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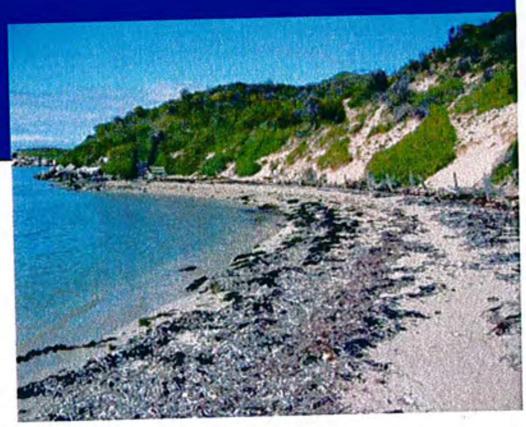
Penguin Island South Beach Rehabilitation

Environmental Referral Document

November 2005



Penguin Island South Beach Rehabilitation

Environmental Referral Document

Prepared for:

Resolve FM

&

Department for Conservation and Land Management

Prepared by:

Oceanica Consulting Pty Ltd

November 2005

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1. Introduction

1.1 This Document

Shoreline erosion on South Beach (Penguin Island) has begun to threaten the islands infrastructure and this report examines several alternate management options. The environmental issues and management measures associated with the two preferred management options are presented. This document is prepared on behalf of the Department for Conservation and Land Management (CALM) to be submitted to the Marine Parks and Reserves Authority for their consideration.

This document provides a detailed assessment of the project, any potential environmental impacts and the management of these impacts.

1.2 The Proponent

Penguin Island lies within the Shoalwater Islands Marine Park (Figure 1.1), and is vested with the Marine Parks and Reserves Authority (MPRA). Penguin Island is managed by the Department of Conservation and Land Management (CALM).

1.3 Location

Shoalwater Islands are a chain of islands extending between Cape Peron and Becher Point (Figure 1.1). These islands are part of a sequence of limestone islands and reefs belonging to the Garden Island Ridge, extending from James Reef in Comet Bay, north to Rottnest Island.

The Shoalwater Islands Marine Park covers an area of approximately 6545 ha and includes the waters of Shoalwater Bay, Warnbro Sound and a part of Cockburn Sound (near Cape Peron). Penguin Island, located between Warnbro Sound and Shoalwater Bay, is the largest (12.5 ha) in the chain of Shoalwater Islands. Penguin Island is a popular visitor destination providing a range of recreational and educational activities; over 80,000 people visit the island each year (Premier 1996).

Penguin Island is characterised by a linear north-south limestone ridge. As with other larger islands in the chain, Penguin Island retains a quantity of unconsolidated sandy sediments, largely contained within high dune sequences located above and eastwards of the limestone ridge. In addition, Penguin Island possesses an extensive wedge-shaped sandy spit on the leeward (eastern) side of the island (Figure 1.3). This feature is comprised of 'recent' Holocene sediment (Morgan 2000) and is connected to Mersey Point by a narrow (ca 50 m wide) 700 m long submerged sand spit (tombolo). During extreme low tides this tombolo may become exposed (Chape 1984). Seal and Bird Islands also possess tombolos and spits, but these are less prominent than the Penguin Island feature.

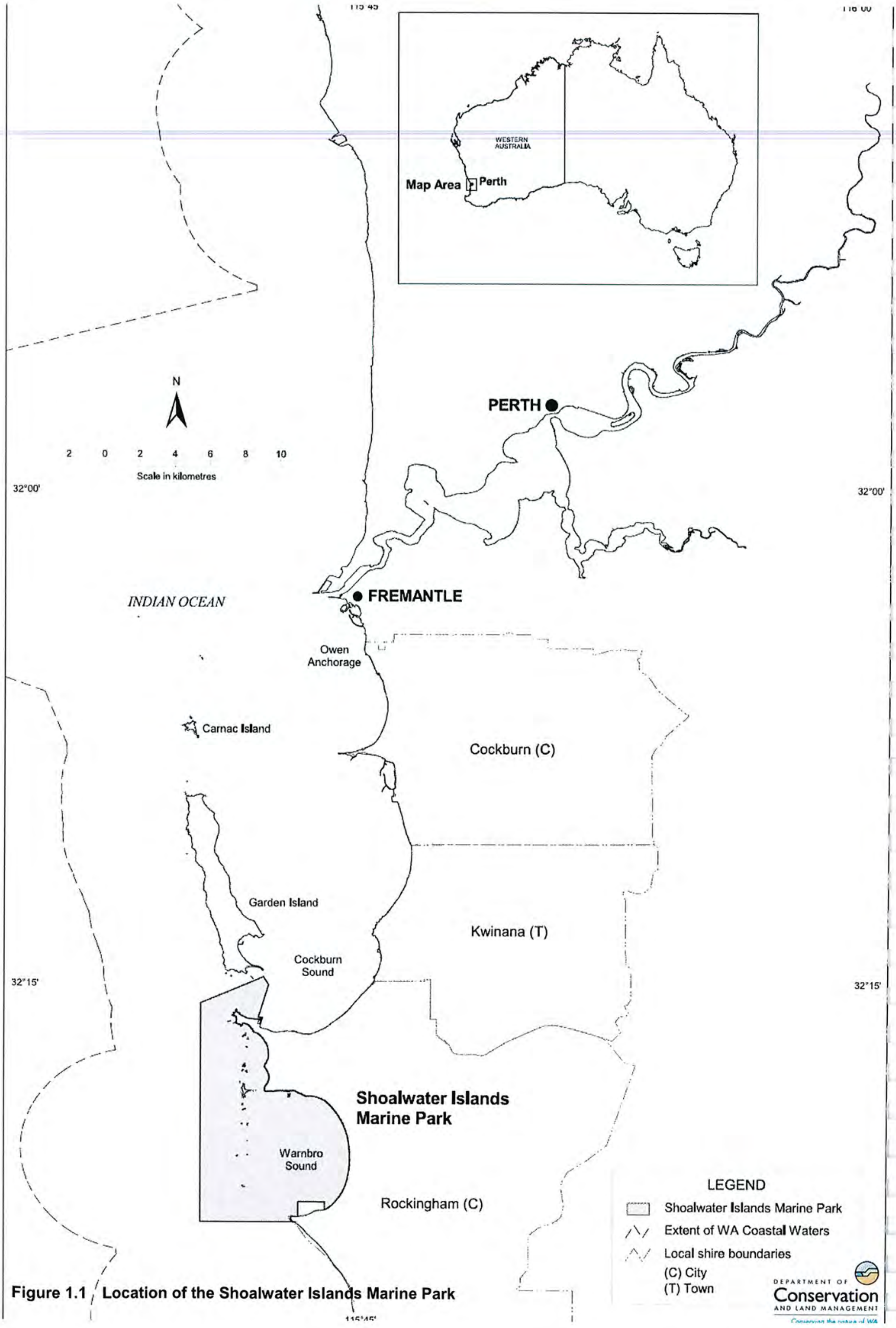


Figure 1.1 Location of the Shoalwater Islands Marine Park

Source: Oceanica Consulting 2004

Figure 1.2 Location Penguin Island, Warnbro Sound

oceanica	**Legend**	**Figure 1.3**
Author: PBH Date: 07/10/05		Penguin Island
Proj Ref: 422_3		
File Ref: 422_3_071005_f13.mxd		
Horizontal Datum: UTM Zone 50 Based on WGS84		Department of Conservation and Land Management
Vertical Datum: N/A		Conserving the nature of WA

1.4 Existing Operations

Penguin Island is recognised as one of the State's nature-based tourism destinations, and home to the largest colony of Little Penguins on the west coast (CALM 2003). The Little Penguins breed in hollows under the dense vegetation and in the limestone caves. There are also breeding colonies of silver gulls, bridled terns and the Australian pelican (*Pelicanus conspicillatus*). The reef areas surrounding the island also provide habitat for a variety of temperate and subtropical invertebrates including sea stars, urchins, molluscs and several fish species.

The Penguin Island Visitor Centre (managed by CALM) is only open to visitors during the day, and is closed completely from early June to mid September—the penguins breeding season (CALM 2003). Access on Penguin Island is limited to the walk trails and demarcated beaches; the rest of the island is classed as a Bird Sanctuary and access is prohibited (CALM 2003).

Facilities for the CALM rangers have been present on the island since the 1980s, and have been constructed towards the eastern end of the island on the sandy spit. These facilities include CALM ranger accommodation, research facilities, and a jetty, which connects the island to the mainland via a regular ferry service.

1.5 Justification for Upgrades

Progressive erosion on South Beach has been observed for decades. Observations by CALM personnel indicate that the erosion of South Beach is highly intermittent and is typically associated with severe winter storm events concurrent with high water levels. Recent storms, including 1996 and 2003, have caused considerable erosion of the shoreline and some damage to infrastructure (Figure 1.4). The current shoreline position is now such that any further erosion to South Beach could result in damage to the research and CALM rangers facilities (Figure 1.5).

Historically, shoreline erosion of South Beach has been managed through the construction of a small limestone groyne[1] at the eastern end of South Beach in 1968, but this became rapidly degraded and no longer provides effective protection to South Beach. More recently, CALM have deployed sand bags (Figure 1.6) and undertaken minor sediment redistribution operations to manage shoreline erosion of South Beach. In response to a request from CALM, comments on the current interim rehabilitation works (sandbagging and brushing) being used on South Beach are provided in Appendix A.

A degree of shoreline recovery is apparent during summer months, although this is typically small in comparison with the rate of erosion. The most significant sediment transports associated with summer conditions include bending of the spit tip and accumulation of wind-blown sediment in the low dunes of the spit. Movement of the end of the spit occurs on both a seasonal and inter-annual basis, with the tip of the spit typically moving northwards during summer months under influence of sea-breeze activity and southwards in winter due to impact of north westerly storm events.

[1] It has also been suggested that this limestone structure was constructed to aid the recovery of a tractor which had become bogged at this location.

Source: Department of Conservation and Land Management 1996

Figure 1.4 Storm Damage to South Beach, winter 1996

Source: Oceanica Consulting 28/09/2004

Figure 1.5 CALM facilities on the shoreline of South Beach, September 2004

Source: Oceanica Consulting 28/09/2004

Figure 1.6 Sandbagging and brushing on South Beach, September 2004

1.6 Ongoing Environmental Management

Management plans for the identified environmental impacts associated with the rehabilitation of South Beach are included in this referral document. With the exception of occasional renourishment works which may be required following particularly severe storms, the proposed rehabilitation works are not expected to generate the need for ongoing environmental management. CALM will be responsible for the ongoing management of Penguin Island.

1.7 Relevant Management Targets

Penguin Island is within the Shoalwater Island Marine Park, and as such is managed by CALM with respect to guidelines presented in the draft Shoalwater Islands Marine Park Management Plan. Table 1.1 summarises the relevant management targets for ecological values within the vicinity of South Beach, Penguin Island. Penguin Island is a proposed 'general use zone' (Kylie Ryan, 30 June 2005, *pers. comm.*).

Table 1.1 Draft Management Targets of the Shoalwater Islands Marine Park Management Plan relevant to Penguin Island

Parameter	Management Target
Geomorphology	• No change of seabed structural complexity in sanctuary zones and special purpose zones as a result of human activity in the Park; and no change of seabed structural complexity in the general use zone apart from the designated areas where some level of acceptable change is approved by appropriate authorities. • No change of coastal landform structure in sanctuary zones and special purpose zones as a result of human activity in the Park; and no change of coastal landform structure in the general use zone apart from the designated areas where some level of acceptable change is approved by appropriate authorities.
Water and Sediment Quality	• No change in water and sediment quality of all waters from "background" levels, per the environmental quality management framework referred to in ANZECC/ARMCANZ (2000), as a result of human activities in the Park, apart from designated areas where some level of acceptable change is approved by appropriate authorities.
Seagrass	• No loss of seagrass diversity as a result of human activity in the Park. • No loss of seagrass biomass as a result of human activity in the Park.
Sub-tidal Reef Communities	• No loss of macroalgae diversity as a result of human activity in the Park. • No loss of macroalgae biomass as a result of human activity in the Park.
Intertidal Reef Communities	• No loss of intertidal reef community diversity as a result of human activity in the Park. • No loss of the abundance of indicator species for the health of intertidal reef communities as a result of human activity in the Park.
Seabirds	• No loss of seabird diversity as a result of human activity in the Park. • No loss of seabird abundance as a result of human activity in the Park.
Little Penguins	• No reduction to the Little Penguin breeding success on Penguin Island as a result of human activity in the Park. • No loss of Little Penguin abundance as a result of human activity in the Park.
Seascapes	• No change in the spatial extent of the existing seascapes in the Park.

2. Background

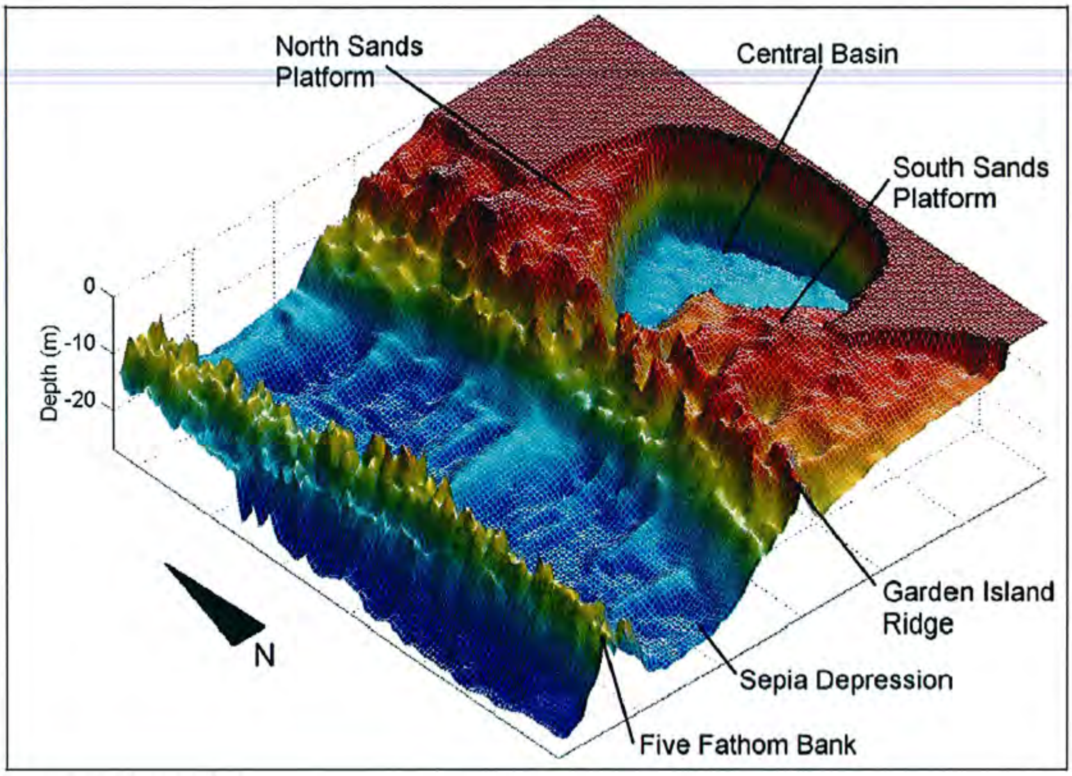
2.1 Warnbro Sound & Shoalwater Islands

Warnbro Sound is located approximately 30 km south of Fremantle, between 32.30°S and 32.37°S. Warnbro Sound is a small, marine, barred-embayment (approximately 7 km long and 4 km wide), with the partially inundated Garden Island Ridge providing significant protection from the open ocean (Figure 1.2).

The Shoalwater Islands are a series of small islands and rocks running parallel to the coast between Becher Point and Cape Peron. These islands are part of a sequence of islands and limestone reefs belonging to the Garden Island Ridge, extending from James Reef in Comet Bay, north to Rottnest Island. West of this ridge, lies another limestone ridge known as Five Fathom Bank (Figure 2.1). Sepia Depression is contained between these two limestone ridges, forming a trough which can channel strong tidal and wind driven currents. The two limestone ridges are believed to be remnant shorelines, with the eastern ridge inundated approximately 150,000 to 200,000 years before present. The basins of Warnbro Sound and Shoalwater Bay are considered to have formed as the result of this marine transgression and subsequent coastal erosion.

Warnbro Sound is characterised by two broad sill platforms and a deep central basin (Figure 2.1). The depth of the northern platform typically ranges between 1 m to 4 m, the southern between 1 m to 9 m, and the basin between 15 m and 20 m (Pascal 1993; Gersbach 1993). The underlying bed rock is composed of Tamala limestone, with calcareous sands of marine origin covering the north and south plateaus, and fine organic muds within the central basin. The shallow northern and southern platforms are covered by extensive seagrass meadows.

The Shoalwater Islands chain is comprised of (north-south order): White Rock, Bird Island, Gull Rock, Seal Island, Shag Rock, Penguin Island, First Rock, Second Rock, Third Rocks, Passage Rock and The Sisters. CALM manages these islands, rocks and adjacent marine waters as part of the Shoalwater Islands conservation reserve, Penguin Island reserve and Shoalwater Islands Marine Park on behalf of the MPRA and the Conservation Commission. The islands are home to a diverse range of wildlife, in particular the Little Penguin and the Australian Sea-lion. Sixteen species use the Shoalwater Islands for courtship, nesting, feeding and roosting (CALM 2003). The natural environment of the Islands is fragile and has a limited capacity to sustain use without unacceptable environmental change (Orr and Pobar 1992).



Source: Hollings 2004

Figure 2.1 Bathymetry of the Warnbro Sound region

2.2 Development History & Usage

2.2.1 Management

During the early twentieth century (1914–1926) a Canadian excentric Seaforth MacKenzie lived alone in a cave on Penguin Island. The island was first gazetted as a reserve for "Public Utility" on 16 October 1918, and legal tenure was granted to Seaforth MacKenzie. The lease granting tenure was cancelled in 1926. Since Seaforth was living on the island, the management of Penguin Island has changed authorities on several occasions. The Island became administered by a trust appointed under the Parks and Reserves Act in November 1935, whom eventually handed management of the Island to the Rockingham Road Board in November 1945. The gazetted purpose of Penguin Island also changed at this time to "Recreation (camping excluded)". After having continual trouble with weekend visitors to the island, the Road Board handed responsibility to the State Gardens Board in September 1949, and the gazetted purposed again changed to become "Recreation camping and enjoyment by the public for holidays and for the purposes ancillary thereto" (Chape 1984). Penguin Island became vested with the National Parks Board in March 1957, and was gazetted as a Class-A Reserve in September 1966. The Island is now managed by CALM.

2.2.2 Infrastructure

When Penguin Island became vested with the State Gardens Board, they were given the power to lease the island. Noteworthy was the desire of the State Gardens Board to transform Penguin Island into a tourist resort, and called for tenders for this development during the 1950s. It was during the term of the second lessee that hut accommodation began to be constructed on the island. Penguin Island Pty Ltd, a group of 15 people, purchased the lease in 1969, and development of the island increased from this time (Chape 1984).

A water pipeline was laid from the mainland to the island in 1970, and a telephone cable in 1972. A power facility was also installed and the accommodation facilities were upgraded. Facilities available on the island included accommodation units, meeting hall and shop, caretaker's residence, resident's ablutions, public toilets and free standing shower, storage and generator sheds, water tanks and a jetty (Chape 1984).

The series of old huts and buildings (Figure 2.2) were removed by CALM during 1989–1990, during which time several white goods (stoves, fridges etc) were found along the shoreline of South Beach and appeared to have been placed as shore protection works (Peter Dans, 01 November, 2004, pers. comm.). A new manager's residence, the WMC Research and Management Centre and the Penguin Island Discovery Centre were built in 1996 (Figure 2.3). November 1999 saw the completion of the new jetty which was the last stage of the six year development plan for Penguin Island.

Source: Department of Conservation and Land Management 1988/1989

Figure 2.2 Infrastructure on Penguin Island during the late 1980's

Source: Department of Conservation and Land Management 1997/1998

Figure 2.3 Infrastructure on Penguin Island during the late 1990's

2.2.3 Usage

The Penguin Island Discovery Centre allows visitors to see the Little Penguins close up and learn about them through feedings, commentaries and displays (CALM 2003). Visitors to the island can also enjoy the picnic areas, lookouts, beaches, as well as snorkelling and other water activities (CALM 2003). The island is also host to the WMC Research and Management Centre, which provides both accommodation and facilities for researchers to study the area's wildlife and landform's (CALM 2003).

3. Environmental Setting

3.1 Geology and Geomorphology

Penguin Island is part of a partially inundated late Pleistocene ridge of aeolianite limestone extending north from the Murray Reefs at Becher Point (Chape 1984). Other features of this Pleistocene ridge also include Seal and Bird Islands, Shag and Gull Rock, the Cape Peron Peninsula and Garden Island. The aeolianite was formed by the leaching of the calcium carbonate of the Pleistocene coastal dunes and its redeposition as limestone at lower levels. The northern and southern promontories of aeolianite limestone are capped with a hard crust of travertine (Chape 1984). Along the edges of these areas undermining has occurred, where the softer exposed limestone has been eroded away to produce shallow caves and talus slopes as a consequence of rock falls. Small limestone outcrops are also present on the western side of the island. The different dissolution rates of the soft aeolianite and the harder travertine crust have resulted in a series of Karst features also being present on the Island, especially on the northern cliffs (Chape 1984).

The island is covered in central areas with recent dunes derived primarily from wind blown calcareous sands of marine origin, and to a lesser extent from the weathering of the limestone bedrock (Chape 1984). The dunes in central part of the island rise to 20 m above sea level, while the highest points on the northern and southern promontories are 10 m and 12 m respectively (Chape 1984). Beaches have formed on the eastern and central western shores; whereas, the northern, western and southern shores of Penguin Island are fringed with limestone platform reefs. The steep eastern side of the central dune drops to the triangular shaped spit feature upon which the settlement is now constructed.

The sediments of Penguin Island consist of calcareous sands of varying depths. Two varieties of the Safety Bay Sand are present on the Island—Dune Sand (including "Young Dune Sand") and the current beach deposits (Morgan 2000). The central portion of Penguin Island is overlain with a series of high sand dunes. These dunes slope steeply down on the eastern side of the island to the Young Dune Sands. These Young Dune Sands also occupy the spit area in the lee (western side) of Penguin Island. The current beach deposits are the modern beach material—typically sand, but include the rock rubble at the feet of the cliffs at the northern and southern promontories of Penguin Island (Morgan 2000).

