Geoscience Australia Record 2003/09

CONCEPTUAL MODELS OF AUSTRALIA'S ESTUARIES AND COASTAL WATERWAYS

APPLICATIONS FOR COASTAL RESOURCE MANAGEMENT

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ISSN: 1039-0073
ISBN: 0 642 46766 8

GeoCat No. 47336

Bibliographic reference: Ryan, D. A., Heap, A. D., Radke, L., and Heggie, D. T., (2003) *Conceptual models of Australia's estuaries and coastal waterways: applications for coastal resource management*. Geoscience Australia, Record 2003/09, 136 pp.

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EXECUTIVE SUMMARY

This report contains comprehensive conceptual models of the biophysical processes that operate in a wide range of estuaries and coastal waterways found around Australia. This document represents part of Geoscience Australia's contribution to the National Estuaries Assessment and Management (NE) project, Theme 5 (Assessment and Monitoring), Task 5A 'Conceptual Models of Australian Estuaries and Coastal Waterways'. The objectives of Task 5A were as follows:

- Integrate hydrological, biological, and geoscience perspectives regarding the relationship between the physical 'form', and the environmental 'function' of all Australian estuaries and coastal waterways (through collaboration with Coastal CRC researchers).
- Enhance cross-disciplinary communication of scientific concepts, in order to give managers a broader and more comprehensive view of estuarine function, at a scale appropriate to environmental resource management.

Task 5A builds upon the work commenced during the National Land and Water Resources Audit (NLWRA 2002, Heap *et al*., 2001). The work is intended to improve and expand the conceptual process models developed during the NLWRA, in order to present simple yet integrative representations for all of the coastal waterways identified during the classification process undertaken by Harris *et al*., (2002). In addition to this document, the conceptual models are also represented as an interactive web production, linked to the OzEstuaries database (http://ozestuaries.org). The Conceptual Models, were developed with close linkages to the Theme 5 Task 5b subproject, 'Indicators of the Condition and Vulnerability of Estuaries and Coastal Waterways', also available as interactive web productions via the OzEstuaries database.

The conceptual models in this report are representations of real-world systems. They are a synthesis of knowledge for each type of coastal waterway, and are intended to be visually stimulating and easier to digest than the complex diagrams often used to represent environmental systems. Geomorphology and sediment type was used as the common 'base layer' in the conceptual models, because sediment is the fundamental, underlying substrate upon which all other estuarine processes depend and operate, and geomorphology is an ideal medium with which to integrate many physical and biological variables.

In the past, numerous physical classification systems have been developed that attempt to encapsulate the diverse physiography exhibited by coastal waterways. While useful for addressing specific environmental issues, these classifications have not been widely applicable or necessarily intended for use by researchers from disciplines other than those used to create the classification schemes. During the NLWRA work, the geomorphology of 974 of Australia's estuaries and coastal waterways was assessed using Landsat TM satellite imagery, aerial photographs, and topographic maps in combination with quantitative data for wave, tide and river energy (Heap *et al*., 2001). From this, seven coastal waterway classes were identified, each waterway type having a distinctive suite of physiological parameters based on the relative combinations of wave, tide, and river influence, providing the first comprehensive classification of all the coastal waterway types found in Australia. The coastal waterway classes comprise:

- Embayments and Drowned River Valleys
- Wave-dominated Estuaries
- Wave-dominated Deltas
- Coastal Lagoons and Strandplain-associated Creeks

- Tide-dominated Estuaries
- Tide-dominated Deltas
- Tidal Creeks

The distribution of these different coastal waterway classes around the Australian coastline suggests a distinct zonation, such that five major coastal regions can be identified. These include the North-east Coast, South-east Coast, Great Australian Bight, South-west Coast, North-west Coast, and the Gulf of Carpentaria. The southern regions are wave-dominated environments, whereas the northern coastal regions are mainly tide-dominated. Linkages have also been made between the geomorphic classes (Harris *et al.*, 2002), the National distribution of estuarine habitats (or sedimentary environments), and classifications of the coastline in terms of climate and rainfall (Heggie *et al.*, 1999b).

Estuaries and coastal waterways are highly dynamic environments in which geomorphic change is driven by the deposition and erosion of sediment, which may occur over a range of timescales, from almost instantaneous (e.g. river floods), to progressive change over thousands of years. Coastal waterways evolve when they receive and accumulate sediment, including fluvial, marine and aeolian (wind) inputs as well as detritus from fringing vegetation, organic material produced within the estuary, and human induced inputs. Evolutionary characteristics provide an important link between the many different types of coastal waterways. Each type of wave- or tide-dominated coastal waterway is at a different stage in an evolutionary continuum, having developed to a greater or lesser extent depending on regional sea level history, and the amount of sediment supplied to it.

Geomorphic conceptual models have been developed for each of the seven types of Australian estuaries and coastal waterways. Each conceptual model comprises a three-dimensional block diagram depicting detailed summaries of the structure, evolutionary characteristics, and geomorphology of each coastal waterway type, which are "overlain" by flow diagrams that depict some of the important biotic and abiotic processes, namely: hydrology, sediment dynamics, and nutrient dynamics.

In the conceptual models, wave-dominated systems are depicted as having a relatively narrow entrance that restricts marine flushing, and low water-column turbidity (in terms of suspended sediment) except during extreme wind or fluvial runoff events. Depictions of tide-dominated systems feature relatively wide entrances, which likely promote efficient marine flushing, very large relative areas of intertidal habitats (relative to wave-dominated systems), and naturally high turbidity due to strong turbulence induced by tidal currents. Strong evidence exists suggesting that estuaries (both wave- and tide-dominated) are the most efficient 'traps' for terrigenous and marine sediments, and these are depicted as providing the most significant potential for trapping and processing of terrigenous nutrient loads. Intertidal areas, such as mangroves and saltmarshes, and also the central basins of wave-dominated estuaries and coastal lagoons, are likely to accumulate the majority of trapped sediments and nutrients.

Conceptual model diagrams, with overlays representing environmental processes, can be used as part of a decision support system for environmental managers, and as a tool for comparative assessment in which a more integrative and shared vision of the relationship between components in an ecosystem can be applied. They provide a framework for organising knowledge, in order to help users understand processes and demonstrate the links between them. In this way, coastal managers are able to consider the dynamics of coastal ecosystems at temporal and spatial scales appropriate to making management decisions, and attempts can be made to fill in the gaps in knowledge. A case study has been provided (featuring Wilson Inlet, WA) demonstrating how conceptual models might be applied to specific coastal waterways. It is intended that the conceptual models presented should continually evolve and be improved through ongoing testing and review by coastal managers and researchers.

A glossary of well-established scientific and technical terms used throughout this publication is provided in the Appendix, as is a list of the specific Australian coastal waterways considered in this work, and technical descriptions of typical estuarine sedimentary environments (or habitats). More information about Australia's estuaries and coastal waterways may be obtained from http://www.ozestuaries.org.

INTRODUCTION

Australia, as an island nation, has a coastline that plays a crucial role in the economy, environment and lifestyle of the vast majority of Australians. Among the many and varied coastal environments, estuaries and coastal waterways represent some of the richest and most diverse, yet often inappropriately managed, habitats. Environmental managers, who are responsible for developing strategies to ensure the appropriate use and conservation of estuarine resources, are increasingly faced with the task of assimilating and synthesising a wide variety of disparate and sometimes contradictory scientific information from many disciplines. Managers responsible for coastal environments require a simple, logical framework to provide a holistic synthesis of the current state of knowledge regarding estuaries, coastal waterways and their catchments, enabling the planning of more structured and informed management strategies. This report, and the conceptual models of estuaries and coastal waterways herein, is intended to provide such an integrated framework, based upon the fundamental geomorphology of the main coastal waterway types observed in Australia.

Value of Estuaries and Coastal Waterways

Traditionally, Australians place a high value on coastal environments, such as estuaries and coastal waterways, as areas for living, working, and recreating - they are sources of economic and social well being, and they provide substantial environmental amenity (Costanza *et al.*, 1997). Because of their importance for both ecological processes and economic development, estuarine environments have been ranked among Australia's most valuable natural resources (Smith *et al.*, 2001). In economic terms, estuaries and coastal waterways provide:

- Sheltered deep water access for ports
- Shorelines for urban and industrial development
- Sites for effluent disposal and recycling
- Fisheries and aquaculture
- Sites for tourism and recreation

Estuaries and coastal waterways also remain shelters for a wealth of ecological communities, and provide numerous environmental 'functions', such as:

- Salt-tolerant vegetation communities
- Shelter, breeding grounds, and 'nursery' habitat for many marine, estuarine, and terrestrial species
- Sediment trapping and “buffering” between coastal catchments and the marine environment (Harris *et al.*, 2003)
- Storing and cycling of nutrients
- Absorbing, trapping, and detoxifying pollutants (Birch, 2000).

Although coastal waterways are dynamic, many human-induced pressures are accelerating change in estuarine environments. The maintenance of both human interests and natural resource capital in coastal waterways largely depends on the ecosystem 'function', or 'services'. These include excessive catchment development, resource exploitation and pollution, highlighting the need for wise, informed, and equitable management strategies. Our scientific understanding of ecosystem processes and factors contributing to their observed degradation is constantly improving. However, our knowledge is still incomplete, because of the extreme complexity of the natural and human processes involved. Therefore, decisions based upon imperfect understanding must continue to take place. With changing environmental pressures and conditions, different types of coastal waterways function in specific and predictable ways. Coastal managers who have an understanding of the relationship between the geomorphic 'form', and the functions that occur in coastal waterways will be better equipped to assess environmental issues, and target appropriate management strategies or responses (Roy *et al.*, 2001). Conceptual models provide an effective and efficient way of communicating and synthesising the extremely complex processes and interactions occurring in Australian coastal waterways.

How Can Conceptual Models Aid Coastal Management?

Conceptual models are useful as planning and management tools because they succinctly communicate the complexity of the biophysical properties of coastal waterways. In this context, they can be used to:

- Provide a framework for organising knowledge, in order to help understand how systems function, and demonstrate the links between geomorphology and other processes
- Present a holistic picture of Australian coastal waterways to assist the application of environmental indicators (including the setting of 'trigger' values)
- Identify areas of uncertainty (and lack of knowledge) that help to prioritise research needs and monitoring activities
- Consider the dynamics of coastal ecosystems at temporal and spatial scales appropriate to making management decisions
- Facilitate stakeholder participation, and foster cross-disciplinary communication and discussion

Development of Conceptual Models

The conceptual models in this report are representations of real-world systems. They are intended to be visually stimulating, and easier to digest than the complex "spaghetti" diagrams (containing numerous boxes and arrows) often used by scientists. The development of holistic models that successfully encapsulate the physical structure, complex biophysical processes, and other interactions in coastal waterways represents a major step forward in our understanding of their environmental function. The models incorporate a significant amount of biophysical information collated from numerous studies of Australian and overseas estuaries and coastal waterways, and build upon the initial work undertaken by Heap *et al.* (2001) for the National Land and Water Resources Audit (NLWRA 2002).. They were developed with the assistance of experts from a variety of disciplines, including ecology, biology, oceanography, geomorphology, sedimentology, and geochemistry (see Acknowledgments). Due to the large number of technical terms necessary throughout this work, a Glossary of Terms has been included near the end of this document.

Each conceptual model comprises a 3-D block diagram depicting detailed summaries of the structure, evolutionary characteristics, and geomorphology of coastal waterways, which is “overlain” by flow diagrams that show some of the important biotic and abiotic processes, namely: hydrology, sediment, and nutrient dynamics. The estuarine conceptual models in this study are intended to represent relatively 'unmodified' conditions, as defined by the NLWRA (2002), rather than impacted or degraded systems. The models also contain links to recognised indicators that may be used to assess the condition of coastal waterways.

DEFINITION AND CLASSIFICATION OF ESTUARIES AND OTHER COASTAL WATERWAYS

The shape of estuaries and coastal waterways is determined by a large number of environmental factors, such as sea level history, climate, antecedent topography, tectonic setting, geology (i.e. the nature of the bedrock), river and marine sediment supply, tidal currents, wave action, river flow, climate, and biota. Consequently, every coastal waterway has intrinsic characteristics that make it different from all others, and determine its needs for, and responses to, management strategies (Perillo, 1995). It is the intention of this study to present a geoscience-based perspective for the management of estuaries and coastal waterways. Thus, from the perspective of the study of estuarine sediment and geomorphology:

'An estuary is defined as the seaward portion of a drowned river valley system which receives sediment from both fluvial and marine sources, and which contains facies influenced by tide, wave and fluvial processes. The estuary is considered to extend from the landward limit of tidal facies at its head to the seaward limit of coastal facies at its mouth' (Dalrymple *et al.*, 1992).

However, we recognise that this definition may be restrictive for the purposes of some fields such as hydrology or ecology, and that no one definition adequately spans all disciplines related to the study of coastal environments. Additionally, some habitats that are frequently referred to as 'estuarine', may in fact occur within a coastal waterway that does not fulfil the requirements of Dalrymple *et al*. (1992). In these events, we suggest that:

'An estuary is a semi-enclosed coastal body of water that extends to the effective limit of tidal influence, within which sea water entering from one or more free connections with the open sea, or any other saline coastal body of water, is significantly diluted with fresh water derived from land drainage, and can sustain euryhaline biological species for either part or the whole of their life cycle' (Perillo, 1995).

For the purposes of this study, the nomenclature described by Dalrymple *et al*. (1992) has been adopted, which reflect the dominance of wave, tide and river processes, although links are made to other naming systems.

Previous Classification of Estuaries and Coastal Waterways

Numerous physical classification systems have been developed that attempt to encapsulate the diverse physiography exhibited by coastal waterways. These classification schemes have been principally based on the dominance of one or more biophysical parameters including:

- Climate (e.g. Rochford, 1959, Eyre, 1998, Heggie *et al.*, 1999b)
- Hydrology (e.g. Finlayson *et al.*, 1988, Digby *et al.*, 1996)
- Water quality (House *et al.*, 1989, Smith, 1989, Eyre, 1998, Eyre *et al.*, 1999)
- Morphology and physical measurements (e.g., Harris *et al.*, 2002, Hume *et al.*, 1988, Hume *et al.*, 1993, Boyd *et al.*, 1992, Gregory *et al.*, 1994, Kench, 1999, Roy *et al.*, 2001)
- Habitat types and extent (e.g. Bucher *et al.*, 1991, Bucher *et al.*, 1994, Dethier, 1992, Galloway *et al.*, 1984)
- Ecological (e.g. Cooper *et al.*, 1994, Edgar *et al.*, 2000, Moverley, 2000)

While useful for addressing specific environmental issues, these classifications have not been widely applicable or necessarily intended for use by researchers from disciplines other than those used to create the classification schemes. Over the last 20 years, geoscientists have developed *facies* models for coastal waterways, that distil the main geomorphic and sedimentary characteristics from numerous examples (e.g. Roy, 1984b, Woodroffe *et al.*, 1989, Boyd *et al.*, 1992, Dalrymple *et al.*, 1992, Reinson, 1992, Woodroffe *et al.*, 1993, Perillo, 1995, Heap *et al.*, 2001, and Roy *et al.*, 2001). The advantage of geomorphic models is that they provide the fundamental framework upon which habitats are built, and are the physical context for biophysical processes (Murray *et al.*, 2002). Geomorphic models are thus applicable to researchers from other disciplines in the natural sciences, for example ecologists and biologists.

A Process-based Geomorphic Classification of Australian Coastal Waterways

Geomorphology, or the study of the nature and history of landforms and the processes which create them, is an easily recognisable end product of a combination of environmental factors. Under stable tectonic and sea level conditions, the gross geomorphology of coastal waterways is principally determined by the relative influence of wave, tide, and river power (Figure 1; Boyd *et al.*, 1992, Dalrymple *et al.*, 1992), with each coastal waterway containing a distinctive suite of geomorphic and sedimentary environments.

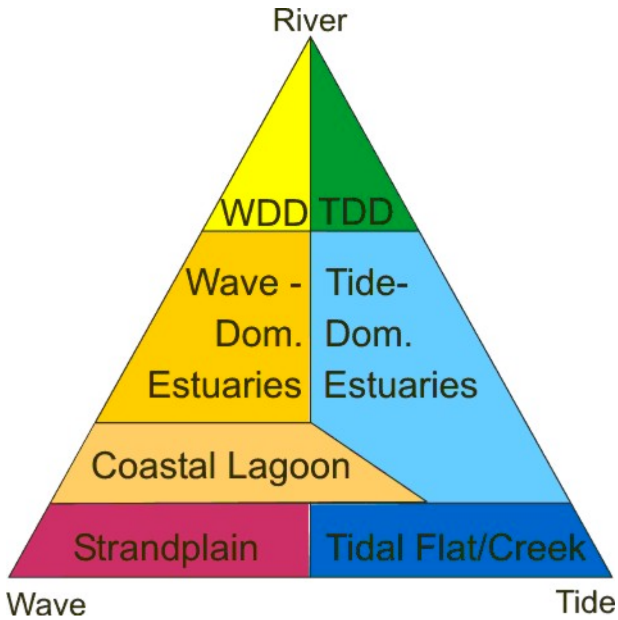

Figure 1 - Ternary classification of coastal systems divided into seven classes (after Dalrymple *et al.*, 1992, Boyd *et al.*, 1992). The position of each coastal waterway type depends on the relative influence of waves, tides, and rivers. Embayments and drowned river valleys are omitted from the diagram as they represent 'immature' coastal waterways (or coastal waterways which are not significantly filled with sediment).

Because geomorphology is directly linked to these three parameters, it can be used to classify coastal waterways. The geomorphology of 974 of Australia's coastal waterways was assessed using Landsat TM satellite imagery, aerial photographs, and topographic maps in combination with quantitative data for wave, tide and river energy (Harris *et al.*, 2002, Appendix 2). From this, seven coastal waterway classes were identified, each waterway type having a distinctive suite of physiographic parameters based on the relative combinations of wave, tide, and river influence (Table 1, Figure 2).

Table 1 - Descriptions of the principal physiographic components of the 7 geomorphic coastal waterway classes, based on Australian conditions (adapted from Heap *et al*., 2001). EMB = Embayment, WDE = Wave-dominated Estuary, WDD = Wave-dominated Delta, CL/SP = Coastal Lagoon/Strandplain associated creek, TDE = Tide-dominated Estuary, TDD = Tide-dominated Delta, TC = Tidal Creek.

Classification	**Landward (Nearer to the river or catchment)**	**Middle (Centre or main water body)**	**Seaward (Entrance or mouth adjacent to the open ocean)**	**Comments**
Embayment, (EMB) (Wave- or Tide-Dominated)	Highly variable river-derived sediment and freshwater input, unrestricted wave penetration.	Deep broad basin flanked by narrow intertidal zone, and exposed bedrock and rocky reef.	Wide, unconstricted entrance, large water exchange with the sea.	Marine conditions prevail throughout system. May evolve into an estuary with time.
Wave-dominated Estuary, (WDE)	River-derived sediment and freshwater input dominates. Fluvial-bayhead delta development	Broad, low energy central basin, flanked by small areas of intertidal environments.	Entrance constricted by a barrier, that attenuates tides within the estuary. Marine sediment dominates	Sediment is mostly trapped in the central basin. Limited oceanic water exchange
Wave-dominated Delta, (WDD)	Riverine sediment input. Floodplain/ alluvial plain, shifting channel.	Channel(s) act as a conduit for transport of sediment offshore, flanked by thin intertidal areas.	Constricted entrance characterised by a barrier and tidal delta deposits, export of sediment to the sea.	Represents a WDE mostly infilled by sediment. River inputs are predominantly transported offshore.
Coastal Lagoon/ Strandplain, (CL/SP)	Very little (or no) freshwater and river-sediment input. No fluvial-bayhead delta	Low energy central basin dominates. Flanked by small areas of intertidal environments.	Intermittent entrance (often closed) characterised by barrier and tidal delta deposits. Tides attenuated/excluded.	Similar to a small WDE. Frequently isolated from the sea, and slow infilling.
Tide-dominated Estuary, (TDE)	Riverine sediment input. Floodplain/ alluvial plain.	Wide tidal channel network, flanked by large areas of inter- & sub-tidal environments.	Wide funnel-shaped entrance containing tidal sand banks, large tidal exchange.	Shifting channels and sand banks, fine sediments trapped in inter- & sub-tidal environments.
Tide-dominated Delta, (TDD)	Riverine sediment input. Floodplain/ alluvial plain, shifting channel.	Tidal channel network acts as conduit for sediments. Smaller intertidal area.	Wide funnel-shaped entrance containing tidal sand banks that may have merged with intertidal environments.	Represents a TDE mostly infilled by sediment. River inputs are predominantly transported offshore.
Tidal Creek, (TC)	Very little (or no) freshwater and river-sediment input. No fluvial-bayhead delta	Wide channel network flanked by large areas of inter- & sub-tidal environments.	Wide funnel-shaped entrance that does not contain tidal sand banks, large tidal exchange.	Similar to a TDE, contains sediment derived from marine sources only

The distribution of these different coastal waterway classes around the Australian coastline displays a distinct zonation, such that five major coastal regions can be identified (Figure 2). These include:

- North-east Coast
- South-east Coast
- Great Australian Bight
- South-west Coast
- North-west Coast
- Gulf of Carpentaria

The southern regions are wave-dominated environments, whereas the northern coastal regions are mainly tide-dominated. This pattern conforms to the general distribution of wave- and tide-dominated shelf environments (Harris *et al.*, 2002). However, each of the five coastal regions contains a mixture of coastal depositional environments.

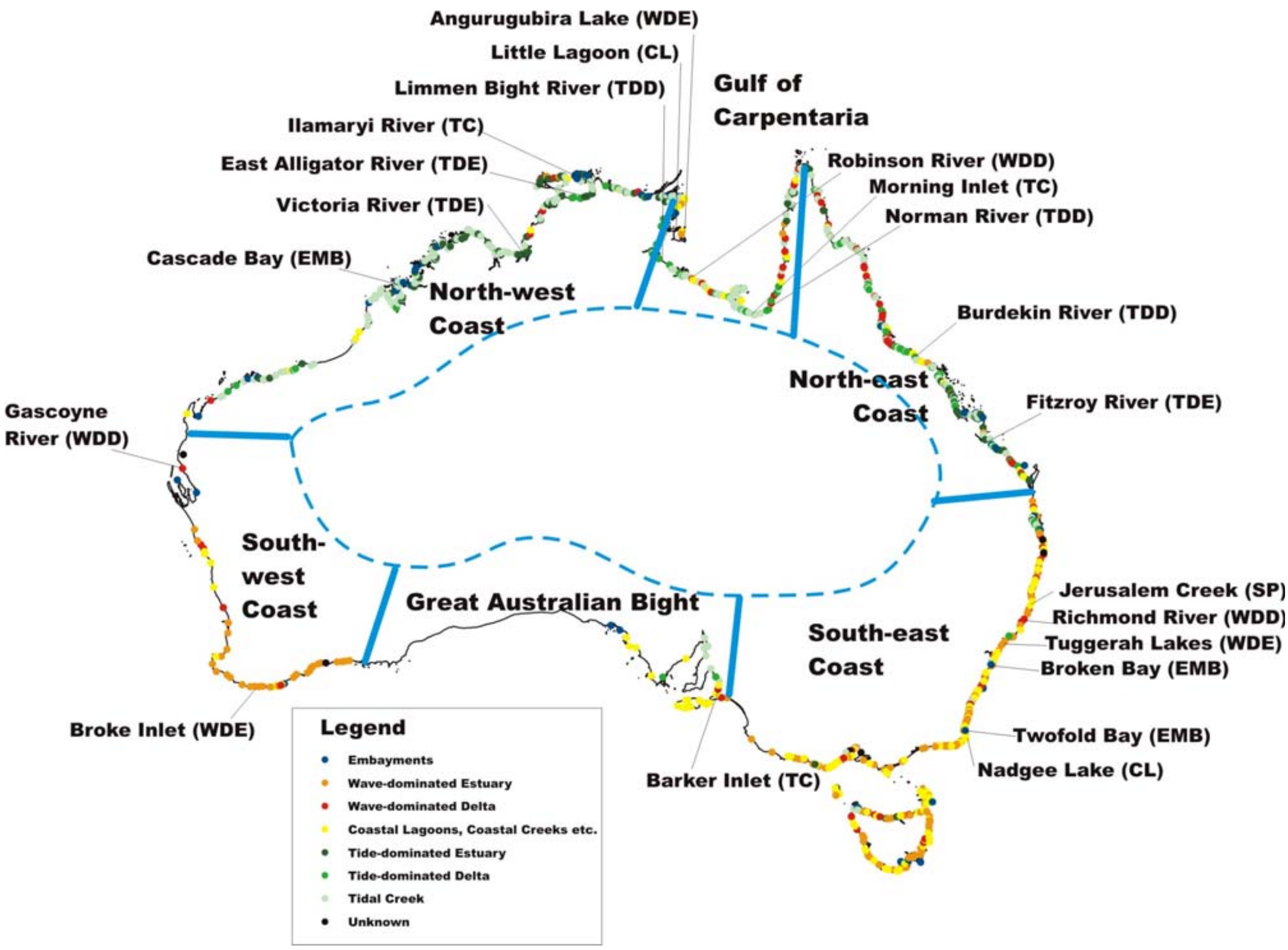

Figure 2 - Geomorphic classification of 974 Australian coastal waterways, including two named examples of each coastal waterway class (from Heap *et al.*, 2001). The geomorphic regions of (Harris *et al.*, 2002) are also depicted. EMB = Embayment, WDE = Wave-dominated Estuary, WDD = Wave-dominated Delta, CL/SP = Coastal Lagoons and strandplain associated creeks, TDE = Tide-dominated Estuary, TDD = Tide-dominated Delta, TC = Tidal Creek.

Habitats in Australian Coastal Waterways

All estuaries and coastal waterways fundamentally comprise assemblages of sedimentary environments, which have distinctive characteristics such as sediment types, nutrient cycling, plant and animal communities, and hydrological properties (Table 2, McLean *et al.*, 1993, Roy *et al.*, 2001). These sedimentary environments, or 'habitats', are distinct geographical entities that can be considered structural components from which all estuaries and coastal waterways are formed. Sedimentary environments are the key components used in the development of conceptual geomorphic 'facies' models (Reinson, 1992). The geomorphic framework presented in this study attempts to identify the inherent links between sedimentary environments, and estuarine ecology. The conceptual models depict the relative associations of thirteen recognisable and well-documented sedimentary environments (Table 2). Key literature references for the sedimentary environments accompany each of the conceptual models (Figures 7-35).

Table 2 - Common sedimentary environments (or habitats) contained in Australia's coastal waterways. Full technical descriptions of each sedimentary environment are given in Appendix 1. EMB = Embayment, WDE = Wave-dominated Estuary, WDD = Wave-dominated Delta, CL = Coastal Lagoon/Strandplain Associated Creek, TDE = Tide-dominated Estuary, TDD = Tide-dominated Delta, TC = Tidal Creek.

Habitat (common alternative names)	**Coastal Waterway Most Commonly Associated With**	**Description**
Inner Continental Shelf	All	Seabed adjacent to the coast. Consists of marine sediment, and is inhabited by marine species
Barrier (beach, sand bar, sand spit, strand, berm, barrier island)	WDE, WDD, CL/SP	Inter- to supra-tidal high-energy barrier and subaqueous dunes and washovers. Comprised of sandy sediment. Stable areas may be vegetated, aquatic areas may support seagrasses
Flood/ebb tidal deltas (entrance bar, marine tidal delta)	WDE, WDD, CL/SP	Sub- to inter-tidal sand bodies formed by tidal and wave-induced currents at the inlet. Seagrasses may be present on surfaces.
Central Basin (muddy basin, estuarine lagoon)	WDE, some CL/SP	Wide, deep basin landward of the barrier. Water movements are weak, allowing mud to be deposited. Both water-column and benthic biota
Fluvial Bay-head Delta (river delta)	WDE	Network of channels, levees, shoals, and mouth bars located at the head of the estuary. Formed from river sediment deposited in a wide basin (e.g., central basin)
Tidal Sand Banks (sand bars)	TDE, TDD	Elongate sand bodies often oriented perpendicular to the tidal current directions. Occur at the entrances of estuaries. Usually associated with strong tidal currents
Intertidal Flats (mud flats, intertidal shores)	All	Unvegetated, low-gradient flats comprised of mud and sand. Generally inundated during high tide, and contains a variety of burrowing organisms.
Saltmarsh (coastal swamp, saltmeadows)	All (esp. high-latitude)	High inter-tidal to supra-tidal salt-tolerant vegetation such as grasses, sedges, reeds, and small shrubs, that occur in muddy sediment.
Salt Flats (saltpans, algal marsh, sabkha)	All in low-latitude or arid regions	Flat, mostly featureless sediment with very high salt content. Inhabited by sparse salt-tolerant vegetation and algae, and only inundated during very high tides.
Mangrove (mangrove forests, Mangal communities)	All, except CL/SP (depends on latitude, none occur in TAS)	Muddy sediment associated with mangrove stands, ranging from trees to shrubs. Generally more extensive and diverse in tropical regions.
Rocky Reef (rocky shores, rock platforms)	Embayments and estuaries	Hard substrate consisting of rock. May occur at any depth, and is important as an environment for sessile (attaching) organisms.
Channels (tidal channels, river channels)	All	Sub-tidal conduits for water and solids. Generally, associated with marine tidal deltas, fluvial deltas, and separating tidal sand banks
Alluvial Floodplain (freshwater wetland, coastal lowlands)	All	Low-lying and often extensive area of sediment deposited by a river at supra-tidal elevations. Most deposition occurs during floods. Often forms 'infilled' area of estuaries.

Habitat associations are based on previous geomorphic and sedimentary models (e.g. Boyd *et al.*, 1992; Dalrymple *et al.*, 1992) and the distribution of habitats found in for Australia's coastal waterways (Heap et al. 2001, Heap *et al.*, In Press). The distribution and abundance of the key sedimentary environments (particularly saltmarshes, saltflats, and mangroves) varies with latitude, and between coastal waterway types (Adam, 1998, Duke *et al.*, 1998, Saenger *et al.*, 1977). An example of typical distributions of habitats within coastal waterways is given in

Figure 3. Full technical descriptions of the sedimentary environments are provided in Appendix 1.

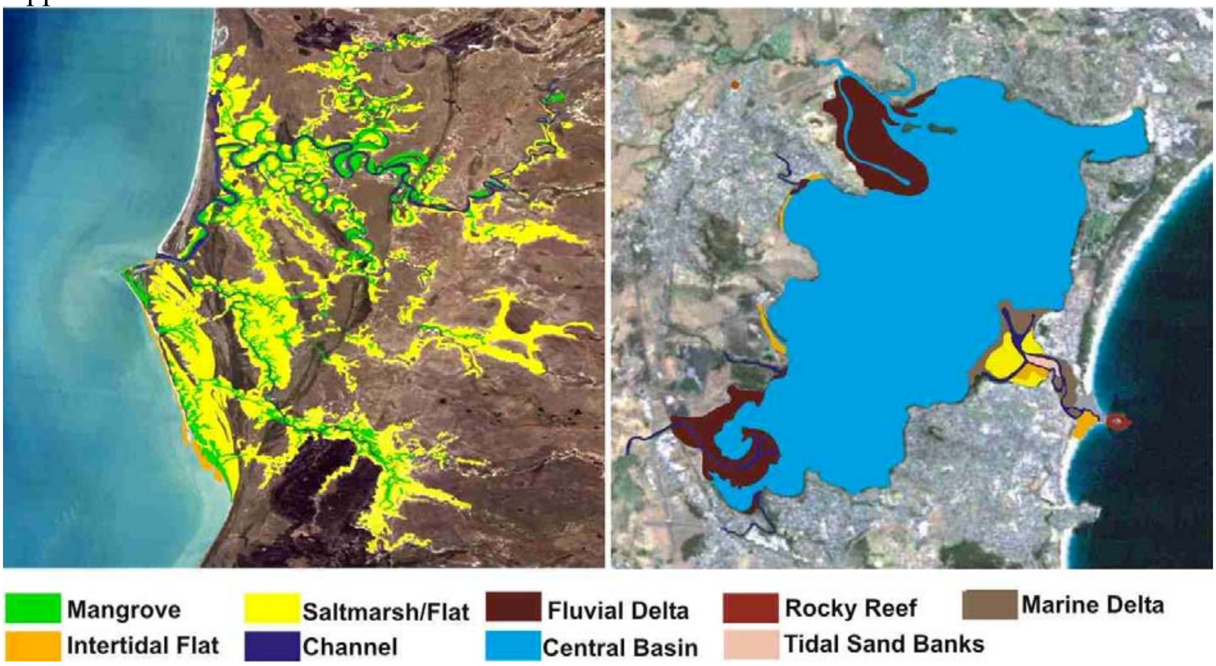

Figure 3 - Distribution and abundance of diagnostic habitats in a tide-dominated delta (Nassau River, QLD), and a wave-dominated estuary (Lake Illawarra, NSW).

Climate, Seasonality, and Circulation

Geomorphic classification schemes that are to be used at a national or regional level also need to recognise environmental parameters that are not strongly reflected in morphology alone, such as variations in climate, vegetation, and other biological aspects. In the development of our conceptual models, linkages are made between the geomorphic classification (Harris *et al.*, 2002, Figure 2), and previous schemes that classify the coastline in terms of climate and rainfall (Heggie *et al.*, 1999b). The relationship between the geomorphic regions and climatic zones is expressed in Table 3.

Table 3 - Linkages between geomorphic classes and climate zones. Percentages indicate the proportions of classes of coastal waterways in each geomorphic region. EMB = Embayment, WDE = Wave-dominated Estuary, WDD = Wave-dominated Delta, CL/SP = Coastal Lagoons and Strandplain Associated Creeks, TDE = Tide-dominated Estuary, TDD = Tide-dominated Delta, TC = Tidal Creek.

Geomorphic Region (after Harris *et al.* 2002)	**Coastal Climatic Zone (Coastal climate zones after Heggie *et al.*, 1999).**	**Type of Coast**	**Summer Runoff**	**Winter Runoff**	**Most Abundant Waterway Classes**
Northeast Coast	Moist Tropical, Moist Temperate	Tide-dominated	High (Monsoon)	Low (Arid)	TC (41%) WDD (17%) TDD (16%)
Southeast Coast	Moist Temperate	Wave-dominated	Moderate	Moderate, even rainfall	WDE (42%) CL/SP (35%) WDD (10%)
Great Australian Bight	Semi-arid	Wave-dominated	Low	Low	CL/SP (53%) TC (31%)
Southwest Coast	Winter Rain/Dry summers (Mediterranean)	Wave-dominated	Low (Arid)	Moderate/High	WDE (66%) CL/SP (17%) WDD (11%)
Northwest Coast	Moist Tropical, Semi-Arid, Arid	Tide-dominated	High (Monsoon)	Low (Arid)	TC (50%) TDE (27%) EMB (10%)
Gulf of Carpentaria	Wet/Dry Tropical	Mixed	High (Monsoon)	Low (Arid)	TC (48%) TDD (17%) CL/SP (14%)

In order to account for seasonality and climatic variation in the estuarine conceptual models, both positive (freshwater-dominated) and negative (evaporation-dominated) hydrodynamic examples of tide- and wave-dominated estuaries have been developed. The distribution of these climatic zones around the coastline of Australia has been depicted in Figure 4. In strongly seasonal areas that alternate between relatively high runoff and arid conditions (e.g. the Wet/Dry Tropical climatic zone), the relevant conceptual model varies between the two climatic extremes. For example, in the Moist Tropical climatic region, a waterway that exhibits the hydrodynamic function of a *tide-dominated estuary* during the wet season, may exhibit the hydrodynamic function of a *tidal creek* (no freshwater runoff) during the dry season. Alternatively, during the dry season, the waterway may function as a 'negative' tide-dominated estuary, due to higher rates of evaporation (Heggie *et al.*, 1999b). Figure 4 illustrates some important differences in the function of estuaries and coastal waterways imposed by climatic variation around Australia (see Appendix 2 for the climatic zones of individual estuaries and coastal waterways).

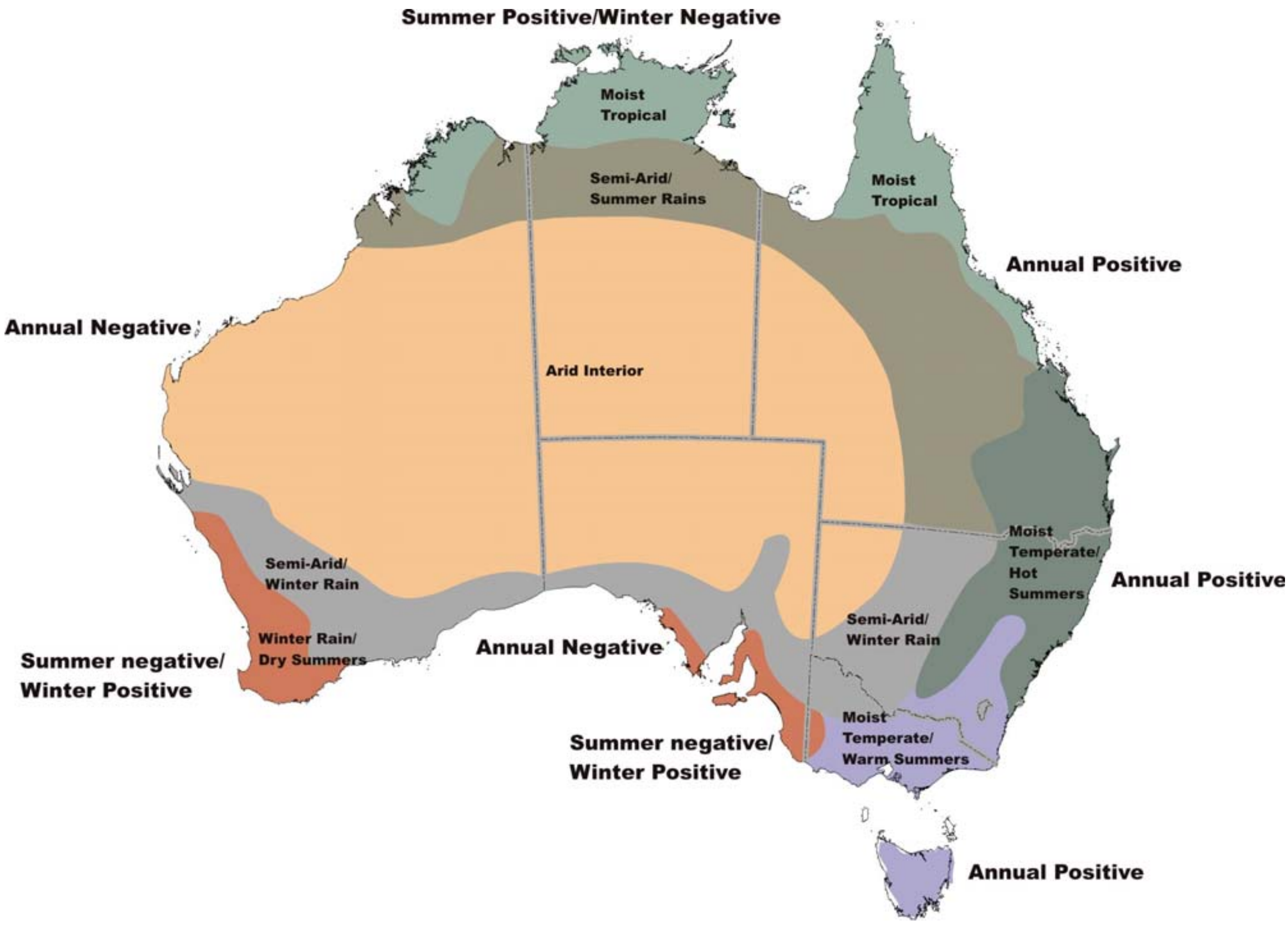

Figure 4 – Climatic zones (after Heggie & Skyring 1999), and the distribution of positive, negative, summer-positive, and winter-positive coastal waterways around Australia (see Appendix 2 for the climatic zones of individual estuaries and coastal waterways).

Evolution of Australian Coastal Waterways

Estuaries and coastal waterways are highly dynamic environments in which geomorphic change is driven by the deposition and erosion of sediment, which may occur over a range of timescales, from almost instantaneous (e.g. river floods), to progressive change over thousands of years (Cooper, 2001). Unlike many geological processes, sedimentation in coastal waterways occurs on timescales relevant to human society. Over time, continued sedimentation leads to the progressive conversion of estuarine waterbodies into intertidal and terrestrial environments, with obvious management implications (Roy *et al.*, 2001). Infilling of coastal waterways by sediment is not constant in time or space. Coastal waterways receive sediment from a variety of sources, including fluvial, marine and aeolian (wind) inputs as well as detritus from fringing vegetation, organic material produced within the estuary, and human induced inputs. A recent study has demonstrated that infilling rates measured in the central basins of Australian wave-dominated estuaries and coastal lagoons can be as much as 20 mm/year (Brooke, 2002). Expansion of intertidal and supratidal environments, and progradation of fluvial deltas into estuaries and coastal waterways is likely to cause even faster infilling rates (Webster *et al.*, 2002, Pasternack *et al.*, 2002). The rate and style of geomorphic evolution determines the observable trends in sedimentation, and the management implications.

Evolutionary characteristics provide an important link between the many different types of coastal waterways. Each type of wave- or tide-dominated coastal waterway is at a different stage in its evolutionary continuum, having developed to a greater or lesser extent depending on regional sea level history, and the amount of sediment supplied to it. Wave- and tide-dominated systems follow different evolutionary pathways (Figure 5). Assuming constant sea level and sediment supply, and tectonic stability, embayments (or drowned river valleys) on wave-dominated coastlines tend to develop shore-parallel sand bodies that may enclose the entrance, creating a central basin behind them and restricting marine exchange. Once the sand bodies rise above sea-level (and become 'subaerial'), they are known as barriers, and the coastal waterway becomes a ‘wave-dominated estuary’ - an effective trap for terrigenous sediment. Continued infilling, mostly by terrigenous sediment, eventually results in the central basin becoming completely filled with sediment, and the river channel then establishes a more direct connection with the ocean. Once the net transport of sediment is offshore, the coastal waterway becomes a ‘wave-dominated delta’, and catchment sediment is transferred to the ocean rather than becoming trapped (Roy *et al.*, 1980, Roy, 1984b, Heap *et al.*, In Press). Similarly, on tide-dominated coastlines, embayments become gradually infilled by sediment until a ‘tide-dominated estuary’ is created. The extensively vegetated intertidal areas trap even more terrigenous and marine sediment, until the estuary becomes totally infilled and begins to prograde (or build out) seawards, becoming a ‘tide-dominated delta’ (Woodroffe *et al.*, 1989, Mulrennan *et al.*, 1998, Chappell, 1993, Woodroffe *et al.*, 1993).

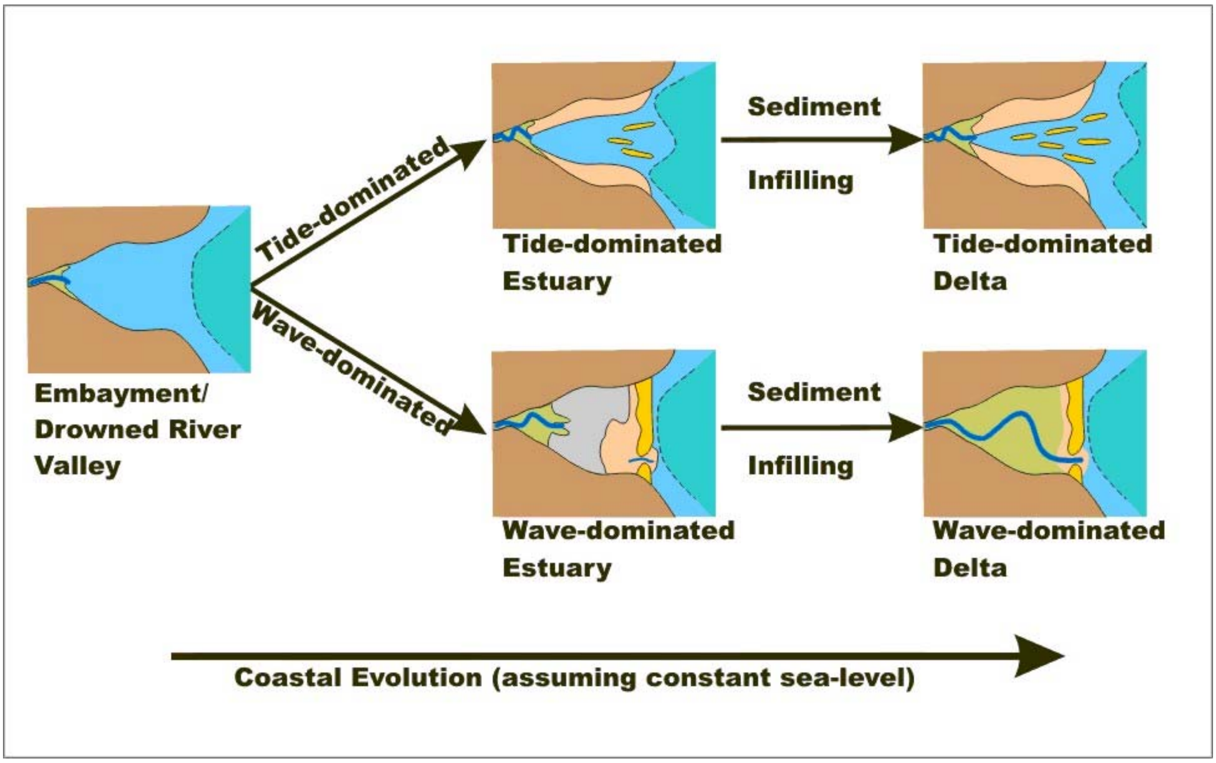

Figure 5 - Evolutionary 'family tree' for Australian coastal waterways, showing different infilling pathways for wave-dominated and tide-dominated systems (Coastal lagoons, strandplain associated creeks, and tidal creeks have been omitted as they do not receive significant amounts of fluvial sediment).

