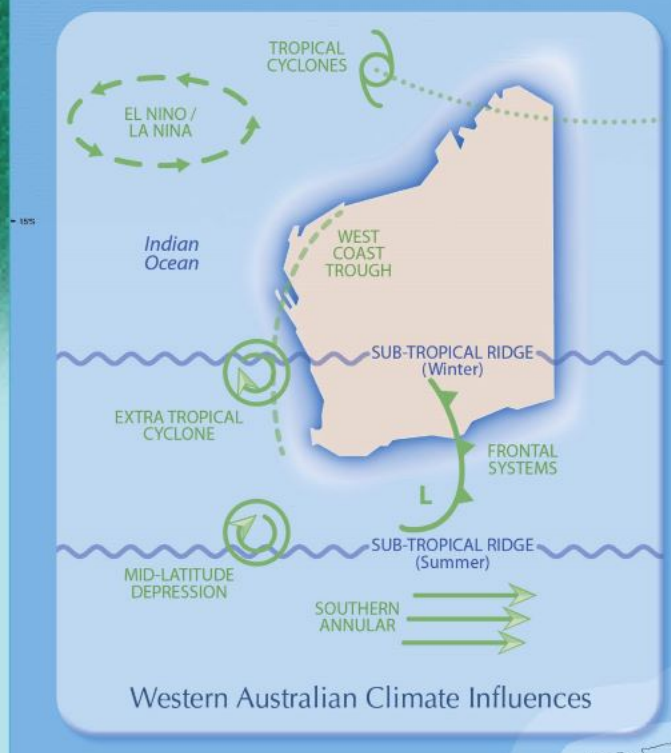
COASTAL LANDFORMS

Department of Planning
GOVERNMENT OF WESTERN AUSTRALIA

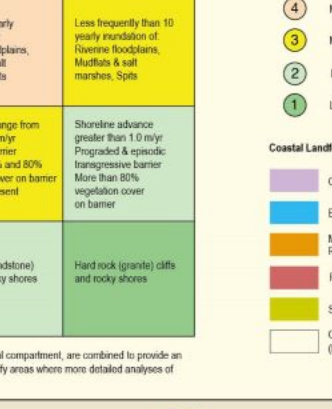
Western Australian Planning Commission

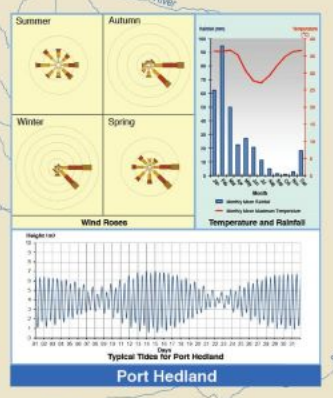


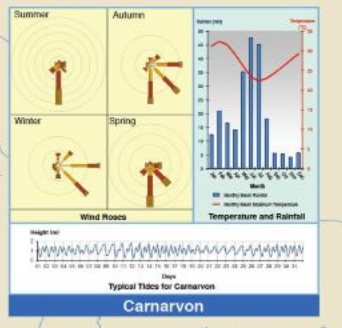
Western Australian Climate Influences

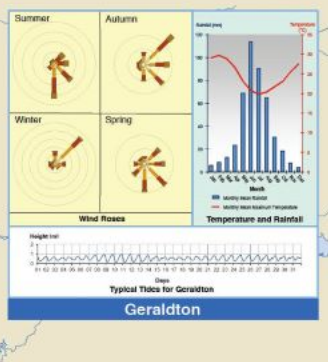
Timor Sea
Indian Ocean
Southern Ocean

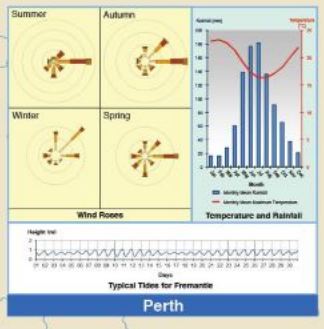
Hall Point
Koolan
Wyndham
Kununurra
Derby
Broome
Port Hedland
Dampier
Karratha
Onslow
Exmouth
Coral Bay
Carnarvon
Denham
Kalbarri
Geraldton
Dongara
Jurien Bay
Lancelin
Perth
Fremantle
Mandurah
Busselton
Augusta
Walpole
Albany
Bremer Bay
Hopetoun
Esperance
Wharton
Eucla