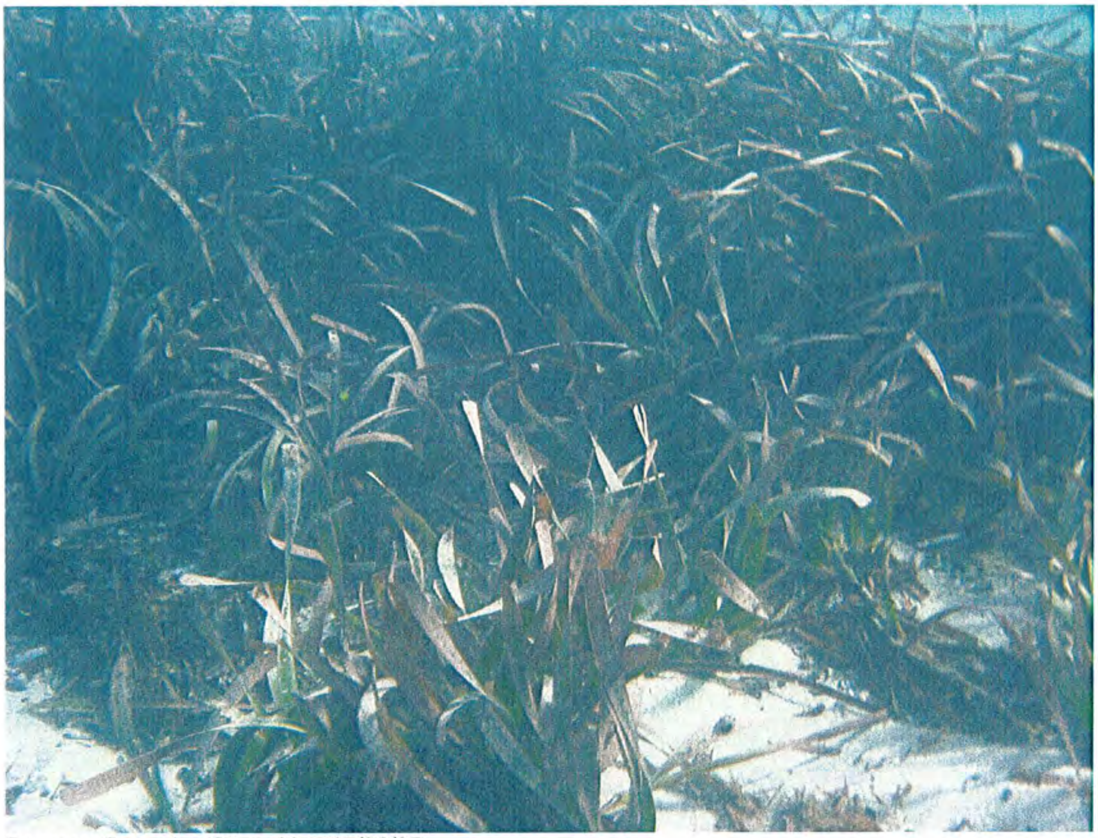
Shallow tombolos connect Penguin, Seal and Bird Islands to the adjacent mainland in Shoalwater Bay. The tombolos form where the diffracting wave patterns around the islands and reef systems intersect resulting in a deposition of material. Historical maps of the area suggest that there may be a cyclic nature to the build up and removal of sand in the northern Warnbro Sound area. Surveys conducted in 1839 by J.S. Roe show a partially vegetated sand spit within Safety Bay, which by 1859, had prograded to join the shoreline and enclosed the body of water known as Peel Harbour. In surveys completed in 1878 by Commander Archdeacon, there appears to be no indication of either of these features. However, in this region, over the last approximately 50 years, the Tern Island sand bar has established and joined to the shoreline in Safety Bay.

3.2 Benthic Habitats

The benthic habitat east of Penguin Island is characterised by seagrass meadows to the north and south of the tombolo feature (bare sand). The dominant seagrass species identified during a 1985 survey of marine communities (Gordon 1986) were *Posidonia sinuosa, Posidonia australis, Amphibolis antartica* and *Amphibolis griffithii*. Meadows in the lee of Penguin Island were typically continuos stands of *P. sinusoa*, with meadows closer to Shoalwater Bay shoreline and east of First and Second Rock are mixed meadows of *P. sinuosa* and *Amphibolis* spp (Figure 3.2).

A brief site inspection of the seagrass meadows nearshore of Penguin Island was completed on 15 June 2005 (Figure 3.1). Table 3.1 provides a brief summary of seagrasses species observed. These results concur with the descriptions provided from surveys completed by Gordon (1986).

West of Penguin Island, the benthic habitats are characterised by limestone reef platforms, which are inhabited by species of red (Rhodophyta), green (Chlorophyta), and brown (Phaeophyta) algae. Species of algae found west of Penguin Island include *Bryopsis spp, Ecklonia radiata, Colpomenia peregrina, Sargassum spp, Curdiea obesa* and *Amansia spp* (Gordon 1986).

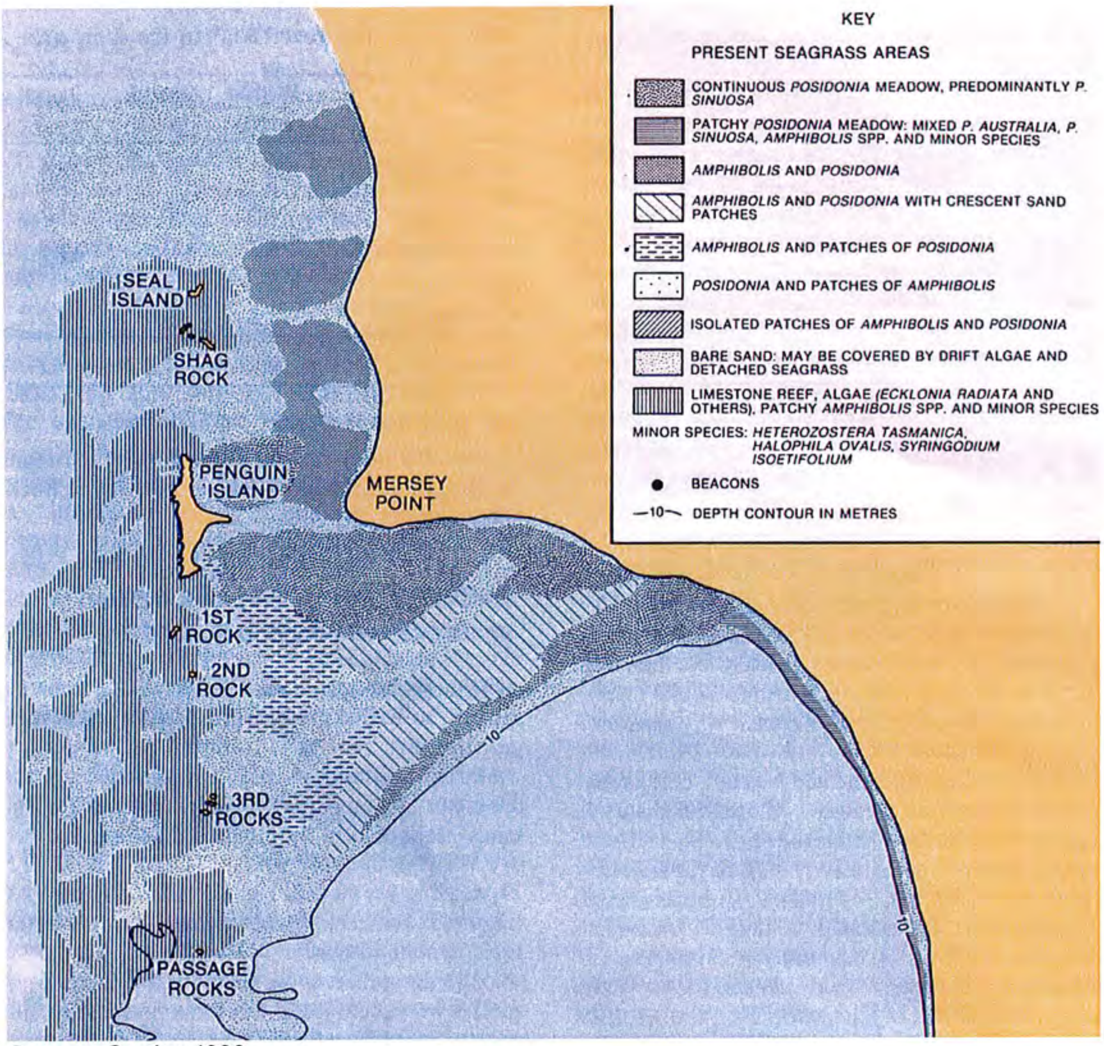


Source: Oceanica Consulting 15/06/05

Figure 3.1 Seagrass beds in the nearshore of South Beach, Penguin Island; *Posidonia australis* is present in the foreground, with *Posidonia sinuosa* in the background

Table 3.1 Summary of site inspection of nearshore seagrass meadows off Penguin Island

Site Location	Description
South of spit	• *Posidonia australis* present, especially in patches closer to shore; • *Posidonia sinuosa* was found in more extensive beds further from shore; • Also patches of mixed *P. sinuosa* and *P. australis*; • Few patches of *Amphilbolis antartica*
North of spit	• Similar patterns to South Beach with *P. australis* nearer to shore, and *P. sinuosa* further offshore. • Few patches of *Amphilbolis antartica;* • The seagrasses on the northern side of the spit had extensive epiphytic growth.



Source: Gordon 1986

Figure 3.2 Seagrass Distribution around Penguin Island

3.3 Meteorological & Oceanographic Conditions

The area of Penguin Island experiences a Mediterranean climate, with characteristic cool wet winters and warm dry summers. Typical annual rainfall is 830 mm, predominantly occurring between May and October. The annual range of sea surface temperatures is typically around 15°C to 23°C (Chape 1984).

3.3.1 Winds

The predominant wind direction for the region is from the south-west quadrant (Figure 3.3 and Figure 3.4). During summer, a typical daily wind pattern is easterly to south-easterly winds during the morning and south to south-westerly winds in the afternoon. This pattern is a product of the presence of high pressure cells, and the influence of the land-sea breeze system. During autumn, as the high pressure belt moves northwards, the winds become predominantly north-easterly. The dominant winter winds are westerly to north-westerly. During the passing of low pressure storm systems, the winds will swing from north-westerly through to west and south-westerly.

Variability of storm wind conditions on an inter-annual basis has been observed (Steedman & Associates, 1982). Similar inter-annual variability is also reflected in land-sea breeze intensity. Observations of 9 am wind speeds at Rottnest Island from the period 1965 to 1995 have been used to generate an index for summer easterlies, being the sum of easterly wind components from December to March (Figure 3.5).

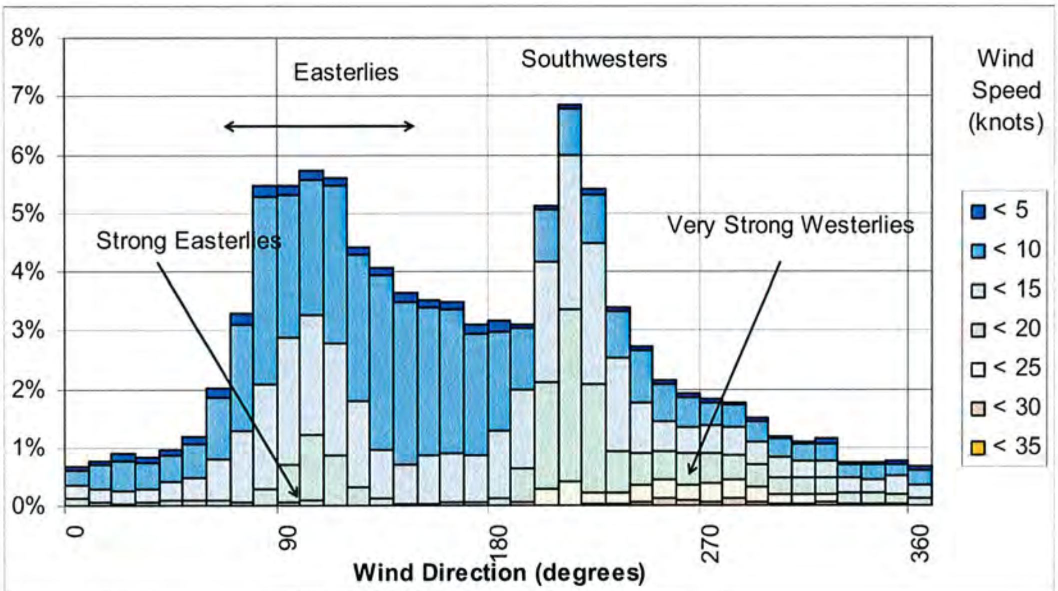


Figure 3.3 Swanbourne Wind Distribution

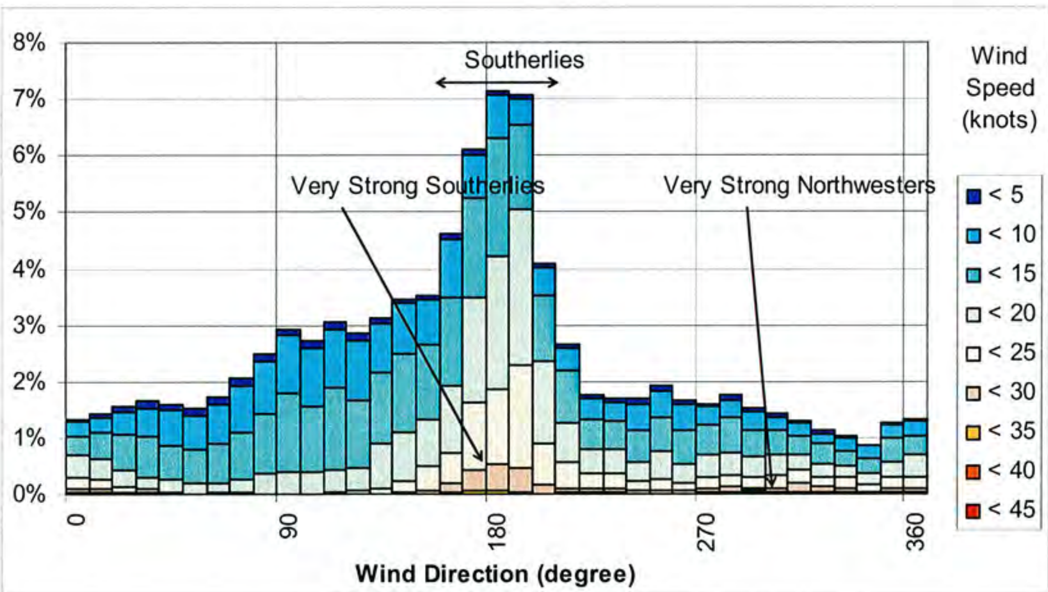


Figure 3.4 Rottnest Wind Distribution

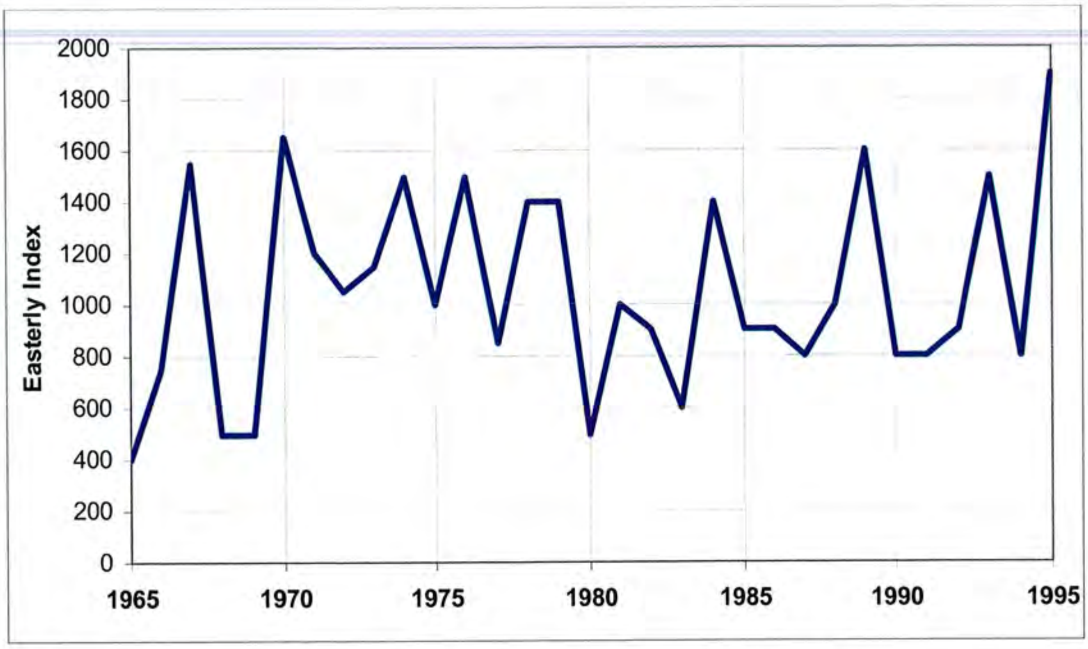


Figure 3.5 Easterly Index (extracted from Rottnest wind records)

3.3.2 Waves

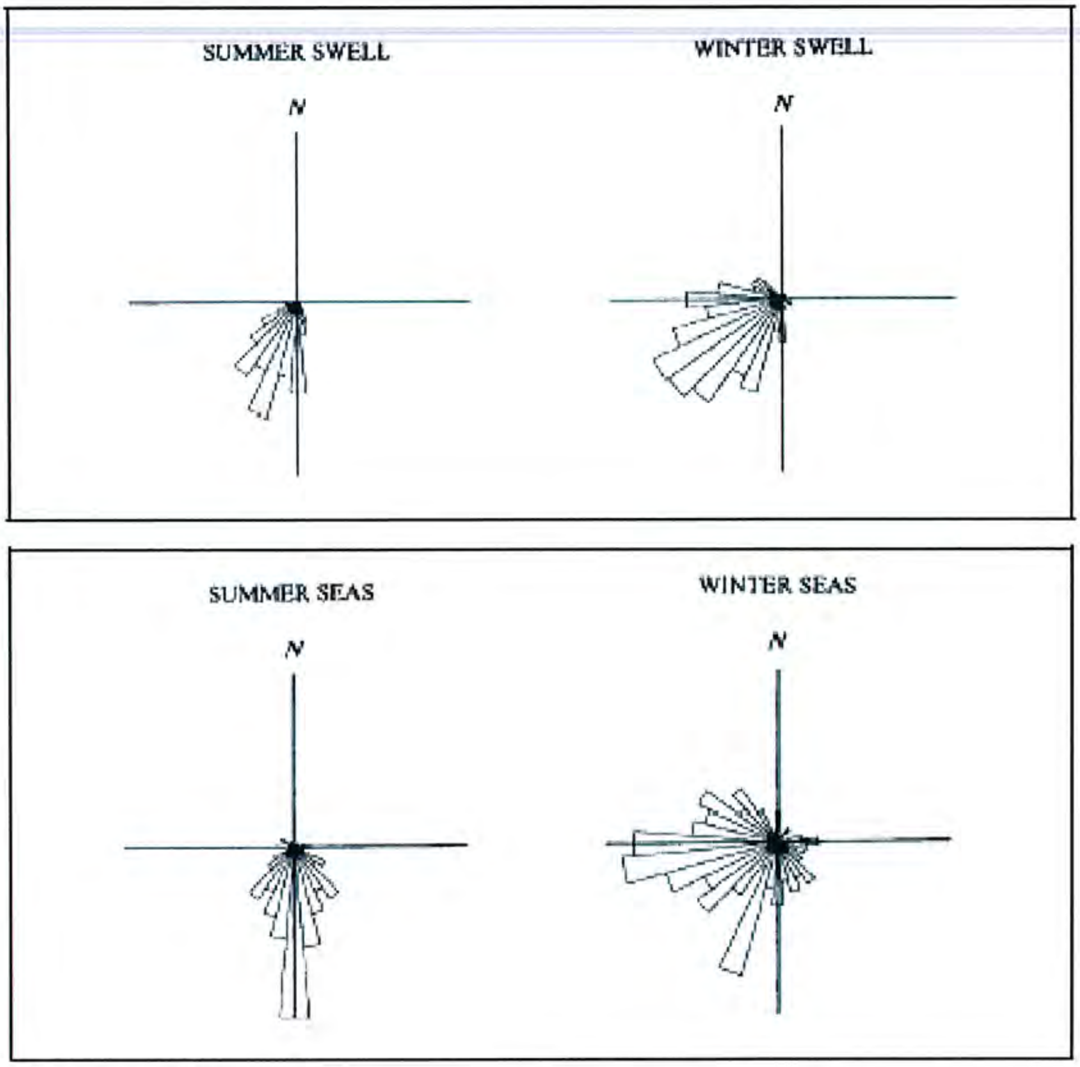
The offshore wave climate of Perth has a distinct seasonal character. Typical summer wave conditions have a mean significant wave height (Hs) of 1.8 m and period 7.6 s, whereas winter conditions have a mean Hs of 2.8 m, and period of 9.7 s (Masselink & Pattiaratchi 2001). The type of wave also alters with season—summer is typically dominated by moderate sea waves as a result of sea breeze activity, and winter is dominated by both high seas and swells due to the passing of mid-latitude depressions (Figure 3.6; Lemm *et al.* 1999). An analysis of extreme wave events using data from 12 years over the period between 1976 and 1996 indicates the ten year return period wave has an offshore significant wave height of 8.3 m (Table 3.2; Lemm *et al.* 1999)

It is important to note that the inshore wave conditions on South Beach will differ significantly from the offshore conditions due to the presence of the limestone reef systems (Five Fathom Bank and Garden Island Ridge) and the south-easterly aspect of this beach. Transmission of wave energy through the reef is highly dependent upon the angle of wave approach and presence of gaps within the reef system. Wave energy can pass over the reef, but is dependent upon wave period and the depth of water over the reef. This is particularly relevant during storm conditions, when surge will increase the water level, and thus allow the more energetic storm wave activity into the system. Swell waves approaching the Penguin Island spit have to refract around the northern and southern promontories of Penguin Island.

Table 3.2 Average return interval of extreme offshore wave heights

Return Period (Years)	Estimated Offshore Hs (m)
1	6.7
2	7.2
5	7.8
10	8.3
25	8.9
50	9.4
100	9.8

Source: (Lemm et al. 1999)



Source: Lemm 1996

Figure 3.6 Swell and Sea Wave roses for summer (November-April), and winter (May-October) seasons

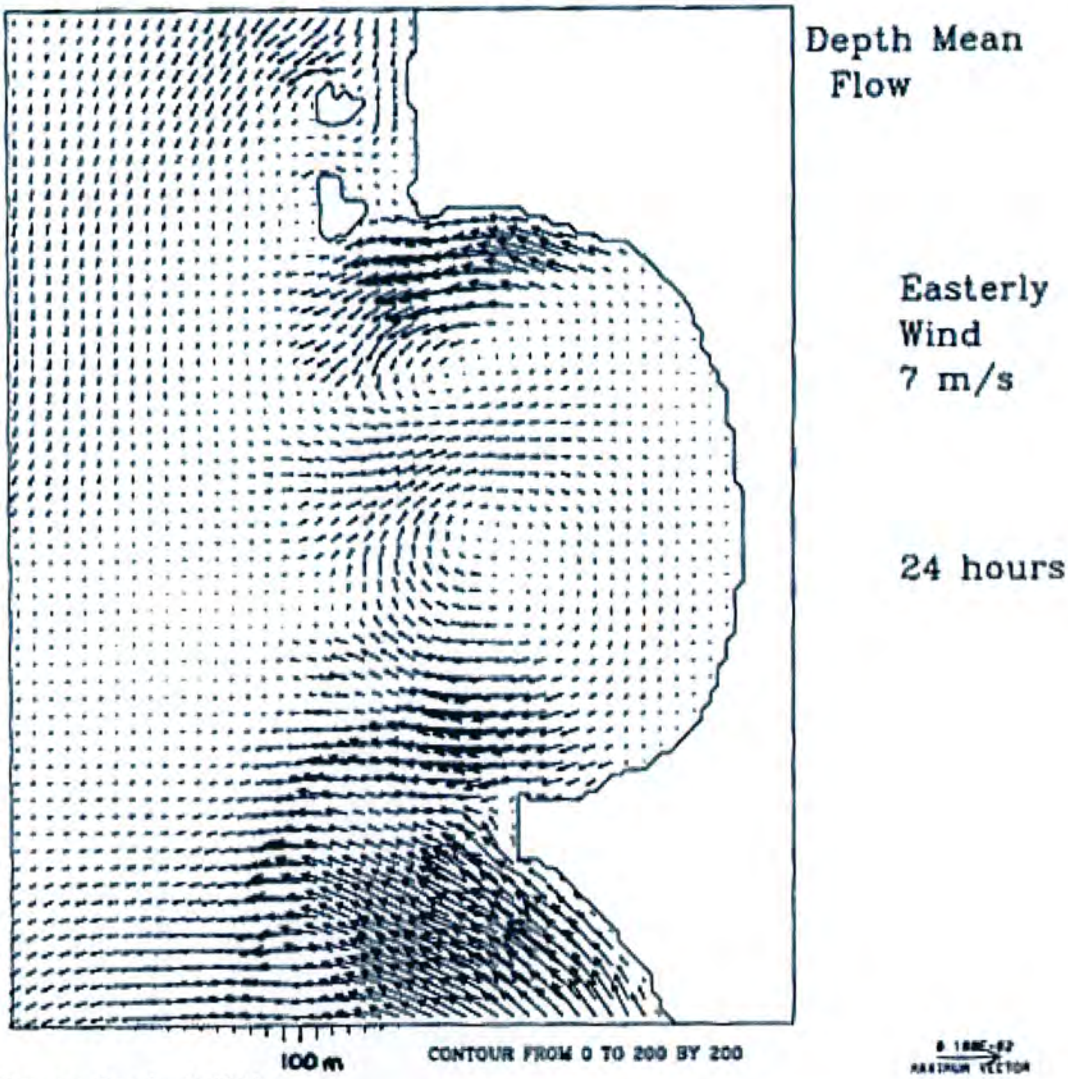
3.3.3 Tides and Water Level Variations

Penguin Island experiences a very low tidal range. The average daily tide range is 0.7 m and there is generally a single tide per day. Maximum tidal ranges occur at winter and summer solstices. This combines with the annual mean sea level change to produce the lowest water levels in November-December and maximum water levels in May-June.

