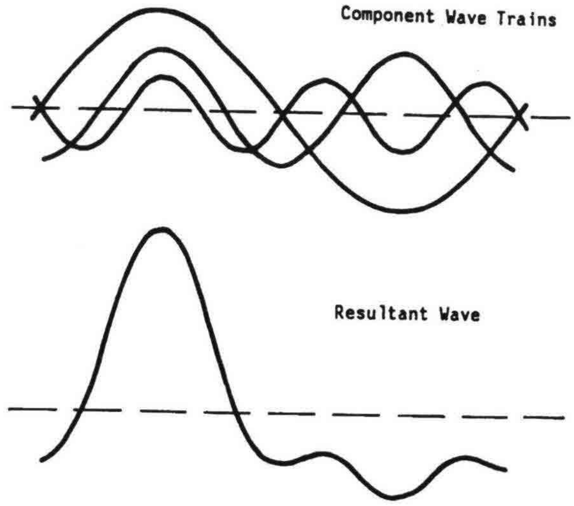

Figure B5.2 The Interaction of Three Simple Wave Trains (After Komar, 1976)

It is often extreme events that are of interest, although periods of calm or average conditions are also important for coastal processes. A common means of presentation of wave climate is in terms of an exceedance plot whereby wave height (or some other parameter) is shown as a function of Annual Exceedance Probability (AEP - see Appendix B3).

Figure B5.3 shows the exceedance plot of significant wave heights for the four sectors of the New South Wales coastline. The "significant wave height" is defined as the average height of the highest one third of waves. In Figure B5.3, significant wave height is plotted against the AEP of storm severity, i.e. the 10% storm event means that there is a 10% chance of a storm of this severity or greater occurring in any one year. The significant wave height associated with the 1% AEP storm event is seen to be considerably greater in the North Coast sector (12.3m) than in the other three sectors (9 to 10m).

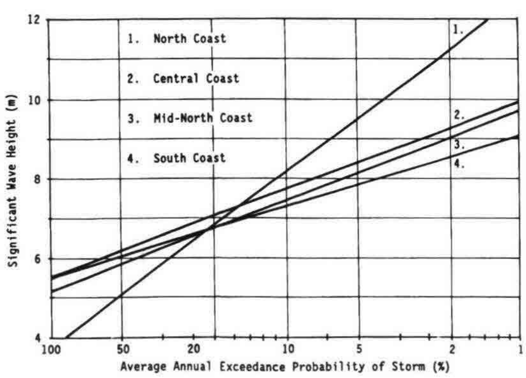

Figure B5.3 Exceedance Plot of Significant Wave Heights, Hindcast Data, New South Wales Coastline

The results of Figure B5.3 are based on 47 years of hindcast data (PWD, 1985). Because of their hindcast nature, these results are regarded as approximate only. Nevertheless, these data are the most comprehensive currently available. The amount of measured wave data being collected along the New South Wales coast by the PWD is constantly increasing (see Section 7 of this Appendix).

5 SUB-SURFACE EFFECTS

Although the motion of water waves is most evident as a surface phenomenon, there are also movements below the water surface that decrease with depth. In deep water, the water particles beneath a wave orbit around a circular path and wave motion does not reach the seabed (see Figure B5.4). In shallow water, the water particles have an elliptical orbit and wave motion is felt at the seabed. In these circumstances, wave-induced oscillatory currents at the sea bottom can mobilise bottom sediments and initiate waterborne sediment transport. For some purposes the measurement and analysis of bottom currents would be more relevant than surface characteristics.

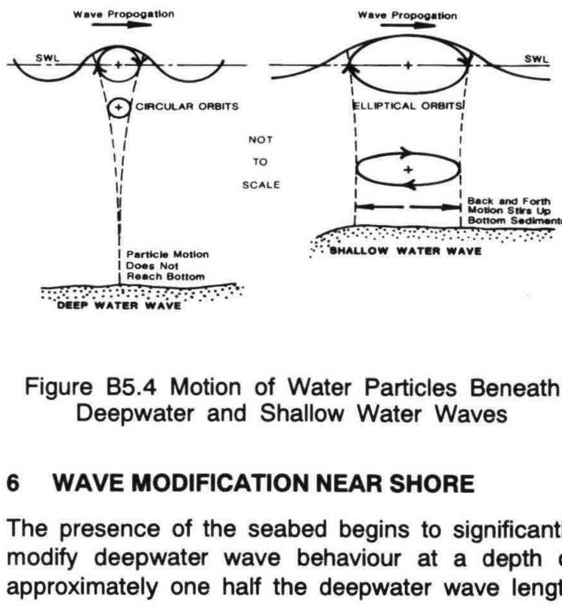

Figure B5.4 Motion of Water Particles Beneath Deepwater and Shallow Water Waves

6 WAVE MODIFICATION NEAR SHORE

The presence of the seabed begins to significantly modify deepwater wave behaviour at a depth of approximately one half the deepwater wave length

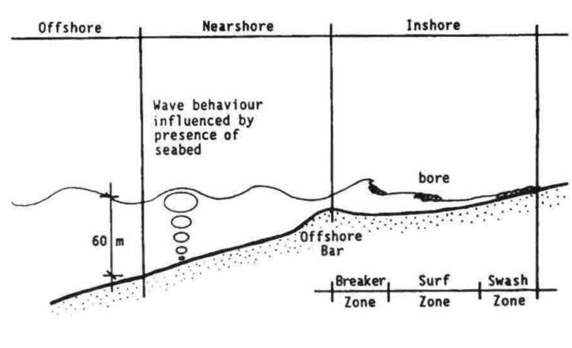

Figure B5.5 Wave Behaviour in the Nearshore and Inshore Zone

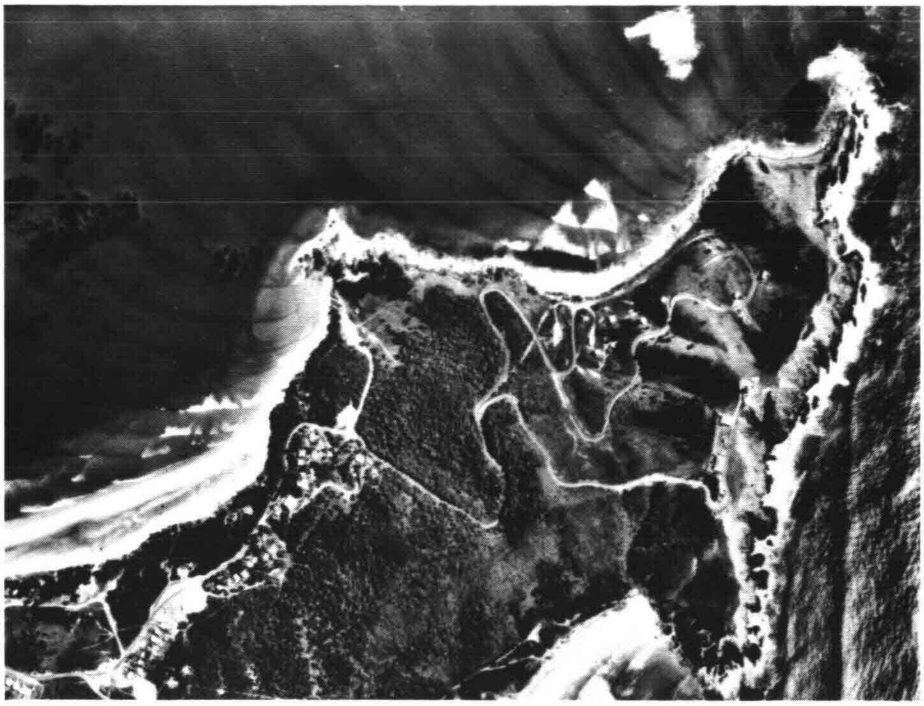

Figure B5.6
Wave Refraction,
Cape Byron,
NSW North Coast.

Figure B5.7
Wave Diffraction,
Physical Model,
Coffs Harbour

(about 60m for ocean swell). This interaction between wave motion and the sea bottom results in several changes to wave behaviour: wave speed and wave length are progressively reduced; wave height, after a small initial reduction, is progressively increased. The increase in wave height culminates in the wave breaking in the "breaker zone", which is typically located around an offshore bar. The broken wave then moves shorewards as a bore in the "surf zone" and ultimately runs up the beach in the "swash zone" (see Figure B5.5).

The morphodynamic coupling of waves and currents with nearshore morphology in the surf zone is analysed further by Wright and Short (1983) and Wright, Short and Green (1985).

Shoaling

Shoaling is the general term for waves moving into shallow water and "feeling bottom". The slower speed of waves in shallow water causes a "bunching up" of wave crests, i.e. wave lengths become shorter.

Refraction

Refraction, refers to the tendency of wave crests, as they move into shallow waters, to come into alignment with bathymetric contours, irrespective of the angle of incidence of the waves to these contours. Refraction can also occur as a result of current action. Refraction results in wave attack being concentrated on headlands. Figure B5.6 shows refracting waves at Cape Byron on the New South Wales North Coast.

Diffraction

Diffraction refers to the transmission of wave energy along wave crests into "shadow" areas created by breakwaters or headlands. Diffracted wave crests are lower and contain less energy than the incident waves. Figure B5.7 shows diffracted waves moving into areas sheltered by breakwaters in a physical model of Coffs Harbour built by the PWD.

These three processes together with reflection in some circumstances, combine to produce a near shore wave climate with wave length, wave height and particularly wave direction being different to those offshore.

Breaking

Breaking occurs when the increase in wave steepness due to shoaling and refraction exceeds a limiting value. Typically, breaking occurs when the water depth is about equal to the wave height. Breaking is one of the main mechanisms for the dissipation of wave energy and is responsible for much of the sand movement within the surf zone. Breaking waves impose much higher forces on structures than equivalent non-breaking waves. Depending upon wave characteristics and the slope of the nearshore seabed, waves break in either a "surging", "spilling" or "plunging" mode, the difference in these types being visually quite obvious.

Reflection

Reflection refers to the re-direction by the shoreline of non-dissipated wave energy back to sea. Reflection is most apparent at solid seawalls where reflected waves can be seen moving seawards, virtually unaffected by incoming waves. Wave motion can be amplified by factors of 1.5 to 1.8 at the point of reflection, which can exacerbate erosion and damage to coastal structures.

7 WAVE MEASUREMENT AND DATA

The Public Works Department, the Maritime Services Board and the Commonwealth Department of Administrative Services all collect basic deepwater wave data along the NSW coastline. The standard instrument used to measure deepwater wave data is the "Waverider Buoy" manufactured by the Dutch firm Datawell. It consists of a stainless steel buoy, 0.7m in diameter, fixed to the seabed by a flexible mooring that allows it to follow movements of the sea surface. An instrument inside the buoy detects and measures these motions, which are transmitted to shore via radio for analysis by computer. Table B5.1 shows details of the location, operating

Table B5.1
Deepwater Wave Data Locations, New South Wales

Location	Operator	Water Depth	Period of Record	
			Start	Finish
Byron Bay	PWD	80m	14/10/76	present
Coffs Harbour	PWD	80m	26/05/76	present
Crowdy Head	PWD	80m	10/10/85	present
Newcastle	MSB	71m	12/02/75	20/10/82
Long Reef	PWD	80m	17/07/87	present
Botany Bay	MSB	73m	18/02/71	present
Port Kembla	PWD	80m	07/02/74	present
Jervis Bay	DAS	50m	01/09/81	present
Batemans Bay	PWD	80m	27/05/86	present
Eden	PWD	80m	08/02/78	present

authority, and periods of record of deepwater wave data along the NSW coast. The locations of the recording stations are shown in Figure B5.8.

In shallow water, other instruments such as wave staffs, pressure sensors and current meters are used to gather wave and current data. These measurements are often used in conjunction with waverider data to infer long-term wave conditions.

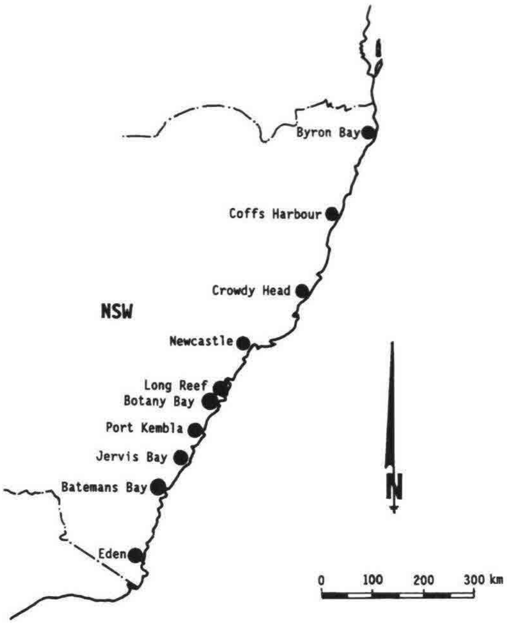

Figure B5.8 Deepwater Wave Recording Stations, New South Wales

8 WAVE DIRECTION

With the exception of current meters, none of the techniques described above provide information on wave direction. Limited directional data are available for the Sydney area from a radar system, but most directional information comes from visual observation or from deductions based on wind patterns supplied by the Bureau of Meteorology.

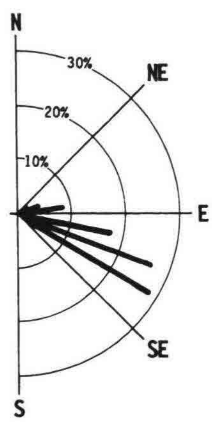

Figure B5.9 Wave Energy Rose, Broken Bay, New South Wales

Because of prevailing weather patterns, most deepwater waves approach the New South Wales coastline from a south-easterly direction. As these waves move into shallower water, refraction and diffraction modify their final direction of approach to the coast.

Figure B5.9 shows the "wave energy rose" at the seabed of the entrance to Broken Bay in 24m of water. These data were obtained with an electromagnetic current meter and depict the directions from which incident wave energy, i.e. the erosion and damage potential of the waves, arrives at this location. Over the period of record, most of the incident wave energy arriving at Broken Bay originated from the ESE direction (55%). Being inferred from near bed current data this method of analysis represents a combination of various incident wave trains.

9 EFFECTS OF WAVES ON THE COASTLINE

Breaking waves, and to a lesser extent non-breaking waves, have great erosive potential. In particular, headlands are subject to concentrated attack as a result of refraction, focusing wave energy onto headlands. During storm conditions, storm waves can cause massive erosion to sandy beaches and foredunes with vast quantities of beach sediments being moved offshore (see Appendix B7). During calm conditions long period ocean swell rebuilds beaches by moving sediment back onshore. Windborne sand is trapped by dune vegetation to rebuild the dune system.

Within the surf zone, waves are the major mechanism of waterborne sediment transport. The rates of erosion, transport and deposition depend, amongst other things, on wave energy, the angle of wave approach to the coastline, and the strength of wave generated currents (see Appendix B7).

10 EFFECTS OF WAVES ON COASTAL STRUCTURES

The response of a coastal structure to wave attack depends not only on the local wave climate but also on the nature of the structure itself.

"Flexible" structures, such as rubble mound breakwaters (see Appendix D6), can suffer considerable and progressive damage before complete structural failure occurs. In contrast, "rigid" structures, such as some masonry seawalls, can fail catastrophically as soon as a critical force is exceeded.

The periodic nature of waves can also affect structural damage. If the dominant wave frequency matches a natural resonant frequency of the structure, then wave induced motion may be amplified so increasing damage.

The design of coastal structures to adequately withstand wave attack usually requires simulation studies, using either mathematical techniques or physical scale models.

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APPENDIX B6 CURRENTS

1 INTRODUCTION

Currents occur within the deep ocean, over the continental shelf and within the offshore and nearshore zones. They may be quasi-steady and persist for several hours to several weeks (ocean and shelf currents), or they may be oscillatory with periods of seconds (currents under waves). Currents may be limited to the surface or to the seabed, or they may extend over the full depth of water. Surface currents can have a different direction to those at the seabed.

2 OCEAN CURRENTS

The largest currents are those of the open ocean, which are driven by global scale interactions between the atmosphere and the sea.

Along the NSW coast, the most significant ocean current is the East Australia Current (EAC), which consists of a series of warm water eddies that originate in the Coral Sea and slowly move southward (see Figure B6.1).

3 SHELF CURRENTS

Along the NSW coast, the continental shelf is some 20 to 30km wide. Continental shelf currents consist of the EAC, the counter currents associated with its eddies, internal waves, coastal trapped waves, tides and local wind induced currents. At any one time, the shelf current is a complex mix of these components.

4 CURRENTS OF THE NEARSHORE ZONE

Shelf and ocean currents are generally of little significance within the shallower waters of the nearshore zone. This area is the preserve of wave induced currents which include:

- oscillatory currents at the seabed prior to wavebreaking (see Appendix B5);
- mass transport of water shoreward as waves break;
- rip currents; and
- longshore currents.

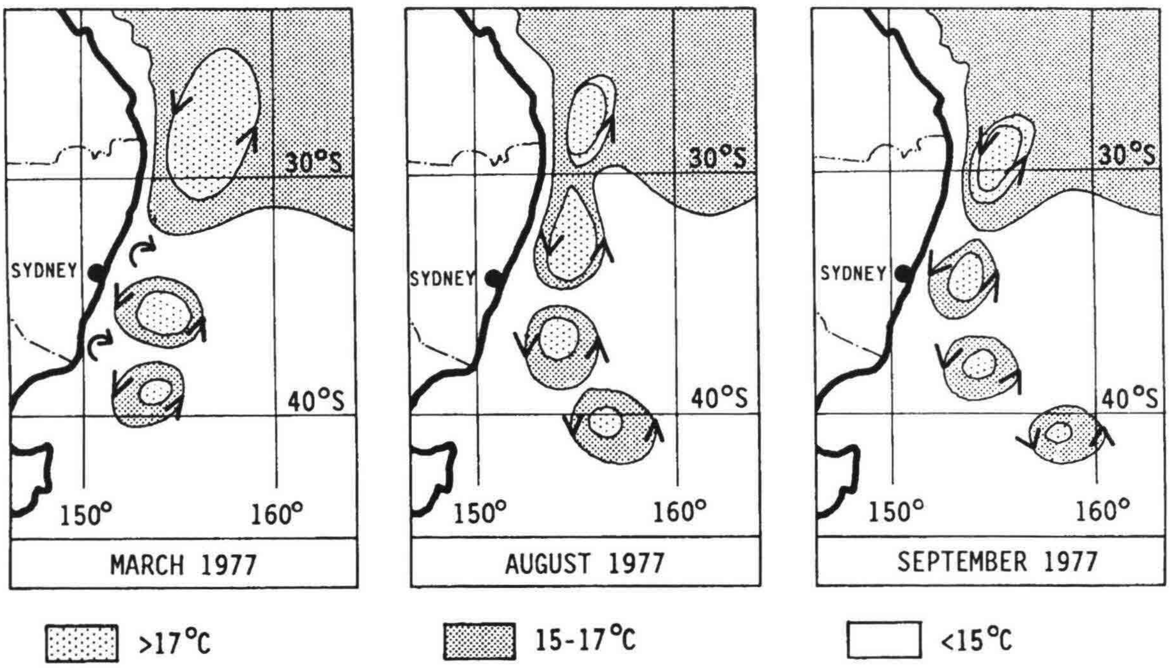

Figure B6.1 East Australia Current, March-September, 1977

Oscillatory Currents

The passage of waves through shallow water causes a back and forth oscillation of water particles above the seabed (see Appendix B5). The motion of this oscillatory current can bring sediment into suspension to be transported elsewhere.

Shoreward Mass Transport

Wave action generates a quasi-steady shoreward current at the seabed. Outside the surf zone, this current is normally small and its effects are negligible. Within the nearshore zone, this onshore current can be of considerable importance. As long period ocean swell moves towards and through the surf zone, the onshore current transports sediment shorewards. This onshore movement is responsible for the rebuilding of beaches after storm erosion.

Rip Currents

Rip cells are a mechanism whereby the water pushed shoreward by wave action and, to a lesser extent, by onshore winds can escape seawards. Rip cells can be identified by a strong longshore current in the nearshore gutter (feeder current) and a return jet of water seawards through the offshore bar (rip current). This is shown in Figure B6.2. Depending on wave conditions, nearshore bar bathymetry and state of the tide, rip cells may establish, dissipate and re-establish. Some rip cells have a more permanent nature, being associated with a controlling feature such as a headland, breakwater, offshore reef, creek, or stormwater outlet. Different rip types have been classified by Short (1985) and are typically associated with the various beach types as defined by Wright and Short (1983).

Rip cells can move significant volumes of sand offshore during storm events. Water is deeper in a rip channel, allowing larger waves to penetrate and attack the beach. Rip currents readily move offshore any sand eroded from the beach. At

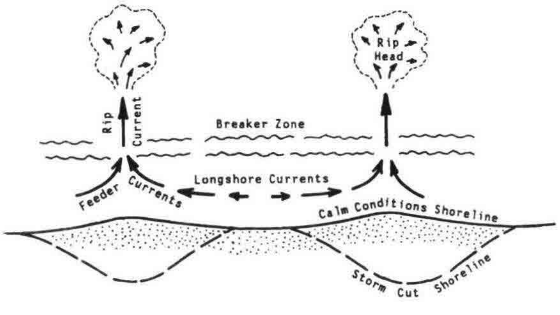

Figure B6.2 Rip Cell Circulation
(After Komar, 1976)

Wamberal Beach during storms in 1978, the maximum beach erosion occurred opposite a rip cell (PWD, 1985).

Rip cells are important to recreational amenity as they can present dangers to unsuspecting swimmers.

Longshore Currents

Longshore currents are generated by waves breaking at an angle to the beach, by feeder currents to rip cells, and from longshore variations in water level resulting from nearshore wave conditions and wind stress. Longshore currents are an important mechanism for transporting sand along a shoreline and into and out of the active beach zone (see Appendix B7).

5 RIVER AND CREEK DISCHARGES

Discharges from rivers, creeks, lagoons and stormwater outfalls can cause currents within and through the surf zone. These currents are usually controlled by the tide, with ebb tide effects being more noticeable. However, following heavy rain, freshwater outflows may become the dominant process.

Discharges from small lagoons and creeks often flow alongshore within a nearshore channel before crossing the offshore bar at a rip location. Larger rivers tend to penetrate the surf zone as a jet normal to the shore.

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1 INTRODUCTION

Waterborne sediment transport is a natural process whereby beaches continually adjust to the ever changing nearshore wave and water level conditions. Sediment is transported onshore, offshore and alongshore by the action of waves and currents. In response to this sediment movement, the beach undergoes a series of erosion and accretion cycles of short-term (weeks), medium term (years) and long-term (decades) nature. Man-made coastal works can disrupt this process.

An understanding of waterborne sediment transport processes is essential to the better management of coastal areas. Buildings constructed in the zone of active sediment movement can be imperilled by storm erosion of the beach. In some cases, beach accretion is beneficial, but it can also block stormwater outlets, reduce tidal flushing in coastal lagoons, inhibit safe navigation and exacerbate freshwater flooding. Coastal structures that interfere with waterborne sediment transport can markedly and permanently alter the shape and extent of a beach. A poorly sited port that interferes with sediment transport may require constant dredging to keep it operable.

2 PARTICLE SIZES

Unconsolidated sediment consists of particles of different sizes. Sediment size is an important factor in determining the ability of water to transport sediment and the rate of that transport. The smaller the particle sizes the greater the rate of transport. Sand and silt sized particles and to a lesser extent clay sized particles are of importance to waterborne sediment transport on the coast. "Clay" consists of particles smaller than 0.002mm; "Silt" consists of particles with sizes between 0.002mm and 0.06mm; "Sand" consists of particles in the range 0.06 to 2.0mm.

Figure B7.1 shows the distribution of particle sizes of three sediment samples collected at different locations along the NSW coast. Sample "A" is a typical sand collected offshore from Sydney beaches. Sample "B" was collected from a beach

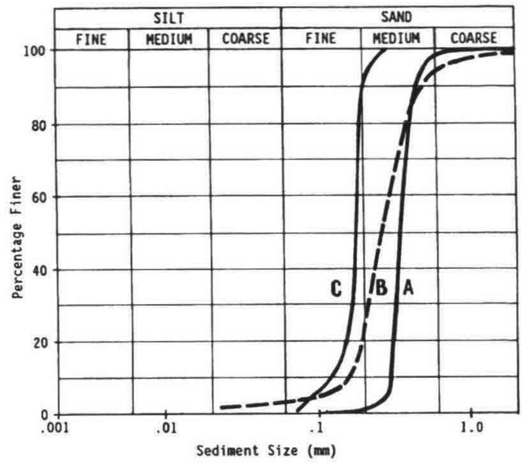

Figure B7.1 Particle Size Distribution, Coastal Sediments, New South Wales

along the lower estuarine reaches of the Clarence River. Sample "C" is a dune sand from Cronulla. Sediment "A" is a poorly graded medium sand. Sediment "B" is a better graded medium sand containing 5% coarse sand, 17% fine sand and 3% silt. The occurrence of silt in Sample "B" is typical of freshwater flooding effects along estuaries. Because of its finer nature, more of Sediment "B" than Sediment "A" will generally be moved by waterborne transport.

3 MOVEMENT OF SEDIMENT BY WATER

Flowing water can transport sediment particles as either "suspended load" or "bed load".

Suspended load transport refers to the suspension of sediment particles in the water mass by the action of turbulence (i.e. velocity fluctuations) and the subsequent transport of this material by currents.

Bed load transport is the process whereby currents "roll" sediment particles along the seabed. This process is assisted by turbulence, which can temporarily bring some particles into suspension. Currents cause these particles to "saltate", or move along the bed in a series of "hops".

Smaller particles are brought more easily into suspension than larger particles. Thus, suspended load typically consists of silt and fine sand particles (plus any clay if present). The more pronounced the turbulence, e.g. in the breaker zone, the more likely larger particles will be brought into suspension to be transported as suspended load or as saltating bed load. A minimum or "threshold" velocity is necessary to initiate bed load transport. This is of the order of 0.1 to 0.3 m/s.

4 SEDIMENT TRANSPORT IN COASTAL WATERS

The surf zone is characterised by high levels of turbulence caused by breaking waves, broken waves moving shorewards as "bores" and reflected waves moving back to sea. Vast quantities of sea bed sediments are brought into motion by this confused interplay of waves and currents. Much of this sediment movement does not contribute to net transport. However, we can distinguish two processes within the surf zone that do result in net transport:

- Longshore Drift
- Onshore/Offshore Transport

The first of these is associated with longshore currents and the second with onshore/offshore currents (see Appendix B5). Seaward of the surf zone, inner shelf currents can also move sediment along the coast.

Finally, the various rivers and estuaries transport large quantities of clay, silt and sometimes sand into coastal waters, especially during times of flood. It should be noted that certain clay particles flocculate and settle out in salt water. This contributes to sediment build up off coastal entrances. The transport of sand sized particles by rivers and estuaries, although significant in the geological past, is now of lesser importance.

5 LONGSHORE TRANSPORT

Surf Zone

"Longshore Transport", or "Longshore Drift", refers to the movement of waterborne sediments along the coast. This occurs predominately in the surf zone, that is landward of the offshore bar.

The magnitude and direction of longshore transport depends in a complex way on wave height and period, the angle of incidence of waves to the shoreline, the bathymetry of the nearshore zone and the size and availability of sediment.

Depending upon wave and current situations, longshore drift will be towards one end of the beach or the other. On some beaches, sediment transport in both directions is balanced, resulting in zero net drift. On the NSW coast, there is commonly a potential for net northerly drift because of the dominant south-easterly wave climate.

Transport Rates

Longshore drift rates can be estimated from empirical formulae or by field measurement. The complexity of the processes that determine longshore transport precludes accurate estimates. (See Sayao and Kamphuis, 1983, for an extensive review of longshore transport).

Empirical methods, which are necessarily approximate, include the "wave energy flux" approach (CERC, 1984) and the "steady flow approximation" (Bijker, 1971).

Field measurement provides the most accurate assessment of longshore drift rates. Common techniques include sediment tracing (using dyed sand, radioactive isotopes, etc.), measurement of sediment build-up against coastal barriers (e.g. groynes, headlands), and the analysis of beach changes over time from survey plans or aerial photography.

Table B7.1 shows estimates of Longshore Drift at 32 locations along the NSW coast (Chapman et. al., 1982). These results indicate an increasing net northerly longshore drift in the North Coast Sector. Longshore drift rates in the Mid-North, Central and South Coast sectors are markedly less.

The higher rates of longshore drift in the North Coast Sector are attributed to the greater number of long beaches, fewer headlands, greater sand bypassing around headlands, greater availability of sediment and the increasing angle of incidence between the shoreline and the predominant wave direction.

It should be noted that the rate of longshore drift is highly variable, both over time and by location. Typically, storm conditions may cause an average year's transport to occur in a single week.

6 ONSHORE/OFFSHORE TRANSPORT

Storm and Swell Wave Profiles

The steep waves that occur during storms erode sand from the beach berm and dune areas and transport it offshore to build a "storm bar". Rip cells are an important mechanism in offshore transport during storm conditions. A pronounced "dune scarp" in the foredune area commonly marks the landward extent of storm erosion. The resulting beach profile is termed the "Storm Profile". This is depicted in Figure B7.2. Multiple storm bars may be formed off exposed beaches or when wave energies are very high.