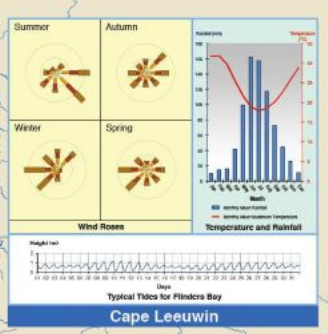


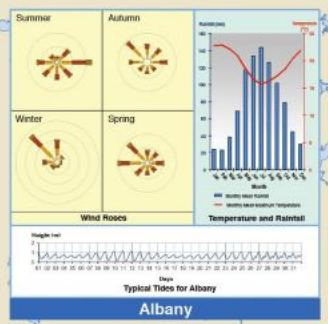


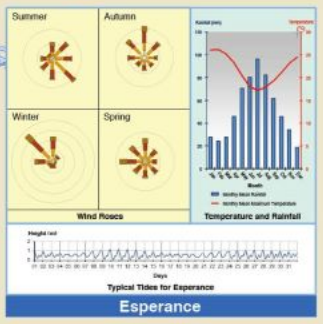


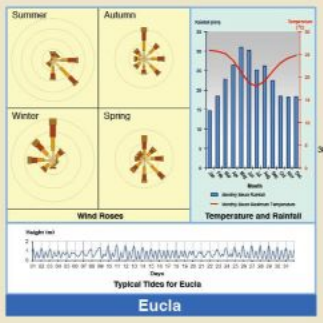












Indicative Risk of Landform Change

SUSCEPTIBILITY (Potential Change)		INSTABILITY (Existing Change) High (Actively eroding)	Moderate (Apparently unchanging)	Low (Apparently accreting)
Coastal Lowlands	High	Annual to 5 yearly inundation of Riverine floodplains, Mudflats & salt marshes, Spits	Five to 10 yearly inundation of Riverine floodplains, Mudflats & salt marshes, Spits	Less frequently than 10 yearly inundation of Riverine floodplains, Mudflats & salt marshes, Spits
Sandy Coast	Moderate	Shoreline retreat greater than 1.0 m/yr Retreating barrier & cuspate foreland Less than 20% vegetation cover on barrier Cliffed frontal dunes	Shoreline change from -1.0 to + 1.0 m/yr Stationary barrier Between 20% and 80% vegetation cover on barrier Foredune present	Shoreline advance greater than 1.0 m/yr Prograded & episodic transgressive barrier More than 80% vegetation cover on barrier
Rocky Coast	Low	Weakly lithified rock (calcarenite) cliffs & rocky shores	Soft rock (sandstone) cliffs and rocky shores	Hard rock (granite) cliffs and rocky shores

Estimated ratings for susceptibility and instability of landforms in coastal compartment, are combined to provide an indication of the risk of environmental change. The potential risks identify areas where more detailed analyses of environmental hazard and risk may be required.

Legend

Risk Level

5 High
4 Medium to high
3 Medium
2 Low to medium
1 Low

Coastal Landform

- Coastal Lowland
- Estuary
- Mixed Sandy and Rocky Coast
- Rocky Coast
- Sandy Coast
- Coastal Compartment (Primary)

Wind Rose

Calm
0-10 10-20 20-30 >30
km/h

Wind Speed Range
Wind direction towards circle

Wind Frequency
The proportion of winds for each speed, and for each direction, is shown on the wind rose.

Bathymetry (depth in metres)

- 0-10
- 10-20
- 20-50
- 50-100
- 100-200
- 200-500
- > 500

0 60 120 kilometres

Produced by:
Mapping & GeoSpatial Data Branch
Department of Planning, WA
On behalf of
Western Australian Planning Commission
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LI 430-2009-8

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Geological Survey of Western Australia

Bathymetric and tidal data supplied by:
Department of Transport (from RAN)

Wind roses, rainfall and temperature data supplied by: Bureau of Meteorology

Coastal Landforms data supplied by:
Bob Gozzard

Coastal sediment compartments data supplied by: Department of Environment and Conservation (April 2010)

Original concept and design by:
Patrick Hesp and Stuart Chape 1984

COASTAL LANDFORMS

Under State Coastal Planning Policy (SPP 2.6) an appropriate foreshore reserve should take into account coastal processes based on the physical and biological features of the particular coastal environment.