Over geologic timescales, estuaries are ephemeral systems that develop during times of slowly rising or stable sea level. Rising sea levels favour the formation of estuaries, embayments, and drowned river valleys; whereas falling sea levels favour the development of deltas (Harris *et al.*, 2002). Potential changes to the present-day sea level, human induced or otherwise, may therefore have a pronounced effect upon estuaries, and the characteristic habitats they support. For example, a rise in sea level might induce a wave-dominated estuary to revert to an embayment (e.g. move from right to left along the evolutionary pathway in Figure 5), as the barrier would be drowned or eroded, and the distribution of sedimentary environments altered (Boyd *et al.*, 1992).

CONCEPTUAL MODEL DIAGRAMS OF AUSTRALIA'S COASTAL WATERWAYS

The geomorphic classification developed by (Harris *et al.*, 2002), based on the conceptual understanding of Dalrymple *et al*. (1992), has been expanded to develop conceptual models displayed as three-dimensional block diagrams. The diagrams illustrate the geomorphic and sedimentary environments (or habitats) in the seven generic geomorphic classes of Australia's coastal waterways, namely:

- Embayments and Drowned River Valley (EMB): Figures 6 to 9
- Wave-dominated Estuaries (WDE): Figures 10 to 14
- Wave-dominated Deltas (WDD): Figures 15 to 18
- Coastal Lagoons and Strandplain-associated Creeks (CL/SP): Figures 19 to 22
- Tide-dominated Estuaries (TDE): Figures 23 to 27
- Tide-dominated Deltas (TDD): Figures 28 to 31
- Tidal Creeks (TC): Figures 32 to 35

Initially, each class of coastal waterway is briefly described with a general introduction to their geomorphology, physical processes, formation, evolution, and typical sedimentary environments and associated habitats. For each class of coastal waterway, several additional alternatively used names are also provided for reference. Each type of coastal waterway has been illustrated within the same background setting or bedrock 'palaeo-valley'. This is intended to assist in demonstrating how coastal waterways vary with respect to different wave, tide or river flow conditions. Additionally, a sense of coastal waterway evolution can be represented by referring to each of the relevant models; for example, the infilling of an embayment (Figure 8) to form a wave-dominated estuary (Figure 13), and subsequently a wave-dominated delta (Figure 17).

For each type of coastal waterway, the following processes are superimposed onto the background geomorphological block diagrams:

- Hydrodynamics - processes related to water movement and salinity variation. For wave- and tide-dominated estuaries, 'negative' estuary scenarios have been included to depict the hydrodynamics expected in arid, low-rainfall regions or seasons (See Climate, Seasonality and Circulation above).
- Sediment dynamics - transport pathways and depositional characteristics of fine-grained and coarse-grained sedimentary material.
- Nutrient dynamics - transport pathways, biological interactions, and key processes that relate to the behaviour of nitrogen, an important nutrient in each system.

For each of the above, specific processes that distinguish each class of coastal waterway are described using a series of dot points, with 'key' references supplied. The movement or transport of materials or energy is depicted using arrows, with a legend provided where required. Important habitats, and how they relate to the processes in question, are also depicted on the models. Users are urged to refer to the preceding sections of this report, Appendix 2, and to the OzEstuaries database (http://www.ozestuaries.org), before deciding which conceptual models to apply to a particular coastal waterway or local area.

The models are not to scale and have been vertically exaggerated for legibility and communication purposes. As such, the orientation and aspect of the models, while arbitrary, has been standardised, and is not intended to represent any particular region of Australia.

Water levels are shown to represent Lowest Astronomical Tide (LAT). The distribution and abundance of habitats are indicative only and do not necessarily represent the actual area or abundance in those systems. While not depicted as such in our models, we recognise that saltmarshes, salt flats, and mangroves are often overlapping habitats whose distributions are determined by biology and climate. They nevertheless exhibit distinct sedimentary characteristics and so are separated in our models for clarity. Saltmarshes are the temperate equivalent of tropical mangrove forests (although the latter often form sparse forests in temperate areas). Salt flats (saltpans) are more sparsely vegetated and generally occur in arid regions at slightly higher elevations in coastal waterways with large tidal ranges or areas prone to infrequent saltwater inundation.

Regardless of the style of communication, it is unavoidable that some components or aspects of the conceptual models may be inaccurate, due to insufficient information. However, we anticipate the need for review by coastal managers, researchers, and other stakeholders, and we welcome and encourage feedback to our models. The models will be reshaped as the collective knowledge improves, and as the models are tested. We hope that this review process will lead to better long-term model credibility and much improved representations of complex coastal ecosystems.

All conceptual models within this document are also represented as an interactive web production, linked to the OzEstuaries database (http://ozestuaries.org).

Embayments

(Also known as: Drowned River Valleys, Oceanic Embayments, Rias, Fjords)

Embayments are the least geomorphologically complex of the seven coastal waterway classes, as they typically comprise a bedrock-lined coastal indentation (Hudson, 1991). In Australia, embayments occur along hard coasts (Figure 2), where they appear as topographic depressions or indentations in the country rock, that have not been significantly infilled by terrigenous or marine sediment (Figure 6). The morphology of embayments may comprise wide and rounded bays, highly indented bays with convolute shorelines, or narrow and tapered drowned river valley systems (Albani *et al.*, 1974, Albani *et al.*, 1975, Perillo, 1995, Morrisey, 1995, Riggs *et al.*, 1995). Embayments are generally bound by steep, rocky shorelines, have relatively wide, unconstricted entrances with free exchange to the ocean, and are deep relative to other coastal waterway types (Roy *et al.*, 1980, Roy *et al.*, 1981). The submarine topography is smooth, and typically slopes gently toward the mouth (Abell *et al.*, 1993). River inputs (although sometimes large during peak flow conditions) are, in the long-term, small relative to the total water volume contained with the embayment and exchanged with the ocean (Hudson, 1991, Roy *et al.*, 2001).

Figure 6 - Examples of oceanic embayments: Cascade Bay (WA) - indented, Twofold Bay (NSW) – rounded, and Broken Bay (NSW) – narrow drowned river valley.

The relative influence of waves and tides in embayments is variable, and depends on regional conditions. In Australia, embayments are equally abundant on both wave- and tide-dominated coasts (Figure 2). Variations in the orientation, configuration, and water depth affect the penetration of waves; strongly indented embayments support more sheltered environments, and tidal processes tend to dominate upstream (Roy *et al.*, 1980). Due to friction, wave and tide influence are generally reduced with distance from the entrance of the embayment. Localised bedrock features such as headlands or offshore islands may also form a protective barrier and limit wave penetration into embayments. Due to a typically large exchange of water during the tidal cycle (or tidal prism), embayments are usually considered to be tide-dominated, even on microtidal coasts (Andersson *et al.*, 1986, Roy *et al.*, 2001, Cooper, 2001).

Generally, embayments are the evolutionary precursors of modern wave- and tide-dominated estuaries and deltas (Roy *et al.*, 2001, Fitzgerald *et al.*, 2000). The rate of infilling by sediment depends on sediment supply from the catchment and marine sources, and the original volume of the basin. Thus, the present-day distribution of embayments is restricted to areas of complex, rocky coastal morphology, and low sediment supply. Given sufficient time, continuous sediment supply, and stable sea level, embayments ultimately 'fill in', and have the potential to become wave- or tide-dominated estuaries, and subsequently wave- or tide-dominated deltas (Heap *et al.*, 2001).

Embayments represent transitional environments between true estuarine and marine environmental conditions (such as salinity, temperature, turbidity, and energy) and thus contain an abundant and highly variable biota (Dethier, 1992, Rainer *et al.*, 1981, Roy *et al.*, 2001). Depending upon energy conditions and climate (latitude), habitats such as saltmarshes, mangroves, intertidal flats, and sandy beach environments fringe the embayment. Swamp areas and freshwater wetlands tend to occur behind prograding sandbars (Abell *et al.*, 1993). Clear shallow waters support various seagrasses (Abal *et al.*, 1996, Humphries *et al.*, 1992), rocky shores, and rocky (or coral) reefs.

EMBAYMENT: HYDRODYNAMICS

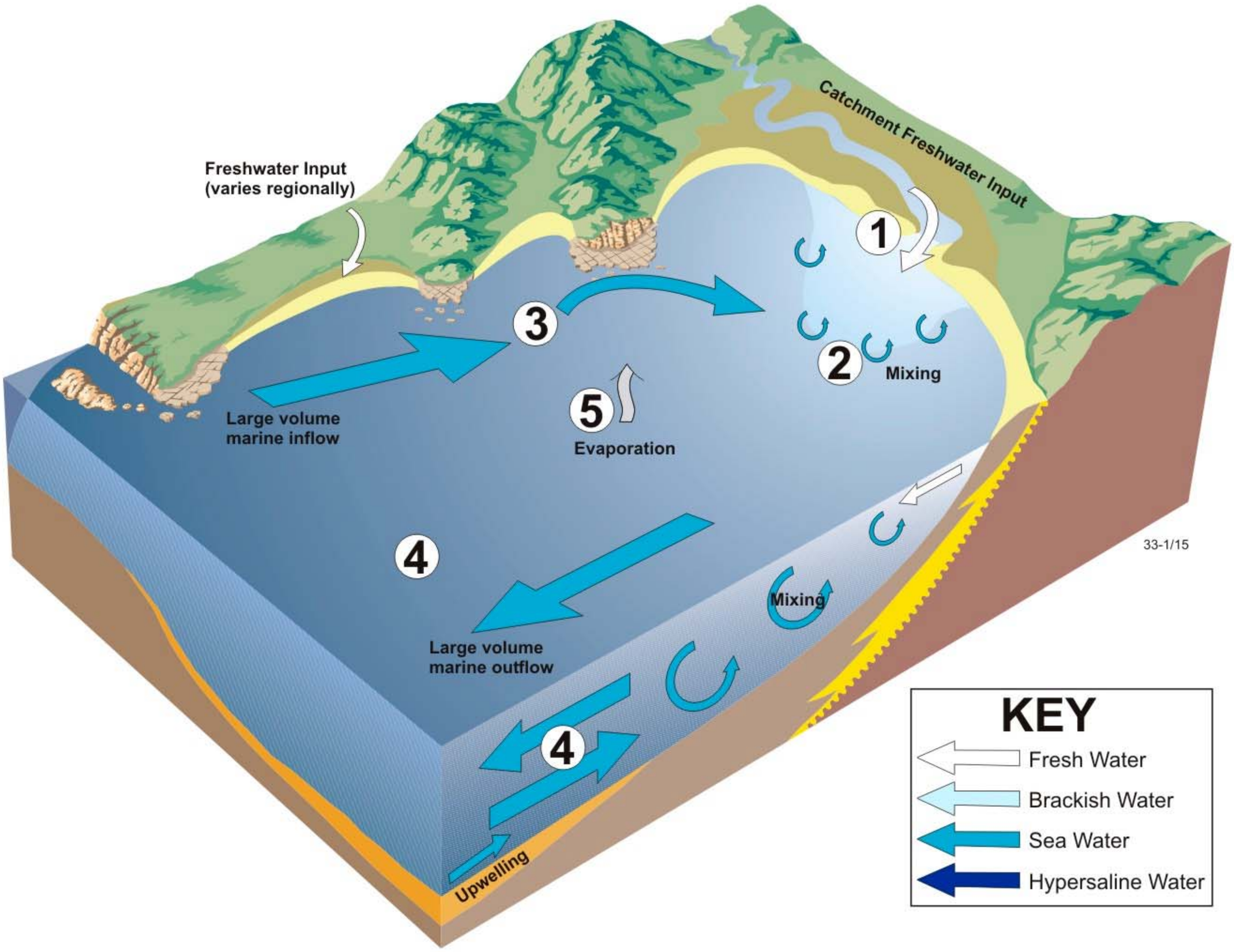

Figure 7 – Conceptual model of major hydrodynamics in an Embayment.

EMBAYMENT: HYDRODYNAMICS

1. Freshwater input from the catchment varies considerably, ranging from intermittent or no flow, to large-volume continuous flows, depending on local catchment and climate conditions. Inputs may occur at a single, or multiple locations, and these sites are often considered as separate estuaries or coastal waterways in their own right.
2. The volume of freshwater entering the embayment is low relative to the total volume of water in the embayment. Stratification is thus less pronounced (Yassini *et al.*, 1995). Mixing between fresh and salt water occurs rapidly, depending on the activity of currents (Holloway *et al.*, 1991). The large water area typical of embayments tends to buffer and reduce the impact of floods upon the flanking environments of embayments (Roy *et al.*, 2001).
3. Due to the coriolis force, flood and ebb tidal streams may have different routes into and out of large embayments, creating a gyre-like circulation pattern (Holloway *et al.*, 1991). This effect is more apparent at higher latitudes. Additionally, tidal range amplification can occur in funnel-shaped drowned river valleys (Dalrymple *et al.*, 1992). Wind-induced currents, in combination with tidal influx, and the coriolis force, are the principal controls on the strength of water circulation within the embayment.
4. Due to a wide, unconstricted entrance and large tidal prism, the exchange of water between the embayment and the ocean dominates hydrological processes. Embayments are thus 'seawater dominated' (Heggie *et al.*, 1999b). Marine 'flushing' depends on the amount of freshwater advection, and the extent of oscillatory water movement (and other mixing processes). Upwelling of water from the inner continental shelf may also be important. Marine conditions and salinity prevail (Yassini *et al.*, 1995).
5. Despite the large surface area, evaporation over the entire embayment is a relatively minor process due to typically large volume and rapid marine flushing.

EMBAYMENT: SEDIMENT DYNAMICS

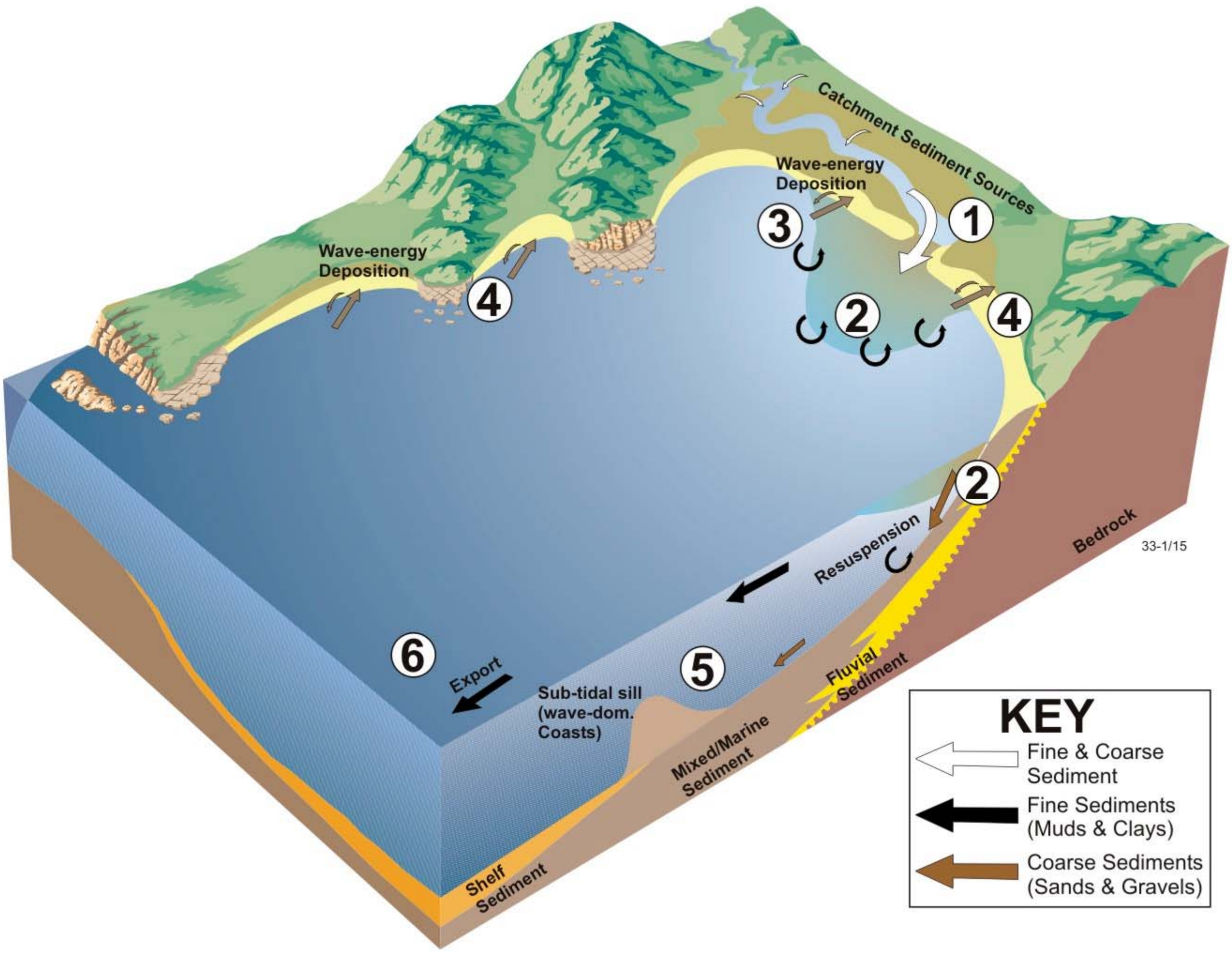

Figure 8 – Conceptual model of major sediment dynamics in an Embayment.

EMBAYMENT: SEDIMENT DYNAMICS

1. Fine and coarse sediment enters the embayment from the catchment. The amount and type of sediment input varies regionally, depending on catchment and climatic conditions, and the volume of freshwater input.
2. Fine sediment (i.e., muds, clays, and some organic material) is transported into the embayment as a plume of suspended sediment, and is mixed with the low-turbidity coastal waters. Coarse grained sediment (i.e., sands and gravels) is deposited on the floor of the embayment, close to the river sediment source (Carter *et al.*, 1996).
3. A small amount of fine sediment is deposited along the edges of the embayment, transported by waves in exposed areas, and by tides in sheltered regions (Semeniuk, 1981, Carter *et al.*, 1996). Off-channel embayments within drowned river valleys also tend to accumulate fine sediment (Taylor *et al.*, 1999). Baffling by saltmarshes and/or mangroves (where present) enhances deposition of fine material along the fringes of the embayment (Boorman *et al.*, 1998, Brown, 1998, Saintlan *et al.*, 1999, Laegdsgaard, 2001). Some coarse-grained sediment is generally transported onshore by wave action (in exposed areas) and deposited along the edges of the embayment (Green *et al.*, 2001). Some resuspension of fine sediment occurs in shallow water due to wave energy (Bulthuis *et al.*, 1984).
4. Onshore sediment transport leads to the development of prograding beach barriers, and occasional extensive dune systems. Limited swamp or estuarine deposits often occur landward of these barriers (Roy *et al.*, 1980, Thom *et al.*, 1978). Beach systems and intertidal flats also form from marine sediment around the narrow internal margins of the embayment, and range in morphology from 'reflective' (steep) to 'dissipative' (low-gradient) beaches in sheltered and exposed regions, respectively (Wright *et al.*, 1979).
5. Accumulation of coarse marine sediment (including carbonate material such as shell), and some fluvial sediment (depending on river inputs) occurs on the smooth and typically gently sloping floor of the embayment. Because of the large entrance typical of embayments, the seabed is dominated by marine-derived sediment (such as siliciclastic and/or carbonate sand). Carbonate content in the sediment generally increases moving seaward (Taylor, 1972, Sussko *et al.*, 1992). Along wave-dominated coasts, a coast-parallel submerged 'sill' may form on the seabed near the entrance of embayments, in place of a sandy barrier and marine tidal delta characteristic of coastal waterways with a higher sediment supply and shallower water depths (Roy, 1984a, Harris *et al.*, 1992, Roy *et al.*, 2001). Where a sub-tidal sill is present, some of the fine sediment may accumulate landward of the sill, due to a reduction in flow energy (Cooper, 2001). Along tide-dominated coasts, coast-perpendicular subaqueous tidal sand banks may occur on the sea bed (Harris *et al.*, 1992, Wells, 1995, Fitzgerald *et al.*, 2000).
6. Due to a wide, unconstricted entrance and large tidal prism, the exchange of water between the embayment and the open ocean results in dilution of river-derived suspended sediment, and transport offshore (Bulthuis *et al.*, 1984).

EMBAYMENT: NUTRIENT DYNAMICS

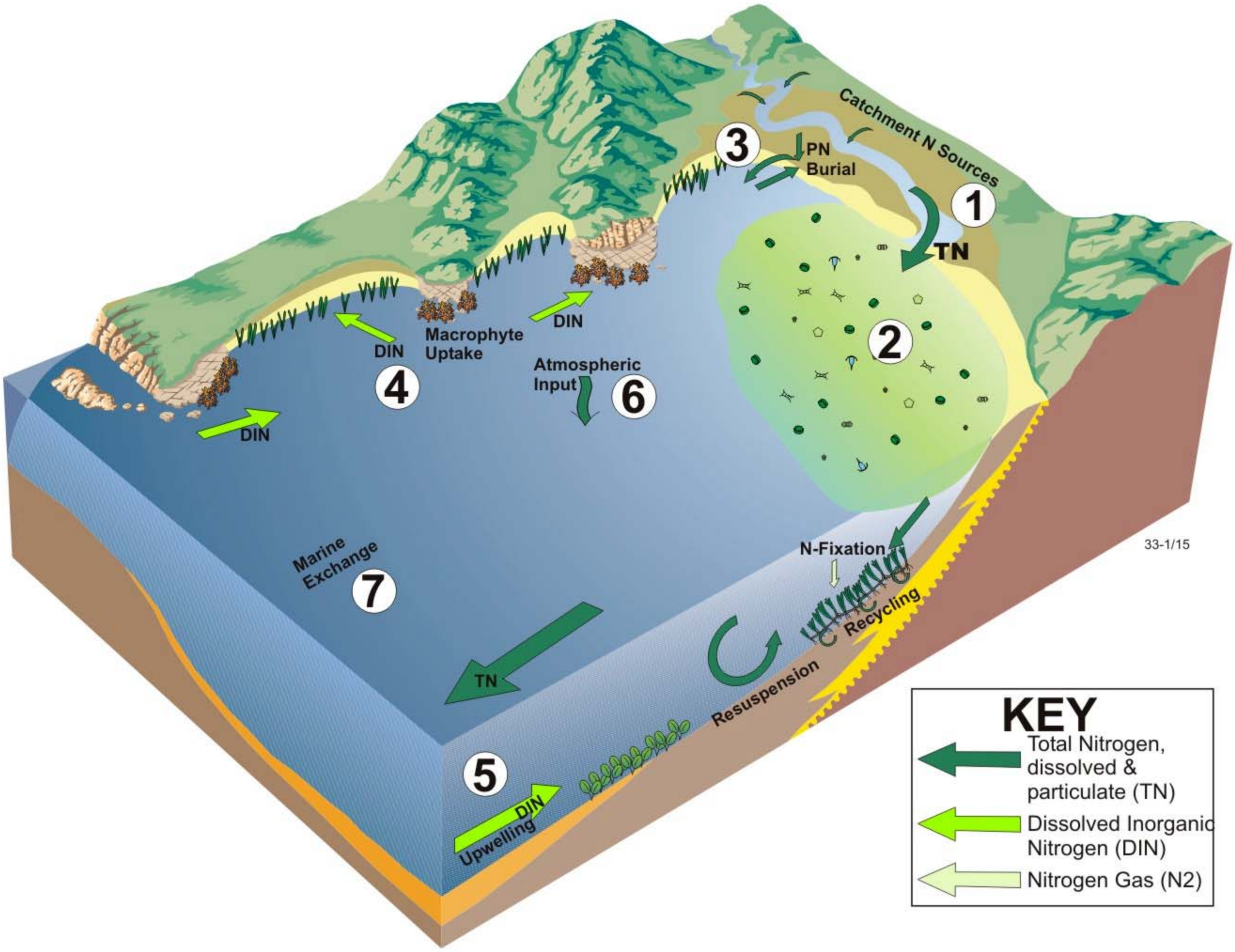

Figure 9 – Conceptual model of major nutrient (nitrogen) dynamics in an Embayment.

EMBAYMENT: NUTRIENT DYNAMICS

1) Nitrogen (both particulate and dissolved, or Total Nitrogen (TN)) enters the embayment system from point- and non-point sources from within the catchment. River flow and nutrient input varies regionally, depending on local catchment and climatic conditions (Harris, 2001).
2) The catchment-derived dissolved inorganic nitrogen (DIN) is transported into the embayment, where it is rapidly processed and assimilated by phytoplankton and benthic micro-algae, if temperature and light levels are suitable (Elosegui *et al.*, 1987, Nicholson *et al.*, 1999, Longmore *et al.*, 1999).
3) Some deposition and burial of particulate nitrogen (PN) occurs on flanking environments, due to wave-induced landward sediment transport (depending on exposure to oceanic swells), and tidal deposition aided by the baffling effects of saltmarsh and/or mangrove vegetation (depending on latitude). Burial and resuspension of PN and dissolved inorganic nitrogen (DIN) can also occur within intertidal flats.
4) Seagrasses and macrophytes take up DIN from the water column. N-fixation occurring in the root-zone of seagrasses contributes additional DIN to this pool. Denitrification is also an important process in seagrass meadows (Pollard *et al.*, 1991). Sandy sediment is permeable, hence can be ventilated by oxygen-rich overlying waters resulting in efficient remineralisation of organic debris (mostly by denitrification) with little preservation of organic matter.
5) Upwelling of nutrient-rich oceanic water is often the overwhelmingly dominant source of N to the embayment system (Cresswell, 1994, Gibbs *et al*., 1997).
6) Input of particulate N (PN) from atmospheric sources such as smoke and ash are typically of low significance.
7) A large tidal prism results in much of the dissolved and particulate nitrogen (including phytoplankton debris) being transported offshore (Bulthuis *et al.*, 1984), and diluted by seawater.

KEY FEATURES OF EMBAYMENTS

1. Habitats are typically marine, with extensive subtidal environments and very narrow intertidal environments.
2. Large entrance and efficient marine flushing, even in microtidal regions. Deep water.
3. River flow varies, floods are buffered and do not expel marine water due to large water area.
4. Turbidity and extent of intertidal habitats are dependant on local tidal range
5. Sediment (and associated contaminants) are generally not trapped. Typically floored by coarse sediment.
6. Nutrient dynamics are generally similar to the coastal ocean, and are largely dominated by oceanic 'upwelling' events.
7. 'Immature' in terms of evolution: morphology may change over time due to infilling. This change is likely to be slow due to the large volume.

Wave-dominated Estuaries

(Also known as: Barrier Estuaries, Bar-built Estuaries, and ICOLL's - Intermittently Closed and Open Lakes and Lagoons)

A wave-dominated estuary (Figure 10) represents a coastal bedrock embayment that has been partially infilled by sediment derived from both the catchment and marine sources, in which waves are the dominant force shaping the gross geomorphology. In Australia, wave-dominated estuaries are most abundant on the south-east and south-west coasts (Figure 2), where they occur on exposed coastlines with a relatively small tidal influence (Roy *et al.*, 2001, Cooper, 2001). Wave-dominated estuaries feature a supra-tidal (or subaerial) barrier at the mouth that encloses a broad central basin. The barrier creates a constricted entrance (which can be periodically closed) that allows the exchange of water between the central basin and the sea. Sediment in wave-dominated estuaries ranges from fine to coarse sands in the barrier and tidal inlet deposits, fine organic muds and sandy muds in the central basin, to coarse, unsorted gravels, sands and muds (mostly of terrigenous origin) in the fluvial bay-head delta (Nichol, 1991). Depending on the degree of sediment infilling, the central basin of wave-dominated estuaries may be irregularly-shaped, following the outline of the drowned bedrock valley (Riggs *et al.*, 1995). In the case of wave-dominated estuaries formed in unconsolidated coastal deposits the central basin may be oval-shaped and oriented parallel to the coast (Chapman *et al.*, 1982, Morrisey, 1995). At the head of a wave-dominated estuary is a fluvial 'bay-head' delta that extends into the central basin and is comprised of vegetated and unvegetated levees, channels, and intertidal areas (Nichol *et al.*, 1997). The fluvial bay-head delta is constructed from terrigenous material from the catchment being deposited and the mouth of the river (Webster *et al.*, 2002, Pasternack *et al.*, 2002).

Figure 10 - Examples of wave-dominated estuaries: Tuggerah Lakes (NSW), Broke Inlet (WA), Angurugubira Lake (NT).

Wave-dominated estuaries are distinguished by relatively high wave energy at the mouth (compared to tidal energy). In the middle of the estuary, the wave and tide energy is dissipated in the broad central basin, resulting in lower total energy. Near the head, the total energy is again relatively high due to river inflow. River energy declines downstream due to a reduction in downstream hydraulic gradient, and is low in the central basin (Heap *et al.*, 2001).

The evolution of wave-dominated estuaries is characterised by infilling of the valley, principally the central basin (Roy *et al.*, 1980). As such, wave-dominated estuaries evolve or mature by the simultaneous seaward progradation of the fluvial bay-head delta, and the landward progradation of the flood tidal delta, and also by the expansion of fringing intertidal flats (Roy, 1984a). Recent studies quantifying the areas of geomorphic and sedimentary environments in Australia's wave-dominated estuaries (e.g., Roy *et al.*, 2001, Heap *et al.*, In Press) have demonstrated that infilling is dominated by the expansion of intertidal environments around the central basin and progradation of the fluvial bay-head delta and alluvial plain, rather than from progradation of the flood tide delta. Given sufficient time and constant sediment supply, wave-dominated estuaries have the potential to evolve into wave-dominated deltas when the central basin is completely infilled (or is bypassed by the river channel), and terrigenous sediment is exported directly to the ocean rather than being trapped (Nichol *et al*., 1992, Heap *et al.*, In Press).

Wave-dominated estuaries generally contain true estuarine (or euryhaline) species, and transient visitors from full marine environments (Paterson *et al.*, 2000, Potter *et al.*, 1994, Rainer *et al.*, 1981). This is because wave-dominated estuaries provide a diverse range of habitats, such as high-energy sandy beaches and channel sands, sheltered deep muddy basins, shallow water habitats, mangroves, saltmarshes, and intertidal flats (Roy et al. 2001). Depending upon entrance conditions, and latitude, saltmarshes and mangroves can occur around the edges of the central basin, and the high-energy conditions of the inlet produce a sandy substrate and relatively clear shallow waters, that generally support various seagrasses (Rainer *et al.*, 1981, Abal *et al.*, 1996, Hannan *et al.*, 1998, Humphries *et al.*, 1992). Central basin muds often support benthic micro-algae (Cahoon *et al.*, 1999). Wave-dominated estuaries that have undergone slow infilling can contain large areas of rocky shore and reef habitats that support a variety of biota (Griffiths, 2001).

WAVE-DOMINATED ESTUARY: HYDRODYNAMICS ("POSITIVE" CONDITIONS)

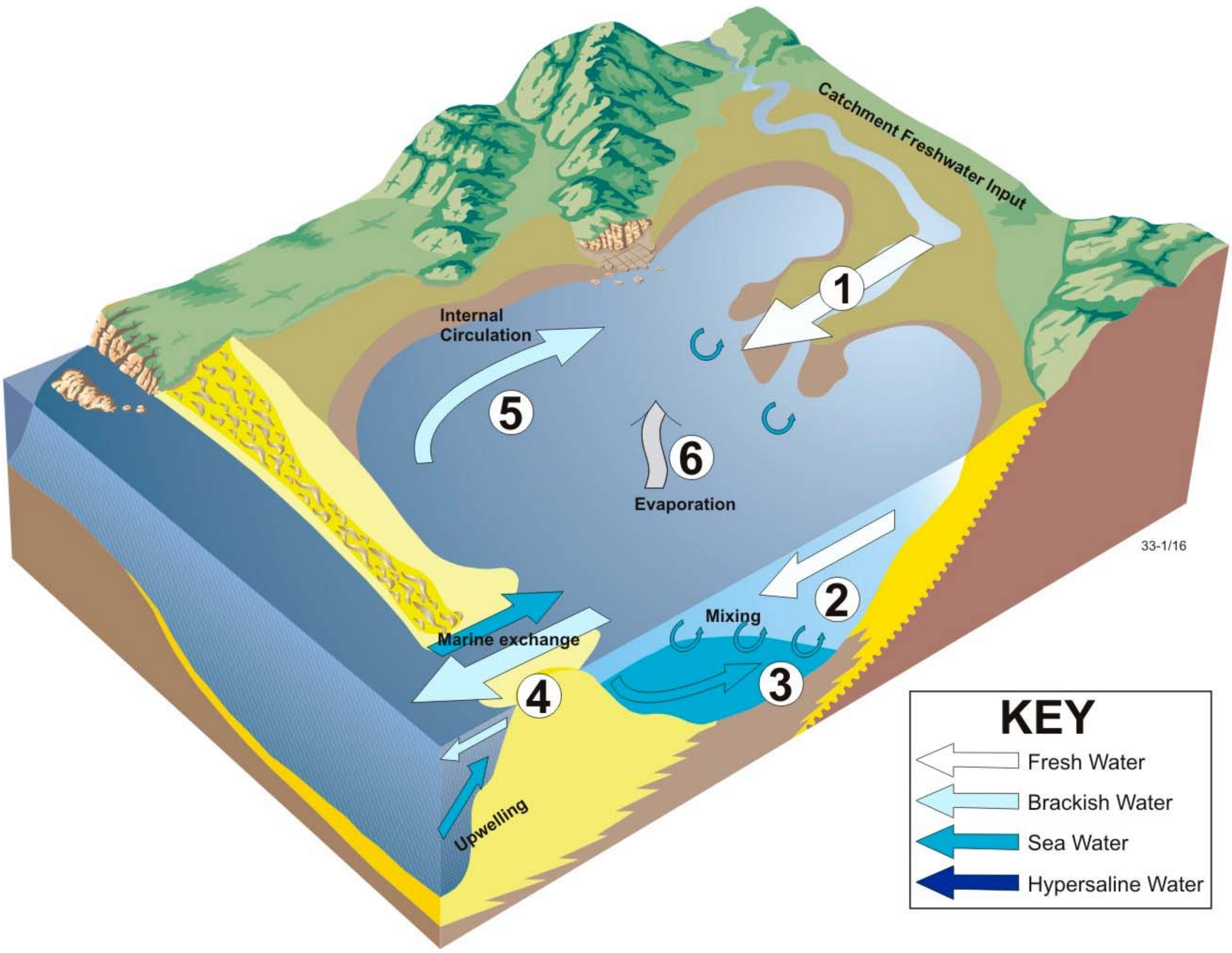

Figure 11 – Conceptual model of major hydrodynamics (positive) in a wave-dominated estuary.

WAVE-DOMINATED ESTUARY: HYDRODYNAMICS ("POSITIVE" CONDITIONS)

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and temporally (depending on local catchment and climatic conditions), it is often relatively high in positive estuaries.
2. Water circulation in wave-dominated estuaries generally ranges from well mixed to salinity-stratified, depending on the degree of wave mixing, volume of freshwater input, and climate (Nichols *et al.*, 1985). 'Positive' wave-dominated estuaries have lower salinity water towards their head, with the salinity of the water in the central basin and next to the inlet approaching that of the adjacent ocean water. The volume of freshwater causes stratification (or layering) in the water column, which varies with seasonal flow. Buoyant low-salinity fresh water floats above the denser, high-salinity ocean water.
3. A 'salt-wedge', or intrusion of denser saline marine water penetrates through the entrance along the bed of the estuary. Some mixing occurs at the interface between the fresh and marine water. The distance that the salt-wedge penetrates is dependant on tidal range and the amount of fluvial flow received by the estuary. During high fluvial flow events (which may be seasonal), fresh floodwater may push the salt water beyond the mouth (Eyre, 1998, Kurup *et al.*, 1998). However, the large volume of central basins typical of wave-dominated estuaries tends to reduce this effect (Hossain *et al.*, 2001).
4. Exchange of ocean water and estuarine water occurs through the entrance of the estuary, although the amount of exchange depends on the size and length of the entrance channel. In positive wave-dominated estuaries, the outflow of freshwater exceeds the inflow of marine water. During dry conditions, the entrance of the estuary may be intermittently closed.
5. Wind-induced currents drive the internal circulation of wave-dominated estuaries. Secondary circulations can be generated by tides, and can be influenced by coriolis effects in estuaries with very large basins. However, inside wave-dominated estuaries, tidal ranges are often small (~0.1 m) compared to tidal ranges in the ocean. Internal circulation patterns are disrupted during extreme high-flow events.
6. While significant evaporation can occur in wave-dominated estuaries characterised by positive circulation, evaporation (by definition) does not exceed the amount of freshwater input (Heggie *et al.*, 1999b).

WAVE-DOMINATED ESTUARY: HYDRODYNAMICS ("NEGATIVE" CONDITIONS)

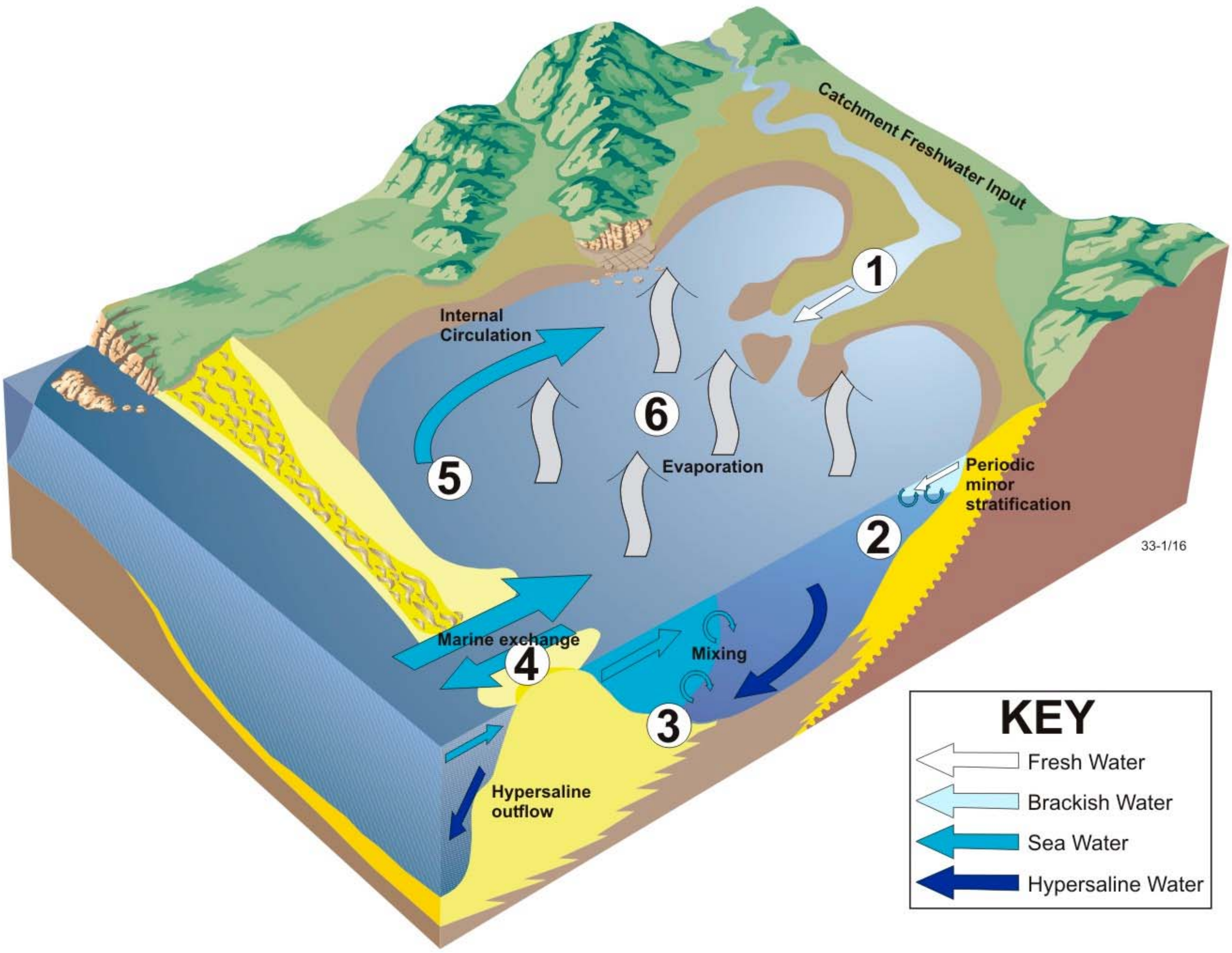

Figure 12 – Conceptual model of major hydrodynamics (negative) in a wave-dominated estuary.

WAVE-DOMINATED ESTUARY: HYDRODYNAMICS ("NEGATIVE" CONDITIONS)

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and temporally (depending on local catchment and climatic conditions), it is typically relatively low in negative estuaries.
2. The volume of freshwater entering the estuary is typically too low to cause significant stratification. When freshwater input does occur (during seasonal rains or extreme runoff events), minor short-lived freshwater stratification may occur.
3. High evaporation rates result in elevated salinity in the central basin. This produces hyper-saline water that sinks beneath the intruding sea water, and may flow out of the entrance (Lennon *et al.*, 1987, de Silva Samarasinghe *et al.*, 1987). A small amount of mixing occurs between the stratified layers.
4. Exchange of sea water and estuarine water occurs through the entrance of the estuary, although the amount of exchange depends on the size and length of the entrance channel. In 'negative' wave-dominated estuaries, the inflow of marine water exceeds the outflow of freshwater. In such cases, the hyper-saline water is usually exported to the ocean (Heggie *et al.*, 1999b). The entrance of the estuary may be intermittently closed.
5. Wind-induced currents drive the internal circulation of wave-dominated estuaries. Secondary circulations can be generated by tides, and can be influenced by coriolis effects in estuaries with very large basins. However, inside wave-dominated estuaries, tidal ranges are often small (~0.1 m) compared to tidal ranges in the ocean. Internal circulation patterns are disrupted during extreme high-flow events.
6. Evaporation is the dominant process in 'negative' wave-dominated estuaries, due to arid climatic conditions. Aridity and evaporation may vary seasonally, however by definition evaporation in 'negative' estuaries is larger than freshwater input (Veeh *et al.*, 1995). Consequently, negative estuaries tend to have longer residence times than positive estuaries (Smith *et al.*, 1989).