Non-tidal variation of water levels in the region is significant, dominated by onshore and offshore wind events (Defence 2003). Cumulative effects of barometric pressure, winds, wave action, water temperature and salinity can result in variations of more than 1.0 m—at least equivalent of the maximum tidal range (Chape 1984). In addition to short-term effects of synoptic systems, fluctuations of mean sea level of 0.3 m have been correlated with ENSO variability, driven by changes to Leeuwin Current intensity (Pariwono *et al* 1986; Pattiaratchi and Buchan 1991).

3.3.4 Currents

Numerical circulation modelling completed by Gersbach (1993) suggests that under the influence of easterly and westerly winds, topographic gyres could occur within Warnbro Sound (though these gyres were not modelled under northerly or southerly wind patterns). The northern gyre moves anticlockwise under easterly winds (summer), and clockwise under westerly wind (winter) conditions (Figure 3.7). Chape (1984) has suggested that the accretion of beaches and sand bars on the northern coast may be facilitated by a predominantly northward, anti-clockwise circulation in the sound during summer. The presence of gyres is not expected in Shoalwater Bay due to the small scale and narrow shape.



Source: Gersbach 1993

Figure 3.7 Depth averaged flows for 100 m cell size models under constant easterly wind of 7 ms^{-1}

3.3.5 Storminess

Assessment of storminess for the Perth coastline has been undertaken over relatively short periods using wind and wave observations (Steedman & Associates 1982; Panizza 1983; Lemm 1996). Using wind records for the coastal region from Cape Leeuwin to north of Perth, it was observed that an average of 8 storms (defined as an event where the mean wind speed exceeded 30 knots for one hour, or 25 knots for three hours) arrive at the coast each year (Table 3.3). However, Silvester (1987) notes that this can fluctuate between 4 and 12. Alternatively analysis of extreme wave conditions (Hs >4 m) indicates that an average of 30 storms are experienced each year, and are most frequent and intense during July (Lemm *et al.* 1999)

During the period between 1968 and 1982, Panizza (1983) identified strong northwest storms in 1968, 1973-1975, 1977 and 1980-1981 whilst strong southwest storms were more evenly distributed. Severe storm events were recorded during 1970-1973, 1975, 1977-1978 and 1981.

To identify periods of storm activity, wind databases from Rottnest and Fremantle were analysed (Figure 3.8). Historical wind records from Rottnest were observed at 9 am and 3 pm from 1965 to 1995, before installation of an automatic weather station. Dominance of the sea breeze at 3 pm prevents the meaningful use of this data for estimating storm events. The 9 am data provides a more clear distinction between storm and non-storm conditions, although it must be noted that a single daily observation is likely to miss the peak wind speed and can not be used for subtle comparison of wind speeds between events. The count of annual storm events is shown in Figure 3.8, indicating high levels of inter-annual variability.

Table 3.3 Number of Storms recorded over 15 years

Season	No. of Storms
Summer	22
Autumn	34
Winter	42
Spring	22
TOTAL	120
Annual (Average)	8

Source: adapted from Silvester 1987

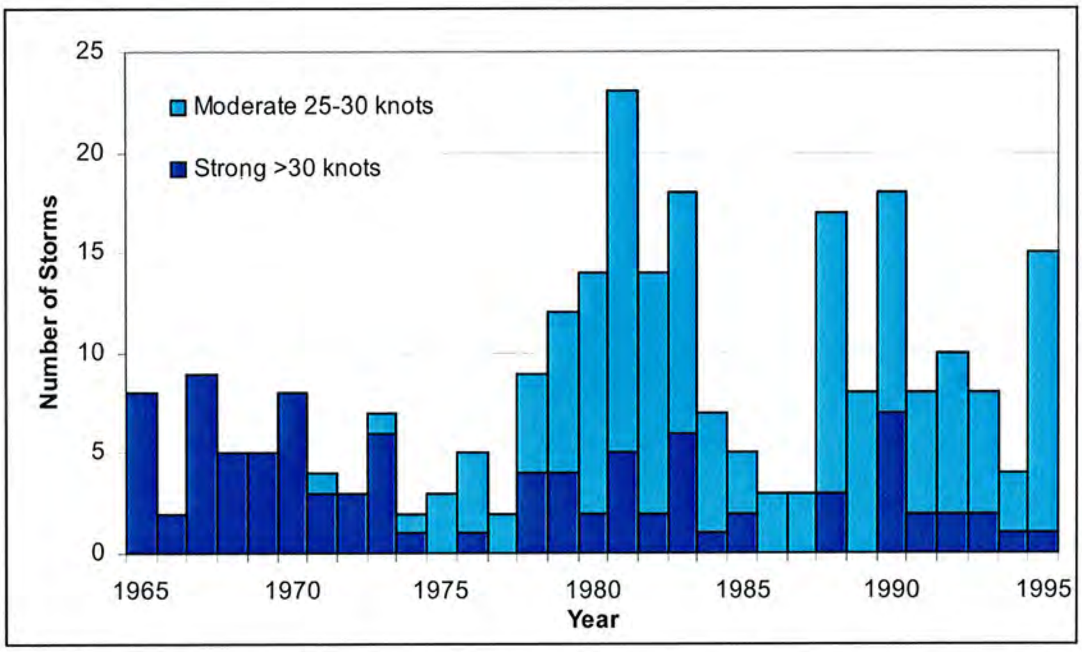


Figure 3.8 Frequency count of moderate and strong 9 am winds recorded at Rottnest Island, 1965-1995

4. Sediment Transport

4.1 Regional Sediment Dynamics

A set of tracings completed by Bill Morgan (Penguin Island Volunteer) shows the differences between the 1843 and 1978 shorelines (Appendix B). The obvious changes include the progradation by approximately 40 m at the point opposite Seal Island, and the loss of the Peel Harbour and sand spit within Warnbro Sound. Even over shorter time scales, shoreline movement in Warnbro Sound has been observed—in 1964 a rock wall was constructed to protect Arcadia Drive in Safety Bay from a receding shoreline, but more recently, jetties and boat ramps in the region are unusable due to sedimentation (Hollings 2004).

There appear to be three key areas of shoreline movement within Warnbro Sound: Safety Bay, Becher Point and Mersey Point. It is suggested that changes to the shoreline at Becher and Mersey Points are likely to be due to changes in the direction of prevailing incident wave energy through the Garden Island Ridge or changing weather conditions, whilst the changes observed at Safety Bay are likely to be influenced by the development of the Tern Island sand bar (Hollings 2004). Note that the changes induced by the establishment of the Tern Island sand bar have been restricted to the accumulation on the western side of the sand bar whilst the beach between Tern Island and Mersey Point has shown little change (Hollings 2004).

In 1839 the Penguin Island tombolo was attached to an east-west aligned sand spit parallel to the northern Warnbro Sound coast, forming a semi-enclosed water body known as Peel Harbour (Figure 4.1). At this time both the tombolo and sand spit were both completely vegetated, but by 1878, the spit and consequently Peel harbour had disappeared (Carrigy 1956).

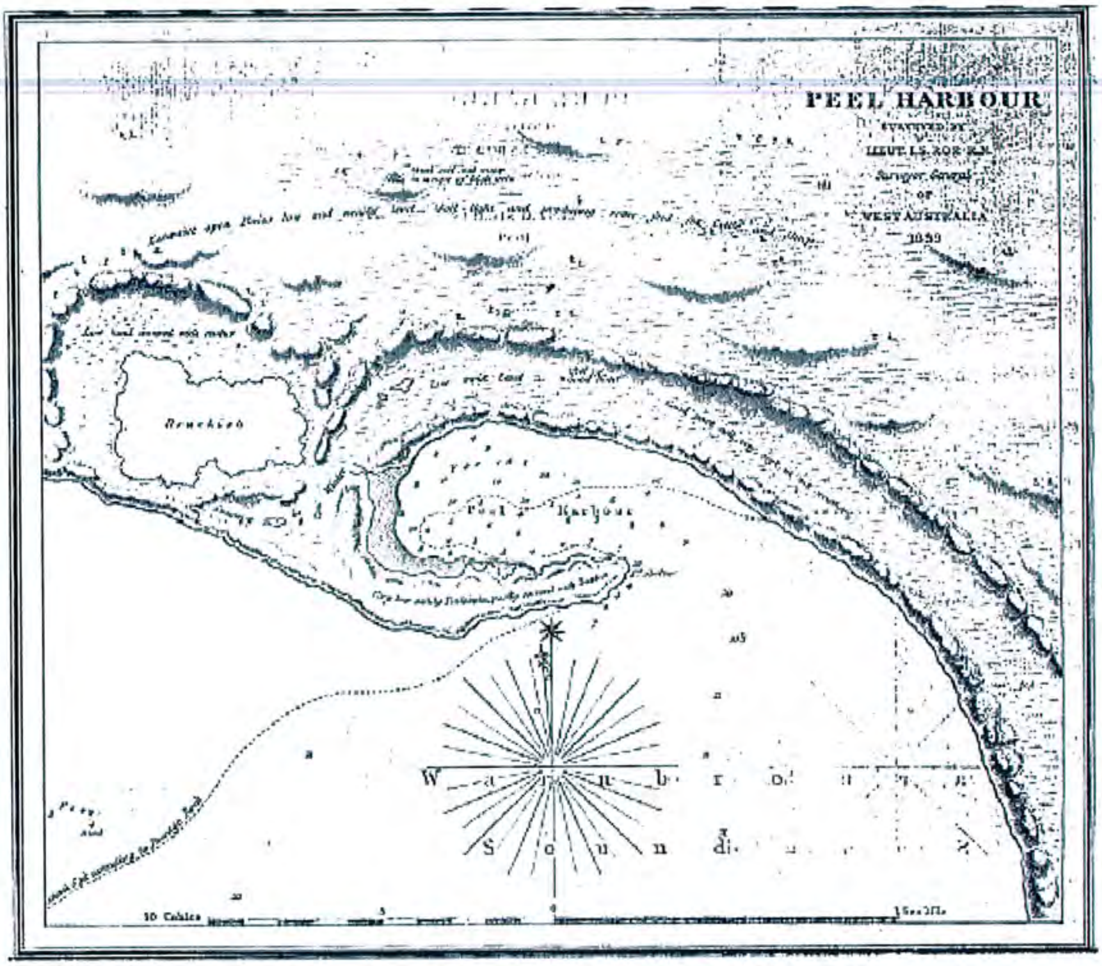


Figure 4.1 1839 Survey of Peel Harbour by J.S. Roe

4.2 Equilibrium Tombolo Form

The concept of an equilibrium plan-shape for sedimentary coastal features is applied to a range of features, suggesting a balance between prevailing conditions and the feature alignment. In reality, variability of sediment supply, wave conditions, currents and water levels, plus sediment transport lag, combine to ensure that a unique position of equilibrium does not occur. However, for many sediment features, shore movements vary about a modal structure, cycling on a seasonal or inter-annual basis. This behaviour is commonly termed dynamic equilibrium and the modal structure is generally assumed to be a qualitative result of the modal forcing conditions.

An equilibrium model for salient formation is described by Hsu & Silvester (1996). Salients are lobate features occurring in the lee of islands or reefs. A tombolo is an 'advanced' salient, such that the shore feature connects with the island. The model of Hsu & Silvester (1996) is essentially driven by the refraction pattern of waves passing around either side of an island. In addition to damping, waves are bent, approximately in a radial pattern. The change in direction encourages shoreline curvature from either side, producing a characteristic lobate feature (Figure 4.2). In a similar manner, the wave damping pattern encourages deposition on the leeside shore of the island. For an island that is close to shore or sufficiently large, the 'shadow' may connect to the landmass, in which case a tombolo is formed, such as present at Penguin Island.

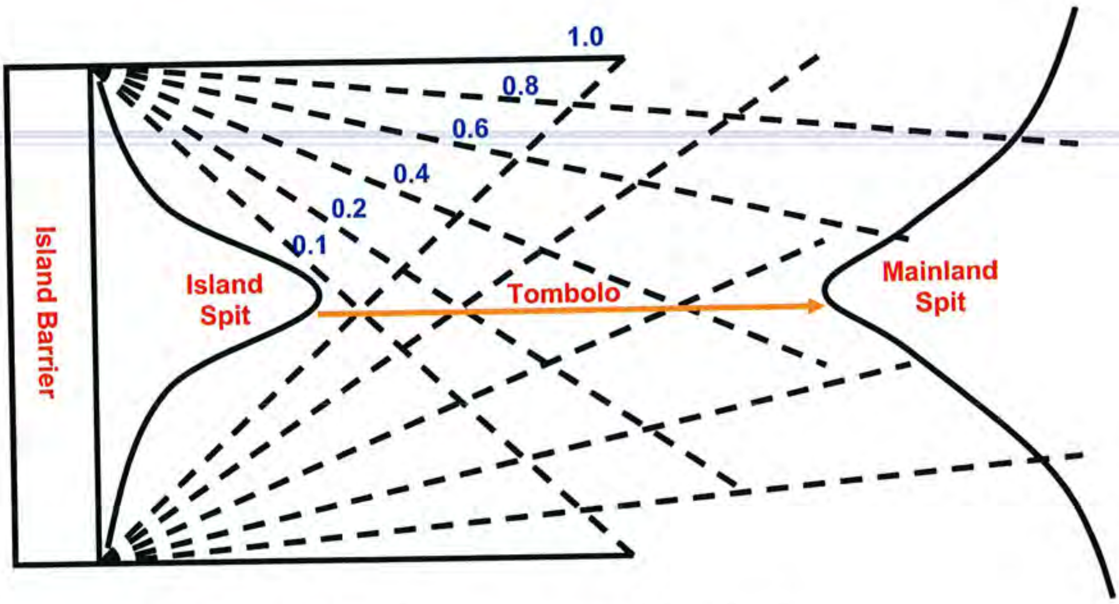


Figure 4.2 Changes in wave direction due to offshore barriers

Salient formation is strongly determined by the wave refraction pattern, which is a function of wave height, period, direction and water depth. For more energetic wave conditions, greater refraction reduces the shelter provided by the island and typically deflates the salient and the island's leeside spit.

Salient and tombolo dynamics may be further complicated by the interaction of wave trains from each side of the island. This has been observed at Penguin Island, with the shoaling, and intersection and breaking of waves in the general region of the tip of the sand spit. This process emphasises easterly sediment transport for the beaches (spit) and tombolo. It is considered likely that this process assists with the formation of breaches along the sand spit.

4.3 Penguin Island Sediment Dynamics

The Penguin Island spit has a direct sediment transport connection with the tombolo and adjacent sand sheets, including vegetated areas. In turn, the tombolo provides connection to Mersey Point, which follows to Safety Bay and Shoalwater Bay.

On a geological time frame, Penguin Island is likely to experience a net sediment loss, with material being transported eastwards onto the tombolo[2]. However, the rate of loss during storm events is far more significant than over the geological time scale, suggesting a process of sediment resupply must occur. Without resupply, the eastern third of Penguin Island could not exist as a long-term feature.

The most likely mechanism of sediment resupply is a westerly sediment movement along the sand spit, driven by wave action. On the northern side of the spit, fetches are too short to generate significant transport from easterlies. On the southern side, open water across Warnbro Sound enables greater wave energy and consequently can encourage westerly transport. However, wind events from the south-east are comparatively rare, which indicates that westerly sediment transport is likely to be

[2] It is noteworthy that the patch of seagrass growth (since approximately 1987) in an area of relatively deep water immediately offshore of South Beach has occurred during a period of ongoing erosion. This suggests that sediment being removed from South Beach is not moving offshore in large volumes, but rather, that the sediment is likely to be moving eastward onto the tombolo or northwards on to the northern beach.

very low. Development of Tern Island is likely to further reduce this transport, as it considerably reduces the available wave fetch. Conversely, if due to changes in the prevailing hydrodynamics in this region, erosion processes were to dominate in this area then Tern Island would provide a large quantity of available sediment, a portion of which is likely to be transported to Penguin Island spit.

4.3.1 Previous studies on Penguin Island Shoreline movements

A small number of studies have been undertaken with regard to shoreline movement on Penguin Island, including:

- **Maunsell (2003)**: Visual inspection of historical aerial photography between March 1964 and May 1983 indicated a loss of seagrass to the eastern side of the southern headland of Penguin Island (and a coincidental loss of sand overlying the limestone platform which extends from the southern headland across the length of the southern beach)—it was implied that this loss of seagrass, resulting in greater wave energy reaching the South Beach shoreline was responsible for the continuing erosion of the site;
- **Stone (2000)**: From comparison of aerial photography taken in 1973 and 2000, it was estimated that approximately 1,000 m^2 of sand has been lost from South Beach over that 27 year period. Using various assumptions on the height of the eroding dune and the width of the active shore, this corresponds to a volume loss of 5,000–10,000 m^3, equivalent to a rate of 200–400 m^3/year;
- **Andrew (2000)**: Suggests that basic element of management should be renourishment, with the tombolo as a likely sediment source due to proximity and ability to dredge the required material; and
- **Andrew (1972)**: Following a site visit, noted that the groyne installed in 1968 appeared to have stabilised approximately one third of the beach, but it was suggested that the erosion at the western end of the spit was expected to continue unless that wave approach angle was artificially varied.

4.3.2 Previous Management Techniques

Different management techniques have been applied previously to South Beach, including:

- **Armour Groyne:** A rock armour groyne was constructed towards the eastern end of South Beach during 1968. The effect of the groyne can been seen on 1968 aerial photography as capturing an additional 5–10 m of beach width, in comparison to its downdrift, eastern side. It appears that the groyne degraded rapidly, settling into the sandy bed. The behaviour of this groyne structure is typical of many such facilities installed during the 1960's along the Western Australian coast. Absence of design criteria and insufficient allowance for wave climate variations provided several under-strength rubble structures. It is likely that the armour groyne was insufficiently bedded, which enabled downdrift erosion to undermine the groyne from the eastern side;
- **Nourishment:** It is understood that occasional renourishment efforts have been undertaken using a bobcat to move sediment from the eastern end of the spit to the western end of the beach. Whilst the principle of sediment renourishment is sound, it is preferred that sediment be removed from a more distant, and preferably less connected source;
- **Dune Management**: Presently a large erosion scarp exists towards the western end of the beach, the lower part of which has been stabilised using brushing techniques. This scarp face is approximately 12 m high and 30 m wide. Consequently, it is sufficiently large to provide a significant quantity of sediment as it erodes, with material transported eastwards feeding South

Beach. Despite positive intentions, the effect of dune management for this area may have reduced the feed of sand to the beach and acted to enhance the rate of erosion occurring along South Beach;

- **Sand Bagging & Brushing**: Brushing and sand bagging works have recently (October 2004) been implemented on South Beach. The sand bagging will provide some protection from marine processes during storm events whereas the brushing activity provides stability against wind blown sand movement from the beach. It is unlikely that this brushing would provide any significant protection during large storm events (Appendix A).

5. Shoreline Movement Analyses

5.1 Aerial Photography

A search of the aerial photography archives at the Department for Land Information (DLI) indicated that the Department holds records of Penguin Island taken at yearly intervals since 1975, and irregularly back to 1953 (Table 5.1). Aerial photography taken at approximately decadal time intervals (1953, 1965, 1979, 1987, 1992, 2002 and 2004; Appendix C) were selected for use in this study to examine shoreline movements on Penguin Island. Additional photographs from 1968 and 1970 are also analysed to enable examination of the influence of the groyne which was installed in 1968.

5.2 Mapping Methods

The Department for Planning & Infrastructure (DPI) has previously mapped the mainland shoreline position for the area between Becher Point and Point Peron approximately every 10 years since the 1940's (Table 5.2). However, this data only contained one occasion of mapping of Penguin Island. For the present study, Oceanica Consulting Pty Ltd (Oceanica) has mapped the shoreline position for both Penguin Island, and the Shoalwater and Safety Bay area, for the following dates:

- March 1965;
- May 1968;
- October 1970;
- May 1979;
- May 1987;
- December 1992;
- April 2002; and
- March 2004.

The majority of photos are taken during autumn and provide an indication of the post-summer beach form. The photos from 1970 and 1992, taken during spring and early summer, provide an indication of post-winter beach form. Note that 1953 stereo imagery was not available for the 1953 dataset, hence it was not possible to compete shoreline mapping for 1953.

For each selected year of aerial photography, both the vegetation and waterline were mapped for Penguin Island (Figure 5.1) and the mainland coast around Mersey Point using standard manual photogrammetric techniques. The vegetation line is defined as the seaward edge of vegetation, which will generally correspond to the toe of the foredune or erosion scarp. The vegetation line is used as an indicator of shoreline change in preference to the waterline since its location does not significantly fluctuate over small times scales as a result of tidal and weather influences. This is consistent with the recommendations of Schedule One of the State Planning Policy 2.6 which pertains to coastal set back distance. The photogrammetry was completed using an aerotriangulated model set up using the 1999 photography at a scale of 1:7,200. The root mean square (RMS) aerotriangulation errors are shown in Table 5.3. The rocky coast of Penguin Island was plotted from the 1999 DLI diapositives.