Table B7.1
Estimates of Long Term Longshore Drift and Shoreline Movement, New South Wales, Beaches

Location	Distance From Sydney (km)	Net Drift (1,000 m^3/yr)	Landward Movement of Shoreline (m/yr)	Analysis Period (yrs)
Fingal	680 (N)	500 (N)	Realignment	33
Dreamtime	675 (N)	350 (N)	0.6	33
Bogangar	668 (N)	250 (N)	0.8	15
Hastings Point	665 (N)	220 (N)	0.2	37
Pottsville	660 (N)	200 (N)	0.2	30
New Brighton	640 (N)	170 (N)	1.4	90
Byron Bay	630 (N)	80 (N)	1.0	90
Tallow Beach	625 (N)	65 (N)	0.2	26
Lennox Head	615 (N)	? (N)	0.9	26
Campbells Beach	448 (N)	? (N)	0.7	98
Macauleys Beach	445 (N)	? (N)	0.6	11
Boambee	440 (N)	75 (N)	-4.5	38
Sawtell	435 (N)	75 ?	0.3	38
Old Bar	240 (N)	?	0.3	39
Diamond Beach	230 (N)	? (N)	0.2	42
Forster/Tuncurry	225 (N)	35 (N)	Accretion	22
Boomerang Beach	215 (N)	30 (N)	0.3	25
Blueys Beach	210 (N)	30 (N)	0	17
Newcastle Bight	120 (N)	0	1.0	21
Soldiers Beach	65 (N)	5 (N)	0.1	36
Wamberal Beach	45 (N)	12 (N)	0.4	19
Avoca Beach	40 (N)	9 (N)	0.4	19
Palm Beach	25 (N)	11	0.5	37
Collaroy Beach	15 (N)	0	0.2	37
Bate Bay	30 (S)	0	0.5	90
Warilla	85 (S)	25 (N)	0.9	34
Shoalhaven Hds	125 (S)	?	1.0	33
Culburra	130 (S)	?	0.3	29
Narrawallee	180 (S)	?	0.2	35
Mollymook	185 (S)	?	0.2	35
Bermagui	310 (S)	?	0.5	20
Tathra	350 (S)	?	0.2	35

Note: N:North S:South ?:Not Assessed

The effect of the storm bar is to widen the surf zone and flatten the slope of the surf and swash zones. This causes waves to break further offshore, which imposes a self regulating limit on beach erosion. Nevertheless, extensive erosion can and does occur before self regulation prevails.

At other times, ocean swell of longer period and lower height tends to rebuild the beach with sand from the offshore bar (see Figure B7.2). The "mass transport" current of these waves is the dominant process which transports sand shorewards (see Appendix B6). The rebuilding process commences immediately after a storm, but several years may be required to transport most of the sand back to the beach after a major storm event.

Swept Prism

The area in which sediment is mobilised by onshore/offshore processes may extend seawards for several kilometres and landwards into the dunefield. This envelope of "active" sand is termed the "Swept Prism" (Chapman and Smith, 1980). Any buildings or structures erected within the onshore area of the swept prism, i.e. the active beach zone, will be exposed at some time to erosion. Structures erected within the offshore area of the swept prism may interfere with the onshore/offshore movement of sediment.

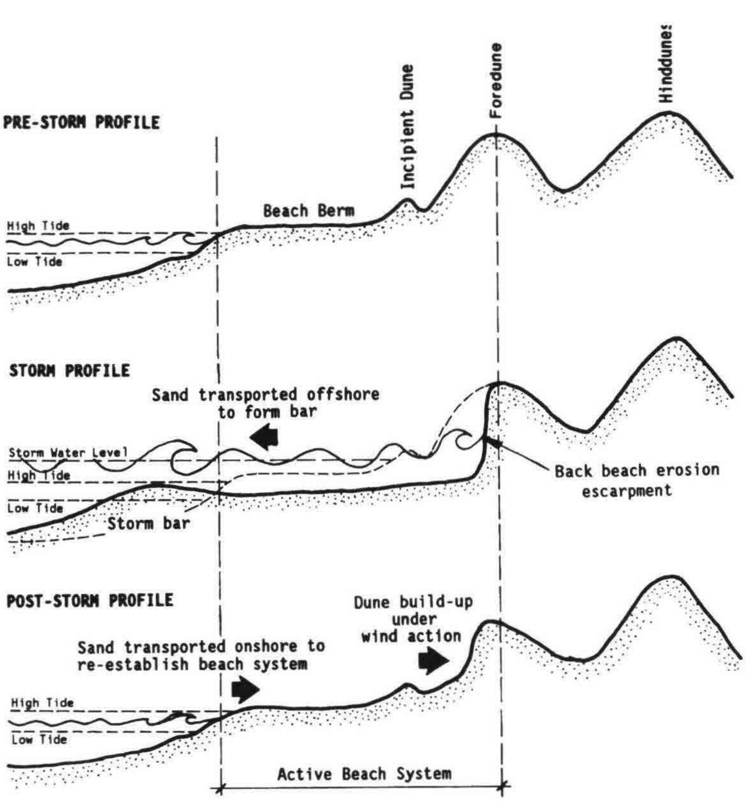

Figure B7.2 Beach Profiles: Accreted and Storm Conditions

Equilibrium Beach Profile

For a given wave height, wave period and sediment size, there exists an equilibrium beach profile for which onshore and offshore transport are in balance. For medium and coarse sands, the equilibrium beach slope is about 4° and 7° respectively. Because of the ever changing wave conditions and the distribution of sediment sizes, the equilibrium beach profile is rarely attained. The ever changing nature of the beach profile is, nevertheless, the natural process of seeking this equilibrium state.

Transport Rates

Onshore/offshore sediment movement can be assessed theoretically or by field measurement. The equilibrium beach profile associated with a particular sediment and a given set of wave conditions can be derived from empirical formulae (Swart 1976; Vellinga, 1983). For any other beach profile and set of wave/sediment conditions, erosion, accretion and final beach profile can be estimated. Field measurements of beach and nearshore profiles made before and after storms indicate the extent and direction of onshore/offshore transport.

7 INNER SHELF TRANSPORT

Shoaling begins to significantly effect swell waves in water depths of about 60m, which marks the seaward limit of the Nearshore Zone or Inner Shelf Zone. The net seabed velocities of wave induced currents in these deeper waters are generally low. However, during storm wave conditions, wave induced oscillatory bottom currents can bring sediments into suspension, which facilitates transport by currents. The active transport of sand by this mechanism has been observed in water depths of over 60m (Gordon and Hoffman, 1984).

At headlands, large scale inner shelf currents can interact with wave induced longshore drift in the surf zone. This can lead to the interception of surf zone sediment, and its "loss" from the beach by offshore transport.

8 SEDIMENT BUDGET

A sediment budget is one means of assessing long-term shoreline recession, i.e. whether or not the coastline is gradually but progressively moving landwards. A coastal "compartment" or control volume is defined, the boundaries of which consist of physical or morphologic features across which the rate of sediment transport can be meaningfully assessed (see Figure B7.3). The net transport rate into the compartment from all sediment transport processes is estimated. If positive, the shoreline is

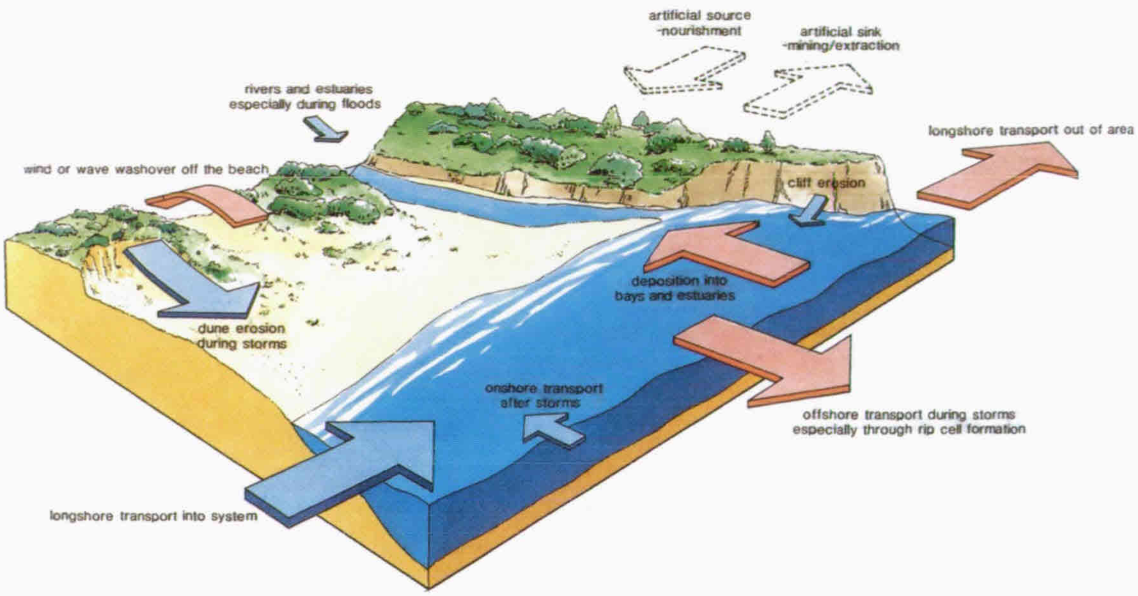

Figure B7.3 Typical Sediment Budget (after NSW Govt.,1987)

accreting. If the net transport rate is negative, then the coastline is receding. Table B7.2 lists various sediment sources and sinks that can respectively supply and remove sediment from the control volume.

Table B7.2
Sediment Source and Sink Processes in a Typical Sediment Budget Study

Sources	Sinks
Longshore Transport	Longshore Transport
Beach Erosion	Beach Accretion
Cliff Erosion	Deposition in Rivers/ Estuaries
Onshore Transport	Offshore Losses
River Supply	Wind Blown Sand Losses
Beach Nourishment	Wave Washover off Beach
	Sand and Mineral Mining

In undertaking sediment budget studies it is often difficult to distinguish between short-term fluctuations (e.g. storm effects) and long-term trends. A detailed investigation of both present day coastal processes and historical trends in shoreline change is necessary. Present day short-term fluctuations in the sediment budget can be identified from the relocation of sediment within the compartment. This in turn enables any long-term sediment gains or losses to be identified, thereby providing an indication of trends in shoreline stability. The undertaking of a sediment budget study and the interpretation of results requires considerable care.

9 IMPACT OF DEVELOPMENTS

All coastal, river and shelf developments need to be assessed to determine their impact on the sediment budget. This impact cannot be adequately assessed without a good understanding of the mechanisms and magnitude of sediment transport. This in turn requires data concerning offshore bathymetry, waves, tides and currents.

If an area is subject to longshore transport, great care needs to be taken with developments built in the surf zone. Structures such as a groynes will interfere with the longshore drift and are likely to cause accretion on the upstream side and erosion on the downstream side (see Appendix C2).

If significant onshore/offshore sediment transport exists, care should be taken with the siting and design of coastal structures. For example, the effects of seawalls and similar structures on waves may generate more turbulence and stronger reflected waves than would naturally occur. This may result in sediment being transported further offshore than would normally be the case. Recovery of the beach in front of the seawall will then take longer.

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APPENDIX B8 DUNE VEGETATION

1 INTRODUCTION

The understanding of coastal dune vegetation, in particular knowledge of the species which are present on the dunes of NSW, their distribution both along the coast and in different dune environments, and of the characteristic associations in which they are found, is critical to the effective management of dunes and their role in coastal processes and coastline hazard management.

Vegetation is the key factor in dune stability and it is the vulnerability of dune vegetation that makes the dunes sensitive to impact. Examples of human activities that can damage dunes are: bush clearing; stock grazing; road building; winning of borrow materials; stockpiling building materials; earthworks in general; construction; fuel storage; housing; most recreational activities; pedestrian and vehicular traffic; brush cutting and bushfires.

Information required to properly manage dune vegetation includes knowledge of species present, the locations of species, and processes by which species persist. Detailed information on dune vegetation and dune management is found in references by Clarke (1989a,b), Chapman (1989) and the Soil Conservation Service (1990). This appendix is based on these references.

2 DUNE VEGETATION : ROLE AND VALUES

For the purposes of coastal dune management, it is convenient to divide dune vegetation into three groups based on performance, growth habit and zone of colonisation. These groups are primary colonising species, (grasses and vines); secondary shrubs and transient species; and tertiary species (enduring trees and understorey) - see Figure B8.1.

Dune vegetation is highly adapted to the salt laden winds of the coast, and maintains the foredunes by holding the sand already in the dune, trapping sand blown up from the beach, and aiding in the repair of damage inflicted on the dune either by natural phenomena or by human impact. The combination of dune height, dune shape and intact vegetation creates a protective system which directs salt-laden winds upwards and over the dune crest, (see Figure B8.1). As a result, salt sensitive vegetation communities, (including littoral

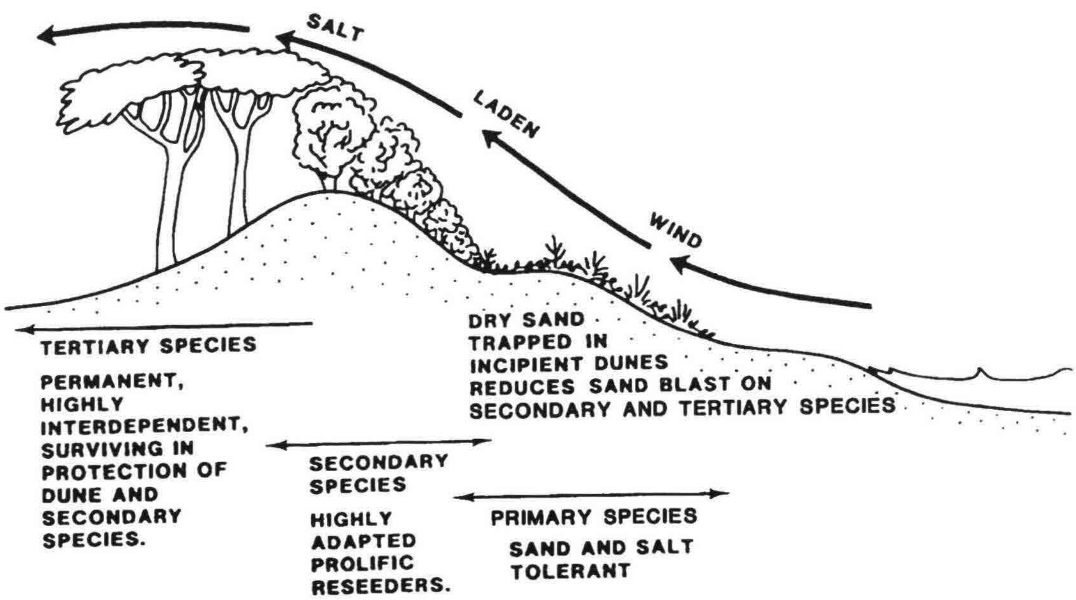


Figure B8.1 Coastal Sand Dune Vegetation – Niches and Function. (After Chapman, 1989).

rainforests), can establish in close proximity to the beach.

However, while the sequence of herbaceous forms followed by shrub and tree forms is true in the general sense, the sequence illustrated in Figure B8.1 is an oversimplification of the patterns that exist. A variety of forms can be found within each of the dune physiographic units, and at many sites the sequence has been truncated by disturbance or by lack of a foredune ridge.

Dune vegetation not only stabilises the dune, but also has habitat, educational and recreational values. The beach and the foredune are used extensively for active and passive recreation, vegetation contributes to recreational and aesthetic values. Indirectly, the stabilising ability of vegetation limits the amount of wind blown sand in the beach environment and thus enhances its recreational utility. Similarly, healthy vegetation significantly contributes to beach user comfort by reducing reflected radiation from the foredune.

The aesthetic values of dune vegetation are generally neglected and it would probably be safe to say that few beach users are aware of them until the vegetation has been degraded or lost. Zonal patterns of natural vegetation on the beach and foredune provide an important visual resource in terms of change in texture, colour and form. The wind sculpted aeroform of coastal shrubs and trees enhances the visual quality of the beach and provides contrast for the stark, rigid, angular shapes of man made structures.

Beyond the foredune, taller hinddune woodlands and forests afford protection from onshore winds and provide ideal opportunities for passive recreation such as picnics, informal camps, and backpack activities. These pursuits are not necessarily incompatible with the dune environment but nevertheless require careful management so as not to degrade the very features which make them attractive.

3 VEGETATION AND COASTAL PROCESSES

Vegetation plays an important role in the stabilisation and formation of coastal dunes. Foreshore vegetation impacts on several of the sand transport pathways, and therefore influences the rate of shoreline recession and dune rebuilding.

The strandline and beach vegetation is generally transient, being removed during storm events. Nevertheless these pioneer plants trap and hold windblown sand so that it does not damage plants on the relatively more stable foredune. The beach vegetation is mainly dominated by the grasses, *Spinifex sericeus* and *Festuca littoralis*, which aid in the creation of beach mounds and ridges, (incipient foredunes), under prograding conditions.

The foredune vegetation proper is usually composed of semi-permanent populations of herbs, shrubs and trees which stabilise the foredune sand mass. Sand trapped in the foredune acts as a reservoir of sand for the beach during periods of wave erosion and to a certain extent, by the development of soil concretions and a dense root web, the foredune vegetation also buffers the effects of storm erosion.

A model showing the relationship between dune vegetation, and other coastal processes is shown in Figure B8.2.

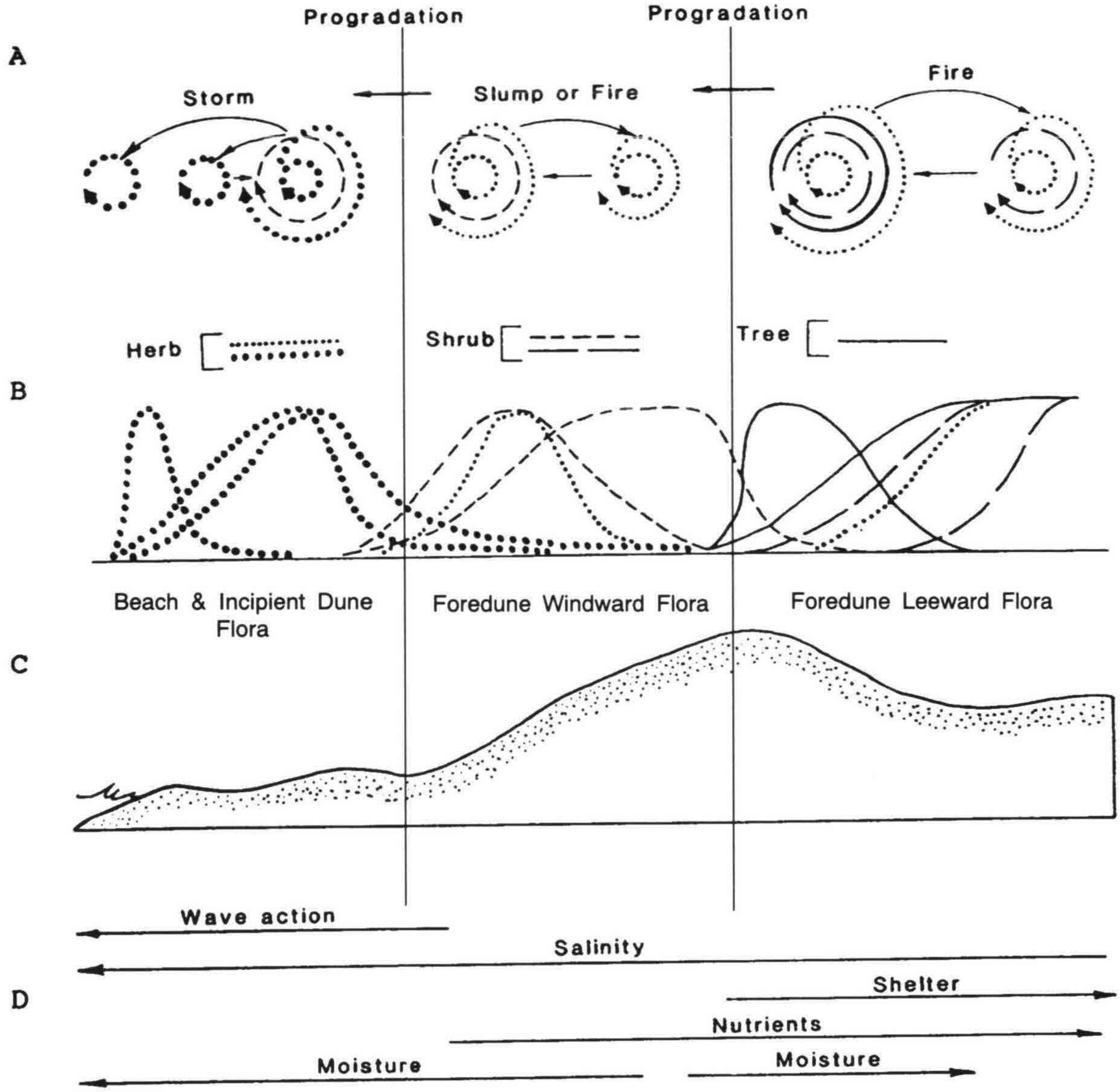
Many dune plant communities have special value arising from previous studies which allow them to be used as temporal reference points. In this regard they can reflect the changing physical nature of the coastline. Shoreline recession and progradation for example, may be detected from vegetative evidence.

Changes in climatic conditions are also frequently reflected in vegetative distributions, for example, changes in the spatial distribution of Spinifex and Festuca could well be related to changes in atmospheric and ocean temperature patterns. Qualitative evidence from old photographic records indicates that Spinifex has replaced Festuca on the central and southern coast of NSW, perhaps suggesting warming of temperature, or nutrient enrichment.

4 VEGETATION DEGRADATION

The foredune complex is a dynamic, resilient landform essential to the long-term stability of the dune system. However, dune vegetation may be degraded or damaged through both natural and artificial processes. Natural instability may be initiated by discrete high energy storm events capable of breaching or scarping the foredune. Failure of the dune vegetation to recover from storm wave attack may result in dune erosion due to the effects of onshore winds mobilising bare sand in the form of blowouts. Movement of sand landward of the foredune complex in blowouts constitutes erosion of the beach/dune system, since sand removed from the swept prism becomes emplaced within the terrestrial environment. The blowouts that induce this mode of erosion may in turn initiate further degradation within landward dunes as drifting sand buries and kills vegetation in its path.

Perhaps the most important "natural" factor responsible for altering the structure of stable vegetation is fire, the effect of which is to reduce the presence of mature shrubs and trees, resulting in a grassland/forbland formation that in some locations is maintained by repeated firing.



A Population dynamics for the three principal dune zones under stable geomorphological conditions. Life cycles are drawn as circles of increasing size to represent length of life of plants; herbs which are long lived owing to clonal perenniation are denoted by spirals. Solid lines and arrows represent directional change.

B Distribution and abundance (as amplitude) of dominant species shown as hypothetical Gaussian curves, some of which are skewed due to abrupt environmental thresholds and competition.

C Typical cross section of the physiography of a stable coastal dune.

D An indication of the environmental gradients which affect the distribution of dune species. Arrows indicate direction of increasing magnitude of factor.

Figure B8.2 A Schematic Model of Physiography, Environmental Gradients, and Distribution of Species Across a Typical Foredune on the Coast of New South Wales. (After Clarke, Examples of the "artificial" degradation of dune vegetation, by human activities, are listed in the introduction to this appendix.

Once degraded, natural healing of dune vegetation may be inhibited by:

a) Breakdown of the vegetation canopy which, when intact, acts like a storm shutter (Fig. B8.1), deflecting winds over it. Entry of salt-laden wind to the internal structure of the vegetation can expose sensitive vegetation elements (especially rainforest species) to salt-burn and resulting in irreversible degeneration of the vegetation binding the foredune.

b) Continued pedestrian and vehicular traffic and other disturbance factors at a level sufficient to prevent recolonisation of the exposed surfaces.

In order to restore the "health" and function of the dune vegetation, active dune management programs must be implemented. These are dealt with in Section 5.2.3 and Appendix D5.

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APPENDIX B9 WINDBORNE SEDIMENT TRANSPORT

1 INTRODUCTION

The major causes of coastal erosion are the waves and elevated water levels associated with storms. Wind also promotes coastal erosion in the form of windborne sediment transport. Although such erosion is slower and less dramatic than the effects of storm waves, the inexorable inland march of migrating or "transgressive" sand dunes can smother coastal developments. "Blowouts" on coastal dunes can result in vegetation loss, potential dune migration, reduced amenity and the loss of sand from the beach system. (see Figure B9.1)

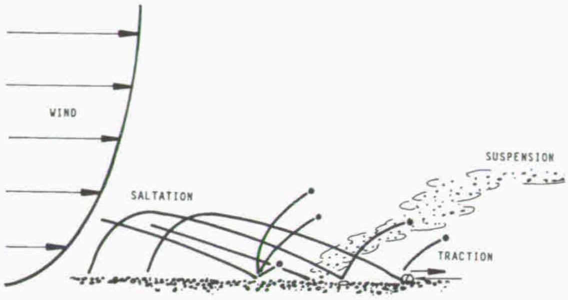

Figure B9.2 Sand Transport by the Wind

2 MOVEMENT OF SAND BY THE WIND

There are three distinct modes whereby the wind can transport non-cohesive sediments or "sand" in a downwind direction. These are "suspension", "saltation" and "traction", and are depicted in Figure B9.2.

Suspension refers to the incorporation of fine grains into the atmosphere itself (silt sized particles or smaller). Saltation is the process whereby larger grains (sand sizes) are briefly brought into suspension before falling back to the surface, thereby moving downwind in a series of "hops". Traction refers to the rolling, sliding and pushing of larger particles along the surface.

Saltation is the most significant form of transport for beach sand. The particles most readily moved by wind have diameters of 0.1 to 0.2mm (fine sand). A threshold wind velocity is necessary to initiate sand movement. Typically this is of the order of 20 km/h. Above this threshold velocity, transport varies as the cube of wind velocity.

Figure B9.1
Younghusband Peninsula, S.A
(Courtesy of Dr. A. D. Short)

3 SAND DRIFT

Sand is transported in a variety of directions in response to changes in wind direction. Where adequate wind data are available, it is possible to estimate potential sand drift. This information can be depicted in the form of a "sand creep" diagram which shows the compass sector from whence the sand originates. Over the course of a year, a number of sand creep movements cancel out. The "sand drift" vector shows the net result of all creep movements and represents the long term direction and amount of potential sand drift.

Figure B9.3 shows potential sand creep diagrams and potential sand drift vectors for selected locations along the New South Wales coast. These figures reflect the effects of average annual wind speed and direction, and represent potential sand movement from a bare sand surface (i.e. not vegetated).

The actual sand drift at a specific location, as opposed to potential drift, depends upon the degree of surface protection. Dense ground cover suppresses sand movement. Shrubs spaced at intervals of three to five times their height significantly inhibit sand drift. Thus, actual sand movement will be less than or equal to the potential values shown in Figure B9.3.

With regard to potential sand creep, it is apparent that Gabo Island, Newcastle, Cape Byron and Cape Moreton are the most active locations. Along the South and Central Coast Sectors, potential sand drift is offshore (easterly) or along shore (north-easterly). In contrast, in the Mid-North and North Coast sectors, potential sand drift is onshore (north-westerly).

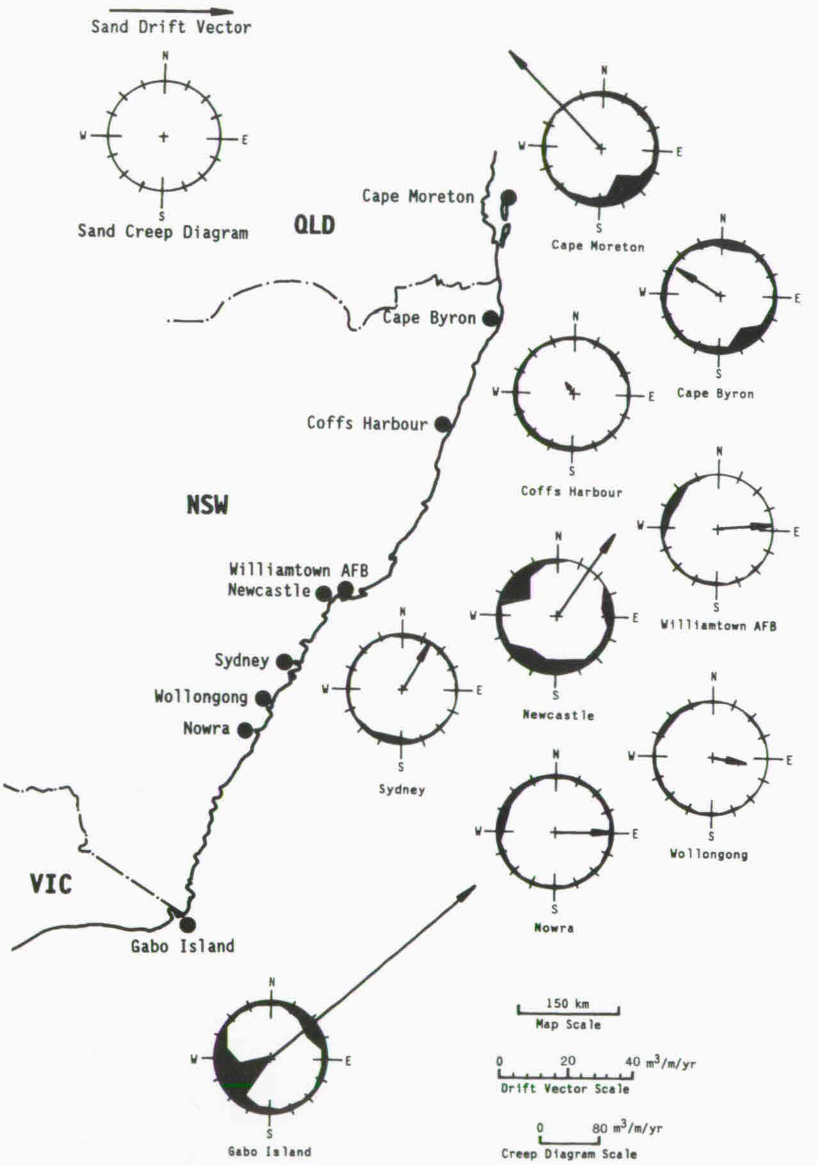

Figure B9.3 Potential Sand Creep Diagrams and Sand Drift Vectors, New South Wales

4 SAND DUNES

Growth

A natural beach will often have a dune on the landward side of the beach berm. Dunes are formed by the action of onshore winds. Sand deposited on the beach by surf zone processes is carried inland by the wind. Topographic features and vegetation interfere with wind transport and cause deposition in the lee of obstacles. In this way an "incipient dune" is initiated. The shielding effects of this dune promote further deposition and so the incipient dune grows in size. As the dune grows, a "slip face" on the leeside develops and the ability of the wind to transport sand up and over the dune is progressively reduced. In time, a "dune system" will be created, consisting of an incipient dune, a foredune and hind dunes (see Figure B9.4). The growth of sand dunes is described in several Government publications (PWD, 1986; SCS, 1990).