In determining the coastal foreshore reserve it is important to recognise time and space scales in which the landforms and their driving processes operate for the planning timeframe. Long-term variation in processes determines the coastal morphology upon which the effects of short-term variability are superimposed.

Long-term scales encompass broad scale changes occurring to land systems over a planning horizon of 100 years or longer. Conversely, short-term scales refer to individual landforms and changes to them. The short-term changes are apparent at site planning scales and time intervals of less than a decade.

Sandy coasts

Sandy coasts are comprised of unlithified/unconsolidated sediments that have accumulated in response to sea level changes and coastal processes operating over millennia. Those formed over the past 10,000 years in response to the Holocene rise and standstill in sea level is of particular interest in coastal planning and management. During this time unconsolidated sediment accumulated in large wedges of sand that occupy large tracts of the modern coast and function as barriers between the open ocean and the coastal hinterland. The barriers are coastal systems comprised of a geographically diverse assemblage of landforms, commonly including beaches and dunes. While extensive changes to whole barriers may be slow, the beach and dune landforms comprising them are responsive to energetic meteorologic or oceanographic events. Individual landforms are highly variable within a planning horizon of less than a century and may be markedly affected by land use activity.

Barriers

Individual barriers incorporate an assemblage of landforms that may include nearshore bars and beaches, foredune ridges, a variety of sand dune formations, and back-barrier flats. Barriers impound coastal lagoons and wetlands on parts of the coast. The particular landform assemblage as well as the geologic structure of a barrier is indicative of whether it is undergoing long-term erosion or accretion, or is apparently stable. Several forms are recognised as parts of an evolutionary or transitional sequence. They range from barrier systems supporting high, wide fields of parabolic dunes; through to low, wide plains of foredune ridges; and narrow, moderately-high ridges of stationary and highly unstable, retreating barriers; to narrow mainland beaches abutting bedrock. The sequence is indicative of a decreased supply of sediment to the coast and increased susceptibility to erosion.

Beaches

Sandy beaches are highly dynamic. They are responsive to short-term variation in coastal processes at all planning and management scales, although some beach morphology is more variable than others. Hence the different sandy beach morphologies should be considered in shoreline change projection.

Two types of beaches are recognised along barrier shores. Each supports a characteristic suite of landforms, responds differently to fluctuating coastal processes and presents different issues for numerical modelling and coastal management. On open ocean coasts beach profile shape varies from a steep, wave-reflective profile form, though transitional morphologies with bars and rips, to a wave-dissipative form with a flat beachface and multiple inshore bars with increasing energy conditions. In sheltered environments, such as in coastal lagoons and estuaries, beach profile shape varies from a flat beachface and extensive subtidal terrace, through a segmented shape a steep beachface abutting a flat subtidal terrace, to a rounded profile form. The impacts of storm surge and sea level inundation processes may be more important on sheltered beaches than on open coast although extreme events have significant effects in both environments.

courtesy - Jayleene Clapp

High energy beach

Open ocean sandy beaches, including wave and tide dominated beaches.

courtesy - Ian Eliot (Damara WA Pty Ltd)

Low energy beach

Sheltered sandy beaches in semi enclosed waters or the lee of large geologic structures.

Dunes

courtesy Jade Dodos (2012)

The pattern and type of coastal dunes on a barrier is related to the manner in which the barrier is evolving as well as to land surface stability. For example, the long-term evolution of a retreating barrier with a low, narrow dune that is penetrated by waves and surge during storms contrasts with a wide, low foredune plain or a transgressive dune field comprised of multiple high ridges of nested parabolic dunes, some of which may be active blowouts. A retreating barrier has dunes that are sediment starved and are actively eroding whereas a foredune plain and field of nested parabolic dunes may be undergoing long-term accretion.