Table 5.1 DLI and Oceanica Aerial Photography archives for Penguin Island

Project Number	Project year(s)	Scale	B/W or Colour	Available
Oceanica (1),(2)	**2004**	**1:25,000**	**Colour**	**Yes**
030001	2003 - end	1:20,000	Colour	Yes
020001	2003 - beginning	1:20,000	Colour	Yes
Oceanica (1),(2)	**2002**	**1:25,000**	**Colour**	**Yes**
010001	2002	1:20,000	Colour	Yes
000001	2001	1:20,000	Colour	Yes
990000	2000	1:20,000	Colour	Yes
980000 (2)	**1999**	**1:20,000**	**Colour**	**Yes**
970000	1998	1:20,000	Colour	Yes
960000	1997	1:20,000	Colour	Yes
950000	1996	1:20,000	Colour	Yes
940900	1995	1:20,000	Colour	Yes
930400	1994	1:20,000	Colour	Yes
920676	1993	1:20,000	Colour	Yes
920400 (2)	**1992**	**1:20,000**	**Colour**	**Yes**
910400	1991	1:20,000	Colour	Yes
900400	1990	1:20,000	Colour	Yes
890004	1989	1:20,000	Colour	Yes
880004	1988	1:20,000	Black/White	Yes
870004 (2)	**1987**	**1:20,000**	**Colour**	**Yes**
860004	1986	1:20,000	Black/White	Yes
850004	1985	1:20,000	Colour	Yes
840004	1984	1:20,000	Black/White	Yes
830004	1983	1:25,000	Colour	Yes
820004	1982	1:25,000	Black/White	Yes
810017	1981	1:25,000	Colour	Yes
800019	1980	1:25,000	Black/White	Yes
790006 (2)	**1979**	**1:25,000**	**Black/White**	**Yes**
780091	1978	1:25,000	Black/White	Yes
770064	1977	1:25,000	Black/White	Yes
760014	1976	1:25,000	Black/White	Yes
Q98	1975	1:25,000	Black/White	Yes
M136	1972	1:25,000	Black/White	Yes
L6 (2)	**1970**	**1:12,000**	**Black/White**	**Yes**
(2)	**1968**	**1:15,840**	**Black/White**	**Yes**
F67	1967	(TBC)	Black/White	Yes
E50 (2)	**1965**	**1:15,840**	**Black/White**	**Yes**
	1964	(TBC)	Black/White	Yes
D28	1963	(TBC)	Black/White	Yes
Metro '60	1959/60	(TBC)	Black/White	Yes
Metro '53	1953	1:15,840	Black/White	Yes
z15a	Special	1:15,000	Black/White	No

Notes: 1. Imagery owned by Oceanica Consulting Pty Ltd.
2. Bolded years are photographs obtained and used for shoreline movement analysis.

Table 5.2 Available DPI Shoreline Movement Plots

Region	Years
Point Peron	January 1942 October 1965 January 1979
Shoalwater and Safety Bay	January 1942 October 1965 January 1979 February 1987 January 1993 December 1994
Penguin Island	January 1993
Warnbro Sound	January 1942 January 1979
Becher Point	January 1942 January 1955 October 1965 January 1979

Table 5.3 Control points and RMS errors for vegetation and waterline mapping

Year	Photo No.	RMS Error		Number of Control Points	
		Horizontal (m)	Vertical (m)	Horizontal	Vertical
1965	5212-5211	0.15	0.18	6	7
	5211-5210	0.14	0.12	3	5
1968	5146-5145	0.37	0.22	5	8
	5145-5144	0.32	0.27	4	6
1970	5226-5225	0.05	0.30	3	5
	5227-5228	0.38	0.26	4	7
	5228-5229	0.25	0.41	4	5
1979	5057-5059	0.47	0.26	3	6
1987	5084-5083	0.08	0.17	3	6
1992	5251-5250	0.06	0.46	4	6
2002	116-117	0.3	0.21	3	6
	122-123	0.46	0.44	3	6
2004	58-57	0.28	0.02	3	6
	72-71	0.58	0.12	3	6

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Author: PBH | Date: 07/10/05
Proj Ref: 422_3
File Ref: 422_3_071005_f13.mxd
Horizontal Datum: UTM Zone 50 Based on WGS84
Vertical Datum: N/A

Legend

Rocky coast

Vegetation Line

1965	1979	1999
1968	1987	2002
1970	1992	2004

Figure 5.1

Penguin Island
Shoreline Movement
1965 - 2004

Department of Conservation and Land Management
Conserving the nature of WA

5.3 Examination of Shoreline Movement Trends

Over the past 39 years, progressive erosion has occurred on the Penguin Island spit. This contrasts strongly with the behaviour of Shoalwater Bay beaches, where accretion has been almost continuous. A short description of the pattern of beach erosion on South Beach, as shown by the vegetation lines, is summarised in Table 5.4. To quantitatively illustrate the history of sediment movement on Penguin Island the following data was extracted: (1) change in the area of the spit; and (2) shoreline position at a series of cross-shore transects. The results of this analysis are presented below.

The possible role of the tombolo in storage and transferral of sediment has not been identified. However, it is considered likely that the tombolo acts as a sink during periods of low energetics and a sediment source during heightened activity—whether these energetics are wave or tidal.

Table 5.4 Summary of changes to South Beach, Penguin Island

Period	Observed Change
1965-1968	Beach rotation
1968-1970	Almost uniform loss
1970-1979	Loss mainly from western part of beach
1979-1987	Broad scale accumulation, with advanced development on the east end of the spit
1987-1992	Loss mainly from the extended spit
1992-1999	Almost uniform loss
1999-2002	General loss, with very small gain on the end of the spit
2002-2004	Small general loss

5.3.1 Spit Area

The "spit area" for Penguin Island is defined between the two rocky outcrops which bracket the spit to the north and south (Figure 5.2). Comparative analysis of the spit area indicated the following:

- An overall area loss of 0.59 ha between 1965 and 2004—corresponds to an average annual rate of area loss of 152 m^2/year (Figure 5.3);
- An overall trend of decreasing area of the spit zone since 1965 (significant trend, $r^2 = 0.78$) (Figure 5.4);
- The greatest periods of net erosion are from 1970 to 1979 (0.33 ha) and 1987 to 1992 (0.27 ha) (Figure 5.5).
- The only periods of net accretion noted in this data set are from 1965 to 1968 (0.05 ha) and 1979 to 1987 (0.29 ha) (Figure 5.5);

Figure 5.2 **Definition of spit area on Penguin Island**

Figure 5.3 **Total area lost (red) and gained (green) on Penguin Island between 1965 and 2004**

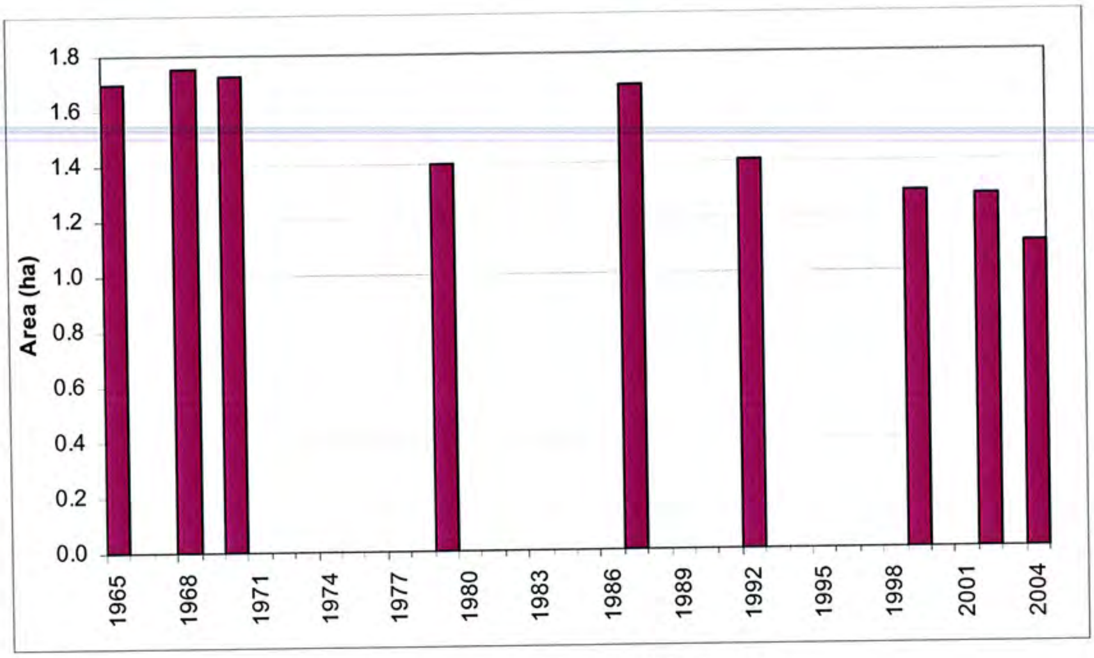


Figure 5.4 Total Spit Area for Penguin Island, 1965 to 2004

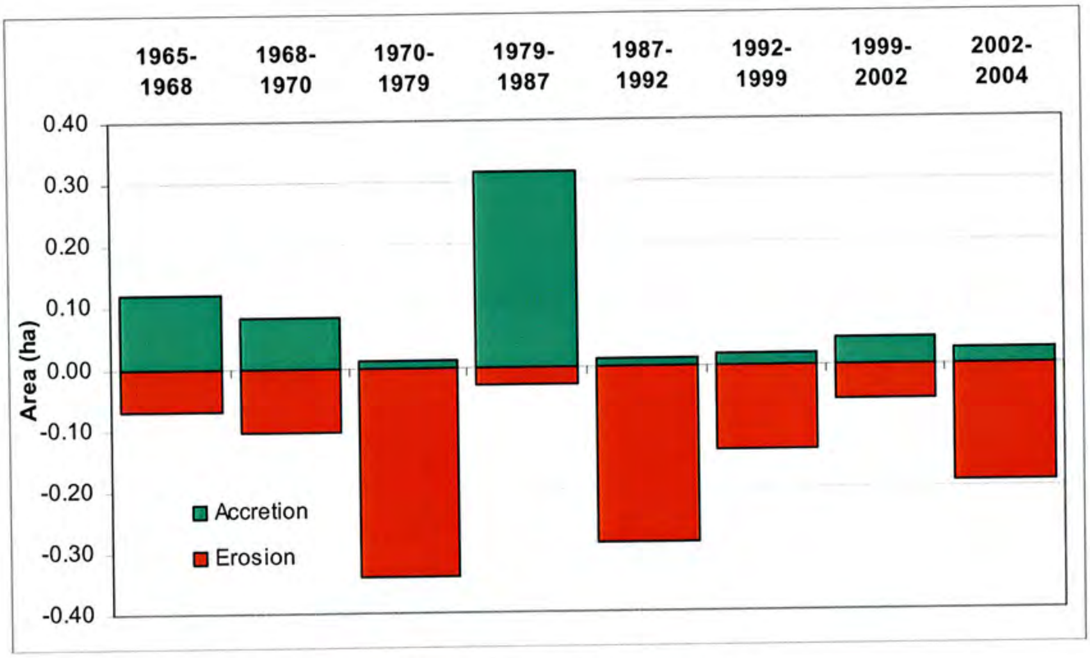


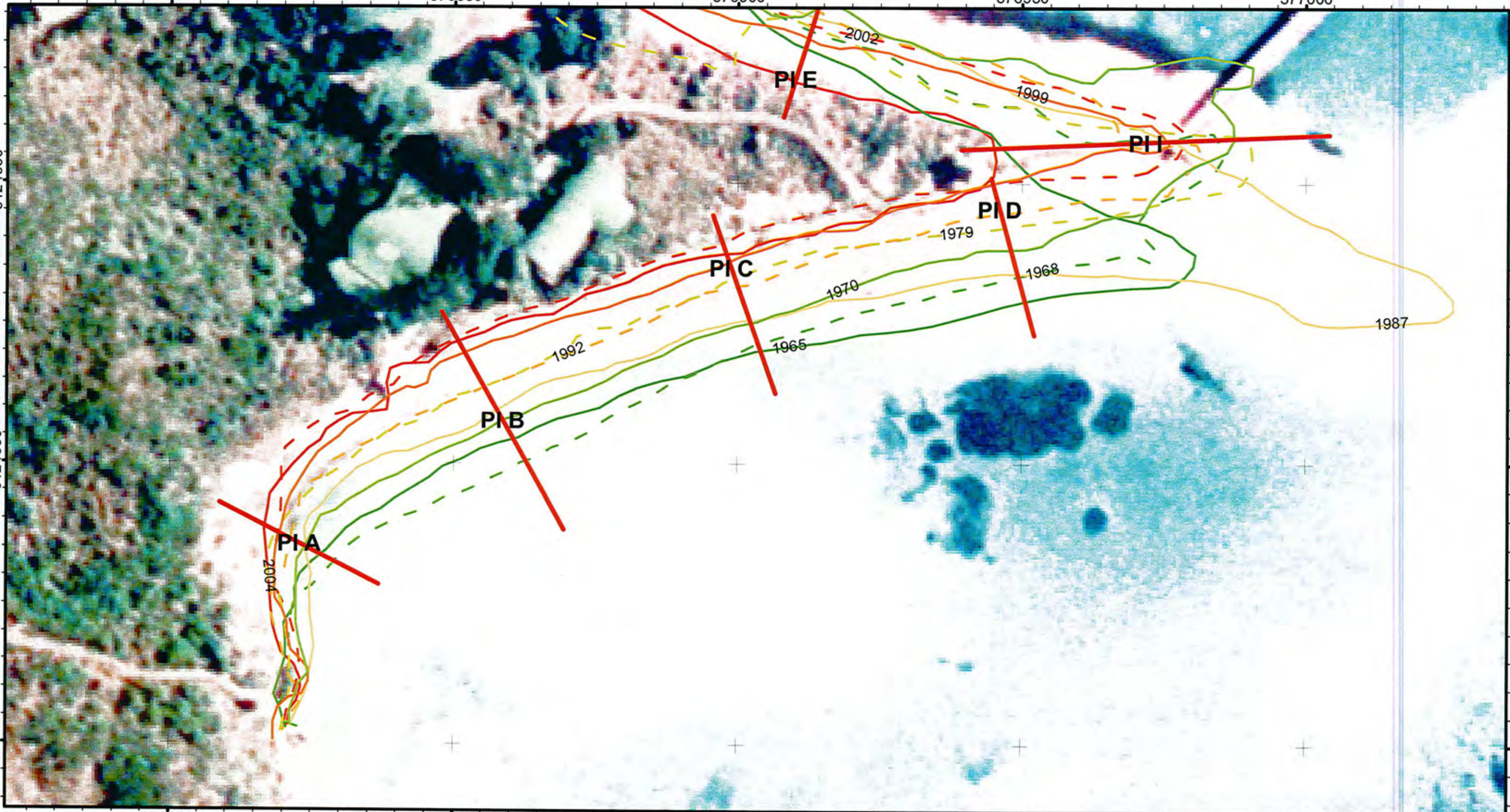
Figure 5.5 Erosion and accretion between 1964 and 2004

5.3.2 Cross-Shore Transects

A series of four shore-perpendicular transects were established along South Beach at approximately 50 m intervals round the Penguin Island spit (Figure 5.6). Along each transect, the distance of the vegetation line relative to the 1965 position, was measured.

Examination of this transect data indicates the following (Figure 5.7):

- South Beach has generally retreated 18–22 m between 1965 and 2004 (excluding transect PI-A which shows only an 11 m retreat—likely due to the greater sheltering offered by the rocky outcrop);



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Author: PBH	Date: 07/10/05
Proj Ref: 422_3	
File Ref: 422_3_071005_f56	
Horizontal: Datum	UTM Zone 50 Based on WGS84
Vertical: Datum	N/A

Legend

Transects

Vegetation lines

1965, 1968, 1970, 1979, 1987, 1992, 1999, 2002, 2004

N

Figure 5.6

Location of cross-shore transects on South Beach

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- Transects PI-A and PI-B show slight shoreline progradation (2.5-4.5 m) between 1965 and 1968, but then all transects on South Beach show shoreline retreat between 1968 and 1979; and
- Rates of change on South Beach vary between -4.13 m/year to 1.48 m/year.

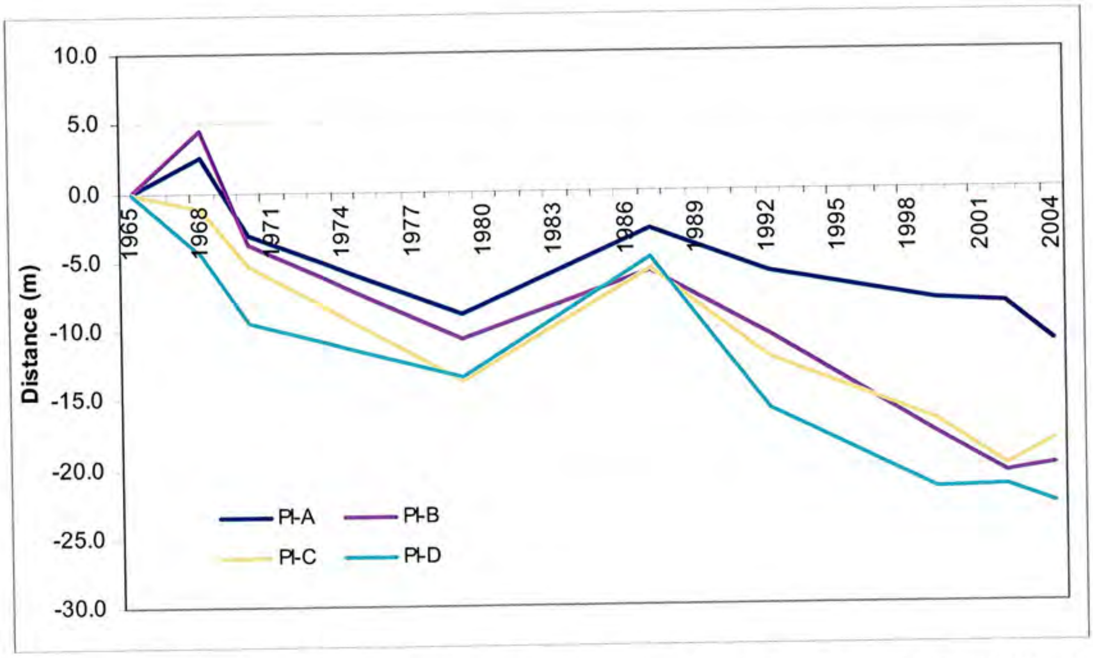


Figure 5.7 **Shoreline Change relative to the 1965 Vegetation Line on South Beach, Penguin Island**

6. Concept Designs for Beach Stabilisation

6.1 Possible Management Elements

To consider the range of management options available to mitigate or prevent a threat, it is appropriate to consider the features under threat and processes by which threat occurs. For this case, features under threat include the physical infrastructure of CALM buildings, aesthetics and beach amenity, including access for penguins. Threat to these features is brought about by the ongoing loss of sediment from Penguin Island, South Beach. The rate of loss is determined by beach resistance to erosion, beach configuration, incident wave energy and alongshore wave distribution. Consequently, intervention measures may include:

- Management of threatened features;
- Sediment management;
- Beach modification; and
- Wave climate modification.

On the basis of previous investigations for the site, plus similar coastal engineering problems, the following shoreline management elements were considered in the present study for the erosion management of the South Beach:

1. Do nothing;
2. Relocate the buildings;
3. Renourish;
4. Renourish with a revetment wall;
5. Revetment wall;
6. Timber groyne field;
7. Single armour groyne;
8. Alongshore groynes;
9. Offshore groyne;
10. Perched Beach;
11. Offshore breakwater; and
12. Headland breakwater.

A brief description of each of the options and possible risks is outlined below in Table 6.1. For each structural alternative, basic specifications are included and are used to prepare order of magnitude cost estimates. Basic costs were considered over a 30 year period, on the basis of previous mainland projects. No contingency was allowed with limited allowance for logistic constraints.

Table 6.1 Risk and estimated costs associated with each of the potential management elements identified for South Beach

Element	Description	Risk
Do Nothing	Allow erosion to take its course.	It is likely that ongoing erosion will continue, causing loss of existing buildings, beach amenity and access for penguins.
Relocate Buildings	Relocate buildings to a new location on the Island. Further assessment of the buildings is required to determine the most cost-effective technique.	Relocation of the buildings will damage further areas of the Island. Penguin access will remain poor. Threat to the jetty remains.

Element	Description	Risk
Renourishment	Artificially nourish the beach using an external source of sediment, 5,000 m3. Repeat nourishment works on a 10-15 year basis.	Renourishment provides disturbance to the adjacent seabed. Erosion scarping may still form, giving poor penguin access. Over the nourishment-erosion cycle, there is a high risk of an extreme erosion event reaching the buildings
Renourishment with 'back-up' wall	Construct a low-level (1.5 m height) wall along the back of the beach. Artificially nourish the front of the beach using an external source of sediment, 5,000 m3. Repeat nourishment works on a 10-15 year basis.	Low risks as this option effectively returns beach to natural width observed in mid-1960's. Intended that 'back-up' wall would never be exposed.
Revetment Wall	Construct a low-level (2.5 m total height) wall along the length of the beach (120 m). Concrete crib units or Geobags may be used.	Results in total loss of beach. Provision for penguin access may be provided.
Timber Groyne Field	Construct a series (3-4) of 15 m long low-profile timber groynes. Maintenance required every 3-5 years at 25% initial costs; replace after 15 years. Renourishment is also required.	Provide low capture capacity and prevent sediment resupply under easterly conditions.
Single Armour Groyne	Construct a single 40 m long shore-normal groyne towards the eastern end of the sand spit. Given the cost and logistic constraints of rock construction, a Geotube structure is likely to be cost-effective; however, limestone may be preferable for aesthetic reasons. Renourishment is also required.	Likely to be undermined by downdrift erosion; prevents any sediment resupply from the east
Alongshore Groynes	Construct a series of 2 to 3 approximately 20 m long shore-parallel groynes close to the existing shoreline. Given the cost and logistic constraints of rock construction, Geotube structures may be cost-effective; however, limestone may be preferable for aesthetic reasons. Renourishment is also required.	Risks expected to be low. However, this option will modify the local sediment transport processes which may affect shoreline stability at the eastern tip of the spit and on the beach on the northern side of the spit.
Offshore Groyne	Construct a single 30 m long shore-parallel groyne approximately 25 m from the existing shoreline, near the end of the spit. Given the cost and logistic constraints of rock construction, Geotube structures are likely to be cost-effective.	May provide limited protection during truly extreme events
Perched Beach	Construct a low-level submerged 'wall' approximately 40 m from the existing shoreline along the length of the beach. A larger volume of renourishment is required; say 10,000 m3 to provide a perched beach. Given the cost and logistic constraints of rock construction, Geotube structures may be cost-effective.	May provide limited protection during truly extreme events. Has large construction cost risks. Presents a significant difficulty in improving beach configuration, but maintains the continuity with sand transport along the spit and tombolo.
Offshore Breakwater	Construct an emergent barrier, possibly partial, approximately 40 m offshore and parallel to the existing beach. This reduces the incident wave. Given the cost and logistic constraints of rock construction, Geotube structures may be cost-effective.	Likely to provide reorientation of the shoreline, causing significant loss of material towards the end of the spit. A groyne near the end of the spit may somewhat mitigate the problem.
Headland Breakwater	Construct a groyne abutting one of the existing rocky headlands to the south, to reduce the incident wave. Given the cost and logistic constraints of rock construction, Geotube structures may be cost-effective.	Likely to provide limited protection only as waves will refract around the breakwater. Erosion caused by different wave directions towards the tip of the spit is likely to continue.

6.2 Preferred Options

Possible management options (excepting a perched beach) were discussed at a meeting with CALM, considering the issues of effectiveness, practical construction, relative cost, risk and possible implications for the Island management, including its fauna and flora. To allow comparison between alternatives, each option was rated in terms of relative construction cost and non-financial performance (described as risk). Ratings for each management alternative are included in Table 6.2 below. The option of using a perched beach was added subsequent to the Community Consultation Review (Section 7).