The size and character of sand dunes are governed by the shape and size of the beach embayment, its orientation to the prevailing wind and wave climates, the grain size and amount of sand available or supplied to the beach, and the type and state of dune vegetation.

Vegetation

Dune vegetation is the primary factor determining the stability of a sand dune. A graduation of primary to secondary to tertiary species occurs from the incipient dune to hind dune areas (see Appendix B9 and Figure B9.4). The vegetation canopy provides "aerodynamic" protection to underlying species from salt laden winds.

In many instances, natural dune vegetation is quite fragile. Significant damage can lead to total degradation and loss of the protective vegetation cover. This in turn leads to dune "blowout" and migrating dunes (see Appendix B8). The importance of dune vegetation and the various types of plants relevant to dune management are discussed in government publications (PWD, 1986; SCS, 1990), and in Appendix B8.

Wave Attack

A stable incipient dune and foredune provide a natural buffer against storm wave attack. On the New South Wales coast, it is quite normal for the incipient dune to be eroded away by wave attack every five years or so. Further, the foredune may suffer significant erosion every 10 years or so.

During a storm, sand stored in the dunes is mobilised by surf zone processes and becomes part of the sediment budget of the beach (see Appendix B7). Given that the sediment budget is balanced, restoration of the prestorm dune occurs by natural processes in the months, or perhaps years, following the storm event.

Wave erosion of the dune produces a pronounced face ("dune escarpment") which effectively reflects wave energy back to sea. Initially, the dune scarp is near vertical. As the sand dries out, the scarp slumps back to the natural angle of repose (a slope of about 1V:1.5H).

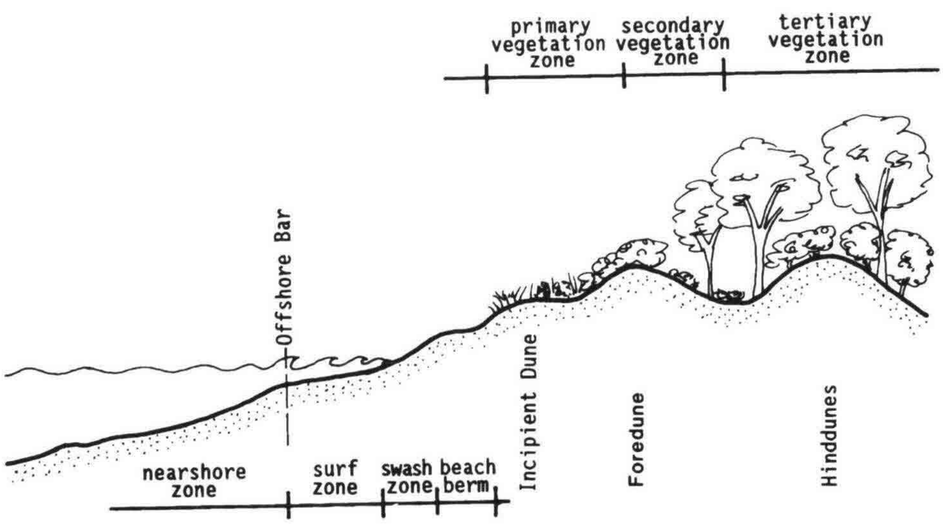

Figure B9.4 Dune System Behind a Sandy Beach

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APPENDIX B10 RAINFALL AND RUNOFF

1 INTRODUCTION

Severe storms are often accompanied by extended periods of heavy rainfall. This is especially so of tropical cyclones, which typically degenerate into rainfall depressions on crossing the coast. The relationship between rainfall and beach erosion is examined by Bryant (1985).

Rainfall and its associated runoff have a number of effects on coastal processes. In many cases these are not as extreme as the primary storm induced forces of wave erosion, increased water levels, etc. Nevertheless, they can be of significance.

2 BEACH BERM AND DUNE EROSION

Many coastal areas are characterised by relatively high groundwater levels. Rainfall onto sandy beaches and dune systems quickly percolates to the groundwater table. Intense rainfall may cause significant increases in groundwater levels, thereby increasing pore water pressures. This facilitates the erosion of dune areas and increases the instability of coastal bluffs (see Appendix C7).

3 FLOODING BEHAVIOUR

Extensive areas of NSW to the east of the Great Dividing Range drain to the coastline via major river systems. The management of freshwater flooding in these river systems is a significant problem in its own right.

Whilst these eastward draining rivers have steep bedslopes in inland areas, their bedslopes become progressively flatter as they approach the coast. This has two effects on hydraulic behaviour. First, flat bedslopes allow tidal effects to propagate a considerable distance upstream from the river mouth and interact with freshwater discharges. Second flat bedslopes reduce the capacity of the main channel to pass flood flows, which typically spill out over the wide floodplain areas which characterise the lower reaches of these rivers.

Flood levels in the lower reaches of coastal rivers depend in a complex way on the interaction of freshwater discharges, tidal effects and the elevation of coastal water levels through storm surge and other effects. Guidelines for the estimation of flood levels and the development of coastal areas subject to flooding are contained in the "Floodplain Development Manual" (NSW, 1986).

4 COASTAL MORPHOLOGY

The discharge of flood waters into the sea can have marked effects on coastal morphology.

Extensive scour around river entrances can occur as major flood discharges debouch into coastal waters. This can result in significant changes to offshore bathymetry that may persist for months or perhaps years (see Appendix C4).

Rivers are an important source of clay and silt sized sediment. During a major flood in a large river, many hundreds of thousands of tonnes of sediment can be delivered to nearshore areas.

Unless stabilised by training walls, the mouths of many coastal rivers tend to "migrate" up and down the coast over considerable distances in response to the combined effects of freshwater discharge, tides and wave action. Often such rivers flow parallel to the coast behind the hind dune area forming elongated spits. Large floods can cause major changes in the location of the river mouth, to the location and nature of river shoal areas and to the entrances of coastal lagoons hydraulically connected to the river (see Appendix B11).

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1 INTRODUCTION

A coastal entrance is an important feature that affects the hydraulics and amenity of the estuary and nearby coastal areas. Entrances are subject to a variety of processes that affect their behaviour: tides, waves, currents, sediment movement, floods, etc. The interaction and ever changing nature of these factors may cause entrances to migrate along the coastline, to shoal, to close up, re-open, etc. At best, an ever restless dynamic equilibrium exists that may be punctuated by irregular and sudden changes of behaviour.

Estuaries are of importance to human use and recreation. Their entrances provide access to and from coastal waters for commercial fishing boats and pleasure craft. Changes to entrance behaviour can be detrimental to boat movements and the use of the estuary.

2 TYPES OF ESTUARIES

Estuaries along the New South Wales coast can be classified into the three types listed below and shown in Figure B11.1.

- drowned river valleys
- barrier estuaries
- saline coastal lakes

Drowned River Valleys

Drowned river valley estuaries generally consist of a semi-enclosed bay with a deep and wide entrance, such as Broken Bay, Sydney Harbour, Port Hacking and Batemans Bay. Typically, such estuaries experience the full ocean tidal range. Entrances are characterised by submerged tidal deltas formed by the deposition of marine sands over the muddy sediments of the estuary floor. The seaward face of the delta is subject to wave and current attack.

Barrier Estuaries

Barrier estuaries such as Wallis Lake and Lake Macquarie, are characterised by long, narrow entrance channels meandering through broad tidal sand flats. Strong tidal flows occur in the entrance channel. Frictional effects progressively reduce the tidal range, which in the estuary basin may be as

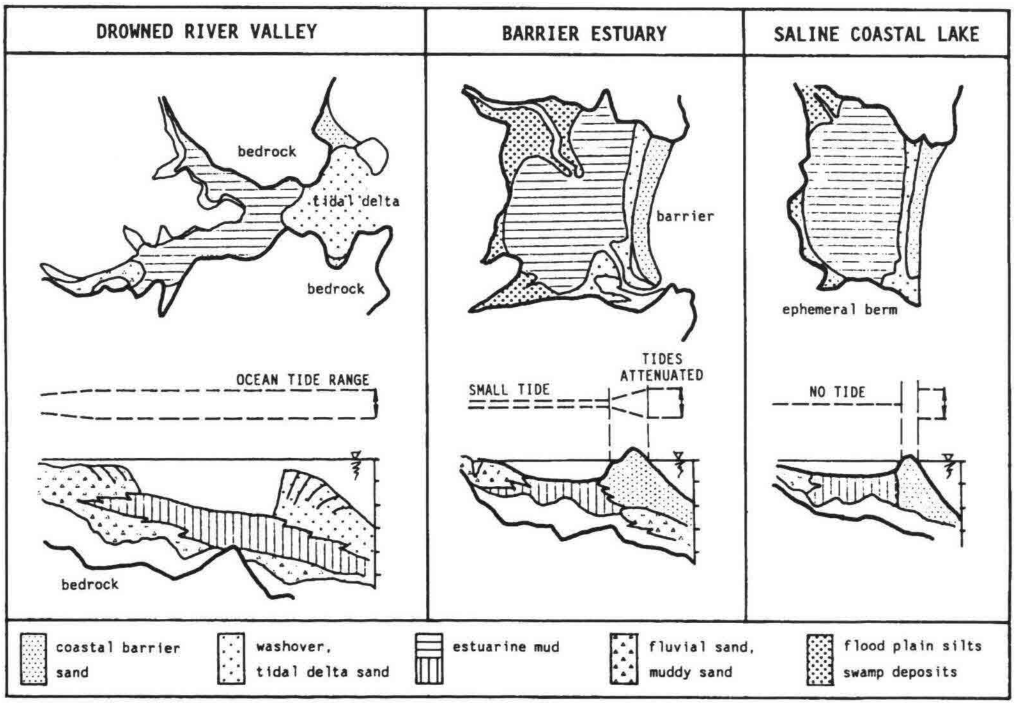

Figure B11.1 Estuary Types in New South Wales (after Roy, 1984) small as 5% of the ocean tide. Wind waves and wind-induced currents are of more importance to water circulation than tidal currents. The entrances of Barrier estuaries normally remain open to the sea.

Mature "river estuaries" such as the major north coast rivers Tweed, Richmond, Clarence and Macleay, are examples of infilled barrier estuaries.

Saline Coastal Lakes

Most saline coastal lakes are small enclosed waterbodies located behind beach foredunes, e.g. Dee Why Lagoon and Coila Lake. Typically, entrances are closed or "choked" and undergo irregular episodic opening by flooding. This results in the lake waters being non-tidal or weakly tidal at best. Generally, lake waters are saline to brackish, although heavy rains may significantly lower salinity levels. Water circulation and mixing are caused mainly by wind. When the entrance is closed, water inflows are lost by evaporation and percolation through the porous sand barrier. After heavy rains, the entrance berm may be breached by superelevated lake waters (Gordon 1981). In these circumstances, the lake becomes saline and tidal for a period of weeks to months until surf zone processes reform the beach berm and close the entrance.

3 FACTORS AFFECTING ENTRANCE BEHAVIOUR

The entrance of any tidal inlet on a littoral drift coast is subject to the competing influences of scouring caused by tidal and flood flows and shoaling caused by sedimentation from the adjacent littoral zone. The interaction of flow, waves and littoral drift is always varying and leads towards what has been termed a "dynamic equilibrium" (Bruun, 1978).

Features of a typical tidal inlet on a littoral drift coast are shown in Figure B11.2. These include an offshore entrance bar, swash bar and shoals, ebb tide channels, marginal flood tide channels and inner shoals. These features are intimately related and together reflect and affect the hydrodynamic response of the inlet.

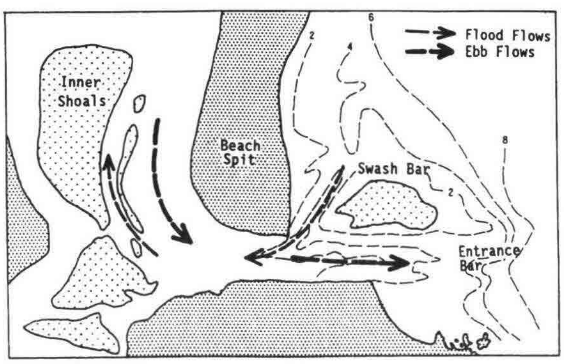

Figure B11.2 Hydraulic Features of a Typical Untrained Coastal Entrance

Conditions of estuary entrances are controlled by the tidal range and discharge, river flow, wave exposure, entrance channel geometry and the rate of longshore sediment transport.

4 ENTRANCE SCOUR AND INFILLING

Sand entrained by waves is transported into the coastal entrances by flood tide currents to be deposited on inner shoals. Depending on inlet and shoal configuration, part of this material is returned in a seaward direction by the ebb tide currents. However, some of this material remains inside the inlet. Sediment trapped in this way tends to be deposited at the landward end of the entrance channel, building up the inner shoals.

If sediment inflow from coastal waters becomes too great the entrance may close. A flood event will be required to break the sand plug and re-establish an entrance channel, at which time scoured sand is returned to nearshore waters.

Bar and shoal formations will be largest at those inlets with the greatest tidal volumes and those where longshore transport is greatest.

5 TRAINING WORKS

Other significant factors affecting the behaviour of coastal entrances are man-made and include breakwaters and training walls. These are constructed to stabilise the location of entrances and maintain their depth. As shown in Figure B11.3, these works can significantly modify the

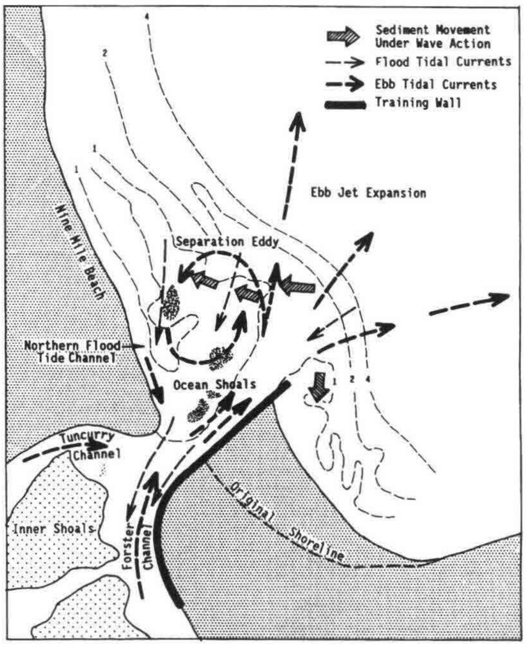

Figure B11.3 Hydraulic Features of a Typical Trained Coastal Entrance hydraulic behaviour and sedimentation processes both within the estuaries and along their adjacent coastlines (Druery and Nielsen, 1980; Nielsen and Gordon, 1980; Nielsen, 1981; Williams, 1981).

Entrances controlled by a single breakwater often have an elongated and unstable offshore bar. With double breakwaters, the offshore bar becomes smaller and more compact.

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APPENDIX B12 CLIMATE CHANGE

1 INTRODUCTION

The term "greenhouse effect" is presently being used to describe a postulated warming of the earth due to the accumulation of certain gases in the atmosphere. In particular, the increase in levels of carbon dioxide (CO_2) resulting from the burning of fossil fuels is of interest.

The current consensus of scientific opinion is that such changes could result in a global warming of 1.5° to 4.5°C over the next 30 to 50 years. Such a warming could lead to a number of changes in climate, weather and sea levels. These in turn could cause significant changes to coastal processes, e.g. increased severity and frequency of storms resulting in increased wave heights and erosion potential.

2 HEAT BALANCE OF THE EARTH

The atmosphere plays a crucial moderating role in the heat balance of the Earth. The principal gases of the atmosphere are nitrogen (78%) and oxygen (21%). However, their ability to absorb heat is low and they play little part in the heat balance. In contrast, carbon dioxide, nitrous oxide, methane and water vapour, which in total amount to less than 1% of the atmosphere, have high heat capacities and play a major role in the heat balance.

Relatively small changes in the concentrations of these gases may result in significant changes to the heat balance and to atmospheric temperatures. Hence the concern over CO_2 levels.

3 CHANGES IN ATMOSPHERIC TEMPERATURE AND CARBON DIOXIDE LEVELS

Radiocarbon dating and the analysis of small air bubbles trapped deep in antarctic ice has made it possible to reconstruct some of the past history of the world's climate. Figure B12.1 shows the variation of CO_2 levels, atmospheric temperature and sea level over the past 160,000 years. CO_2 levels were determined from air in the ice; temperatures at the time of ice formation were estimated from the relative concentrations of the isotopes oxygen-16 and deuterium (Fifield, 1988; Barnola et. al., 1987). The sea level changes

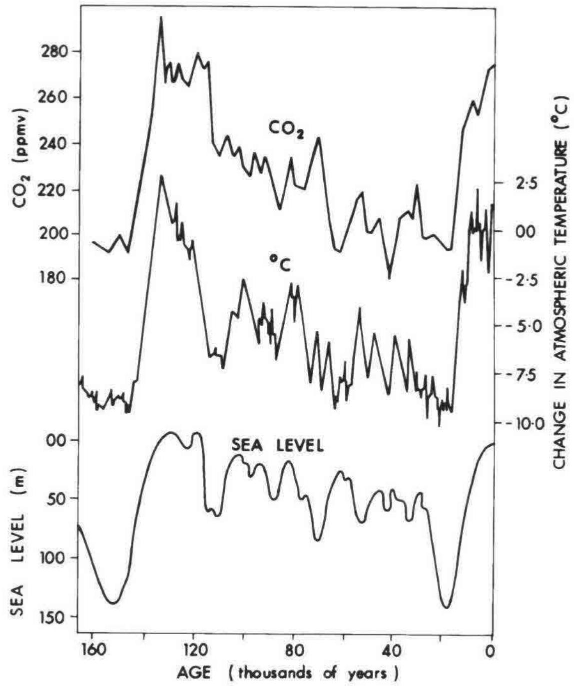

Figure B12.1 Atmospheric CO_2 Concentrations, Atmospheric Temperature and Sea Level over the Past 160,000 years. (After Gordon, 1989).

shown in Figure B12.1 are taken from Chapman et. al., 1982, and are the same as those shown in Figure B2.5. The variations of Figure B12.1 indicate two ice ages (150,000 and 20,000 years Before Present) and two warm periods (125,000 years ago and present time).

The data shows a good correlation between the variation of CO_2 levels in the atmosphere and change in surface temperature. The correlations between sea level and surface temperature and between sea level and CO_2 concentration appear reasonably good. These correlations are not as distinct as that between surface temperature and CO_2 concentration because of the relatively inferior accuracy and density of the sea level data set.

Carbon dioxide levels in the atmosphere are thought to have increased by about 50 ppmv since the industrial revolution. This has been attributed to the burning of fossil fuels but a variety of other factors, often surprising in their nature, make significant contributions (bovine flatulence, paddy fields, etc.). Figure B12.2 shows the increase in CO_2 levels in Hawaii between 1958 and 1980. Over this period of time, the mean monthly level increased from 315 to 340 ppmv.

To summarize: To date, the "hard" evidence in support of a "greenhouse" increase in temperatures is limited to the observed increase in CO_2 levels from 1958 onwards and global temperature trends over the last 100 years.. Historical evidence suggests that CO_2 levels have varied between 190 and 340 ppmv over the last 160,000 years. Again, historical evidence suggests that atmospheric temperature changes follow changes in CO_2 levels. The relationships between CO_2 levels, temperature and sea level are reasonably good.

Scientific opinion is divided regarding the timing and the likely degree of "greenhouse" warming. There is however a general consensus that warming will occur. If warming occurs it is generally agreed that sea level will rise.

4 POSSIBLE CLIMATIC EFFECTS IN AUSTRALIA

It is believed that any "greenhouse" warming will not be uniform over the earth's surface or throughout the year. Warming is expected to be greater at higher latitudes and in winter time. In Australia, it is postulated for example that surface temperatures may increase by 2°C in the northern tropics and by 3 to 4°C in southern latitudes.

In terms of average climatic conditions, the greenhouse effect may only produce rather small changes. However, its effect on extreme events may be much more marked. For example, a rise of 2 to 3°C in the surface temperature of the Tasman Sea may enable cyclones along the east Australian coast to move an additional 200 to 300 km southwards. Thus, the North and Mid-North Coast sectors of the New South Wales coastline will be more prone to cyclonic events. Additional details are given in Appendix C9.

5 SEA LEVEL RISE

In addition to climate change, global warming may also produce a worldwide sea level rise (eustatic rise). In the first instance this will be caused by the thermal expansion of the upper ocean layers. Sea level rise of between 0.5 and 1.5m by the year 2100 has been adopted by one technical committee (NAS, 1987). Sea level rise to the year 2050 of between 7 and 67cm (best estimate range 24 to 38cm) has been projected by others using box diffusion models. (Warrick, 1990, Pers. Comm.) (See Appendix C9.)

Any sea level rise is expected to lag behind global warming by some one to two decades because of the slow nature of heat transfer from the atmosphere to the oceans. Further, the rate of sea level rise will not be uniform, but will accelerate with time (see Appendix C9).

6 RESPONDING TO CLIMATE CHANGE

There are a number of uncertainties with respect to the timing and degree of any global warming. There is little evidence to suggest that existing coastal development and/or structures will be directly threatened in the immediate future. However, with the weight of scientific opinion suggesting that climatic change and associated sea level rise may become significant within the next 30 to 50 years, there is a need to incorporate these effects in coastal planning, management, and engineering works of the future.

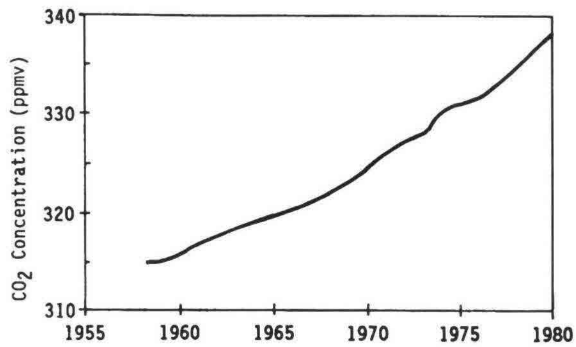

Figure B12.2 Mean Monthly CO_2 Levels, Mauna Loa, Hawaii (NRC, 1983)

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APPENDIX B13 HUMAN ACTIVITIES

1 INTRODUCTION

Human activities in the coastal zone are many and varied, e.g. the construction of coastal protection works, passive and active recreational pursuits, the use of certain areas for residential, commercial or ecological purposes, etc.

Human activities can significantly affect coastal processes. These effects can be both beneficial and detrimental. For example, consider the construction of a seawall. Benefits include the protection of properties at risk of erosion or recession hazard. Detrimental effects may include the loss of beach sand through interference with the sediment budget, more limited access to the beach and reduced recreational amenity.

"Problems" in the coastal zone are largely perceived in terms of interference with human activities. This appendix indicates possible detrimental impacts arising from various human activities. This is done through identification of the interrelationships between human activities, their impact on coastal processes and the detrimental consequences to coastal amenity.

The beneficial effects of human activities are largely ignored in the following discussion. This is not because benefits are unimportant, costs and benefits must be objectively weighed in the rational management of coastal lands, but because detrimental impacts are often ignored.

2 ACTIVITIES, IMPACTS AND CONSEQUENCES

Human activities affect coastal processes in a rich and varied way. To facilitate discussion, a three-way classification of "activities", "impacts" and "consequences" has been adopted.

Types of Activities

Three broad classes of human activities that may have detrimental impacts on coastal processes have been identified for the purposes of this analysis:

- the building of coastal structures for protective, recreational, commercial or other purposes;

- the development of coastal lands for residential, commercial, tourism or other purposes; and

- the use of coastal lands by the community.

Within these broad classifications, a variety of potentially detrimental activities can be identified.

For example, the type of coastal structure will influence its impact on coastal processes; development activities such as the clearing of vegetation, earthworks, and the construction of roads all have different impacts on coastal processes; the use of coastal lands by people introduces potential problems associated with sewage disposal, vehicular traffic, boat movements, etc.

The chart of Figure B13.1 shows the different human activities with potentially detrimental impact that are considered in this analysis.

Impacts on Coastal Processes

The coastal processes or attributes that can be significantly modified by the above activities include the following:

- wave climate;
- longshore sediment transport;
- onshore/offshore sediment transport;
- vegetation;
- sand drift;
- tidal prism;
- stormwater flows; and
- water quality.

Wave climate is discussed in Appendix B5; longshore and onshore/offshore transport are discussed in Appendix B7; vegetation is discussed in Appendix B8; sand drift is discussed in Appendix B9. Tidal prism refers to the volume of tidal water that moves into and out of estuaries and coastal lakes each tide cycle. Stormwater flows typically enter coastal waters via a creek that crosses the beach berm. Water quality has not been discussed, but is a parameter that affects the amenity and use of coastal and estuarine waters.

In general terms, human activities can either increase, reduce or disrupt the above processes. Figure B13.1 shows the specific impacts included in the present analysis.

Detrimental Consequences

As a consequence of the above impacts, the amenity and attractiveness of the coastal zone may be altered and perhaps significantly degraded. Figure B13.1 shows the detrimental consequences of relevance to this analysis. They have been classified into the following three categories on the basis of location:

- Beach Berm/Nearshore Zone;
- Dune Zone; and
- Estuarine Zone;

3 THE INTERACTION MATRIX

Figure B13.1 shows the interrelationships between human activities, impacts and potential detrimental consequences in matrix form. The potential nature of the detrimental consequences is emphasized. The matrix is intended to alert readers to possible adverse consequences of human activities. A variety of interrelated and site specific factors determine the actual consequences that accompany human activities in the coastal zone.

Two examples illustrate how the matrix works:

First consider the clearing of dune vegetation for a coastal development. One impact of this activity may be damage to nearby vegetated areas. Possible consequences are the invasion of dune areas by exotic vegetation or dune erosion (blowouts).

Next consider the disposal of stormwater from a coastal development. This may have a number of adverse impacts on water quality, one of which may be increased nutrient levels in estuarine and coastal waters. Possible detrimental consequences include lower dissolved oxygen levels, algal blooms and the death of aquatic flora/fauna.

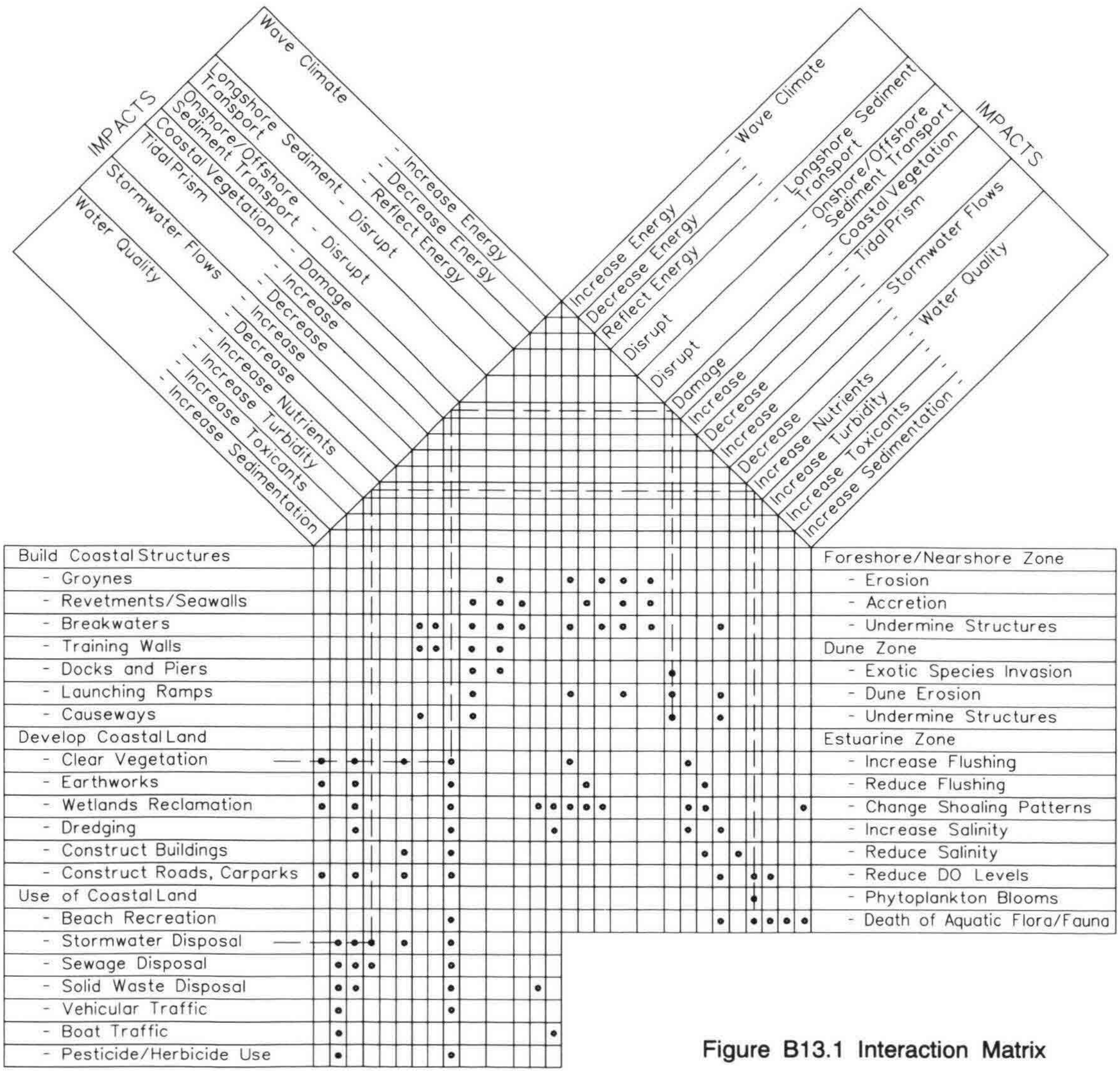

Figure B13.1 Interaction Matrix

APPENDIX C : COASTLINE HAZARDS

APPENDIX C

APPENDIX C1 PREAMBLE

This suite of appendices examines the hazards associated with the various coastal processes. These hazards are perceived in terms of their interference with human use and amenity of the coastal zone. The various hazards described here include:

- Beach Erosion
- Shoreline Recession
- Coastal Entrance Behaviour
- Sand Drift
- Coastal Inundation
- Slope and Cliff Instability
- Stormwater Erosion
- Climate Change

Beach erosion, shoreline recession and coastal entrance behaviour can markedly alter foreshore morphology and coastal bathymetry. If not properly catered for, such changes can imperil coastal developments and reduce amenity: houses built in the active erosion zone of a beach will be exposed to hazards; remorseless shoreline recession may provide a future risk to buildings currently outside the active erosion zone; training works at estuary entrances can foster erosion and threaten bridges and other coastal structures with collapse. All of these potential problems are capable of solution provided they are recognized at an appropriate point in the decision making process.