Long-term changes to the assemblage of dunes on a barrier are likely to be related to changes in the coastal sediment budget and may be difficult to manage. Conversely, short-term changes to coastal dunes are related to the state of vegetation cover, a function of physical, biologic and anthropogenic factors. Stable dunes have a full cover of vegetation whereas unstable dunes are apparent as active blow-outs or mobile sand sheets that are unvegetated.

Coastal lowlands

Coastal lowlands north of the Murchison River include coastal plains and tidal flats associated with highly active river deltas as well as features inherited from sea level inundation of deltaic lowlands over the past two million years of the Quaternary geologic period. River deltas and outwash plains are not mutually exclusive terms or landforms, but from a shoreline perspective they signify whether a stream debouches directly into marine waters or discharges onto tidal flats before flood waters spread and drain into the ocean via tidal creeks. The difference also highlights disparate sources of sediment for coastal processes with direct deposition of fluvial sediments via the active rivers and reworking of older sediments from the outwash plains. South from the Murchison River coastal lowlands have developed in the lee of barrier systems. The southern lowlands include foredune plains and the estuarine systems respectively described in Sections 3.1 and 3.5. They are commonly associated with alluvial and marine filling of coastal lagoons landward of river mouths that are seasonally blocked by sand bars. Coastal lowlands, together with landforms adjoining the tidal reaches of inland waters (Section 3.5) are vulnerable to river flooding and marine inundation, separately and coincidentally. The frequency and duration of both processes, as well their joint occurrence as extreme events are important factors in the development of coastal lowlands as well as factors to be considered in coastal planning and management.

River deltas

courtesy John Dodos (2012)

The classic definition of a river delta is that it is a D shaped body of sediment formed at the mouth of a river, where the river discharges into marine, estuarine or lacustrine waters. At the coast deltas are formed from the deposition of sediment carried by the river as the flow leaving its mouth interacts with coastal processes. Landforms of active deltas include beaches, cheniers and dunes as well as the alluvial flats to landward. These landforms should be regarded as highly unstable. This is particularly applicable in areas where there is evidence of evulsion, the river channel intermittently changing position with the occurrence of extreme flood events; and in areas where storm ridges have formed as cheniers along the shore.

Outwash plains

courtesy Ian Eliot (Damara WA Pty Ltd)

Outwash plains are eroded or eroding deltas. Streams discharge onto the plains and into inherited overbank basins or former coastal lagoons. Minor deltas and fans are common features at stream mouths and separate the streams from tidal creeks draining tidal flats closer to the shore. Landforms include islands of residual land surface, alluvial flats and fans on the landward side of the mudflats; tidal creeks, tidal flats and levees supporting mangroves in the basins; and chenier ridges, spits, dunes and beaches along the shore. Potentially, all are subject to flooding and marine inundation during extreme meteorological events such as tropical cyclones and storm surge.

Rocky coasts

Rocky coasts are defined for the purposes of this policy as sectors of shore where rock outcrops continuously along the shore and extends above the level of the highest astronomical tide (HAT). Alternatively, rocky coasts are those that continuously outcrop above the horizontal shoreline datum (HSD). They have been classed into three groups according to their geology: hard rock, sedimentary rock and weakly lithified sedimentary rock coast. The definition principally includes cliffed coast ranging from low bluffs to high vertical cliffs, but also encompasses reaches of coast with steeply sloping and rounded profiles.

The cross-shore profile shape of rocky coast primarily varies with rock resistance and the relative efficacy of marine and terrestrial processes as well as due to secondary features such as platforms, ramps and colluvial boulder deposits inherited from a previous geological time. Profile shapes range from sheer, vertical cliffs plunging into deep water, through cliffs abutting sub-tidal pavements and intertidal rock platforms, to low bluffs and rounded forms.

Rocky coast may support unconsolidated sediments subtidally as well as above the reach of the tide. Above HAT level the seaward crest of an outcrop is likely to be exposed by a combination marine and of terrestrial processes. Depending on the height of the outcrop the marine processes potentially include wave run up, splash, overwash and wave cast. Terrestrial processes include seepage, run off and mass movement. Further landward the outcrop may be buried by unconsolidated sediment. The extents to which unusual conditions and extreme events are likely to affect a rock outcrop near its crest have been considered in the recommended 50 metre set back of coastal development from the crest line on rocky coast.