WAVE-DOMINATED ESTUARY: SEDIMENT DYNAMICS

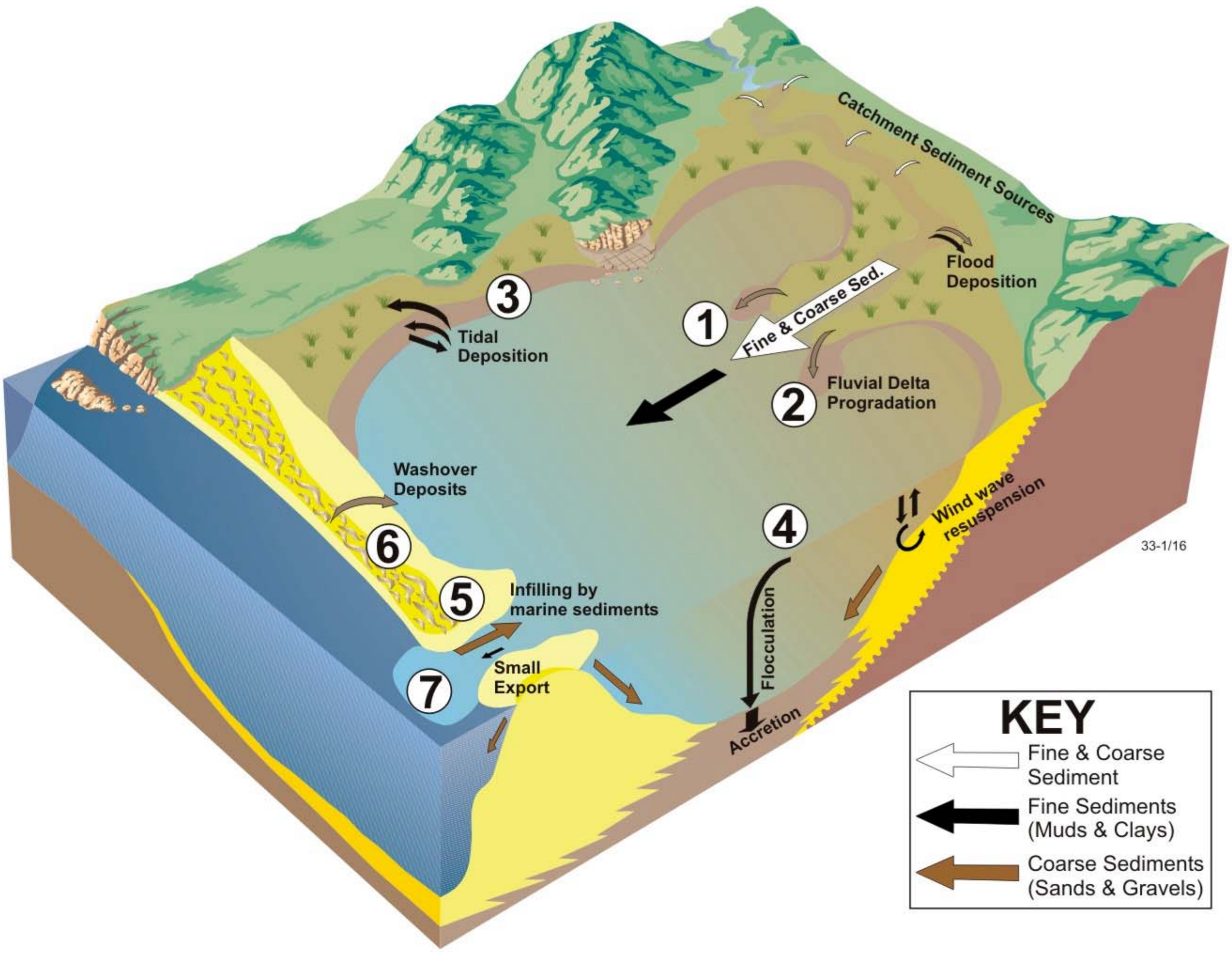

Figure 13 – Conceptual model of major sediment dynamics in a wave-dominated estuary.

WAVE-DOMINATED ESTUARY: SEDIMENT DYNAMICS

1. Fine and coarse sediment enters the estuary from the catchment. The amount of sediment input varies regionally, depending on catchment and climate conditions, and the volume of freshwater input. However, the amount of terrigenous sediment delivered to wave-dominated estuaries is usually relatively large.
2. Coarse sediment (i.e., gravels and sands) is deposited at the head of the estuary forming a fluvial bay-head delta that, unless disturbed by waves, progrades into the central basin. Terrigenous sediment from the catchment is supplied by rivers and mostly deposited in the fluvial deltas, although some of the fine load may be transported to the central basin (Webster *et al.*, 2002, Pasternack *et al.*, 2002).
3. Fine sediment (i.e., muds, clays, and organic material) is deposited on the fringes of the central basin by river processes, tides, and internally generated waves. Deposition in these environments is aided by the baffling effects of vegetation such as saltmarshes and mangroves (Boorman *et al.*, 1998, Brown, 1998, Saintlan *et al.*, 1999, Temmerman *et al.*, 2003, Laegdsgaard, 2001). Coarse sediment (i.e., sands and gravels) may also accumulate in the fringing environments during floods. Biological activity and waves cause significant reworking of fine sediment on un-vegetated intertidal flats.
4. Suspended sediment is transported into the central basin, where it is deposited in a low-energy environment. Flocculation, or particle aggregation due to changes in salinity, is also an important process that enables fine particles to settle out from the water column. Benthic micro-algae (BMA) assist in the stabilisation of fine sediment (Wulff *et al.*, 1997, Cahoon *et al.*, 1999, Murray *et al.*, 2002). Seagrasses, where present, also promote sedimentation and stabilise the substrate (Moriarty *et al.*, 1985). The low-energy conditions, and large relative size of the central basin means that this region is the primary repository for fine material and particle-associated contaminants (Hodgkin *et al.*, 1998, Heggie *et al.*, 1999b, Heap *et al.*, 2001, Harris *et al.*, 2002). Resuspension of the fine sediment can occur in wave-dominated estuaries with either very shallow central basins or a lack of stabilising vegetation, causing significant turbidity.
5. At the entrance, tidal currents are locally accelerated in the constricted entrance, and form flood and ebb tidal deltas (Roy, 1984a). Sedimentary processes are dominated by the landward transport of coarse sediment derived from the marine environment (Green *et al.*, 2001). Sediment can be exported to the ocean through the inlet, particularly during spring tides and flood events (Harvey, 1996).
6. Coarse marine sediment is driven along the coast by strong wave energy and is deposited as a supra-tidal (subaerial) barrier, and tidal deltas at the entrance (Melville, 1984, Otvos, 2000, Roy *et al.*, 2001). During storms, large waves transport sediment over the barrier and form washovers that extend into the central basin. Marine sediment is transported into the estuary by aeolian, tidal, and wave processes, forming a sandy barrier and washover deposits that also may extend into the central basin (Boyd *et al.*, 1992).
7. The sediment trapping efficiency of wave-dominated estuaries is very high because sediment from the catchment and marine sources is trapped in the low-energy central basin, which may capture up to 80% of fine sediment (Patchineelam *et al.*, 1999, Roy *et al.*, 2001). Infilling by marine sand transported through the entrance can also be a significant source of sediment in immature wave-dominated estuaries.

WAVE-DOMINATED ESTUARY: NUTRIENT DYNAMICS

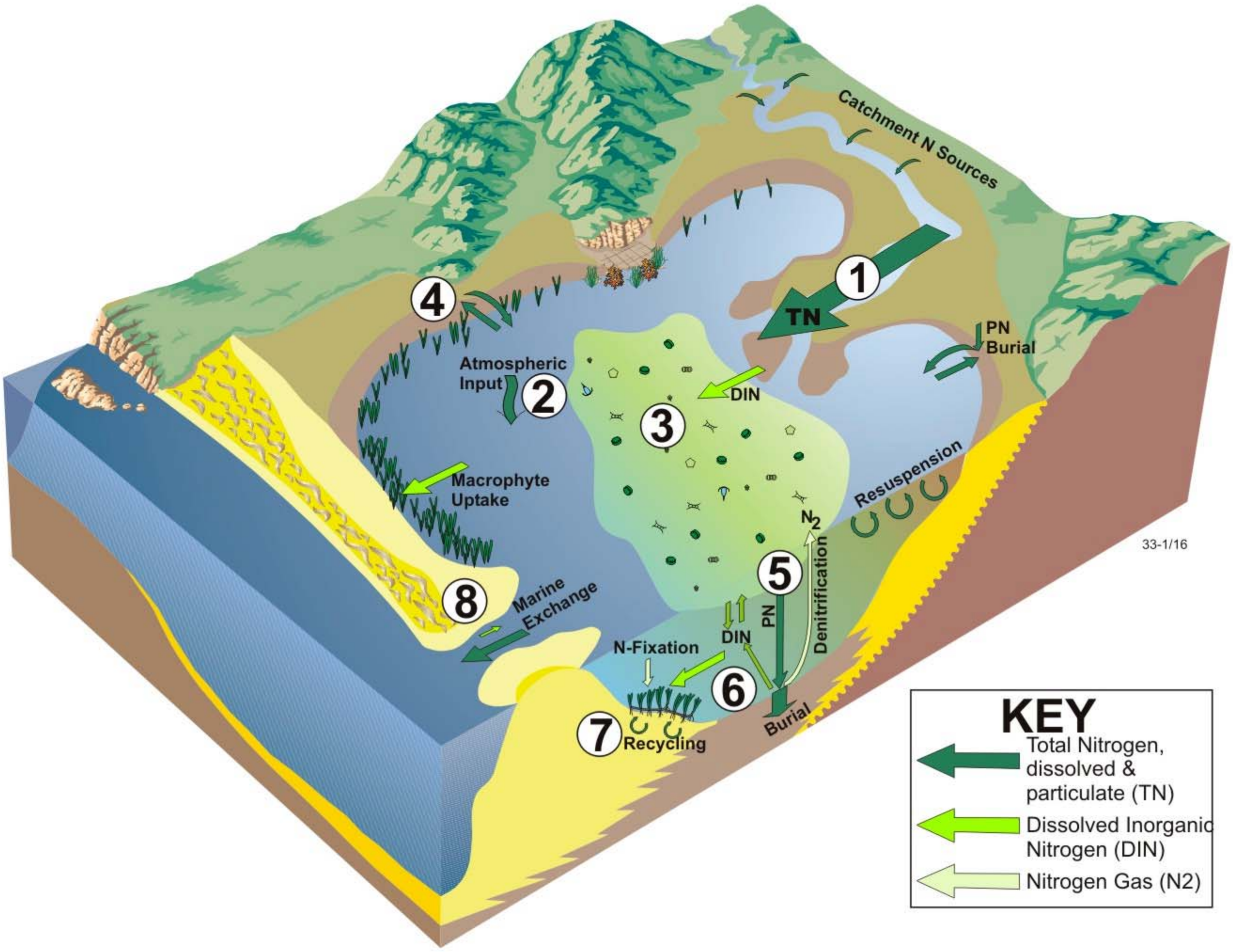

Figure 14 – Conceptual model of major nutrient (nitrogen) dynamics in a wave-dominated estuary.

WAVE-DOMINATED ESTUARY: NUTRIENT DYNAMICS

1) Nitrogen (both particulate and dissolved, or Total Nitrogen (TN)) enters the estuarine system from point- and non-point sources from within the catchment. River flow and nutrient input varies regionally, depending on local catchment and climatic conditions. However, the input of catchment-derived nutrients into estuaries and deltas is typically high (Harris, 2001).
2) Input of particulate N (PN) from atmospheric sources such as smoke and ash is significant in some wave-dominated estuaries.
3) The DIN is transported into the central basin of the estuary, with biological uptake by phytoplankton (Gaughan *et al.*, 1995, Webster *et al.*, 1998), seagrass, benthic micro-algae (Webster *et al.*, 2002), and macrophytes occurring along the way, if residence times are long enough, and if temperature, turbidity, and light levels are suitable. The balance between planktonic and benthic primary productivity may depend on catchment nitrogen loads (Eyre *et al.*, 2002).
4) Some deposition and burial of particulate nitrogen (PN) occurs on flanking environments, due to the baffling effect of saltmarsh and/or mangrove (where present) vegetation (Boon *et al.*, 1988, Nedwell *et al.*, 1988, Howes *et al.*, 1994, Laegdsgaard, 2001). Burial and resuspension of PN and dissolved inorganic nitrogen (DIN) can also occur within intertidal flats (Alongi *et al.*, 1999). Some PN may be deposited and buried within the fluvial delta.
5) PN is deposited in the sediment as phytoplankton debris.
6) Decomposition of organic matter within the sediment produces dissolved inorganic nitrogen (potentially available for further plant/phytoplankton growth). Denitrification within the sediment converts nitrate (NO_3^{2-}) to N_2 gas, which escapes from the system to the atmosphere (Heggie *et al.*, 1999a). Some of the particulate nitrogen (PN) deposited into the sediment of the central basin is buried.
7) Seagrasses take up dissolved inorganic nitrogen (DIN) from the water column, and from the sediment pore-waters (Bulthuis *et al.*, 1984, Bulthuis *et al.*, 1992). The pore-water dissolved inorganic nitrogen (DIN) is derived from the metabolism of phytoplankton, seagrass and other organic matter debris. The seagrass debris therefore, in part, is “recycled” back to the plants. N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) occurring in the root-zone contributes additional DIN to this pool (Moriarty *et al.*, 1985, Smith, 1990). Denitrification is also an important process in seagrass meadows. Sandy sediment is permeable, hence can be ventilated by oxygen-rich overlying waters resulting in efficient remineralisation of organic debris (mostly by denitrification) with little preservation of organic matter.
8) Due to the long residence time typical of wave-dominated estuaries, most catchment-derived N is processed and effectively trapped by the estuary. Typically, only very small quantities of the TN load are exported to the marine environment, however export is much larger during significant during flood events (Nixon *et al.*, 1996).

KEY FEATURES OF WAVE-DOMINATED ESTUARIES

1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported.
2. Narrow entrance restricts marine flushing, only a small proportion of the estuarine water volume is exchanged each tide.
3. River flow typically high, and flooding may expel marine water and flush material from the estuary.
4. Turbidity, in terms of suspended sediment, is naturally low except during extreme wind or fluvial runoff events.
5. Central basin is an efficient 'trap' for terrigenous sediment and pollutants.
6. Long residence time encourages trapping and processing (e.g. denitrification) of terrigenous nutrient loads.
7. 'Semi-mature' in terms of evolution: morphology will rapidly change over time due to infilling, resulting in shallowing of the central basin, and expansion of the fluvial delta.

Wave-dominated Deltas

(Also known as: Riverine Estuary)

Wave-dominated deltas (Figure 15) are comprised of a river that is directly connected to the sea via a channel(s) that is usually flanked by low-lying vegetated floodplain and swampy areas. Entrances of wave-dominated deltas are relatively narrow due to constriction by a barrier (or sandbar) and, due to the relatively high river influence throughout the system, are rarely closed off from the ocean. In Australia, wave-dominated deltas are most abundant on the north-east, south-east, and south-west coasts (Figure 2), and represent 'mature' forms of wave-dominated estuaries, having been largely infilled by sediment from terrigenous and marine sources (Roy *et al.*, 2001, Roy, 1993). Therefore, they do not necessarily display the morphology of the ancestral bedrock valley in which they have developed (Boyd *et al.*, 1992, Dalrymple *et al.*, 1992, Hinwood *et al.*, 1999). Australia's high relative aridity, low relief, and geological antiquity has resulted in a distinct lack of large deltas (by world standards) and associated continental river systems, and total discharge of terrigenous material is small by world standards (Fryirs *et al.*, 2001). Many wave-dominated deltas in Australia do not contain large coastal protuberances, due to this lack of sediment supply, in combination with shoreline erosion and sediment redistribution by wave energy (Heap *et al.*, In Press).

Figure 15 - Examples of wave-dominated deltas: Robinson River (NT), Richmond River (NSW), Gascoyne River (WA).

Wave-dominated deltas are distinguished by relatively high wave influence at the mouth (compared to tidal influence). Because waves are unable to penetrate far through the entrance of the delta, the total amount of wave influence declines rapidly adjacent to the entrance. Further landward, river influence becomes dominant, as tides are also attenuated in the channels due to friction (Albani *et al.*, 1974).

During the later stages of deltaic evolution (or sediment infilling), the connectivity between the river channel and tidal inlet increases. This results in more efficient delivery of fluvial sediment to the ocean, and the bypassing of remnant central basin features (i.e. 'cut-off embayments'), which slowly infill and become swamp areas. As a consequence, the gross morphology (and thus habitat distribution and abundance) of wave-dominated deltas is relatively stable, and may persist over long periods of time with little change (Heap *et al.*, In Press). In areas with increased sediment supply, such bypassing to the coast can allow the barrier to prograde, which may result in the formation of a coastal protuberance adjacent to the mouth of the river (Roy *et al.*, 1980). Large magnitude river floods may also cause temporary delta-front progradation, however wave erosion and currents tend to disperse this sediment (Cooper, 1993, Hume *et al.*, 1993).

Wave-dominated deltas typically support 'euryhaline' estuarine species, as well as transient visitors from full marine environments, depending on river flow conditions (Roy *et al.*, 2001). Intertidal habitats are limited in extent, and are restricted mainly to the barrier and flood tidal delta (Cooper 1993). Wave-dominated deltas typically support high-energy sandy beaches and channels, intertidal mudflats, saltmarshes, and mangroves (Alongi *et al.*, 1999). Typically, sandy channel margins support various macrophytes such as seagrasses (Abal *et al.*, 1996).

WAVE-DOMINATED DELTA: HYDRODYNAMICS

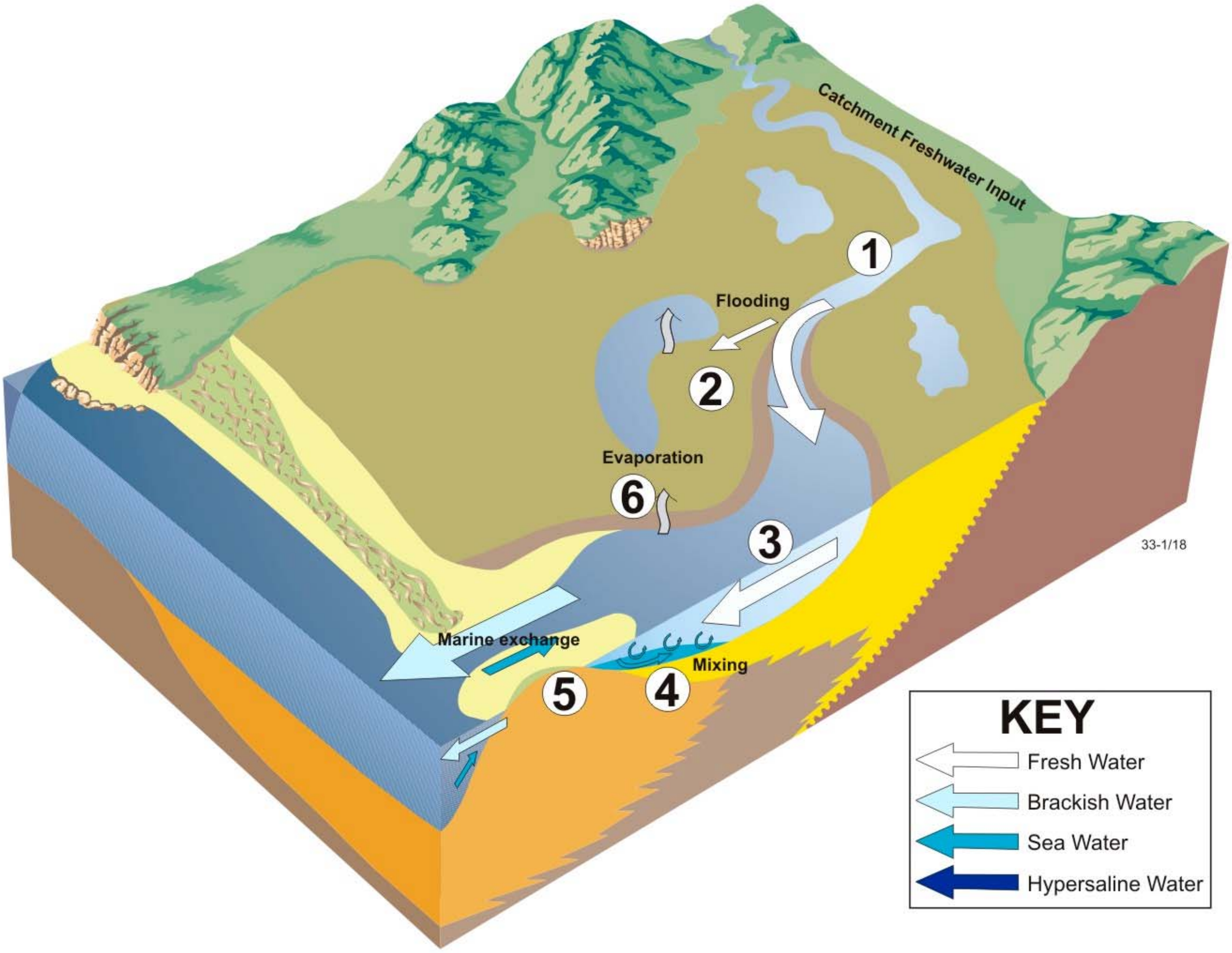

Figure 16 – Conceptual model of major hydrodynamics in a wave-dominated delta.

WAVE-DOMINATED DELTA: HYDRODYNAMICS

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and seasonally (depending on local catchment and climatic conditions), it is typically relatively high in most deltas.
2. Floods, or high runoff events, driven by climatic and catchment processes, can result in the inundation of low-lying swamp and marsh areas by fresh water. This water often supports freshwater wetland ecosystems, and typically is either taken up by vegetation, or evaporates. Many wave-dominated deltas are more prone to flooding, due to relatively high freshwater input and relatively low total volume (compared to estuaries and embayments).
3. The volume of freshwater may cause significant stratification within the channel, which varies with seasonal flow. Current flow in channels is strong, due to their small relative volume, and the consequent short residence time of water (the time taken for water to travel through the delta). Due to the small water volume, floods may completely force marine water out of the delta.
4. A 'salt-wedge', or intrusion of denser saline marine water penetrates the delta through the entrance (which is usually open on a permanent basis). Wave-dominated deltas are generally characterised by limited tidal intrusion because of friction effects and the relatively strong river flow. Some mixing occurs at the interface between the less-dense freshwater, and higher-density marine water. The distance that the salt-wedge penetrates is dependant on tidal range and the amount of fluvial flow received by the delta (Kurup *et al.*, 1998). During high fluvial flow events (which may be seasonal), fresh floodwater rapidly pushes the salt water intrusion seaward (beyond the mouth), completely removing stratification from the delta (Hossain *et al.*, 2001, Eyre, 1998).
5. Exchange of sea water and river water occurs through the entrance of the delta, depending on the width of the entrance channel. In deltas, the net outflow of catchment-derived river water typically exceeds the inflow of marine water.
6. Due to the relatively low surface area of most wave-dominated deltas, evaporation is a minor component (depending on climatic conditions) and does not exceed river input.

WAVE-DOMINATED DELTA: SEDIMENT DYNAMICS

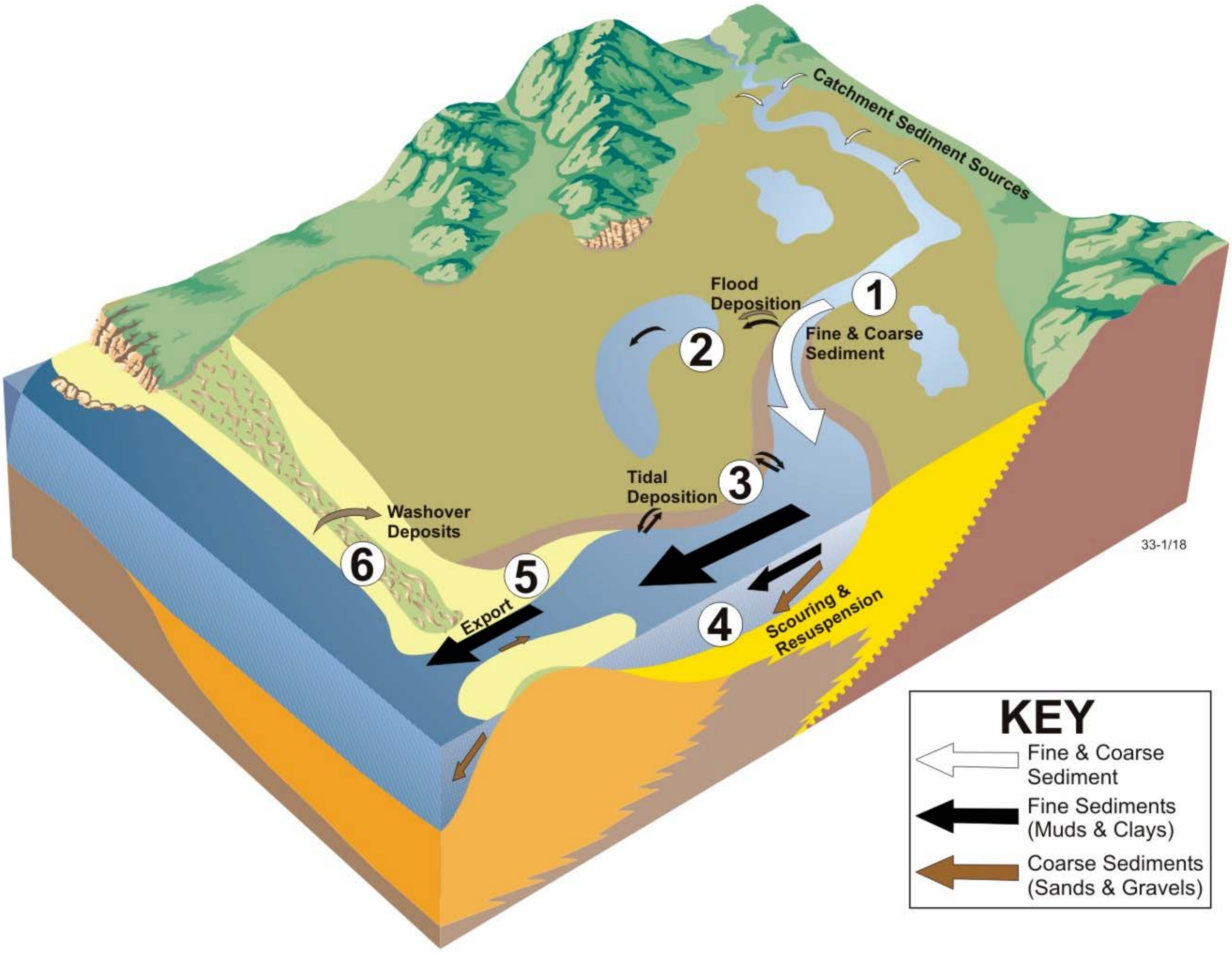

Figure 17 – Conceptual model of major sediment dynamics in a wave-dominated delta.

WAVE-DOMINATED DELTA: SEDIMENT DYNAMICS

1. Fine and coarse sediment enters the delta from the catchment. The amount of sediment input varies regionally, depending on catchment and climate conditions, and the volume of freshwater input. However, the amount of terrigenous sediment delivered to wave-dominated estuaries is usually relatively large. Seasonal and climate factors dominate the function of deltas, with episodic high-flow events causing intense flushing, sedimentation, and erosion in the main channels and floodplain (Eyre *et al.*, 1999).
2. Limited deposition of fine sediment (including clays, muds and organic material) occurs upon the floodplain during high flow events (Jones *et al.*, 1993). This is enhanced by the baffling effects of floodplain vegetation associated with swamp and marsh areas, and leads to slow vertical accretion of the floodplain. Some lateral deposition of sediment can occur, including the development of coarse sediment point-bar deposits.
3. Some tidal deposition and burial of fine sediment occurs on flanking intertidal environments, aided by the baffling effects of vegetation such as saltmarshes and mangroves. Coarse sediment (such as sands and gravels) may also accumulate here during flood/high flow conditions. Some burial and resuspension of sediment can also occur within intertidal flats. Flanking environments typically play a much smaller role in deltas in comparison to estuaries, as there is very little space remaining for deposition within deltas.
4. Wave-dominated deltas are characterised by net seaward-directed sediment transport, associated with the relatively high river discharge and relative absence of available accommodation space for sediment deposition (Bhattacharya *et al.*, 1992). Consequently, fine suspended sediment, and coarse sediment (as bedload) is moved downstream along the bottom of the deltaic channels, due to unimpeded river flow. Some lateral deposition of both types of sediment can occur, including the development of coarse sediment point-bar deposits. Deposition may be limited at the bottom of channels due to scouring by strong currents.
5. The majority of deposition occurs seaward of the delta mouth, and results in the net export of sediment into the marine environment (Jones *et al.*, 1993, Hume *et al.*, 1993). Fine suspended sediment is generally transported offshore, with some flocculation occurring over the salinity gradient. Coarser sediment tends to accumulate close to the entrance of the delta, although this material is generally redistributed by wave action (Melville, 1984, Cooper, 1993). The sediment trapping capacity of wave-dominated deltas is low, because most terrigenous sediment is exported to the marine environment and lost to the coastal sediment budget (Davies, 1974, Roy *et al.*, 1977, Hacker, 1988).
6. High wave energy results in the distribution of sediment along the coastline proximal to the delta, forming a barrier (Melville, 1984, Otvos, 2000, Roy *et al.*, 2001). In situations where the river delivers sediment to the coast faster than waves are able to transport it away, the coastline tends to slowly prograde into the marine environment, forming a 'coastal protuberance'.

WAVE-DOMINATED DELTA: NUTRIENT DYNAMICS

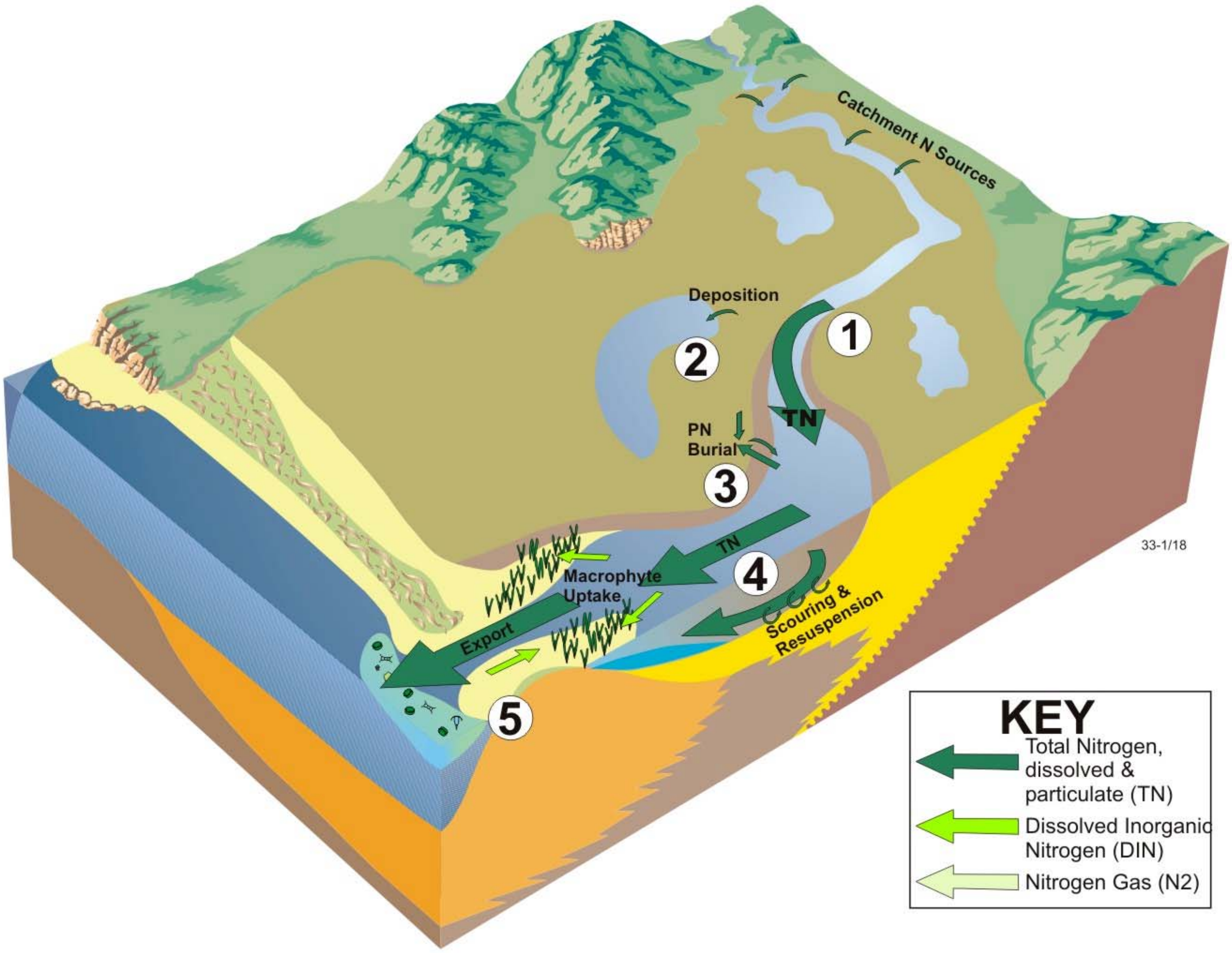

Figure 18 – Conceptual model of major nutrients (nitrogen) dynamics in a wave-dominated delta.

WAVE-DOMINATED DELTA: NUTRIENT DYNAMICS

1) Nitrogen (both particulate and dissolved, or total nitrogen (TN)) enters the deltaic channels from point- and non-point sources from within the catchment. River flow and nutrient input varies regionally, depending on local catchment and climatic conditions. Typically, a high proportion of catchment-derived nutrient material is transported into estuaries and deltas (Harris, 2001).
2) Limited deposition of particulate nitrogen (PN) occurs upon the floodplain during high flow events. This process is enhanced by the effects of 'baffling' by floodplain vegetation. Biological uptake of DIN also occurs on the flanks of the river channel.
3) Limited deposition and burial of particulate nitrogen (PN) occurs in flanking environments, due to the baffling effect of saltmarsh and/or mangrove vegetation, depending on latitude. Burial and resuspension of particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) can also occur within intertidal flats. Flanking environments typically play a much smaller role in deltas in comparison to estuaries.
4) The majority of the river-borne TN is transported through the delta by strong river flow or downstream displacement (Keil *et al.*, 1997), especially during flood events (Eyre, 2000). Deposition typically does not occur in the channels due to scouring.
5) A large proportion of the total nitrogen (TN) load is exported through the mouth of the delta into the marine environment (Eyre, 1994, Eyre, 2000, Nixon *et al.*, 1996). Uptake of dissolved inorganic nitrogen (DIN) by seagrasses may occur in the mouth of the delta. The nitrogen exported into the ocean is typically assimilated by marine phytoplankton.

KEY FEATURES OF WAVE-DOMINATED DELTAS

1. Habitats supported are variable, generally mostly brackish subtidal, intertidal and supratidal habitats.
2. Narrow entrance restricts marine flushing, only a small proportion of the water volume is exchanged each tide.
3. River flow typically high, and flooding commonly expels marine water and flushes material from the delta.
4. Turbidity, in terms of suspended sediment, is highly dependant on catchment inflow, however is naturally low except during extreme fluvial runoff events.
5. Sediment (and associated contaminants) are mostly expelled into the coastal ocean.
6. Short residence time (e.g. efficient flushing) results in little processing or trapping of nutrients.
7. 'Mature' in terms of evolution. Tend to be stable in terms of morphology (given stable sea level).

Coastal Lagoons, and Strandplain-associated Coastal Creeks

(Also known as: ICOLL's, Closed or Blind Estuary, Interbarrier Estuary, Dune-Swale Creek)

Coastal lagoons and strand plain-associated coastal creeks are small, shallow basins that have very low (or negligible) freshwater input (Figure 19). In Australia, they are most abundant on the south-east coast, south-west coast, and in the Gulf of Carpentaria (Figure 2). The catchment for these systems is limited to the immediate hinterland. Due to the lack of significant freshwater input (and associated terrigenous sediment) and strong tidal currents, the entrances to these coastal waterways are often intermittently or permanently closed, resulting in isolation from marine influence for long periods (Ranasinghe *et al.*, 1999). The geomorphology of coastal lagoons is similar to wave-dominated estuaries, however they lack a distinct fluvial bay-head delta (Roy *et al.*, 2001). Strand plain-associated coastal creeks are narrow, generally shallow water bodies that occur on wave-dominated coasts (Otvos, 2000). They are generally oriented parallel to the coast, and develop on prograding coastal sequences formed from beach ridges, dunes, and barriers.



Figure 19 - Examples of coastal lagoons: Nadgee Lake (NSW), Little Lagoon (NT), and a strand plain-associated coastal creek: Jerusalem Creek, NSW. *Oblique photos courtesy of the NSW Department of Land and Water Conservation*.

Coastal lagoons, and other small waterways associated with wave-dominated coastlines, tend to experience very low wave and tide energy within, as tidal waters are often unable to penetrate the closed (or very narrow and intermittent) entrances (Harris *et al.*, 2003). Additionally, low or non-existent river flow is conducive to very low energy conditions, except during extreme flood conditions. The most significant physical energy source in many systems is internally generated wind-induced waves, however these usually remain quite small due to the limited size of the waterway (Morrisey, 1995).

Coastal lagoons and strandplain-associated creeks evolve on wave-dominated coastlines by the partial or total closure of small coastal embayments, by a subaerial sand barrier, or by the flooding of beach ridges (Harris *et al.*, 2003). Coastal lagoons represent an end member of the spectrum of wave-dominated coastal waterways where fluvial input is negligible, and experience the same or similar evolutionary trends as wave-dominated estuaries except for the lack of significant infilling by terrigenous material (Boyd *et al.*, 1992). Infilling is slow, and is dominated by marine-derived sediment when the entrance is open (Boyd *et al.*, 1992).

Despite intermittently experiencing significant variations in salinity, coastal lagoons and strand plain-associated coastal creeks are usually colonised by estuarine invertebrates and other 'euryhaline' aquatic organisms that can tolerate a wide range of salinity conditions (Rainer *et al.*, 1981). There is usually a high mortality of marine species during periods of closure that provides an opportunity for recruitment and development of estuarine and/or low salinity species. Even very small (<100 m^2) coastal lagoons and strand plain-associated coastal creeks are important habitats for a diverse assemblage of juvenile (and small-sized) fishes, some of which are economically important (Griffiths, 2001, Hannan *et al.*, 1998, Norris *et al.*, 1993, Pollard, 1994). The duration of water exchange between the ocean and the coastal lagoon is probably the most important factor influencing the recruitment of marine organisms (Potter *et al.*, 1994). Many coastal lagoons and strand plain-associated coastal creeks support macroalgae, limited seagrass beds, saltmarshes, and floodplain species. Mangroves typically do not occur, due to the lack of connection with the open ocean (Roy *et al.*, 2001).

COASTAL LAGOON/STRANDPLAIN-ASSOCIATED CREEK: HYDRODYNAMICS

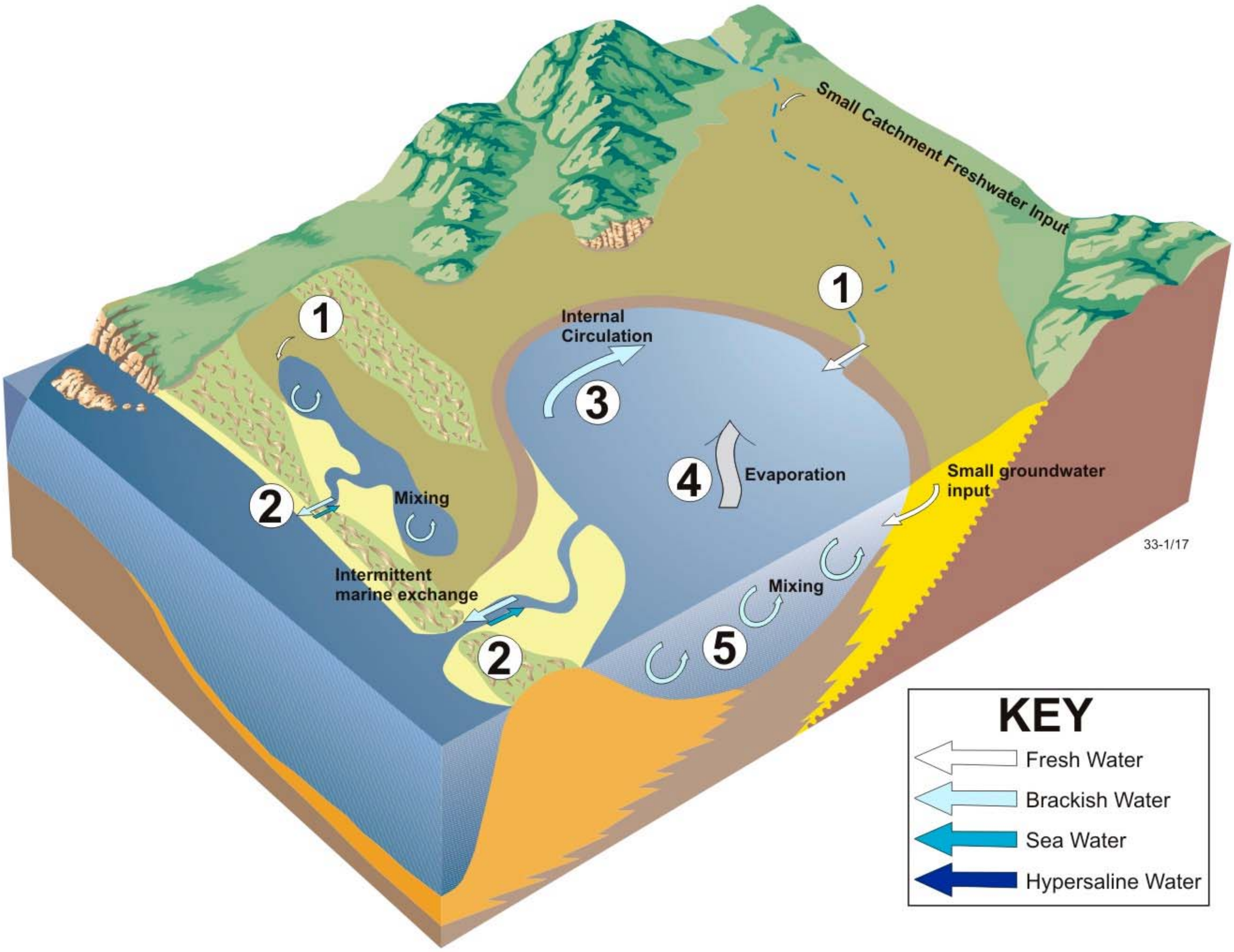

Figure 20 – Conceptual model of major hydrodynamics in a coastal lagoon/strandplain-associated creek.

COASTAL LAGOON/STRANDPLAIN-ASSOCIATED CREEK: HYDRODYNAMICS

1. Very little freshwater enters from the catchment, which itself may be very small. The quantity of freshwater input can vary seasonally, depending on regional climatic conditions, however is, by definition, very low in coastal lagoons. Many coastal lagoons lack distinct river or creek channels, and receive freshwater from sheet runoff only. Groundwater input may also be significant.
2. Some exchange of marine and estuarine water occurs through the entrance of the coastal lagoon, although this can be restricted by a narrow channel. Entrances of coastal lagoons tend to be intermittently open and closed, and many tend to remain closed for long periods of time, only opening during floods (Ranasinghe *et al.*, 1999). Sub-surface exchange of marine and estuarine water through the permeable barrier may also occur during periods of closure. Coastal lagoons and strand plain-associated coastal creeks that are permanently closed to the ocean exhibit a long-term balance between freshwater inputs, barrier overwashing, and rainfall, and outputs via evaporation, seepage, and evapotranspiration by fringing vegetation (Cooper, 2001).
3. Internal circulation within coastal lagoons is typically driven by wind-induced currents and internally generated waves. Internal circulation patterns may be altered during extreme high-flow events, and periods of entrance opening. Because the entrance to coastal lagoons and strand plain-associated coastal creeks is usually intermittently or permanently closed, ocean wave and tidal influence is negligible inside the basin (Harris *et al.*, 2003).
4. Evaporation may be significant in certain climatic regions, and can exceed freshwater input in arid climatic regions (see 'Negative' wave-dominated estuary conceptual model). During long periods of entrance closure, this may result in hypersaline conditions, and water column stratification.
5. Salinity can vary significantly, from brackish conditions to hypersaline, depending upon the amount of freshwater input, climate (aridity), and the frequency and duration of entrance opening. Stratification is common during periods of freshwater input, except during significant internal wind-induced wave activity. Systems with low barriers are more often well mixed and contain saline water due to frequent wash-overs by waves, and landward percolation of seawater through the barrier at high tide (Roy *et al.*, 2001). Some coastal lagoons and strand plain-associated coastal creeks contain elevated water levels in the basin (i.e. they are 'perched' systems). If the barrier in these systems is breached, the basin can almost completely drain, resulting in near complete subaerial exposure. As the average depth of coastal lagoons tends to be above the wave base, they tend to be well mixed by wind waves and currents.