Sand drift is at best a nuisance and at worst a major hazard that, if uncontrolled, can overwhelm nearby developments or cause significant and permanent loss of sand from the beach system.

Low lying areas of the coast are at risk of flooding from coastal inundation and freshwater discharges. Coastal inundation is caused by a rise in Mean Sea Level (MSL) or by wave overwash across coastal barriers, such as dune systems and seawalls.

Slope and cliff stability problems are a threat to the structural integrity of buildings and works constructed on coastal bluffs, sea cliffs and sand dunes. Bluff slopes can fail due to landslip, sea cliffs can collapse and dune escarpments can slump, thereby putting buildings at risk.

The uncontrolled disposal of stormwater across the beach berm may create unsightly erosion areas and foster the migration of creek outlets.

Climate change may exacerbate all the above hazards.

Thus, the coastal zone is exposed to a variety of hazards that may threaten human activities and coastal amenity. In extreme cases, these hazards can lead to major financial loss. Notwithstanding such hazards, the pressure to develop additional areas of the coastline is intensifying.

An understanding of coastline hazards and their effects on developments and amenity is essential if the coastline is to be better managed. The solution lies first in the recognition of hazards and their impacts, and second, in the adoption of a balanced management approach.

APPENDIX C2 BEACH EROSION HAZARD

1 INTRODUCTION

The large waves, elevated water levels and strong winds generated by a storm can cause severe erosion to sandy beaches. Storm wave attack can move significant quantities of sand offshore (up to 250 cubic metres per metre run of beach, as measured above MSL). Storm waves undercut the beach berm and frontal dune to form a pronounced erosion escarpment. The foredune may be cut back by up to 20m during a major storm event.

Erosion is part of the natural response of a beach to changing wave and water level conditions. Generally, the eroded sand is returned to shore and the beach is rebuilt during calmer periods of swell waves.

Buildings and facilities located within the "active" beach system, or area subject to erosion, will be undermined, and if not designed for this hazard, may collapse. Figure C2.1 shows property damage at Wamberal in 1978 due to beach erosion.

2 MEASUREMENT OF BEACH EROSION

Erosion can be measured in terms of the volume of sand transported offshore or in terms of the landward advance of a significant beach feature, such as HWM or the "backbeach erosion escarpment" (erosion escarpment). Of these two features, the position of the erosion escarpment is preferred: it is a more definite and longer lasting feature than the HWM, which is subject to a much greater variation in position.

Figure C2.2 shows the landward advance of HWM and the erosion escarpment under storm conditions. During major storms, the HWM may advance 50 to 80m and foredunes may be cut back by up to 20m. The beach and foredune are rebuilt over time, but the erosion escarpment will remain clearly evident for several years. Figure C2.3 illustrates hypothetical examples of variations in the positions of HWM, incipient dune and foredune at a beach over a period of several

Figure C2.1 Undermining and Collapse of Buildings Caused by Beach Erosion

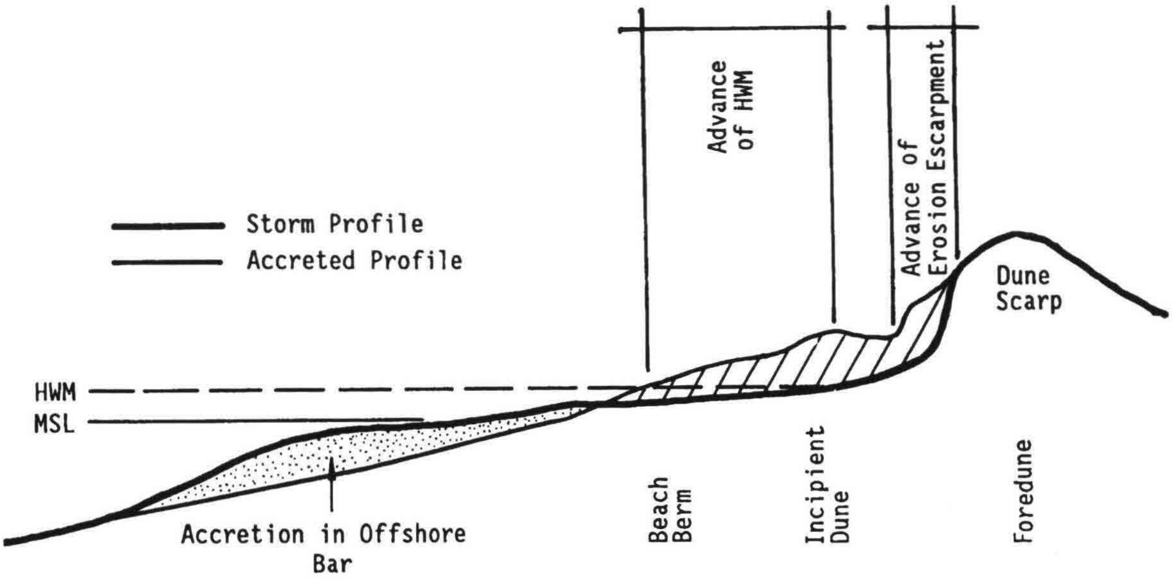

Figure C2.2 Beach Erosion Under Storm Conditions

3 FACTORS AFFECTING EROSION

The extent of beach erosion during a particular storm event depends upon a variety of factors that include:

- the wave conditions and elevated water levels generated by the storm, i.e. the severity of the storm;
- the presence of rip cells;
- the "condition" of the beach, i.e. the amount of rebuilding that has occurred since the last storm and the volumes of sand in dune and nearshore areas;
- the condition of dune vegetation which can influence the volume of sand in the foredune and incipient dune which helps to buffer the effects of storm erosion; and

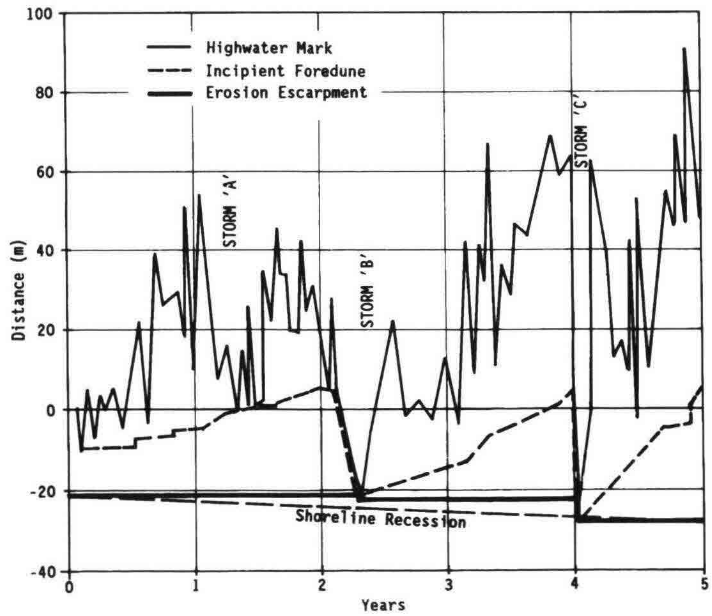

Figure C2.3 Variation in Position of Beach Features with Time.

- the presence and influence of adjacent headlands or coastal structures, which can modify local wave conditions and the supply of sediment.

Wave conditions and elevated water levels at a coastline depend upon the extent, intensity and duration of storm winds, and the distance of the fetch from the shoreline (see Appendix B3). The duration of peak wave and elevated water level conditions also influence the extent of erosion.

Variations in wave and current patterns along the nearshore zone also affect beach erosion. The most important of these mechanisms is rip cells, which greatly facilitate the offshore transport of sediment (see Appendix B6).

During storm conditions, most beaches attempt to establish an equilibrium profile which is largely determined by sediment size, storm wave climate and elevated water levels (see Appendix B7). The duration of the storm often determines the degree of establishment of this profile. Several storms in succession enhance the establishment of the equilibrium profile. During calm periods, the beach is rebuilt.

If a beach is in "poor" condition when a storm occurs, i.e. only partially rebuilt, a lesser volume of material will be removed than if the beach is in "good" condition.

Dune vegetation contributes to a beach and dune system being in "good" condition. "Healthy" dune vegetation speeds dune rebuilding following storms and will help to maximise the volume of sand available as a buffer to storm attack.

The presence of headlands, groynes and other features that influence sediment transport can also affect the extent of erosion. Under certain beach and storm conditions, these features can disrupt the local erosion/accretion processes and may lead to greater erosion than otherwise expected.

Dune height has a significant effect on the landward advance of erosion. In general, the higher the dune, the lesser the landward advance of the erosion escarpment. Storm waves impinging on the shore have a specific capacity to erode sand and transport it offshore. Generally, for a particular storm, there is a smaller recession of the dune escarpment for high dunes than for lower dunes, although the volume of sand eroded from the higher dunes may be greater.

If the eroding dune has a high groundwater level, it may suffer considerably more erosion than otherwise expected.

4 SLUMPING OF EROSION ESCARPMENT

The erosion escarpment formed during a storm may be nearly vertical. As the sand dries out, the escarpment will slump to a more stable slope of about 1V:1.5H. Dune rebuilding processes may further flatten the escarpment. This slumping defines a zone of "slope readjustment" in which buildings are at hazard of collapse (see Figure C2.4).

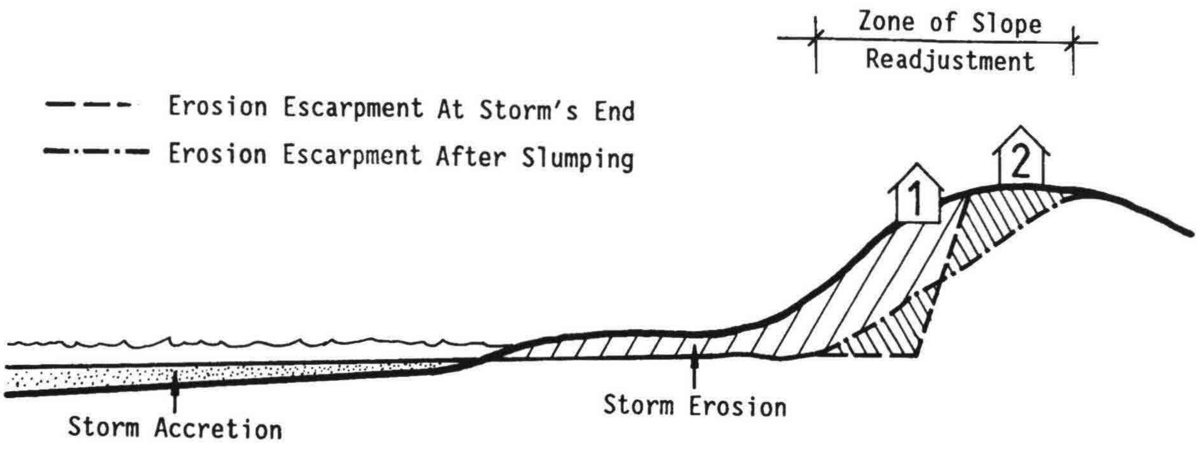

Figure C2.4 Zone of Slope Readjustment of Erosion Escarpment

5 BEACH EROSION IN NEW SOUTH WALES

The nature and behaviour of beaches along the New South Wales coast varies considerably because of differences in sediment characteristics, degree of compartmentalisation, wave climate and evolutionary history. Consequently, there may be significant differences in storm demand from beach to beach.

Table C2.1 shows the erosive impact measured in PWD studies of some storm events at various locations along the New South Wales coast: The results for the open coast indicate storm demand during major storm events ranging from 200 to 240 m^3/m of beach above AHD with the exception of the measurement for Byron Bay of 320 m^3/m of beach above AHD. This stormbite was measured immediately downdrift of a seawall protecting a carpark. Downdrift erosion would have been increased by the presence of rock protection on this high longshore transport rate coast. The largest landward movement of erosion escarpments measured by PWD in NSW during major storms are 17m at Wamberal in 1978 and 18m at Byron Bay in 1989. Again, this second figure would have been influenced by the rock protection immediately updrift of the measured location.

The storm demand measured in protected embayments is up to 130 m^3/m of beach above AHD.

As indicated in Appendix B2, further data re beach erosion is available from the data sets collected at Moruya and Narrabeen by members of the Coastal Studies Unit, University of Sydney (Thom and Hall (in press) and Hall, 1988).

Most post-storm volumetric measurements of beach erosion, whether made by ground level survey or by photogrammetry, usually reflect beach conditions after partial rebuilding has occurred. Thus, the full volume of beach erosion is usually underestimated in such measurements.

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Table C2.1
Beach Erosion Along the New South Wales Coast

Location	Year	Beach Erosion above AHD m^3/m run	Method of Assessment
Open Coast Beaches			
Narrabeen	1974	200	Photogrammetry
Collaroy	1945	210	Ground Survey
Wamberal	1974	240	Photogrammetry
Forresters	1986	200	Photogrammetry
Byron Bay	1989	320	Photogrammetry & Ground Survey
Protected Embayments			
Pearl, Broken Bay	1986	120	Photogrammetry
Callala, Jervis Bay	1974	130	Photogrammetry

APPENDIX C3 SHORELINE RECESSION HAZARD

1 INTRODUCTION

Shoreline recession is the progressive landward shift of the average long term position of the coastline. Recession is a different phenomena to beach erosion, although they both may be caused by the same processes.

Consideration of recession hazard is essential if coastal buildings and facilities are not to be ultimately subject to the threat of collapse. For example, on a receding coastline it is misleading to establish "setback" limits to cater for other coastline hazards. The receding coastline moves shorewards to eventually threaten the supposedly "safe" buildings and facilities.

2 CAUSES OF RECESSION

The two causes of shoreline recession are sediment loss and an increase in sea levels.

Sediment Loss

Recession of a sandy beach is the result of a long term and continuing net loss of sand from the beach system. According to the sediment budget concept, this occurs when more sand is leaving than entering the beach compartment (see Appendix B7). Recession tends to occur when:

- the outgoing longshore transport from a beach compartment is greater than the incoming longshore transport;
- offshore transport processes move sand to offshore "sinks" from which it does not return; and
- there is a landward loss of sediment by windborne transport.

Sea Level Rise

A progressive rise in sea level will result in shoreline recession through two mechanisms: first, by drowning low lying coastal land, and second, by shoreline readjustment to the new coastal water levels. The second mechanism is probably the more important: deeper offshore waters expose the coast to attack by larger waves; the nearshore refraction and diffraction behaviour of waves will change; a significant volume of sediment will move offshore as the beach seeks its new equilibrium profile.

Major changes in ocean levels and shoreline position have occurred over the ages, the most recent ending some 6,500 years ago when the MSL rose by some 140m (see Appendix B2). Present day shoreline recession can be viewed as the continuing long term readjustment of the coast to these changed ocean levels.

The postulated cause of significant sea level rise in the immediate future is the "Greenhouse Effect". To the year 2100, one authority has provided scenarios for planning purposes of an increase in sea level of the order of 0.5 to 1.5m (NAS,1987).

3 MEASUREMENT OF SHORELINE RECESSION

Shoreline recession is typically a long term process which in some cases is imperceptible. Its effect on a beach is often masked by the more rapid and dramatic erosion and accretion that accompanies storm events. Consequently, it can be difficult to identify recession from historical data, even if it extends over many years. Shoreline recession on undeveloped beaches may be completely unnoticeable: there are no fixed man-made features to act as reference points.

Trends in shoreline recession can be estimated in two ways:

- by assessment of changes over time in the volume of sand contained within the beach dune system (sediment budget approach); and
- by measurements over time of the position of various beach features, such as the erosion escarpment.

Sediment Budget Approach

The best indication of shoreline movement is obtained from a volumetric sediment budget survey which includes the total volume of sand in the active beach system. By measuring sand volumes in both offshore and onshore areas, the short term effects of storm erosion and beach rebuilding under swell wave conditions can be taken into account. However, such investigations are expensive because of the need for offshore survey data. This approach is not usually practical on a routine basis, especially for long sections of coastline.

Sediment budget surveys are more commonly limited to the volume of sand in the active beach and dune system above MSL. This can be relatively inexpensively determined by conventional ground survey or by photogrammetry. Such an approach does not give a direct measure of total beach change. Nevertheless, with care and careful interpretation, acceptable estimates of long term recession trends can be obtained. Such an approach is shown in Figure C3.1.

Position of Beach Features

Figure C2.3 of Appendix C2 depicts the change in the position of three beach features: HWM, the incipient dune and the backbeach erosion escarpment. Long term trends in the position of these features can be used as a measure of shoreline recession. The backbeach erosion escarpment is an obvious beach feature that is not affected by minor storms. Figure C2.3 shows the estimate of long term recession based on the position of this feature.

4 RELIABILITY OF RECESSION ESTIMATES

The time span, reliability of data and type of method used to determine shoreline recession all influence the reliability of the final estimate.

Most recession estimates are based on a relatively short period of historical data (typically 20 to 50 years). It is implicitly assumed that coastal processes over this period are representative of the long term situation. This may or may not be the case.

Shoreline recession progresses in a series of steps, as indicated in Figure C2.3. It only becomes evident as the landward advance of the backbeach erosion escarpment during major storm events. Thus, it is important to check the frequency and severity of storms over the time span of the data on which recession estimates are based.

Even the best recession estimates are only accurate to about ±30 %.

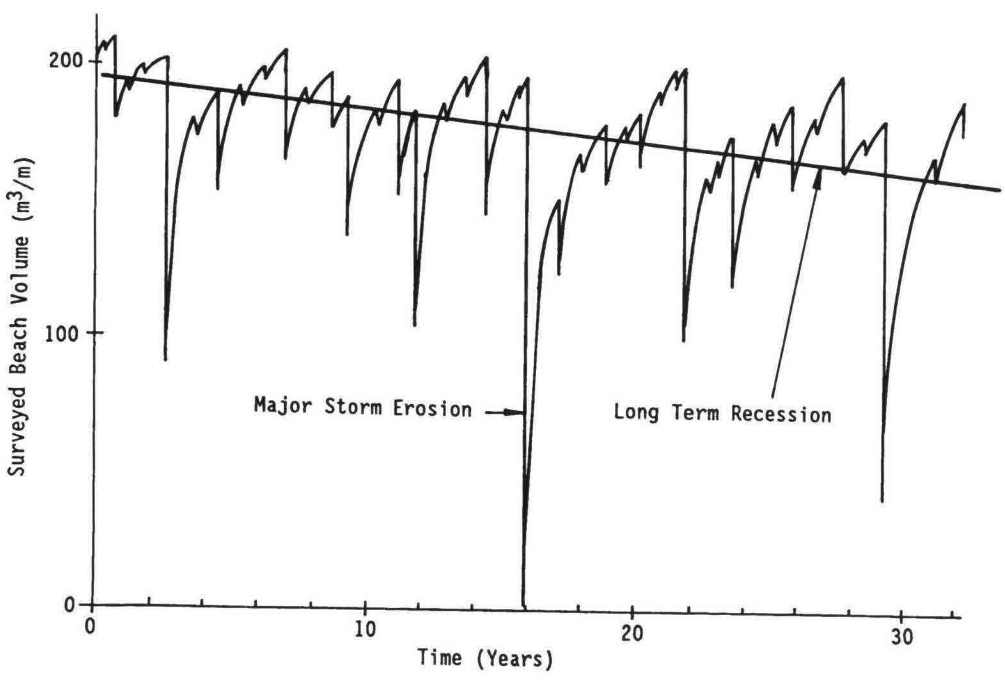

Figure C3.1 Long Term Recession Estimates Based on Changes in the Volume of Beach Sediments

5 RECESSION INDICATORS

Beaches undergoing significant shoreline recession usually display the following characteristic features or "recession indicators":

- a well defined backbeach erosion escarpment that progressively erodes landward over time; (there may or may not be an incipient foredune);

- a poorly vegetated erosion escarpment characterised by primary and secondary vegetation, such as spinifex grass and immature trees and shrubs. (The frequency of erosion incidents may not allow shrubs and trees to develop to maturity); and/or

- foredune vegetation that is characteristic of hinddune areas (i.e. mature trees, the seedlings of which would not normally survive in such an exposed location. Their presence behind the erosion escarpment indicates complete loss of the original foredune with the escarpment now located in what was originally a hind dune area. In fact these trees may often be found fallen onto the beach).

6 SHORELINE RECESSION IN NSW

Over the past 15 years or so, coastal process studies have been undertaken at a number of sites along the New South Wales coast. The results of these studies are shown in Table B7.1 of Appendix B7. Although the quality and extent of available data were limited in many cases, the results show a general recession trend at most beaches of 0.2 m/year or greater (up to 1.4 m/year).

7 FACTORS AFFECTING RECESSION

Shoreline recession along the NSW coast is caused principally by an imbalance in longshore or onshore/offshore sediment movement or windblown sand losses. The dominant cause depends upon the nature of the beach.

Pocket Beaches

Typically, pocket beaches experience little if any net loss of sand through longshore transport. Their bounding headlands tend to protect pocket beaches from longshore drift. Any recession is generally caused by wind losses or by an imbalance in onshore/offshore transport (loss to offshore sinks).

Extended Beaches

On extended beaches with significant longshore drift, recession is typically caused by an imbalance between incoming and outgoing longshore transport. This may be caused by the natural and continuing evolution of the coast following the post-glacial sea level rise, or by interference with sand movement along the coast e.g. by groynes, training walls, etc.

Coastal Features

Coastal features such as headlands, reefs and nearshore islands can also influence recession at adjacent beaches. Where longshore drift occurs past such features, the beach will tend to experience greatest recession immediately downdrift of the feature, i.e. coastal embayments with a net northerly longshore drift will tend to experience greatest recession at their southern ends.

8 REFERENCES

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APPENDIX C4 COASTAL ENTRANCE HAZARD

1 INTRODUCTION

Both natural and trained coastal entrances can create a variety of hazards. Natural entrances tend to migrate along the beach in response to freshwater flooding and coastal storm effects, so threatening any adjacent developments and the amenity of affected beaches. Training works will stabilise the location of an entrance, but may engender significant changes to the estuary and nearby beaches. Some training works in New South Wales have had detrimental effects of an unforeseen nature.

2 HAZARDS OF UNTRAINED ENTRANCES

Breakthrough

The location of untrained coastal entrances can vary markedly in response to freshwater floods and coastal storm conditions. This is illustrated in Figure C4.1, which shows breakthrough of an entrance spit caused by river erosion. Similar behaviour on a smaller scale is readily evident at many beaches, where stormwater discharges breakthrough the normally closed entrances of creeks and lagoons.

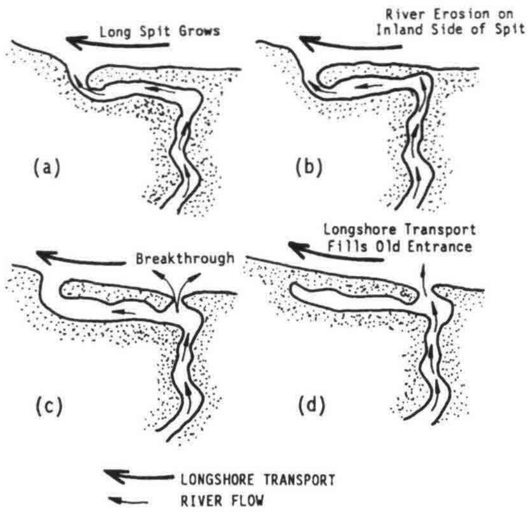

Figure C4.1 Entrance Breakthrough

Narrow low sand spits separating an estuary from coastal waters are vulnerable to breakthrough. This is especially so when the hinterland catchment has a rapid rainfall response time, which ensures high freshwater discharges of maximum erosion potential.

Whilst entrances to major estuaries can remain stable for many years, major floods can cause breakthrough at unexpected locations. This is illustrated in Figure C4.2, which shows the breakthrough at the Shoalhaven River entrance that occurred in 1988.

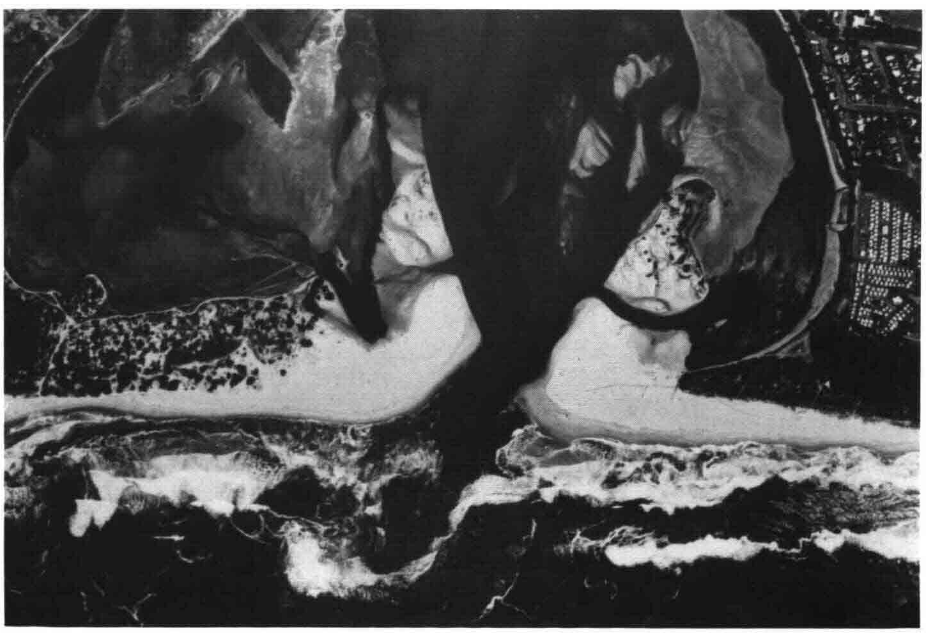

Figure C4.2 Breakthrough of Shoalhaven River, 1988

The breakthrough of low sand spits can also occur from the ocean. This was dramatically illustrated in the storm of 1974, when breakthrough and wave runup on a spit of the North Arm of the Brunswick River virtually destroyed the village of Sheltering Palms (PWD, 1978). In extreme cases, the entire spit can be destroyed by breakthrough in a single storm event, as occurred at Myall Point, Port Stephens, in 1927 (PWD, 1987).

Scour

Even where an inlet is stabilised by training works, entrance scour due to major floods can have considerable short and long term impacts on the estuary and adjacent shorelines. Flood scour can damage structures built in the active scour zone, as was illustrated dramatically in 1971 by the loss of Hancock Bridge which spanned the Bega River Entrance (see Figure C4.3). Other effects of entrance scour include improved estuary flushing, a drop in water levels along the estuary, the exposure of previously submerged estuarine fringes, and improved navigability (Williams, 1981).

Infilling and Closure

Entrance infilling refers to the buildup of sediment in coastal entrances. Under certain conditions, the entrance may be completely closed (this generally occurs only for small creeks and lagoons). Entrance infilling can restrict tidal flows and navigable access, reduce flushing and foster nutrient buildup and associated algal growth in the estuary. In addition, infilling provides a mechanism for the loss of sand from the beach compartment.