Hard rock coast

courtesy Johanna Cole

Hard rock coasts are those comprised of erosion resistant rock. They are commonly of plutonic, igneous and metamorphic origin. Access and safety factors should be considered in coastal plans although little shoreline change is likely to occur on these coasts over a planning time frame.

Sedimentary rock coast

courtesy Ian Eliot (Damara WA Pty Ltd)

Sedimentary rock coasts are comprised of strongly lithified sediments. They include landforms cut in sandstone, limestone and calcillutite. Access and safety factors should be considered in coastal plans although shoreline retreat is slow, commonly taking place at time spans longer than the planning horizon. In some places undercutting by marine processes occurs and may result in localised slumping, rock-fall and slab collapse.

Weakly lithified sedimentary rock coast

courtesy Ian Eliot (Damara WA Pty Ltd)

Sedimentary rocks which are poorly cemented or have been highly weathered and have a lower resistance to erosion than more strongly lithified forms. Hence weakly lithified sedimentary rock coasts form low cliffs and bluffs with substantial fracturing along their crest. The cliffs and bluffs are likely to abut rock platforms, talus slopes, block-fall or collapsing slabs. Additionally, localised erosion of weakly lithified rock coast may expose unconsolidated sediments to erosion in places where the rocks occur in narrow ridges that can be breached. Geotechnical factors should be considered in determination of coastal setback to development.

Tidal reaches of inland waters

The tidal reaches of inland waters are water bodies landward of the general trend of the shoreline and which are predominantly controlled by ocean processes, particularly tides and surges. They include rias, river valleys that were drowned during the Holocene sea level rise of the past 10,000 years; the estuarine reaches of river mouths and coastal lagoons formed in association with barrier dunes. The three water bodies are associated with landform development in and geologically, oceanographically and climatologically different regions of the State: rias in the Kimberley, estuaries on the west coast between the Hill and de Grey Rivers and coastal lagoons along the southwest and south coast. Attributes shared by shores of the three water bodies include formation of well vegetated coastal lowlands that are maintained through inundation by marine inundation and flooding. Their beaches are idiosyncratically affected by locally generated wind waves and are mainly low-energy, sheltered beaches dominated by tides and sea level ranging.

Rias (Drowned river valleys)

courtesy Cape Duchesne

With the exception of Waychinicup Inlet on the south coast, rias are common features of the Kimberley region between Point Usborne, near Derby, and Cape Londonderry but not elsewhere in the State. The region is subject to large excursions of sea level, especially when storm surge is coincidental with high tides. These frequently inundate the valley lowlands which are flanked mainly by spectacular sandstone cliffs. The shores of the rias are lined by extensive mangrove forests (mangals) commonly growing in shallow sediments overlying rock platforms. Tidally dominated beaches occur where there is a sufficient sediment supply to the shore to form storm ridges and narrow chenier plains. The beaches are tide dominated forms of sheltered beaches.

Estuaries

courtesy Trevor Ward (2012)

Estuaries occur as narrow basins in the tidal reaches of rivers and streams discharging directly onto the coast south of Cape Keraudren, particularly the seasonally flowing streams of the Gascoyne region and northern Swan Coastal Plain. Alluvial flats adjoining the estuary water bodies were originally vegetated with sedges to the water's edge. They are subject to marine inundation when the river mouth is open and to river flooding during high fluvial discharge following periods of intense or protracted rainfall. Many, if not all estuaries have sand bars at their mouths and river flooding may be severe when the mouth is closed by a high, wave constructed bar. In most estuarine environments the alluvial flats are separated from the ocean by limestone barriers overlain with Holocene dunes. Sandy shores in the estuaries are small and in places flanked by broad subtidal terraces.