Table 6.2 Relative cost and risk matrix

Management Option	Relative Cost							Relative Risk						
	Low						High	Low						High
Do Nothing					X	X								X
Relocate Buildings		X	X								X			
Renourishment	X	X									X			
Renourish, with Wall		X	X						X					
Revetment Wall	X	X							X					
Timber Groyne Field		X	X							X				
Single Armour Groyne		X	X	X						X				
Alongshore Groynes		X	X						X					
Offshore Groyne		X	X	X						X				
Perched Beach					X	X	X					X		
Offshore Breakwater					X	X	X					X		
Headland Breakwater			X	X	X								X	

On the basis of the relative cost and risk matrix, and discussions between the project team (CALM, Resolve FM and Oceanica) it was determined that the following three options would be presented in more detail at the community consultation meeting:

(i) Relocating the buildings;
(ii) Renourishment, with a backing wall; and
(iii) Construction of alongshore groynes.

7. Community Consultation Review

As part of the present study, a workshop was held with key stakeholders at the Cape Peron Camp School on Wednesday 15/12/2004 to discuss the proposed shoreline management options. Representatives from CALM, Department of Environment, Conservation Council, University of Western Australia, Department for Planning and Infrastructure, City of Rockingham, Naragebup (Rockingham Regional Environmental Centre), Penguin Island Volunteers, Department of Fisheries and the Penguin and Seal Island Cruises were invited to attend the meeting (Appendix D).

7.1 Presentation

Mr Alan Robson (Resolve FM) was the chair for the meeting and introduced the CALM project team and Oceanica representatives. Mr Paul Brown (CALM) then provided a brief introduction to the project and why it is being completed.

Dr Bruce Hegge (Coastal Geomorphologist, Oceanica) and Mr Matt Eliot (Coastal Engineer, Oceanica) delivered a technical presentation. Dr Hegge provided a regional context to the study, and a history of erosion and accretion patterns on the spit of Penguin Island. Following this, Mr Eliot presented a series of possible management elements (Section 6.1) and more detailed description of the three preferred management options (Section 0).

7.2 Stakeholder Feedback

The general preference for management of South Beach was either renourishment, or a combination of renourishment with a buried revetment wall. Participants generally did not support the use of offshore structures nor the option to move the existing buildings. A summary of points raised are detailed in Table 7.1 (full stakeholder feedback comments are provided in Appendix D).

Table 7.1 Stakeholder feedback on the management options for South Beach

Attendee	Response
Peter Boreham	• Renourishment is the preferred option—it is the lowest impact and most cost effective; • There is the possibility to extract sands from the southern side of the tombolo to be used as a renourishment source; • If CALM's outcome is to protect the buildings then a revetment wall can be considered—but this option is likely to increase the rate of erosion if the wall is ever exposed to wave activity; and • Erosion volumes are comparatively small, and renourishment could be expected to maintain the beach for 10-15 years.
Belinda Cannell	• Relocation of buildings is not a viable option—will disturb the prime breeding area of the Little Penguins; • Erosion also has an impact on the penguins as a vertical obstacle of 15 cm creates an insurmountable barrier for the penguins; and • Support of renourishment with a buried revetment wall.
Bill Morgan	• Suggested use of a perforated offshore breakwater (Matt Eliot response to this option was that it would result in an accretionary area in the lee of the structure which could result in sediment erosion from other parts of the spit).
Nic Dunlop	• Preferred option is renourishment without a revetment wall; • Suggested the use of either the landward edge of Tern Island, the northern edge of tombolo or the Mangles Bay boat ramp area as a sediment source for renourishment works; • Need for rapid revegetation of nourished sands to inhibit wind blown sediment loss; • Noted the need to consider the timing of management activities—from both an oceanographic and penguin/seabird ecology perspective

Attendee	Response
Murray Banks	• Relocation of buildings is not an option—due to logistics and lack of power (cooling) in the buildings; • Worst damage occurs when a storm combines with a high tide and full moon, often associated with the swell waves which follow after the main impact of the storm.
Paul Neilson	• The penguins should be the priority and hence the option with the least environmental impacts should be chosen.
Larry Adams	• Preference is the renourishment option; • Risk of building a structure that will be ineffective as a result of no clearly defined pattern between coastal processes and degree of erosion.
Bob Goodall	• 30-40 years is a 'short-term' study and not enough information to justify the construction of any hard structure
Elizabeth Rippey	• Should carry out a cash value assessment of the Penguin Island facilities to help in the justification for expenditure on protective works
Chris Coffey	• Most suitable option appears to be ongoing nourishment, with revetment wall if required for building protection; • CALM needs to ensure the ongoing funds are available to maintain renourishment works; • Need to identify any impact on local seagrass beds during any dredging/slurry pipe activity.

7.3 Selected Management Options

Following both the stakeholder meeting, and a follow-up meeting between Paul Brown, Martine Holland and John Edwards (CALM) on 21/12/2004, it was decided by the client to provide preliminary designs and costings for the following *two* options:

- Renourishment and revetment wall; and
- Renourishment and along-shore groynes.

Completing the engineering design for both options gives CALM the opportunity to present two different management options for funding and building approval and enables a consideration of the environmental impacts of the two alternatives.

8. Preliminary Engineering Design

This section assesses the following two alternative options to a preliminary design level:

1) Revetment wall and renourishment; and
2) Alongshore groynes with backing revetment walls and renourishment.

Final design should be undertaken in conjunction with the tendering process. Requirements prior to undertaking works should include a complete site survey and re-evaluation of nourishment volumes.

8.1 Revetment Wall and Renourishment

8.1.1 Revetment Requirements

It is intended that the revetment is not exposed to wave action, with the renourishment providing sufficient buffer to cover the revetment throughout the entire nourishment-erosion cycle. Consequently, structural loads on the wall are comparatively minor. Preliminary design is on the basis of a 1.5 m high concrete crib wall, which enables transport of wall units using comparatively small vessels and machinery, such as a bobcat. The wall should be placed along the line of the existing erosion scarp, with a stepped face and have a length of approximately 120 m.

8.1.2 Renourishment Requirements

Previous estimates have suggested that as little as 5,000 m^3 of material would replace the sediment that has eroded from South Beach (Stone 2000). However, if only this volume of material were initially placed, then the nourishment-erosion cycle would return the beach to its present state every 10–15 years, which is unacceptable. To provide a 30 m wide beach buffer (which would return the beach to the approximate width observed in 1965), extending around the end of the spit, an estimated volume of 13,500 m^3 of equivalent material is required, factored up with an overfill ratio[3] as appropriate. A consideration of the potential sediment sources and the actual required volumes of sediment required for effective renourishment are presented in Section 9 and Appendix E. After deposition at the top of the beach, this material must be reshaped by excavator to a suitable beach profile, no steeper than 1 in 6 grade. The revetment wall should be covered by at least 0.5 m of sediment.

8.2 Alongshore Groynes, Revetment and Renourishment

8.2.1 Groyne Requirements

To provide fixed protection of infrastructure along South Beach, it is necessary to have three alongshore groynes, constructed as indicated by Figure 8.1. As these structures will be exposed under all conditions, it is necessary that they be constructed using relatively 'natural' materials, hence limestone is suggested. Choice of armour size depends on the gradient at which the armour is placed. However, a practical limit for transporting rock via barge is estimated to be 2.5 tonne units. Preliminary evaluation suggests that this would require placement at a grade

[3] The overfill ratio is the estimated number of cubic metres of fill material required to produce an equivalent one cubic metre of natural beach material (see Appendix E).

of 1 in 3, with a crest level approximately +1.5 m CD and toe level on the existing firm stratum, estimated at –0.5 m CD.

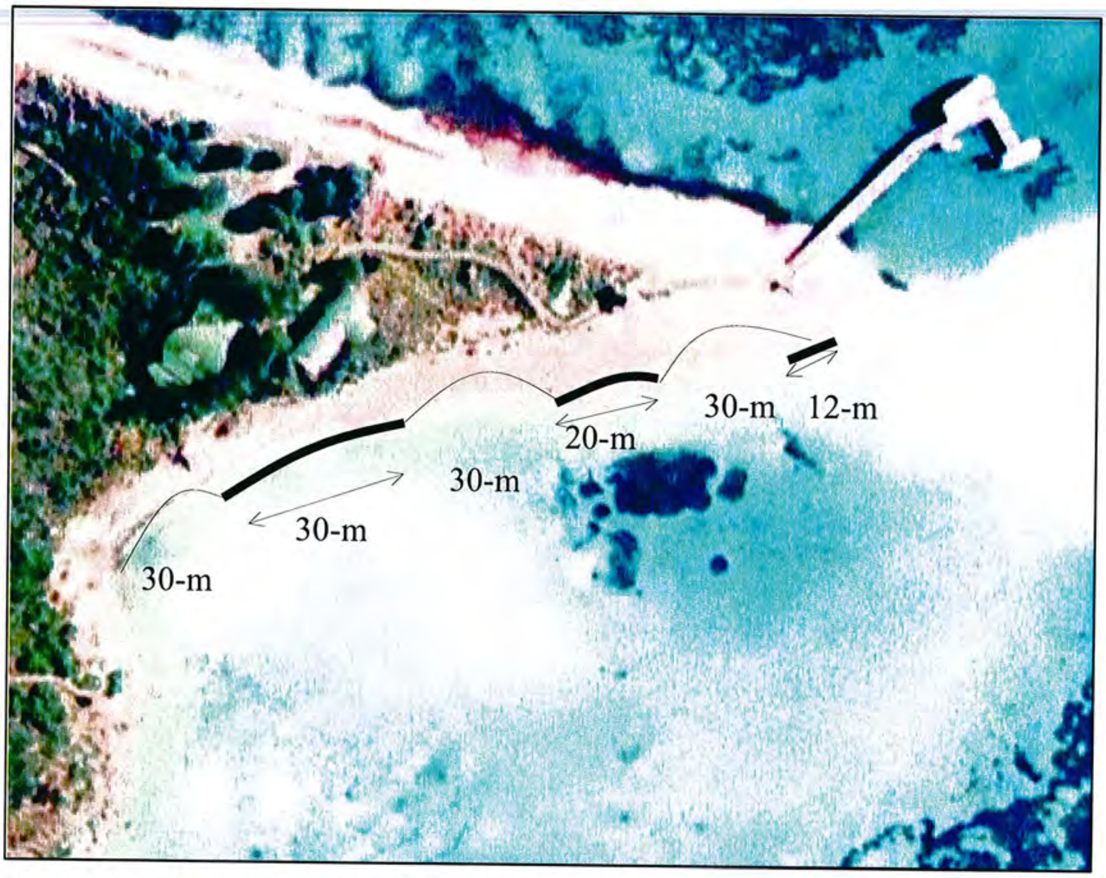


Figure 8.1 Notional Layout of Alongshore Groynes

8.2.2 Revetment Requirements

To minimise the possible impact of extreme storm events, it is appropriate to provide 'back-up' revetments in the gaps between the alongshore groynes. As these structures should be buried under almost all conditions, a concrete crib-wall is considered appropriate, allowing transport of materials across to the site. The wall should be stepped and placed along the line of the existing scarp between the gaps in the alongshore groynes.

8.2.3 Renourishment Requirements

The groynes and back-up revetments provide the majority of the required protection against a storm event. Consequently, renourishment is required to return the beach to a functional width. To provide a 30 m wide beach buffer (which would effectively return the beach to the approximate width observed in 1965) an estimated volume of 7,000 m^3 of equivalent material is required, factored up with an overfill ratio as appropriate. A consideration of the potential sediment sources and the actual required volumes of sediment required for effective renourishment is presented in Section 9 and Appendix E. After transport, this material must be reshaped by excavator to a suitable beach profile, no steeper than 1 in 6 grade. The revetment wall should be covered by at least 0.5 m of sediment.

9. Potential Sediment Sources

The two preferred options for the management of shoreline erosion on South Beach (Section 8) will require sediment renourishment. Three potential sediment sources were initially identified: Tern Island; the tombolo connecting Penguin Island to Mersey Point; and Point Peron.

Tern Island is currently an A-Class Reserve and a noted bird sanctuary site; hence the removal of material from this site is likely to be in conflict with the management commitments for this reserve. In light of the conservation value of this area, Tern Island was not considered a viable sediment source and no sediment analysis was completed on this material.

Key considerations in the selection of a final sediment source include the sediment grain size and the transport logistics. Ideally the sediment grain size of the "borrow" material and the "natural" beach sand should be equivalent (or coarser). The finer the grain size of the borrow material, the greater volume of material required, and it is also more susceptible to marine and wind erosion.

9.1 Sediment Characteristics

Grain size distributions[4] were determined from sediment cores collected along South Beach, across the tombolo and from Point Peron. The cores from both South Beach and Point Peron show typically medium grain carbonate sands, which are yellow to brown in colour; the cores from the tombolo show typically medium to coarse sands, with a high proportion of shell fragments and darker particles (Figure 9.1; Appendix E).

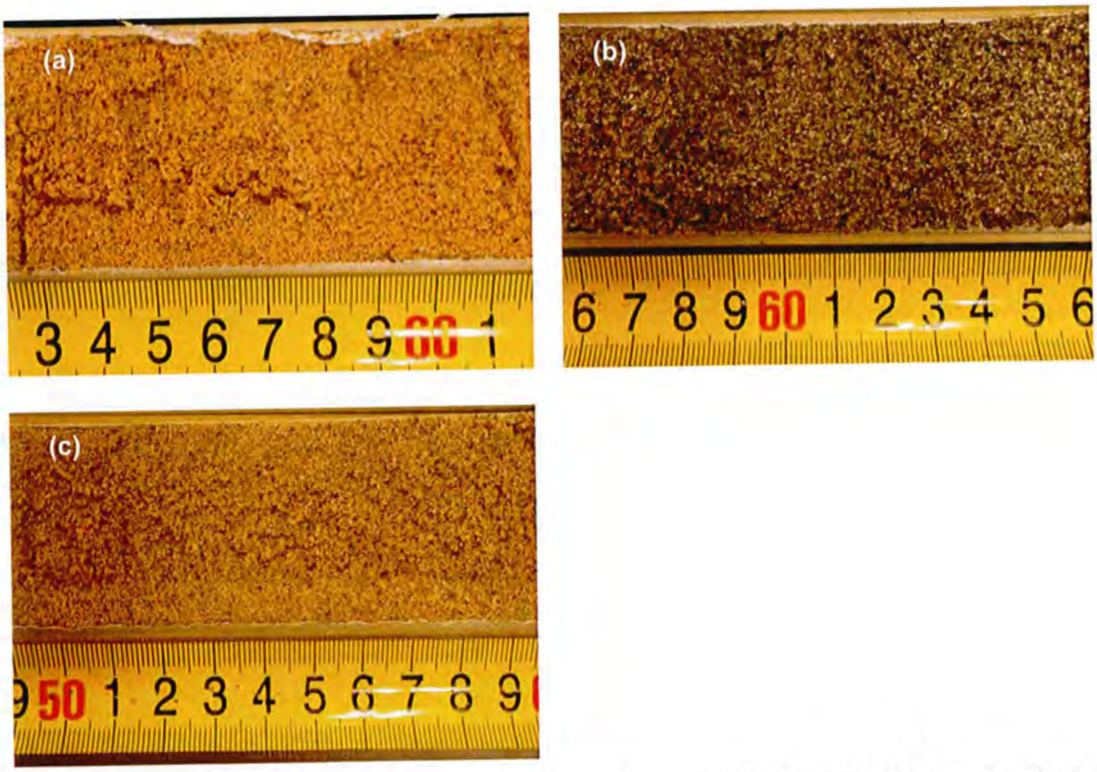


Figure 9.1 Photographs of core sections at approximately 50-60 cm depth for (a) South Beach, (b) the tombolo, and (c) Point Peron

There was a considerable degree of natural variability in the particle size distributions of the three individual cores taken at each site (see Appendix E).

[4] Grain size distribution was determined from sieve analysis.

However, the average particle size distribution for each of the sites suggests that the sediment from the tombolo appears to be slightly coarser than that of either South Beach or Point Peron (Figure 9.2).

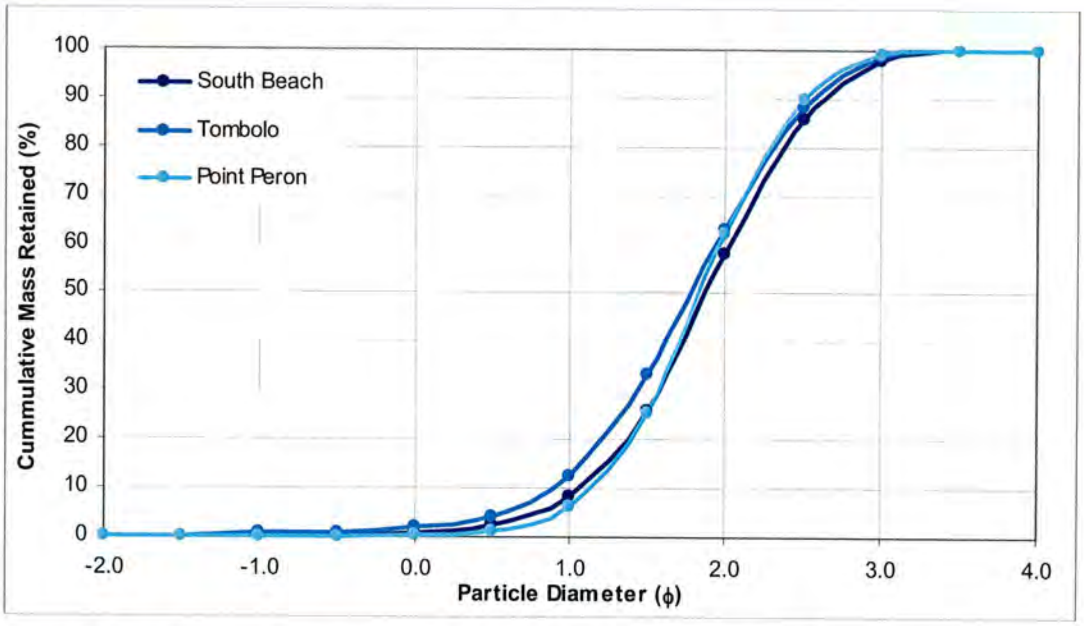


Figure 9.2 **Average particle size distribution of the sediment cores collected from South Beach, the tombolo and Point Peron**

Analysis of the core samples indicates that the sediment from both potential source sites show similar grain size characteristics to the natural material found on Penguin Island. The material from the tombolo does contain a proportion of darker particles and shell fragments, however it would be expected that over time, exposure to the sun would bleach this darker material. Hence, it is concluded that sediments from either the tombolo or Point Peron would be appropriate for the renourishment of South Beach. Table 9.1 indicates the approximate volume of material required for a 30 m buffer for both the alternate rehabilitation options for the southern beach of Penguin Island (see Appendix E for detailed sediment sampling and anaysis). The dimensions of the tombolo (~700 m long, ~50 m wide and ~1 m high) suggest a total sediment volume of approximately 35,000 m^3. Hence, the required renourishment volume is likely to represent a significant volume (40% for the revetment wall and 20% for the alongshore groynes) of the tombolo.

Table 9.1 **Estimated sediment volumes required for rehabilitation works**

Sediment Volume Required (m^3)	Tombolo	Point Peron
	Estimated Volume Required (1) (m^3)	Estimated Volume Required (1) (m^3)
OPTION 1—REVETMENT WALL		
13,500	14,000	15,000
OPTION 2—ALONGSHORE GROYNES		
7,000	7,500	8,000

Note: 1. Volumes have been rounded up to the next 500 m^3, and includes consideration for the overfill ratios required for the sediment from the tombolo and Point Peron (refer to Appendix E for further details).

9.2 Transport Logistics

A renourishment programme to South Beach poses several logistical problems due to its offshore location and the shallow waters surrounding the island. Several options for the abstraction and transport of material from each of the two alternative locations have been considered:

1. Loader at Point Peron, trucked to adjacent mainland shore then (a) barged or (b) slurry-pumped to South Beach;
2. Cutter-suction dredge from Penguin Island tombolo; or
3. Slurry-pump from Penguin Island tombolo.

It is anticipated that the logistics of using a suitable slurry-pump system (if available) would be easier than to use a barge. Possible issues which would have a more significant affect on the barge (when compared to the slurry-pump) are likely to include: weather constraints, tide state/water depths constraints and the limited ability to directly spread the sediment across the beach during barge unloading.

The method for transporting the material to Penguin Island will be confirmed after approval from MPRA, and also needs to include an assessment of costs and availability of the slurry pump equipment for the proposed works.

9.3 Environmental & Social Considerations

The following key environmental and social considerations were identified for the two potential sediment sources (Table 9.2).

Table 9.2 Environmental and social considerations for the use of (a) Point Peron, or (b) the tombolo, as a sediment source for South Beach renourishment works

Sediment Source	Potential Impacts
Point Peron	• Transport of this material will require significant trucking activity through the Rockingham region. It is anticipated that it may require approximately 750 return trips for the revetment wall option and 400 truck movements for the alongshore groynes. However, as the distance is relatively small (ca 3 km one way), it is estimated that the trucking activity could be completed in a relatively short period of time. • It will be necessary to control pedestrian access to the beaches at Point Peron, Mersey Point and South Beach in the immediate vicinity of plant during the renourishment operation.
Tombolo	• A detailed bathymetric profile of the tombolo feature would be necessary prior to dredging activities—to determine morphology and total volume of material within the tombolo. • Rough estimates suggest the tombolo consists of 35,000 m^3 of material. To provide a 30 m buffer on South Beach, 14,000 m^3 of sediment is required and this would represent approximately 40% of the total tombolo feature. It is likely that this will have a significant impact on the stability of the tomobolo, the local hydrodynamics, sediment transport process and safety of waders crossing the tombolo. • The tombolo between Mersey Point and Penguin Island is used as an access route to the island by some visitors, and has been a concern for Island managers for some time. However, use of the tombolo for pedestrian access to the island raises safety issues. It is recommended that, if the tombolo is used as a source of material, then a detailed hydrographic surveys of the tombolo are completed prior to and following the dredging works to ensure that the dredging proceeds as planned. During the dredging activities, the use of the tombolo by pedestrians shall be actively discouraged (additional sign-postings and media releases). It is anticipated that the dredging works could be completed in approximately 6-10 weeks for the revetment wall option and approximately 3-5 weeks for the alongshore groyne option. • It will be necessary to control pedestrian access to South Beach in the immediate vicinity of plant during the renourishment operation

10. Key Characteristics

The key elements of the proposed shoreline management for South Beach, Penguin Island are summarised below for the two preferred options:

(1) Revetment wall and renourishment (Table 10.1); and
(2) Alongshore groynes, backing revetment walls and renourishment (Table 10.2).

It is estimated that it would take a total of approximately seven to eleven weeks to complete management works required for South Beach. It is recommended that the construction works are timed between early-June and mid-September when the island is closed to visitors to minimise impacts on users—though we note that this is the breeding season for penguins.

Table 10.1 Key elements of proposals for shoreline management of South Beach, Penguin Island using revetment wall and renourishment

Element	Description
Location	South Beach, Penguin Island
Proponent	Department of Conservation and Land Management
Timing	Nominally July-August 2006
Estimated duration	7 to 11 weeks [(1)]
Estimated volume required to fill beach and cover revetment wall	13,500 m^3
Renourishment Source	Either 15,000 m^3 from Point Peron or 14,000 m^3 from the tombolo.
Approximate dimensions of crib wall	1.5 m high and approximately 120 m long

Note: 1. Timing will depend on the sediment source site and transport method and prevailing weather conditions.