COASTAL LAGOON/STRANDPLAIN ASSOCIATED CREEK: SEDIMENT DYNAMICS

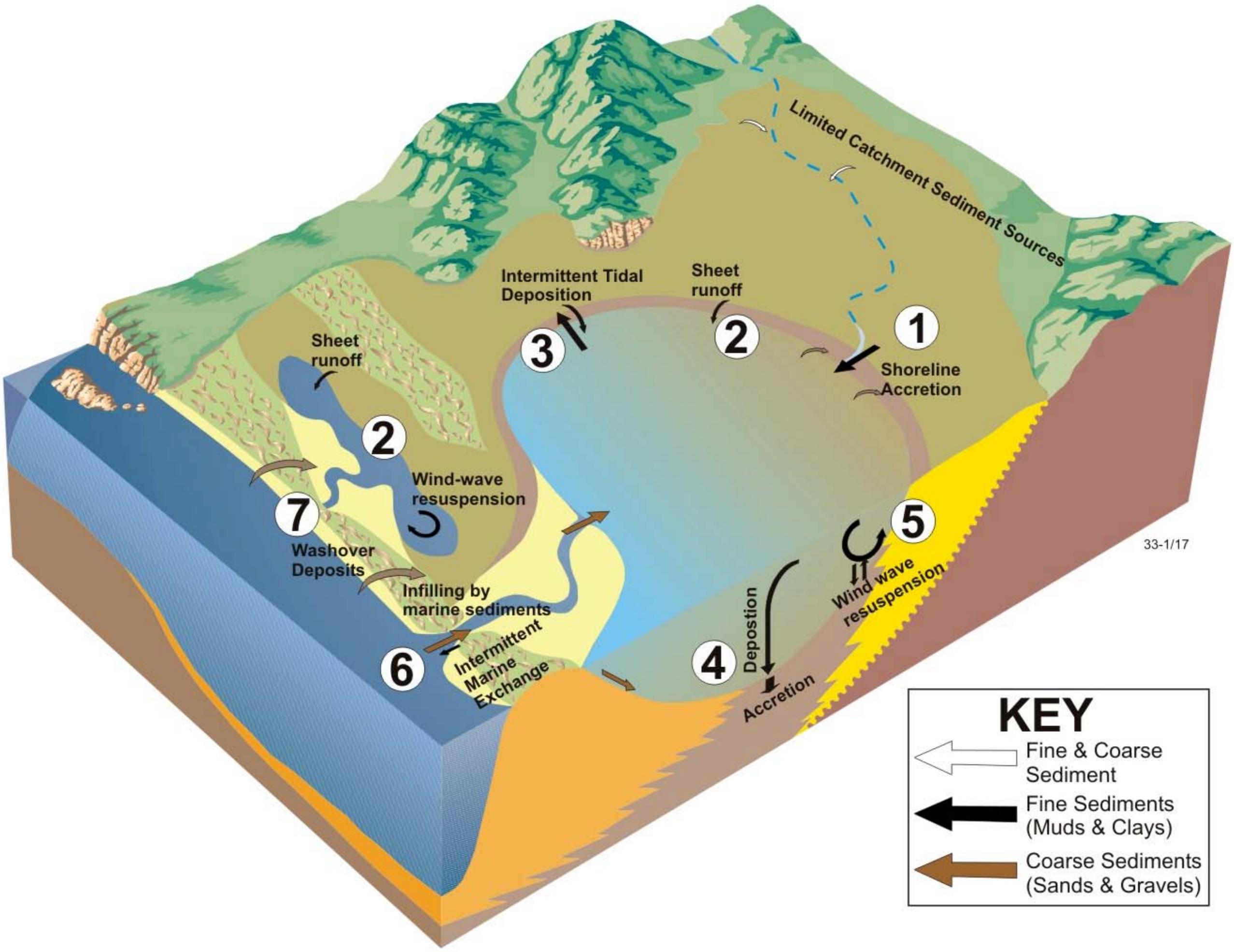

Figure 21 – Conceptual model of major sediment dynamics in a coastal lagoon/strand plain.

COASTAL LAGOON/STRANDPLAIN ASSOCIATED CREEK: SEDIMENT DYNAMICS

1. Sediment inputs from the catchment are less important in coastal lagoons - significant input typically occurs during high rainfall events only. Most terrigenous sediment tends to be fine, and is derived from sheet runoff and aeolian inputs.
2. Fine sediment (e.g. muds, clays and organic material) undergoes both deposition and erosion on unvegetated intertidal flats, aided by biological activity such as burrowing. A general trend of slow growth of intertidal flats is observed.
3. Some deposition of fine sediment occurs on flanking environments, aided by the baffling effects of vegetation such as saltmarshes (Boorman *et al.*, 1998, Brown, 1998, Saintlan *et al.*, 1999, Laegdsgaard, 2001), however this is limited by poor tidal penetration into the lagoon.
4. Fine suspended sediment is transported into the central basin, where deposition can occur, depending on wind-wave conditions within the coastal lagoon. Benthic micro-algae (BMA), where present, assist in the stabilisation of fine sediment (Wulff *et al.*, 1997, Cahoon *et al.*, 1999, Murray *et al.*, 2002). Seagrasses, where present, also promote sedimentation and stabilise the substrate (Moriarty *et al.*, 1985), however seagrass growth may be limited by poor tidal penetration. Flocculation (particle aggregation due to changes in salinity) is less important in coastal lagoons as they often lack fresh water input. Organic matter (derived from the catchment and also produced *in situ*) accumulates, and may be eroded during open phases. Coastal lagoons and strand plain-associated coastal creeks with closed entrances trap nearly 100% of the sediment delivered to the basin. Due to the negligible freshwater input, even during floods this material may not be completely eroded, even during floods that manage to cut a new opening in the barrier.
5. As the average depth of coastal lagoons tends to be above the wave base, wind-wave induced resuspension of fine sediment is common. Lack of seagrasses and other stabilising vegetation also contributes, leading to high water column turbidity.
6. Entrances of coastal lagoons tend to be intermittently open and closed, and many tend to remain closed for the majority of the time. Sedimentary processes here are dominated by the landward transport of coarse sediment derived from the marine environment, although this is restricted by the narrow and often closed entrance channel. This coarse sediment tends to choke the entrance, and builds out into the central basin, forming a flood (or marine) tidal delta. A small amount of fine sediment can be exported into the marine environment during extreme high flow events.
7. Coarse sediment derived from the marine environment is driven along the coast by strong wave energy (particularly during storms), forming a distinctive barrier at the entrance (Otvos, 2000). During extreme events, washovers can occur, depositing further coarse sediment into the central basin of the coastal lagoon.

COASTAL LAGOON/STRANDPLAIN ASSOCIATED CREEK: NUTRIENT DYNAMICS

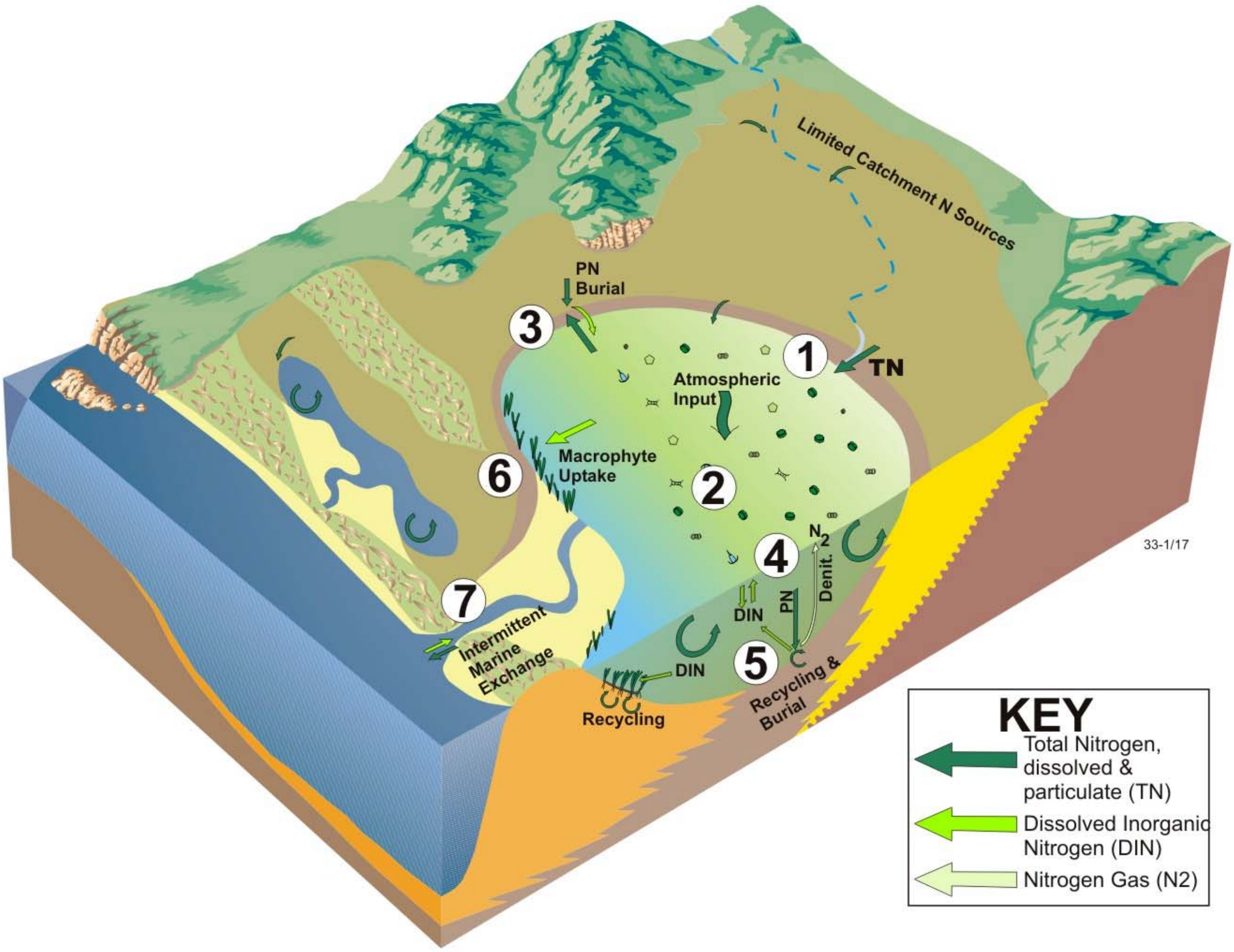

Figure 22 – Conceptual model of major nutrient (nitrogen) dynamics in a coastal lagoon/strand plain.

COASTAL LAGOON/STRANDPLAIN ASSOCIATED CREEK: NUTRIENT DYNAMICS

1) Catchment-derived sources of nitrogen are less important in coastal lagoons and strandplain-associated creeks - significant input typically occurs during extreme rainfall events only. Groundwater inputs, and input of particulate N (PN) from atmospheric sources such as smoke and ash is significant (Harris, 2001).
2) Any nitrogen entering the lagoon is typically processed mostly by phytoplankton, if temperature and light levels are suitable (Gaughan *et al.*, 1995, Webster *et al.*, 1998). Long residence times (during barrier closure) ensure that processing of dissolved inorganic nitrogen is complete. Coastal lagoons and strand plain-associated coastal creeks that are open to the ocean can intermittently undergo dramatic changes in their physical and chemical parameters over short periods, owing to their dynamic connection to the sea (e.g. Pollard, 1994, Griffiths, 2001).
3) Some deposition and burial of particulate nitrogen (PN) occurs on flanking environments, due to the baffling effects of saltmarsh vegetation. Burial and resuspension of PN and dissolved inorganic nitrogen (DIN) can also occur within intertidal flats.
4) PN is deposited in the sediment as phytoplankton debris. Typically, coastal lagoons experience a large degree of nutrient recycling in comparison to catchment inputs. Large reserves of nutrients are often held in the form of dense stands of micro- and macroalgae growing on the bed and in the water column of the lagoon (Webster *et al.*, 2002).
5) Decomposition of organic matter within the sediment produces dissolved inorganic nitrogen (potentially available for further plant/phytoplankton growth). Denitrification within the sediment converts some nitrate (NO_3^{2}-) to N_2 gas, which escapes from the system to the atmosphere (Heggie *et al.*, 1999a, Usui *et al.*, 2001). A small proportion of the particulate nitrogen (PN) deposited into the sediment is buried, although due to the shallow nature of these systems, resuspension is common.
6) Seagrasses, if present, take up dissolved inorganic nitrogen (DIN) from the water column, and from the sediment pore-waters. Higher nutrient concentrations may limit seagrass growth due to increased turbidity from phytoplankton and epiphyte growth (Moriarty *et al.*, 1985, Pollard *et al.*, 1993).The pore-water dissolved inorganic nitrogen (DIN) is derived from the metabolism of phytoplankton, seagrass and other organic matter debris. The seagrass debris therefore, in part, is "recycled" back to the plants (Moriarty *et al.*, 1985). N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) occurring in the root-zone may also contribute additional dissolved inorganic nitrogen (DIN) to this pool (Pollard *et al.*, 1991).
7) Very small quantities of the total nitrogen (TN) load are exported to the marine environment only during periods of open entrance conditions. Export is more significant during flood events. Due to limited marine flushing, coastal lagoons and strandplain-associated creeks may be highly susceptible to increased nutrient input.

KEY FEATURES OF COASTAL LAGOONS & STRANDPLAIN ASSOCIATED CREEKS

1. Habitats supported are limited by chemical conditions induced by poor exchange with the marine environment, and highly variable salinity.
2. Intermittent entrance isolates the coastal waterway from the ocean for long periods.
3. River flow is intermittent to non-existent. Flooding is therefore uncommon, however can cause large impacts such as entrance breaching and scouring of the central basin.
4. Turbidity is naturally low, however shallow basins are susceptible to wind-wave resuspension, particularly if seagrasses are not present.
5. Central basin (where present) is an efficient 'trap' for terrigenous sediment and pollutants.
6. Long residence time encourages trapping and processing (e.g. denitrification) of terrigenous nutrient loads, however the system may be susceptible to overloading due to small size.
7. Evolution, in terms of infilling, is very slow due to the lack of significant sediment input.

Tide-dominated Estuaries

(Also known as: Macrotidal Estuaries, Open Estuaries)

A tide-dominated estuary (Figure 23) represents a bedrock coastal embayment that has been partially infilled by sediment derived from both the catchment and marine sources, in which tidal currents, rather than waves, are the dominant force shaping the gross geomorphology. In Australia, tide-dominated estuaries are generally found on the northern, north-eastern and north-western coasts (Figure 2), and are most abundant on low-gradient coasts characterised by meso- to macro-tidal ranges (Harris *et al.*, 2002, Dalrymple, 1992). Tide-dominated estuaries generally consist of a landward-tapering funnel shaped valley, bounded by various intertidal sedimentary environments such as intertidal flats, mangroves, saltmarshes, and salt flats. Depending on the degree of sediment infilling, the boundaries of tide-dominated estuaries may follow the irregular outline of the drowned valley (Riggs *et al.*, 1995), or, in more mature cases are smooth and intersected by small tidal creek dendritic drainage networks (Wells, 1995, Wolanski *et al.*, 1992). Major structural elements inside the estuary include elongate tidal sand banks, which occur in the wide entrance, oriented perpendicular to the coast and aligned parallel to the direction of dominant tidal currents (Fitzgerald *et al.*, 2000, Green *et al.*, 2001). The tidal sand banks are usually dissected by deep channels containing strong tidal currents. Landward of the estuarine channels, the source river that feeds into tide-dominated estuaries often features a straight–meandering–straight river channel profile (see East Alligator River, Figure 23). This represents the point at which the convergence of seaward-directed water and sediment transport by the river, and landward-directed water and sediment transport by tides occurs (Dalrymple *et al.*, 1992, Chappell *et al.*, 1994, Bryce *et al.*, 1998). Tide-dominated estuaries usually contain large areas of intertidal environments that fringe the tidal sand banks and channels because of the low coastal gradient, and large tidal ranges (Cook *et al.*, 1977). Due to strong tidal currents generated by large tidal ranges, tide-dominated estuaries are usually highly turbid.

Figure 23 - Examples of tide-dominated estuaries: the Fitzroy River (QLD), the Victoria River (NT), and the East Alligator River (NT).

Tide-dominated estuaries are distinguished by relatively high tidal energy at the mouth (compared to wave energy). Tidal sand banks dissipate any wave energy that does exist. Inside the estuary, total energy increases landward, caused by amplification of the tidal wave as it penetrates into the tapering valley. Further landward, energy decreases as frictional forces take effect (Dalrymple *et al.*, 1992), until near the head of the estuary, where the total hydraulic energy may again be high due to river flow (Heap et al. 2001).

Tide-dominated estuaries evolve by infilling of the valley with terrigenous and marine-derived sediment, and a gradual translation of geomorphic and sedimentary environments in a seaward direction (Dalrymple *et al.*, 1992). Quantification of the area of geomorphic and sedimentary facies in Australia's tide-dominated estuaries (Heap *et al.*, In Press) has demonstrated that there is no (or very little) significant change in the distribution of sedimentary environments during evolution. However, infilling is characterised by the expansion of intertidal flats and salt flats around the margins of the estuary, and expansion and merging of tidal sand banks in the tidal channels (Harris, 1988), reflecting the deposition of sediment trapped within the estuary. Vegetation associated with mangrove, saltmarsh, and salt flat environments plays a major role in determining the form of the estuary during early stages of evolution, because of its capacity to trap fine sediment (Woodroffe, 1992, Woodroffe *et al.*, 1993). As such, tide-dominated estuaries have undergone a 'Big Swamp' evolutionary phase, or a period characterised by the rapid expansion of marginal marine environments. This was followed by relatively slow accumulation that enabled freshwater wetlands to gradually replace mangroves and saltmarshes, and slow seaward progradation (Woodroffe *et al.*, 1989, Mulrennan *et al.*, 1998, Chappell, 1993, Woodroffe *et al.*, 1993, Chappell *et al*., 1994).

Tide-dominated estuaries contain habitats such as channels, intertidal mudflats, mangroves, saltmarshes, salt flats, and rocky shores and rocky reefs (Semeniuk, 1982). These habitats typically support marine species, including transient visitors and permanent residents (Cyrus *et al.*, 1992, Pusey *et al.*, 1993), however the biota of these estuaries is less well documented than their wave-dominated counterparts (Boyd *et al.*, 1992). Plant productivity seems to increase with increasing tidal range, due to greater rates of flushing and the consequent renewal of nutrients (Morrisey, 1995). Littoral mangrove forests dominate many of Australia's tide-dominated estuaries, and plains vegetated with grasses, sedges and herbs, as well as freshwater wetlands and floodplain vegetation (such as *Melaleuca* spp.) lie above the influence of most (but not all) tides (Woodroffe *et al.*, 1989). Turbid water within the estuary largely precludes the growth of subaquatic benthic macrophytes (such as seagrasses), and also limits the distribution and depth range available as habitat for phytoplankton. These species are able to survive further seaward due to lower turbidity (Semeniuk, 1996).

TIDE-DOMINATED ESTUARY: HYDRODYNAMICS: ("POSITIVE" CONDITIONS)

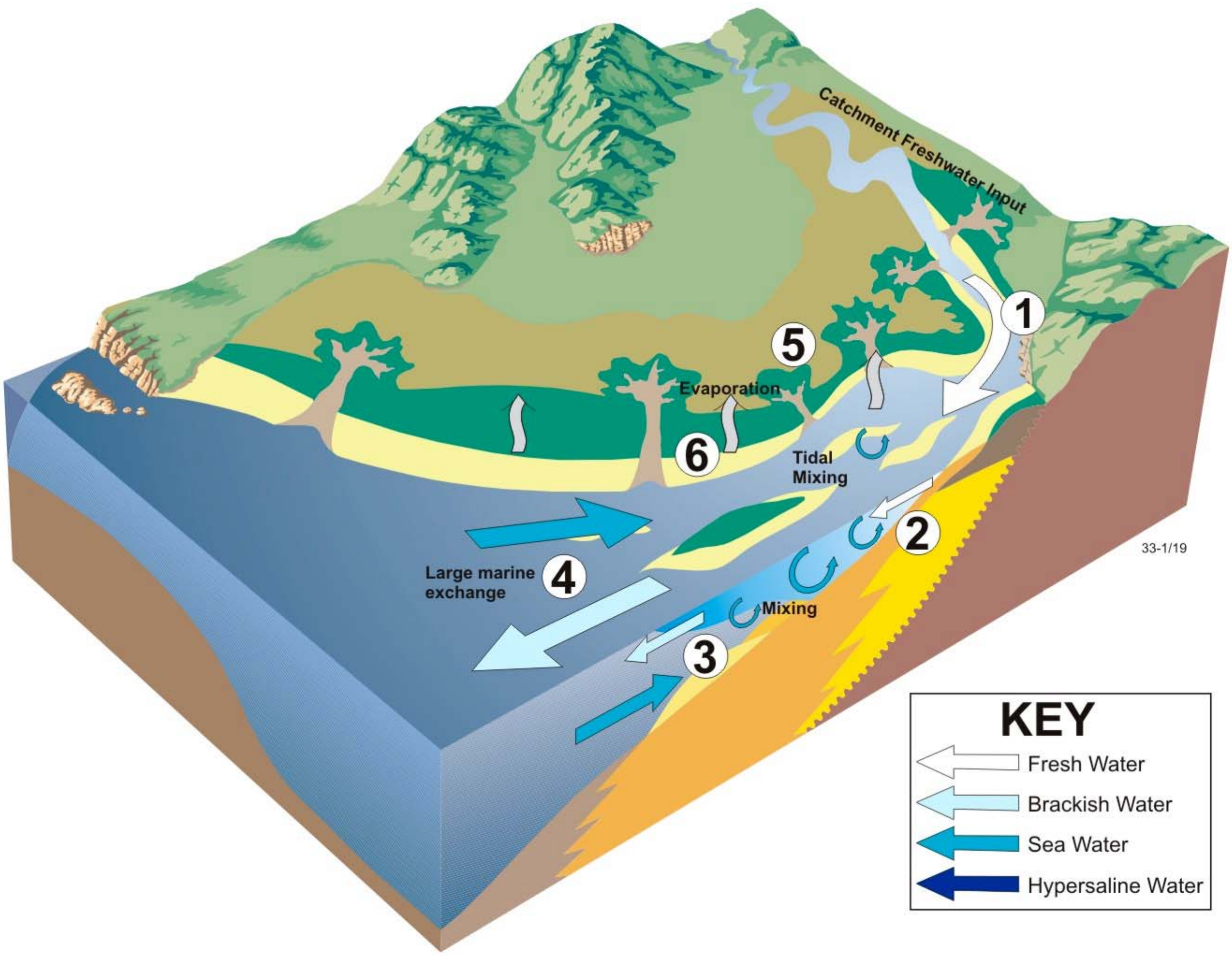

Figure 24 – Conceptual model of major hydrodynamics (positive) in a tide-dominated estuary.

TIDE-DOMINATED ESTUARY: HYDRODYNAMICS: ("POSITIVE" CONDITIONS)

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and temporally (depending on local catchment and climatic conditions), it is often relatively high in positive estuaries.
2. The volume of freshwater can cause stratification (or layering) within the estuarine water column, which varies with seasonal flow. Buoyant low-salinity fresh water tends to float above denser, high-salinity sea water. However, high tidal ranges and turbulence associated with tidal currents tends to accelerate the mixing of freshwater and marine water.
3. A 'salt-wedge', or intrusion of denser saline marine water penetrates the estuary through the wide entrance. Mixing occurs between less-dense freshwater, and higher-density marine water. Circulation processes are complicated by the massive area of intricate dendritic drainage system (Wolanski *et al.*, 1992). The salt-wedge typically penetrates most of the estuarine system (due to a large tidal prism and tidal amplification), however during high fluvial flow events (which may be seasonal), strong river flow may force the salt-wedge in a seaward direction.
4. Exchange occurs through the wide entrance of the estuary. Tide-dominated estuaries are generally well-flushed, having a tidal prism that can be several orders of magnitude larger than the volume of freshwater input by rivers. As a consequence, lower salinity water occurs only at the head of tide-dominated estuaries due to the direct influence of the river, and the rest of the estuary contains water with salinities approaching that of the open ocean (Chin *et al.*, 1994). Flood and ebb tides may follow different routes into and out of the estuary, and the tidal prism tends to be large. In positive estuaries, the net outflow of catchment-derived water exceeds the net inflow of marine water, however this may be less significant in comparison to the large volume of the tidal prism.
5. Saltflats environments are inundated rarely (e.g. 3-4 days per month), resulting in hypersaline groundwater and often a saline crust on the surface (Ridd *et al.*, 1997).
6. Evaporation is a significant process in tide-dominated estuaries due to the extensive intertidal area (also depending on climatic conditions), however in positive estuaries does not exceed freshwater river input.

TIDE-DOMINATED ESTUARY: HYDRODYNAMICS: ("NEGATIVE" CONDITIONS)

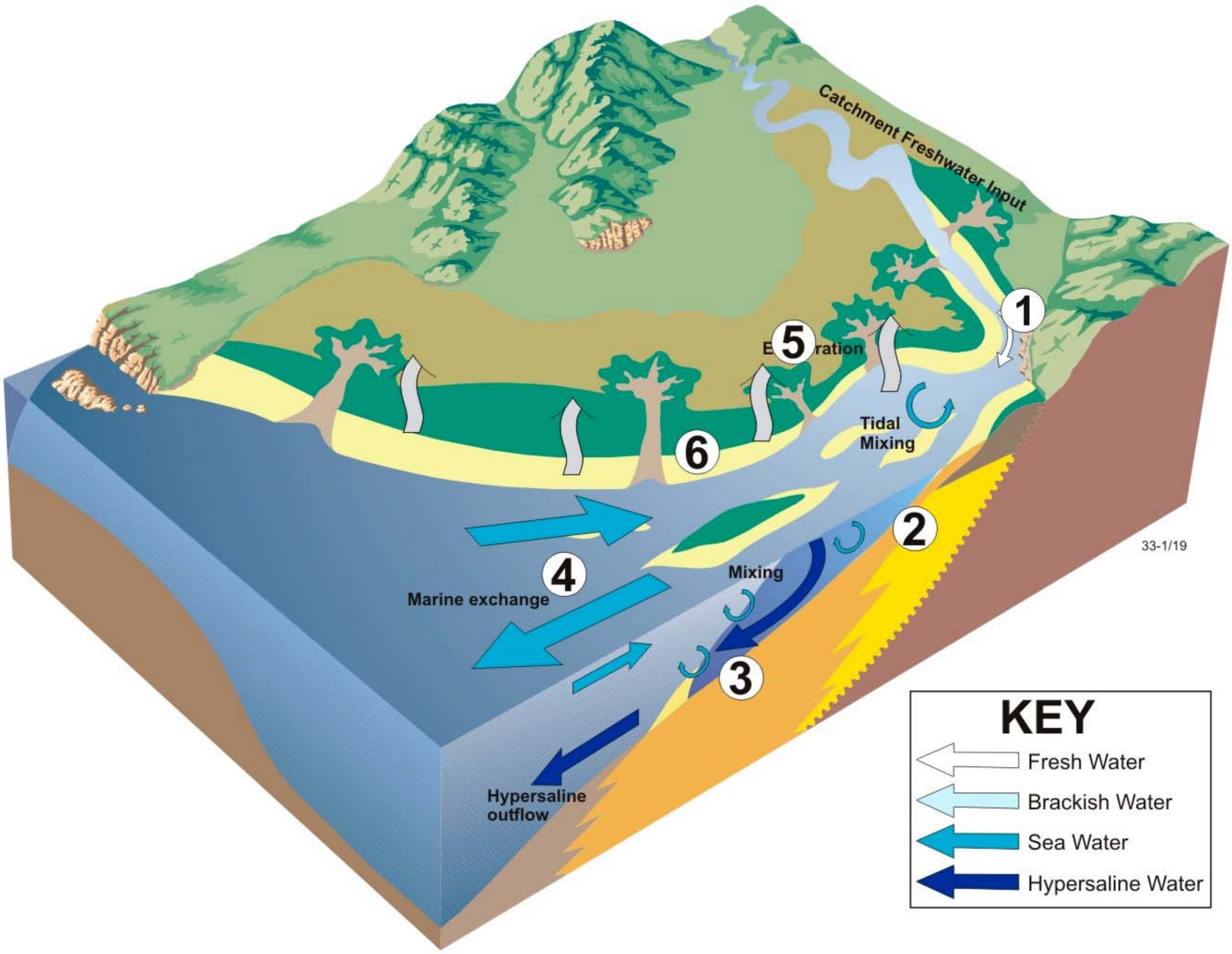

Figure 25 – Conceptual model of major hydrodynamics (negative) in a tide-dominated estuary.

TIDE-DOMINATED ESTUARY: HYDRODYNAMICS: (“NEGATIVE" CONDITIONS)

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and temporally (depending on local catchment and climatic conditions), it is typically relatively low in negative estuaries.
2. Except during extreme events, the volume of freshwater entering the estuary is typically too low to cause significant stratification (Nunes *et al.*, 1986). High tidal ranges may tend to accelerate mixing of any freshwater inputs, and marine water.
3. High rates of evaporation cause increases in salinity within the estuary. The resulting high-density hypersaline water sinks beneath the less buoyant marine water (which penetrates through the estuary mouth), and flows out of the estuarine entrance into the coastal ocean (a process known as reverse stratification)(Lennon *et al.*, 1987). A large degree of mixing occurs between the two layers (de Silva Samarasinghe *et al.*, 1987). Circulation processes are complicated by the large area of intricate dendritic drainage systems (Wolanski *et al.*, 1992).
4. Exchange of sea water and estuarine water occurs through the wide entrance of the estuary. Flood and ebb tides may follow different routes into and out of the estuary, and the tidal prism tends to be large. In negative estuaries, the net inflow of marine water exceeds the outflow of catchment-derived (fresh) water. In such cases, the hypersaline water is usually exported to the ocean (Wolanski, 1986a).
5. Saltflats environments are inundated rarely (e.g. 3-4 days per month), resulting in hypersaline groundwater and often a saline crust on the surface (Ridd *et al.*, 1997).
6. Evaporation is the dominant process in negative tide-dominated estuaries due to arid climatic conditions, and the extensive area of shallow intertidal environments. Aridity and the degree of evaporation may vary seasonally, however by definition evaporation in 'negative' estuaries is much larger than freshwater input (Heggie *et al.*, 1999). Consequently, negative estuaries tend to have longer residence times than positive estuaries (Smith *et al.*, 1989).

TIDE-DOMINATED ESTUARY: SEDIMENT DYNAMICS

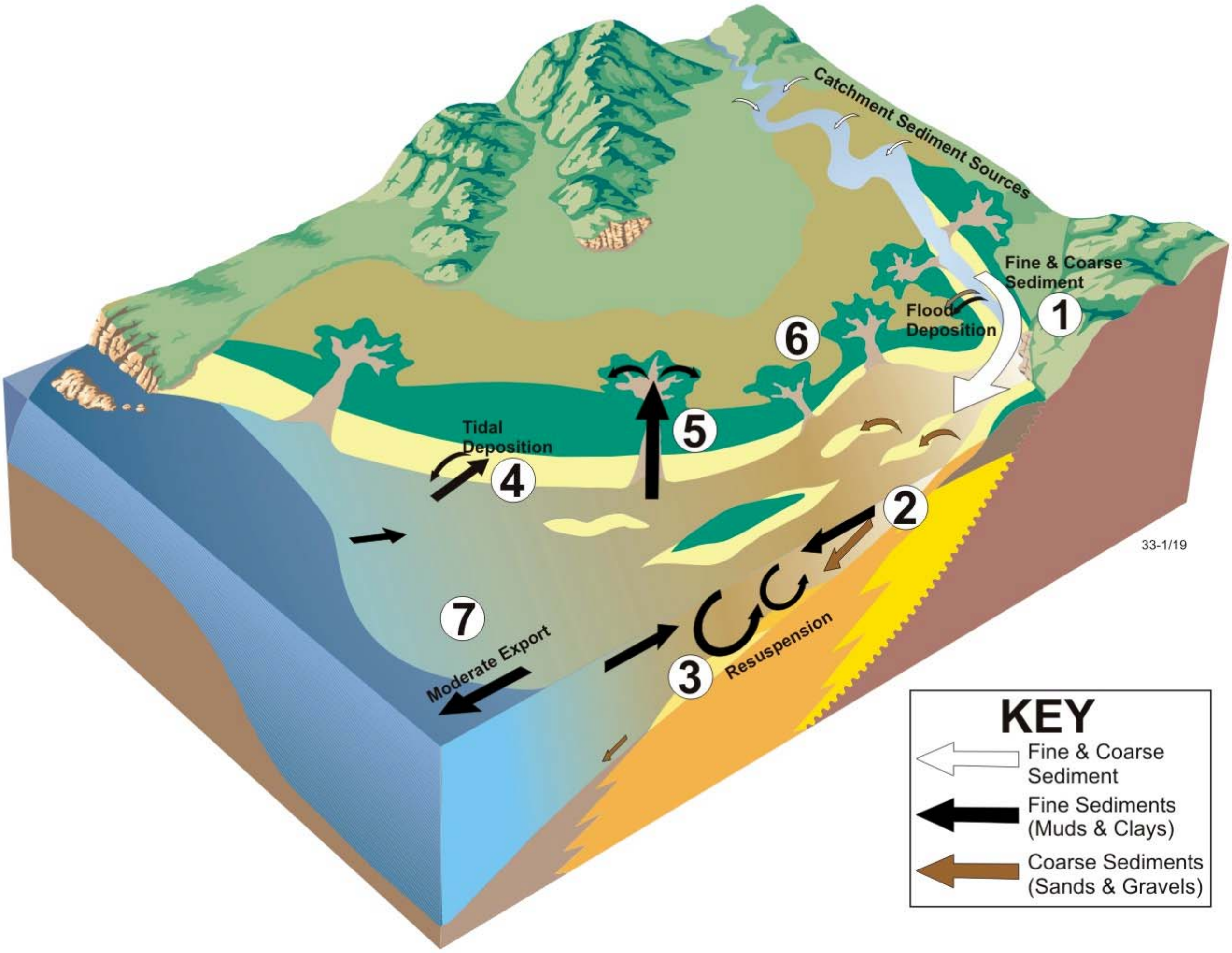

Figure 26 – Conceptual model of major sediment dynamics in a tide-dominated estuary.

TIDE-DOMINATED ESTUARY: SEDIMENT DYNAMICS

1. Fine and coarse sediment enters the estuary from the catchment. The amount of sediment input varies regionally, depending on catchment and climate conditions, and the volume of freshwater input. However, the amount of terrigenous sediment delivered to tide-dominated estuaries is usually relatively large.
2. Sediment is deposited at the point where the river flow and tidal currents meet and cancel each other out. As a result of this rapid decrease in the capacity of the river to transport sediment, most of the coarse material (such as gravels and sands) is deposited. Reworking and redeposition of material by tidal currents occurs, typically preventing the development of a distinct fluvial delta in tide-dominated estuaries.
3. Large quantities of suspended sediment are characteristic of tide-dominated estuaries - strong tidal currents continually resuspend and rework fine sediment in the channels, so that the water column is naturally highly turbid (Turner *et al.*, 1994, Wells, 1995). Quantities of fine and coarse sediment can pool temporarily within the channel, forming tidal sand banks. A zone of abnormally high suspended sediment can occur in many tide-dominated estuaries, known as the ‘turbidity maximum’ (Wells, 1995). This typically transient feature develops as a result of trapping and resuspension of particles, and contributes to the deposition of material in the tidal sand banks. High suspended sediment loads can also lead to a phenomenon known as 'fluid muds', a gel-like accumulation of low density muddy sediment which may be stationary, or mobilised by tidal currents (Wells, 1995). Turbidity is especially marked during spring tides, and the location of the turbidity maximum is variable within estuaries, depending on the tidal cycle (spring to neap) and river flow velocity (Semeniuk, 1982). Ebb and flood tides can follow mutually-evasive channels (which periodically migrate), and currents may be powerful enough to cause scouring at the channel base, leaving gravel and bioclastic debris at the base (Green *et al.*, 2000, Harris, 1988).
4. Fine sediment undergoes both deposition and erosion on the extensive intertidal flats (Dyer, 1998, Woodroffe *et al.*, 1999, Masselink *et al.*, 2000). Deposition is aided by biological activity such as burrowing and improved cohesiveness (Ruddy *et al.*, 1998, Murray *et al.*, 2002), whereas erosion is typically related to storms and tides (Dyer, 1998). Coarser material is also deposited on flanking environments by tidal currents and flood events. Over time, intertidal flats tend to expand seawards (Nichols 1999, Green *et al.*, 2001).
5. Mangrove environments, with interspersed tidal drainage channels, commonly flank tide-dominated estuaries, and serve as a depocentre for fine sediment. Tidal asymmetry (higher energy short duration flood tides, and lower energy long duration ebb tides), baffling by mangrove vegetation, and percolation of tidal water through animal burrows results in the trapping and rapid deposition of fine sediment and organic material (Bowers *et al.*, 1997, Alongi *et al.*, 2001). Over time, mangroves tend to expand onto, and replace intertidal flats (Woodroffe *et al.*, 1999).
6. Saltflat environments experience inundation only during king tides, during which some deposition of fine sediment occurs (Flood *et al.*, 1986). Sediment in supra-tidal regions (including the floodplain) is mostly mud, which is deposited during high tides or river floods (Roy *et al.*, 1981). Ebb tide waters often flow back to the main estuarine channel through tidal drainage channels.
7. The sediment trapping efficiency of tide-dominated estuaries is moderate, as they are generally highly energetic, and mixing of seawater and freshwater results in the loss of suspended sediment to the ocean (Harris *et al.*, 2003). Coarse sediment tends to be redistributed by tides, and results in the seaward expansion of intertidal habitats and infilling of the main channels with tidal sand banks. Net sediment export is more significant during floods, when large quantities of sediment are moved offshore.

TIDE-DOMINATED ESTUARY: NUTRIENT DYNAMICS

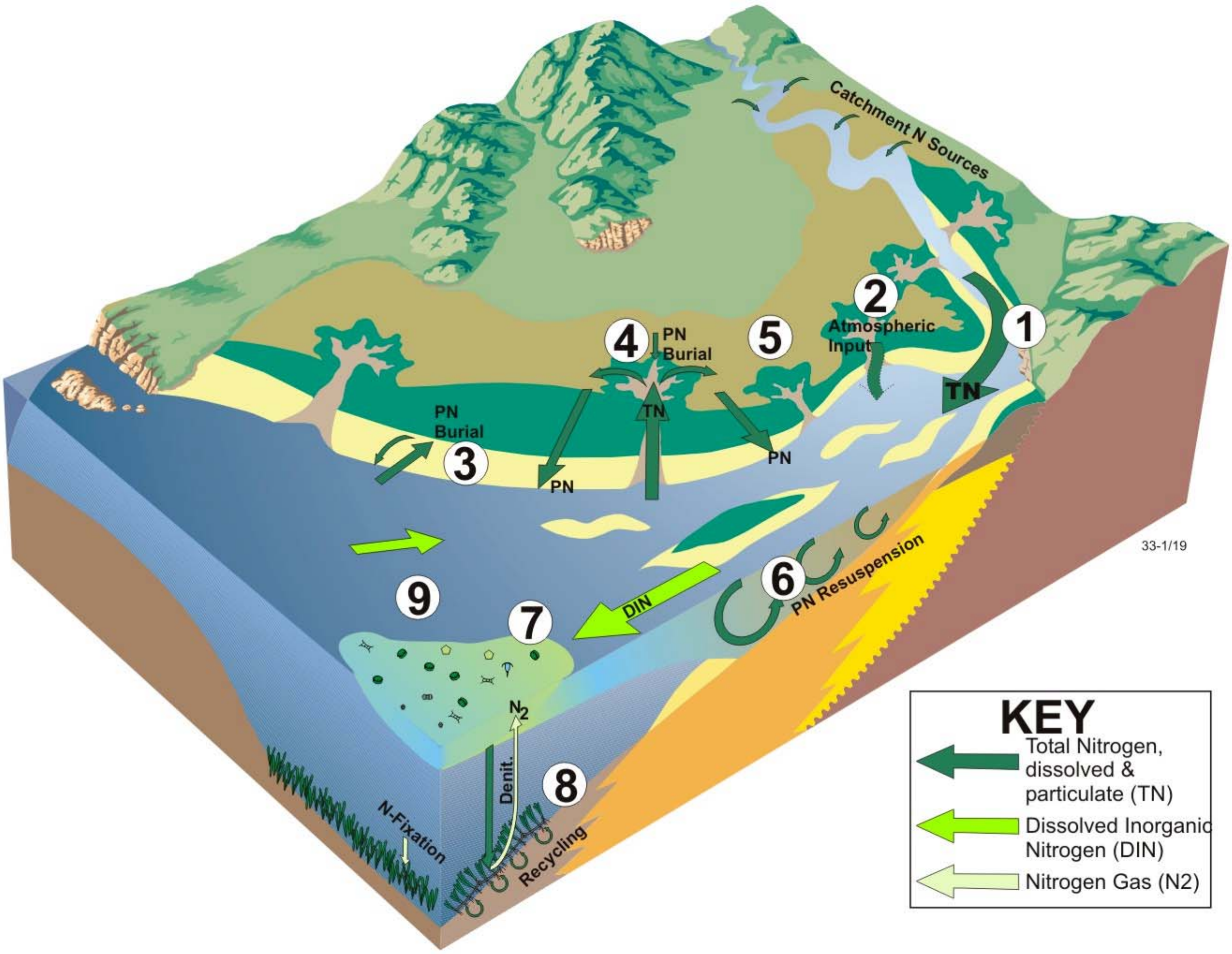

Figure 27 – Conceptual model of major nutrient (nitrogen) dynamics in a tide-dominated estuary.

TIDE-DOMINATED ESTUARY: NUTRIENT DYNAMICS

1) Nitrogen (both particulate and dissolved, or total nitrogen (TN)) enters the estuarine system from point- and non-point sources from within the catchment. River flow and nutrient input varies regionally, depending on local catchment and climatic conditions. However, the input of catchment-derived nutrients into estuaries and deltas is typically high (Harris, 2001).
2) Input of particulate N (PN) from atmospheric sources such as smoke and ash is significant in some tide-dominated estuaries.
3) Large tidal movements on the flanks of the estuary transport particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) onto the intertidal flats (Alongi *et al.*, 1999), where some of the dissolved inorganic nitrogen (DIN) is converted to particulate nitrogen (PN) through the activity of benthic micro-algae and other sediment-dwelling organisms.
4) Mangrove sediment is a net sink for dissolved inorganic nitrogen (DIN), and (PN), particulate nitrogen (Alongi, 1996). Nutrient uptake is driven by high rates of plant productivity and microbial activity. N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) is active in the root-zone and contributes to the dissolved inorganic nitrogen (DIN) pool (Kristensen *et al.*, 1998). Some N is liberated to the atmosphere as N_2 gas through denitrification (Rivera-Monroy *et al.*, 1996, Trott *et al.*, 2000). Particulate nitrogen (PN) is typically processed by sediment-dwelling biota such as crabs, or is exported to the coastal waters in the form of leaf litter and fine particulate matter (Ayukai *et al.*, 1998). This material is redistributed during ebb tides and may be exported from the estuary.
5) Small amounts of particulate nitrogen (PN) are buried in saltflats during king tides. Most particulate nitrogen (PN) is exported back into the estuarine system during the ebb tide (Ridd *et al.*, 1988).
6) Particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) exist within the water column. However due to turbidity and low light penetration, phytoplankton productivity is limited (Cloern, 1987, Monbet, 1992). Circulation and re-suspension of particulate nitrogen (PN) occurs in this zone. Particulate nitrogen (PN) is probably reworked during the resuspension process, and dissolved inorganic nitrogen (DIN) can be released into the water column through the process of remineralisation.
7) A proportion of the DIN reaches the less turbid zone at the mouth of the estuary. The nitrogen exported into the ocean is typically assimilated by marine phytoplankton, and converted into particulate nitrogen (PN).
8) Seagrasses, which colonise the tidal sand banks near the mouth of the estuary, may also process nitrogen that has been exported from within the estuary. Denitrification may also occur here (Moriarty *et al.*, 1993, Pollard *et al.*, 1993).
9) Typically, moderate quantities of nitrogen are exported to the marine environment, due to the large exchange of seawater and lack of a constricted entrance. Export is more significant during extreme flood events, when large quantities of total nitrogen (TN) and other organic material are moved offshore.

KEY FEATURES OF TIDE-DOMINATED ESTUARIES

1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas.
2. Large entrance promotes efficient marine flushing.
3. River flow is typically high, however the effects of floods are buffered by large water area, and large tidal exchange.
4. Turbidity is naturally high due to strong turbulence induced by tides.
5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats tend to trap terrigenous sediment and pollutants. Marine flushing results in loss of some material to the coastal ocean.
6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of terrigenous nutrient loads. Marine flushing results in loss of some material to the coastal ocean.
7. 'Semi-mature' in terms of evolution: infilling by marine and terrigenous sediment will result in expansion of flanking environments, narrowing of channels, and seaward progradation.