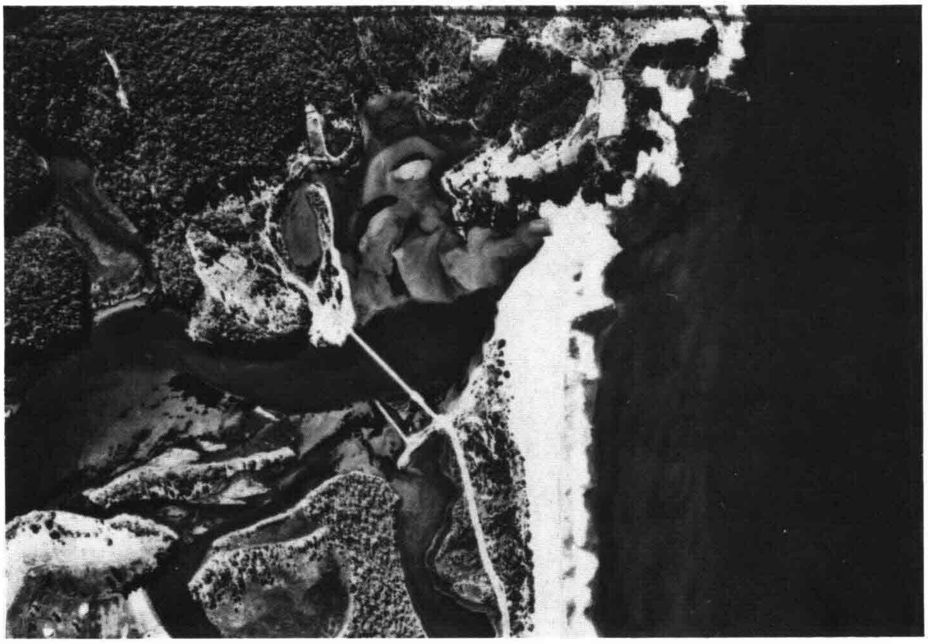

Figure C4.3a Bega River Entrance Before the 1971 Flood

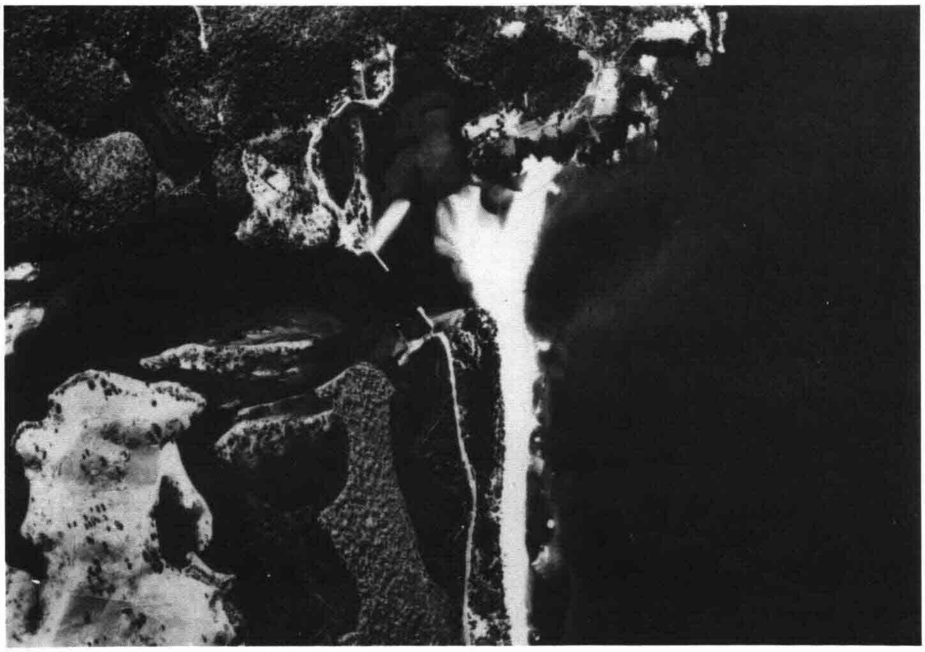

Figure C4.3b Bega River Entrance After the 1971 Flood

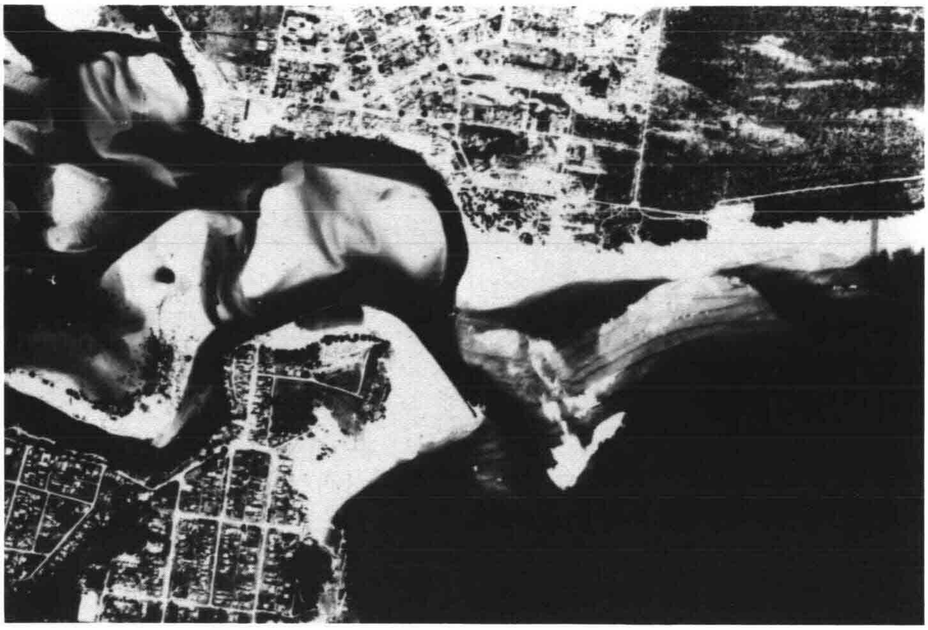

Figure C4.4a Wallis Lake Entrance, 1952

Figure C4.4b Wallis Lake Entrance, 1974

Infilling at the Bega River entrance, after scouring of the entrance during the 1971 flood, caused general erosion at nearby beaches (see Figure C4.3). In this case, beaches eroded as sand was lost to the scour "sink" (PWD, 1980).

3 HAZARDS OF TRAINED ENTRANCES

Training works at coastal entrances can markedly change the hydraulic behaviour of the estuary: the tidal range, water levels, current speeds, flushing behaviour and salinity levels all may be altered. In addition, training works may reduce or prolong freshwater flooding and can significantly alter waterborne sediment transport processes, both within the estuary and along nearby beaches.

The hazards of training works are demonstrated by the impact of the northern breakwater used to train the entrance to Wallis Lake at Forster/Tuncurry. Figures C4.4 shows photographs of the entrance and estuary prior and subsequent to the construction of the breakwater, which was constructed in 1966. The presence of the breakwater led to a number of major changes in the estuarine/beach system. First, significant and rapid scour of the entrance bar and shoals occurred. This threatened the foundations of the road bridge resulting in expensive remedial works to the bridge abutments. Second, there was massive sand relocation from the estuary to the margins of adjacent beaches. Finally, the tidal range of the estuary increased threefold (Nielsen & Gordon, 1980).

These changes are still occurring and it is estimated that it will take 50 years for the estuary to adjust to the altered entrance conditions.

Entrance breakwaters or training walls that project seawards may interfere with littoral transport along the coastline. Accretion may occur on updrift beaches or within estuary deltas with a resulting reduction in sand supply to down drift beaches (see Figure C4.5).

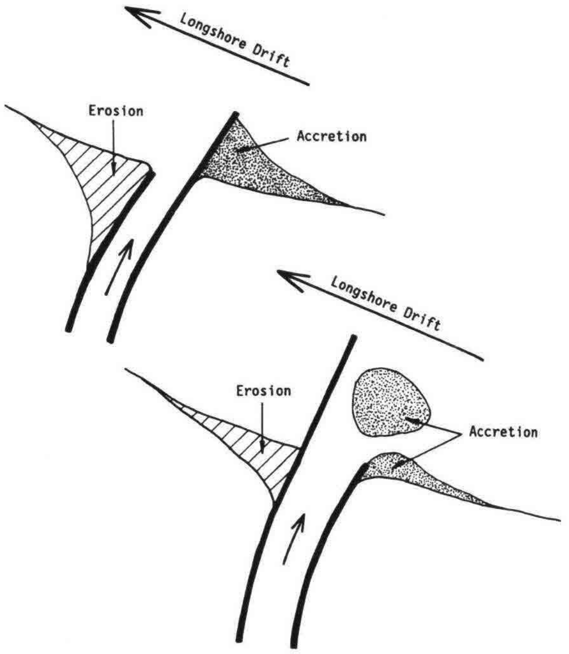

Figure C4.5 Effects of Seaward Breakwaters/Training Walls on Littoral Drift

Estuaries with multiple entrances may also be sensitive to entrance works. Two examples serve to illustrate this effect.

First, the training of one entrance may cause another to close, such as occurred on the Macleay River at Grassy Head.

Second, the interconnection of entrances may result in a substantial redistribution of flows, as has occurred between the Crookhaven and Shoalhaven Rivers. To use the more navigable entrance of the Crookhaven River, Alexander Berry organised the cutting of a small canal between the Crookhaven and Shoalhaven estuaries in 1822. The original canal was 6m wide and 200m long. Today, that canal is some 200m wide and 16m deep, and has resulted in a 50% division of flood flows between both river systems, i.e. 50% of the floodwaters in the Shoalhaven River pass out through the Crookhaven entrance. The enlargement of the original canal was caused by natural scour and by dredging works last century (PWD, 1977).

4 ASSESSMENT OF ENTRANCE HAZARDS

Detailed studies are required to assess the effects of training works on coastal processes and the nearby coastal zone. A sediment budget analysis is required to assess the significance of all forms of waterborne sediment transport. Detailed measurements of estuary and entrance currents may be required. Computer models can be used to investigate likely response to changed entrance conditions. Physical models may also be required to investigate changed erosion and accretion patterns.

5 REFERENCES

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APPENDIX C5 SAND DRIFT HAZARD

1 INTRODUCTION

Sand drift is caused by windborne sediment transport and is a seemingly inexorable coastal phenomenon: all sandy beaches experience sand drift to a greater or lesser extent. Moreover, it is a seemingly slow moving and gradual process, but short episodes of strong wind can move surprisingly large volumes of sand (transport is proportional to the cube of the wind's velocity).

Sand drift is a serious problem along the NSW coastline. A recent study has shown that 5,600 ha, or 11% of the total area of coastal dunes, is completely bare of vegetation and is undergoing active drift (Chapman, et al., 1987). A further 4% of the total dune area is in a state of incipient destabilisation leading to unimpeded drifting.

Sand drift creates a variety of hazards. At best drifting sand is a nuisance; at worst it represents a permanent loss of sand from the beach system and may completely overwhelm coastal developments. Detrimental effects include the abrasion of motor vehicles, buildings, vegetation and park and garden fittings; the burial of roadways, rail lines, agricultural land and coastal ecosystems; the blockage of street gutters and stormwater drains; and structural damage to buildings caused by forces imposed by the sand.

2 THE IMPORTANCE OF DUNE VEGETATION

In its natural state, dune vegetation provides an aerodynamic "cover" which deflects salt laden wind over the dunes. This minimises wind attack in dune areas and acts to trap any wind blown sand (see Appendices B8 and B9).

Breakdown of the vegetation canopy can expose sensitive foredune species to salt burn (especially rainforest plants). This can lead to irreversible degradation of protective vegetation, which in turn leads to dune "blowouts". Wind velocities are faster through the throat of the blowout, which causes more sand to drift. Thus, the blowout grows in a seemingly inexorable fashion and a moving "slipface" is formed at the rear of the dune (see Figure C5.1).

The revegetation of exposed dune and beach areas is hindered by sand drift. Difficulties can also arise if exposed areas are first, remote from a source of nutrient supply (normally the hinddune and strandline areas), second, remote from the source of recolonising seedlings, and finally, exposed to a microclimate considerably harsher than that of hinddune areas.

Figure C5.1 Dune Blowout and Slipface

3 FACTORS CAUSING SAND DRIFT

Sand drift in a coastal location is usually initiated by the degeneration or destruction of vegetation protecting the vital foredune. Common causes are foot and vehicle tracks devoid of vegetation running down the face of the dune. Studies have shown that as few as 50 vehicular passes per year are sufficient to prevent the revegetation of tracks.

Sand blown inland is permanently lost to the beach system and is not available to assist in the natural rebuilding of the dune system following wave damage. This leaves the dune system in a weakened condition to combat the next series of storm waves, which in turn results in progressively more serious beach erosion and may ultimately lead to shoreline recession.

4 SAND DRIFT PROBLEMS ALONG THE NSW COASTLINE

There are many examples along the New South Wales coastline of damage caused to adjacent land and property by sand drift. These include:

- on the South Coast, large migrating dunes at Wairo Beach, Windang and Port Kembla threatened to close a coastal road before expensive dune stabilisation works were implemented;
- on the Mid-North Coast, several urban and rural dwellings at Anna Bay are presently threatened by a 10 to 30m wall of sand drifting towards them (see Figure C5.2);
- the encroachment of urban development into the dunal area at Merewether Beach, Newcastle, requires the Local Council to regularly remove drifting sand from public roadways;
- on the NSW Coast, valuable wetland areas at Kurnell and Hat Head have been inundated by sand drift and their recreational and ecological amenity reduced; and
- again, on the NSW Coast, sand drift (at Hams Beach, Lake Macquarie aggravated by cattle grazing, sand mining, urban development and uncontrolled recreational vehicle use) has resulted in complete degradation of the dune system.

Figure C5.3 shows the change over the period 1967 to 1987 in the area of active sand drift along the New South Wales coast. The quite striking decrease in the drift area north of latitude 31° is largely attributable to invasion of these areas by bitou bush.

Bitou is a vigorous coloniser. In addition to colonising bare areas, it also displaces native dune vegetation and destroys the habitat of native animals.

In the long term, bitou provides a less resilient protection against wind and wave erosion than native vegetation. The removal of significant areas of bitou by storm attack or through biological or herbicidal control could trigger widespread sand drift in areas where it presently dominates dune vegetation.

5 THE CONTROL OF SAND DRIFT

With regard to the control of sand drift hazards, it is a case of prevention being much better than cure. The dune system of a beach plays a vital role in coastal processes. Dune vegetation, especially native vegetation, can be quite fragile. Stabilisation of the source area to cut off the supply of sand is the only way to control a moving

Figure C5.2
Dwellings
Threatened by
Sand Drift,
Anna Bay,
New South Wales

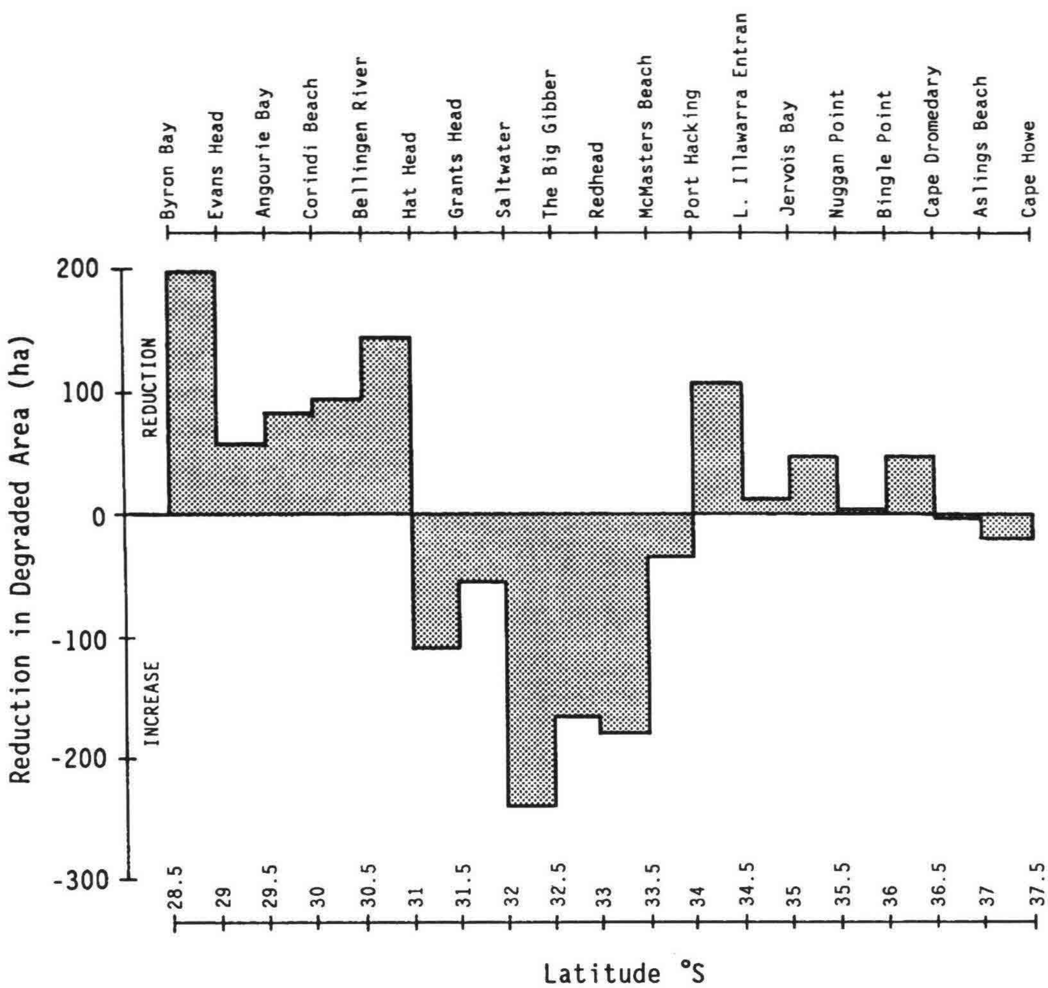

Figure C5.3 Change in Areas of Active Sand Drift Along the New South Wales Coastline, 1967 to 1987

dune slip face. Any other means of control (short of complete removal of the sand itself) is doomed to failure.

The prevention and control of sand drift requires a dune management plan. This should incorporate a dune survey to delineate areas at risk plus appropriate management practices to sustain healthy dunes and revegetate blowouts. All of these issues are addressed in the Coastal Dune Management Manual of the Soil Conservation Service (SCS, 1990). Techniques of dune stabilisation and dune maintenance are thoroughly described in this manual. Officers of the Service are available to assist local councils formulate and implement dune management plans.

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APPENDIX C6 COASTAL INUNDATION HAZARD

1 INTRODUCTION

Coastal inundation is the flooding of coastal lands by ocean waters. Unlike Holland, NSW has no significant areas below normal high tide level that are protected by artificial barriers. However, along the coast there are many low lying areas above normal high tide level that are subject to coastal inundation. These include wetland and other fringe areas of coastal lagoons and rivers, and the areas behind beach and dune systems. The inundation of these areas can be caused by large waves and elevated water levels associated with severe storms.

Severe coastal inundation is an infrequent event and is normally of short duration (peak flooding usually persists for several hours). Nevertheless, it can cause significant damage to public and private property: crops and livestock can be lost; the contents of flooded buildings can be damaged; problems can be caused by the breakdown of transport and communications. In addition, coastal inundation can be a threat to the life and limb of inhabitants of flood prone areas.

2 MECHANISMS OF INUNDATION

Elevated Water Levels

Storms increase Still Water Level (SWL) along the coast by the mechanisms of wind setup, barometric setup and wave setup (see Appendix B4). This increase in coastal water level can inundate low lying beach areas and low lying backbeach areas that are hydraulically connected to coastal waters.

Wave Runup and Overtopping

Wave runup is another mechanism whereby coastal inundation occurs (see Appendix B4). Waves can runup and overtop a coastal barrier, such as a dune or seawall, thereby inundating landward areas protected by the barrier. The vertical height of runup can be very high. During the storm event of August 1986, wave runup to a level of 7.3m AHD (i.e. about 7.3m above MSL) was measured at Narrabeen (PWD, 1987).

The height of wave runup on beaches depends upon many factors that include wave height and period, the slope, shape and permeability of the beach, the roughness of the foreshore area and wave regularity. Similar factors affect runup on rocky coasts and seawalls. Wave runup is difficult to predict accurately. Charts are available which indicate runup for specified beach slopes, seawall designs and wave characteristics (CERC, 1984).

3 AREAS AT RISK

Foreshores of Estuaries, Lagoons and Waterways

In general, the foreshores of estuaries, lagoons and coastal waterways are not protected from coastal inundation by natural or artificial barriers (e.g. sand dunes or seawalls). Flooding in these areas tends to be a gradual process. In those instances where the coastal entrance is relatively wide and deep, the variation of water levels in the waterbody closely mirrors the variation in coastal waters. In other instances where the coastal entrance is a narrow, shallow and tortuous channel, peak water levels in the waterbody caused by the ocean will be less than those of the open coast (see Appendix B10), however rainfall derived problems may be greater.

Low Lying Land Protected by Coastal Barriers

Low lying land behind coastal barriers, such as dune systems and seawalls, tends to remain completely protected until a certain critical combination of waves, elevated water levels and possibly beach erosion occurs. Inundation then commences, typically by wave runup and overtopping. The inundation of protected areas can also occur via backflow through stormwater pipes. This is often a gradual process. However, if the barrier is completely overtopped or breached, inundation of back areas can be rapid. If back areas are poorly drained, flooding behind a breached or overtopped barrier may persist for some time when coastal water levels fall.

4 INTERACTION WITH FRESHWATER FLOODING

Many areas within the coastal zone can be affected by a combination of coastal inundation and freshwater flooding, e.g. the "big" rivers of northern NSW. The extent and behaviour of such flooding is complex and depends upon the magnitude, variation and relative timing of freshwater inflows and coastal water levels.

In general, flooding along areas close to the coast is dominated by coastal water levels. The contribution of freshwater effects to flood levels becomes greater with distance upstream. Nevertheless, coastal water levels can influence river levels for a considerable distance upstream along major coastal rivers, e.g. flood levels at Ulmarra on the Clarence River are influenced by coastal water levels at its mouth, which is 30km downstream at Yamba.

5 EXTENT OF INUNDATION

Identification of the levels of coastal inundation is an essential starting point in the management of this hazard. This requires information concerning design storms and their associated storm surge, wave setup and wave runup effects. Computer models may be required to simulate coastal water levels and the extent of coastal inundation.

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APPENDIX C7 SLOPE AND CLIFF INSTABILITY HAZARD

1 INTRODUCTION

Slope and cliff instability hazards refer to the possible structural incompetence of these features and associated potential problems with the foundations of buildings, seawalls and other coastal works. Coastal bluffs and the erosion escarpments of sand dunes can slump, sea cliffs can collapse, and foundations can fail, so imperilling coastal developments and structures.

Slope and cliff instability is a different phenomenon from coastal erosion and recession. This is illustrated in Figure C7.1, which shows the loss of two houses from a foredune area. The first house was lost to erosion. The second house was lost due to the collapse of the dune escarpment. Whilst beach erosion and scour can cause stability problems, the collapse of a foreshore slope or the failure of a foundation depends upon the properties of the associated soil and rock constituents. The disciplines of soil and rock mechanics are essential to a stability analysis of coastal slopes, cliffs and foundations built thereon. Relevant aspects of these disciplines are briefly mentioned in the addendum to this appendix.

2 FAILURE MECHANISMS

Sand Dunes

Typically, a sandy beach in its accreted state consists of a beach berm, a well grassed incipient dune, a higher frontal dune and hind dunes. Severe storms can cause erosion of the berm and frontal dune, leaving a pronounced erosion escarpment. As it dries out, the escarpment tends to "fail" by slumping back to the angle of repose of the sand (about 1V:1.5H). A zone of "Slope Readjustment" can be defined (see Figure C7.1). Any buildup and seepage of groundwater during the storm event will facilitate slumping of the erosion escarpment.

Bluffs

The term coastal bluff refers to headlands and foreshores of weathered rock and to soils perched on rock platforms. Typically, bluff escarpments are sloping rather than vertical (unlike sea cliffs). Examples of coastal bluffs include the foreshore of Bateau Bay in Wyong Shire, Long Reef Headland in Warringah Shire and the headland at Thirroull

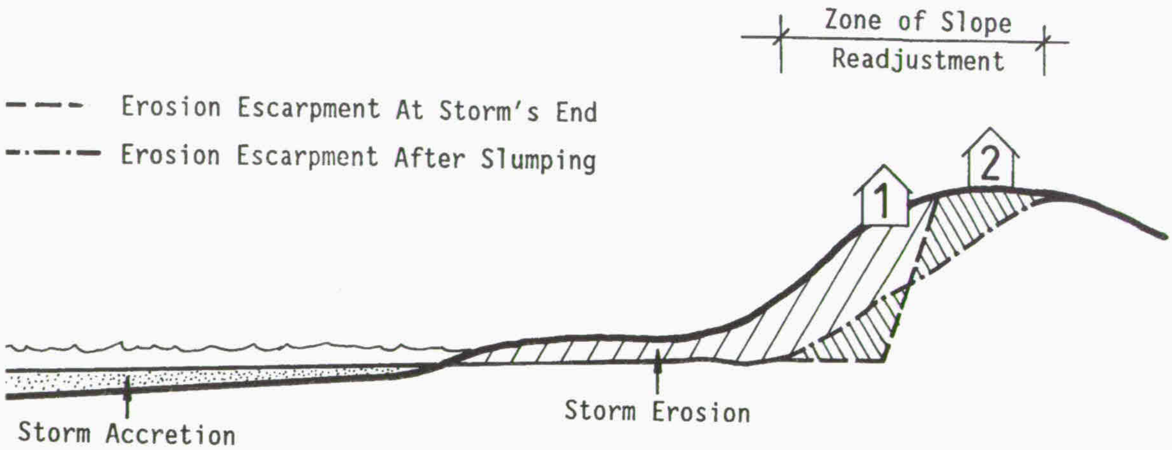

Figure C7.1 Loss of Houses Due to Beach Erosion and Collapse of Erosion Escarpment

Figure C7.2 Landslip Failure of Coastal Bluff, Bateau Bay, Wyong Shire

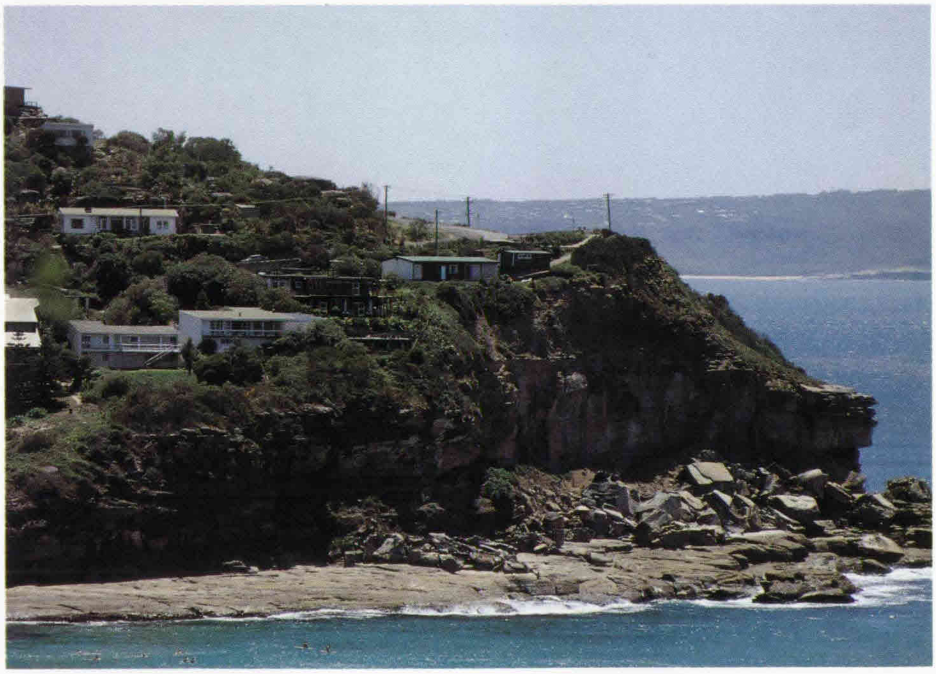

Figure C7.3 Cliff Collapse, Whale Beach, Warringah Shire

near Wollongong. The soil areas of coastal bluffs "fail" by "slipping" along a circular failure surface ("slip circle"); weathered rock areas "fail" by a mixture of collapse and sliding. Figure C7.2 shows a slip circle failure of the coastal bluff at Bateau Bay.

Cliffs

A cliff is a sheer or precipitous rockface that stands nearly vertical. Cliffs are subject to infrequent but sudden collapse. Figure C7.3 shows a recent cliff failure at Whale Beach, Warringah Shire.

3 FACTORS AFFECTING STABILITY

Erosion

Severe beach erosion cuts a pronounced escarpment in the frontal dune, which reduces the stability of the dune area immediately behind it. The stability of coastal bluffs is also reduced by erosion, but this is often a gradual process that only takes effect over many years.

Scour Level

The greater the depth of scour in front of a slope or structure, the greater the resulting instability.

During severe storms, a large body of sand is kept in constant motion over the berm. Immediate post-storm measurements indicate eroded berm levels only 0.5m above MSL. However, post-storm drilling in the berm has indicated erosion limits at depths of 1.0 to 1.5m below MSL, i.e. open beach berms are scoured to a level of at least 1.0m below MSL during severe storms (GS, 1985; 1986).

Scour in front of a reflective seawall is likely to be significantly greater than this amount. A scour level of 2.0m below MSL is often adopted for design purposes.

The rock platform that forms the base of some coastal bluffs is resistant to scour. Typically, this platform is located at about MSL.

Groundwater and Seepage

Seepage reduces the stability of a slope by making it easier for the soil particles to slide over each other during failure. Similarly, pore water pressures associated with a groundwater table reduce the inherent strength and stability of a soil mass.

The heavy rainfall that often accompanies severe storms may cause ponding behind the frontal dune, thereby increasing pore water pressures at the toe of the escarpment and the likelihood of failure. Often heavy rainfall is the triggering mechanism in land slip failures on bluffs. The generally poor drainage characteristics of these soils allow a buildup of pore water pressure.

The groundwater level in the beach berm fluctuates in response to tides and waves. When storms increase the average water level on the beach, groundwater levels in the dunes may rise accordingly. If coastal water levels should fall rapidly, e.g. through reduced wave heights on a falling tide, the water table in the dune may remain elevated for some time. A water table "setup" of 2m has been observed through this effect (PWD, 1988). Elevated groundwater levels reduce the stability of the erosion escarpment.

4 ASSESSMENT OF STABILITY PROBLEMS

Potential slope, cliff and foundation stability problems can be overcome by proper investigation and design. The limit of beach erosion/recession adopted for design purposes needs to be determined; field work to determine soil and rock properties and likely seepage and groundwater behaviour is required. The assessment of slope stability and the safe design of foundations lies in the fields of soil and rock mechanics. Salient features of these fields are briefly introduced in the Addendum to this Appendix.

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ADDENDUM: SOIL AND ROCK MECHANICS

A: Soil Properties

Cohesive and Non-Cohesive Soils

Sand is a non-cohesive soil that generates its strength or ability to sustain loads by the interlocking of sand grains (internal friction). Clay is a cohesive soil that generates its strength from the cohesion or "stickiness" between clay particles.

The behaviour of frictional and cohesive soils is quite different. A clay face can be cut to a vertical angle and remain stable; a sand face will collapse to the angle of repose of the sand. Most natural soils exhibit a mixture of frictional and cohesive behaviour.

Saturation

The degree of saturation of a soil and the depth to the water table have a major impact on the strength of the soil. The higher the degree of saturation, the more easily soil and clay particles can slide over each other. Pore water pressures associated with a water table reduce the carrying capacity and strength of a soil.