Table 10.2 Key elements of proposals for shoreline management of South Beach, Penguin Island using alongshore groynes, revetment wall and renourishment

Element	Description
Location	South Beach, Penguin Island
Proponent	Department of Conservation and Land Management
Timing	Nominally July-August 2006
Estimated duration	6 to 9 weeks [(1)]
Estimated volume required to fill beach and cover revetment wall	7,000 m^3
Renourishment Source	Either 8,000 m^3 from Point Peron or 7,500 m^3 from the tombolo.
Approximate dimensions of alongshore groynes	30 m, 20 m and 12 m from west to east with crest height of +1.5 m CD and toe height of -0.5 m CD with grade of 1 in 3
Approximate dimensions of crib wall	Three segments 1.5 m high and approximately 30 m long

Note: 1. Timing will depend on the sediment source site and transport method and prevailing weather conditions.

11. Key Environmental and Socio-Economic Impacts

The key environmental and socio-economic issues which may arise from the implementation of shoreline management activities on South Beach, Penguin Island are discussed below. Many of these issues are common to both preferred management options; however, where distinctions occur these are described below under the relevant sections.

11.1 Turbidity

The renourishment works on South Beach will result in two localised areas of turbidity: at the sediment source site; and at the disposal site on South Beach. It is unlikely that the turbidity at the sediment source sites will be significant as land based excavation works are likely at Point Peron which would not generate any turbidity, conversely, if dredging of the tombolo is the preferred option then it is unlikely that any significant turbid plume will be observed at the dredging site due to the nature of the cutter-suction dredging operation. However, some turbidity is expected at the discharge site on South Beach.

The construction of the alongshore groynes will result in a small amount of turbidity due to the washing of the limestone rocks *in situ* as they are placed into position. Clean limestone with no clay content will be used in this construction to minimise the extent and intensity of any turbid plume.

The impact of any potential turbidity associated with the rehabilitation works will be minimised by construction being scheduled to occur during winter when water column turbidity is naturally elevated due to recurrent storm events. This is also a period when seagrass growth rates are reduced and hence their light requirements are considerably less than during summer. It has previously been shown that *Posidonia* species can tolerate moderate periods of low light conditions and will rapidly recover when light climate is restored (Gordon et al. 1994). Furthermore, due to: (1) the short duration of the dredging activities; and (2) shallow depths of the seagrass meadows adjacent to South Beach, it is unlikely that turbidity levels would cause significant impacts on the seagrass meadows located approximately 150 m offshore would occur.

However, to ensure minimal impacts from smothering of the adjacent seagrass meadows a sentinel monitoring programme is recommended and presented in Section 12.2 and 12.3.

11.2 Penguin Habitat

The Little Penguins breed in hollows under the dense vegetation and in the limestone caves. The rehabilitation works themselves do not impact on the habitat of the Penguins as they are largely confined to the sandy beach area of the island. The rehabilitation works, once established, are unlikely to impact on the colony of Little Penguins on the island and revegetation of the revetment wall may create some further breeding habitat for these Penguins. Once construction has finished, the beach will be contoured to allow easy access for the Penguins—vertical drops of greater than 15 cm inhibit the movement of the Penguins.

During the construction activity it will be important that access between the dunes and the waters is maintained for the Penguins. If access is disrupted during constructions works, for example during the construction of the crib revetment wall, alternate pathways/ramps shall be put in place at the end of each day.

Construction and rehabilitation works shall be restricted to the hours between 06:00-19:00 hours; allowing the Penguins to maintain their normal nocturnal activities.

11.3 Coastal Processes

The impacts on coastal processes will be slightly different for the two sediment sources and the also for the two preferred management options and these are discussed below. Impacts on the coastal processes, if any, are likely to be restricted to the spit area of Penguin Island and the western end of the tombolo.

It is unlikely that the removal of the required volumes of material from Point Peron will significantly affect coastal processes at this site. The Point Peron beach has historically been an area of sediment accumulation and regular sand removal has been required to ensure minimal sedimentation of the Point Peron boat ramp. Conversely, the required renourishment volumes required would represent a significant proportion of the total volume of the tombolo. It is likely that the removal of this volume of material from the tombolo would impact on: the stability of the tombolo, the local hydrodynamics and sediment transport process. It is possible that the removal of this significant volume of material from the tombolo may in fact encourage rapid erosion of sediment from South Beach in order to re-establish an equilibrium sediment volume across the tombolo.

The revetment wall and renourishment option is unlikely to significantly affect coastal processes and sediment movement around Penguin Island. The renourishment works will be effectively returning the southern side of the spit to its natural condition in the 1960s. The revetment wall acts as a final backstop—only being uncovered if all beach material in front of it is removed. If the revetment wall is uncovered, the wave reflection will increase energy conditions in immediate vicinity potentially causing scouring and further erosion. It is expected that natural conditions will accrete and erode this 'new' beach as has been observed over the past 50 years. It is likely that some of the renourished sand will migrate around to the northern beach and some may be transported on to the tombolo.

The use of alongshore groynes is intended to interrupt sediment transport along South Beach, Penguin Island. The groyne fields will trap sediment and reduce the transport of sediment from South Beach to both the tombolo and the northern beach. Additionally, the groynes may restrict the westerly movement of sediment from the tombolo to South Beach. It is possible that the reduction in sediment transport around the tip of the spit may result in enhanced erosion of the northern beach. However, the extent to which this lack of sediment flow will change the sediment supply and coastal process on the northern beach and western end of the tombolo is difficult to quantify, with complex and sporadic storm events driving the major sediment fluxes in the area. Note that it is expected that the wind-blown transport between the south and north beaches will continue.

11.4 Hydrocarbon Spills

The revetment wall and beach reshaping works will be constructed using land-based methods and as such a hydrocarbon spill to the marine environment is unlikely. The dredge and barge contractor will be required to prepare a Safety Management Plan that will include re-fuelling, spill response and cleanup procedures. Construction will not commence until CALM has approved the Safety Management Plan. If refuelling of marine vessels is required to be undertaken on site it will be undertaken using appropriate equipment under close supervision with spill response equipment immediately available. Spill response and cleanup procedures will include the requirement for:

- Materials to enable a cleanup of spills shall be available onsite prior to the commencement of construction; and
- Work will cease following a spill until the completion of the cleanup.

11.5 Noise & Vibrations

Rehabilitation works will involve the generation of some noise from the operation of marine vessels and earthmoving equipment on the beach. The construction contractor will be required to take appropriate measures to ensure the operation of all vessels and equipment complies with relevant statutory requirements relating to noise generation and control.

The rehabilitation works will not require the use of construction techniques that cause significant vibrations such as pile driving. It is not anticipated that vibration generated during construction will have any impact on the marine environment. The construction contractor will be required to prepare a Works Methodology that will include effective control of noise and vibration during the works. Rehabilitation works will not commence until CALM has approved the Works Methodology.

Noise and vibration is expected to have minimal impact on public amenity as works are timed when public access to the island is restricted. The duration of construction will be short (7–11 weeks) and will be restricted to the hours 06:00-19:00 Monday to Saturday to minimise the disturbance to users.

11.6 Public Amenity

CALM will advise the local community and stakeholders that the rehabilitation works on Penguin Island are occurring, and provide contact details if questions arise. Notification of the construction works will be displayed on signs near Mersey Point outlining the need, timing and extent of the works and warning against accessing the tombolo during the works. The signs will be in place for the duration of the construction works. Public notice of the construction will also include:

- A 'Notice to Mariners' in The West Australian newspaper prior to commencement of the dredging works; and
- An information sheet will be provided to the Mersey Point cafe for display on their notice board.

The island is closed to the public from early-June through to mid-September, and rehabilitation works will be timed to occur as much as possible within this closed season. Should the construction period extended beyond the island's closed season, public access to the construction area shall be restricted.

The impact of the construction equipment and marine vessels on the visual amenity of Penguin Island is an unavoidable consequence of the works. However, as noted above, these works shall be timed to occur when Penguin Island to closed to the public. The revetment wall and renourishment option will effectively result in a larger beach width on South Beach and no negative visual impacts are expected. The alongshore groynes will result in a change to the visual amenity of South Beach and the spit. However, this impact should be reduced through the use of limestone for the groynes which is commonly seen around the shoreline of Penguin Island.

As noted above, the removal of material from the tombolo may result in changes to the stability of the tombolo, the local hydrodynamics and sediment transport process. This in turn could adversely affect the safety of people wading across the tombolo. It is also noteworthy that the sediments from the tombolo were found to have a high proportion of shell fragments and dark sediment particles. This material, if used for renourishment, could negatively impact on the aesthetics of South Beach.

12. Monitoring and Management

We provide below a series of recommendations for monitoring and management which should be implemented in conjunction with the proposed shoreline management works on South Beach, Penguin Island.

12.1 Beach surveys

To enable ongoing proactive shoreline management of South Beach, it is recommended that beach surveys of the active spit be undertaken regularly.

12.1.1 Responsibility

The survey of these monitoring transects shall be the responsibility of CALM.

12.1.2 Sampling scheme

A series of approximately equi-spaced shoreline profile transects should be established along the active spit of Penguin Island. The landward limit of these transects should be identified with a fixed benchmark located at least 10 m landward of the existing vegetation line. The initial profile transects should extend seaward a distance of 200 m and subsequent transects should extend seaward to wading depth (at least 1 m). It is anticipated that approximately 8 to 10 profiles would be established along the active spit (including both South Beach and the northern beach) and the actual locations would be determined following selection of the preferred management option.

12.1.3 Timing

The first three surveys shall be undertaken at the following times:

- The initial beach survey shall be completed as close as practicable prior to commencing the shoreline management works (maximum of two weeks, weather permitting);
- The second beach survey shall be undertaken immediately following the completion of the revetment wall (and should include a detailed survey of the position and elevation of the revetment wall, including the toe, crest and seaward profile); and
- The third survey shall be undertaken as close as practicable following the completion of the renourishment works (maximum of two weeks, weather permitting).

Subsequent surveys should be completed annually in autumn.

12.1.4 Indicators

For each transect, the first three profile surveys shall be overlain and shall be used as the baseline to determine the requirement for future renourishment works. Each subsequent annual profile survey shall be overlain to determine: (1) minimum and average depth of sand overlaying the revetment wall; (2) change in sand volume across the profile.

12.1.5 Criteria and management contingency

The need for minor sediment rearrangement or renourishment shall be considered if any profile shows a minimum depth of sand overlying the revetment wall of less than 20 cm. Similarly, if the volume of "renourished" sediment across the transects on

South Beach falls below 25% of the initial renourishment volume the need for further renourishment shall be considered. Note, that the "initial renourished volume" shall be determined from the difference between the initial beach survey and the third survey.

12.2 Water quality

No nutrient or contaminant impacts are expected from the proposed shoreline management works as clean natural marine sands (sourced from the adjacent tombolo or Point Peron) are to be used for the renourishment works. In addition, the materials for the crib wall and alongshore groynes (if implemented) will consist of clean, low nutrient, uncontaminated materials. Hence, it is not considered that nutrient and contaminant monitoring is required.

As noted above, the turbid plume associated with the discharge of the renourishment sands on South Beach may extend over the fringe of adjacent seagrass meadows. However, it is recognised that the seagrasses in this nearshore area are subjected to a highly dynamic natural environment and naturally variable light climate. A site survey has identified that the majority of the seagrasses in the immediate vicinity of South Beach are *Posidonia australis*, with *Posidonia sinusoa* located further offshore. These species has been found to recover from moderate periods (i.e. several months) of severe shading (Neverauskas, 1988, and Gordon et al., 1995). Furthermore, the renourishment activity of the shoreline management works will be of short duration and have been timed to occur during the winter months when seagrasses are naturally dormant. In addition, the shallow waters adjacent to South Beach should ensure that the seagrasses continue to receive sufficient light in spite of occasional turbid waters.

However, in line with the draft management targets of the Shoalwater Islands Marine Park (Table 1.1), and to ensure that the suspended solids in the return water from the nourishment works do not result in significant smothering of the adjacent seagrasses, a sentinel monitoring programme is recommended. This monitoring shall include measurements of light attenuation coefficients (LACs) to ensure ANZECC guidelines for water quality are met beyond the immediate vicitity of the works. In addition, daily photographs shall be obtained to document the extent of the turbid plume. This monitoring should help to ensure protection of the environmental values of the Shoalwater Islands Marine Park

12.2.1 Responsibility

The water quality monitoring shall be the responsibility of CALM or a nominated agent.

12.2.2 Sampling Scheme

The extent and direction of the turbid plume will be documented daily during the renourishment works via a photograph from the viewing platform located on the southern hill of Penguin Island (see example of view in Figure 12.1). Information on the plume extent/direction and prevailing weather conditions will also be recorded (see pro-forma in Appendix F)

LAC measurements will occur daily during the rehabilitation works at seven sites as shown in Figure 12.2. The LACs shall be determined at each site from instantaneous light readings at fixed depths below the water surface (nominally 0.5 m and 1.5 m, water depth permitting).

Source: Oceanica Consulting 28/09/2004

Figure 12.1 Example photograph taken from viewing platform on southern hill of Penguin Island

12.2.3 Timing

A photograph shall be taken daily from the top of the southern viewing platform on Penguin Island between 13:00 and 15:00 such that the effect of sunglint is minimised.

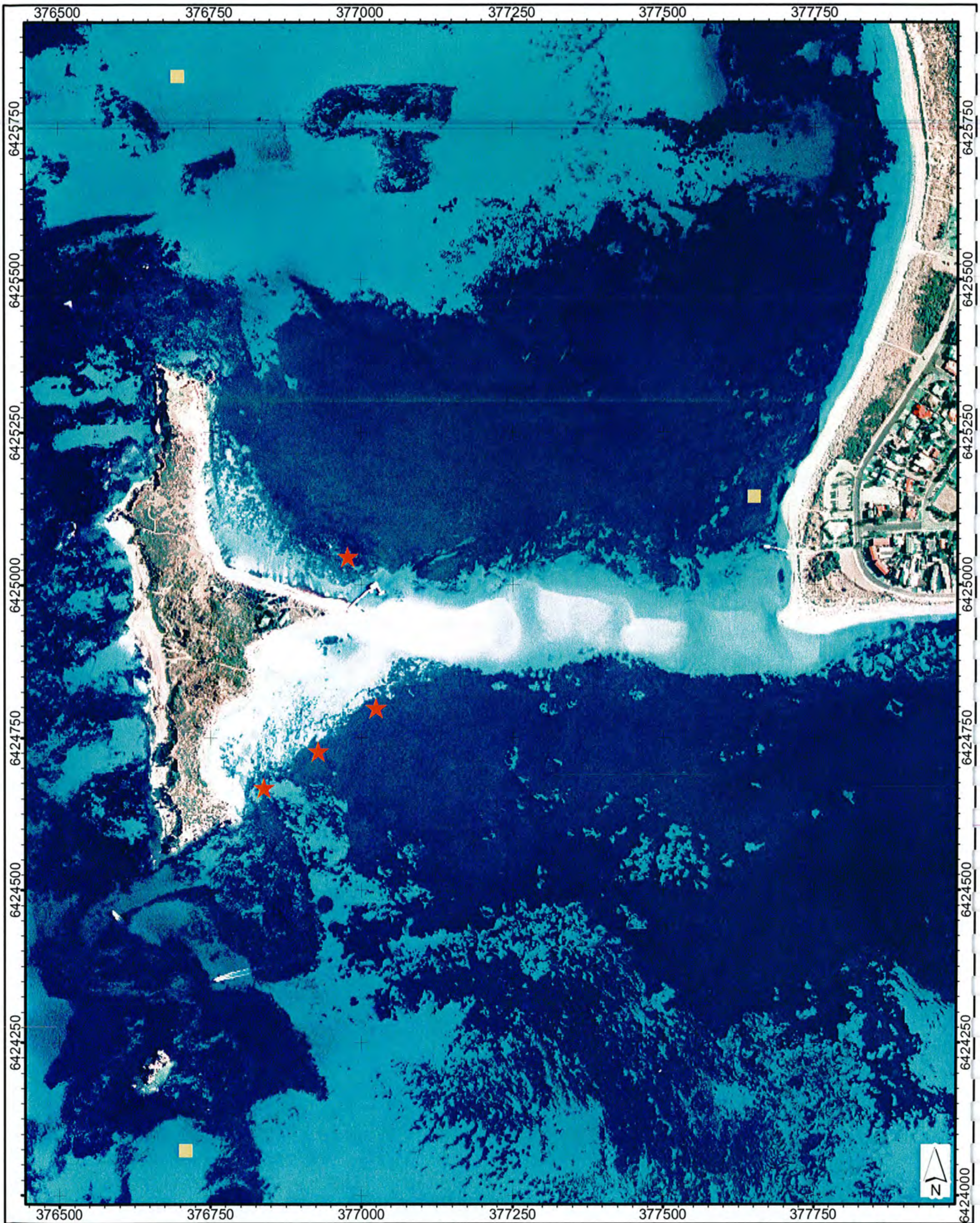
Weather permitting, LAC measurements shall be taken at approximately the same time each day (within the two hour period described above) during the rehabilitation works. Monitoring will commence two weeks prior and extend two weeks beyond the completion of the rehabilitation works.

12.2.4 Indicators

The daily photographs shall be used to provide a visual record of the extent and direction of the turbid plume. The LAC measurements will provide a record of the water quality and shall be used to trigger seagrass coverage monitoring as described in Section 12.3.2.

12.2.5 Criteria

The daily LAC readings from each site shall be combined to determine a five-day rolling median (and the 80^{th} percentile from the reference site). A management response (as outlined in 12.2.6) shall be initiated if the median LAC from any single monitoring site is greater than the 80^{th} percentile of the reference site for a period 14 consecutive days.



oceanica
marine & estuarine specialists

Author: PBH	Date: 07/10/05
Proj Ref: 422_3	
File Ref: 422_3_071005_f122_2.mxd	
Horizontal: Datum	UTM Zone 50 Based on WGS84
Vertical: Datum	N/A

Legend

★ Impact Site

■ Reference Site

Figure 12.2

Nominal Locations of Water Quality Sites

Department of Conservation and Land Management
Conserving the nature of WA

12.2.6 Management Responses

Should the LAC criteria specified above be exceeded then the following management actions will be implemented as appropriate:

- Consider the installation of a silt curtain;
- Restrict the renourishment activity until suitable conditions arise (e.g. when current flow is away from the area of impact);
- Implement the seagrass monitoring program as described in Section 12.3

If the post rehabilitation works water quality survey indicates that there has been a significant impact on local water quality, MPRA will be notified of this and any further management/monitoring will be at MPRA discretion.

12.3 Seagrasses

The seagrass monitoring program is based upon direct measurement of percentage seagrass coverage. Monitoring of seagrass shoot density was considered as an alternative measure of seagrass health for this project; however, it was considered that this measure would not prove sufficiently sensitivity to enable early detection of a rapid smothering event which could occur during the renourishment works. Shoot density is an indicator of the overall health of plant, and it is unlikely that a response in seagrass shoot density will be noticed over the short-time period of the rehabilitation works. As the key potential impact of the nourishment works will be the short-term smothering of the seagrasses, measurement of the percentage cover provides an immediate indication of this. Similarly, the use of total suspended solids (TSS) could be used as a surrogate measure of sediment loading in the water column; however, if TSS levels were elevated it would still require measurement of seagrass coverage to determine the nature and extent of any impact on the seagrasses.

12.3.1 Responsibility

The seagrass monitoring shall be the responsibility of CALM or a nominated agent.

12.3.2 Sampling scheme

A series of five seagrass monitoring sites shall also be established: two "impact" sites and three reference sites. One seagrass impact site shall be located in the seagrass meadows to the south of South Beach and one shall be located in the seagrass meadows northeast of the jetty. The reference sites shall be located in an equivalent water depth at previously established CALM monitoring sites: one north-east of Penguin Island, one also in the Safety Bay shoreline and one within Warnbro Sound (east of Tern Island).

Each of the five seagrass monitoring sites should have approximately the same percentage seagrass cover. At each of the five monitoring sites, a series of four 10 m transects will be randomly located and marked. Along each transect, six randomly assigned permanent quadrats (0.2 m x 0.2 m) will be established. For those quadrats where the randomly assigned position was predominantly bare sand, the quadrat was moved to another position. During each seagrass monitoring occasion, a high resolution digital underwater photograph shall be taken from each quadrat from each monitoring site. In addition, the percentage seagrass coverage shall be visually inspected to determine the percentage cover using the Braun Blanquet coverage class system. This method uses a visual que card to distinguish the following six coverage classes: (1) = <1%; (2) = 2–5%; (3) = 6–25%; (4) = 26–50%; (5) = 51–75%; and (6) = 76–100%. The Braun-Blanquet method has been commonly used to examine long-term changes in vegetation coverage. However, this method is considered appropriate for the present monitoring programme due to the potential for rapid changes to occur due to physical smothering of the seagrasses during the renourishment activities.

12.3.3 Timing

Weather permitting, seagrass percentage coverage monitoring at each of the five sites shall occur every two days once the requirement for monitoring has been triggered. A seagrass monitoring survey shall also be conducted prior to the commencement of the renourishment activity (to provide a baseline measurement); and following the completion of the works. Weather permitting, these surveys shall be take within two weeks of commencement and completion, respectively.

12.3.4 Indicators

The underwater photographs from the seagrass monitoring sites shall be archived pending further analysis if required. The visual Braun-Blanquest coverage class for each quadrat shall be used to determine if an impact on the seagrasses has occurred due to the renourishment activity.

12.3.5 Criteria

An impact on the seagrass meadows will be deemed to have occurred at any one of the three impact sites if, on two consecutive sampling occasions, two or more quadrats show a decrease of one coverage class (over and above the modal change measured during the baseline survey or the modal change measured at the reference sites during the same period).

12.3.6 Management contingency

Should the seagrass percentage cover criteria above be exceeded during the rehabilitation works then the following management actions shall be implemented as appropriate:

- Continue seagrass monitoring (including seagrass density monitoring at the impacted site) until such time as the sediment smothering clears from the impacted quadrats;
- Restrict the renourishment activity until suitable conditions arise (eg when current flow is away from the area of impact).
- Consider the implantation of a silt curtain;
- Cease all rehabilitation works until water quality levels return to natural background levels ; and/or
- Re-assess the potential zone of impact, advise MPRA and seek MPRA approval to continue works accordingly.

The MPRA will be notified of any loss of seagrass area following the post-construction survey and the requirement for further management/rehabilitation will be determined by the MPRA.

12.4 Terrestrial Vegetation

Prior to constructing the revetment wall, the existing vegetation and topsoil along the wall alignment shall be removed and stockpiled. On completion of the revetment wall, the wall shall be backfilled and covered with (renourished) sand (approximately 0.5 m thick) and contoured to match the existing dune profile. The stockpiled vegetation and topsoil material will then be placed over the site of the revetment wall together with any available wrack material found on the beach. A temporary sand fence may be constructed to prevent migration of this dune and assist in stabilising the site and reducing wind erosion. Revegetation would best be undertaken as soon as possible after the rain season commences—as the construction works are due to take place during the winter months, revegetation works should immediately follow the completion of the shoreline restoration works. Some additional planting may be required the following winter depending on mortality rates. As far as possible, revegetation should use seeds/seedlings collected from Penguin Island (with the permission of CALM). November and December are considered to be the optimal time for seed collection as many species that drop seeds each year (geo-sporous species) would still hold seed at this time. Following seed collection, the seed would be stored in a temperature controlled seed storage facility until revegetation works begin.

13. Acknowledgements

This report has been prepared by **Michelle Carey, Matt Eliot** and **Bruce Hegge** (Oceanica). GIS analyses of shoreline movement, and preparation of figures for this report were completed by **Ewan Buckley** (Oceanica) and **Piers Higgs** (Gaia Resources).