Tide-dominated Deltas

(Also known as: Riverine Estuary)

Tide-dominated deltas (Figure 28) are comprised of a river that is directly connected to the sea via channels, that are typically flanked by low-lying vegetated floodplains and swamp areas. Because of the dominance of tidal processes, the geomorphology of tide-dominated deltas features a landward tapering funnel-shaped valley, and the river is connected to the sea via a series of distributary channels. Channels may be separated by large expanses of low-gradient vegetated swamps (Bhattacharya *et al.*, 1992, Woolfe *et al.*, 1996). In Australia, tide-dominated deltas are most abundant on the north-east coast (Figure 2), and represent the 'mature' form of tide-dominated estuaries, which have largely been infilled by sediment from terrigenous and marine sources (Heap *et al.*, In Press). Because net bedload transport is offshore, tide-dominated deltas do not exhibit the 'straight-meandering-straight' channel morphology seen in many tide-dominated estuaries (Dalrymple *et al.*, 1992). Due to the degree of sediment infilling, the gross geomorphology of tide-dominated deltas may not exhibit the morphology of the antecedent valley (if present). Tidal sand banks are a major structural element within the entrances of tide-dominated deltas, and are oriented perpendicular to the coast, and aligned parallel to the direction of dominant tidal currents. The tidal sand banks are usually dissected by deep channels containing strong tidal currents (Jones *et al.*, 1993). Australia's high relative aridity, low relief, and geological antiquity has resulted in a distinct lack of large deltas (by world standards) and associated continental river systems, and total discharge of terrigenous material is small by world standards (Fryirs *et al.*, 2001). The dominance of offshore sediment transport and generally low wave-energy at the coast means that tide-dominated deltas usually construct lobate shoreline 'protuberance', which extends onto the inner continental shelf. Due to strong tidal currents generated by large tidal ranges, tide-dominated deltas are usually highly turbid.

Figure 28 - Examples of tide-dominated deltas: Burdekin River (QLD), Limmen Bight River (NT), and Norman River (QLD).

Tide-dominated deltas are distinguished by relatively high tidal energy at the mouth (compared to wave energy). Tidal sand banks dissipate any wave energy that does exist. Inside the delta, total energy increases landward, caused by amplification of the tidal wave as it penetrates into the tapering valley. Further landward, tidal energy decreases as frictional forces take effect (Dalrymple *et al.*, 1992). Further upstream, the total hydraulic energy may again be high due to river flow (Heap *et al.*, 2001), however this point of river and tidal convergence is typically nearer to the mouth in tide-dominated deltas relative to tide-dominated estuaries.

During the latter stages of deltaic evolution (or sediment infilling), the connectivity between the river channel(s) and tidal inlet increases. This results in more efficient transmission of fluvial sediment directly to the ocean, as much of the system is comprised of a floodplain area that is above the influence of most tides (Evans *et al.*, 1992). The distribution of environments such as intertidal flats, mangroves and saltmarshes is not significantly different from tide-dominated estuaries, except for the formation of tidal sand banks seaward of the mouth due to the net offshore bedload transport. Tide-dominated deltas have reached a point in their development where further evolution involves progradation of the coastline onto the inner continental shelf, although this process can be limited by sediment supply and the effects of sediment redistribution by tidal (and other) currents (Heap *et al.*, In Press).

Tide-dominated deltas provide habitats such as channels, intertidal mudflats, mangroves, saltmarshes, and saltflats (Semeniuk, 1982). These habitats typically support marine species, however the biota of these systems is less well documented than their wave-dominated counterparts (Dalrymple *et al.*, 1992). Plant productivity seems to increase with increasing tidal range, due to greater rates of flushing and the consequent renewal of nutrients (Morrisey, 1995). Littoral mangrove forests are common in many of Australia's tide-dominated deltas, however tide dominated deltas have far less mangrove and saltmarsh area relative to estuaries (Woodroffe *et al.*, 1989). Plains vegetated with grasses, sedges and herbs, as well as freshwater wetlands and floodplain vegetation (such as *Melaleuca* spp.) lie above the influence of most tides. Turbid water within the delta largely precludes the growth of subaquatic benthic macrophytes (such as seagrasses), and also limits the distribution and depth range available as habitat for phytoplankton. These organisms are able to survive further seaward due to lower turbidity (Semeniuk, 1996).

TIDE-DOMINATED DELTA: HYDRODYNAMICS

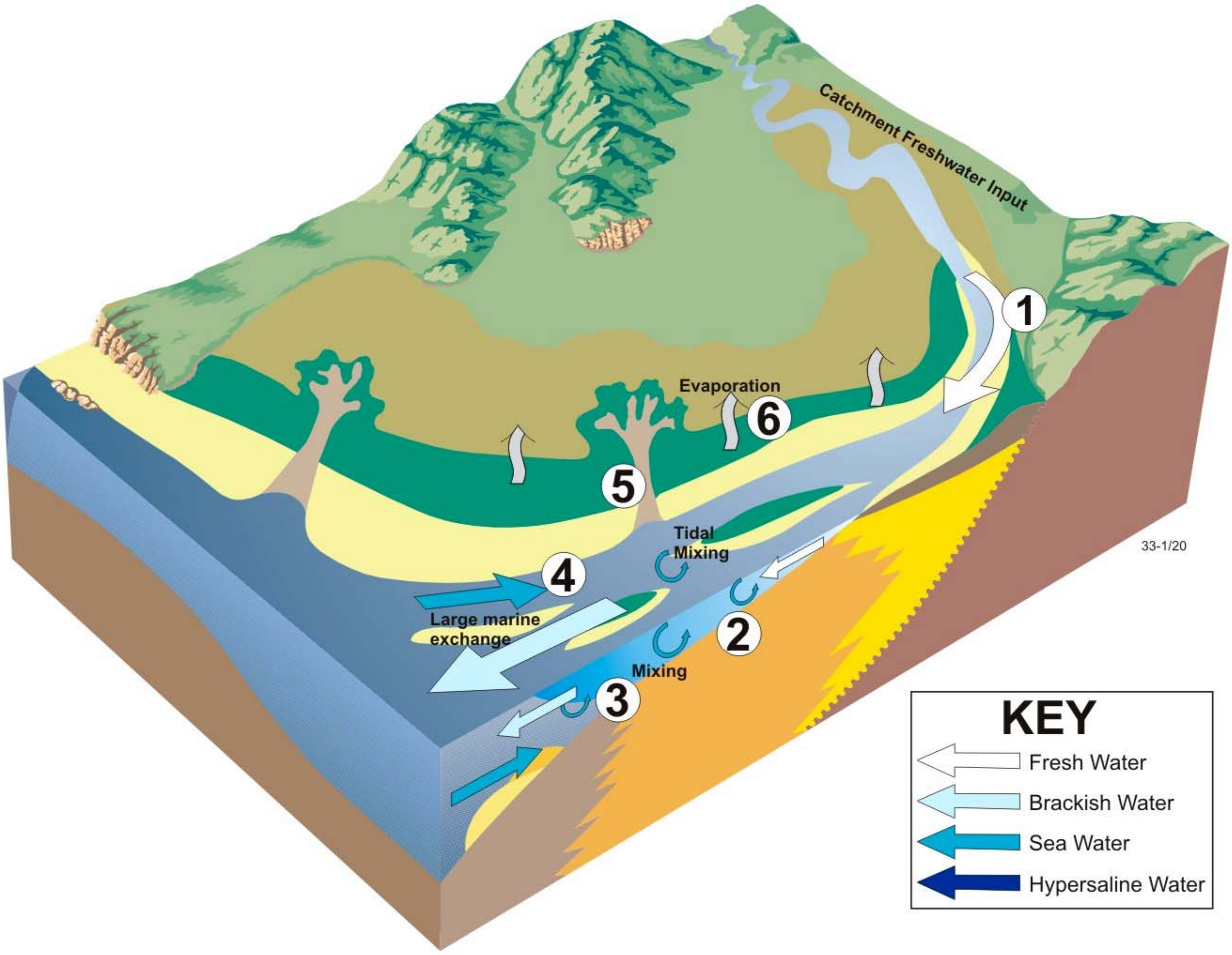

Figure 29 – Conceptual model of major hydrodynamics in a tide-dominated delta.

TIDE-DOMINATED DELTA: HYDRODYNAMICS

1. Freshwater enters from the catchment. Although the volume of freshwater input varies regionally and seasonally (depending on local catchment and climatic conditions), it is typically relatively high in most deltas.
2. The volume of freshwater may cause significant stratification within the channel, which varies with seasonal flow. Buoyant low-salinity fresh water tends to float above denser, high-salinity marine water. High tidal ranges and turbulence associated with tidal currents tends to accelerate the mixing of freshwater and marine water.
3. A 'salt-wedge', or intrusion of denser saline marine water penetrates the delta through the wide entrance. Mixing occurs between less-dense freshwater, and higher-density marine water. The salt-wedge typically penetrates most of the deltaic system (due to a large tidal prism and tidal amplification). The distance that the salt-wedge penetrates into the delta depends on the fluvial flow rate and tidal range (Kurup *et al.*, 1998, Wolanski, 1986b). Current flow in channels is quite strong, due to a small cross-sectional area, and the residence time of water (the time taken for water to travel through the delta) is typically short. During periods of extreme flow the freshwater can push the salt water seaward, beyond the mouth.
4. Exchange occurs through the wide entrance of the delta. Tide-dominated deltas are generally well-flushed, featuring a tidal prism that can be several orders of magnitude larger than the volume of freshwater input by rivers. As a consequence, lower salinity water occurs towards the head of tide-dominated delta due to the direct influence of the river, whereas the lower reaches and the entrance typically contain water with salinities approaching that of the open ocean. Flood and ebb tides may follow different routes into and out of the delta, and the tidal prism tends to be large. Except during flood conditions, the volume of freshwater is typically small in comparison to the large volume of the tidal prism (Heap *et al.*, 2001).
5. Delta-top environments (low elevation marshes) are subject to tidal influence, and the channels are subject to either reverses in flow or periods of stagnation as a flood tide balances the fluvial discharge. Overbank areas on the delta top may be more subject to flooding during periods of high fluvial discharge coupled with high tides (Nichols 1999). Saltflats environments are inundated rarely (e.g. 3-4 days per month), resulting in hypersaline groundwater and often a saline crust on the surface (Ridd *et al.*, 1997).
6. Evaporation is a significant process in tide-dominated deltas due to the extensive intertidal area (also depending on climatic conditions), however does not exceed freshwater river input.

TIDE-DOMINATED DELTA: SEDIMENT DYNAMICS

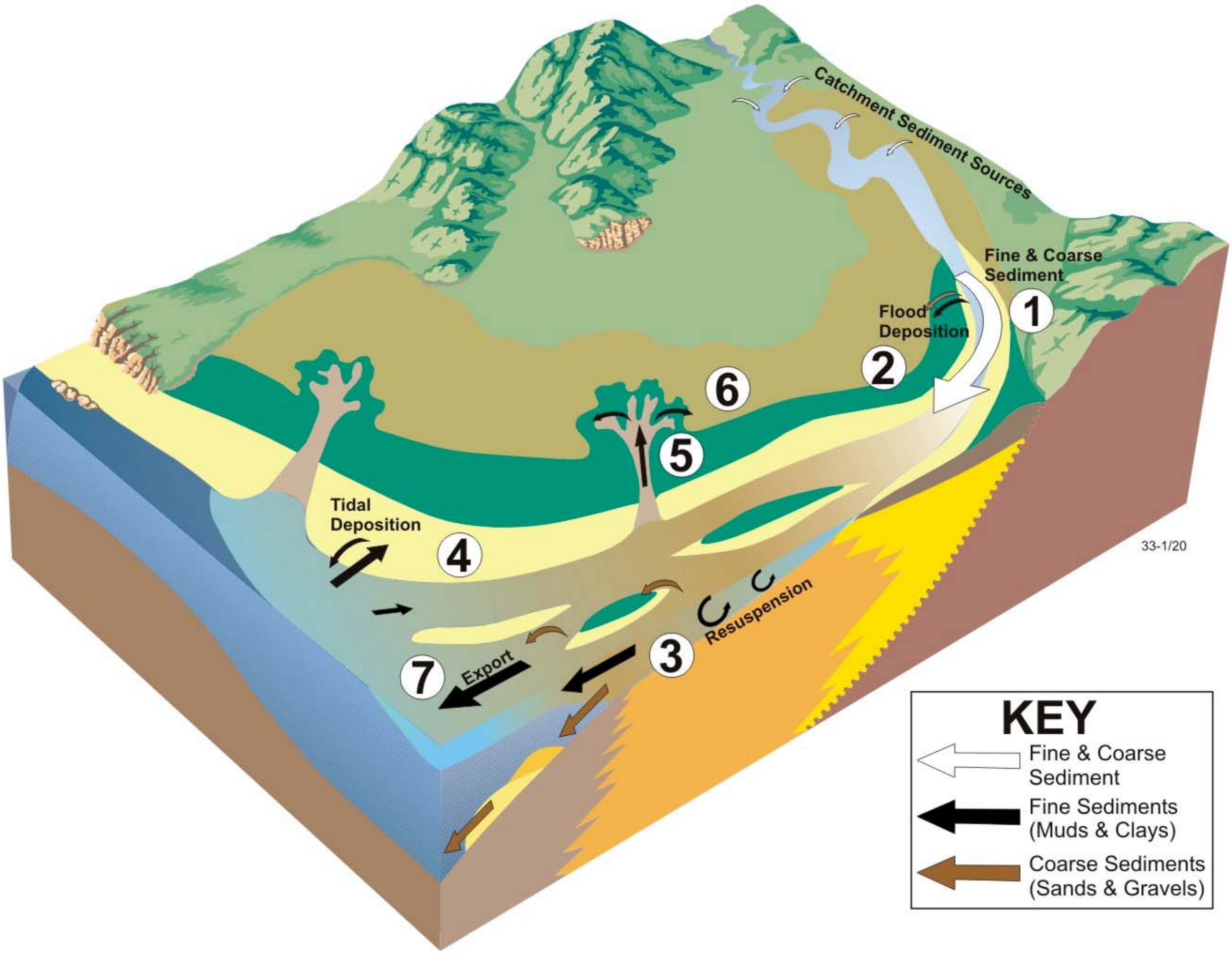

Figure 30 – Conceptual model of major sediment dynamics in a tide-dominated delta.

TIDE-DOMINATED DELTA: SEDIMENT DYNAMICS

1. Fine and coarse sediment enters the delta from the catchment. River flow and sediment supply vary regionally, depending on local catchment and climatic conditions, and the volume of river input. However, the input of catchment-derived sediment into estuaries and deltas is typically high.
2. Limited deposition of fine sediment (including clays, muds and organic material) occurs upon the floodplain during high flow events (Jones *et al.*, 1993). This is enhanced by the baffling effects of floodplain vegetation associated with swamp and marsh areas, and leads to slow vertical accretion of the floodplain. Some lateral deposition of sediment can occur, including the development of coarse sediment point-bar deposits.
3. Large quantities of suspended sediment are characteristic of tide-dominated deltas - strong tidal currents continually resuspend and rework fine sediment in the channels, so that the water column is naturally highly turbid (Turner *et al.*, 1994, Wells, 1995). Fine suspended sediment, and coarse sediment (as bedload) is moved downstream along the bottom of the deltaic channels. Quantities of fine and coarse sediment can pool temporarily within the channel, forming tidal sand banks. A zone of abnormally high suspended sediment can occur in many tide-dominated deltas, known as the 'turbidity maximum' (Wells, 1995). This typically transient feature develops as a result of trapping and resuspension of particles, and contributes to the deposition of material in the tidal sand banks. Ebb and flood tides can follow mutually-evasive channels (which periodically migrate), and deposition typically does not occur at the bottom of channels due to scouring by strong currents (Nichols 1999, Green *et al.*, 2000, Harris, 1988).
4. Fine sediment undergoes both deposition and erosion on the extensive intertidal flats (Dyer, 1998, Woodroffe *et al.*, 1999, Masselink *et al.*, 2000). Deposition is aided by biological activity such as burrowing and improved cohesiveness (Ruddy *et al.*, 1998, Murray *et al.*, 2002), whereas erosion is typically related to storms and tides (Dyer, 1998). Coarser material is also deposited on flanking environments by tidal currents and flood events. Over time, intertidal flats tend to expand seawards (Nichols 1999, Green *et al.*, 2001).
5. Mangrove environments, with interspersed tidal drainage channels, commonly flank tide-dominated deltas, and serve as a depocentre for fine sediment. Tidal asymmetry (high energy flood and lower energy ebb tides), baffling by mangrove vegetation, and percolation of tidal water through animal burrows result in rapid deposition of fine sediment and organic material (Bowers *et al.*, 1997, Alongi *et al.*, 2001). Over time, mangrove environments tend to expand onto, and replace intertidal flats (Woodroffe *et al.*, 1999).
6. Saltflat environments experience inundation only during king tides, during which some deposition of fine sediment occurs (Flood *et al.*, 1986). Sediment in supra-tidal regions (including the floodplain) is mostly mud, which is deposited during high tides or river floods Roy *et al.*, 1981). Ebb tide waters often flow back to the main estuarine channel through tidal drainage channels.
7. The majority of deposition occurs seaward of the delta mouth, and results in the export of sediment into the marine environment (Jones *et al.*, 1993). Fine suspended sediment is generally transported offshore, whereas coarser sediment tends to accumulate close to the entrance, forming an ebb-tidal delta. Quantities of coarse sediment can pool within the channel, forming tidal sand banks, and result in the seaward expansion of intertidal habitats. The sediment trapping capability of tide-dominated deltas is therefore moderate to low, as most sediment is flushed through the deltaic channels and deposited into the ocean (Harris *et al.*, 2003).

TIDE-DOMINATED DELTA: NUTRIENT DYNAMICS

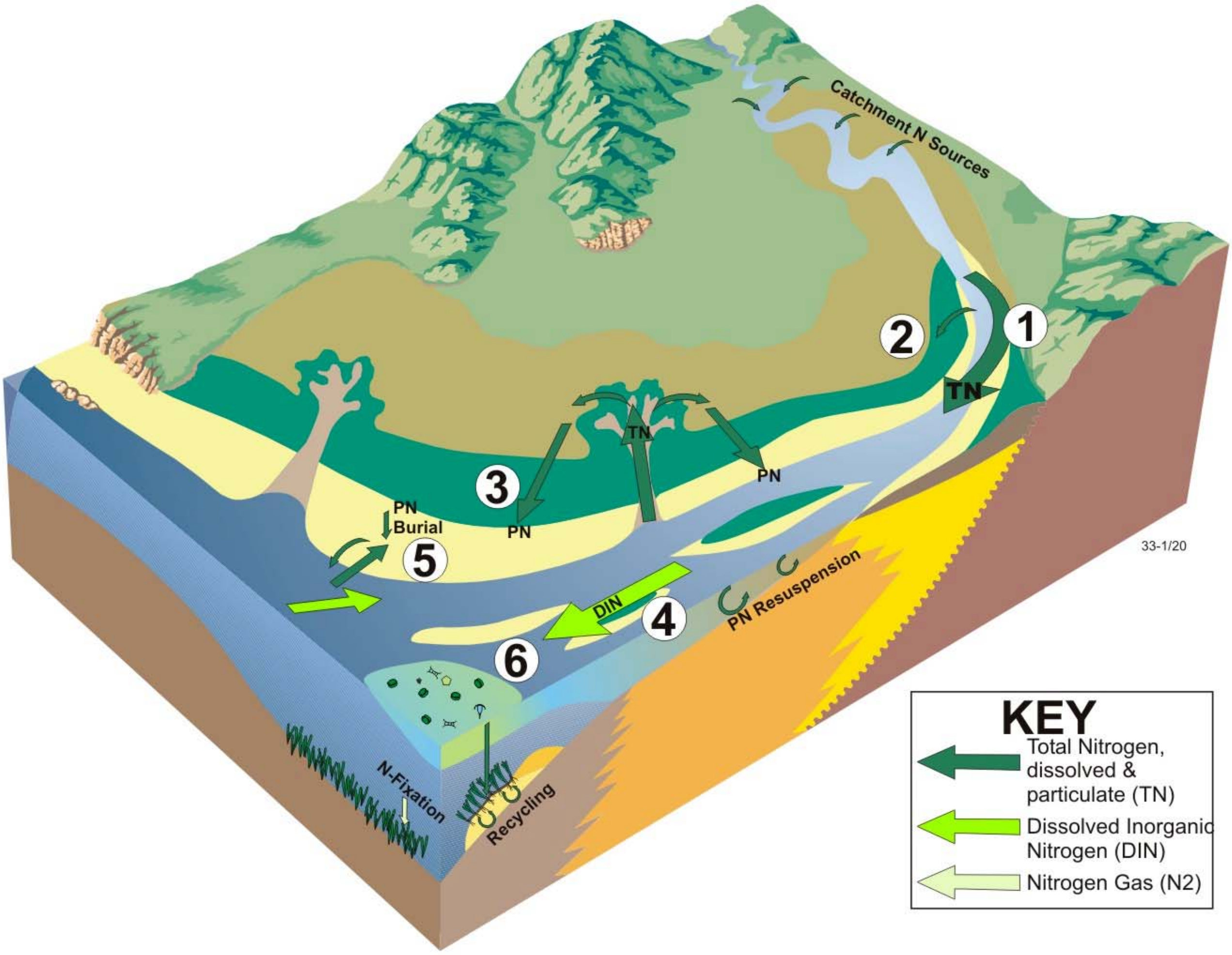

Figure 31 – Conceptual model of major nutrient (nitrogen) dynamics in a tide-dominated delta.

TIDE-DOMINATED DELTA: NUTRIENT DYNAMICS

1) Nitrogen (both particulate and dissolved, or total nitrogen (TN)) enters the deltaic channels from point- and non-point sources from within the catchment. River flow and nutrient input varies regionally, depending on local catchment and climatic conditions. Typically, a high proportion of catchment-derived nutrient material is transported into estuaries and deltas (Harris, 2001).
2) Limited deposition of particulate nitrogen (PN) occurs upon the floodplain during high flow events. This process is enhanced by the effects of 'baffling' by floodplain vegetation. Biological uptake of DIN also occurs on the flanks of the river channel.
3) Mangrove sediment is a net sink for dissolved inorganic nitrogen (DIN), and (PN) particulate nitrogen (Alongi, 1996). Nutrient uptake is driven by high rates of plant productivity and microbial activity. N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) is active in the root-zone and contributes to the dissolved inorganic nitrogen (DIN) pool (Kristensen *et al.*, 1998). Some N is liberated to the atmosphere as N_2 gas through denitrification (Rivera-Monroy *et al.*, 1996, Trott *et al.*, 2000). Particulate nitrogen (PN) is typically processed by sediment-dwelling biota such as crabs, or is exported to the coastal waters in the form of leaf litter and fine particulate matter (Ayukai *et al.*, 1998). This material is redistributed during ebb tides and may be exported from the delta.
4) The majority of the river-borne TN is transported through the delta by strong downstream displacement. Deposition typically does not occur in the channels due to strong tidal and fluvial scouring. Penetration of strong tidal currents result in high turbidity in the deltaic channels, which tends to limit the activity of phytoplankton (Cloern, 1987, Monbet, 1992).
5) Tidal movements on the flanks of the delta transport particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) onto the intertidal flats (Alongi *et al.*, 1999), where some of the DIN is converted to PN through the activity of benthic micro-algae.
6) A large proportion of the total nitrogen (TN) load is exported through the mouth of the delta into the marine environment. Assimilation of nutrients by phytoplankton the marine environment is typical, as turbidity levels become lower in the marine environment.

KEY FEATURES OF TIDE-DOMINATED DELTAS

1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas.
2. Large entrance promotes efficient marine flushing.
3. River flow typically high, and flooding may expel marine water and flush material from the delta.
4. Turbidity is naturally high due to strong turbulence induced by tides.
5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats may trap terrigenous sediment and pollutants. River flow and marine flushing result in the loss of some material to the coastal ocean.
6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of terrigenous nutrient loads. River flow and marine flushing result in the loss of some material to the coastal ocean.
7. 'Mature' in terms of evolution. Tend to be stable in terms of morphology (given stable sea level).

Tidal Creeks

(Also known as: Tidal Channels, Mangrove Creeks, Macrotidal Mud Flats)

Tidal creeks are wide, funnel-shaped coastal waterways, that have very low (or negligible) freshwater input, and typically develop in low-gradient, seaward-sloping coastal flats (Figure 32; Dalrymple, 1992, Semeniuk, 1996, Semeniuk, 1982, Semeniuk *et al.*, 1982). Tidal creeks are the most common type of coastal waterway in Australia, and are most abundant in north-western Australia and the Gulf of Carpentaria, where they occur along mostly macrotidal, low-gradient coastal plains (Figure 2). Due to the overwhelming influence of tidal currents in these systems, the geomorphology of tidal creeks is usually comprised of a straight, sinuous, or dendritic tidal channel(s) that taper (in a negative-exponential fashion upstream) and shoal to landward (Wolanski *et al.*, 1992). The coastal mudflats that generally surround tidal creeks tend to be at or above the limit of high tide, and seawater is mainly confined to the tidal channel, except during spring tides. Because of their relatively small size, and low freshwater input, they lack the major structural elements such as tidal sand banks that are characteristic of tide-dominated estuaries and deltas. Tidal channels are frequently interconnected, and flanked by large areas of low-gradient intertidal flats, mangroves, saltmarsh, and salt flat environments (Wells, 1995). The outline of tidal creeks may partially follow the irregular outline of the drowned bedrock embayments in which they have developed (Riggs *et al.*, 1995), or may be smooth and funnel-shaped, sometimes intersected by smaller creek networks (Wells, 1995). Tidal creeks are highly variable in size (Heap *et al.*, 2001) and, due to strong tidal currents generated by large tidal ranges, are usually highly turbid.

Figure 32 - Examples of tidal creeks: Ilamaryi River (NT), Morning Inlet (QLD), and Barker Inlet (SA).

Tidal creeks are generally distinguished by relatively high tidal energy throughout the system. However, frictional forces reduce tidal energy to landward, and in some of the more tapered systems, amplification of the tidal wave occurs to locally to elevate water levels inside the system and on the surrounding intertidal flats (Dalrymple *et al.*, 1992).

The evolution of tidal creeks is characterised by slow progradation and seaward translation of the tidal channel and surrounding intertidal flats, which is driven mostly by landward transport of marine sediment (Belperio, 1993, Woodroffe, 1992). Because of the low freshwater input, the system does not usually contain an alluvial floodplain, and remains bounded by intertidal environments, even in the most mature cases (Boyd *et al.*, 1992, Green *et al.*, 2001, Fitzgerald *et al.*, 2000). Marine sediment moves into tidal creeks by shoreward-directed bedload transport, and infilling occurs as the channel shoals, and the intertidal flats merge (Harris, 1988, Knighton *et al.*, 1992).

Tidal creeks provide habitats, such as channel sands, intertidal mudflats, mangroves, saltmarshes, saltflats and rocky shores and rocky reefs in some areas (Semeniuk, 1996, Semeniuk, 1982, Semeniuk *et al.*, 1982, Barnett *et al.*, 1997). These habitats typically support marine species, including transient visitors and permanent residents, however the biota of these waterways is less well documented than their wave dominated counterparts (Connolly *et al.*, 2000, Dalrymple *et al.*, 1992). Plant productivity seems to increase with increasing tidal range, due to greater rates of flushing and the consequent renewal of nutrients (Morrisey, 1995). Littoral mangrove forests dominate many of Australia's tide-dominated coasts, and plains vegetated with grasses, sedges and herbs, as well as freshwater wetlands and floodplain vegetation (such as *Melaleuca* spp.) lie above the influence of most tides. Turbid water within the channels largely precludes the growth of subaquatic benthic macrophytes (such as seagrasses), and also limits the distribution and depth range available as habitat for phytoplankton. These species are able to survive further seaward due to lower turbidity (Semeniuk, 1996).

TIDAL CREEK: HYDRODYNAMICS

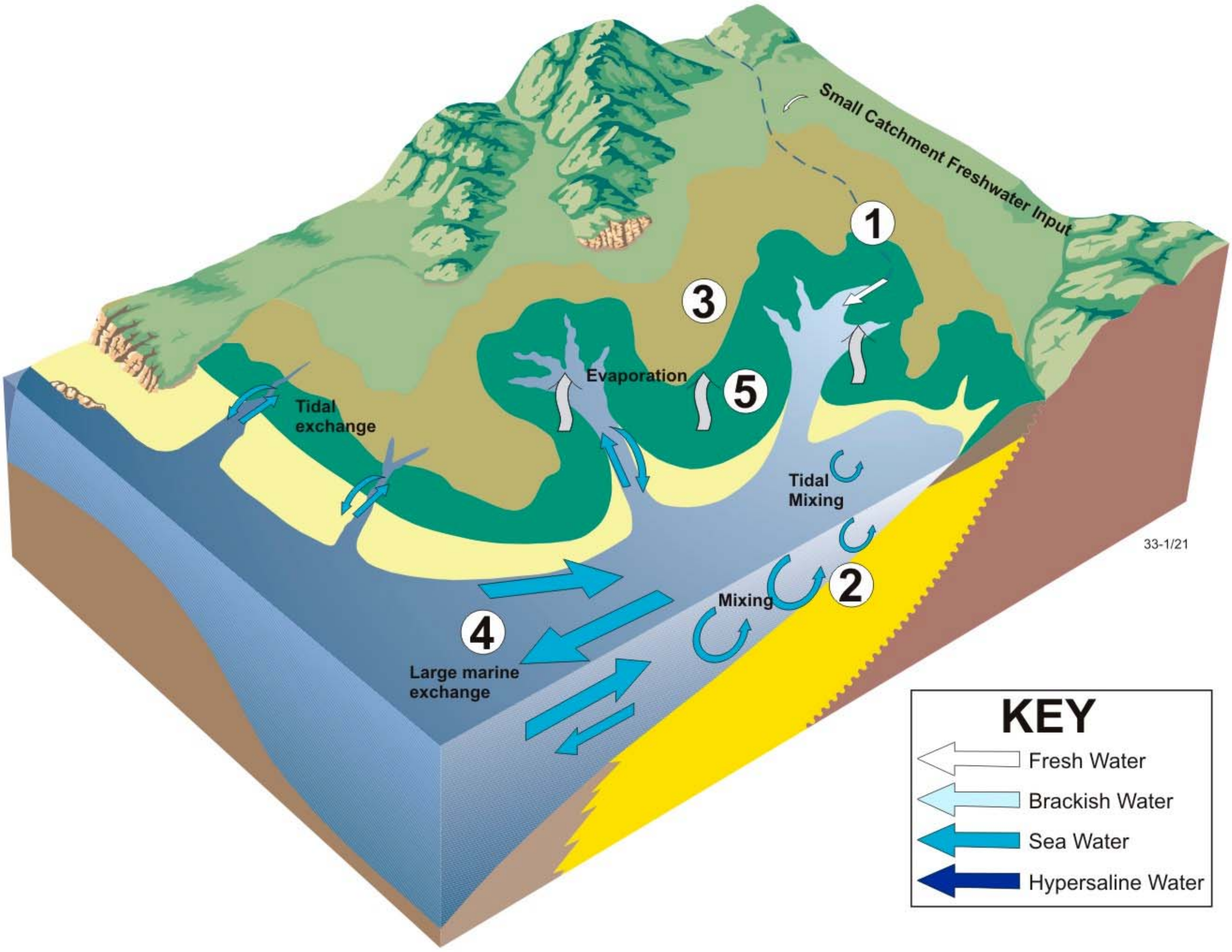

Figure 33 – Conceptual model of major hydrodynamics in a tidal creek.

TIDAL CREEK: HYDRODYNAMICS

1. Very little freshwater enters from the catchment, which itself may be very small. The quantity of freshwater input can vary seasonally, depending on regional climatic conditions, however is, by definition, very low in tidal creeks. Tidal creeks lack distinct river or creek input channels, and receive freshwater from sheet runoff only. Groundwater input may also be a significant source of freshwater.
2. Tidal creeks typically exhibit very well-mixed water circulation conditions, due to the mixing effect of strong tidal currents. Circulation processes are complicated by the large area of intricate dendritic drainage system (Wolanski *et al.*, 1992). Mixing regimes may also vary seasonally (Eyre, 1998, Digby *et al.*, 1996). Salinity is homogenous throughout the channels, and due to the limited input of freshwater, stratification does not occur. The tidal range within tidal creeks may be amplified in comparison to the adjacent coastal ocean (depending on the geometry of the channel), and tides also tend to penetrate further inland with increasing tidal range.
3. Saltflats environments are inundated rarely (e.g. 3-4 days per month), resulting in hypersaline groundwater and often a saline crust on the surface (Ridd *et al.*, 1997).
4. Exchange of marine water occurs through the wide entrance of the tidal creek. Flood and ebb tides may follow different routes into and out of the tidal creek, and the volume of the tidal prism tends to be large (Wolanski, 1986b).
5. Evaporation is a significant process in tidal creeks due to the extensive intertidal area (also depending on climatic conditions). Hypersaline conditions may occur (particularly in arid regions) if dry weather conditions continue for a long period (Heggie *et al.*, 1999b, Yassini *et al.*, 1995), however due to mixing this typically does not cause significant stratification.

TIDAL CREEK: SEDIMENT DYNAMICS

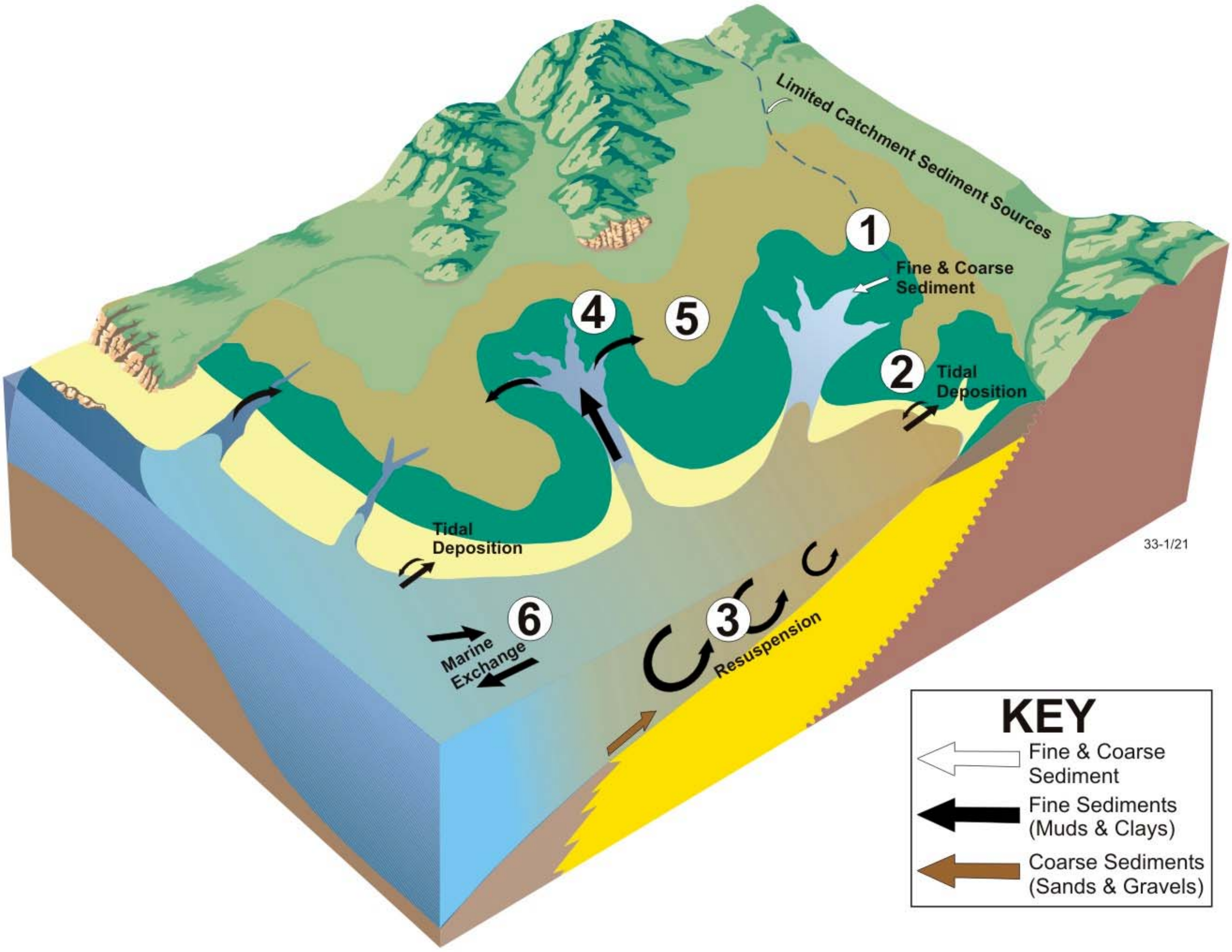

Figure 34 – Conceptual model of major sediment dynamics in a tidal creek.

TIDAL CREEK: SEDIMENT DYNAMICS

1. Sediment inputs from the catchment are less important in tidal creeks - significant input typically occurs during high rainfall events only. Most terrigenous sediment tends to be fine, and is derived from sheet runoff and aeolian inputs. Landward movement of marine-derived sediment is more important in tidal creeks.
2. Fine sediment (including muds and clays) undergoes both deposition and erosion on the extensive intertidal flats (Dyer, 1998, Woodroffe *et al.*, 1999, Masselink *et al.*, 2000). Deposition is aided by biological activity such as burrowing and improved cohesiveness (Ruddy *et al.*, 1998, Murray *et al.*, 2002), whereas erosion is typically related to storms and tides (Dyer, 1998). Coarser material (sands and gravels) is also deposited on flanking environments by tidal currents and extreme runoff events. Over time, intertidal flats tend to slowly expand seawards (Nichols 1999, Green *et al.*, 2001).
3. Large quantities of suspended sediment are characteristic of tidal creeks - strong tidal currents continually resuspend and rework fine sediment in the channels, so that the water column is naturally highly turbid (Turner *et al.*, 1994, Wells, 1995). Turbidity is especially marked during spring tides (Semeniuk, 1982). Ebb and flood tides can follow mutually-evasive channels (which periodically migrate), and currents may be powerful enough to cause scouring at the channel base, leaving gravel and bioclastic debris at the base (Nichols 1999, Green *et al.*, 2000, Harris, 1988). Tidal creeks lack significant quantities of terrigenous sediment, and comprise predominantly marine sediment.
4. Mangrove environments, with interspersed tidal drainage channels, commonly flank tidal creeks, and serve as a depocentre for sediment (Boyd *et al.*, 1992, Woodroffe *et al.*, 1993, Barnett *et al.*, 1997). Tidal asymmetry (high energy short duration flood and lower energy long duration ebb tides), baffling by mangrove vegetation, and percolation of tidal water through animal burrows result in rapid deposition of fine sediment, and accumulation of coarse sediment derived from the shelf. Over time, mangrove environments tend to expand onto and replace intertidal flats (Woodroffe *et al.*, 1999).
5. Saltflat environments experience inundation only during king tides, during which some deposition of fine sediment occurs. Sediment in supra-tidal regions (including the floodplain) is mostly mud, and is deposited during high tides (Roy *et al.*, 1981). Ebb tide waters often flow back to the main estuarine channel through tidal drainage channels.
6. Typically, net movement of coarse sediment occurs in a landward direction, resulting in the slow infilling of tidal creeks by marine sediment from the continental shelf (Green *et al.*, 2001, Bryce *et al.*, 1998). During extreme rainfall events, small quantities of sediment may be exported to the marine environment. The ability of tidal creeks to trap catchment derived sediment is therefore moderate to low (Harris *et al.*, 2003).

TIDAL CREEK: NUTRIENT DYNAMICS

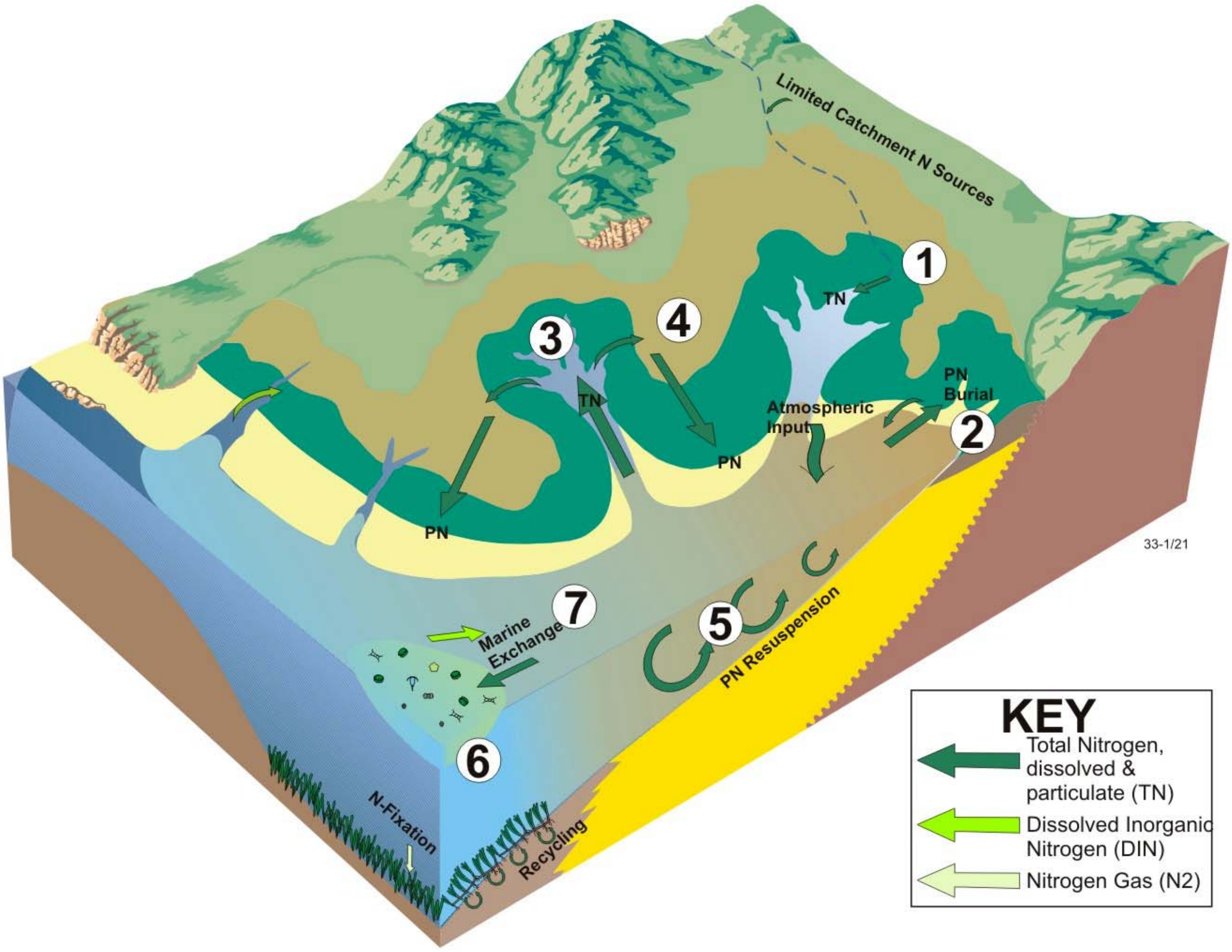

Figure 35 – Conceptual model of major nutrient (nitrogen) dynamics in a tidal creek.

TIDAL CREEK: NUTRIENT DYNAMICS

1) Catchment-derived sources of nitrogen are less important in tidal creeks - significant input typically occurs during extreme rainfall events only (Harris, 2001).
2) Large tidal movements on the flanks of the tidal creek transport particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) onto the intertidal flats (Alongi *et al.*, 1999), where some of the dissolved inorganic nitrogen (DIN) is converted to particulate nitrogen (PN) through the activity of benthic micro-algae and other sediment-dwelling organisms.
3) Mangrove sediment is a net sink for dissolved inorganic nitrogen (DIN) and (PN) particulate nitrogen (Alongi, 1996). Nutrient uptake is driven by high rates of plant productivity and microbial activity. N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) is active in the root-zone and contributes to the dissolved inorganic nitrogen (DIN) pool (Kristensen *et al.*, 1998). Some N is liberated to the atmosphere as N_2 gas through denitrification (Rivera-Monroy *et al.*, 1996, Trott *et al.*, 2000). Particulate nitrogen (PN) is typically processed by sediment-dwelling biota such as crabs, or is exported to the coastal waters in the form of leaf litter and fine particulate matter (Ayukai *et al.*, 1998). This material is redistributed during ebb tides and may be exported from the tidal creek.
4) Small amounts of particulate nitrogen (PN) are buried in saltflats during king tides. Most particulate nitrogen (PN) is exported back into the channel during the ebb tide (Ridd *et al.*, 1988).
5) Particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) exist within the water column. However due to turbidity and low light penetration, phytoplankton productivity is limited (Cloern, 1987, Monbet, 1992). Circulation and re-suspension of particulate nitrogen (PN) occurs in this zone. Particulate nitrogen (PN) is probably reworked during the resuspension process, and dissolved inorganic nitrogen (DIN) can be released into the water column through the process of remineralisation.
6) A proportion of the total nitrogen (TN) load escapes through the mouth of the tidal creek into the marine environment. Assimilation of nutrients by phytoplankton the marine environment is typical, as turbidity levels become lower in the marine environment.
7) Typically, only small quantities of the catchment-derived total nitrogen (TN) load is exchanged with the marine environment, due to efficient trapping and processing by intertidal vegetation. Export is more significant during extreme runoff events.