Dune Sands

Dune sands are generally composed of fine to medium sized quartz grains of subangular to rounded shape. Figure B7.1 of Appendix B7 shows the size distribution of a typical dune sand. Often dune sands are loosely packed at the surface, but become denser with depth. There are exceptions to the above rules: dune materials can include silty sands, peats and indurated sands (sands loosely cemented together and known as "beach rock" or "coffee rock").

The behaviour of dune sands is almost wholly frictional with little if any cohesive effects. Particle grading, size, angularity and in-situ density all influence the strength or load carrying capacity of sands.

The behaviour of "coffee rock" is not well understood: some indurated sands are soft when buried, but on exposure to air, turn into a brittle "coffee rock" that fractures easily; other "coffee rock" decomposes when wetted. Recent studies indicate that the long term erosion rates of indurated sands are similar to those of loose dune sands (Lord and Burgess, 1987).

Bluff Soils

Coastal bluffs are usually composed of weathered igneous rocks. Bluff soils typically comprise clays derived from the weathering of these rocks interspersed with boulders. Bluff soils typically display a predominately cohesive behaviour, but some frictional effects may be present. Because of their clay nature, bluff soils are often poorly drained. This facilitates the build-up of pore water pressure, which in turn lowers the stability of the bluff.

Stratigraphy

A stability analysis of a frontal dune or bluff requires information concerning the extent and nature of the principal soil strata and the depth to groundwater. This information can be obtained from a drilling program, from a close inspection of the dune face (especially if eroded) and possibly from local authorities (if sewerage, bridge or other construction works have been undertaken in the area).

Field and Laboratory Tests

Field and laboratory testing will often be required to determine the physical properties of the underlying soils. Field tests include Hollow Flight Augering and the Standard Penetration Test (which indicates the in-situ density of sands). Laboratory tests include grading, permeability testing, shear box and triaxial testing (the latter two tests indicate the properties of cohesive soils).

B: Rock Properties

The stability of rock cliff face or a rock bluff depends upon the type, jointing and other properties of the component rocks. The assessment of the stability of rock faces is much less exact than for soil slopes. Cliff failures are difficult to analyse. Analytical methods often incorporate finite element techniques applied to rock mechanics.

C: Slope Stability Analysis

Soil slopes generally tend to fail by "slipping" along circular failure surfaces. The presence of a weaker stratum of soil can modify both the failure surface and the failure mechanism (see Figure C7.4).

"Slip Circle Analysis" is a technique for assessing the stability of such slopes and their "Factor of Safety" against failure. Such computations serve as a guide to determining minimum setback distances from the erosion escarpment of the frontal dune or from the crown of a bluff subject to slipping.

A variety of trial failure surfaces needs to be investigated if the slope contains different soil types, weak strata or is affected by groundwater seepage. Computer methods of analysis are of benefit in these circumstances.

Slip Circle Analysis does not provide exact solutions. Major uncertainties can arise in the selection of pore water pressure and soil strength parameters. For these reasons, a minimum Factor of Safety against failure is adopted (Lambe and Whitman, 1969). Where details of soil stratigraphy and soil strength have been determined by field and laboratory measurements, a Factor of Safety of 1.5 is recommended. Where this information is less certain, the Factor of Safety should be increased accordingly.

D: Foundation Failure Analysis

The Standards Association of Australia has not published any codes of practice for the design and construction of foundations in the active zone of the beach. Moreover, there is no Local Government Building Code in New South Wales for such foundations. Thus, the designer must rely on design codes for non-coastal areas of the State and adapt them for coastline hazards. Particular factors to be considered include the landward limit of erosion/recession, the zone of slope re-adjustment of the erosion escarpment on sandy

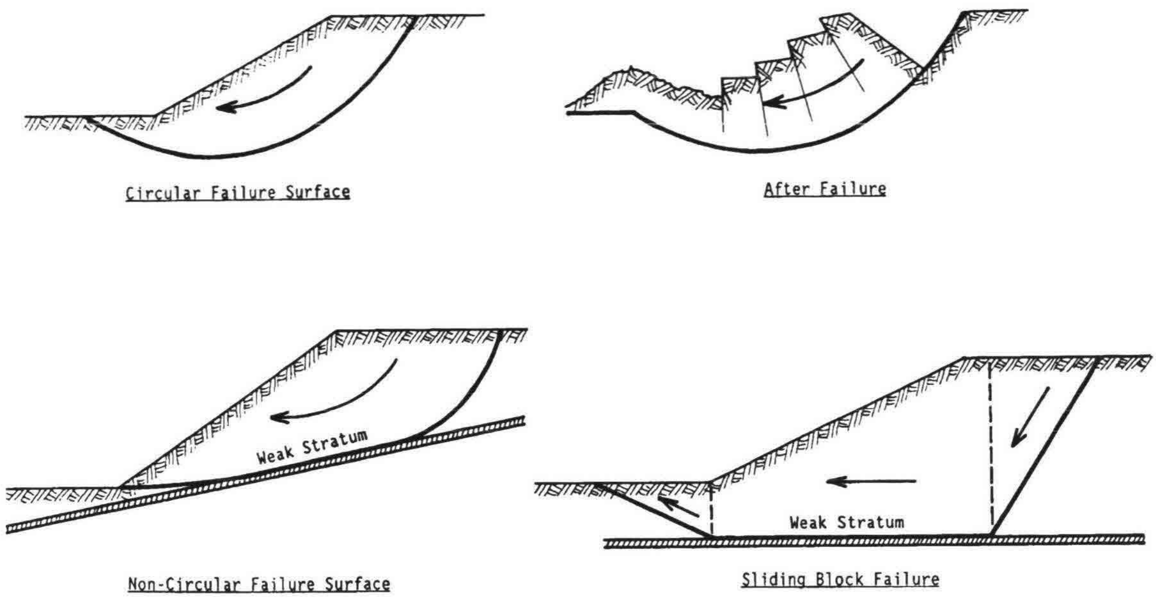

Figure C7.4 Types of Failure Surfaces

beaches, and foundation/soil interactions under changing groundwater and seepage conditions.

Shallow Foundations

Shallow foundations include piers, strip footings and slabs. Figure C7.5 shows the failure surfaces for a strip footing. Should such a footing be located within a zone of potential slip circle failure, the bearing capacity of the footing should be adjusted accordingly.

Piled Foundations

Piled foundations can be used to transmit foundation loads to the soil mass below the zone of potential slip circle failure. In this way, a structure can be safely located within the zone of potential slope instability. However, a slip circle failure can impose high lateral loads on piles that intersect the failure surface. This effect needs to be taken into account in the design of such foundations.

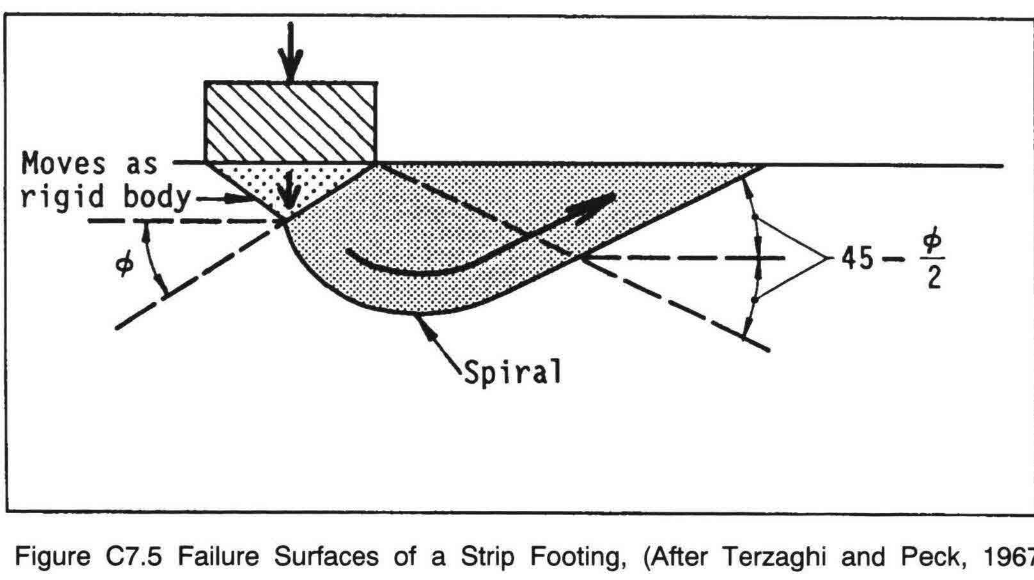

Figure C7.5 Failure Surfaces of a Strip Footing, (After Terzaghi and Peck, 1967)

Seawalls

The use of a seawall to protect a foreshore slope does not necessarily ensure stability of the slope. First, the seawall itself may fail under extreme conditions. Vertical, non-porous seawalls are vulnerable to sudden collapse caused by toe scour and by pore water pressure build-up behind the wall. Second, the failure surface of the slope may extend under and beyond the seawall, i.e. the seawall forms part of the mass of soil that fails. To maximise stability, seawalls should be porous with a gently sloping face, especially if development is to be allowed close to the crest.

APPENDIX C8 STORMWATER EROSION HAZARD

1 INTRODUCTION

Many backbeach areas are drained by semi-perennial small creeks that cross the beach berm to discharge stormwater into coastal waters. During major runoff events, such creeks can cause significant erosion to the beach berm and the nearshore area around their entrance. This in turn allows larger waves to attack the creek entrance, which if unstable, may migrate along the beach.

Stormwater disposal hazard is a local problem. It should not be confused with the regional problem of freshwater flooding and the interaction of the latter with coastal inundation (these hazards are covered in Appendix C6). Similarly, the entrance behaviour of these minor creeks is essentially a local phenomenon. Although subject to the same coastal processes, the behaviour of these local creeks should not be confused with the behaviour of major coastal entrances (these hazards are described in Appendix C4).

2 FACTORS AFFECTING STORMWATER EROSION POTENTIAL

One of the major factors affecting stormwater erosion potential is the degree of development in the catchment area draining to the creek. Urban developments such as carparks, roads, shops and other buildings result in the replacement of porous natural surfaces (very much so in the case of sandy areas) with impermeable surfaces. This has two effects on stormwater runoff. First, the volume of runoff tends to increase significantly. Second, the peak rate of runoff also increases. Both effects result in a significant increase in the erosion potential of stormwater discharges in the creek.

Creek outflows during storm events can be a triggering mechanism for the formation of rip cells. This can markedly increase the degree of berm erosion around the creek entrance (see Appendix B6).

Creek entrances on sandy beaches tend to be unstable in location. Migration of the entrance during stormwater runoff episodes may pose a threat to adjacent developments. (Creek entrances can be readily stabilised using low cost training walls, such as that recently built at Dee Why Lagoon on the Sydney coast).

The rebuilding of a beach after a major storm event may close a creek entrance, especially if the creek only flows intermittently. When subsequent rainfall occurs, this can result in local flooding in upstream areas before the blockage is flushed away.

3 STORMWATER DRAINAGE STUDIES

A regional drainage study of the catchment draining to the creek is required to define the volumes and peak discharge generated by the design storm event. Once these data are to hand, various options to reduce the hazards of stormwater erosion can be investigated. These include the use of retarding basins to reduce peak discharges, the diversion of runoff into adjacent catchments where erosion problems are less critical, stabilisation of the creek entrance, protective bank works, and the use of dissipation structures to reduce beach scour.

1 INTRODUCTION

In coastal areas, the most discussed potential hazard of the postulated warming known as the Greenhouse Effect, is the scenario of rising in sea level. However, climate change may alter wind and wave climates, both of which may produce a realignment of the coast. The impact of any sea level rise would then be exacerbated by the accompanying foreshore erosion.

As yet, little detailed information is available regarding the likely impact of climate change. The situation is further clouded by the highly interrelated nature of impacts on coastal processes. Nevertheless, broad scenarios have been postulated by the scientific community.

2 SEA LEVEL RISE

Figure C9.1a illustrates sea level scenarios to the year 2100 adopted by the U.S. National Research Council after deliberations by a technical committee (NAS, 1987). These scenarios were adopted after review of information available from the scientific community. The three scenarios adopted are for a sea level rise of 0.5m, 1.0m and 1.5m by the year 2100.

Figure C9.1b illustrates sea level scenarios to the year 2050 based on box diffusion modelling of ocean warming which was undertaken at the University of East Anglia (Commonwealth Group of Experts, 1989). These projections to the year 2050 range from a sea level rise of 7 to 67 cm (best estimate range 24 to 38 cm).

Figure C9.1c illustrates "Scenario A" of sea level scenarios developed by the United Nations Environmental Program Intergovernmental Panel on Climate Change (UNEP–IPCC, 1990). "Scenario A" is based on no limitation of greenhouse gas production which is considered the most realistic option to choose for planning purposes at this time.

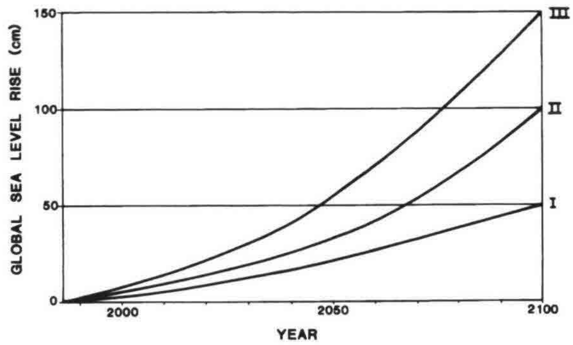

Figure C9.1a Sea Level Scenarios (NAS, 1987)

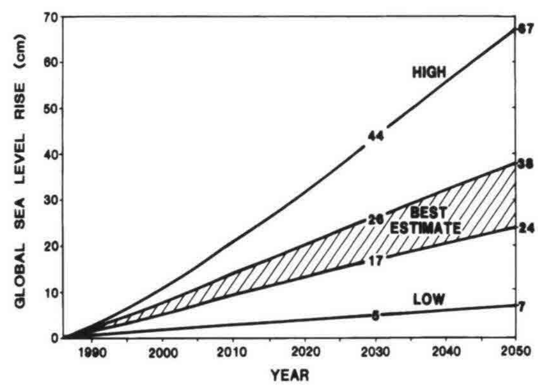

Figure C9.1b Sea Level Scenarios (Commonwealth Group of Experts, 1989)

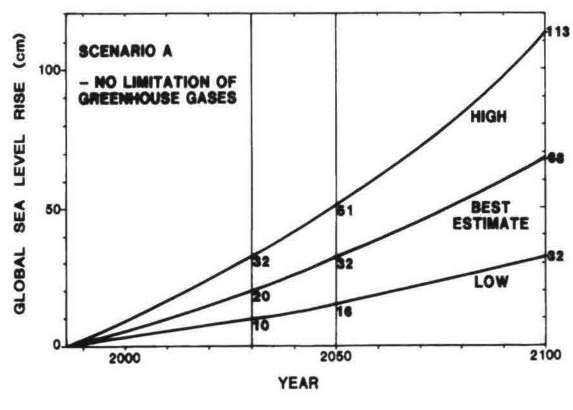

Figure C9.1c Sea Level Scenarios (UNEP/IPCC, 1990)

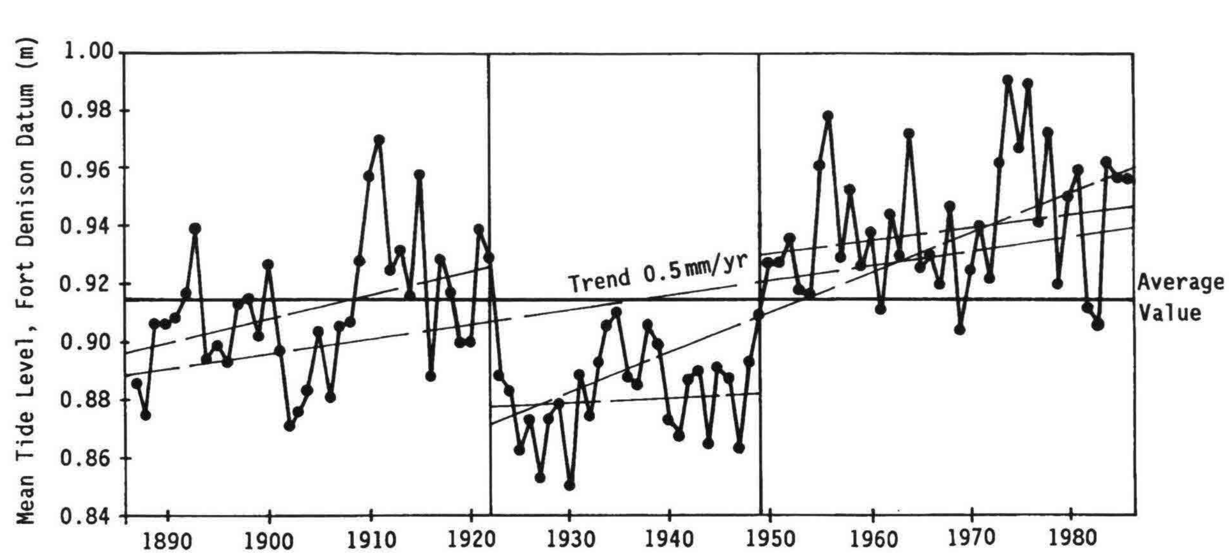

Figure C9.2 Variation in Average Annual Tide Level, Fort Denison, 1887 to 1987

Examination of Figures C9.1a, b and c indicates that the sea level scenarios for say 2050 are very similar. As the IPCC Working Group report is the most recent and it accounts for the views of the international scientific community, it is considered that Figure C9.1c illustrates the currently available "best estimate" of sea level scenarios.

Average Annual Tide Level at Fort Denison

Now what of sea level changes along the New South Wales coastline in the immediate past? Figure C9.2 shows the variation in average annual sea level at Fort Denison in Sydney Harbour over the 101 year period, 1887 to 1987.

Over this period of time, the average annual sea level was 0.914m (Fort Denison datum). Mean sea levels have fluctuated around this figure by ±70mm in response to the changing position and gravitational influence of the sun and planets and any other factors that influence long term tidal behaviour.

Three distinct sub-periods are apparent in the tidal record: 1887 to 1921, 1921 to 1949 and 1949 to 1987. During the first of these periods, water levels fluctuated around the long term average value. During the second and third periods, water levels were consistently below and above the long term average value. The reason for the "drop" in water levels between 1921 and 1949 and the "rise" between 1949 and 1987 is not known.

Also shown in Figure C9.2 are trend lines for the change in mean sea level over various periods. The trend over the entire 101 year period is a mean sea level rise of about 0.5mm per year. In the first sub-period, the trend is 0.9mm per year, which is about twice the long term value. The trend in the second sub-period is only 0.05mm per year, which is one tenth the long term value. The trend in the third sub-period is 0.4mm per year and is close to the long term value. If the last two sub-periods are considered together, the trend in sea level rise over the period 1921 to 1987 is 1.4mm per year, or about three times greater than the long term value.

The above results demonstrate a number of difficulties in attempting to confirm climate change in the immediate past. First, only a relatively short period of data is generally available. Second, the data may not be consistent and may contain errors (monitoring techniques are constantly changing). Third, the number of factors that affect climate and the resulting "natural" variation make it difficult to identify the effects of a single factor.

On the basis of the above discussion, it can be suggested that mean sea level off the New South Wales coast has been increasing at an average value of about 0.5mm per year over the last 100 years. Before a more definite conclusion can be drawn, the reason for the distinct change in sea level behaviour over the last two sub-periods would need to be determined.

3 METEOROLOGICAL EFFECTS

Storms

Some scenarios suggest that the severity and frequency of storm events may increase. This would be caused by a southward movement of the cyclone belt, i.e. more of the NSW coast would become susceptible to cyclones, and by the increased storm activity associated with greater temperature gradients in the temperate zone.

Rainfall

Rainfall intensity may similarly increase in some areas, resulting in higher flood levels and increased scour at river, creek and lagoon entrances and at stormwater outlets.

4 WAVE AND CURRENT EFFECTS

Any increased storminess would generate a more severe wave climate, i.e. larger waves would occur more frequently. Moreover, the principal direction of wave attack on the coast could also alter in response to changed patterns of storm generation. Increased coastal water levels would modify the shoaling, refraction and diffraction behaviour of waves as they move towards the shoreline.

The temperature of ocean and shelf currents is an important factor in storm generation and intensity. Where currents move close inshore they can also affect waterborne sediment transport and water quality. Changes to climatic zones and wind patterns could produce changes in ocean and shelf currents, which in turn could affect storm behaviour and sediment transport.

5 SHORELINE POSITION

If the Greenhouse Effect develops as postulated, the shoreline would move landwards because of two effects: inundation due to increased sea levels; and increased shoreline recession due to greater storminess, higher waves, increased sea levels and any changes to the direction of wave attack . The second effect may be of far more significance than the first.

Bruun (1962) proposed a methodology to estimate coastal recession resulting from sea level rise. Gordon (1988) has suggested a tentative link between coastal recession in New South Wales over the past 40 years and increased sea levels over this period.

6 SEDIMENT TRANSPORT

Longshore Drift

Longshore drift is sensitive to long term changes in wave height and wave direction, both of which would be expected to be altered by climate change.

Onshore/Offshore Transport

The amount of sand removed from a beach and dune system depends upon a number of factors, the most important being the intensity and duration of storms. A possible increase in the severity and frequency of intense storm events associated with the postulated greenhouse effect would accelerate beach erosion.

7 FRESHWATER FLOODING

The severity of freshwater flooding may increase in some areas if greater intensities of rainfall eventuate. Areas may become prone to coastal inundation and freshwater flooding. The increased storm surge and wave setup at estuary and river entrances could also increase flood levels in the lower reaches of rivers.

8 ENTRANCE BEHAVIOUR

Changes in coastline position and alignment would affect the behaviour of both natural and trained entrances. Changes in the hydraulics and sediment transport behaviour of entrances could be expected.

9 COASTAL STRUCTURES

Important factors in the design of coastal structures are wave climate and the depth of scour in front of the structure. Both of these factors may be exacerbated by climate change; the stability of coastal structures could also be reduced.

10 SALINITY LEVELS

The tidal and salinity limits of many coastal waterways would move inland in response to any long term rise in sea level. New areas could be exposed to salt and brackish water. Current low lying areas would become saline wetlands; current wetlands would become shallow lagoons. The increases in salinity and inundation would affect terrestrial flora and fauna and aquatic life. In addition, the changes would interfere with present land use practices, e.g. the use of low lying land for farming purposes.

A long term rise in sea level would also be reflected in changes to coastal groundwater tables. Coastal groundwater levels would rise; the underlying saline lens would move further inland; salinity levels of the existing groundwater regime could change markedly. These changes would be of considerable moment to the use of groundwater by plants and humans.

11 COPING WITH CLIMATE CHANGE

Whilst the available evidence suggests that climate change is occurring, there is as yet little reliable information available on which to base planning and design decisions. "Natural" fluctuations in world climate make it difficult to identify and define long term trends. Both the magnitude and in some cases the nature of various impacts are as yet poorly understood. Even where prediction has been attempted, e.g. sea level rise, the decision maker is faced with a very large range of choices.

In the light of the present uncertainty, an adaptive approach towards planning and design in the coastal zone is necessary. This approach should be sufficiently flexible or "robust" to be able to cater for a range of possible outcomes (see Appendix D7 for details).

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APPENDIX C10 HAZARDS, PROCESSES AND COASTLINE TYPES

1 INTRODUCTION

The previous Appendices C have examined the hazards associated with various coastal processes. Seven separate hazards can be identified:

- Beach Erosion
- Shoreline Recession
- Coastal Entrance Behaviour
- Sand Drift
- Coastal Inundation
- Slope and Cliff Instability
- Stormwater Erosion

The first four of these hazards relate to the "stability" or behaviour of sandy beaches, i.e. the position of the backbeach erosion escarpment and the onshore profile of a sandy beach.

By way of summary of coastline hazards, this appendix identifies the coastal processes giving rise to the various hazards and the broad relevance of the hazards to the three coastline types of New South Wales. This allows councils to rapidly obtain an indication of the potentially more important hazards of relevance to their stretch of coastline.

2 PROCESSES AND HAZARDS

Table C10.1 shows the principal processes that contribute to the different hazards. Because of their interrelated nature, various processes contribute to the same hazard. Note that the processes of Climate Change and Human Activity can contribute to all hazards.

Table C10.1
Principal Processes Causing Coastline Hazards

COASTAL PROCESS	COASTLINE HAZARD						
	BEACH STABILITY						
	Erosion	Recession	Entrances	Sand-Drift	Inundation	Instability	Stormwater
Elevated Water Levels	*	*	*		*		*
Waves	*	*	*		*		
Currents	*	*	*				
Waterborne Sediment Transport	*	*	*				
Vegetation Degradation	*	*		*			
Windborne Sediment Transport				*			
Rainfall & Runoff					*	*	*
Climate Change	*	*	*	*	*	*	*
Human Activities	*	*	*	*	*	*	*

3 HAZARDS AND COASTLINE TYPES

To identify and assess specific hazards of relevance to a particular length of coastline, a detailed coastal process and hazard definition study is recommended. However, some hazards are generally of more significance to certain coastline types than others. Table C10.2 shows the hazards of potential relevance to the three coastal types of NSW.

All coastline hazards are of potential relevance to Sandy Beaches. Slope and foundation problems and stormwater disposal are of particular concern to Coastal Bluffs, where slumping or foundation failure exacerbated by seepage can occur. The likelihood of inundation should also be checked for Coastal Bluffs. The stability of the rock face is the major potential hazard for Sea Cliffs.

Table C10.2
Hazards of Potential Significance to the Three New South Wales Coastline Types

COASTLINE TYPE	COASTLINE HAZARD						
	BEACH STABILITY						
	Erosion	Recession	Entrances	Sand-Drift	Inundation	Instability	Stormwater
Sandy Beach	*	*	*	*	*	*	*
Coastal Bluff					*	*	*
Sea Cliff						*	

APPENDIX D : HAZARD MANAGEMENT OPTIONS

APPENDIX D

APPENDIX D1 PREAMBLE

1 INTRODUCTION

Coastal developments are subject to a variety of hazards, the nature and consequences of which are described in Appendix C. Coastline hazards can cause enormous damage, financial loss and social disruption to properties and communities at risk.

Coastline hazard conservation and management aims to achieve a balance between the use of the coast to meet human needs and desires on the one hand, and the financial loss and social disruption associated with hazard events on the other. This is done by attempting to ensure that hazards are avoided in the first instance and otherwise ensuring that the damage potential of properties at risk is consistent with that risk.

The major categories of options for managing coastline hazards are:

- environmental planning strategies to prevent new developments from occurring in hazardous areas or to remove existing developments from hazardous areas;

- application of development control conditions to ensure that damage potential is limited and is consistent with hazard risk;

- beach and dune rehabilitation and management to control sand movement, reduce inundation and contribute towards buffer zones where appropriate; and

- the construction of works to protect the coastline and properties at risk.

This suite of appendices describes these four broad options for managing coastline hazards. First, however, the planning process in New South Wales is described in some detail in Appendix D2 because of its fundamental importance to the effective control of the damage potential of future developments. Next, planning environmental approaches, development control conditions, dune management and structural measures are described in Appendices D3, D4, D5 and D6 respectively. Finally, a strategy for planning under uncertainty is presented in Appendix D7. This is of importance to coastline planning because of uncertainties in coastline hazards and in the effects of climate change.

2 HAZARD MANAGEMENT

Environmental planning measures are broad in scope and are aimed at ensuring that coastal developments are not placed at an unacceptable risk. Such measures can be an effective means of avoiding future damage in relatively undeveloped areas of the coastline, as well as facilitating the most appropriate forms of protection and land use for the coast generally.

Development control conditions consist of siting, design and construction requirements on a site specific, development specific and hazard specific basis. Such controls are more limited in scope than broader planning measures, and are aimed at limiting the damage potential at individual building sites. They can be an effective means of containing the damage potential of new developments and redevelopments.

Rehabilitation and management of dune systems, including control of beach access, can be an effective contribution to the provision of a buffer zone, where appropriate and possible, between development and hazards.

Protective works, which encompass measures such as seawalls, groynes and beach nourishment, provide protection for existing developments at risk.

Often, coastline hazard management consists of a mix of all management options. Needless to say, if management is to be cost effective and successful, it must be based on a thorough understanding of the coastal processes affecting the area of interest and their associated hazards.

3 EXISTING AND FUTURE DEVELOPMENTS AT RISK

There are two aspects to coastline hazard management: the protection of existing developments at risk; and the need to ensure that future developments are not placed at unjustifiable risk.

Protection works may appear to be the only way to manage the former; environmental planning measures and development controls may appear to be the only way to manage the latter. This is not necessarily so.

Other measures commonly used to manage existing properties at risk include voluntary purchase and removal of properties at undue risk, often in conjunction with particular zonings. Protection works may be incorporated in new developments to address existing and/or future hazard problems, providing the social and economic benefits associated with the development justify its impact. Dune management measures may be used in both instances.

4 MERIT APPROACH

The merit approach of the Policy requires that environmental planning factors, such as social, economic, recreational, aesthetic and ecological issues, be weighed along with hazard considerations and beach amenity requirements when making decisions regarding coastal management options for specific sites or for sections of the coastline.

APPENDIX D2 PLANNING IN NEW SOUTH WALES

1 INTRODUCTION

The coast of New South Wales is used by various groups of the community for a variety of purposes. Environment planning attempts to achieve a balance between these often competing desires and needs. This is done by recognizing and weighing up the many attributes of the coastline. These include its scenic, aesthetic, ecological and recreational qualities; its social and commercial importance; and the presence of coastline hazards.

The basic aim of environmental planning (with respect to hazard management) is to ensure that the location and type of development is consistent with the risk and the impact of the hazard. In this way, the social and economic impacts of coastline hazards can be eliminated, or minimised.