Coastal lagoons

courtesy Ian Eliot (Damara WA Pty Ltd)

In southwestern Australia coastal lagoons are inherited basins located landward of barriers that formed during the past half million years before present and have been lithified to form coastal limestone. Rivers debouche into the basins and contribute to delta building in them but do not flow directly to the ocean. Mixing of fluvial and marine waters occurs within the basins when they are open to the sea, usually in spring. Opening regimes are highly variable from lagoon to lagoon and principally depend on the construction of bars at the lagoon entrances by ocean processes as well as river discharge from the hinterland. Alluvial flats adjoining the lagoonal waters were originally vegetated by sedges and paperbark trees to the water's edge. Much of this has been cleared for settlement and the establishment of infrastructure. As with the estuaries the alluvial flats are subject to marine inundation when the river mouth is open and to river flooding during high fluvial discharge following periods of intense or protracted rainfall. The lagoonal beaches controlled by sediment movement within the lagoonal basins. Sheltered sandy beaches on the lagoon shores are commonly flanked by broad subtidal terraces comprised of sediments of marine origin.

Mixed sandy & rocky coasts

Extensive tracts of the Western Australian coast consist of mixed sandy and rocky coast. These are areas where rock outcrops significantly affect coastal processes through provision of fixed, geological frameworks in which unconsolidated sediments are distributed and components of coastal sediment budgets are organised. Within the geologic framework the sandy seascapes and landforms of mixed sandy and rocky coast are highly dynamic. Morphologic change, including shoreline movement occurs at all time and space scales.

Three mixed sandy and rocky coast systems are identifiable according to the location of the major rock outcrops with respect to sea level and distance from the shore. With increased proximity to the shore and decreasing depth, they include sandy coast tied to fringing reefs, rock platforms and discontinuous outcrops of rock along the shoreline. Distinctly different sandy beaches, herein referred to as perched beaches, are associated with each system. Caution is necessary in estimating perched beach and shoreline responses to changing coastal processes by using current numerical models. Geotechnical investigation is recommended as part of any assessment of shoreline stability to ensure the distribution of rock is known and its interaction with coastal processes determined.

Fringing reefs

courtesy Damien Thompson (2012)

Fringing reefs include long ridges of submerged reefs and islands on the inner continental shelf that impound a coastal basin in the nearshore waters. The reefs and islands cause wave refraction and attenuation, thus sheltering the coast to various degrees. As a result the supply of sediment across the reef lines as well as along the coast is critical for shoreline change. The circulation of the nearshore waters is commonly driven by winds and tidal currents. Cuspate forelands and tombolos develop in the lee of reefs and islands. Beaches on the leeward side of these landforms commonly are more characteristic of sheltered than open-ocean sandy coasts.

Sediment transport along the seaward margin of the ridges commonly occurs in water less than 30 metres deep and is a significant component of the long-term coastal sediment budget. In the short-term, gaps in reef lines may carry sediment onshore or offshore, depending on prevailing wave, weather and tidal conditions, and inshore basins potentially function as sediment sinks. These factors affect potential beach responses to changing meteorological and ocean conditions and should be considered in estimating shoreline movement.

Rock platforms

courtesy Ian Eliot (Damara WA Pty Ltd)

Rock platforms are approximately flat rock surfaces in shallow nearshore subtidal and intertidal waters. Platforms may be continuous along extensive tracts of shore, as is common in the Gascoyne region, or smaller discontinuous features like those of the Perth Metropolitan Coast. They are mainly inherited features that adjoin beachrock ramps, low bluffs or merge with other, buried bedrock topography to landward.

The landward margin of a platform may be strewn with wave cast boulders, tempestite deposits quarried from the seaward margin where the platform has been undercut and collapsed. Finer unconsolidated sediments, beach sands may form beaches that unconformably overlie the platform surfaces. Accretion and erosion of the perched beaches occurs interannually, if not seasonally. Under depositional conditions sands are moved onto platforms by some combination of eolian transport along beaches updrift of the platforms, sediment bypassing of headlands by littoral drift and construction of ramps against the seaward margin of the platforms. Erosion takes place rapidly when water depth over the platform is highest and wave and current processes scour the unconsolidated sands from the platform surface. It may be further exacerbated by groundwater and stormwater runoff from the land. Under extreme erosional events perched beaches may be permanently eroded and older sediments overlying rock in the backshore exposed. These processes and the shoreline movement associated with them require consideration in the calculation of set-back to development.