KEY FEATURES OF TIDAL CREEKS

1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas.
2. Large entrance promotes efficient marine flushing.
3. River flow is intermittent to non-existent. Flooding is therefore uncommon, however, the effects of any floods are buffered by the large water area and high tidal exchange.
4. Turbidity is naturally high due to strong turbulence induced by tides.
5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats tend to trap sediment and pollutants. Marine flushing results in loss of some material to the coastal ocean.
6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of nutrient loads. Marine flushing results in loss of some material to the coastal ocean.
7. Evolution, in terms of infilling, is driven by trapping of marine sediment, which results in the gradual expansion of flanking environments and seaward progradation.

DISCUSSION - CONCEPTUAL MODELS AS A TOOL FOR THE MANAGEMENT OF ESTUARIES AND COASTAL WATERWAYS

Estuaries and coastal waterways are an extremely important natural resource from many perspectives, and are clearly in need of more integrated and holistic management approaches in order to understand their driving processes, and maintain their function into the 21st century. The conceptual understanding incorporated in this study is an important step towards this goal, as it represents the first occasion in which multi-disciplinary information for hundreds of estuaries and coastal waterways, on a continental scale, has been integrated. Geomorphology (and sediment) provide the substrate for estuarine habitats, which determine the 'function' of the coastal waterway, essential for maintaining environmental 'health'. The conceptual diagram representations of each of the seven main classes of coastal waterway demonstrate the important differences in processes and management implications between classes (Table 4).

Table 4 - Summary of the key functional characteristics of Australian estuaries and coastal waterways (refer to individual conceptual model diagrams for full explanation of processes, and references).

Coastal Waterway	Summarised Characteristics
Embayments (Figures 6-9)	1. Habitats are typically marine, with extensive subtidal environments and very narrow intertidal environments. 2. Large entrance and efficient marine flushing, even in microtidal regions. Deep water. 3. River flow varies, floods are buffered and do not expel marine water due to large water area. 4. Turbidity and extent of intertidal habitats are dependant on local tidal range 5. Sediment (and associated contaminants) are generally not trapped. Typically floored by coarse sediment. 6. Nutrient dynamics are generally similar to the coastal ocean, and are largely dominated by oceanic 'upwelling' events. 7. 'Immature' in terms of evolution: morphology may change over time due to infilling. This change is likely to be slow due to the large volume.
Wave-dominated Estuaries (Figures 10-14)	1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. 2. Narrow entrance restricts marine flushing, only a small proportion of the estuarine water volume is exchanged each tide 3. River flow typically high, and flooding may expel marine water and flush material from the estuary. 4. Turbidity, in terms of suspended sediment, is naturally low except during extreme wind or fluvial runoff events. 5. Central basin is an efficient 'trap' for terrigenous sediment and pollutants 6. Long residence time encourages trapping and processing (e.g. denitrification) of terrigenous nutrient loads. 7. 'Semi-mature' in terms of evolution: morphology will rapidly change over time due to infilling, resulting in shallowing of the central basin, and expansion of the fluvial delta.
Wave-dominated Deltas (Figures 15-18)	1. Habitats supported are variable, generally mostly brackish subtidal, intertidal and supratidal habitats are supported. 2. Narrow entrance restricts marine flushing, only a small proportion of the water volume is exchanged each tide. 3. River flow typically high, and flooding commonly expels marine water and flushes material from the delta. 4. Turbidity, in terms of suspended sediment, is highly dependant on catchment inflow, however is naturally low except during extreme fluvial runoff events. 5. Sediment (and associated contaminants) are mostly expelled into the coastal ocean. 6. Short residence time (e.g. efficient flushing) results in little processing or trapping of nutrients. 7. 'Mature' in terms of evolution. Tend to be stable in terms of morphology (given stable sea level).
Coastal Lagoons and Strandplain	1. Habitats supported are limited by chemical conditions induced by poor exchange with the marine environment, and highly variable salinity. 2. Intermittent entrance isolates the coastal waterway from the ocean for long periods.

Creeks (Figures 19-22)	3. River flow is intermittent to non-existent. Flooding is therefore uncommon, however can cause large impacts such as entrance breaching and scouring of the central basin. 4. Turbidity is naturally low, however shallow basins are susceptible to wind-wave resuspension, particularly if seagrasses are not present. 5. Central basin (where present) is an efficient 'trap' for terrigenous sediment and pollutants. 6. Long residence time encourages trapping and processing (e.g. denitrification) of terrigenous nutrient loads, however the system may be susceptible to overloading due to small size. 7. Evolution, in terms of infilling, is very slow due to the lack of significant sediment input.
Tide-dominated Estuaries (Figure 23-27)	1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas. 2. Large entrance promotes efficient marine flushing. 3. River flow typically high, however the effects of floods are buffered by large water area and high tidal exchange. 4. Turbidity is naturally high due to strong turbulence induced by tides. 5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats tend to trap terrigenous sediment and pollutants. Marine flushing results in loss of some material to the coastal ocean. 6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of terrigenous nutrient loads. Marine flushing results in loss of some material to the coastal ocean. 7. 'Semi-mature' in terms of evolution: infilling by marine and terrigenous sediment will result in expansion of flanking environments, narrowing of channels, and seaward progradation.
Tide-dominated Deltas (Figures 28-31)	1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas. 2. Large entrance promotes efficient marine flushing. 3. River flow typically high, and flooding may expel marine water and flush material from the delta. 4. Turbidity is naturally high due to strong turbulence induced by tides. 5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats may trap terrigenous sediment and pollutants. River flow and marine flushing result in the loss of some material to the coastal ocean. 6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of terrigenous nutrient loads. River flow and marine flushing result in the loss of some material to the coastal ocean. 7. 'Mature' in terms of evolution. Tend to be stable in terms of morphology (given stable sea level).
Tidal Creeks (Figures 32-35)	1. A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Intertidal and supratidal areas are often extensive, whereas turbidity may preclude seagrasses in some areas. 2. Large entrance promotes efficient marine flushing. 3. River flow is intermittent to non-existent. Flooding is therefore uncommon, however, the effects of any floods are buffered by the large water area and high tidal exchange. 4. Turbidity is naturally high due to strong turbulence induced by tides. 5. Flanking environments such as intertidal flats, mangroves, saltmarshes and saltflats tend to trap sediment and pollutants. Marine flushing results in loss of some material to the coastal ocean. 6. Tidal movement over flanking environments encourages the trapping and processing (e.g. denitrification) of nutrient loads. Marine flushing results in loss of some material to the coastal ocean. 7. Evolution, in terms of infilling, is driven by trapping of marine sediment, which results in the gradual expansion of flanking environments and seaward progradation.

The conceptual model diagrams provide an ideal framework for explaining the processes outlined in Table 4 to managers, the general public, and other groups involved in the coastal zone. Following are some examples of how the conceptual understanding of estuaries and coastal waterways can assist in the application of environmental indicators, and also a simple case study demonstrating the links between geomorphic form and environmental function in a specific Australian estuary.

Application of Conceptual Understanding to Environmental Indicators

Environmental indicators are parameters that can be used to provide a measure of water quality or ecosystem condition (Environment Australia, 2002). The conceptual models constructed in this study can assist in the customising of relevant 'trigger values' (values for key indicators, above or below which there is a risk of adverse biological effects) and targets appropriate for the general application of indicators (ANZECC and ARMCANZ, 2000, Environment Australia, 2002). Table 5 illustrates some key examples of areas in which conceptual models can aid the use and application of environmental indicators.

Table 5 - Application and relevance of key environmental indicators to different types of estuaries and coastal waterways (after Smith *et al.*, 2002).

Environmental Indicator (ANZECC & ARMCANZ 2000)	**Relevance to Coastal Waterways**
Turbidity	Naturally higher in tide-dominated systems (Figures 23-35) because tidal currents resuspend fine sediment (Heap *et al.*, 2001).
Chlorophyll a	Naturally lower in tide-dominated systems (Figures 23-35) because tidal mixing reduces the residence time of algae in the photic zone, and because sediment resuspended by tides increases turbidity, which reduces light available for photosynthesis (Monbet, 1992).
Dissolved Nutrients	Natural levels are probably higher in tide-dominated systems (Figures 23-35), because turbidity and mixing reduce the capacity of plants and algae to take up the nutrients.
Total nitrogen and total phosphorus	Natural levels are probably higher in tide-dominated systems (Figures 23-35) because turbidity and mixing reduce biological uptake, and because particulate nutrients are associated with suspended sediment.
pH	The pH of coastal waterways depends on many factors making differences between wave- and tide-dominated systems difficult to predict. However, tide-dominated systems (Figures 23-35) should have less photosynthetic consumption of carbon dioxide (for above reasons), and are more likely to be impacted by low-pH runoff from acid sulfate soils than wave-dominated systems.
Dissolved Oxygen	Dissolved oxygen in coastal waterways depends on many factors making differences between wave- and tide-dominated systems difficult to predict. However, tide-dominated systems (Figures 23-35) may have less photosynthetic production of dissolved oxygen but more replenishment of dissolved oxygen by tidal exchange.
Heavy Metals, toxicants (&organic matter)	The central basins of wave-dominated estuaries (Figures 10-14) and coastal lagoons (Figures 19-22) are important sinks for fine sediment, organic matter and sediment-bound contaminants. Flanking environments (mangroves and salt marshes) are the main sink for contaminants in tide-dominated systems (Figures 23-35).
Denitrification Efficiency	Denitrification efficiency is a good indicator of sustainable carbon loading rates in embayments, coastal lagoons, and wave-dominated estuaries, when it is coupled to nitrification occurring in the sediment. Denitrification efficiency is probably not a good indicator of sustainable carbon loadings in coastal waterways in which denitrification is linked to nitrate in the water column (Eyre and Ferguson, 2002a). High water column nitrate concentrations are likely to be found in waterways with large amounts of suspended sediment because these conditions reduce the amount of light available for photosynthesis, and therefore the ability of plants to take up nutrients. Denitrification efficiency is therefore not a good indicator in tide-dominated systems.
Mangrove area, Saltmarsh area	Mangroves and salt marshes are naturally more ubiquitous and widespread in tide-dominated systems (Figures 23-35) compared to wave-dominated systems (Figures 10-18). Whilst these habitats are more important in tide-dominated systems, the natural scarceness of mangroves in wave-dominated estuaries and deltas suggests that they are more vulnerable in these systems.

Users should note that there are many exceptions to the general rules stated above, and established default targets may be unrealistic in those situations. For a complete list of Environmental Indicators applicable to the coastal zone, refer to the Indicator Fact Sheets available on the OzEstuaries database (http://www.ozestuaries.org).

Applying Conceptual Models to Specific Australian Estuaries and Coastal Waterways

A case study illustrating how the conceptual models can be applied to specific estuaries and coastal waterways in Australia is given below. Wilson Inlet is a well-studied example of a West Australian wave-dominated estuary, and has been selected in order to demonstrate some simple but important functional characteristics that can be determined about a coastal waterway through conceptual knowledge of its geomorphic form, and the climatic region in which it lies. Whilst effective management strategies are already in place for Wilson Inlet, the principals applied here are easily transferable to other coastal waterways of the same geomorphic class. In the absence of published information (very little data and information is available for most Australian coastal waterways), useful predictions can be made about important issues, the behaviour of key processes (e.g. hydrology, sediment and nutrients), and management requirements through the use of conceptual models.

CASE STUDY: GEOMORPHIC FORM AND ENVIRONMENTAL FUNCTION OF WILSON INLET, WA

Wilson Inlet is a medium-sized wave-dominated estuary, located on the southwestern coast of temperate Western Australia (Figure 36). The estuarine waterbody is approximately 47km^2 in size, and is surrounded by about 5.5 km^2 of estuarine shoreline habitats (see OzEstuaries database, http://www.ozestuaries.org). The entrance of the estuary is usually closed for seven months each year, between January and July (Lukatelich *et al*., 1987).

Figure 36 - Wilson Inlet, a wave-dominated estuary situated on the southern coast of Western Australia.

Geomorphology of Wilson Inlet

Wilson Inlet has been classified as a wave-dominated estuary, due to its distinctive geomorphology (Table 1). The estuary is almost totally isolated from the ocean by a barrier constructed from marine sands, known as the Nullaki Peninsula. Behind the barrier, the main water-body of Wilson Inlet comprises a broad, shallow-water central basin environment, which is linked to the sea by a narrow (seasonally closed) inlet. Fluvial (or bayhead) deltas have also formed on the shores of Wilson Inlet, namely the entrances of the Denmark, Hay, and Sleeman Rivers, which drain into the central basin. Wilson Inlet contains sedimentary environments (or habitats) typical of wave-dominated estuaries, including a barrier, intertidal flats, saltmarshes, channels, flood- and ebb-tidal deltas, fluvial delta, and rocky reefs (Table 2).

Key Characteristics of Wilson Inlet
As Wilson Inlet has developed on a wave-dominated coastline, marine sediment is continually driven onshore by waves (Figure 13). This tends to close the entrance when freshwater runoff from the land is low, which mostly occurs during the summer months in south-west Australia (Table 3). The wide, deep central basin is typical of wave-dominated estuaries, and is an effective trap for fine and coarse-grained terrigenous sediment. Flushing, or removal of sediment from the central basin typically only occurs during floods. The fluvial deltas on the margins of the estuary are repositories for coarser terrigenous sediment, and may prograde into the central basin. Similarly, intertidal flats and saltmarshes will gradually encroach on the central basin during the evolutionary progression towards the deltaic stage (Figure 13). Nutrient inputs from catchment sources also accumulate in the central basin due to uptake by macrophytes such as seagrasses, and are also removed from the system by the process of denitrification (Figure 14). When the entrance is open, marine water flushes the estuary to some degree (Figure 7). When the entrance is closed, no marine flushing occurs, and the function of the estuary resembles a coastal lagoon.

Regional and Climatic Characteristics
As a wave-dominated estuary, Wilson Inlet is typical of other coastal waterways that occur in the Southwest Coast geomorphic region of Australia (Table 3, Figure 2). The Mediterranean climate of this region is unique in Australia, therefore few other analogues for the hydrology of this estuary can be found in Australia. The rainfall regime is thus strongly seasonal, affecting the function of the estuary - Wilson Inlet functions as a stratified, 'positive' wave-dominated estuary during winter rains (Figure 11), and as a potentially hypersaline 'negative' wave-dominated estuary (Figure 12) or a coastal lagoon (Figure 20) during the summer (when closed). Management strategies for 'positive' wave-dominated estuaries for Wilson Inlet may also be compared with strategies used in the Southeast Coast geomorphic region of Australia, as this area is also dominated by wave-dominated estuaries, and coastal lagoons (Figure 2).

Relevant Environmental Indicators
Although all environmental indicators may have relevance in Wilson Inlet, certain indicators should have more relevance in wave-dominated estuaries (Table 5). Following are some possible key indicators, and their expected general trends, that should be considered in Wilson Inlet:

- Turbidity targets should be low, except during high wind events;
- Chlorophyll *a* levels may be naturally high in comparison to tide-dominated systems;
- Targets for nutrient levels should be low;
- The central basin (rather than flanking environments) is the main locus for over-sedimentation and pollutant accumulation; and
- Denitrification efficiency should be high.

Implications for Environmental Managers

- Synthesis of complex information, at an appropriate scale, allows managers to gain a broad understanding of estuarine function, and understand the context that natural processes operate within. New process overlays can be developed, and compared with existing knowledge.
- As wave-dominated estuaries are effective sediment, nutrient, and pollutant 'traps', management will need to focus on inputs from, and practices within the catchment.

Additionally, as the entrance conditions change, the opening and closure of the bar is a key management issue.

- Managers can apply and evaluate environmental indicators more effectively, and set more appropriate targets.
- Over time, the morphology of Wilson Inlet is likely to change: the basin will shoal, and the margins will expand. However, the rate of change needs to be monitored (and compared with other wave-dominated estuaries), in order to determine if anthropogenic factors are having any effects.
- Consideration of regional geomorphology, climatic zones, and inherent functional processes is vital for regional policy development.
- Conceptual Model diagrams (Figures 11-14) can be reproduced to explain key processes, and provide reasons for management/monitoring decisions, to stakeholders and the general public.

FINDINGS AND OUTCOMES

- Synthesis of complex information into simple and robust models allows environmental managers to gain a broader understanding of estuarine function.
- Significant differences exist not only between the geomorphic form, but also the environmental function of each of the seven key geomorphic classes of estuaries and coastal waterways (Table 4).
- Sediment is the fundamental, underlying substrate upon which all other estuarine processes depend and operate, and geomorphology is an ideal medium with which to integrate many physical and biological variables.
- Estuaries and coastal waterways that are geographically close together often experience similar climatic conditions and tidal range, hence climatic zones are an important management consideration.
- Conceptual model diagrams, with overlays representing environmental processes, can be used as part of a decision support system for environmental managers, as a tool for comparative assessment.
- An understanding of the current state of knowledge defining the 'pristine' or undisturbed state can be gained through the process of developing conceptual models. As very little information is available about 'pristine' estuaries (NLWRA 2002) - a conceptual understanding can be applied in the absence of other information.
- Conceptual models should continually evolve through testing, review and research. Information from various disciplines can be linked on the geomorphic models.
- As the general public is increasingly playing a role in environmental management, there is a need for effective environmental education (Cooper *et al.*, 1994). Conceptual models are a useful tool in this endeavour.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support, communication and discussion with numerous members of the CRC for Coastal Zone, Estuary and Waterway Management. This study has also benefited from the constructive advice and feedback provided by scientific colleagues and State representatives at several conferences, NLWRA technical workshops, and Coastal CRC workshops, including: J. Parslow (CSIRO), B. Dennison, Dieter Tracey, and Jackie Robinson (University of Queensland), A. Moss (QEPA), Malcolm Dunning and John Baumer (QDPI), A. Steven (VIC NRE), B. Coates, D. Miller and P. Scanes (NSW EPA), D. Fotheringham and L. Barnett (DEH, SA), M. Robb (WRC, WA), Lynne Turner, Rob Fearon, and Don Alcock (Coastal CRC), Phil Haines (WBM Oceanics), Jane Harris (FRDC), C. Creighton, J. Tait and R. Lawson (NLWRA). Also B. Allen and the GA library staff, who conducted several comprehensive literature searches, Joe Mifsud and Leanne McMahon for graphic design of the 3d block models, Jim Mason for printing, Craig Smith and Neville Montgomerie for web support, NSW DLWC for use of oblique aerial photographs, and GA staff who extensively reviewed this document, namely Emma Murray, Brendan Brooke, Peter Harris, and Graham Logan. This work represents a contribution to Theme 5: Assessment and Monitoring of the Coastal CRC.

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APPENDIX

Appendix 1 - Technical Descriptions of Sedimentary Environments

TIDAL SAND BANKS (ALSO KNOWN AS SAND BARS)

Tidal Sand Banks are sedimentary features commonly found within tide-dominated estuaries, deltas and tidal creeks. Tidal sand banks are typically subtidal to intertidal in elevation, and consist of elongate linear to sinuous sand bars comprised of moderate- to well-sorted fine muds to sands. Channels dissecting tidal sand banks are scoured by strong currents, exposing the underlying bedrock or leaving a lag gravel, composed of shell debris and rock fragments. The banks and channels are often approximately aligned with the main tidal currents (typically perpendicular to the shoreline), and sediments may fine towards the head of the estuary. Concentrations of carbonate material are generally high, whereas concentrations of organic material is generally low (these tend to be higher in tropical estuaries). Strong tidal shear stresses and highly variable bottom morphology result in turbulent, well oxygenated, and turbid waters. Tidal Sand Banks may be vegetated, however high turbidity often limits primary productivity.

CENTRAL BASIN (ALSO KNOWN AS MUDDY BASIN, LAGOON, CLASTIC LAGOON)

Central Basins are uniform, lower energy environments in the deeper and quieter parts of estuaries, and are often formed landward of barrier bar deposits in wave-dominated estuaries and coastal lagoons. Sedimentologically, Central Basins typically comprise poorly-sorted, organic-rich sub-tidal mud and sandy mud. The shallower margins of Central Basins often feature coarser sediments (sands), which result from the action of wind waves and fluctuating water level in some estuaries. Carbonate concentrations are generally low, however, localised shell bioherms made up of gravel-sized estuarine bivalve shells may develop. Concentrations of organic material are generally very high, causing a black to dark grey appearance in the sediments. Surfaces are generally planar and not vegetated, however seagrass growth in the shallower parts of the Central Basin usually occurs (depending on turbidity). Sub-surface sediments may be anoxic, but is generally heavily bioturbated due to an abundance of infauna and epifauna which in some areas result in prolific mounds and burrow structures.

FLUVIAL (OR BAY-HEAD) DELTA

Fluvial Deltas are complex associations of geomorphological settings, sediment types and ecological habitats, at the point where a freshwater source enters an estuarine water body. Environments range from subtidal channels through intertidal to terrestrial levees, shoals and mouth bars. At the mouth of the channel, the flow velocity is abruptly reduced as the river water enters the standing water of the lake or sea (often into a Central Basin). The delta front immediately forward of the channel mouth is the site of deposition of bedload material. Sediment types range from clean fluvially-derived sands and gravels, to poorly sorted sands, muds and terrestrial organic material. Deposition of sediments and associated organic materials follows a cyclic pattern, driven by episodic floods. Carbonate concentrations are generally low, whereas concentrations of organic material are generally very high. Bedforms in the channel and inter-distributary bays are poorly developed due to large fluctuations in river energy and generally low tidal energy. Supra-tidal regions are usually well vegetated with saltmarsh, mangrove or terrestrial woodland ecosystems. Due to large salinity variation, the diversity of fish and crustacean species is often limited.

BARRIER/BACK-BARRIER (ALSO KNOWN AS BEACH BARRIER, SAND BAR, SAND SPIT, BARRIER ISLAND, STRAND)

Barrier environments are a distinctive component of wave-dominated estuaries and deltas, and are common shoreface features on any coastline subjected to high wave energy. Barriers often consist of an intertidal to supratidal beach-face, cusps, shallow channels, a berm, and dunes interspersed by blow-outs. Back-barrier regions may contain wash-overs (sediment washed into the estuary during major storms). Sediments comprise well-sorted fine to coarse, quartz-rich sands. Heavy minerals may occur in low concentrations. Carbonate concentrations are generally high (particularly in tropical estuaries), except in the supra-tidal dunes, and concentrations of organic material are generally low. The porous nature of the sandy sediments generally results in well-oxygenated sub-surface sediments. On prograding, wave-dominated coastlines, ancient barriers may be landlocked as younger barriers form (resulting in strandplains). Except for the active beach-face, surfaces are generally vegetated. Infauna and epifauna (eg. interstitial microfauna, crustaceans, worms and molluscs) occur at supra-tidal to sub-tidal elevations. The stability of biological communities is variable, and is generally associated with dune-stabilising vegetation above supra-tidal elevations. These habitats may also intermittently support birds, turtles and seals.

FLOOD- AND EBB-TIDE DELTA (ALSO KNOWN AS ENTRANCE BARS, ENTRANCE CHANNELS)

Flood and Ebb Tidal Deltas are subtidal to supratidal dunes and channels, typically found in the entrances of wave-dominated estuaries and deltas (adjacent to the Barrier), and are formed by redistribution of sediment by tidal movement in and out of the entrance. Sediments comprise moderately- to well-sorted, quartz-rich sand. Gravels often occur as a lag in the main tidal channels, where tidal currents are strong. Heavy minerals may occur in low concentrations. Carbonate concentrations are generally high, and concentrations of organic material are generally low. Flood oriented bedforms can occur on the shoals (eg. straight crested, full-bedded small dunes) and ebb-oriented bedforms (eg. sinuous crested, full-bedded small to medium dunes) can occur in the channels. Seagrasses and associated communities are common. Infauna and epifauna (eg. interstitial microfauna, crustaceans, worms and molluscs) occur at supra-tidal to sub-tidal elevations.

INTERTIDAL FLATS (ALSO KNOWN AS TIDAL MUDFLATS)

Intertidal mud flats are unvegetated, generally low gradient, and low energy environments, consisting of poorly- to moderately-sorted sandy mud and muddy sand. Gravel may be present in moderate concentrations at the base of shallow drainage channels, and coarser sediments typically occur closer to the low tide mark. Carbonate concentrations are moderate (reflecting shelly material in the sediments) and the concentration of organic material is variable, but generally high. Intertidal Flats are wider and more extensive in macrotidal systems. Surfaces tend to occur from mean low water spring to mean high water spring elevations and are usually flat and not vegetated, but may be dissected by shallow (and often vegetated by saltmarsh species) drainage channels. Biological activity consists of both high and low tide visitors, as well as permanent inhabitants. Burrowing infauna, crustaceans, molluscs, fish and birds are generally abundant.

MANGROVE (ALSO KNOWN AS MANGAL COMMUNITIES)

Mangrove environments generally consist of sediments associated with stands of salt-tolerant mangrove forest (comprised of various species of mangrove trees and shrubs). In some ways, mangroves can be considered the tropical equivalent of saltmarsh communities (although the two often co-exist). Surfaces beneath the mangrove forests generally occur from mean sea level to mean high water spring elevations, and are often associated with tidal creek drainage networks. Mangrove forests are generally more common and extensive in tropical regions. Sediment that accumulates (due to trapping and baffling by vegetation) beneath the mangrove forests generally comprises strongly-reduced, poorly- to moderately-sorted silts and clays. Carbonate concentrations are generally low. Concentrations of organic material are generally high. Mangroves typically support a diverse and productive community of flora and fauna. Burrowing infauna, epifaunal invertebrates (such as sessile organisms and crustaceans), molluscs, and low-tide and high-tide visitors (such as fish and water birds) are common inhabitants of mangrove forests.

SALTMARSH (ALSO KNOWN AS TIDAL MARSHES)

Saltmarsh environments generally consist of high-intertidal to supratidal halophytic vegetation (such as salt-tolerant grasses, reeds, sedges and small shrubs) which stabilise fine sediments that have been transported by water. Sediments generally consist of poorly-sorted anoxic sandy silts and clays. Carbonate concentrations are generally low, and concentrations of organic material are generally high. Saltmarshes are generally more common in temperate regions (as they often occupy environments that would typically be colonised by mangroves in tropical regions). Saltmarshes have low gradients and may be dissected by shallow brackish pools. Saltmarshes and associated vegetation are habitats for a wide range of bioturbating infaunal and epifaunal invertebrates, as well as low-tide and high-tide visitors (such as fish and water birds).

SALTFLATS (ALSO KNOWN AS SALTPANS, SABKHAS)

Salt flats, or saline supratidal mudflat facies, occur in dry evaporative environments (often in the tropics) that undergo infrequent tidal inundation. Sediments comprise poorly-sorted sandy silts and clays, including mineral deposits such as gypsum and halite, and desiccation cracks. Carbonate concentrations are generally high, and concentrations of organic material are generally low. Salt flats tend to be low gradient, and mostly featureless, with a varying degree of algal colonisation, and often with vertically accreting algal mats. Saltflats generally occur above mean high water spring, and infrequent inundation by king tides creates a highly evaporative environment in which algal mats and salt tolerant grasses may be present. Very high levels of surface and groundwater salinity often precludes the growth of higher vegetation and biota (some infauna and epifauna may occur at lower elevations). Saltflats are habitats for birds, particularly during the wet season.

ROCKY REEF (ALSO KNOWN AS BEDROCK)

Rocky Reefs feature a hard substrate that may occur from the shoreline to any depth. Surfaces are generally non-depositional and sometimes erosional, and are usually dominated by epifaunal and algal communities. Bedrock is often a major control on waterway shape (width, length and depth). Habitats vary, dependant on depth, turbidity and salinity. Below the waterline, common habitats include intertidal rocky shorelines to subtidal reefs. Bedrock or Rocky Reefs limit the available habitat for burrowing organisms, but are important habitats for sessile organisms, organisms requiring sheltered conditions, and their associated fish communities.

CHANNELS (ALSO KNOWN AS TIDAL CHANNELS OR RIVER CHANNELS)

Channels are environments of frequently high energy, in terms of tidal movement (eg. tidal channels) or fluvial flow (eg. river channels). Thus, salinity, water quality and sediment types are variable, however, coarser grained sand to gravel (lag) deposits are common on the Channel floor. Channels are often found in association with Fluvial (Bayhead) Deltas, Flood and Ebb Tidal Deltas, Tidal Sand Banks, and intersecting Intertidal Flats and Mangroves in macrotidal environments. Channels may be intermittent, and may also be abandoned as river or tidal flows change course. Concentrations of carbonate and organic material vary, and are typically higher in tropical estuaries. Channels are often non-depositional environments and are sometimes erosional. Channels are typically subtidal, however in macrotidal regions entire channel networks may be exposed at low tide. Channels are important environments for a wide range of marine and estuarine organisms (depending on salinity and turbidity), and provide shelter and access for larger estuarine predators, as well as potential seagrass habitat.

INNER CONTINENTAL SHELF

The Inner Continental Shelf environment represents the shallow marine environment directly seaward of the entrance of the estuary/coastal waterway. Seabed morphology and sediment types are variable, as this environment occurs throughout wave- and tide-dominated coastlines, and in any climatic zone. Biota existing in this environment are typically marine or ocean-dwelling organisms only, as this environment is influenced by freshwater during extreme flood events only (depending on local conditions).

Appendix 2 - List of Estuaries and Coastal Waterways

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Arrawarra Creek	NSW	153.1972	-30.0584	CL/SP	SEC	Annual Pos
Avoca Lake	NSW	151.4351	-33.4647	CL/SP	SEC	Annual Pos
Back Lagoon	NSW	149.9285	-36.8830	CL/SP	SEC	Annual Pos
Baragoot Lake	NSW	150.0648	-36.4711	CL/SP	SEC	Annual Pos
Bega River	NSW	149.9838	-36.7064	WDE	SEC	Annual Pos
Bellambi Creek	NSW	150.9202	-34.3640	CL/SP	SEC	Annual Pos
Bellambi Lake	NSW	150.9208	-34.3770	CL/SP	SEC	Annual Pos
Bellinger River	NSW	153.0335	-30.5004	WDD	SEC	Annual Pos
Belongil Creek	NSW	153.5917	-28.6262	CL/SP	SEC	Annual Pos
Bermagui River	NSW	150.0652	-36.4247	WDD	SEC	Annual Pos
Berrara Creek	NSW	150.5482	-35.2092	CL/SP	SEC	Annual Pos
Boambee Creek	NSW	153.1375	-30.2968	WDE	SEC	Annual Pos
Bonville Creek	NSW	153.1005	-30.3757	WDE	SEC	Annual Pos
Botany Bay	NSW	151.2343	-34.0030	WDE	SEC	Annual Pos
Brisbane Water	NSW	151.3337	-33.5236	WDE	SEC	Annual Pos
Brunswick River	NSW	153.5573	-28.5382	WDD	SEC	Annual Pos
Bunga Lagoon	NSW	150.0553	-36.5471	WDE	SEC	Annual Pos
Burrill Lake	NSW	150.4453	-35.3895	WDE	SEC	Annual Pos
Camden Haven River	NSW	152.8367	-31.6370	WDE	SEC	Annual Pos
Candlagan Creek	NSW	150.1787	-35.8420	WDD	SEC	Annual Pos
Clarence River	NSW	153.3606	-29.4277	WDE	SEC	Annual Pos
Clyde River/Batemans Bay	NSW	150.2550	-35.7471	WDE	SEC	Annual Pos
Cockrone Lake	NSW	151.4278	-33.4940	CL/SP	SEC	Annual Pos
Coffs Harbour Creek	NSW	153.1394	-30.2659	CL/SP	SEC	Annual Pos
Coila Lake	NSW	150.1392	-36.0483	WDE	SEC	Annual Pos
Congo Creek And Lagoon	NSW	150.1571	-35.9530	CL/SP	SEC	Annual Pos
Cooks River	NSW	151.1683	-33.9498	TC	SEC	Annual Pos
Corindi River/Red Rock River	NSW	153.2323	-29.9806	WDD	SEC	Annual Pos
Corunna Lake	NSW	150.1330	-36.2882	WDE	SEC	Annual Pos
Crooked River And Lagoon	NSW	150.8155	-34.7722	CL/SP	SEC	Annual Pos
Cudgen Lake	NSW	153.5859	-28.2575	WDE	SEC	Annual Pos
Cudgera Creek	NSW	153.5772	-28.3599	CL/SP	SEC	Annual Pos
Cullendulla Creek	NSW	150.2090	-35.7035	TC	SEC	Annual Pos
Curalo Lagoon	NSW	149.9209	-37.0483	WDE	SEC	Annual Pos
Curl Curl/Harbord Lagoon	NSW	151.2978	-33.7671	CL/SP	SEC	Annual Pos
Currambeen Creek	NSW	150.6710	-35.0370	WDD	SEC	Annual Pos
Cuttagee Lake	NSW	150.0537	-36.4948	WDE	SEC	Annual Pos
Dalhousie Creek	NSW	153.0263	-30.5236	CL/SP	SEC	Annual Pos
Dee Why Lagoon	NSW	151.3037	-33.7479	CL/SP	SEC	Annual Pos
Deep Creek	NSW	153.0116	-30.6002	WDE	SEC	Annual Pos
Durras Lake	NSW	150.3049	-35.6394	WDE	SEC	Annual Pos
Evans River	NSW	153.4377	-29.1132	WDD	SEC	Annual Pos
Fairy Creek	NSW	150.9013	-34.4089	CL/SP	SEC	Annual Pos
Georges River	NSW	151.1560	-33.9982	EMB/DRV	SEC	Annual Pos
Hastings River	NSW	152.9157	-31.4262	WDD	SEC	Annual Pos
Hawkesbury River	NSW	151.3405	-33.5630	WDE	SEC	Annual Pos
Hearns Lake	NSW	153.2011	-30.1331	CL/SP	SEC	Annual Pos
Hunter River	NSW	151.7937	-32.9183	WDE	SEC	Annual Pos
Jerusalem Creek	NSW	153.3959	-29.2085	CL/SP	SEC	Annual Pos
Jervis Bay	NSW	150.7866	-35.1066	EMB/DRV	SEC	Annual Pos
Karuah River	NSW	151.9891	-32.6714	TDD	SEC	Annual Pos
Khappinghat Creek	NSW	152.5649	-32.0101	WDD	SEC	Annual Pos
Kianga Lake	NSW	150.1322	-36.2002	CL/SP	SEC	Annual Pos
Killick Creek	NSW	152.9619	-31.2511	CL/SP	SEC	Annual Pos
Kioloa Lagoon	NSW	150.3827	-35.5492	CL/SP	SEC	Annual Pos
Korogoro Creek	NSW	153.0542	-31.0548	CL/SP	SEC	Annual Pos
Lake Arragan And River	NSW	153.3377	-29.5653	CL/SP	SEC	Annual Pos
Lake Brou	NSW	150.1245	-36.1368	WDE	SEC	Annual Pos
Lake Brunderee	NSW	150.1316	-36.0976	CL/SP	SEC	Annual Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Lake Cakora/Lagoon	NSW	153.3322	-29.6022	CL/SP	SEC	Annual Pos
Lake Cathie/Innes	NSW	152.8585	-31.5499	WDE	SEC	Annual Pos
Lake Conjola	NSW	150.5082	-35.2688	WDE	SEC	Annual Pos
Lake Illawarra	NSW	150.8728	-34.5443	WDE	SEC	Annual Pos
Lake Macquarie	NSW	151.6619	-33.0863	WDE	SEC	Annual Pos
Lake Mummuga	NSW	150.1287	-36.1618	WDE	SEC	Annual Pos
Lake Tarourga	NSW	150.1344	-36.1149	WDE	SEC	Annual Pos
Macleay River	NSW	153.0239	-30.8740	WDD	SEC	Annual Pos
Manly Lagoon And Creek	NSW	151.2885	-33.7879	CL/SP	SEC	Annual Pos
Manning River	NSW	152.6860	-31.8795	WDD	SEC	Annual Pos
Merimbula Lake	NSW	149.9219	-36.8955	WDE	SEC	Annual Pos
Meringo Creek	NSW	150.1499	-35.9781	CL/SP	SEC	Annual Pos
Meroo Lake	NSW	150.3909	-35.4845	WDE	SEC	Annual Pos
Merrica River	NSW	149.9513	-37.2967	CL/SP	SEC	Annual Pos
Middle Lagoon	NSW	150.0083	-36.6563	WDE	SEC	Annual Pos
Minnamurra River	NSW	150.8608	-34.6280	WDD	SEC	Annual Pos
Mollymook Creek	NSW	150.4753	-35.3338	CL/SP	SEC	Annual Pos
Mooball Creek	NSW	153.5698	-28.3888	CL/SP	SEC	Annual Pos
Moonee Creek And Lagoon	NSW	153.1603	-30.2118	CL/SP	SEC	Annual Pos
Moruya River	NSW	150.1509	-35.9052	WDD	SEC	Annual Pos
Murrah Lagoon	NSW	150.0537	-36.4948	WDE	SEC	Annual Pos
Myall Lake And Myall River	NSW	152.1447	-32.6788	WDE	SEC	Annual Pos
Nadgee Lake And Inlet	NSW	149.9727	-37.4688	CL/SP	SEC	Annual Pos
Nambucca River	NSW	153.0152	-30.6495	WDD	SEC	Annual Pos
Nangudga Lake	NSW	150.1426	-36.2606	WDE	SEC	Annual Pos
Narrabeen Lagoon	NSW	151.3072	-33.7045	WDE	SEC	Annual Pos
Narrawallee Inlet	NSW	150.4747	-35.3022	WDE	SEC	Annual Pos
Nelson Lagoon	NSW	149.9941	-36.6914	WDE	SEC	Annual Pos
Nerrindillah Creek	NSW	150.5318	-35.2286	CL/SP	SEC	Annual Pos
Nullica River	NSW	149.8716	-37.0920	WDE	SEC	Annual Pos
Oyster Creek	NSW	153.0171	-30.5626	CL/SP	SEC	Annual Pos
Pambula Lake	NSW	149.9157	-36.9481	WDE	SEC	Annual Pos
Pittwater	NSW	151.3168	-33.5802	WDE	SEC	Annual Pos
Port Hacking	NSW	151.1631	-34.0723	WDE	SEC	Annual Pos
Port Jackson	NSW	151.2825	-33.8279	WDE	SEC	Annual Pos
Port Kembla Harbour	NSW	150.9000	-34.4696	WDE	SEC	Annual Pos
Port Stephens	NSW	152.1902	-32.7076	WDE	SEC	Annual Pos
Richmond River	NSW	153.5918	-28.8770	WDD	SEC	Annual Pos
Saint Georges Basin	NSW	150.5935	-35.1845	WDE	SEC	Annual Pos
Saltwater Lagoon	NSW	153.0428	-30.8839	WDE	SEC	Annual Pos
Sandon River	NSW	153.3310	-29.6736	WDD	SEC	Annual Pos
Shoalhaven/Crookhaven River	NSW	150.7634	-34.9005	WDD	SEC	Annual Pos
Smiths Lake	NSW	152.5194	-32.3925	CL/SP	SEC	Annual Pos
South West Rocks Creek	NSW	153.0378	-30.8835	CL/SP	SEC	Annual Pos
Station Creek	NSW	153.2531	-29.9508	WDE	SEC	Annual Pos
Swan Lake	NSW	150.5610	-35.2007	WDE	SEC	Annual Pos
Tabourie Lake	NSW	150.4112	-35.4383	WDE	SEC	Annual Pos
Tallow Creek	NSW	153.6218	-28.6681	CL/SP	SEC	Annual Pos
Termeil Lake	NSW	150.3950	-35.4620	WDE	SEC	Annual Pos
Terrigal Lagoon	NSW	151.4427	-33.4442	CL/SP	SEC	Annual Pos
Tilba Tilba Lake	NSW	150.1000	-36.3395	WDE	SEC	Annual Pos
Tilligery Creek	NSW	152.0461	-32.7281	WDE	SEC	Annual Pos
Tomaga River	NSW	150.1852	-35.8368	WDD	SEC	Annual Pos
Towamba River	NSW	149.9126	-37.1122	WDE	SEC	Annual Pos
Towradgi Creek	NSW	150.9154	-34.3832	CL/SP	SEC	Annual Pos
Tuggerah Lakes	NSW	151.5022	-33.3462	WDE	SEC	Annual Pos
Tuross Lake	NSW	150.1317	-36.0672	WDE	SEC	Annual Pos
Tweed River	NSW	153.5558	-28.1703	WDE	SEC	Annual Pos
Twofold Bay / Eden	NSW	149.9471	-37.0784	EMB/DRV	SEC	Annual Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Ulladulla Harbour	NSW	150.4853	-35.3570	CL/SP	SEC	Annual Pos
Wagonga Inlet	NSW	150.1318	-36.2144	WDE	SEC	Annual Pos
Wallaga Lake	NSW	150.0794	-36.3647	WDE	SEC	Annual Pos
Wallagoot Lake	NSW	149.9587	-36.7953	WDE	SEC	Annual Pos
Wallis Lake	NSW	152.5102	-32.1743	WDE	SEC	Annual Pos
Wamberal Lagoon	NSW	151.4482	-33.4306	CL/SP	SEC	Annual Pos
Wapengo Lagoon	NSW	150.0210	-36.6349	WDE	SEC	Annual Pos
Werri Lagoon	NSW	150.8391	-34.7281	WDE	SEC	Annual Pos
Willinga Lake	NSW	150.3914	-35.5003	WDE	SEC	Annual Pos
Wollumboola Lake	NSW	150.7758	-34.9402	WDE	SEC	Annual Pos
Wonboyn River	NSW	149.9661	-37.2499	WDE	SEC	Annual Pos
Woolgoolga Lake	NSW	153.1984	-30.0988	WDE	SEC	Annual Pos
Wooli Wooli River	NSW	153.2685	-29.8875	WDE	SEC	Annual Pos
Angurugubira Lake	NT	136.7665	-13.9667	WDE	GOC	Summer Pos/Winter Neg
Anguruki Creek	NT	135.9413	-13.9534	WDE	GOC	Summer Pos/Winter Neg
Bing Bong Creek	NT	136.3244	-15.5971	TC	GOC	Summer Pos/Winter Neg
Calvert River	NT	137.7430	-16.2575	WDD	GOC	Summer Pos/Winter Neg
Fat Fellows Creek	NT	136.9920	-15.8684	TC	GOC	Summer Pos/Winter Neg
Hart River	NT	135.8892	-14.0941	TC	GOC	Summer Pos/Winter Neg
Koolatong River	NT	135.9463	-13.2536	TDD	GOC	Summer Pos/Winter Neg
Limmen Bight River	NT	135.7207	-15.1080	TDD	GOC	Summer Pos/Winter Neg
Little Lagoon	NT	136.7947	-13.8434	CL/SP	GOC	Summer Pos/Winter Neg
Mcarthur River	NT	136.6762	-15.8112	TDD	GOC	Summer Pos/Winter Neg
Miyangkala Creek	NT	135.6108	-14.4434	TDD	GOC	Summer Pos/Winter Neg
Mule Creek	NT	136.4265	-15.6377	TC	GOC	Summer Pos/Winter Neg
Muntak Creek	NT	135.8788	-14.1699	TC	GOC	Summer Pos/Winter Neg
Nayampi Creek	NT	135.3968	-14.8087	TDD	GOC	Summer Pos/Winter Neg
NT082	NT	136.6293	-12.7002	CL/SP	GOC	Summer Pos/Winter Neg
NT093	NT	135.4419	-14.6912	TC	GOC	Summer Pos/Winter Neg
NT096	NT	135.4157	-14.8580	TC	GOC	Summer Pos/Winter Neg
NT104	NT	136.7933	-15.9062	TC	GOC	Summer Pos/Winter Neg
NT106	NT	136.9007	-15.9113	TC	GOC	Summer Pos/Winter Neg
NT111	NT	137.4106	-16.1392	CL/SP	GOC	Summer Pos/Winter Neg
NT112	NT	137.5008	-16.1655	CL/SP	GOC	Summer Pos/Winter Neg
NT113	NT	137.5150	-16.1635	CL/SP	GOC	Summer Pos/Winter Neg
NT114	NT	137.5784	-16.1766	TC	GOC	Summer Pos/Winter Neg
NT115	NT	137.6349	-16.2013	TC	GOC	Summer Pos/Winter Neg
NT117	NT	137.8192	-16.3616	CL/SP	GOC	Summer Pos/Winter Neg
NT118	NT	137.8406	-16.3896	TC	GOC	Summer Pos/Winter Neg
Port Bradshaw	NT	136.7672	-12.5639	WDE	GOC	Summer Pos/Winter Neg
Robinson River	NT	137.2663	-16.0327	WDD	GOC	Summer Pos/Winter Neg
Roper River	NT	135.4045	-14.7556	TDE	GOC	Summer Pos/Winter Neg
Rose River	NT	135.7403	-14.2855	TC	GOC	Summer Pos/Winter Neg
Rosie Creek	NT	136.2110	-15.3974	TDD	GOC	Summer Pos/Winter Neg
Seven Emu Creek	NT	137.3533	-16.1119	CL/SP	GOC	Summer Pos/Winter Neg
Shark Creek	NT	137.3052	-16.0847	CL/SP	GOC	Summer Pos/Winter Neg
Spillen Creek	NT	135.5787	-15.0393	TC	GOC	Summer Pos/Winter Neg
Towns River	NT	135.4348	-14.9038	TDD	GOC	Summer Pos/Winter Neg
Trial Bay	NT	136.4962	-12.9915	EMB/DRV	GOC	Summer Pos/Winter Neg
Walker River	NT	135.8370	-13.5903	TDD	GOC	Summer Pos/Winter Neg
Wearyan River	NT	136.8604	-15.9110	TDD	GOC	Summer Pos/Winter Neg
Adelaide River	NT	131.2137	-12.2045	TDE	NWC	Summer Pos/Winter Neg
All Night Creek	NT	133.6725	-11.7874	TC	NWC	Summer Pos/Winter Neg
Anamayirra Creek	NT	134.4751	-12.0701	TC	NWC	Summer Pos/Winter Neg
Andranangoo Creek	NT	130.8465	-11.3532	WDD	NWC	Summer Pos/Winter Neg
Apsley Strait	NT	130.3705	-11.3193	TDE	NWC	Summer Pos/Winter Neg
Arnhem Bay	NT	136.0983	-12.2199	EMB/DRV	NWC	Summer Pos/Winter Neg
Baralminar River	NT	136.0308	-12.4614	TDE	NWC	Summer Pos/Winter Neg
Barungbirinung River	NT	136.3223	-12.2039	TC	NWC	Summer Pos/Winter Neg