Successful coastline hazard planning can provide a number of community benefits. First, public and private expenditure for evacuation, relief and rehabilitation operations can be reduced. Second, the need for expensive coastal protection works funded from the public purse is minimized. Finally, planning facilitates the equitable use of the coastline by the different community groups, e.g. ecologically significant areas can be protected, coastal housing allowed in specified areas, etc.

Local Government is responsible for local planning and decision making on the coast. This appendix describes the planning system in New South Wales.

2 PLANNING INSTRUMENTS IN NSW

Planning in New South Wales is carried out under the statutory control of the Environmental Planning and Assessment Act, 1979. The New South Wales Department of Planning is responsible for the administration of this Act.

There are essentially four tiers of planning instruments under the EPA Act:

- State Environmental Planning Policies (SEPP's)
- Regional Environmental Plans (REP's)
- Local Environmental Plans (LEP's)
- Development Control Plans (DCP's)

These tiers encompass firstly, statewide planning issues and principles (SEPP's), secondly, regional planning concerns (REP's) that may involve several local authorities, thirdly, local plans (LEP's) administered by a single local authority, and finally, development control plans (DCP's) outlining the detailed controls, consistent with the LEP, which apply to the land.

The local authority has responsibility for planning within its statutory area and plays the major role in the formulation and implementation of LEP's and DCP's. Planning on the coastline is merely the application of this general responsibility to a particular area characterised by special hazards. LEP's are finally made by the Minister for Planning, having regard to coastal management policies and state and regional planning concerns of the time.

3 STATE ENVIRONMENTAL PLANNING POLICIES

SEPP's address specific issues of state and regional significance. Environmental issues subject to current SEPP's include coastal wetlands (SEPP 14) and littoral rainforests (SEPP 26).

SEPP's generally take precedence over other planning instruments. They can be implemented through LEP's, regardless of existing zonings, by direct imposition on development proposals.

In principle, an SEPP could be used to address coastal erosion problems, but would only be appropriate where statewide issues of management were involved.

4 REGIONAL ENVIRONMENTAL PLANS

REP's have wide scope and form. They address broad issues on a regional basis and provide a consistent regional framework for local planning. REP's often encompass a number of local government areas with similar demands, opportunities or constraints with regard to planning issues. The EPA Act requires that LEP's are consistent with the provisions of REP's.

An REP may address single environmental issues or regional planning strategies.

To date, single issue REP's have been published for wetlands and tourism. As yet, no single issue REP has been formulated for coastline hazards, but it is possible. To date coastal management issues have been referred to in more general REP's for coastal regions. As a single issue plan, an REP could address particular problems of coastal management that extend across Local Government Authority (LGA) boundaries.

As a planning strategy, an REP could integrate coastline hazard management with other aspects of coastal planning and development, e.g. scenic protection, environmental protection, wetlands and regional development priorities.

There are two parts to the preparation of an REP. First, an environmental study may be undertaken to provide background information on the existing situation, likely changes, the way in which change can best be managed, environmental constraints, etc. Second, a plan is prepared on the basis of this study.

5 LOCAL ENVIRONMENTAL PLANS

LEP's are the means used to prescribe land use policies and controls for an LGA. They supercede Town and Country Planning Schemes and Interim Development Orders made under previous planning legislation in New South Wales.

While LEP's focus on development control by land use zoning, they are not limited to this traditional function. For example, they may deal with the protection of heritage items, urban conservation, environment protection, local works and area protection programs.

Under Section 117(2) of the Environmental Planning and Assessment Act, 1979, the Minister for Local Government and Minister for Planning may make directions which councils are required to consider when preparing new LEP's. Issues such as conservation of environmental heritage, provision of open space and floodplain development have been the subject of previous Section 117(2) directions. In the case of floodplain development, the direction provides statutory effect to the guidelines and principles contained in the Floodplain Development Manual.

Local councils are responsible for preparing LEP's. Where directed by the Minister, councils may be required to undertake a Local Environmental Study to identify the opportunities and constraints for various land uses. Before the Minister approves an LEP, it must be consistent with State policies and regional plans and the necessary public participation procedures must have been followed.

LEP's are commonly formulated for the following reasons:

- the major planning of areas, involving a complete review of existing plans;
- the consolidation and updating of existing plans where a number of individual amendments have been made; and
- to make specific amendments to existing plans.

The implementation of any strategy for the control of coastline hazards would most likely involve either a new or an amended LEP.

Councils may wish to develop an LEP that either indicates a special zone for the hazardous shoreline areas or nominates special planning controls for such areas. An advantage in identifying a special zone in an LEP is that specific objectives can be described and related to coastline hazards.

The land use categories employed in an LEP are discussed in some detail in Appendix D3.

If a hazardous area is zoned residential or other urban use, development consent should be a requirement if it does not already apply. The need for such consent should be incorporated in the LEP.

Other issues that can be incorporated in an LEP include the acquisition of any undeveloped land as a management measure and the requirement that properties at risk should be severely limited in scale and have maximum protection, if avoidance of the hazards is not possible.

6 DEVELOPMENT CONTROL PLANS

An LEP should be a reasonably flexible planning instrument that can cater to changing circumstances without requiring unnecessary amendment. As such, LEP's are often not appropriate for the imposition of specific land use controls. DCP's are a useful means of exercising control in those cases, or where the council wishes to specify details of actual developments. A DCP is also used if council wants to give more formal status to its policies for a particular type or aspect of development.

The DCP is the most specific of the four planning instruments, and enables the implementation of specific land use controls aimed at particular coastline hazards at nominated locations along the coastline.

A DCP is the appropriate instrument to introduce detailed planning provisions. Redevelopment of properties can be controlled in this way. One example of the use of a DCP is the approach taken by Byron Shire Council to provide planning control for areas with different degrees of recession/erosion. This planned retreat is described in Appendix D3.

7 ENVIRONMENTAL IMPACT ASSESSMENT

The following provisions reflect the concern of the Environmental Planning and Assessment Act with the protection, use and management of the environment:

- regional or local plans require an environmental study to ensure that plans are sensitive to the environment;
- all development applications must be accompanied by information on likely environmental impact [s.77 (3)(c)];
- "designated development" applications require an environmental impact statement [s.77 (3)(d)]; and
- councils are required to consider the environmental, social and economic impact of a development proposal, in deciding whether it should be approved or not (s.90).

Application of Part V of The Act

Some activities of State and Local Government which are not covered by plan making or development control processes may affect the environment. These include development which does not require consent under a plan (particularly works by public utilities which have traditionally been exempted from plans), decisions on land management policies, expenditure of public funds and the granting of licences and permits.

Part V places a duty on all public authorities to consider the environmental impact of proposed activities before making a decision (s.111). If the activity is "prescribed" by the regulations or if in an individual case the impact is likely to be significant, an environmental impact statement must be prepared (s.112).

Where an environmental impact statement (EIS) is prepared, it must be exhibited to enable people to make submissions. The Department may be required to examine it and publish a report (s.113). In major cases, the Minister may call for a public inquiry instead of the report. In both cases, recommendations on minimising adverse environmental impact are made to the public authority responsible for the decision, which is obliged to consider them.

The Act does not alter the power or responsibility of those bodies to make decisions but ensures that environmental impact is assessed by them before a decision is made.

Preparation of EIS

In the case of designated development and in many cases under Part V, the need for an environmental impact statement is known in advance. For example, a council is not able to request an EIS after it has received an application. This is to ensure that environmental considerations are incorporated in the early stages of the project and matters raised in the EIS are reflected in its design.

8 COUNCIL RESPONSIBILITIES

Councils are generally responsible for matters of planning in their own area. In particular, they have definite responsibilities for the preparation and implementation of LEP's and DCP's. Councils are also the main consent authorities for development control in coastal areas, except in those instances where development applications are deemed to be of State or regional significance (s.101 EPA Act).

Under the Environmental Planning and Assessment Act, councils bear prime responsibility for the following planning tasks:

- liaising with relevant bodies in plan preparation (s.62);
- assessing and weighing the interests and demands of different sections of the community with those of the development applicant in the determination of planning policies (s.61 and s.68) and development applications (s.90 and s.91);
- ensuring that LEP's and development control decisions are related to the sound management of the coastal environment and its resources;
- identifying local planning needs; and
- developing policies addressing coastal issues in the LEP; and
- ensuring that responsibilities for Environmental Impact Assessment are met.

Councils also have responsibilities under Part II of the Local Government Act with respect to Building Applications. Where Development Applications are not required (because of the provisions of the planning instrument), Building Applications are the first approach to a council with respect to a development. Conditions may be applied which are similar in principle to those applied to a development consent.

APPENDIX D3 ENVIRONMENTAL PLANNING OPTIONS

1 Introduction
2 Coastal Land Use Zones
3 Buffer Zones
4 Voluntary Purchase
5 Planned Retreat
6 Freeze on Development
7 Planning Implications of Structural Controls

1 INTRODUCTION

A variety of environmental planning options are available to manage coastline hazards, the most obvious one being land use zoning. The basic aim of zoning is to generally separate new developments from hazardous areas, or to ensure that the type of development and its damage potential are consistent with hazard risk.

This appendix discusses land use zones of relevance to coastal planning, other planning controls and a variety of financial measures for the management of coastline hazards.

2 COASTAL LAND USE ZONES

A basic means of implementing planning controls is through land use zones. The broad categories of zones appropriate to coastline planning and incorporation in LEP's are as follows:

- environmental protection
- coastal protection
- open space
- rural
- tourist
- residential
- commercial
- industrial
- special uses

The selection of zones is a matter for council discretion, but they must be consistent with directions given by the Minister for Planning under Section 117 of the EPA Act. The State Government recognises the special significance of the coastline and accordingly the Department of Planning provides special guidance on coastal zoning through formal planning instruments such as REP's and through advice to councils by departmental circulars.

Selection of coastline zones is an important part of planning for the broader coastal environment. Coastal planning strategies relating to a variety of issues, such as urban development, environmental protection, access links to settlements and the sea, tourism, etc., will effect the choice of suitable coastline zones. Various factors that affect the choice of coastal zones are discussed below.

Environment Protection Zones

Areas with special environmental, scientific, heritage or scenic significance can be incorporated into "Environment Protection Zones".

Such areas may include special vegetation and special faunal habitats in backbeach areas, as well as the vegetated sand dune system of the beach. Areas of State or regional significance, as identified under SEPP 14 (Coastal Wetlands) or SEPP 26 (Littoral Rainforests) are appropriate for inclusion in Environment Protection Zones. Such zones are similarly appropriate for areas of aboriginal heritage and areas of geological or geomorphological significance.

The land use table accompanying this zone should generally prohibit any development liable to have detrimental impacts on environmental values.

An "Environmental Protection (Foreshore Protection) Zone" can also be used to designate a buffer zone over natural environments, such as undeveloped beaches, vegetated dunes, and coastal bluffs and headlands.

Coastal Lands Protection Zones

Areas identified under the New South Wales Government's Coastal Lands Protection Scheme are appropriate for inclusion in "Environment Protection (Coastal Lands Protection) Zones".

Lands designated "yellow" under the scheme are important because of their scenic qualities. Such lands require special protection and should be zoned "Environment Protection 7(f1) - Coastal Lands Protection".

Lands designated "red" under the scheme have important environmental or access characteristics and are to be acquired by the Government. Such lands should be zoned "Environment Protection 7(f2) - Coastal Lands Acquisition".

The concurrence of the Director of Planning is required for certain developments in these zones.

Land use tables generally only permit low key forms of agriculture without consent and more intensive agriculture with consent in these zones. Other land uses are usually prohibited. However, in the 7(f1) zone, certain uses with consent may be permitted, including forestry, dwellings, caravan parks and camping grounds.

Open Space Zones

Where recreation use and appreciation of the shoreline are significant aspects of an area, an "Open Space Zone" may be appropriate. Such zones may incorporate both public and private coastal land on beaches and headlands.

In developed coastal areas where there is no long term shoreline recession, this zone can be useful as a coastal buffer zone to allow the beach to erode and accrete without damaging urban developments to the rear of the zone.

Land use tables may, with consent, permit recreation and structures relating to recreation activities in Open Space Zones, e.g. surf lifesaving facilities. In these cases, councils should treat each application on its merits having regard to the damage potential to the development itself and its impact on the beach, especially if protective works are proposed. Relocatable structures can also be considered in Open Space Zones.

In rural locations the Open Space Zone may, with consent, permit such uses as camping areas, agriculture and forestry. Most other uses are generally prohibited.

Rural Zones

Agricultural lands and areas used for farming purposes, market gardening, plantations, orchards and the like, can be included in "Rural Zones". Vegetated dune systems may require protection from the disturbance of agricultural operations. This can be achieved by restricting agricultural practices on dune areas by means of development conditions. If the coastline is not receding, the use of a buffer zone facilitates public access to the beach and the enjoyment thereof.

A wide range of non-urban uses is generally permitted with and without consent in Rural Zones, including rural tourist facilities in some cases.

Tourist Zones

A "Tourist Zone" may be appropriate where key areas of the coastline have been identified as potential sites for major tourist development. An Environmental Study is generally required to assess the impact of major tourist developments. The study should include consideration of coastline hazards with a view to minimising social disruption, property damage and human risk.

Substantial buildings are likely to be a feature of major tourist developments. There will usually be a desire to site these structures in close proximity to the beach and sea. The Environmental Study is the appropriate vehicle to address the social and environmental issues involved, as well as appropriate design conditions to take account of coastal development hazards.

On receding shorelines, consideration should be given to planning approaches such as relocatable buildings, planned retreat, abandonment of use at a specified future time.

The full range of tourist related facilities and uses is generally permitted with consent in a "Tourist Zone". Any residential component of a tourist development should be consistent with the residential development strategy for the wider coastal area. Matters outlined below for residential zones are also relevant for any residential component of a tourist proposal.

Residential Zones

Places designated for living areas and containing houses, duplexes, units, flats and homes for the aged are to be included in "Residential Zones".

These areas are particularly sensitive to coastline hazards and once zoned will continue to be developed and redeveloped for urban use. Residents are generally prepared to go to great lengths and costs to retain coastal residential sites, even in the aftermath of extremely hazardous events and notwithstanding that their actions may be at community cost and cause disruption to beach amenity.

It is essential that great care be taken in the siting of "Residential Zones" and in the management of coastline hazards that may affect them.

Residential zones can be separated from the coastline by a buffer zone which should provide for extreme movements of the beach erosion escarpment or cliff line, both now and in the future. However, such an approach is only viable in the long term on a stable coastline. Great care needs to be taken with the siting of residential developments on receding coastlines.

When a residential zone is in proximity to a hazardous section of the coastline, it is recommended that any dwelling require development consent. In this way, the adequacy of the design, the siting of the dwelling on the land and its likely exposure to hazard can be checked. Commercial, industrial, agricultural and other uses incompatible with living areas are prohibited in Residential Zones.

Commercial Zones

Shops and offices are included in "Commercial Zones". In addition, coastal activities and enterprises such as motels and waterfront developments, including commercial fishing outlets, boating and leisure related activities, are also appropriate to this zone.

Consideration of entrance and coastal inundation hazards is required when commercial developments are sited along the waterfront of the coast or an estuary.

Consent is generally required for all commercial uses in coastal Commercial Zones.

Industrial Zones

All industrial related activities including factories, engineering workshops, garages, workshops and the like are generally included in "Industrial Zones". Many of these activities are in conflict with the use of coastal areas for recreation and amenity.

Consideration of entrance and coastal inundation hazards is required when industrial developments are sited along the waterfront of the coast or an estuary.

Coastal Industrial Zones are generally quite specific with regard to allowable uses, nearly all of which will require consent, and with regard to prohibited uses.

Special Use Zones

Uses relating to hospitals, schools, public halls, churches, police and fire stations, telephone exchanges, electricity sub-stations and sewerage works can be included in "Special Use Zones".

Because a number of these facilities may be extremely important during a hazard event, it is essential that special use zones are sited in safe positions. The continued operation of buildings and services for emergency purposes may be important in reducing social disruption during the course of a hazard event.

Safe inland sites are preferred for these uses. Special Use Zones generally permit only identified uses with consent and prohibit most other uses.

3 BUFFER ZONES

A "Buffer Zone" is the most fundamental form of land use control. Its purpose is to accommodate shoreline fluctuations caused by storm erosion and swell wave rebuilding, but it has severe shortcomings as a means of addressing high rates of coastal recession. On receding coastlines, history has shown that many developments sited behind buffer zones have been subject to major social, economic and political problems.

Buffer zones can be secured through zoning in LEP's, reservation, acquisition of existing land, or by reclamation of the beach by groynes or sand nourishment. The required width of buffer zone will vary according to the sediment budget, dune stability, wind/wave climate, and the orientation and configuration of the coastline and social, economic, aesthetic and ecological factors.

An adequate maintenance program is essential for designated buffer zones. Otherwise the result may be beach abandonment rather than beach protection. An important aspect of buffer zone management is the preservation or re-establishment of dune and backbeach vegetation.

Creation of a buffer zone need not imply that the land falls into misuse. A variety of sympathetic uses are possible, including certain types of recreation, recreation facilities such as surf lifesaving facilities, scenic amenity, and commercial enterprises using portable or expendable facilities.

It is often the case that a land use other than "development" is established adjacent to the coastline for social, ecological or recreational purposes. The width required for those purposes may be adequate to accommodate beach fluctuation or low rates of recession, although the motive should be explicit and not justified on coastal hazard grounds alone. It should be realised that where recession is occurring the width of such a zone will reduce as time passes and may ultimately become too narrow for the purpose for which it was established.

4 VOLUNTARY PURCHASE

The voluntary purchase of properties at undue risk, especially if they are few in number and isolated from other major developments, is often a cost-effective means of hazard mitigation. The land can then be rezoned into a category appropriate to the risk and consequences of the hazard. Voluntary purchase can become expensive if there are a large number of properties at risk. The costs to the community become even higher if urban services have been provided on a substantial scale. (These services are sacrificed when the properties are resumed).

5 PLANNED RETREAT

Planned retreat would appear to be an effective and equitable way of maximizing the use of a receding coastline. The recession of the coastline is acknowledged and becomes a dominant factor in planning for the use of coastal areas. A variety of responses are possible, including time limited occupation, relocatable buildings, etc.

Byron Shire Council has recently adopted planned retreat as a means of managing their receding coastline. The Byron Shire Development Control Plan recognises three recession/erosion "lines" for planning purposes: an "immediate impact line", a "50 year erosion line" and a "100 year erosion line". These lines were identified in a coastal process study. Development conditions for the zones formed by these lines, as specified in the DCP, are as shown below:

1. Between the beach escarpment and the "immediate impact line", generally no new buildings or works are preferred. Community buildings not requiring a major extension of services may be allowed. Such buildings must be easily removable.

2. Between the "immediate impact line" and the "50 year erosion line", development will be considered on the understanding that any consent granted will be subject to the proviso that, when the erosion escarpment comes to within 50m of any building, the development consent will then cease. The owner will then be responsible for the removal of any or all buildings from the site, or, if possible, to a location on the site further than 50m from the erosion escarpment.

3. Similar controls apply to the area between the "50 year" and "100 year" erosion lines. The option of demolition as the means of removal is available for all buildings.

By this approach, Byron Shire facilitates a planned retreat from a receding coastline whilst encouraging responsible use of hazardous coastal areas at minimum future cost to council.

The performance of this approach has yet to be tested in the sense that significant movement of the erosion escarpment has not occurred since the introduction of the plan. The question of "enforcing" the lapse of consent and consequent removal of structures needs careful consideration.

6 FREEZE ON DEVELOPMENT

In certain circumstances, a council may wish to impose a freeze on all beachfront development until more information is available. In such cases, a coastal engineer's report may be required for all building applications for additions to existing buildings or for the redevelopment of areas at risk.

To ensure that existing property is not exposed to additional risk and that Council's liability is minimised, Council should treat any addition to buildings fronting the beach as a potential risk.

7 PLANNING IMPLICATIONS OF STRUCTURAL CONTROLS

Voluntary purchase and planned retreat from hazardous coastlines may be viable means of management in undeveloped or partly developed areas. However, such an approach becomes increasingly expensive and difficult in more intensively developed areas.

In such cases, coastal protection may be the only economically viable and socially acceptable means of management. This has a number of potentially detrimental planning implications. Recreational use and scenic appeal of the beach may be reduced if seawalls are built. Alternatively, further costly works may be required in the future to replace beach sand. Protection of developed areas of the beach may be at the expense of increased erosion in other areas.

In cases where no overall management program is adopted, individual property owners may resort to a variety of approaches to protect their properties. Moreover, individual efforts may exacerbate problems at neighbouring properties. In these circumstances, the community suffers the visual blight of a variety of "protective" features along the beach, the cost of emergency services in times of hazard, and ultimately the cost of remedial measures to repair damage and address the problem.

APPENDIX D4 DEVELOPMENT CONTROL OPTIONS

1 INTRODUCTION

The purpose of development control conditions is to reduce the damage potential to new developments and redevelopments by the imposition of development, design and construction conditions. Such conditions are usually imposed on a site specific, development specific and hazard specific basis. Consequently, these controls are generally considerably more detailed and localized than those measures which might be contained in environmental plans.

2 MEANS OF CONTROL

Councils can exert site specific development controls through the development application and building application procedures. Such controls can be an effective way of ensuring that the damage potential of new developments and redevelopments is consistent with the hazard exposure of the site.

Under an LEP, a development application is required for consent uses; a building application is required for all developments. Thus the consent process provides council with a means of ensuring that the developer is aware of necessary development conditions at the initial design stage of the project.

3 DEVELOPMENT CONTROL CONDITIONS

Buildings and developments in the coastal zone are subject to the usual controls and regulations of standard building codes. However, it is often desirable to impose additional development control conditions to reflect the special nature of coastline hazards. Such conditions may include the following:

- setback lines, seaward of which certain types of development of high damage potential may be prohibited or require substantial protection or special design, the type and nature of which to be determined by council;
- provision of coastal engineering works to protect a site from coastline hazards where the project is clearly justified and considered on a regional basis;
- provision of piled foundations to provide protection against undermining during extreme storm events, thus allowing more permanent solutions to be considered later;
- flood protection measures, such as minimum floor levels, flood proofing, the use of specified water resistant building materials, etc., to minimise damage from coastal inundation;
- minimum height and vegetation controls on foredunes to ensure an adequate and stable supply of sand to buffer erosion processes, or to provide protection from oceanic inundation;
- implementation of dune management measures, both to protect the development from hazards, and to protect the dune system from damage either during construction or as a result of use of the development (such as by pedestrian access to the beach from a tourist resort).
- control over the disposal of sand excavated during construction operations, which may have to be returned to the active beach system, used to build or repair frontal dunes, etc;
- provision of access for emergency protection, e.g. roads or access paths facilitating rock dumping, the supply of sandbags, etc;
- the design of buildings, service roads and other infrastructure for easy relocation should erosion exceed expectations, e.g. the use of relocatable buildings, etc;
- requirements that the site be vacated after a certain time or when the erosion escarpment has come within a certain distance, as part of a planned retreat strategy; and
- the separation of low cost and high cost facilities into appropriate hazard exposure areas, wherever possible.

4 COUNCIL RESPONSIBILITIES

When considering development applications and imposing development conditions, councils must have regard to matters set out in Section 90 of the

EPA Act. Of particular relevance are the following subsections:

s.90(1)(b) the impact of the development on the environment and whether harm to the environment is likely to be caused, and means that may be employed to protect the environment or to mitigate that harm;

s.90(1)(c) the effect of the development on the landscape or scenic quality of the locality;

s.90(1)(d) the social and economic effects of the development in the locality;

s.90(1)(f) the size and shape of the land to which the development relates, the siting of any particular buildings or works thereon and the area to be occupied by the development;

s.90(1)(g) whether the land to which the development application relates is suitable for that development by reason of its being, or being likely to be, subject to flooding, tidal inundation, subsidence, slip or bushfire or any other risk;

s.90(1)(h) the relationship of the development to developments on adjoining land or on other land in the locality;

s.90(1)(m) whether adequate provision has been made for the landscaping of the land to which the development application relates and whether any trees or other vegetation on the land should be preserved;

s.90(1)(mi)whether that development is likely to cause soil erosion;

s.90(l)(n) any representations made by a public authority in relation to that development application, or to the development of the area, and the rights and powers of that public authority; and

s.90(1)(r) the public interest.

Note that Section 90(1)(g) is general in nature and encompasses coastline hazards as "any other risk".

In some cases the relevant planning instrument may allow certain types of developments without specific council consent. In these cases a Building Application must be lodged and dealt with as provided under Part XI of the Local Government Act. Section 313 sets out the mattters which can be considered in granting consent and is wide enough to allow the imposition of whatever conditions are required to cater for coastline hazards.

5 FINANCIAL MEASURES

A number of financial measures can be used to manage coastline hazards. Although most of these measures are in use in overseas countries, many have not yet been implemented in Australia. Financial measures include:

- insurance against damage with premiums based on the level of risk. Such a scheme has been instituted in the USA, but it suffers a number of shortcomings, not the least being its subsidised nature and the fact that residents are forced to repair their houses after a hazard event and do not have the option of using the insurance payout to move;

- voluntary purchase of properties at risk. A scheme similar to that implemented for NSW Floodplain Management could be introduced for coastline hazards. Since 1950, Warringah Shire Council has purchased some 30 residential properties in hazardous areas of the coast;

- acquisition and lease back of coastal lands at risk. Under such schemes, local government acquires land at risk and leases it to existing or future users for a specified period of time, after which the land reverts to public ownership. This is one means of ensuring that future land use is revised and if necessary altered whilst maximising the gains from short term land use. Such a scheme is readily applicable to a receding coastline;

- Voluntary purchases and resale for development. Under such schemes, the resale of land at risk might be dependent on its use for purposes compatible with the governing hazards; and

- special rates levied on existing development at risk to offset the cost of necessary protective works.

6 AN EXAMPLE OF DEVELOPMENT CONTROLS IN NSW

Consider a specific application of development controls to a hazardous area of the New South Wales coastline, namely the way in which Warringah Shire Council implements development controls for the coastal bluff and sandy beach areas of its coastline.

According to Appendix C7, the major potential hazards of bluff coastlines are slope instability problems, whereas all 7 coastline hazards may be of significance to sandy beaches.

Prior to determining these development conditions, Warringah Shire Council had a Coastal Process Study undertaken to identify the type, nature and extent of hazards. The following development application conditions are specific to coastline hazards in Warringah and to the means of management adopted by council. They serve as an example of what is currently being done by one coastal council, rather than as a "template" for the New South Wales coast in general.

Building Applications for Bluff Areas

As part of the Building Application for developments in designated coastal bluff areas, Warringah Shire Council requires a geotechnical report from a suitably qualified and experienced engineer. The report is to address the following issues:

1. The existing stability of:

   (a) the individual allotment; and
   (b) the locality.

2. The effect of the proposal on the stability of:

   (a) the property subject to the application;
   (b) adjoining properties; and
   (c) the bluff or locality in general.

3. The effects of existing and proposed stormwater and groundwater drainage system on site and area stability.

Building Applications for Beach Areas

For developments in designated risk areas of the coastline, Warringah Shire Council requires a coastal engineer's report to be submitted to council before a building application will be considered. This report should address the following matters:

1. General stability of the site and locality in respect of the following processes:

   (a) long term trends in sand transport and beach movements;
   (b) sea level rise, both historic and predicted as a result of the Greenhouse Effect; and
   (c) the effect of the proposal on adjacent structures.

2. The stability of the site and locality in a severe storm event. The following factors are to be taken into account:

   (a) oceanic inundation as a result of elevated sea levels, wave setup and runup;
   (b) beach scour levels and dune scarp stability; and
   (c) the effect of the proposal on adjacent structures.

APPENDIX D5 DUNE MANAGEMENT OPTIONS

1 INTRODUCTION

Effective dune management is based on maintenance of a satisfactory vegetative cover. Specific dune management techniques are described in the Soil Conservation Service's "Coastal Dune Management" manual (SCS, 1990). This appendix considers the principles of coastal dune management and complements the discussion of dune vegetation as a coastal process given in Appendix B8. This appendix is based generally on the more comprehensive work of Chapman (1989).

2 VEGETATION AND DUNE MANAGEMENT

The interactions between coastal processes and dune vegetation are, in natural circumstances, very positive. The principal species are well suited to stabilising dune sands and initiating beach recovery following severe storms. During storms, sand is removed from the beach to form an offshore bar, and during intense storms, a demand for dune sand is created which involves reserves held by primary species.

Beach vegetation, such as Spinifex, provides some resistance to the removal of sand during the storm, but its principal role is to quickly stabilise the sand which returns within a few weeks of the return of fine weather. With loss of vigour of primary species, sand is free to move inland, where it impacts vegetation which does not have the capacity to tolerate burial and further dieback results.

Secondary species (as seen in Figure B8.1), have an important function of stabilising seaward of the of the permanent dune crest. Their survival mechanism relies on an adaptable growth habit and capacity to reseed prolifically; they cannot develop quickly and require the stabilising influence of primary species to establish successfully. Degradation of species composition ultimately leads to monocultures and catastrophic losses of dune cover. The loss of vegetation zonation also contributes to a change in dune conformation, reducing the capacity of the dune barrier to absorb high wave energy.

Permanent tertiary species on and behind the crest of the foredune are slow growing and highly interdependent in that they need to cooperatively maintain an unbroken canopy. Wherever wind and light penetrate, die-back occurs and weed species volunteer. Some beaches, particularly those which are receding, depend on close-knit communities of permanent species standing high above the dune escarpment for their stability. Vantage points, access tracks, housing and parking take heavy toll on these stands and caution is required before urbanisation is allowed. Management of vegetation on a receding coast is discussed in some detail by Wickham (1984).

Coastal dunes have been and are used for a variety of purposes including mining (both placer mining and sand extraction), water extraction, waste water disposal, housing, agriculture and recreation. Problems that have arisen from some of these uses include sand drift, shoreline recession, soil over-nutrification, loss of species, destruction of archaeological sites and reduced recreational amenity. Past experience indicates that coastal dune vegetation has limited capacity to recover from some of these uses. Much of the coast has already sustained some loss of intrinsic value which may be costly and difficult to rehabilitate. There is potential for heavy mineral sands mining to stabilise and rehabilitate unstable or eroded dune systems and in appropriate situations this could be used as a positive management concept.