Assistance in obtaining the aerial photography for 1953, 1965, 1968, 1970, 1979, 1987 and 1992 was provided by **Joel Campbell** (Department of Land Information). Photogrammetry to determine the shoreline position was undertaken by **Chris Dixon** (Mercator Holdings).

The client contacts for this project were **Alan Robson** (Resolve FM), **Martine Holland**, **Kylie Ryan** and **Ben Tannock** (Department of Conservation and Land Management).

This report was formatted by **Charlotte Tuckerman** (Oceanica).

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Appendix A

Short-term Rehabilitation Works

Appendix A Short-term Rehabilitation Works

Email correspondence from Dr Bruce Hegge (Oceanica) to Alan Robson (Resolve FM) and Martine Holland (CALM), 02 November 2004.

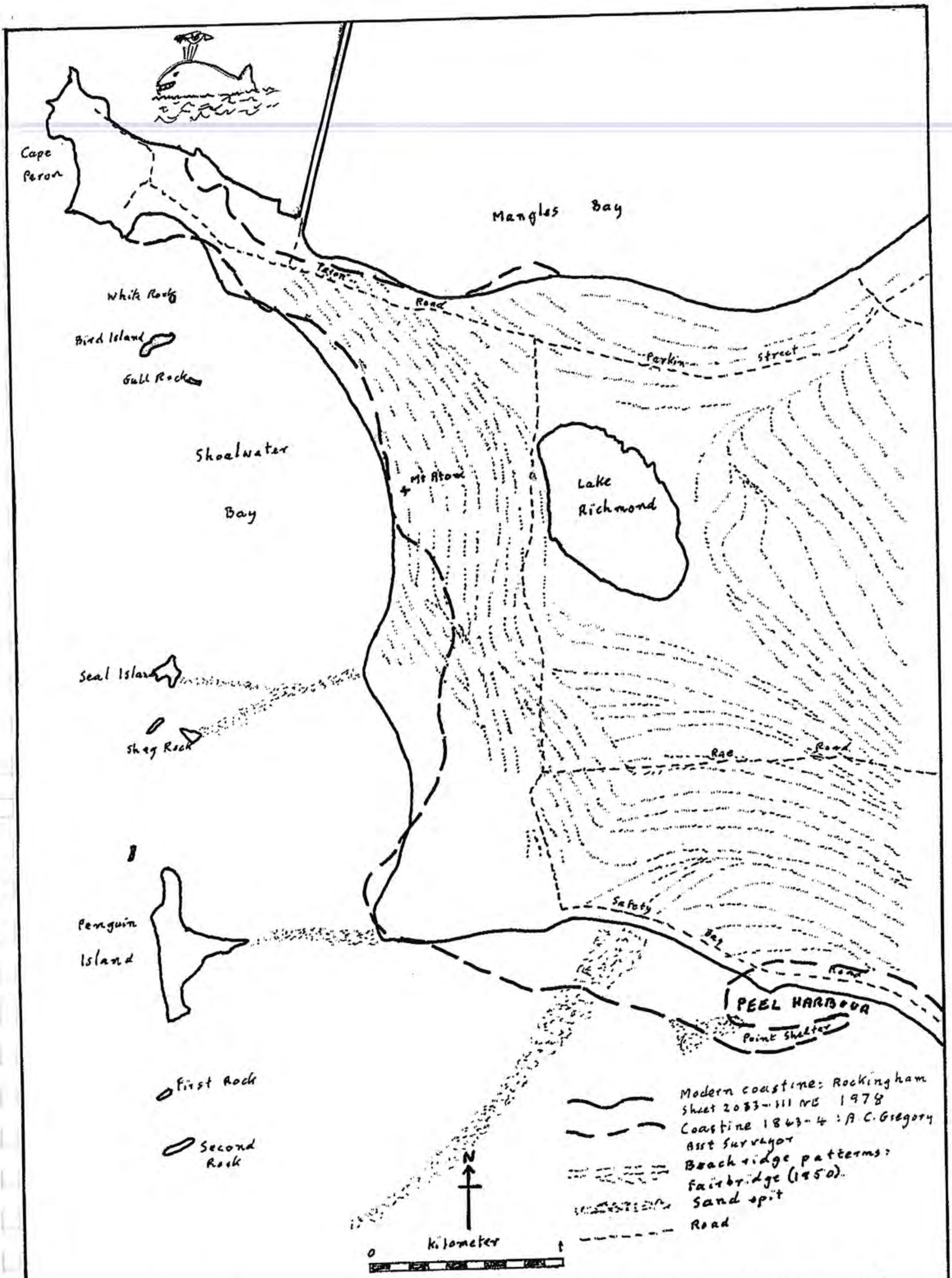
We note that any recommended works resulting from this study may not be implemented until the 2005/2006 financial year. Some rehabilitation works have been undertaken on South Beach by CALM and the Penguin Island volunteers and in the interim period prior to implementing any engineering works we provide the following comments and advice regarding these rehabilitation works:

- Brushing and sand bagging works have recently (October) been implemented on South Beach;
- We understand that the erosion of South Beach primarily results from the impact of major storm events, often associated with high water level conditions and that the sea breeze winds can result in minor transfer of sand from the beach to the dunes/boardwalk
- The sand bagging will provide some protection from marine processes during storm events whereas the brushing activity provides stability against wind blown sand movement from the beach. It is unlikely that this brushing would provide any significant protection during large storm events.
- We note that it is appropriate to make maximum usage of materials from the Island as it is impractical at this stage to transport bulky materials from the mainland. However, the use of unsecured heavy pine branches, although they may provide some aesthetic relief from the erosion scarp, are unlikely to provide significant protection against storm erosion and may in fact be dislodged and float away during a storm and distributed across the beach where sharp branches could cause hazard to pedestrians. To improve the capacity of the brushing to retain sand, it is necessary that the branches remain in contact with the sand face. Consequently, it is appropriate to use smaller branches towards the bottom of the brush treatment. A matrix of larger branches placed over the top are used to hold the lower layer in place. This technique has been taken several steps further by Syrinx Environmental (Kathy Meney kmeney@syrinx.net.au) to incorporate pinning, wire restraints and planting.
- The use of sand bagging with Hessian bags (which are biodegradable) focused in areas to protect the key infrastructure under immediate threat (eg soak well, Managers building, steps) is to be encouraged as an interim measure. However, to be most effective control against storm impacts it would be advisable to orient the sand bags with their long axis perpendicular to the shoreline (thereby presenting minimal surface area to the direction of maximum impact). In addition, it would be advisable to create a wider more stable base (say 4-5 sandbags wide at the base, 4 on next layer etc) and terrace the sandbags bags to create a sloping face (with smooth plan shape minimising corners which may act as focal points for wave action) which will dissipate wave energy more effectively than a vertical wall of single sandbags which could be easily undermined and toppled during a storm.
- If sandbags are left in over a longer term, it may be advisable to remove sandbags over non-winter periods to promote maximum beach recovery.

Prior to onset of winter 2005 (eg May) if may be advisable to remove the steps onto the beach so they are not damaged during storm event, or alternatively consider redesigning these steps to a more resilient design (eg chained logs?).

Appendix B

Shoalwater and Safety Bay Coastline, 1843-1978



SHOALWATER - SAFETY BAY COASTLINE

1843 - 1978

Appendix C

Aerial Photography 1953-2004

Appendix C Aerial Photography, 1953 to 2004

1953 Aerial Photography (27/11/1953, Scale 1:15,840)

1965 Aerial Photography (11/03/1965, Scale 1:15,840)

1968 Aerial Photography (26/05/1968, Scale 1:15,840)

1970 Aerial Photography (21/10/1970, Scale 1:12,000)

1979 Aerial Photography (03/05/1979, Scale 1:42,000)

1987 Aerial Photography (05/05/1987, Scale 1:20,000)

1992 Aerial Photography (10/12/1992, Scale 1:20,000)

2002 Aerial Photography (05/04/2002, Scale1:25,000)

2004 Aerial Photography (12/03/2004, Scale 1:25,000)

Appendix D

Stakeholder Presentation, 15 December 2004

Attendee	Stakeholder Group
Paul Brown	CALM
Steve Slavin	CALM
John Edwards	CALM
Steve Dutton	CALM
Murray Banks	CALM
Wayne Taylor	CALM
Martine Holland	CALM
Chris Coffey	Department of Environment
Nic Dunlop	Conservation Council
Belinda Cannell	University of Western Australia
Peter Boreham	Department for Planning & Infrastructure
Paul Neilson	City of Rockingham
Larry Adams	City of Rockingham
Bob Goodall	Naragebup (Rockingham Regional Environmental Centre)
John Rippey	Penguin Island Volunteer
Elizabeth Rippey	Penguin Island Volunteer
Bill Morgan	Penguin Island Volunteer
Alan Robson	Resolve FM
Bruce Hegge	Oceanica Consulting
Michelle Carey	Oceanica Consulting
Matthew Eliot	Oceanica Consulting
Henry Crawford	Oceanica Consulting
Apologies:	
Graeme Deague	Penguin and Seal Island Cruises
Mark Kleeman	Department of Fisheries
Jason Barrow	CALM

Stakeholder Feedback

Peter Boreham

Workshop Discussion Session:

- Renourishment is the preferred option; it is the lowest impact and most cost effective. It is the system being used world wide and the volume required for Penguin Island is minimal compared to some of the other projects being done.
- Need to give consideration to where the sand is sourced and how the renourishment is carried, including the availability of a slurry track plant for sediment transport to the Island.
- In WA typically use beach renourishment with earth works to grade the profile whereas in eastern States have used profile nourishment distribute sands across the nearshore profile.
- There is a possibility to extract sand from the south side of the tombolo sandbar to use for the renourishment.
- If CALM's outcome is to protect the buildings, then a revetment wall can be considered, but this option is also likely to increase the rate of erosion if the revetment wall is ever exposed to wave activity.
- Suggested investigating the option of a perched beach for South Beach.

Email to Martine Holland (21/12/2004):

Some comments on the Penguin Island beach stabilisation. These are necessarily limited, as we do not have the actual report.

- The material underwater at the end of the spit is probably the remains of one of the old groynes. The 1968 groyne was still holding some of the beach in 1972, but was insufficiently maintained and too short to provide long term stability. The later groyne was a tyre-sandbag assemblage and was inadequately designed for the wave climate.
- There are recent examples of timber groynes at Palm Beach next to Hymus St, built by DPI and the City of Rockingham a couple of years ago. These are the standard DPI design, which we have also used at Busselton. This type of structure could be used at Penguin Island, but would require regular maintenance if it is to have a reasonable life. However, it may be easier to construct on the island than a conventional rock groyne, given the access difficulties for heavy plant. However, if there is a rock substrate it will be impossible to jet in the piles, and the cost of drill and driving or blasting and driving would be unacceptably high. A properly designed geotextile groyne may be feasible at this site, but its suitability would be dependent on the inshore wave climate.
- I have attached a copy of our earlier advice to CALM on the erosion on Penguin Island. This suggests that erosion from the southern beach is only in the order of 200 to 400 m3/yr. At these low volumes, it would be expected that sand nourishment without structures would be the most cost effective management tool for this beach.
- The next steps you should be considering are:
  - Estimation of the rate of erosion. This is essential to quantify the scale of the problem and to establish time frames and cost estimates. In this case a refinement of the DPI estimate would be appropriate, expanded to include the northern beach.
  - Make an estimate of the recession which could be expected under a reasonable design storm. I suggest the storm sequence in SPP2.6 would be appropriate.
  - From the above, estimate a beach recession rates (chronic and storm) and establish the time frame for when the buildings will be under immediate threat
  - Undertaking a discounted cash flow analysis to determine the most cost effective of your options.
  - Agree on the primary outcomes you require (eg, building protection, beach maintenance, visual impact, cost effectiveness, etc) for input into a "triple bottom line" analysis of the options.
  - Shortlist the options.
  - Scope the environmental impacts of the shortlisted options, including the "do-nothing" option.
- As discussed, the Penguin Island erosion problem is really very minor. With erosion volumes of say 300 m3/yr, and allowing for the expected short-term increase in loss rates, about 5,000 m3 of nourishment could be expected to maintain the beach for 10 to 15 years, without any structures. Using a dredge, with mobilisation and demobilisation and assuming an offshore sand source within say 500 to 1000 m, a total cost would be about $70,000, add another $30,000 for a similar nourishment of the north beach at the same time. You are probably already spending a significant part of this on the investigations.

Belinda Cannell

Workshop Discussion Session:

- Erosion is not just a problem facing the buildings; it also has an impact on little penguin breeding habitat. Erosion can create insurmountable obstacles that the penguins may not be able to negotiate on returning to land. A vertical face of 15 cm high is enough to create a barrier for a penguin.

- Relocation of the buildings is not an option since it doesn't address the erosion problem from the penguin point of view, and will create too much disturbance on the prime breeding area for the little penguins (even if the buildings are stilted).
- The buildings under threat from the erosion are important buildings whose function is for research and for the ranger to live on the island (and protect the birds). These buildings need to be retained on the Island.
- Penguins are first priority—after all that is what the Island is about. Need to consider the method of erosion control, how long it will take to complete, and what possible effects it could have on the penguins.
- Support renourishment with a buried revetment wall since it would just do a better job than what is currently being employed – sandbags.

Bill Morgan

Workshop Discussion Session:

- Suggested use of perforated offshore breakwater structure. Matt Eliot responded to suggest that this would result in an accretionary area in the lee of this structure which consequently could result in sediment erosion from other parts of the Penguin Island spit.

Nic Dunlop

Workshop Discussion Session:

- Supported using sand from Tern Island since it would have the added benefit of returning Tern Island to an island and increase sand flow back to Penguin Island. (Since Tern Island is a nature reserve, CALM is managing its own land and it would reduce predators getting onto Tern Island).
- Supports the extraction of sand from tombolo for renourishment to ensure Penguin Island is kept as an island.
- Northern beach of spit is distinct limestone pavement habitat. Noted that caves at northern end of island have now become infilled with sand and possibility that this sediment is from erosion of the South Beach.
- Suggested ensuring rapid revegetation of nourished sands to prevent wind blown loss of sands.
- Need to consider timing of activities from both oceanographic and penguin – seabird ecology perspectives.

Email to Martine Holland (16/12/2004):

My preferred option is a beach nourishment program without permanent revetments. I would suggest that we continue the curvy-linear sand-bagging technique until such time as we have rebuilt and stabilized a new seaward foredune. Such a foredune should provide enough protection for one bad winter event if we have to go back to square one. Wooden groynes could be employed to help retain the sand in the area).

The sand could be sourced from either

1) the landward side of Tern Island (possibly re-instating some of the natural sand supply and prolonging the period for re-nourishing),or
2) the northern shelving edge of the sand-bar (probably the cheapest option),or
3) from the Mangles Bay launching ramp. (council could cover the trucking but the material will have to be slurried somewhere so that it can be pumped to the island).

Moving the buildings or constructing long-shore groynes are both environmentally unacceptable options.

Murray Banks

Workshop Discussion Session:

- Relocation of buildings not an option. Besides being a logistical nightmare, they were placed in that location for a reason – the Island has no power and the only way of cooling is to make use of the SW breeze. If the buildings were relocated to the proposed site near the toilets, they would not take advantage of these SW winds and would be like ovens.
- Storm damage only really occurs 5 days out of the year – the worst damage occurs when a storm combines with high tide and a full moon—often is associated with the swell waves which follow after the main impact of the storm has subsided.
- Friable limestone beach rock underlies South Beach and has been exposed occasionally.

Paul Neilson

Workshop Discussion Session:

- Penguins should be the priority and the option with least impact to the environment chosen.

Larry Adams

Workshop Discussion Session:

- Prefer the option with lowest impact – renourishment.
- It may be a mistake to put in a structure – it will be very expensive and may not work as planned (especially if there is no clear pattern/correlation occurring with coastal processes and the degree of erosion).

Bob Goodall

Workshop Discussion Session:

- 30-40 years is a short term study, and not enough information to justify the construction of a hard structure. The sea is too dynamic and unpredictable, anything could happen.
- Early literature indicates period when tombolo had trees on it and back in 1840's Peel Harbour existed—Peter Boreham suggested that the "Peel Harbour" may have been a "real estate agent's imagination" to encourage investment.
- Noted that boulders from Mersey Point seawall moved during large storm events.
- Questioned whether barging sand to Island would be an option. Matt Eliot responded that costs likely to be similar to use of slurry track.

Elizabeth Rippey

Workshop Discussion Session:

- Should carry out a cash value assessment of the Penguin Island facilities to help in justification for expenditure on protective works.

Chris Coffey

Email to Martine Holland (22/12/2004):

As discussed please find below general comments following the stakeholder meeting regarding erosion control at Penguin Island.

- The most suitable option would appear to be ongoing renourishment. There may also be a need for a hidden/buried revetment wall to protect infrastructure from major storm events. If renourishment was the approved option a reliable source of sand would be needed and CALM would need to ensure on-going funds are available to continue renourishment as required.
- In regards to coastal access (a major issue in Cockburn Sound), offshore breakwaters (as used at James Pt) could also be a suitable option as they do not restrict access to the beach in the same way as groynes or breakwaters.
- If a slurry pipe was used for renourishment it may be necessary to take into account possible impacts upon nearby seagrass. (I note the picture shown during the presentation of a slurry pipe being used and there appeared to be significant suspended sediments in the water).
- I note the comment made by Nic Dunlop regarding accessing sand from Tern Island. Our office has had various enquires from members of the community who are concerned about the ongoing erosion and accretion problems in the Safety Bay/Warnbro Sound area. We were most likely approached as some people believe the Garden Island Causeway could be a contributing factor. It seems that the Causeway is unlikely to be having a major impact but the issue still gets debate and there is no definite answer. I raise this issue as one for the memory bank but eventually (obviously with available funds) there may be a need for a broad study of the area, highlighting sources/reasons of such problems and possible management actions.

Appendix E

Sediment Analysis Results

Penguin Island South Beach Rehabilitation

Potential Sediment Sources
Data Report

Prepared for:

Resolve FM

&

Department for Conservation and Land Management

Prepared by:

Oceanica Consulting Pty Ltd

November 2005

Report No. 422/2

Client: Resolve FM and Department for Conservation and Land Management

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Version	Author	DISTRIBUTION			REVIEW	
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Status

This report is "Draft" until the author and director have signed it off for final release. A "Draft" report should not be used for any purpose other than to be reviewed with the intention of generating a "Final" version.

Approved for final release:

Author Director Date:23/11/05

Disclaimer

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1. Potential Sediment Sources

The two preferred options for the management of shoreline erosion on South Beach, Penguin Island (a buried revetment wall or a series of alongshore groynes) will also require sediment nourishment. Three potential sediment sources have initially been identified:

- Tern Island;
- The tombolo between Penguin Island and Mersey Point; and
- Point Peron.

Tern Island is an A-Class Reserve and an identified bird sanctuary site; hence the removal of material from this site is likely to be in conflict with the management commitments for this reserve. In light of the conservation value of this area, Tern Island was not considered further as a viable sediment source.

A key consideration in the selection of a sediment source for the required renourishment is the particle size characteristics between the "borrow" sediments and the "native" site sediments. The relative particle size characteristics determine the volume of sediment required and the frequency of ongoing renourishment works. Ideally the sediment grain size of the borrow material and the native beach material should be equivalent (or coarser). If the borrow material is finer, then (a) a greater volume of material is required; and (b) it is also more susceptible to marine and wind erosion (hence, renourishment may be required more frequently). These two concepts are captured in the overfill and renourishment factors presented below.

1.1 Overfill factor

Where sediment is required to be placed on a natural beach that has been relatively stable (exhibiting a steady rate of change, a state of dynamic stability or only slowly receding), the size characteristics of the native material can be used to evaluate the suitability of the potential borrow material (US Army 1984). Borrow material with the same grain size distribution as the native material is most suitable for fill—in cases where this is not possible, the additional volume of fill required may be estimated using the *overfill factor*.

The overfill factor (R_A) is the estimated number of cubic metres of borrow material required to produce an 'equivalent' cubic metre of native material. The overfill factor is estimated using the following two elements (using the phi scale) which describe the relative difference in the sorting and grain size of the native and borrow sediments:

$$F1 = \frac{\sigma_{\phi b}}{\sigma_{\phi n}} \qquad F2 = \frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}}$$

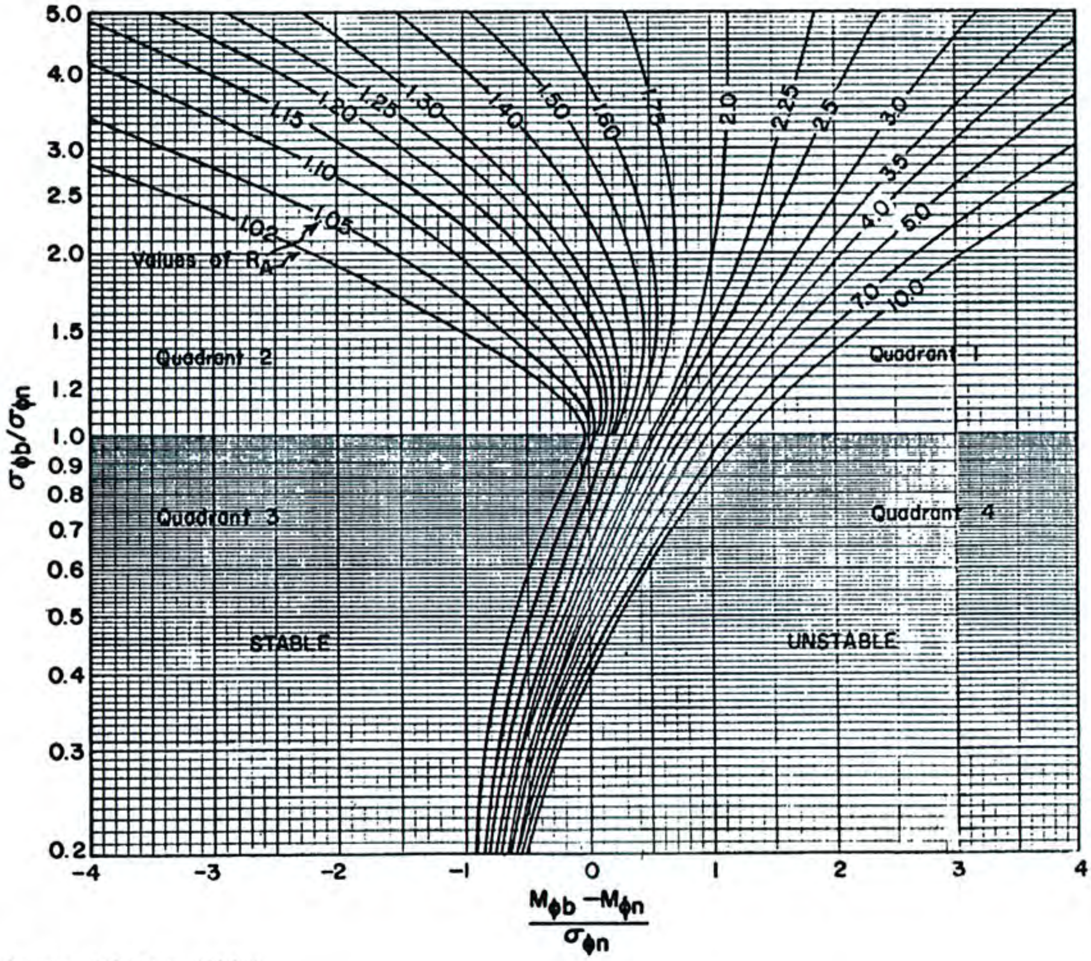
Where $F1$ is the phi sorting ratio, $F2$ is the phi mean difference, b refers to the borrow material and n refers to the native beach material.