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Blue Mud Bay	NT	131.8509	-11.1985	EMB/DRV	NWC	Summer Pos/Winter Neg
Blyth River	NT	134.5899	-12.0549	TDE	NWC	Summer Pos/Winter Neg
Bonkalii Creek	NT	131.0840	-11.8358	TC	NWC	Summer Pos/Winter Neg
Buckingham River	NT	135.7290	-12.2669	TDE	NWC	Summer Pos/Winter Neg
Buffalo Creek	NT	130.9106	-12.3384	TC	NWC	Summer Pos/Winter Neg
Bynoe Harbour	NT	130.5433	-12.5596	TDE	NWC	Summer Pos/Winter Neg
Cato River	NT	136.3510	-12.2728	TDD	NWC	Summer Pos/Winter Neg
Corrawara Creek	NT	130.6184	-12.4486	TC	NWC	Summer Pos/Winter Neg
Cullala Creek	NT	130.1970	-11.5119	TDE	NWC	Summer Pos/Winter Neg
Curtis Haven	NT	130.6802	-11.3942	TDE	NWC	Summer Pos/Winter Neg
Daly River	NT	130.2318	-13.3121	TDE	NWC	Summer Pos/Winter Neg
Darwarunga River	NT	135.9757	-12.3902	TC	NWC	Summer Pos/Winter Neg
Darwin Harbour	NT	130.8016	-12.4212	TDE	NWC	Summer Pos/Winter Neg
De Vere Creek	NT	131.0183	-11.8881	TC	NWC	Summer Pos/Winter Neg
Djigagila Creek	NT	134.9224	-12.1339	EMB/DRV	NWC	Summer Pos/Winter Neg
Dongau Creek	NT	131.3820	-11.2966	TC	NWC	Summer Pos/Winter Neg
Dudwell Creek	NT	130.2478	-11.3689	WDD	NWC	Summer Pos/Winter Neg
East Alligator	NT	132.6156	-12.0977	TDE	NWC	Summer Pos/Winter Neg
East Arm	NT	130.8876	-12.4954	TDE	NWC	Summer Pos/Winter Neg
Finnis River	NT	130.3352	-12.8895	WDD	NWC	Summer Pos/Winter Neg
Fitzmaurice River	NT	129.6561	-14.7939	TDE	NWC	Summer Pos/Winter Neg
Forsyth Creek	NT	129.3844	-14.9093	TDE	NWC	Summer Pos/Winter Neg
Giddy River	NT	136.6650	-12.2794	TC	NWC	Summer Pos/Winter Neg
Glyde River	NT	135.0575	-12.2613	TDD	NWC	Summer Pos/Winter Neg
Goomadeer River	NT	133.8228	-11.8432	TDD	NWC	Summer Pos/Winter Neg
Goromuru River	NT	136.2248	-12.4597	TC	NWC	Summer Pos/Winter Neg
Gudgerama Creek	NT	134.2536	-12.0300	TC	NWC	Summer Pos/Winter Neg
Habgood River	NT	135.9956	-12.4410	TC	NWC	Summer Pos/Winter Neg
Hope Inlet	NT	131.0116	-12.3330	TDE	NWC	Summer Pos/Winter Neg
Hutchinson Strait	NT	135.2395	-12.2149	EMB/DRV	NWC	Summer Pos/Winter Neg
Ilamaryi River	NT	132.5210	-11.5246	TC	NWC	Summer Pos/Winter Neg
Jessie River	NT	131.0284	-11.3644	TDE	NWC	Summer Pos/Winter Neg
Johnston River	NT	131.1820	-11.2634	TDE	NWC	Summer Pos/Winter Neg
Keep River	NT	129.1811	-14.9170	TDE	NWC	Summer Pos/Winter Neg
Kilu-Impini Creek	NT	130.5164	-11.2795	WDE	NWC	Summer Pos/Winter Neg
King Creek	NT	131.0079	-12.3569	TC	NWC	Summer Pos/Winter Neg
King River	NT	133.5410	-11.8114	TDE	NWC	Summer Pos/Winter Neg
Kurala River	NT	135.8916	-12.1784	TC	NWC	Summer Pos/Winter Neg
Latram River	NT	136.7464	-12.2654	TC	NWC	Summer Pos/Winter Neg
Leaders Creek	NT	131.1153	-12.1737	TC	NWC	Summer Pos/Winter Neg
Little Moyle Inlet	NT	129.7842	-13.7822	CL/SP	NWC	Summer Pos/Winter Neg
Liverpool River	NT	134.2098	-12.0308	TDE	NWC	Summer Pos/Winter Neg
Majari Creek	NT	133.9196	-11.9127	TC	NWC	Summer Pos/Winter Neg
Marligur Creek	NT	133.2484	-11.7285	TDD	NWC	Summer Pos/Winter Neg
Melville Bay	NT	136.6592	-12.2175	EMB/DRV	NWC	Summer Pos/Winter Neg
Micket Creek	NT	130.9500	-12.3431	TC	NWC	Summer Pos/Winter Neg
Middle Arm	NT	130.8753	-12.5851	TDE	NWC	Summer Pos/Winter Neg
Minimini Creek	NT	132.6126	-11.7539	TC	NWC	Summer Pos/Winter Neg
Mirikau-Yunga Creek	NT	130.5833	-11.4001	TDE	NWC	Summer Pos/Winter Neg
Moyle River	NT	129.7453	-13.9748	WDD	NWC	Summer Pos/Winter Neg
Murgenella Creek	NT	132.6553	-11.8843	TDE	NWC	Summer Pos/Winter Neg
New Moon Inlet	NT	129.5577	-14.5886	TDE	NWC	Summer Pos/Winter Neg
Ngandadauda Creek	NT	134.7639	-11.9953	WDD	NWC	Summer Pos/Winter Neg
NT001	NT	129.0415	-14.8842	TC	NWC	Summer Pos/Winter Neg
NT007	NT	129.4775	-14.5010	TC	NWC	Summer Pos/Winter Neg
NT009	NT	129.5860	-14.0849	TDE	NWC	Summer Pos/Winter Neg
NT014	NT	130.3858	-12.6712	TC	NWC	Summer Pos/Winter Neg
NT037	NT	132.1196	-11.5147	TC	NWC	Summer Pos/Winter Neg
NT038	NT	132.0500	-11.4558	TC	NWC	Summer Pos/Winter Neg

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NT039	NT	132.0435	-11.4228	TC	NWC	Summer Pos/Winter Neg
NT055	NT	134.1562	-11.9671	TC	NWC	Summer Pos/Winter Neg
NT079	NT	136.9105	-12.2833	CL/SP	NWC	Summer Pos/Winter Neg
NT080	NT	136.9278	-12.3457	CL/SP	NWC	Summer Pos/Winter Neg
NT128	NT	131.3276	-11.2673	TDE	NWC	Summer Pos/Winter Neg
NT130	NT	131.4838	-11.3981	CL/SP	NWC	Summer Pos/Winter Neg
Nungbalgarri Creek	NT	134.0760	-11.9283	TC	NWC	Summer Pos/Winter Neg
Perakery Creek	NT	130.1509	-11.7066	TC	NWC	Summer Pos/Winter Neg
Peter John River	NT	136.3622	-12.2533	TC	NWC	Summer Pos/Winter Neg
Popham Bay	NT	131.8200	-11.2560	EMB/DRV	NWC	Summer Pos/Winter Neg
Port Bremer	NT	132.2544	-11.1828	TDE	NWC	Summer Pos/Winter Neg
Port Essington	NT	132.1129	-11.1704	EMB/DRV	NWC	Summer Pos/Winter Neg
Port Hurd	NT	130.1955	-11.6484	TDE	NWC	Summer Pos/Winter Neg
Port Keats	NT	129.5512	-14.0850	TC	NWC	Summer Pos/Winter Neg
Raffles Bay	NT	132.3965	-11.2246	EMB/DRV	NWC	Summer Pos/Winter Neg
Reichardt Creek	NT	130.8899	-12.4670	TC	NWC	Summer Pos/Winter Neg
Reynolds River	NT	130.2255	-13.2509	TC	NWC	Summer Pos/Winter Neg
Robinson Inlet	NT	131.0842	-11.3031	WDE	NWC	Summer Pos/Winter Neg
Saltwater Creek	NT	132.6442	-11.8625	TC	NWC	Summer Pos/Winter Neg
Sampan Creek	NT	131.7746	-12.2672	TDD	NWC	Summer Pos/Winter Neg
Saunders Creek	NT	131.3833	-11.5906	TC	NWC	Summer Pos/Winter Neg
Shamrock Bay	NT	131.9332	-11.3804	EMB/DRV	NWC	Summer Pos/Winter Neg
Silvio Bay	NT	131.9930	-11.4078	TC	NWC	Summer Pos/Winter Neg
Slippery Creek	NT	135.9631	-12.2709	TC	NWC	Summer Pos/Winter Neg
South Alligator River	NT	132.3955	-12.2177	TDE	NWC	Summer Pos/Winter Neg
Tommycut Creek	NT	131.6985	-12.2800	TDD	NWC	Summer Pos/Winter Neg
Trepang Bay	NT	131.9286	-11.1604	EMB/DRV	NWC	Summer Pos/Winter Neg
Tunganapu Creek	NT	130.0562	-11.7578	TC	NWC	Summer Pos/Winter Neg
Victoria River	NT	129.5000	-14.8830	TDE	NWC	Summer Pos/Winter Neg
West Alligator River	NT	132.2808	-12.2215	TDE	NWC	Summer Pos/Winter Neg
West Arm	NT	130.7830	-12.5470	TDE	NWC	Summer Pos/Winter Neg
Wildman River	NT	132.0758	-12.3037	TDD	NWC	Summer Pos/Winter Neg
Woods Inlet	NT	130.7603	-12.4797	TC	NWC	Summer Pos/Winter Neg
Woolen River	NT	135.1534	-12.2347	TDE	NWC	Summer Pos/Winter Neg
Wurugoij Creek	NT	133.8869	-11.9054	CL/SP	NWC	Summer Pos/Winter Neg
Accident Inlet	QLD	140.9385	-17.1839	WDD	GOC	Summer Pos/Winter Neg
Albert River	QLD	139.7582	-17.5663	TDD	GOC	Summer Pos/Winter Neg
Andoom Creek	QLD	141.8795	-12.5867	TC	GOC	Summer Pos/Winter Neg
Archer Bay	QLD	141.6505	-13.3485	TDE	GOC	Summer Pos/Winter Neg
Beeber Creek	QLD	139.2811	-16.7331	TC	GOC	Summer Pos/Winter Neg
Boyorunga Inlet	QLD	139.2077	-16.7099	TC	GOC	Summer Pos/Winter Neg
Brannigan Creek	QLD	140.9223	-17.2119	TC	GOC	Summer Pos/Winter Neg
Channon Creek	QLD	139.4946	-17.4143	TC	GOC	Summer Pos/Winter Neg
Chapman River	QLD	141.6196	-14.9186	CL/SP	GOC	Summer Pos/Winter Neg
Cliffdale Creek	QLD	138.7570	-16.8329	CL/SP	GOC	Summer Pos/Winter Neg
Crystal Creek	QLD	142.1513	-11.0869	TC	GOC	Summer Pos/Winter Neg
Dalmumeah Creek	QLD	139.6317	-16.5389	TC	GOC	Summer Pos/Winter Neg
Disaster Inlet	QLD	139.9388	-17.6447	TC	GOC	Summer Pos/Winter Neg
Doughboy River	QLD	142.0852	-11.4571	CL/SP	GOC	Summer Pos/Winter Neg
Ducie River	QLD	142.0257	-12.0456	TDE	GOC	Summer Pos/Winter Neg
Duck Creek	QLD	141.0894	-16.8024	WDD	GOC	Summer Pos/Winter Neg
Edward River	QLD	141.5727	-14.7708	WDD	GOC	Summer Pos/Winter Neg
Eight Mile Creek	QLD	138.5369	-16.7833	TC	GOC	Summer Pos/Winter Neg
Elizabeth River	QLD	139.5558	-16.5016	TDD	GOC	Summer Pos/Winter Neg
Embley River	QLD	141.8168	-12.6639	TDE	GOC	Summer Pos/Winter Neg
Flinders River/Bynoe River	QLD	140.7316	-17.5129	TDD	GOC	Summer Pos/Winter Neg
Gilbert River	QLD	141.2705	-16.5515	TDD	GOC	Summer Pos/Winter Neg
Gin Arm Creek	QLD	139.5445	-17.4653	TDD	GOC	Summer Pos/Winter Neg
Gum Creek	QLD	138.0839	-16.6182	CL/SP	GOC	Summer Pos/Winter Neg

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Hersey Creek	QLD	141.5553	-14.3708	TC	GOC	Summer Pos/Winter Neg
Horse Creek	QLD	141.4356	-15.6596	TC	GOC	Summer Pos/Winter Neg
Horse Place Creek	QLD	139.1796	-16.5966	CL/SP	GOC	Summer Pos/Winter Neg
Jackson River	QLD	142.0122	-11.6689	WDD	GOC	Summer Pos/Winter Neg
Janie Creek	QLD	141.8234	-12.0260	TC	GOC	Summer Pos/Winter Neg
Jardine River	QLD	142.2131	-10.9222	WDD	GOC	Summer Pos/Winter Neg
John's Creek	QLD	139.4522	-17.3949	TC	GOC	Summer Pos/Winter Neg
Kendall River	QLD	141.5940	-14.1634	WDD	GOC	Summer Pos/Winter Neg
Kirke River	QLD	141.4716	-13.9320	WDE	GOC	Summer Pos/Winter Neg
Kungunmeah Creek	QLD	139.3573	-16.6887	TC	GOC	Summer Pos/Winter Neg
Lagoon Creek	QLD	138.4607	-16.7737	TC	GOC	Summer Pos/Winter Neg
Leichhardt River	QLD	139.7961	-17.5754	TDD	GOC	Summer Pos/Winter Neg
Love River	QLD	141.5622	-13.4949	WDE	GOC	Summer Pos/Winter Neg
Macdonald River	QLD	142.0610	-11.5292	WDD	GOC	Summer Pos/Winter Neg
Malaman Creek	QLD	141.6642	-15.0332	CL/SP	GOC	Summer Pos/Winter Neg
Marless Creek	QLD	139.2857	-17.3511	TC	GOC	Summer Pos/Winter Neg
Massacre Inlet	QLD	138.3350	-16.7358	TDD	GOC	Summer Pos/Winter Neg
Mckenzie Creek	QLD	139.4722	-17.0979	TC	GOC	Summer Pos/Winter Neg
Mission River	QLD	141.8941	-12.5970	TDE	GOC	Summer Pos/Winter Neg
Mitchell River	QLD	141.6479	-15.0678	TDD	GOC	Summer Pos/Winter Neg
Moonkan Creek	QLD	141.5898	-14.8522	CL/SP	GOC	Summer Pos/Winter Neg
Moonlight Creek	QLD	139.2190	-17.2998	TC	GOC	Summer Pos/Winter Neg
Morning Inlet	QLD	140.2151	-17.7062	TC	GOC	Summer Pos/Winter Neg
Namaleta Creek	QLD	141.9464	-11.9809	TC	GOC	Summer Pos/Winter Neg
Nassau River	QLD	141.3936	-15.9085	WDD	GOC	Summer Pos/Winter Neg
Ngulwonmeah River	QLD	139.4831	-16.5355	TC	GOC	Summer Pos/Winter Neg
Norman Creek	QLD	141.6189	-13.0479	TC	GOC	Summer Pos/Winter Neg
Norman River	QLD	140.8203	-17.4632	TDD	GOC	Summer Pos/Winter Neg
Pascoe Inlet	QLD	139.6057	-17.5051	TDD	GOC	Summer Pos/Winter Neg
Passmore Creek	QLD	138.9767	-16.8884	TDD	GOC	Summer Pos/Winter Neg
Pennefather River	QLD	141.7227	-12.2292	TC	GOC	Summer Pos/Winter Neg
Pine River Bay	QLD	141.7078	-12.5313	TDE	GOC	Summer Pos/Winter Neg
Port Musgrave	QLD	141.9243	-11.9534	TDE	GOC	Summer Pos/Winter Neg
Q001	QLD	138.0319	-16.5672	CL/SP	GOC	Summer Pos/Winter Neg
Q003	QLD	138.1177	-16.6487	CL/SP	GOC	Summer Pos/Winter Neg
Q006	QLD	138.4303	-16.7682	TC	GOC	Summer Pos/Winter Neg
Q008	QLD	138.4770	-16.7769	TC	GOC	Summer Pos/Winter Neg
Q010	QLD	138.6163	-16.7712	TC	GOC	Summer Pos/Winter Neg
Q013	QLD	139.0341	-16.9273	TC	GOC	Summer Pos/Winter Neg
Q017	QLD	139.1899	-16.6672	TC	GOC	Summer Pos/Winter Neg
Q029	QLD	139.4732	-17.0238	TC	GOC	Summer Pos/Winter Neg
Q030	QLD	139.4949	-17.0005	TC	GOC	Summer Pos/Winter Neg
Q031	QLD	139.5574	-17.0676	CL/SP	GOC	Summer Pos/Winter Neg
Q033	QLD	139.3071	-17.3645	TC	GOC	Summer Pos/Winter Neg
Q034	QLD	139.3400	-17.3752	TC	GOC	Summer Pos/Winter Neg
Q037	QLD	139.5053	-17.4288	TC	GOC	Summer Pos/Winter Neg
Q039	QLD	139.5789	-17.4766	TC	GOC	Summer Pos/Winter Neg
Q040	QLD	139.5925	-17.4870	TC	GOC	Summer Pos/Winter Neg
Q045	QLD	139.9105	-17.6144	TC	GOC	Summer Pos/Winter Neg
Q047	QLD	140.1240	-17.7183	TC	GOC	Summer Pos/Winter Neg
Q048	QLD	140.1595	-17.7112	TC	GOC	Summer Pos/Winter Neg
Q049	QLD	140.1836	-17.7068	TC	GOC	Summer Pos/Winter Neg
Q061	QLD	141.2974	-16.4959	TC	GOC	Summer Pos/Winter Neg
Q062	QLD	141.2959	-16.4960	TC	GOC	Summer Pos/Winter Neg
Q093	QLD	142.1568	-11.1256	TC	GOC	Summer Pos/Winter Neg
Salt Arm Creek	QLD	141.3888	-16.1599	CL/SP	GOC	Summer Pos/Winter Neg
Sandalwood River	QLD	139.3500	-16.4670	TC	GOC	Summer Pos/Winter Neg
Skardon River	QLD	141.9939	-11.7567	TC	GOC	Summer Pos/Winter Neg
Smithburne River	QLD	140.9523	-17.0491	TDD	GOC	Summer Pos/Winter Neg

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Snake Creek	QLD	141.2053	-16.6906	TDD	GOC	Summer Pos/Winter Neg
Spring Creek	QLD	140.4553	-17.6449	TC	GOC	Summer Pos/Winter Neg
Staaten River	QLD	141.2946	-16.3978	TDD	GOC	Summer Pos/Winter Neg
Syrell Creek	QLD	139.0931	-17.0035	TC	GOC	Summer Pos/Winter Neg
Toongoowahgun Inlet	QLD	139.3864	-16.6390	TC	GOC	Summer Pos/Winter Neg
Topsy Creek	QLD	141.4819	-15.4997	WDD	GOC	Summer Pos/Winter Neg
Towbulbulan River	QLD	139.6863	-16.4637	TC	GOC	Summer Pos/Winter Neg
Tully Inlet	QLD	138.1595	-16.6749	WDD	GOC	Summer Pos/Winter Neg
Walbor Inlet	QLD	139.4653	-16.5729	TC	GOC	Summer Pos/Winter Neg
Wenlock River	QLD	141.9272	-12.0510	TDE	GOC	Summer Pos/Winter Neg
Williams Inlet	QLD	139.6469	-17.5367	TC	GOC	Summer Pos/Winter Neg
Alligator Creek	QLD	146.9271	-19.3031	TDD	NEC	Annual Pos
Althaus Creek	QLD	146.6009	-19.1518	WDD	NEC	Annual Pos
Annan River	QLD	145.2708	-15.5304	WDD	NEC	Annual Pos
Auckland Inlet	QLD	151.2522	-23.8327	TC	NEC	Annual Pos
Baffle Creek	QLD	152.0591	-24.5137	TDD	NEC	Annual Pos
Bakers Creek	QLD	149.1875	-21.2160	TDE	NEC	Annual Pos
Barramundi Creek	QLD	147.1679	-19.4112	TDD	NEC	Annual Pos
Barratta Creek	QLD	147.2525	-19.4330	TDD	NEC	Annual Pos
Barron River	QLD	145.7648	-16.8629	WDD	NEC	Annual Pos
Basin Creek	QLD	149.4352	-21.7492	TDD	NEC	Annual Pos
Bauer Inlet	QLD	145.3634	-15.8708	CL/SP	NEC	Annual Pos
Beelbi Creek	QLD	152.6625	-25.2490	CL/SP	NEC	Annual Pos
Bizant River	QLD	144.0313	-14.4796	TC	NEC	Annual Pos
Black River	QLD	146.6515	-19.1779	WDD	NEC	Annual Pos
Blackrock Creek	QLD	148.8283	-20.8110	TDE	NEC	Annual Pos
Blackwater/Mitchell Creek	QLD	152.0108	-24.4395	WDD	NEC	Annual Pos
Bloomfield River	QLD	145.3631	-15.9219	WDD	NEC	Annual Pos
Bluewater Creek	QLD	146.5930	-19.1470	WDD	NEC	Annual Pos
Bohle River	QLD	146.7003	-19.1919	TDD	NEC	Annual Pos
Boyne River	QLD	151.3027	-23.8585	TDD	NEC	Annual Pos
Branch Creek	QLD	147.9860	-19.9255	CL/SP	NEC	Annual Pos
Breakfast Creek	QLD	143.6284	-13.9748	TC	NEC	Annual Pos
Burdekin River	QLD	147.6111	-19.6874	TDD	NEC	Annual Pos
Burnett River	QLD	152.4053	-24.7549	TDD	NEC	Annual Pos
Burrum River	QLD	152.6206	-25.1785	TDD	NEC	Annual Pos
Calliope River	QLD	151.2182	-23.8231	TDD	NEC	Annual Pos
Canoe Passage	QLD	150.4632	-22.2668	EMB/DRV	NEC	Annual Pos
Cape Creek	QLD	149.4461	-21.5509	TDE	NEC	Annual Pos
Carmila Creek	QLD	149.4645	-21.9060	TC	NEC	Annual Pos
Castrades Inlet	QLD	149.3119	-21.3702	WDE	NEC	Annual Pos
Cattle Creek	QLD	146.2752	-18.8610	TDE	NEC	Annual Pos
Causeway Lake	QLD	150.7930	-23.2007	WDE	NEC	Annual Pos
Cawarral Creek	QLD	150.7932	-23.3157	TC	NEC	Annual Pos
Chester River	QLD	143.5452	-13.7017	TC	NEC	Annual Pos
Clairview Creek	QLD	149.5564	-22.1883	TDE	NEC	Annual Pos
Claudie River	QLD	143.3578	-12.8397	WDD	NEC	Annual Pos
Coconut Creek	QLD	149.4065	-21.5445	TC	NEC	Annual Pos
Colloseum Inlet	QLD	151.4354	-23.9881	TDE	NEC	Annual Pos
Constant Creek	QLD	149.0313	-20.9822	TDE	NEC	Annual Pos
Coonar Creek	QLD	152.4898	-24.9685	CL/SP	NEC	Annual Pos
Cooper Creek	QLD	145.4409	-16.1769	WDD	NEC	Annual Pos
Coral Creek	QLD	146.2304	-18.2431	TC	NEC	Annual Pos
Corio Bay	QLD	150.7852	-22.9515	TDE	NEC	Annual Pos
Cowal Creek	QLD	142.3221	-10.9097	TC	NEC	Annual Pos
Crocodile Creek	QLD	146.9515	-19.3008	TDD	NEC	Annual Pos
Crystal Creek	QLD	146.3237	-18.9276	WDD	NEC	Annual Pos
Curtis Island Creek	QLD	151.1144	-23.4866	TC	NEC	Annual Pos
Daintree River	QLD	145.4514	-16.2915	TDD	NEC	Annual Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Dallachy Creek	QLD	146.0093	-18.1641	TC	NEC	Annual Pos
Dead Dog Creek	QLD	144.8800	-14.6123	TC	NEC	Annual Pos
Deep Creek	QLD	146.2254	-18.2757	TC	NEC	Annual Pos
Dempster Creek	QLD	148.7213	-20.6710	TC	NEC	Annual Pos
Dicksons Inlet	QLD	145.4587	-16.4827	TC	NEC	Annual Pos
Don River	QLD	148.2236	-19.9621	WDE	NEC	Annual Pos
East Creek	QLD	150.5633	-22.5106	TC	NEC	Annual Pos
Elliot River	QLD	147.8877	-19.8794	CL/SP	NEC	Annual Pos
Elliot River	QLD	152.4893	-24.9322	TC	NEC	Annual Pos
Endeavour River	QLD	145.2454	-15.4593	WDD	NEC	Annual Pos
Escape River	QLD	142.7107	-10.9582	TDE	NEC	Annual Pos
Euri Creek	QLD	148.1621	-19.9486	TC	NEC	Annual Pos
Eurimbula Creek	QLD	151.8433	-24.1705	TC	NEC	Annual Pos
Feather Creek	QLD	149.4825	-21.9582	TDD	NEC	Annual Pos
Fig Tree Creek	QLD	146.2832	-18.8747	TC	NEC	Annual Pos
Fitzroy River	QLD	150.8748	-23.5234	TDE	NEC	Annual Pos
Five-Mile Creek	QLD	143.6961	-14.0913	TC	NEC	Annual Pos
Gentle Annie Creek	QLD	146.3436	-18.5637	WDD	NEC	Annual Pos
Georges Creek	QLD	150.5508	-22.5618	TC	NEC	Annual Pos
Glennie Inlet	QLD	143.1040	-12.3442	TC	NEC	Annual Pos
Great Sandy Strait	QLD	152.9709	-25.4355	EMB/DRV	NEC	Annual Pos
Gregory River	QLD	148.4275	-20.1595	TDD	NEC	Annual Pos
Half Moon Creek	QLD	145.7152	-16.8014	TC	NEC	Annual Pos
Harmer Creek	QLD	142.9564	-11.9132	TDD	NEC	Annual Pos
Haughton River	QLD	147.1262	-19.4161	TDD	NEC	Annual Pos
Head Creek	QLD	150.5758	-22.5610	TDE	NEC	Annual Pos
Herbert Creek	QLD	149.8889	-22.3926	TDE	NEC	Annual Pos
Herbert River	QLD	146.2726	-18.5029	TDD	NEC	Annual Pos
Hervey Bay	QLD	152.7099	-24.7191	EMB/DRV	NEC	Annual Pos
Hervey Creek	QLD	148.7336	-20.7162	TC	NEC	Annual Pos
Hinchinbrook Channel	QLD	146.0533	-18.2584	EMB/DRV	NEC	Annual Pos
Howick River	QLD	144.7170	-14.5566	TC	NEC	Annual Pos
Hull River	QLD	146.0766	-17.9925	WDD	NEC	Annual Pos
Hummock Creek	QLD	144.9591	-14.7388	TC	NEC	Annual Pos
Hunter Inlet	QLD	143.1325	-12.3465	TC	NEC	Annual Pos
Island Head Creek	QLD	150.6541	-22.3481	TDE	NEC	Annual Pos
Jeannie River	QLD	144.9215	-14.6558	WDD	NEC	Annual Pos
Johnstone River	QLD	146.0663	-17.5087	TDD	NEC	Annual Pos
Kangaroo River	QLD	143.1273	-12.3470	TC	NEC	Annual Pos
Kennedy Inlet	QLD	142.5713	-10.8412	TDE	NEC	Annual Pos
Knobler Creek	QLD	149.4458	-21.6627	TC	NEC	Annual Pos
Kolan River	QLD	152.1881	-24.6505	WDD	NEC	Annual Pos
Leichhardt Creek	QLD	146.5103	-19.0991	WDD	NEC	Annual Pos
Littabella Creek	QLD	152.1076	-24.5789	WDD	NEC	Annual Pos
Liverpool Creek	QLD	146.1090	-17.7089	WDD	NEC	Annual Pos
Lockhardt River	QLD	143.3712	-12.8771	TDE	NEC	Annual Pos
Logan Jack Creek	QLD	142.7870	-11.2201	TC	NEC	Annual Pos
Longford Creek	QLD	148.4109	-20.1626	TC	NEC	Annual Pos
Louisa Creek	QLD	149.2699	-21.2718	TDE	NEC	Annual Pos
Mackenzie Creek	QLD	145.4446	-16.2024	TC	NEC	Annual Pos
Macmillan River	QLD	143.1702	-11.9727	TC	NEC	Annual Pos
Maria Creek	QLD	146.0926	-17.8027	WDD	NEC	Annual Pos
Marion Creek	QLD	149.4580	-21.7290	TC	NEC	Annual Pos
Marrett River	QLD	144.1676	-14.3802	TDD	NEC	Annual Pos
Mary River	QLD	152.9264	-25.4329	TDE	NEC	Annual Pos
Massey Creek	QLD	143.6053	-13.9143	TC	NEC	Annual Pos
Mcivor River	QLD	145.2361	-15.1420	TC	NEC	Annual Pos
Meunga Creek	QLD	146.0186	-18.2314	TDD	NEC	Annual Pos
Miralda Creek	QLD	148.4633	-20.1219	TC	NEC	Annual Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Missionary Bay	QLD	146.1772	-18.2162	EMB/DRV	NEC	Annual Pos
Moresby River	QLD	146.1296	-17.6004	TDD	NEC	Annual Pos
Mossman River	QLD	145.4054	-16.4339	TDD	NEC	Annual Pos
Mowbray River	QLD	145.4884	-16.5448	TDD	NEC	Annual Pos
Mud Creek	QLD	147.5327	-19.5210	CL/SP	NEC	Annual Pos
Murray Creek	QLD	148.8685	-20.8493	TDE	NEC	Annual Pos
Murray River	QLD	146.0293	-18.0853	WDD	NEC	Annual Pos
Mutchero Inlet	QLD	145.9684	-17.2238	WDD	NEC	Annual Pos
Nesbit River	QLD	143.5856	-13.5430	WDD	NEC	Annual Pos
Noah Creek	QLD	145.4481	-16.1433	WDD	NEC	Annual Pos
Nobbies Inlet	QLD	147.7619	-19.8261	TC	NEC	Annual Pos
Normanby River	QLD	144.1443	-14.4068	TDD	NEC	Annual Pos
North Kennedy River	QLD	143.9466	-14.4898	TDD	NEC	Annual Pos
O'Connell River	QLD	148.6619	-20.5710	TDD	NEC	Annual Pos
Olive River	QLD	143.0922	-12.1660	WDD	NEC	Annual Pos
Ollera Creek	QLD	146.3608	-18.9652	WDD	NEC	Annual Pos
Orient Creek	QLD	146.2770	-18.8077	WDD	NEC	Annual Pos
Oyster Creek	QLD	150.4398	-22.5060	TC	NEC	Annual Pos
Palm Creek	QLD	146.2864	-18.7661	WDD	NEC	Annual Pos
Pancake/Jenny Lind Creek	QLD	151.7323	-24.0118	TDE	NEC	Annual Pos
Pascoe River	QLD	143.2736	-12.4952	WDD	NEC	Annual Pos
Pioneer River	QLD	149.2207	-21.1493	TDD	NEC	Annual Pos
Plantation Creek	QLD	147.5367	-19.5225	CL/SP	NEC	Annual Pos
Plantation Creek	QLD	148.9828	-20.8998	CL/SP	NEC	Annual Pos
Port Clinton	QLD	150.7624	-22.4981	EMB/DRV	NEC	Annual Pos
Port Curtis	QLD	151.3739	-23.9115	EMB/DRV	NEC	Annual Pos
Proserpine River	QLD	148.7291	-20.4905	TDD	NEC	Annual Pos
Pumpkin Creek	QLD	150.7979	-23.3393	TC	NEC	Annual Pos
Q100	QLD	142.9185	-11.8929	TC	NEC	Annual Pos
Q102	QLD	143.0624	-11.9230	TC	NEC	Annual Pos
Q105	QLD	143.0883	-12.3459	TC	NEC	Annual Pos
Q113	QLD	143.5500	-13.6452	CL/SP	NEC	Annual Pos
Q124	QLD	144.3427	-14.3072	TC	NEC	Annual Pos
Q125	QLD	144.4122	-14.2720	TC	NEC	Annual Pos
Q128	QLD	144.6839	-14.5523	TC	NEC	Annual Pos
Q134	QLD	144.9957	-14.7542	TC	NEC	Annual Pos
Q136	QLD	145.0425	-14.7983	TC	NEC	Annual Pos
Q137	QLD	145.0539	-14.7987	TC	NEC	Annual Pos
Q138	QLD	145.1065	-14.8195	TC	NEC	Annual Pos
Q139	QLD	145.1131	-14.8243	TC	NEC	Annual Pos
Q140	QLD	145.1327	-14.8312	TC	NEC	Annual Pos
Q171	QLD	146.2352	-18.2617	TC	NEC	Annual Pos
Q195	QLD	147.2142	-19.4220	TC	NEC	Annual Pos
Q221	QLD	149.0588	-20.9777	TC	NEC	Annual Pos
Q223	QLD	149.2124	-21.0736	TC	NEC	Annual Pos
Q245	QLD	149.9140	-22.3304	TC	NEC	Annual Pos
Q246	QLD	149.9160	-22.2998	TC	NEC	Annual Pos
Q256	QLD	150.5361	-22.4492	TC	NEC	Annual Pos
Q257	QLD	150.5377	-22.4299	TC	NEC	Annual Pos
Q259	QLD	150.4838	-22.3154	TC	NEC	Annual Pos
Raspberry Creek	QLD	150.4071	-22.4869	TDE	NEC	Annual Pos
Reliance/Leila Creek	QLD	149.1261	-21.0012	TC	NEC	Annual Pos
Repulse Creek	QLD	148.7973	-20.4560	TDD	NEC	Annual Pos
Rocky Creek	QLD	144.7974	-14.5968	TC	NEC	Annual Pos
Rocky Dam Creek	QLD	149.3056	-21.4804	TDE	NEC	Annual Pos
Rocky Ponds Creek	QLD	147.6662	-19.8159	TC	NEC	Annual Pos
Rocky River	QLD	143.5418	-13.7769	TC	NEC	Annual Pos
Rodd's Harbour	QLD	151.5880	-24.0200	TDE	NEC	Annual Pos
Rollingstone Creek	QLD	146.4018	-19.0083	WDD	NEC	Annual Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Ross Creek	QLD	150.2201	-22.3898	TC	NEC	Annual Pos
Ross River	QLD	146.8291	-19.2500	TC	NEC	Annual Pos
Round Hill Creek	QLD	151.8768	-24.1639	TC	NEC	Annual Pos
Saint Lawrence Creek	QLD	149.6134	-22.2841	TDE	NEC	Annual Pos
Saltwater Creek	QLD	144.6195	-14.4646	TC	NEC	Annual Pos
Saltwater Creek	QLD	145.4096	-16.4103	TC	NEC	Annual Pos
Sandfly Creek	QLD	146.8622	-19.2891	TC	NEC	Annual Pos
Sandy Creek	QLD	149.2328	-21.2459	TDE	NEC	Annual Pos
Sarina Inlet	QLD	149.3204	-21.4021	TDE	NEC	Annual Pos
Shoalwater Creek	QLD	150.4791	-22.5204	TDE	NEC	Annual Pos
Sleeper Log Creek	QLD	146.5329	-19.1137	WDD	NEC	Annual Pos
Starke River	QLD	145.0183	-14.7814	TDD	NEC	Annual Pos
Stewart River	QLD	143.6924	-14.0703	WDD	NEC	Annual Pos
Styx River	QLD	149.7851	-22.3764	TDE	NEC	Annual Pos
The Narrows	QLD	151.1655	-23.7478	EMB/DRV	NEC	Annual Pos
Theodolite/Lagoon Creek	QLD	152.5515	-25.0700	WDD	NEC	Annual Pos
Thirsty Sound	QLD	149.9037	-22.2720	EMB/DRV	NEC	Annual Pos
Thompson Creek	QLD	148.6750	-20.5511	TC	NEC	Annual Pos
Trinity Inlet	QLD	145.7855	-16.9045	TC	NEC	Annual Pos
Tully River	QLD	146.0543	-18.0328	WDD	NEC	Annual Pos
Victor Creek	QLD	148.9351	-20.8862	TC	NEC	Annual Pos
Victoria Creek	QLD	146.3384	-18.6193	WDD	NEC	Annual Pos
Wadallah Creek	QLD	150.5504	-22.4804	TC	NEC	Annual Pos
Wakooka Creek	QLD	144.6249	-14.4873	TC	NEC	Annual Pos
Walter Hall Creek	QLD	149.4615	-21.7132	TC	NEC	Annual Pos
Waverly Creek	QLD	149.6686	-22.3398	TDE	NEC	Annual Pos
West Hill Creek	QLD	149.4582	-21.8334	TDE	NEC	Annual Pos
Wreck Creek	QLD	146.0102	-18.1906	TC	NEC	Annual Pos
Yeates Creek	QLD	148.3420	-20.1525	TC	NEC	Annual Pos
Zoe Bay	QLD	146.3316	-18.3825	CL/SP	NEC	Annual Pos
Brisbane River	QLD	153.1655	-27.3726	TDD	SEC	Annual Pos
Burpengary Creek	QLD	153.0395	-27.1624	TC	SEC	Annual Pos
Caboolture River	QLD	153.0444	-27.1530	TDD	SEC	Annual Pos
Coombabah Lake	QLD	153.3997	-27.8698	WDE	SEC	Annual Pos
Coomera River	QLD	153.3963	-27.8313	TDD	SEC	Annual Pos
Currimundi Creek	QLD	153.1349	-26.7661	CL/SP	SEC	Annual Pos
Currumbin Creek	QLD	153.4842	-28.1276	TC	SEC	Annual Pos
Eprapah Creek	QLD	153.2944	-27.5620	TC	SEC	Annual Pos
Hilliards Creek	QLD	153.2664	-27.4901	TC	SEC	Annual Pos
Kedron Brook	QLD	153.1108	-27.3477	TC	SEC	Annual Pos
Logan Albert River	QLD	153.3493	-27.6943	TDD	SEC	Annual Pos
Maroochy River	QLD	153.1018	-26.6467	WDE	SEC	Annual Pos
Mooloolah River	QLD	153.1328	-26.6808	WDD	SEC	Annual Pos
Moreton Bay	QLD	153.2840	-27.0710	WDE	SEC	Annual Pos
Nerang River	QLD	153.4236	-27.9746	WDD	SEC	Annual Pos
Noosa River	QLD	153.0790	-26.3800	WDE	SEC	Annual Pos
Nundah/Cabbage Tree Creek	QLD	153.0877	-27.3304	TC	SEC	Annual Pos
Pimpama River	QLD	153.3957	-27.8200	TDD	SEC	Annual Pos
Pine River	QLD	153.0629	-27.2790	TDE	SEC	Annual Pos
Pumicestone Passage	QLD	153.1513	-27.0760	EMB/DRV	SEC	Annual Pos
Southern Moreton Bay	QLD	153.4475	-27.7403	EMB/DRV	SEC	Annual Pos
Tallebudgera Creek	QLD	153.4615	-28.0947	TC	SEC	Annual Pos
Tingalpa Creek	QLD	153.2003	-27.4682	TDD	SEC	Annual Pos
American River	SA	137.7747	-35.7848	CL/SP	GAB	Annual Neg.
Baird Bay	SA	134.3604	-33.1516	CL/SP	GAB	Annual Neg.
Blanche Port	SA	134.2180	-32.7502	CL/SP	GAB	Annual Neg.
Breakneck River	SA	136.5803	-35.9312	CL/SP	GAB	Annual Neg.
Chapman River	SA	138.0694	-35.7862	CL/SP	GAB	Annual Neg.
Cygnet River	SA	137.6031	-35.6861	CL/SP	GAB	Annual Neg.