If remaining intact coastal dunes are to retain their natural plant and animal communities there exist a limited number of compatible land use options. Existing vegetated dunes can be utilised for recreation, education, research, and conservation with little permanent damage if such use is correctly managed. Other uses such as sand extraction, housing and waste disposal are more disruptive and permanent loss of vegetation is unavoidable. Where dune development is still demanded in spite of expected permanent loss of dune value, thorough evaluation of trade-offs is required.

Heavy mineral sand mining requires complete removal of existing vegetation but experience shows that a stable vegetation cover can be re-established on mined areas.

3 MANAGEMENT OBJECTIVES AND OPTIONS

Management of coastal dunes, as with the management of any land system requires the planning and control of desired human activity within the limits imposed by physical, biological and cultural resources. A fundamental goal of the management of dune vegetation is to provide the means for the community to enjoy the widest possible range of coastal orientated activities without degrading the resource base which supports them. In the case of vegetation management, an objective which follows from the above goal is that of maintaining populations that are self perpetuating, so as to minimise maintenance.

However, it is also important to retain diversity, preserve endemic and rare species, and protect the structural integrity of plant communities in a manner which satisfies strategies for their conservation.

Maintenance of existing plant populations and processes by means of management is necessary, given the vulnerability of dunes and dune vegetation to disturbance. However, there is still much to be learned about management measures that best enhance natural maintenance of plant populations. The simple exclusion of people and vehicles from the vegetated sections of dunes does not necessarily ensure the maintenance of plant populations.

With these objectives in mind land use options can be considered in terms of their likely impact on the vegetation and ultimately the whole dune system. Land use options may first be considered in the light of their effect on the removal or retention of vegetation:-

i) Vegetation Removed

- Sand extraction (temporary)
- Mineral sand mining (temporary)
- Dwellings & infrastructure
- Cultivation

ii) Vegetation Retained

- Recreation
- Grazing
- Water extraction
- Effluent disposal
- Education & research
- Commercial fishing

Those options which require vegetation removal can be further subdivided on the basis of being extensive (as dwellings and infrastructure development and cultivation), or intensive (as sand extraction and heavy mineral sands mining). Furthermore, those options which allow retention of vegetation may be subdivided into a disruptive class (as active recreation, water extraction, effluent disposal, and grazing might be), or non-disruptive, (as passive recreation, education, research and commercial fishing should be).

The potential effects of disruptive activities or those that require vegetation removal include changes in species diversity, loss of structural complexity, extinction of rare and endangered species, introduction of exotic weeds, and interference to population dynamics and critical life cycles. Any of these outcomes would result in loss of vegetation which would require costly and careful rehabilitation which, although it may never replicate the original situation, may achieve a stable vegetative cover. Therefore, land development and management decisions must be made with full cognisance of their potential effect on dune environments. Management decisions at both the land use planning scale and the site scale should be based on a sound knowledge of the vegetation resources of the area.

Special attention is needed with regard to human impact on the critical parts of life cycles of dune plants (such as reproduction), the influence of fire, and establishment and growth of plants under conditions of constant physical disturbance. In the absence of such information, it is possible that one or more of the following outcomes will ensue:

a) Development and management policy will be over-restrictive.

b) The community will have to commit more resources to dune management programs.

c) Irreparable dune damage will completely change the intrinsic values of the New South Wales coastline.

In order to forestall problems as far as possible, it is recommended that priority should be given to the formulation of conservative policies with respect to permanent dune vegetation, with the onus on the proponents of development to provide proof of development acceptability.

Where it is not possible to preserve the pristine state of a natural dune system, management must be concerned with both the form and function of the dunes. The concept of maintained "function" includes the preservation of a reservoir of sand close to the foreshore to meet the demands of short term fluctuations in sea level and storm wave attack.

Problems arise when human usage interrupts the "symbiosis" which exists between the dune form and its vegetation. In these situations use may be made of devices which complement natural sand accretion and accommodate erosion with minimal damage to plants and fixtures (e.g. board and chain pavement, protective or dune forming fencing, and "managed" vegetation). Dune forming fences may be utilised where a loss of dune form has created a focus for wind and drifting sand to develop a blowout.

A further management option where economic quantities of heavy mineral sands are present is to allow mining. The statutory requirement would ensure rehabilitation of damaged or disturbed dunes at no cost to the State or local council. Rehabilitation would be subject to a Mining Rehabilitation and Environmental Management Plan in accordance with the Rehabilitation Policy of the Department of Minerals and Energy and would require annual review to critically assess the status and suitability of the rehabilitation programme. Such land use would enable re-establishment of a vegetative cover which may eventually resemble the natural state.

Where it is not possible to establish a complete self sustaining cover of vegetation, dune maintenance programs should be introduced to ensure the persistence of vegetative protection. Such programs may include enclosure of primary and secondary vegetation by fencing, and the institution of an ongoing program of fertilising, plant replacement and pest control. The cost of such a program is the price of beach usage.

4 SITE SPECIFIC MANAGEMENT CONSIDERATIONS

The coastal manager is concerned with three broad categories of on site management problems:

(a) Minimising disturbance to dunes.

(b) Management of access by humans and their vehicles.

(c) Rehabilitation of damaged dunes.

(a) Disturbance

Removal or excavation of foredunes or incipient foredunes can cause instability, render the sand mobile, and reduce the sand storage capacity which augments the beach during storm wave erosion. No excavation of foredunes should be permitted unless plans are developed for their rehabilitation which are acceptable to the appropriate authority. In addition, no excavation of incipient dunes should be permitted unless designed with the objective of correcting dune instability or a dune restoration problem identified in the Coastline Management Plan.

The following criteria are suggested to guide the manager in deciding whether a form of land use should be encouraged:

- Land use must complement the ebb and flow of sand in the nearshore zone; the maintenance of an elevated dune, and its stabilising vegetation.

- Land use which cannot meet the above requirements without causing sand drift, or requiring engineered foreshore protection should be regarded as unsuitable and sited elsewhere. Land use which contributes to the permanent degeneration of the complex relationships existing in dune plant communities is not acceptable.

- Land use which is ocean dependent, and for which a coastal dune location is imperative, but causes damage through normal wear and tear, must be supported by maintenance programs and structures which control sand drift.

Essentially all disturbance to incipient foredunes and foredunes should be prevented, as any damage to the vegetation will affect dune stability. Once the vegetation has been destroyed in one part, a blowout may result which in turn may become a transgressive dune or sand sheet. Where there is considerable human activity the dunes should be fenced and access controlled and limited. Stock should not be allowed to graze, and during nesting and breeding periods of bird species using dune habitats, very careful control is necessary to prevent their disturbance. Cooking facilities, firewood and toilets should be provided where appropriate to prevent the use of the dunes for these purposes.

Ideally, no buildings should be sited in the coastal hazard zone, but if encroachment is absolutely unavoidable, structures should be relocatable, or elevated on deep anchored piles, or expendable structures may be used. Contractors in control of access to building sites should take responsibility for protecting and stabilising the dunes in and around their sites.

(b) Access

Dunes are held together by plants and damage to these by excess traffic can cause total destruction of a stable area and greatly increased mobility of unstable dunes. Both public access paths and vehicle tracks need to be carefully sited and controlled. Rotation of access points can help. Pedestrian access should be via properly constructed walkways if traffic is moderately high. Elevated walkways of boards are perhaps the best and most aesthetically pleasing solution as they can be built above the vegetation, but less expensive and equally effective access may be provided with board and chain walkways.

Hard paving or fill should be avoided in dune areas since it is not consistent with the concepts of maintained form and function, and inflexible elements can provide focal points for wind erosion.

In addition, if the hard surfacing is attacked by storm waves, the incorporation of fragments of paving or fill into the beach can reduce amenity.

Vehicles travelling on the beach between high and low water marks have little impact on the sedimentary beach system. However vehicles can readily damage or destroy vegetation on coastal sand dunes. Plants growing on newly forming dunes are particularly sensitive to vehicle impact. Beach traffic should be diverted around drift lines and other zones of embryonic dune formation. The closure of beaches to vehicles during periods of 'king' tides, which would force drivers to run up the face of dunes or through bird nesting sites and embryonic dunes, is recommended. So too is the closure of beaches that are so narrow as to force drivers to run along the very toe of the dunes at high tide; bypass routes around such sections should be provided.

(c) Rehabilitation

Techniques for the rehabilitation of coastal dunes are discussed by the Soil Conservation Service (SCS, 1990). In any dune rehabilitation program it is important to appreciate that the incipient dune, and occasionally the foredune, are destined to be eroded during storms, with inevitable damage to vegetation, walkways and fences. An important objective of good rehabilitation practice is, therefore, to minimise maintenance commitments by providing vegetation which regenerates naturally and by using flexible or expendable structures which can accept storm attack or be replaced at minimum cost.

The Department of Minerals and Energy has produced general guidelines for the management and rehabilitation of heavy mineral sands mining. Guidelines are also determined for each individual heavy mineral sands mining operation in NSW.

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APPENDIX D6 PROTECTIVE WORKS OPTIONS

1 INTRODUCTION

A variety of coastal protection measures can be used to enhance or preserve beach amenity and to protect coastal developments at risk of erosion or recession. These include seawalls, groynes, offshore breakwaters, artificial headlands, beach nourishment and dune rehabilitation and management. Structural works are also used to stabilize coastal entrances (training walls).

To be effective, the type of protection must be compatible with coastal processes at the site. Information is required concerning the magnitude and mechanisms of existing longshore sediment transport, together with likely long term shoreline changes from erosion, accretion or recession. A detailed understanding of coastal processes and hazards is essential to the successful design, construction and operation of coastal protection works.

Protection works have the potential to impact on areas outside those being protected. Therefore any proposal for protection works must take account of the wider implications and consider the impact in a whole embayment or region, as well as the marine environment.

2 SEAWALLS

Description

A seawall is a structure built along the shoreline parallel to the beach. Its purpose is to impose a landward limit to coastal erosion and to provide protection to development behind the wall. Seawalls can be built of many materials including timber, steel, concrete, rock, gabions, bitumen, plastics, ceramics and specially designed armour units. Along the NSW coastline, seawalls are commonly constructed from dumped rock, concrete and gabions. The face of a seawall may be vertical, curved, stepped or sloping. Figures D6.1 shows various types of seawalls.

Seawalls are best designed as continuous structures over the full length of coastline to be protected. They are not well suited to the protection of isolated properties. In these circumstances, erosion around the ends of the wall can lead to collapse if this problem is not addressed in the design.

Whilst seawalls can be constructed anywhere up the beach profile, they are best located in the "higher" regions where only waves from extreme

Figure D6.1(a) Rigid Vertical Seawall

Figure D6.1(b) Rigid Sloping Seawall with Rubble Toe Protection

Figure D6.1(c) Sloping Gabion Seawall

Figure D6.1(d) Semi–rigid Seawall of SEABEES®

storm events can reach them. During normal conditions sand is returned to the beach in front of the seawall and recreational amenity of the beach is re-established.

Seawalls are commonly used in conjunction with other beach protection measures such as groynes and beach nourishment.

Types of Seawalls

Depending upon the type and materials of construction, seawalls can be classified as:

- rigid;
- flexible; or
- semi-flexible.

Rigid seawalls include gravity walls, sheet piling, caissons and concrete revetments. Advantages of rigid seawalls include their compact nature (minimum plan area) and their tendency not to harbour rubbish. However, they can be subject to catastrophic failure by freak waves or toe erosion.

Flexible seawalls are constructed from quarry rock, shingle and from specially manufactured concrete units. Whilst not as compact as rigid seawalls, flexible seawalls can sustain considerable deformation caused by erosion and settlement without total failure occurring. Because of the broken nature of their surface, flexible seawalls tend to harbour rubbish.

Semi-flexible seawalls are constructed from gabions, bitumen, grouted rock, specially designed units of concrete, ("SEABEES", "DOLOSSE", "TRIBARS", etc.), ceramics and geotextiles. They are more compact than flexible seawalls and may not be as susceptible to the catastrophic failure of rigid seawalls.

Rigid Seawalls

Whilst many rigid seawalls have been built along the NSW coastline in the past (often in an apparent attempt to recreate the Victorian beach promenades of England), there is now a general tendency away from this form of construction for the following reasons:

- failure can occur from a single freak wave or group of waves;
- most rigid structures tend to be highly reflective to incoming waves; and
- toe scour at the base of the wall can result in failure by undermining.

Because of their sensitivity to freak waves, more severe design wave conditions are adopted for rigid structures than for flexible and semi-flexible seawalls. The high reflectivity of rigid seawalls can result in accelerated sand loss in front of the wall during a storm, and delay beach rebuilding following a storm. Rock scour blankets, gabions, etc. can be used to protect the foundations of a rigid structure from undermining. Alternatively, this protection can be provided by founding such structures at depth on non-erodible materials.

The performance of rigid seawalls can be improved by incorporating various features such as a curved wave deflection barrier along the crest of the wall, which significantly reduces wave overtopping and enables the crest to be lowered (see Figure D6.2).

Flexible and Semi-Flexible Seawalls

In recent years, flexible and semi-flexible seawalls constructed from rock, shingle or proprietary concrete units have been the most common form of construction along the New South Wales coast.

Figure D6.2
Curved Wave
Deflection Barrier on
Crest of Seawall

Figure D6.3
A Conventional
Two-Layer Armoured
Seawall

A typical conventional two layer armoured seawall is shown in Figure D6.3. Provided design wave conditions are not exceeded, this form of construction has the following advantages:

- settlement can often be accommodated without weakening the overall integrity of the seawall;
- failure is progressive rather than catastrophic; and
- a seawall built of dumped rock or concrete units is less reflective than a rigid structure.

Note that some of the proprietary concrete units need to be formally interlocked to achieve their strength and protection potential, e.g. "SEABEES". In this case, the resulting seawall may behave more as a rigid than semi-rigid structure, and be subject to the same types of failure as the former.

Because of their permeable nature, flexible and semi-flexible seawalls are susceptible to scour behind the wall caused by wave overtopping or poor seepage control. If extreme, soil loss caused by this scour can lead to the landward collapse of the wall. The risk of scour by wave overtopping can be reduced by incorporating a relatively impermeable blanket of rock, clay, grass, etc. along the crest.

Regular maintenance of the flexible and semi-flexible seawalls is generally required to ensure their structural integrity.

The mass of the armour unit used to protect flexible structures is proportional to the cube of the design wave height. A doubling of the design wave height for long term coastal erosion, recession or increasing sea levels would require an eight fold increase in armour unit mass to provide the same level of protection. For this reason, careful consideration must be given to the effects of long term erosion or increases in sea level on design wave height.

Storm Profile Seawalls

A recent development has been to construct seawalls from rocks of much smaller size than required for conventional design. Provided a sufficient volume of rock is placed, a stable "beach" profile is naturally developed during storm conditions. Physical model tests are usually required to determine this profile. The advantages of this form of construction include:

- almost any size of rock can be used provided a sufficient volume is placed;
- wave reflection is low enabling lower crest elevations; and
- problems of toe scour and beach recovery after storms are reduced.

One disadvantage is that this form of protection may be aesthetically displeasing: the "beach" consists of a mixture of rocks and sand which may reduce amenity. The structure also occupies a larger space than conventional walls.

3 GROYNES

Groynes are coastal structures built approximately normal to the shoreline. Their purpose is to trap sand and thereby increase the width of the beach. Groynes can be constructed from a similar range of materials as seawalls. When used on the open coast, they must be strong enough to withstand substantial wave forces.

For groynes to be effective, there must be a supply of sand from either longshore transport or from beach nourishment. In a longshore transport situation, sand is trapped on the updrift side of the groyne. As the groyne embayment fills, the alignment of the shoreline changes to become more normal to the wave direction. During this filling process, there is a consequent reduction in sand supply downdrift of the groyne. This results in shoreline erosion at downdrift locations. Dune management measures may be required both up drift and down drift to accommodate changes in the beach and dune systems.

Where groynes are used, it is essential that their effect on the downdrift coastline and the consequences of a changed shoreline alignment be closely examined.

Downdrift erosion can be reduced by artificially filling the groyne embayment under a beach nourishment program. This minimises disruption to the longshore transport process as the embayment fills.

Groynes do not significantly affect onshore/offshore movement during storms and are therefore not usually effective as a means of managing short term erosion.

4 BEACH NOURISHMENT

Where there is insufficient sand on a beach to meet storm erosion or long term sediment loss, additional sand can be placed by mechanical means. This is referred to as beach nourishment. It is a favoured means of beach protection for resort and high amenity beaches because it promotes amenity and unlike some other structural measures, does not have adverse effects on adjacent areas of the coastline.

Provided sufficient sand is used, beach nourishment can provide total protection. However, it may be an expensive means of control, and it is often used in conjunction with other control measures such as seawalls and groynes. Dune management measures would be needed to accommodate the increased sand volume.

To prevent excessive offshore losses of the placed material, the nourishment sand should be similar in size or preferably slightly coarser than the natural beach material. Common sources of nourishment sand include dunes, coastal inlets and offshore areas. When the source material is borrowed from offshore areas it is important to ensure that the dredged area does not alter the existing wave refraction patterns to the detriment of the adjacent coastline. Many potential nourishment sources are being removed or sterilised through coastal development and dredging operations, which will hinder future nourishment programs should they be necessary. Local authorities should consider setting aside reserves for future use. Some local authorities require sand excavated during the construction of coastal developments to be returned to the beach. Where there is long term sediment loss it is desirable that the source of material is outside that particular active beach system.

In a beach nourishment program, the volume and frequency of placement of sand depend upon the rates of offshore and onshore losses. Offshore loss depends upon the wave exposure of the site and the size of the sand. Onshore loss is by sand drift.

5 SAND BYPASSING

"Sand bypassing" is a special form of beach nourishment used to alleviate the downdrift erosion caused by training walls. Training walls are typically constructed at the entrances of coastal inlets for flood mitigation purposes or to improve navigation. They can act as groynes, trapping sand on the updrift side and causing shoreline erosion on the downdrift side. Training walls often project much further out to sea than ordinary groynes. Hence, the associated downdrift erosion can be extensive. To limit this erosion, sand can be pumped from the updrift embayment or from other sources to the downdrift shoreline, thereby bypassing the training walls. Sand bypassing, like beach nourishment, is a relatively expensive and continuing operation.

6 OFFSHORE BREAKWATERS

Offshore breakwaters are structures built approximately parallel to the beach but some distance offshore. They may protrude above water level or be submerged; they may be continuous or consist of a series of segments. The purpose of offshore breakwaters is to reduce the intensity of wave action in inshore waters and thereby reduce coastal erosion. Offshore breakwaters are normally constructed from the same materials as seawalls. A particular form of the offshore breakwater is the "T-groyne" in which the offshore structure is connected to the shore for ease of construction, maintenance or for subsequent use.

Fully submerged breakwaters consisting of underwater mounds or artificial reefs of sand and small rocks have been used for coastal protection purposes overseas, e.g. at Durban in South Africa. Under normal conditions, waves pass over the mound or reef with little modification. Under storm conditions, the larger waves break on the mound thereby dissipating energy and reducing shoreline erosion.

Unlike groynes, offshore breakwaters can be used to reduce erosion at a beach which has no net longshore transport. However, if longshore transport exists, an offshore breakwater will act like a groyne and cause downdrift erosion.

Offshore breakwaters are not a common form of coastal protection along the shoreline of New South Wales. They are costly to construct because of the prevailing wave climate and their use is generally limited to the protection of sheltered areas not exposed to full wave attack.

7 ARTIFICIAL HEADLANDS

The natural headlands of a pocket beach restrict longshore sand transport. Such headlands act as groynes, but on a much larger scale. Artificial headlands can be constructed to achieve a similar effect, e.g. large groynes that extend into deep water, or offshore breakwaters connected to shore (T-groynes). On the open coast, this form of protection requires large and expensive structures. Consequently, their use has been restricted to more protected shallow areas with less severe wave conditions.

8 CONFIGURATION DREDGING

Configuration dredging is dredging to a pattern such that wave refraction limits the effects of wave action on a stretch of coastline. Its usefulness on the open coast is restricted by the variety of wave directions possible and the scale and cost of works required. It is more applicable to sheltered bays and could only be considered in an environment where there was great confidence in the understanding of coastal processes.

9 DESIGN CONSIDERATIONS

Design Wave Height

Coastal protection structures are generally located within the surf zone and are therefore subject to forces associated with "depth limited broken waves". The design wave height for such structures can be expressed as follows:

$$H = a \cdot d$$

where H is the design wave height,
d is the water depth which controls breaking
a is a coefficient referred to as the "Breaker Index"

The governing water depth is the difference between SWL and the seabed level to the seaward end of the structure. The SWL used for design purposes should reflect the effects of astronomical tide, storm surge and wave set up (see Appendix B4). The seabed level used for design purposes must take into account likely scour during design storm conditions and include an allowance for any long term erosion or accretion resulting from an imbalance in the sediment budget. Beach profiles taken immediately after a storm provide the best data to assess scour and seabed levels for design purposes. However, such data are only available at a limited number of sites where local authorities have had the foresight to make such measurements. In most cases estimates of scour level are determined from aerial photography, often taken some time after a storm event.

The breaker index is a function of several variables which include wave period, bed slope and wave grouping. Its value is presently poorly defined. A value commonly used in practice has been 0.8, which is reasonable for flat slopes and long period waves, but underestimates the maximum wave height for relatively steep beach slopes and short period waves. For the latter conditions, model tests and field data indicate values between 0.8 and 1.2.

In choosing a design value for the breaker index, consideration should be given to the susceptibility of the structure to failure or damage from a group of three of four extreme waves. Rigid structures are more prone to failure under these conditions, and a correspondingly higher value of the breaker index should be adopted. Flexible structures such as rubble mounds may be damaged, but rarely fail from a group of high waves. Consequently, lower values can be adopted. For high cost structures, or structures where the consequence of failure is significant, wave model testing should be used to verify the design.

Toe Scour

In selecting the foundation level of a coastal structure, consideration must be given to the possibility of local scour at the toe. This may result in the failure of rigid structures; flexible structures can tolerate settlement without failure. Incorporation of a scour blanket to protect against toe erosion is commonly used as a safeguard against failure or damage from this cause.

Crest Level

The crest level adopted in the design of coastal protection structures needs special attention. A crest level which is never overtopped will significantly increase the cost of the structure. As the crest level is reduced, so the probability of failure caused by overtopping is increased.

Most structures are designed to allow for some overtopping. For seawalls, scour blankets landward of the crest and/or wave reflecting walls can be used to protect the structure from damage and to limit overwash. For breakwaters and groynes, a significant increase in strength of the crest can be achieved by careful placement of the armour units to ensure good interlocking and by the use of concrete or bitumen grouting. If grouting is used it is essential that good drainage is provided to prevent the excessive uplift pressures. To achieve this purpose, intermittent rather than continuous grouting is generally used.

Soil and Drainage Considerations

Whilst coastal structures are designed primarily to resist forces from waves and currents, they also act as retaining structures for the material behind them. Thus, they are subject to soil and water pressures in the same way as any other retaining structure and must be designed to resist these forces.

The drainage of coastal structures needs careful consideration. Many impermeable structures have failed by collapse in the seaward direction caused by soil and water pressures behind them. For permeable structures, seepage may result in the removal of material from behind the structure and eventual failure by collapse landwards. This can be avoided by correctly designed soil filters or geotextiles. Where geotextiles are used, protection against light is essential.

Availability of Materials

All coastal protective works require materials of one sort or another. The availability of material and its suitability for coastal protection will largely determine the overall costs of a project. The coastal engineer would be greatly assisted if this knowledge was readily available.

Special attention needs to be given to the availability of sand suitable for beach nourishment programs. The major sources of sand are:

- residual dunes formed during previous variations in sea level and which are now outside the active beach system;
- prograding beaches, especially those resulting from artificial causes (e.g. Boambee Beach near Coffs Harbour).
- natural sand losses which occur at tidal inlets; and
- offshore sand seaward of the active beach system.

The last source is expensive as compared to land based sources. However, many of the land sources are presently becoming unavailable as a result of removal for the construction industry, commercial and private development of the land and a general trend for environmental protection irrespective of the consequences of that protection. It would be desirable that sources of beach nourishment sand be identified, and where appropriate, be reserved for that purpose.

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APPENDIX D7 THE MANAGEMENT OF UNCERTAINTY

1 INTRODUCTION

To a greater or lesser extent, all planning studies are confronted with uncertainties arising from inferred future conditions. This is particularly true of planning within the coastal zone, with the extent of the sea level rise and other climatic changes postulated to accompany the Greenhouse Effect being one example of future uncertainty which is relevant to coastline hazard management.

In addition to future uncertainties, planning studies for coastline hazard management are also subject to other, more inherent uncertainties in the estimation of the extent of current coastline hazards. These uncertainties arise from the complex and interrelated nature of coastal processes, data deficiencies in coastal process studies, and our less than complete understanding of these processes.

As all planning and management studies must address the problems of uncertainty, a general procedure for dealing with uncertainty is of interest.

2 A STRATEGY FOR PLANNING UNDER UNCERTAINTY

A simple strategy for dealing with uncertainty is as follows:

- first, identify the likely range of the uncertain factor(s)/events;

- second, investigate the consequences of this range of outcomes; and

- third, develop a management plan that is flexible and/or robust in addressing these outcomes.

A robust strategy is one in which planning and management decisions remain viable even if the actual future outcome is more or less extreme than assumed in the original analysis.

3 DEVELOPING STRATEGIES

The stages involved in developing a strategy for planning for uncertainty are discussed below. It should be noted that these stages are relevant both for developing management strategies which take account of the inherent uncertainties associated with the coastal process, and also, for responding to future uncertainties associated with climate change.

3.1 Identifying Ranges of Values

The need to test the outcomes of management options against a range of scenarios is discussed in relation to both existing and future uncertainties involved in coastal planning and management.

The inherent uncertainties associated with the coastal process relate (in this instance) to the accuracy of predictions of the processes resulting from coastal process or hazard definition studies. These studies are largely based on analysis of a relatively short, recent history of events. Of particular concern is the question of how representative the weather patterns were during this period. For example, the late sixties and the seventies appear to have been quite stormy, while the eighties have been relatively quiet. It is quite difficult to place numerical estimates of accuracy on the results of these studies but it would be prudent to test management options against a range of values for the events being considered.

Regarding the uncertainties associated with climate change, these can be assessed in terms of a possible sea level rise over time, the possibility of increased storminess, the possibility of increased rainfall and flooding, the possibility of increased cyclone activity in the north of State, etc.

The range of scenarios which might be selected for assessment of their effects on management options will depend on a number of factors including the physical or economical life of the development, its importance and cost, and the consequences of damage. Given the early stage of research into some of the issues associated with climate change, it is not considered appropriate to nominate a specific range of values which might be applied to a particular circumstance. The Public Works Department, the Department of Planning, other State agencies and the CSIRO will continue to monitor research in the area of climate change and its implications, and will be in a position to provide advice on the most up to date information at a given time. It will be the responsibility of the developers to ensure that they possess the best available information when considering the likely impact that climate change may have on a development proposal.

3.2 Investigating Consequences

Once a range of scenarios relating to the uncertain factors/events has been determined, it is then necessary to interpret the outcome of those events in terms of whether they represent a potential coastal hazard. In terms of future uncertainties associated with climate change, these may result directly from the effects of sea level rise, or may be due to other aspects of climate change.

It should be noted that in terms of sea level rise these are well accepted theories as the extent of resultant coastline recession. However, methods available for predicting other impacts of climate changes are less well understood, and are constantly being refined. Nevertheless, it should be possible to broadly indicate areas of the coast which may be subject to future additional hazards of this order. This may lead to particular sites along the coast being identified as susceptible to specific threats such as erosion, inundation or cyclonic activity, and this may assist in the selection of appropriate coastal management strategies.

The Public Works Department will provide advice on the outcome of various scenarios and also provide comment on the accuracy of previous technical studies. This advice can be provided in the first instance, in general terms, within the context of a hazard definition study. More specific advice can be provided during the coastal management study when the sensitivity of the option is being considered.

3.3 Robust Planning

Given the uncertainty that exists concerning a number of factors relating to planning and development control in the coastal zone, the most appropriate planning response is to ensure that management strategies are flexible and therefore robust enough to withstand future changes not precisely predicted now. This may involve considering a number of approaches in preparing management plans depending upon the likely developments involved, and the nature of the hazards being planned for. For example, it may be necessary to adopt strategies which temporarily permit certain types of development in localities which may be subject to coastal hazard in the future. Similarly, a policy of "planned retreat" may give the same type of flexibility for future decision making, given the uncertainties concerning future climate change, and in our understanding of workings of the coastal processes.

Another more general method of achieving robust planning is after having decided upon the appropriate management option, to examine the effect of future changes being more or less extreme than originally predicted. This approach is assisted by ensuring that there is flexibility in the design of coastal developments, as the following examples help illustrate:

- In designing protective structures it is prudent to consider the possibility of increased sea level and thus increased runup level and wave height. At little or no extra cost it may be possible to provide for the increased wave height and to ensure that the crest level can be raised in the future.

- In considering forming or managing a dune as a natural barrier against inundation it may be possible to provide sufficient space for the dune crest to be raised at a later date.

- Where floor level controls are proposed to deal with inundation or flooding of streams near the coast it should be kept in mind that houses on piers can be raised in the future, whereas slab-on-ground designs do not provide that flexibility.

In view of the uncertainties associated with development in the coastal zone, such flexibility in the design of development should be considered an essential element of robust planning.

4 CONTINGENCY PLANNING

As part of the planning for uncertainty it is necessary to consider that future events may differ significantly from predictions either in relation to future climate change or the uncertainties associated with coastal processes being more or less extreme than were planned for. Contingency plans for such developments should be thought out at the feasibility and design stages of the project. Council may look more favourably at developments that can be protected by cost effective contingency measures.

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