Discontinuous rocky shorelines

courtesy Jayleene Clapp

Discontinuous rocky shores occur as irregular subtidal pavements and rock outcrops close to shore, beachrock ramps on the beach face, headlands that cross the shore and divide sandy beaches into discrete embayments of various sizes and plan shape and some combination of these. The headlands may be skirted by rock platforms and fringing reefs may be present offshore. Embayment shapes vary from arcuate shorelines in small bays, through half-heart (zeta-form) embayments of various sizes to straight beaches. The shape of embayed beaches and their shoreline responses to variation in coastal processes is determined by sand supply and interaction of tide, wave and currents with the rocky landforms. The sandy beaches are highly dynamic, particularly near tide ends.

Rock outcrops on the beachface are commonly the boundaries of sediment cells, even where sediment by-passing occurs around them and beaches may be perched on buried pavements or platforms. Sandy beaches are highly dynamic where they adjoin rock outcrops. Close to the junctions they are likely to display a higher variability of shoreline movement than the same beaches further away. This is due to the effects of seasonal and longer term variation in the direction of littoral drift and beach rotation within the embayments. Additionally, embayed beaches may incorporate tracts of perched beach likely to be associated with substantial alongshore variation in shoreline movement in response to fluctuating sea levels and variability of coastal processes. Geotechnical factors and the complex beach responses to environmental change should be considered in determining coastal setback to development.

Islands

Islands abundantly occur around the coast, with the principal archipelagos on the inner continental shelf being the Recherche Archipelago; islands of the Garden Island Ridge, which includes Rottnest Island; Houtman's Abrolhos; Dampier Archipelago; and the Buccaneer Archipelago. Other islands, coral atolls and cays are located further offshore, either on the outer shelf or in the open ocean. These include the Rowley Shoals, Ashmore Reef, Cocos Islands and Christmas Island. The size and composition of islands are important considerations for management. Islands display many of the characteristics of rocky coasts and, depending on their size may incorporate a variety of coastal landforms, including sandy beaches, tidal reaches of inland waters and coastal lowlands. The variability of processes around an island should be considered due to changes in aspect and the variety of landforms related to it. Here, islands are considered in three groups for convenience; hard rock islands, soft rock islands and coral atolls and sand cays.

Hard rock islands

courtesy Ian Eliot (Damara WA Pty Ltd)

Hard rock islands are resistant to erosion. Examples are the plutonic rocks of the Recherche Archipelago and the igneous rocks of the Dampier Archipelago. The shores of the former are moderate to steeply sloping smooth rock on which wave runup may be hazardous for fisher folk. Shores of islands in the Dampier Archipelago commonly have rock platforms and boulder ramps abutting steep slopes to landward. Access and safety factors should be considered in coastal plans although little shoreline change is likely to occur on these coasts over a planning time frame.

Soft rock islands

courtesy Ian Eliot (Damara WA Pty Ltd)

Many of the islands around the calcareous coast of Western Australia are comprised of soft rock, particularly coastal limestone in various degrees of lithification. They also include islands comprised of sandstone, such as islands in the Kimberley; biogenic material such the Montgomery Islands; and those with a hard rock layer overlying softer sediments, like the Murat Islands. The calcarenite limestone islands are commonly flanked by rock platforms and sand shoals. Tempestite boulder deposits apparent in some areas indicate islands with them are subject to wave cast and other storm impacts. Additionally, some soft rock islands show evidence of active undercutting and block collapse on their windward shores.

Coral atolls & sand cays

courtesy Peter Stokes (2012)

An atoll is a coral island or series of coral islands, such as the Cocos Islands, forming a ring that nearly or entirely encloses a shallow lagoon. Atolls are surrounded by deep ocean water and range in diameter from about 1 km to over 100 km. They are believed to form along the fringes of underwater volcanoes. Smaller sandy islets, like those on the Ashburton Reef, form cays. They are usually of very low-elevation and formed on the surface of a coral reef platform.

Coral atolls and sand cays are low lying islands which are highly likely to be altered by changes in storminess or sea level. Fresh water supplies and infrastructure on low lying islands are particularly at risk where land is likely to be lots in response to rising sea levels.

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