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Eleanor River	SA	137.2022	-35.9742	CL/SP	GAB	Annual Neg.
First Creek	SA	137.9756	-33.1482	TC	GAB	Annual Neg.
Fisherman Creek	SA	137.8478	-33.2055	TC	GAB	Annual Neg.
Franklin Harbour	SA	136.9775	-33.7307	CL/SP	GAB	Annual Neg.
Gawler River	SA	138.4614	-34.6733	TC	GAB	Annual Neg.
Harriet River	SA	137.1795	-35.9851	CL/SP	GAB	Annual Neg.
Hindmarsh River	SA	138.6311	-35.5441	WDD	GAB	Annual Neg.
Inman River	SA	138.6156	-35.5603	CL/SP	GAB	Annual Neg.
Light River Delta	SA	138.3687	-34.5759	TDD	GAB	Annual Neg.
Middle River	SA	137.0746	-35.6653	CL/SP	GAB	Annual Neg.
Myponga River	SA	138.3845	-35.3727	CL/SP	GAB	Annual Neg.
Northern Spencer Gulf	SA	137.8484	-32.7678	TC	GAB	Annual Neg.
Onkaparinga River	SA	138.4697	-35.1645	WDD	GAB	Annual Neg.
Patawalonga Creek	SA	138.5109	-34.9750	CL/SP	GAB	Annual Neg.
Port Broughton Estuary	SA	137.9263	-33.5976	TC	GAB	Annual Neg.
Port Davis Creek	SA	137.8230	-33.2493	TC	GAB	Annual Neg.
Port Douglas/Coffin Bay	SA	135.3659	-34.5262	CL/SP	GAB	Annual Neg.
Port Pirie	SA	138.0157	-33.1491	TC	GAB	Annual Neg.
Port River Barker Inlet System	SA	138.5284	-34.7605	TC	GAB	Annual Neg.
Second Creek	SA	137.9493	-33.1585	TC	GAB	Annual Neg.
Smokey Bay	SA	133.9147	-32.3970	EMB/DRV	GAB	Annual Neg.
South West River	SA	136.8544	-36.0163	CL/SP	GAB	Annual Neg.
Stunsail Boom	SA	137.0156	-36.0201	CL/SP	GAB	Annual Neg.
Third Creek	SA	137.9196	-33.1803	TC	GAB	Annual Neg.
Tod River	SA	135.9025	-34.5922	TDD	GAB	Annual Neg.
Tourville Bay	SA	133.4945	-32.1695	EMB/DRV	GAB	Annual Neg.
Venus Bay	SA	134.6600	-33.2288	CL/SP	GAB	Annual Neg.
Wakefield River	SA	138.1444	-34.1894	TC	GAB	Annual Neg.
Western River	SA	136.9714	-35.6758	CL/SP	GAB	Annual Neg.
Willson River	SA	137.9351	-35.8644	CL/SP	GAB	Annual Neg.
Lake George	SA	140.0195	-37.4767	WDE	SEC	Annual Pos
The Coorong & Lower Lakes	SA	138.8897	-35.5610	WDE	SEC	Annual Pos
Ansons Bay	TAS	148.2975	-41.0627	WDE	SEC	Annual Pos
Arthur River	TAS	144.6628	-41.0542	WDD	SEC	Annual Pos
Bathurst Harbour	TAS	145.9838	-43.3268	WDE	SEC	Annual Pos
Big Lagoon	TAS	148.2709	-41.1803	CL/SP	SEC	Annual Pos
Black River	TAS	145.3158	-40.8365	WDD	SEC	Annual Pos
Blackman Bay	TAS	147.8864	-42.8445	WDE	SEC	Annual Pos
Blyth River	TAS	145.9846	-41.0742	WDD	SEC	Annual Pos
Brid River	TAS	147.3984	-41.0012	WDE	SEC	Annual Pos
Browns River	TAS	147.3290	-42.9774	WDE	SEC	Annual Pos
Bryans Lagoon	TAS	148.2898	-42.2606	CL/SP	SEC	Annual Pos
Buxton River	TAS	148.0154	-42.2685	WDD	SEC	Annual Pos
Cam River	TAS	145.8400	-41.0386	CL/SP	SEC	Annual Pos
Cameron Inlet	TAS	148.2660	-40.1050	WDE	SEC	Annual Pos
Carlton River	TAS	147.6413	-42.8772	WDE	SEC	Annual Pos
Catamaran River	TAS	146.8900	-43.5533	CL/SP	SEC	Annual Pos
Cloudy Bay Lagoon	TAS	147.2022	-43.4395	WDE	SEC	Annual Pos
Cockle Creek	TAS	146.8925	-43.5823	CL/SP	SEC	Annual Pos
Crayfish Creek	TAS	145.3977	-40.8570	CL/SP	SEC	Annual Pos
Crookes Rivulet	TAS	146.9628	-43.1585	EMB/DRV	SEC	Annual Pos
Curries River	TAS	146.9491	-41.0250	CL/SP	SEC	Annual Pos
Denison Rivulet	TAS	148.2300	-41.8270	CL/SP	SEC	Annual Pos
D'entrecasteaux Channel	TAS	147.0596	-43.4150	EMB/DRV	SEC	Annual Pos
Derwent River	TAS	147.3827	-42.9442	WDE	SEC	Annual Pos
Detention River	TAS	145.4495	-40.8711	WDD	SEC	Annual Pos
Don River	TAS	146.3350	-41.1602	WDE	SEC	Annual Pos
Douglas River	TAS	148.2670	-41.7830	CL/SP	SEC	Annual Pos
Dover River	TAS	148.2900	-40.3600	CL/SP	SEC	Annual Pos

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Duck Bay	TAS	145.1073	-40.7938	WDE	SEC	Annual Pos
Earlham Lagoon	TAS	147.9568	-42.6546	WDE	SEC	Annual Pos
East Inlet	TAS	145.2773	-40.7891	TC	SEC	Annual Pos
Emu River	TAS	145.8802	-41.0424	CL/SP	SEC	Annual Pos
Esperance River	TAS	147.0600	-43.3415	WDE	SEC	Annual Pos
Ettrick River	TAS	143.9700	-40.0100	CL/SP	SEC	Annual Pos
Foochow Inlet	TAS	148.1230	-39.8990	CL/SP	SEC	Annual Pos
Forth River	TAS	146.2501	-41.1572	TDE	SEC	Annual Pos
Frederick Henry Bay	TAS	147.5868	-42.9935	EMB/DRV	SEC	Annual Pos
Freney Lagoon	TAS	146.2291	-43.4912	CL/SP	SEC	Annual Pos
Freshwater Lagoon	TAS	148.2990	-42.0640	CL/SP	SEC	Annual Pos
Garden Island	TAS	147.1430	-43.2504	CL/SP	SEC	Annual Pos
Georges Bay	TAS	148.3310	-41.2764	WDE	SEC	Annual Pos
Giblin River	TAS	145.6840	-43.0666	CL/SP	SEC	Annual Pos
Grants Lagoon	TAS	148.2993	-41.2500	WDE	SEC	Annual Pos
Great Musselroe River	TAS	148.1734	-40.8287	WDE	SEC	Annual Pos
Great Swanport	TAS	148.2354	-42.0998	WDE	SEC	Annual Pos
Grindstone	TAS	147.9975	-42.4376	CL/SP	SEC	Annual Pos
Henderson Lagoon	TAS	148.2680	-41.5076	WDE	SEC	Annual Pos
Henty River	TAS	145.2513	-42.0608	WDE	SEC	Annual Pos
Hibbs Lagoon	TAS	145.3023	-42.5716	CL/SP	SEC	Annual Pos
Huon River	TAS	147.1237	-43.2806	WDE	SEC	Annual Pos
Inglis River	TAS	145.7395	-40.9866	WDD	SEC	Annual Pos
Lagoon River	TAS	144.8351	-41.5101	CL/SP	SEC	Annual Pos
Lee River	TAS	148.2000	-40.3800	CL/SP	SEC	Annual Pos
Levan River	TAS	146.3701	-41.1676	WDE	SEC	Annual Pos
Lewis River	TAS	145.4945	-42.9506	WDE	SEC	Annual Pos
Lisdillon Lagoon	TAS	148.0106	-42.2912	CL/SP	SEC	Annual Pos
Little Forester River	TAS	147.3637	-40.9704	WDD	SEC	Annual Pos
Little Henty River	TAS	145.1965	-41.9490	WDE	SEC	Annual Pos
Little Musselroe River	TAS	148.0381	-40.7627	CL/SP	SEC	Annual Pos
Little Swanport	TAS	148.0004	-42.3118	WDE	SEC	Annual Pos
Logan Lagoon	TAS	148.2900	-40.1700	CL/SP	SEC	Annual Pos
Louisa Creek	TAS	146.3449	-43.5159	CL/SP	SEC	Annual Pos
Louisa River	TAS	146.3706	-43.5260	CL/SP	SEC	Annual Pos
Macquarie Harbour	TAS	145.2189	-42.2126	WDE	SEC	Annual Pos
Mainwaring River	TAS	145.4363	-42.8696	WDE	SEC	Annual Pos
Meredith River	TAS	148.0740	-42.1116	WDD	SEC	Annual Pos
Mersey River	TAS	146.3701	-41.1676	WDE	SEC	Annual Pos
Middle Inlet	TAS	148.1540	-39.9260	CL/SP	SEC	Annual Pos
Mines Creek	TAS	147.8720	-39.8890	CL/SP	SEC	Annual Pos
Modder River	TAS	148.0620	-40.4250	WDE	SEC	Annual Pos
Montagu	TAS	144.9402	-40.7477	TC	SEC	Annual Pos
Mosquito Inlet	TAS	144.9517	-40.6245	EMB/DRV	SEC	Annual Pos
Mulcahy River	TAS	145.7146	-43.1116	CL/SP	SEC	Annual Pos
Nelson Bay River	TAS	144.6791	-41.1402	CL/SP	SEC	Annual Pos
New River	TAS	146.6010	-43.5539	WDE	SEC	Annual Pos
North East River	TAS	147.9770	-39.7890	WDE	SEC	Annual Pos
North West Bay	TAS	147.3093	-43.0717	EMB/DRV	SEC	Annual Pos
Patriarch River	TAS	148.1490	-39.9580	CL/SP	SEC	Annual Pos
Pats River	TAS	148.0000	-40.0950	CL/SP	SEC	Annual Pos
Payne Bay	TAS	145.9433	-43.2983	WDE	SEC	Annual Pos
Pedder River	TAS	144.7779	-41.4053	CL/SP	SEC	Annual Pos
Pieman River	TAS	144.9236	-41.6669	WDD	SEC	Annual Pos
Pipeclay Lagoon	TAS	147.5390	-42.9602	WDE	SEC	Annual Pos
Pipers River	TAS	147.1585	-41.0096	WDE	SEC	Annual Pos
Pitt Water	TAS	147.6149	-42.8487	WDE	SEC	Annual Pos
Port Arthur	TAS	147.8875	-43.1926	EMB/DRV	SEC	Annual Pos
Port Cygnet	TAS	147.0787	-43.2245	EMB/DRV	SEC	Annual Pos

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Port Sorell	TAS	146.5551	-41.1385	WDE	SEC	Annual Pos
Prosser River	TAS	147.8807	-42.5529	WDE	SEC	Annual Pos
Ralphs Bay	TAS	147.4101	-42.9515	EMB/DRV	SEC	Annual Pos
Recherche Bay	TAS	146.9166	-43.5573	WDE	SEC	Annual Pos
Rices River	TAS	148.3100	-40.4130	CL/SP	SEC	Annual Pos
Ringarooma River	TAS	147.8879	-40.8607	WDE	SEC	Annual Pos
Robbins Passage	TAS	145.0585	-40.7302	EMB/DRV	SEC	Annual Pos
Rocky Head Rivulet	TAS	148.1370	-40.4420	CL/SP	SEC	Annual Pos
Saltwater Lagoon	TAS	148.2780	-42.0400	CL/SP	SEC	Annual Pos
Scamander River	TAS	148.2645	-41.4655	WDE	SEC	Annual Pos
Sea Elephant River	TAS	143.9870	-39.9160	CL/SP	SEC	Annual Pos
Seal River	TAS	143.9400	-40.0700	WDE	SEC	Annual Pos
Sellars Lagoon	TAS	148.2700	-40.0300	CL/SP	SEC	Annual Pos
Shag Lagoon	TAS	148.2060	-40.1620	CL/SP	SEC	Annual Pos
Sloop Lagoon	TAS	148.2756	-41.2086	CL/SP	SEC	Annual Pos
South Cape Rivulet	TAS	146.7856	-43.6027	CL/SP	SEC	Annual Pos
Southport	TAS	146.9613	-43.4474	WDE	SEC	Annual Pos
Southport Lagoon	TAS	146.9817	-43.4892	WDE	SEC	Annual Pos
Spero River	TAS	145.3346	-42.6357	CL/SP	SEC	Annual Pos
Spring Bay	TAS	147.9226	-42.5487	EMB/DRV	SEC	Annual Pos
Stoney Lagoon	TAS	148.0761	-42.1528	CL/SP	SEC	Annual Pos
Tamar River	TAS	146.7763	-41.0688	TDE	SEC	Annual Pos
Templestowe Lagoon	TAS	148.2790	-41.7270	WDE	SEC	Annual Pos
Thirsty Lagoon	TAS	148.4380	-40.3900	EMB/DRV	SEC	Annual Pos
Tomahawk River	TAS	147.7607	-40.8649	CL/SP	SEC	Annual Pos
Wanderer River	TAS	145.3869	-42.7330	WDE	SEC	Annual Pos
Welcome Inlet	TAS	144.7710	-40.7166	TC	SEC	Annual Pos
West Inlet	TAS	145.2610	-40.7867	TC	SEC	Annual Pos
Yarra Creek	TAS	144.1080	-40.0090	CL/SP	SEC	Annual Pos
Yellow Rock River	TAS	143.9100	-39.7200	CL/SP	SEC	Annual Pos
Aire River	VIC	143.4609	-38.8070	WDE	SEC	Annual Pos
Anderson Creek	VIC	143.6559	-38.7551	CL/SP	SEC	Annual Pos
Anderson Inlet	VIC	145.7208	-38.6497	WDE	SEC	Annual Pos
Anglesea River	VIC	144.1910	-38.4125	WDD	SEC	Annual Pos
Barham River	VIC	143.6681	-38.7658	CL/SP	SEC	Annual Pos
Barwon River	VIC	144.5011	-38.2857	WDE	SEC	Annual Pos
Benedore River	VIC	149.6224	-37.7003	CL/SP	SEC	Annual Pos
Betka River	VIC	149.7421	-37.5845	WDE	SEC	Annual Pos
Corner Inlet	VIC	146.4842	-38.7812	WDE	SEC	Annual Pos
Cumberland River	VIC	143.9484	-38.5765	CL/SP	SEC	Annual Pos
Curdies Inlet	VIC	142.8830	-38.6081	WDE	SEC	Annual Pos
Darby River	VIC	146.2684	-38.9891	CL/SP	SEC	Annual Pos
Easby Creek	VIC	149.5224	-37.7408	WDE	SEC	Annual Pos
Elliot River	VIC	143.6176	-38.7944	CL/SP	SEC	Annual Pos
Erskine River	VIC	143.9791	-38.5320	CL/SP	SEC	Annual Pos
Fitzroy River	VIC	141.8498	-38.2625	CL/SP	SEC	Annual Pos
Gellibrand River	VIC	143.1571	-38.7070	WDE	SEC	Annual Pos
Gippsland Lakes	VIC	147.9705	-37.8894	WDE	SEC	Annual Pos
Glenelg River	VIC	140.9838	-38.0611	WDE	SEC	Annual Pos
Grey River	VIC	143.8393	-38.6868	CL/SP	SEC	Annual Pos
Hopkins River	VIC	142.5089	-38.3987	WDD	SEC	Annual Pos
Jack Smith Lake	VIC	147.0395	-38.4969	WDE	SEC	Annual Pos
Jamieson River	VIC	143.9191	-38.5964	CL/SP	SEC	Annual Pos
Kennett River	VIC	143.8621	-38.6673	CL/SP	SEC	Annual Pos
Kororoit Creek	VIC	144.8659	-37.8592	TC	SEC	Annual Pos
Lake Tyers	VIC	148.0880	-37.8594	WDE	SEC	Annual Pos
Lake Yambuk	VIC	142.0398	-38.3367	WDE	SEC	Annual Pos
Limeburners Bay	VIC	144.4006	-38.0749	TC	SEC	Annual Pos
Mallacoota Inlet	VIC	149.7632	-37.5690	WDE	SEC	Annual Pos

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Merri River	VIC	142.4779	-38.3612	CL/SP	SEC	Annual Pos
Merriman Creek	VIC	147.1300	-38.4259	CL/SP	SEC	Annual Pos
Moyne River	VIC	142.2417	-38.3836	WDE	SEC	Annual Pos
Mueller River	VIC	149.3265	-37.7806	WDE	SEC	Annual Pos
Painkalac Creek/Aireys Inlet	VIC	144.0937	-38.4670	CL/SP	SEC	Annual Pos
Port Campbell River	VIC	142.9799	-38.6319	TDE	SEC	Annual Pos
Port Phillip Bay	VIC	144.6322	-38.2973	WDE	SEC	Annual Pos
Powlett River	VIC	145.5108	-38.5833	CL/SP	SEC	Annual Pos
Red River	VIC	149.5627	-37.7268	WDE	SEC	Annual Pos
Shallow Inlet	VIC	146.1842	-38.8715	WDE	SEC	Annual Pos
Sherbrook River	VIC	143.0568	-38.6438	CL/SP	SEC	Annual Pos
Shipwreck Creek	VIC	149.6994	-37.6492	CL/SP	SEC	Annual Pos
Skeleton Creek	VIC	144.8004	-37.8986	CL/SP	SEC	Annual Pos
Skenes Creek	VIC	143.7122	-38.7248	CL/SP	SEC	Annual Pos
Snowy River	VIC	148.5566	-37.8046	WDE	SEC	Annual Pos
Spring Creek	VIC	144.3199	-38.3414	WDD	SEC	Annual Pos
St George River	VIC	143.9645	-38.5689	CL/SP	SEC	Annual Pos
Surrey River	VIC	141.7042	-38.2602	CL/SP	SEC	Annual Pos
Swan Bay	VIC	144.6973	-38.2309	CL/SP	SEC	Annual Pos
Sydenham Inlet	VIC	149.0166	-37.7814	WDE	SEC	Annual Pos
Tamboon Inlet	VIC	149.1483	-37.7786	WDE	SEC	Annual Pos
Thompson Creek	VIC	144.3773	-38.3052	CL/SP	SEC	Annual Pos
Thurra River	VIC	149.3114	-37.7840	CL/SP	SEC	Annual Pos
Tidal River	VIC	146.3449	-39.0617	CL/SP	SEC	Annual Pos
Werribee River	VIC	144.6882	-37.9804	WDD	SEC	Annual Pos
Western Port Bay	VIC	145.2162	-38.4286	WDE	SEC	Annual Pos
Wild Dog Creek	VIC	143.6889	-38.7337	CL/SP	SEC	Annual Pos
Wingan Inlet	VIC	149.5134	-37.7488	WDE	SEC	Annual Pos
Wye River	VIC	143.8913	-38.6350	CL/SP	SEC	Annual Pos
Yarra River	VIC	144.9051	-37.8522	WDD	SEC	Annual Pos
Yeerung River	VIC	148.7751	-37.7915	CL/SP	SEC	Annual Pos
Ashburton River	WA	114.9145	-21.6902	WDD	NWC	Summer Pos/Winter Neg
Baldwin Creek	WA	122.3670	-17.0170	TC	NWC	Summer Pos/Winter Neg
Banningarra Creek	WA	119.7170	-20.0000	TC	NWC	Summer Pos/Winter Neg
Beagle Bay	WA	122.5632	-16.9421	TC	NWC	Summer Pos/Winter Neg
Beebingarra Creek	WA	118.6715	-20.3272	TC	NWC	Summer Pos/Winter Neg
Berkeley River	WA	127.7810	-14.3492	TDE	NWC	Summer Pos/Winter Neg
Boongaree Island Creek	WA	125.1364	-15.0468	TC	NWC	Summer Pos/Winter Neg
Buckle Head Creek	WA	127.8322	-14.4508	TC	NWC	Summer Pos/Winter Neg
Cane River	WA	115.3775	-21.5462	TC	NWC	Summer Pos/Winter Neg
Cape Londonderry Creeks	WA	126.8351	-13.7656	TC	NWC	Summer Pos/Winter Neg
Cape Londonderry Creeks	WA	126.8998	-13.7463	TC	NWC	Summer Pos/Winter Neg
Cape Londonderry Creeks	WA	127.0810	-13.8867	TC	NWC	Summer Pos/Winter Neg
Cape Londonderry Creeks	WA	127.2047	-13.9450	TC	NWC	Summer Pos/Winter Neg
Cape Torrens Embayment	WA	125.0933	-15.0415	TC	NWC	Summer Pos/Winter Neg
Cape Whiskey Creek	WA	127.4574	-14.0636	TC	NWC	Summer Pos/Winter Neg
Carnot Bay	WA	122.2634	-17.1506	EMB/DRV	NWC	Summer Pos/Winter Neg
Cascade Bay	WA	123.5156	-16.5975	EMB/DRV	NWC	Summer Pos/Winter Neg
Chile Creek	WA	122.8500	-16.5219	TC	NWC	Summer Pos/Winter Neg
Cone Bay	WA	123.5778	-16.5072	EMB/DRV	NWC	Summer Pos/Winter Neg
Coppermine Creek	WA	123.5701	-16.1652	EMB/DRV	NWC	Summer Pos/Winter Neg
Dampier	WA	116.6529	-20.6880	EMB/DRV	NWC	Summer Pos/Winter Neg
Dampier Creek (Broome)	WA	122.2497	-17.9611	TC	NWC	Summer Pos/Winter Neg
De Grey River	WA	119.1599	-19.9901	TDE	NWC	Summer Pos/Winter Neg
Deception Bay	WA	124.4132	-15.6306	EMB/DRV	NWC	Summer Pos/Winter Neg
Disaster Bay	WA	123.1560	-16.9163	TC	NWC	Summer Pos/Winter Neg
Doctors Creek	WA	123.6348	-17.1849	TC	NWC	Summer Pos/Winter Neg
Doubtful Bay East	WA	124.5836	-16.1175	TC	NWC	Summer Pos/Winter Neg
Doubtful Bay South	WA	124.5214	-16.1573	TC	NWC	Summer Pos/Winter Neg

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Drysdale River	WA	126.7996	-13.9470	TDE	NWC	Summer Pos/Winter Neg
Eagle Point	WA	124.4308	-16.1772	TC	NWC	Summer Pos/Winter Neg
False Mouth Of Ord	WA	128.3697	-14.8507	TC	NWC	Summer Pos/Winter Neg
Fitzroy River	WA	123.5420	-17.3903	TDD	NWC	Summer Pos/Winter Neg
Fortescue River	WA	116.1034	-20.9974	TDD	NWC	Summer Pos/Winter Neg
Fraser River	WA	123.3968	-17.2969	TC	NWC	Summer Pos/Winter Neg
George River	WA	117.3812	-20.7364	TC	NWC	Summer Pos/Winter Neg
George Water	WA	124.5890	-15.9556	TDE	NWC	Summer Pos/Winter Neg
Giralia Bay	WA	114.3459	-22.4373	EMB/DRV	NWC	Summer Pos/Winter Neg
Goodenough Bay	WA	123.1155	-16.7791	TC	NWC	Summer Pos/Winter Neg
Hanover Bay	WA	124.7751	-15.3043	EMB/DRV	NWC	Summer Pos/Winter Neg
Harding River	WA	117.1963	-20.6751	TDE	NWC	Summer Pos/Winter Neg
Helby River	WA	128.1823	-14.7476	TC	NWC	Summer Pos/Winter Neg
High Bluff Creek	WA	124.4033	-16.2409	TC	NWC	Summer Pos/Winter Neg
Hoon Creek	WA	123.2926	-17.1091	TC	NWC	Summer Pos/Winter Neg
Hunter River	WA	125.3794	-15.0425	TDE	NWC	Summer Pos/Winter Neg
Jaubert Creek	WA	121.5711	-18.9500	TC	NWC	Summer Pos/Winter Neg
Jinunga River	WA	123.6016	-16.3258	TC	NWC	Summer Pos/Winter Neg
Jones River	WA	117.3558	-20.7344	TC	NWC	Summer Pos/Winter Neg
Kammargoorh River	WA	123.6239	-16.3937	TC	NWC	Summer Pos/Winter Neg
Kelk Creek	WA	122.7648	-16.7381	TC	NWC	Summer Pos/Winter Neg
King Edward River	WA	126.5875	-14.1793	TDE	NWC	Summer Pos/Winter Neg
King George River	WA	127.3302	-13.9581	TDE	NWC	Summer Pos/Winter Neg
King Sound	WA	123.3102	-16.7027	TDE	NWC	Summer Pos/Winter Neg
Lawley River	WA	125.9172	-14.6322	TC	NWC	Summer Pos/Winter Neg
Little Sherlock River	WA	117.4315	-20.7321	TC	NWC	Summer Pos/Winter Neg
Lombadina Creek	WA	122.8186	-16.5411	TC	NWC	Summer Pos/Winter Neg
Lyne River	WA	128.1495	-14.8607	TDE	NWC	Summer Pos/Winter Neg
Maitland River	WA	116.5141	-20.7769	TC	NWC	Summer Pos/Winter Neg
May River	WA	123.7887	-17.0737	TDE	NWC	Summer Pos/Winter Neg
Mckelson Creek	WA	121.6500	-18.8170	CL/SP	NWC	Summer Pos/Winter Neg
Meda River	WA	123.8175	-16.9683	TC	NWC	Summer Pos/Winter Neg
Mission Cove	WA	126.6966	-14.1226	TDE	NWC	Summer Pos/Winter Neg
Mitchell River	WA	125.6967	-14.4271	TDE	NWC	Summer Pos/Winter Neg
Montague Sound Creeks	WA	125.4528	-14.5373	EMB/DRV	NWC	Summer Pos/Winter Neg
Montague Sound Creeks	WA	125.6745	-14.3397	TC	NWC	Summer Pos/Winter Neg
Montague Sound Creeks	WA	125.6582	-14.3901	TC	NWC	Summer Pos/Winter Neg
Montague Sound Creeks	WA	125.6641	-14.4119	TC	NWC	Summer Pos/Winter Neg
Mt Connor Creek	WA	126.0427	-14.5354	TDE	NWC	Summer Pos/Winter Neg
Mt Waterloo Creeks	WA	124.8614	-15.1902	TC	NWC	Summer Pos/Winter Neg
Mudge Bay	WA	125.3735	-14.5692	TDE	NWC	Summer Pos/Winter Neg
Myridi Bay	WA	123.6182	-16.1598	TC	NWC	Summer Pos/Winter Neg
Nickol River	WA	116.9250	-20.7120	TC	NWC	Summer Pos/Winter Neg
Ningbing Range Creeks	WA	128.5246	-14.7768	TC	NWC	Summer Pos/Winter Neg
Ningbing Range Creeks	WA	128.6088	-14.7955	TC	NWC	Summer Pos/Winter Neg
Ningbing Range Creeks	WA	128.7450	-14.8333	TC	NWC	Summer Pos/Winter Neg
Ord River	WA	128.3073	-14.7642	TDE	NWC	Summer Pos/Winter Neg
Pardoo Creek	WA	119.5767	-20.0812	TC	NWC	Summer Pos/Winter Neg
Pauline Bay	WA	126.3449	-14.1834	TC	NWC	Summer Pos/Winter Neg
Peawah River	WA	117.9259	-20.5347	TC	NWC	Summer Pos/Winter Neg
Petermarer Creek	WA	118.7561	-20.2887	TDD	NWC	Summer Pos/Winter Neg
Point Torment Creeks	WA	123.6099	-17.0034	TC	NWC	Summer Pos/Winter Neg
Point Torment Creeks	WA	123.6928	-17.0373	TC	NWC	Summer Pos/Winter Neg
Port Hedland Harbour	WA	118.5754	-20.3071	CL/SP	NWC	Summer Pos/Winter Neg
Port Robinson	WA	117.0920	-20.6203	EMB/DRV	NWC	Summer Pos/Winter Neg
Port Smith	WA	121.7949	-18.5101	CL/SP	NWC	Summer Pos/Winter Neg
Prince Regent River	WA	124.8596	-15.2462	TDE	NWC	Summer Pos/Winter Neg
Prior Point Creek	WA	124.3974	-15.7273	TDE	NWC	Summer Pos/Winter Neg
Ridley River	WA	118.8528	-20.2243	TDD	NWC	Summer Pos/Winter Neg

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Robe River	WA	115.7095	-21.2790	TDD	NWC	Summer Pos/Winter Neg
Robinson River	WA	123.8104	-16.9323	TDE	NWC	Summer Pos/Winter Neg
Rocky Cove	WA	126.2454	-14.2198	TDE	NWC	Summer Pos/Winter Neg
Roe River	WA	125.3735	-15.1328	TDE	NWC	Summer Pos/Winter Neg
Saddle Hill Creeks	WA	123.7575	-16.8406	TC	NWC	Summer Pos/Winter Neg
Saddle Hill Creeks	WA	123.7209	-16.7932	TC	NWC	Summer Pos/Winter Neg
Saddle Hill Creeks	WA	123.7001	-16.7632	TC	NWC	Summer Pos/Winter Neg
Sale River	WA	124.5970	-15.9724	TDE	NWC	Summer Pos/Winter Neg
Sampson Inlet	WA	124.4586	-15.5124	EMB/DRV	NWC	Summer Pos/Winter Neg
Scott Straight Creeks	WA	125.2723	-14.9785	TC	NWC	Summer Pos/Winter Neg
Scott Straight Creeks	WA	125.2344	-14.9738	TC	NWC	Summer Pos/Winter Neg
Scott Straight Creeks	WA	125.3065	-14.8870	TC	NWC	Summer Pos/Winter Neg
Scott Straight Creeks	WA	125.2298	-14.8650	TC	NWC	Summer Pos/Winter Neg
Scott Straight Creeks	WA	125.2112	-14.6636	TC	NWC	Summer Pos/Winter Neg
Secure Bay	WA	124.3312	-16.4164	TDE	NWC	Summer Pos/Winter Neg
Sherlock River	WA	117.6523	-20.6638	TDE	NWC	Summer Pos/Winter Neg
Shoal Bay	WA	124.2071	-16.3457	EMB/DRV	NWC	Summer Pos/Winter Neg
Tabba Tabba Creek	WA	118.8218	-20.2652	TC	NWC	Summer Pos/Winter Neg
Talbot Bay	WA	123.8662	-16.2110	EMB/DRV	NWC	Summer Pos/Winter Neg
Tappers Inlet	WA	122.5544	-16.8161	TC	NWC	Summer Pos/Winter Neg
Thompson River	WA	128.1307	-14.8978	TC	NWC	Summer Pos/Winter Neg
Thurburn Creek	WA	127.9557	-14.5808	TC	NWC	Summer Pos/Winter Neg
Turner River	WA	118.4048	-20.3495	TC	NWC	Summer Pos/Winter Neg
Unnamed East Of Roe	WA	125.3241	-15.1508	TDE	NWC	Summer Pos/Winter Neg
Unnamed North Of Roe	WA	125.3730	-15.0883	TC	NWC	Summer Pos/Winter Neg
Wade Creek	WA	126.2965	-14.2201	TDE	NWC	Summer Pos/Winter Neg
Walcott Inlet	WA	124.3940	-16.3430	TDE	NWC	Summer Pos/Winter Neg
Wedge Hill Creeks	WA	124.4466	-15.8850	TC	NWC	Summer Pos/Winter Neg
Willies Creek	WA	122.2000	-17.7670	TC	NWC	Summer Pos/Winter Neg
Woppinbie Creek	WA	126.5170	-14.1500	TC	NWC	Summer Pos/Winter Neg
Yammaderry Creek	WA	115.4658	-21.5016	TC	NWC	Summer Pos/Winter Neg
Yanyare River	WA	116.4397	-20.8255	TC	NWC	Summer Pos/Winter Neg
Yardoogarra Creek	WA	122.1977	-18.2236	TC	NWC	Summer Pos/Winter Neg
Yule River	WA	118.2076	-20.3711	TC	NWC	Summer Pos/Winter Neg
Yuraddagi River	WA	123.5528	-16.2221	TC	NWC	Summer Pos/Winter Neg
Barker Inlet	WA	121.3501	-33.8209	WDE	SWC	Summer Neg/Winter Pos
Beaufort Inlet	WA	118.9025	-34.4719	WDE	SWC	Summer Neg/Winter Pos
Bowes River	WA	114.4544	-28.4116	WDD	SWC	Summer Neg/Winter Pos
Broke Inlet	WA	116.3733	-34.9367	WDE	SWC	Summer Neg/Winter Pos
Chapman River	WA	114.6195	-28.7282	CL/SP	SWC	Summer Neg/Winter Pos
Cheyne Inlet	WA	118.7563	-34.6031	WDE	SWC	Summer Neg/Winter Pos
Culham Inlet	WA	120.0441	-33.9220	WDE	SWC	Summer Neg/Winter Pos
Dempster Inlet	WA	119.6689	-34.0789	WDE	SWC	Summer Neg/Winter Pos
Donnelly Inlet	WA	115.6765	-34.4881	WDE	SWC	Summer Neg/Winter Pos
Fitzgerald Inlet	WA	119.6340	-34.1056	WDE	SWC	Summer Neg/Winter Pos
Gardner Lake	WA	118.1782	-34.9726	WDD	SWC	Summer Neg/Winter Pos
Gascoyne River	WA	113.6144	-24.8672	WDD	SWC	Summer Neg/Winter Pos
Gordon Inlet	WA	119.5044	-34.2898	WDE	SWC	Summer Neg/Winter Pos
Greenough River	WA	114.6356	-28.8645	CL/SP	SWC	Summer Neg/Winter Pos
Hamersley Inlet	WA	119.9083	-33.9688	WDE	SWC	Summer Neg/Winter Pos
Hardy Inlet	WA	115.1764	-34.3238	WDE	SWC	Summer Neg/Winter Pos
Hill River	WA	115.0504	-30.3870	CL/SP	SWC	Summer Neg/Winter Pos
Hutt Lagoon	WA	114.3046	-28.2219	WDE	SWC	Summer Neg/Winter Pos
Irwin Inlet	WA	116.9585	-35.0206	WDE	SWC	Summer Neg/Winter Pos
Irwin River	WA	114.9203	-29.2588	CL/SP	SWC	Summer Neg/Winter Pos
Leschenault Inlet	WA	115.6715	-33.3041	WDE	SWC	Summer Neg/Winter Pos
Margaret River	WA	114.9859	-33.9717	WDE	SWC	Summer Neg/Winter Pos
Moore River Estuary	WA	115.4990	-31.3530	WDD	SWC	Summer Neg/Winter Pos
Murchison River	WA	114.1591	-27.7077	WDE	SWC	Summer Neg/Winter Pos

Name	State	Longitude	Latitude	Class	Region	Hydrodynamic Type
Normans Inlet	WA	118.2173	-34.9241	CL/SP	SWC	Summer Neg/Winter Pos
Oakajee River	WA	114.5819	-28.5833	WDD	SWC	Summer Neg/Winter Pos
Oldfield Estuary	WA	120.7874	-33.8876	WDE	SWC	Summer Neg/Winter Pos
Oyster Harbour	WA	117.9485	-34.9999	WDE	SWC	Summer Neg/Winter Pos
Parry Inlet	WA	117.1617	-35.0311	WDE	SWC	Summer Neg/Winter Pos
Peel-Harvey Estuary	WA	115.7102	-32.5262	WDE	SWC	Summer Neg/Winter Pos
Princess Royal Harbour	WA	117.9192	-35.0386	CL/SP	SWC	Summer Neg/Winter Pos
Saint Marys River	WA	119.5776	-34.1632	WDE	SWC	Summer Neg/Winter Pos
Shark Bay	WA	113.3565	-25.4041	EMB/DRV	SWC	Summer Neg/Winter Pos
Stokes Inlet	WA	121.1363	-33.8551	WDE	SWC	Summer Neg/Winter Pos
Swan River	WA	115.7346	-32.0548	WDE	SWC	Summer Neg/Winter Pos
Taylor Inlet	WA	118.0632	-34.9987	WDE	SWC	Summer Neg/Winter Pos
Tobys Inlet	WA	115.1528	-33.6318	CL/SP	SWC	Summer Neg/Winter Pos
Torbay Inlet	WA	117.6757	-35.0463	WDE	SWC	Summer Neg/Winter Pos
Torradup River	WA	121.0163	-33.8614	WDE	SWC	Summer Neg/Winter Pos
Vasse-Wonnerup Estuary	WA	115.4139	-33.6190	WDE	SWC	Summer Neg/Winter Pos
Walpole/Nornalup Inlet	WA	116.7390	-35.0298	WDE	SWC	Summer Neg/Winter Pos
Warren River	WA	115.8292	-34.6106	WDE	SWC	Summer Neg/Winter Pos
Waychinicup Inlet	WA	118.3304	-34.8986	EMB/DRV	SWC	Summer Neg/Winter Pos
Wellstead Estuary	WA	119.3995	-34.3918	WDE	SWC	Summer Neg/Winter Pos
Wilson Inlet	WA	117.3332	-35.0258	WDE	SWC	Summer Neg/Winter Pos
Wooramel River	WA	114.2490	-25.9781	EMB/DRV	SWC	Summer Neg/Winter Pos
Yardie Creek	WA	113.8106	-22.3259	CL/SP	SWC	Summer Neg/Winter Pos

GLOSSARY OF TERMS

Aeolian: the erosion, transport, and deposition of material by wind, and work best when vegetation cover is sparse, or absent.

Anoxic: The condition of oxygen deficiency or absence of oxygen. Anoxic sediments and anoxic bottom waters are commonly produced where there is a deficiency of oxygen due to very high organic productivity and a lack of oxygen replenishment to the water or sediment, as in the case of stagnation or stratification of the water body.

Assimilation: The utilisation by a living organism of absorbed food materials in the processes of growth, reproduction, or repair

Baffling: A reduction in the energy of flowing water (typically caused by plant material), such that sediment particles may settle from suspension.

Bedload: Sedimentary material subject to transport by flowing water (e.g. currents) which is moved by rolling, pushing, and saltation. The size of particles moved is proportional to the strength of water movement.

Benthic: Pertaining to the seafloor (or bottom) of a river, coastal waterway, or ocean.

Benthic Micro-Algae (BMA): Microscopic plants, which inhabit the sediment surface (or substrate) including diatoms and dinoflagellates.

Bio-clastic: sediments made up of broken fragments of organic skeletal material, e.g. shells.

Bioturbation: Are organisms, mainly worms or crustaceans, that disturb the sediment by burrowing or during feeding. Their activities mix the sediment layers and may cause substantial sediment resuspension.

Carbonate: minerals containing CO_3^{2-}, e.g. $CaCO_3$ or limestone.

Catchment: The area of land which collects and transfers rainwater into a waterway.

Clay: A weathered form of aluminosilicate mineral particles, less than 0.002 mm in diameter.

Coarse sediment: A sediment comprising coarse-grained material such as sand or gravel particles.

Coastal Waterway: A body of water situated on or near the ocean coast, with some association with the ocean. Includes embayments, wave- and tide-dominated estuaries, wave- and tide-dominated deltas, coastal lagoons, and tidal creeks.

Coastal Lagoon: Coastal waterways in which waves are the principal factor that shapes the overall geomorphology. Characterised by a sandy barrier that can partially or totally constrict the entrance, backed by a mud basin, and typically have negligible river input.

Coastal Protuberance: A prominence or bulging out of the coastline, typically formed from deltaic sediments.

Conceptual Model: A depiction or representation of the most current understanding of the major ecosystem features and processes (including biological, physical, chemical and geomorphic components) of a particular environment (e.g. estuaries).

Cut-Off Embayment: Typically small basins within wave-dominated estuaries or wave-dominated deltas that have been bypassed by the principal fluvial current flow, and therefore have restricted exchange with the main body of the coastal waterway.

Denitrification: Conversion of oxidised forms of nitrogen, such as NO_3^- to nitrogen gas (N_2) by anaerobic bacteria.

Deposition: The dropping of material which has been picked up and transported by wind, water, or other processes.

Desiccation: Drying out, usually due to subaerial exposure of a normally submerged environment.

Dissolved Inorganic Nitrogen (DIN): Nitrogen compounds, present post-filtration, that are detectable by accepted analytical chemical methods, e.g. nitrite, nitrate, and ammonium.

Drowned River Valley: A bedrock valley which has been submerged by rising sea-level, and has not been significantly infilled by sediment. Also: Embayment.

Ebb tide: A falling tide - the phase of the tide between high water and the succeeding low water.

Embayment: A coastal indentation (or bedrock valley) which has been submerged by rising sea-level, and has not been significantly infilled by sediment. Also: Drowned River Valley

Energy (hydraulic): Energy or intensity of water turbulence or movement, current speed.

Epifauna: Animals that live on the sediment but do not burrow into it.

Erosion: Breakdown of material (e.g. rock) due to chemical, physical or biological processes.

Euryhaline: Organisms able to tolerate a wide range of salinity.

Facies: Sum total of features that reflect the specific environmental conditions under which a given sediment was formed or deposited. The features may be lithologic, sedimentological, or faunal.

Fine sediment: A sediment comprising fine-grained material such as mud or clay particles.

Flood tide: A rising tide - the phase of the tide between low water and the next high tide.

Flushing: Exchange of water between an estuary or coastal waterway and the ocean.

Fluvial: Pertaining to a river or freshwater source

Freshwater: Water, typically derived from inland or rainfall, with less than 0.03% ionic content.

Function: The function of an estuary is how it acquires the materials and energy needed, processes its waste products, and interacts with adjacent waters and the surrounding landscape.

Geomorphology/Geomorphic: The study of the nature and history of landforms and the processes which create them.

Gravel: grains with diameters between 2 and 4 mm

Gypsum: Mineral formed by evaporation, with the molecular structure: $CaSO_4.2H_2O$

Halite: Mineral formed by evaporation, composed of NaCl.

Halophytic: Salt-tolerant vegetation.

Headward: the landward or upstream section of an estuary or coastal waterway

Hypersaline: Water with a high concentration of salt, e.g. greater than the ionic content of seawater.

ICOLLs: Acronym - Intermittently Closed and Open Lakes and Lagoons, referring to Coastal Lagoons and some Wave-Dominated Estuaries under low runoff conditions.

Infauna: Animals that live within the sediment.

Intertidal: The environment between the level of high tide and low tide.

Lag: A coarse-grained residue left behind after finer particles have been transported away, due to the inability of the transporting medium to move the coarser particles.

Levee: Raised embankment of a river, showing a gentle slope away from the channel. It results from periodic overbank flooding, when coarser sediment is immediately deposited due to a reduction in velocity.

Macroalgae: Large algae including red, green and brown algae.

Macrotidal: Coastal ocean or waterway with a high mean tidal range, e.g. greater than 4 metres.

Mesotidal: Coastal ocean or waterway with a moderate mean tidal range, e.g. between 2 and 4 metres.

Microtidal: Coastal ocean or waterway with a low mean tidal range, e.g. less than 2 metres.

Mouth: The entrance of the coastal waterway, or the place where the sea meets or enters the coastal waterway.

Mud: Fine sedimentary material, typically comprising both inorganic (mineral) and organic material.

Neap tide: Tide smaller than the mean tidal range. Occurs about every two weeks, during half-Moons.

Negative Estuary: an estuary in which evaporation exceeds freshwater inflow and therefore hypersaline conditions exist.

N-Fixation: Conversion of N_2 gas to a form that is available for use by organisms.

Non-point sources: A source of sediment or nutrients that is not restricted to one discharge location.

Organic material: Once-living material (typically with high carbon content), mostly of plant origin.

Particulate Nitrogen (PN): Comprises nitrogen compounds associated with or a constituent of mineral particles and organic material.

Phytoplankton: Microscopic, planktonic plants which exist within the water column.

Point sources: A source of sediment or nutrients that is restricted to one discharge location.

Prograde: The outward building of a sedimentary deposit, such as the seaward advance of a delta or shoreline.

Quartz: A highly resilient mineral based on silica (SiO_2).

Residence Time: The average time a hypothetical particle of water spends in solution between the time it first enters and the time it is removed from a coastal waterway.

Resuspension: Process in which sediment particles on the substrate are brought back into water column suspension by waves, tides, or wind.

Salt-wedge: An intrusion of sea water into a coastal waterway in the form of a wedge along the seabed. The lighter fresh water from riverine sources overrides the denser salt water

Sand: grains with diameters between 0.06 mm to 2 mm

Seagrass: Marine flowering plants which generally attach to the substrate with roots.

Sheet runoff (or Surface Runoff): The flow across the land surface of water that accumulates on the surface when the rainfall rate exceeds the infiltration capacity of the soil.

Silt: grains with diameters between 0.002 mm to 0.06 mm

Sorting: An expression of the range of grain sizes present in a sediment. A well-sorted sediment has a narrow range of grain sizes, whereas a poorly sorted sediment has a wide range of grain sizes.

Spring Tide/King Tide: Tide greater than the mean tidal range. Occurs about every two weeks, when the Moon is full or new.

Stakeholders: Those with an interest or concern (including financial) in a particular resource.

Strand Plain: A series of dunes, typically associated with and parallel to a beach, and sometimes containing one or more small creeks or lakes.

Stratification: Physical layering of the water column resulting from density differences caused by salinity or temperature variation.

Subaerial: Occurring on land or at the earth's surface, as opposed to underwater or underground.

Substrate: The sediment and other material that comprises the seabed (or floor of coastal waterway).

Sub-tidal: Permanently below the level of low tide, an underwater environment.

Supra-tidal: Above the level of high tide, a terrestrial environment.

Suspended Sediment: Sedimentary material subject to transport by flowing water (e.g. currents) that is carried in suspension. Typically comprises relatively fine particles that settle at a lower rate than the upward velocity of water eddies.

Tidal Creek: coastal waterways in which tides are the principal factor that shape the overall geomorphology. Typically occur on prograding, muddy coasts and contain a narrow channel that drains the immediate hinterland that is fringed by intertidal habitats.

Tidal Current: An alternating, horizontal movement of water associated with the rise and fall of the tide, these movements being caused by gravitational forces due to the relative motions of Moon, Sun and Earth.

Tidal Prism: Volume of water moving into and out of an estuary or coastal waterway during the tidal cycle.

Tide-dominated Delta: coastal waterway in which tides are the principal factor that shapes the overall geomorphology, and river input is sufficient to have filled the basin. Typically funnel-shaped, and the wide entrance may form a coastal protuberance that contains elongate tidal sand banks that fringed by inter- and supra-tidal habitats.

Tide-dominated Estuary: coastal waterway in which tides are the principal factor shaping the overall geomorphology. Typically funnel-shaped with a wide entrance containing elongate tidal sand banks. The margins are fringed by extensive intertidal habitats, separated by tidal channels.

Total Nitrogen (TN): Includes DIN, PN, but not gaseous N (e.g. N_2).

Turbidity: The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.

Upwelling: The rise of sea water from depths to the surface, typically bringing nutrients to the surface.

Vertical Accretion: Accumulation of sediments or other material resulting in the building-up or infilling of an area in a vertical direction.

Washover/Back barrier Deposit: Deposit of marine-derived sediment landward of a barrier system, often formed during large storm events.

Wave-dominated Delta: coastal waterway in which waves are the principal factor that shape the overall geomorphology, and river input is sufficient to have filled in the basin so that there is limited space for continued sediment accumulation. They are characterised by a sandy barrier and a river channel that has a direct connection with the sea

Wave-dominated Estuary: coastal waterway in which waves are the principal factor in shaping the overall geomorphology. Characterised by a sandy barrier (partially constricting the entrance) that is backed a broad central basin and a fluvial delta, where the river enters the basin.

Zooplankton: Non-photosynthetic, heterotrophic planktonic organisms, including protists, small animals, and larvae, which exist within the water column.