The standard deviation, σ, (also considered an indication of the degree of sorting) and mean grain size, M, are determined using Folk & Ward (1957) equations, where:

$$\sigma_\phi = \left(\frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6} \right)$$

$$M_\Phi = \frac{(\phi_{16} + \phi_{54} + \phi_{84})}{3}$$

Solutions to the overfill factor calculation are shown graphically in Figure 1.1.



Source: US Army (1984)

Figure 1.1 Isolines of the overfill factor (R_A) for values of phi mean difference and phi sorting ratio

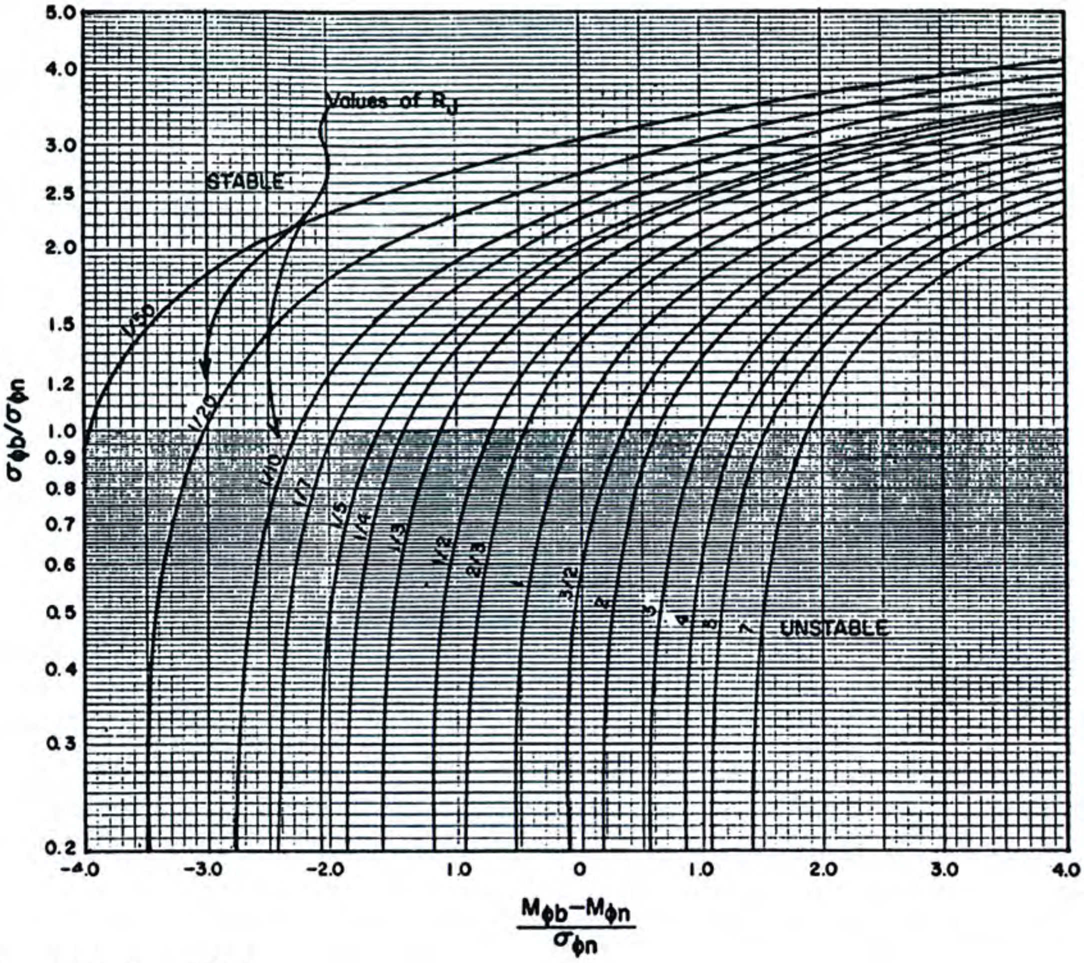
1.2 Renourishment factor

Different sediment sizes will have different residence times within a dynamic beach system—coarse particles will generally pass more slowly through the system than finer particles. However, coarser material moved offshore during storm events may not be returned to the beach during post-storm periods.

James (1975) defines a *renourishment factor*, R_J, which is the ratio of the rate at which borrow material will erode, to the rate at which the native material is eroding, as:

$$R_J = e\left[\Delta \left(\frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}} \right) - \frac{\Delta^2}{2} \left(\frac{\sigma^2_{\phi b}}{\sigma^2_{\phi n}} - 1 \right) \right]$$

where Δ is a dimensionless parameter representing the scaled difference between the means of non-eroding and actively eroding native beach sediment. James (1975) recommends Δ = 1 for common situations. Solutions to the renourishment factor equation for cases were Δ = 1 are shown in Figure 1.2.



Source: US Army (1984)

Figure 1.2 Isolines of the renourishment factor (R_J) for values of for values of phi mean difference and phi sorting ratio, and Δ = 1

2. Sediment Sampling

To examine the characteristics of the potential sediment sources for the renourishment works on South Beach, sediment samples where obtained from the tombolo, Point Peron and South Beach. Sediment samples were initially collected via surface grab sampling and then subsequently core samples were obtained from each site.

2.1.1 Surface grab samples

Three surface grab samples were taken from along the edge of the swash zone of South Beach and Point Peron on 15 June 2005. Three surface samples were also taken along the tombolo. The three samples from each location were mixed and then analysed for grain size distribution (determined using sieve analysis).

2.1.2 Sediment cores

Three sediment cores were taken from each of the following sites on 22 July 2005:

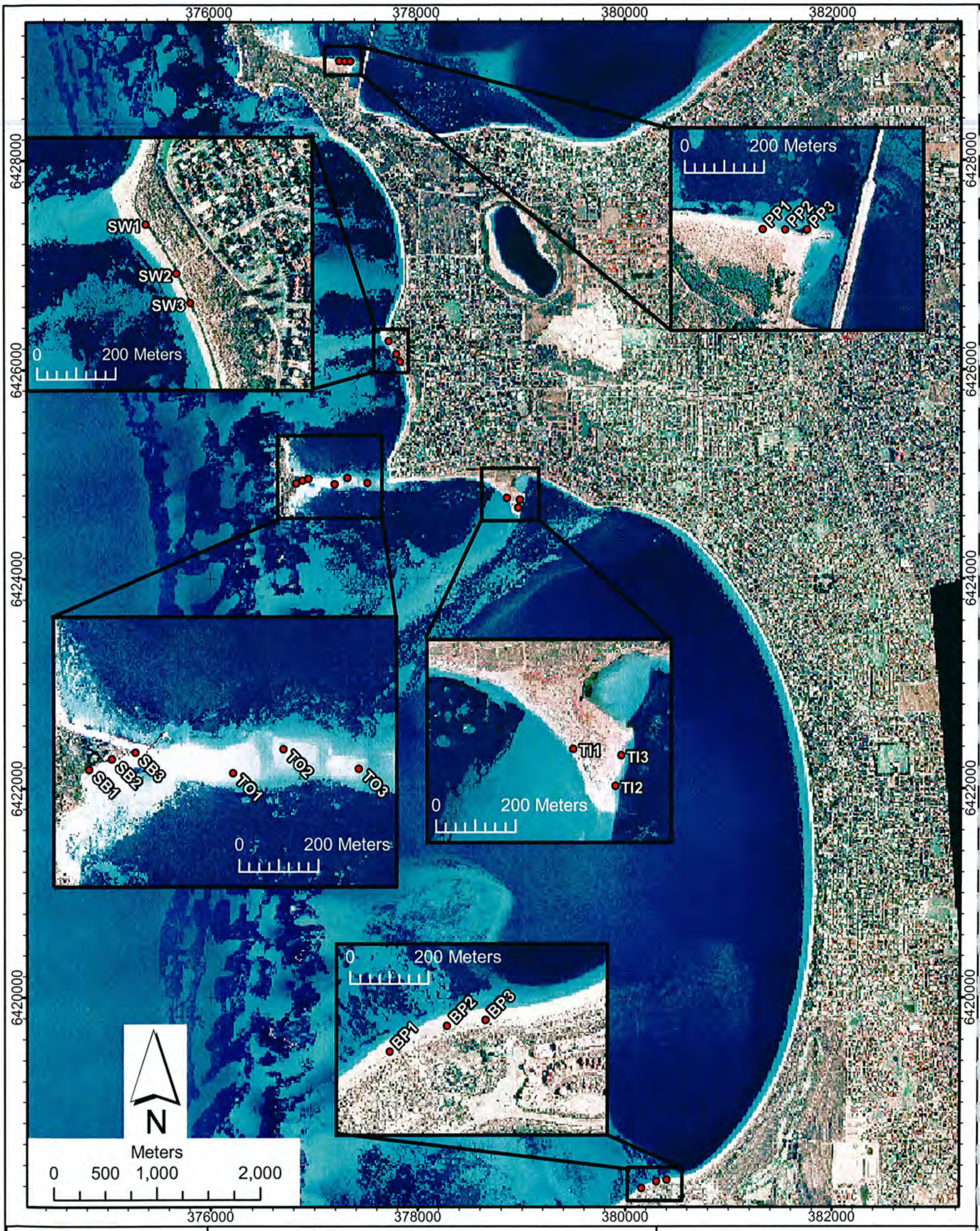
- South Beach, Penguin Island;
- Point Peron;
- Shoalwater Bay;
- Tombolo (Penguin Island to Mersey Point);
- Tern Island; and
- Bridport Point.

The location and penetration depth of each of the cores is presented in Table 2.1 and Figure 2.1. The cores from South Beach, the tombolo and Point Peron have been individually logged, photographed and analysed for grain size distribution. The remaining cores (from Shoalwater Bay, Tern Island and Bridport Point) have been held temporarily pending future analysis if required.

Table 2.1 Core site location and penetration depth

Location	Site Code	Easting (WGS84)	Northing (WGS84)	Penetration Depth (cm)
South Beach	SB1	376830	6424908	83
	SB2	376888	6424934	99
	SB3	376948	6424951	109
Tombolo	TO1	377198	6424900	103
	TO2	377325	6424960	107
	TO3	377517	6424910	85
Point Peron	PP1	377253	6428949	103 (1)
	PP2	377310	6428947	103 (1)
	PP3	377365	6428947	78 (1)
Shoalwater Bay	SW1	377723	6426266	101
	SW2	377802	6426142	109
	SW3	377836	6426068	101
Tern Island	TI1	378856	6424766	102
	T12	378963	6424673	94
	T13	378978	6424750	89
Bridport Point	BP1	380158	6418181	83 (1)
	BP2	380305	6418246	66 (1)
	BP3	380403	6418261	62 (1)

Note: 1. Core reached a point of refusal during sampling



oceanica marine & estuarine specialists	**Legend**	**Figure 2.1**
Author: MAG Date: 15/08/05	● Core Locations	Location of Core Samples July 2005
Proj Ref: 422_4		DEPARTMENT OF Conservation AND LAND MANAGEMENT *Conserving the nature of WA*
File Ref: CoreSamples.mxd		
Horizontal: Datum UTM Zone 50 Based on WGS84		
Vertical: Datum N/A	Data Sources: Oceanica 2004 Aerial Imagery, BeachCore.GPS.Depth.xls	

3. Results

3.1 Surface samples

The surface grab samples indicate that the material on South Beach was coarser than either of the potential source sites (Figure 3.1). These results varied from previous visual observations of surface samples collected in September 2004 which indicated that the material from the tombolo and South Beach were much more similar in size (Table 3.1).

Due to the observable differences between the surface samples collected, core sampling was conducted. Whereas surface sediments characteristics can change rapidly in response to the prevailing conditions, these core profiles will provide a more complete description of the sediment body at each site. The surface grab samples have not been included in any further analysis work.

Table 3.1 Visual and lab analysed median grain sizes for surface samples taken on South Beach, the tombolo and Point Peron

Sediment Source	Visual Inspection (μm) September 2004	Grab Sample Lab Analysis June 2005		
		d_{10} (μm)	d_{50} (μm)	d_{90} (μm)
South Beach	350-500	215	427	875
Tombolo	350-500	191	310	502
Point Peron	250-350	157	266	485

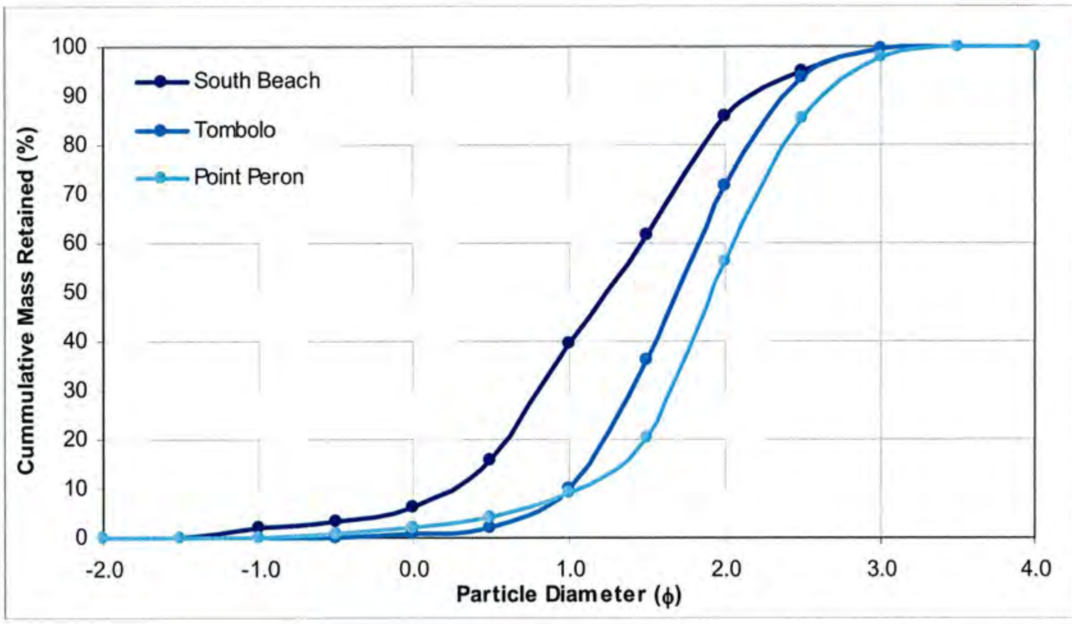


Figure 3.1 Particle size distribution of grab samples taken at South Beach, tombolo and Point Peron

3.2 Core logs

The cores from both South Beach and Point Peron show typically medium grain carbonate sands, which are yellow to brown in colour (Table 3.2). The cores from the tombolo show typically medium to coarse sands, with a high proportion of shell fragments and darker particles. Photographs of the cores are presented in Appendix A.

Table 3.2 Core descriptions

Core Depth (cm)	Attribute Description	Munsell Colour	Colour Description
South Beach—SB1			
0–11.0	Medium carbonate sand	2.5Y6/2	light brownish gray
11.0–75.5	Medium carbonate sand	2.5Y8/4	pale yellow
75.5–78.5	Fine to medium carbonate sand	2.5Y8/4	pale yellow
South Beach—SB2			
0–28.5	Fine to medium carbonate sand	2.5Y6/4	light yellowish brown
28.5–30.0	Medium carbonate sand, organic rich	2.5Y4/4	olive brown
30.0–73.0	Fine to medium carbonate sand	2.5Y6/4	light yellowish brown
73.0–97.0	Medium to coarse carbonate sand	2.5Y8/6	yellow
South Beach—SB3			
0–3.0	Medium carbonate sand, organics evident	2.5Y6/2	light brownish gray
3.0–64.5	Medium carbonate sand	2.5Y6/2	light brownish gray
64.5–110.0	Medium to coarse carbonate sand	2.5Y7/2	light gray
Tombolo—TO1			
0–24.5	Medium carbonate sand, shell fragments, minor sub-population of dark particles	2.5Y6/4	light yellowish brown
24.5–30.0	Medium to coarse carbonate sand, shell fragments, subpopulation of dark particles	2.5Y6/2	light brownish gray
30–116	Medium carbonate sand, predominantly dark particles, some whole gastropods and limestone fragments	N6	gray
Tombolo—TO2			
0–41.0	Medium to coarse carbonate sand	2.5Y6/2	light brownish gray
41.0–95.0	Medium to coarse carbonate sand, predominantly dark particles, shell fragments	U6	gray
95.0–111.0	Medium carbonate sand, predominantly dark particles, shell fragments	U6	gray
Tombolo—TO3			
0–14.0	Medium carbonate sand	2.5Y6/4	light yellowish brown
14.0–89.0	Medium carbonate sand, predominantly dark particles, some whole gastropods	U6	gray
Point Peron—PP1, PP2 and PP3			
	Medium carbonate sand, minor subpopulation of dark particles, structurally massive with poor vertical differentiation	2.5Y6/2	light brownish gray

3.3 Grain size distribution

There was a high natural variability in sediment grain size at each of the locations sampled (Figure 3.2 to Figure 3.4). At each site, the results from all three cores were averaged before overfill and renourishment factors were calculated (Section 3.4). The average particle size distribution of each of the sites shows that the sediment from the tombolo appears to be slightly coarser than the other two sites (Figure 3.5).

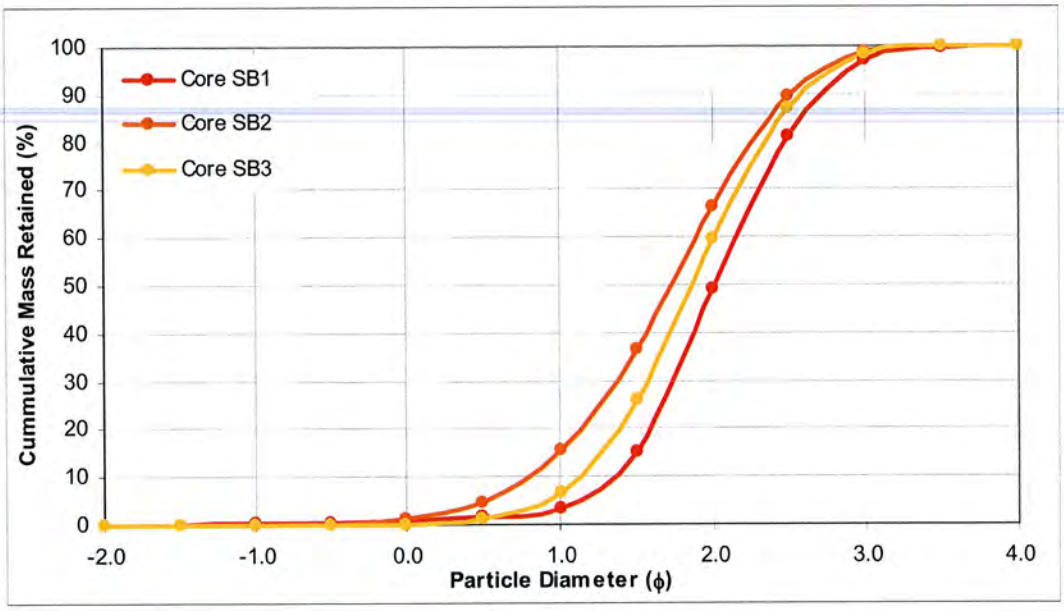


Figure 3.2 Particle size distribution of the core samples taken along South Beach, Penguin Island

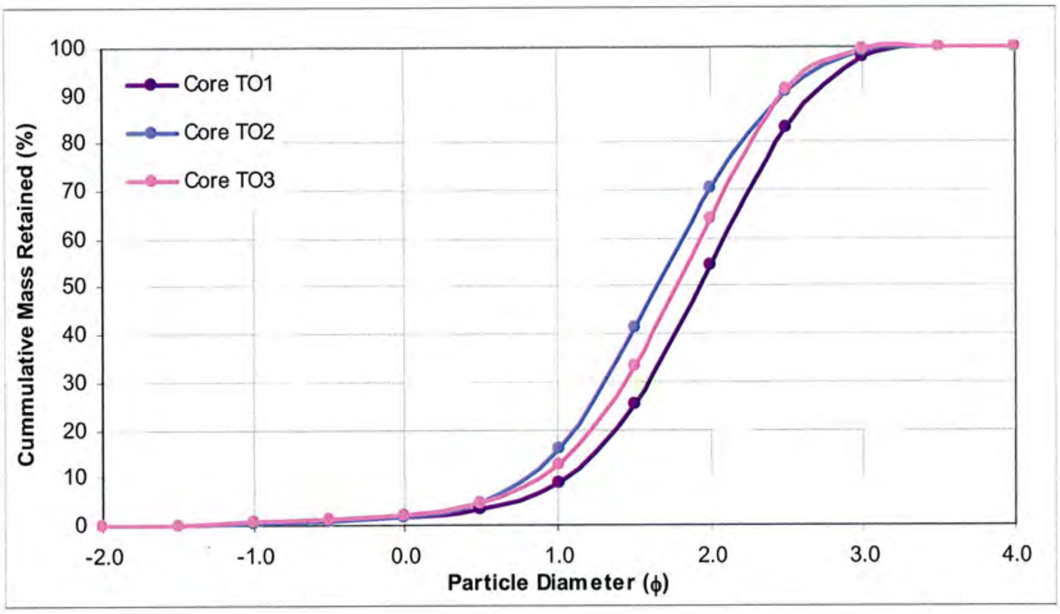


Figure 3.3 Particle size distribution of the sediment samples taken across the tombolo joining Penguin Island to Mersey Point

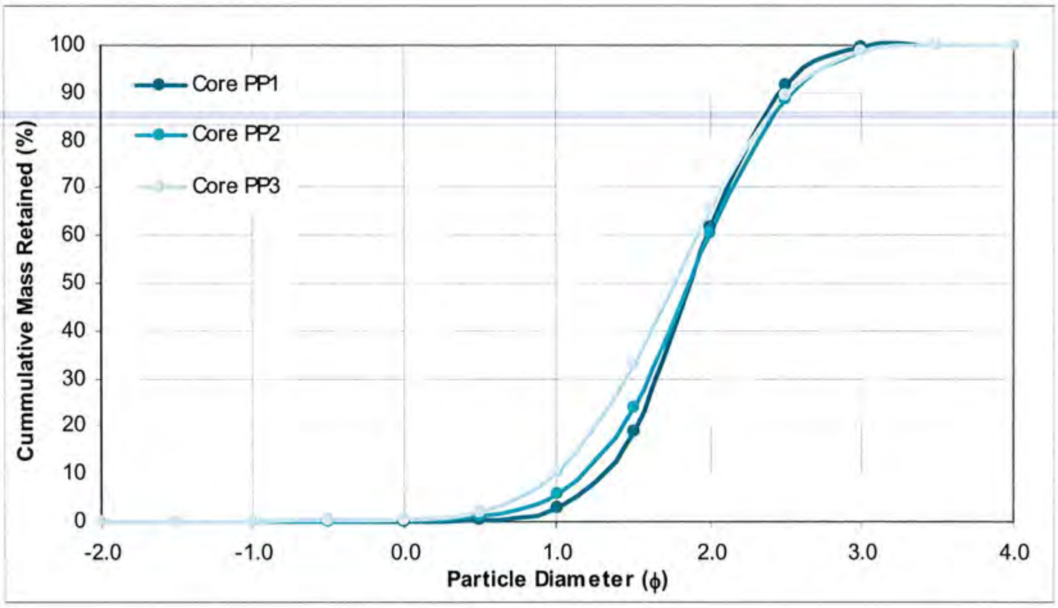


Figure 3.4 Particle size distribution of the sediment samples taken at Point Peron

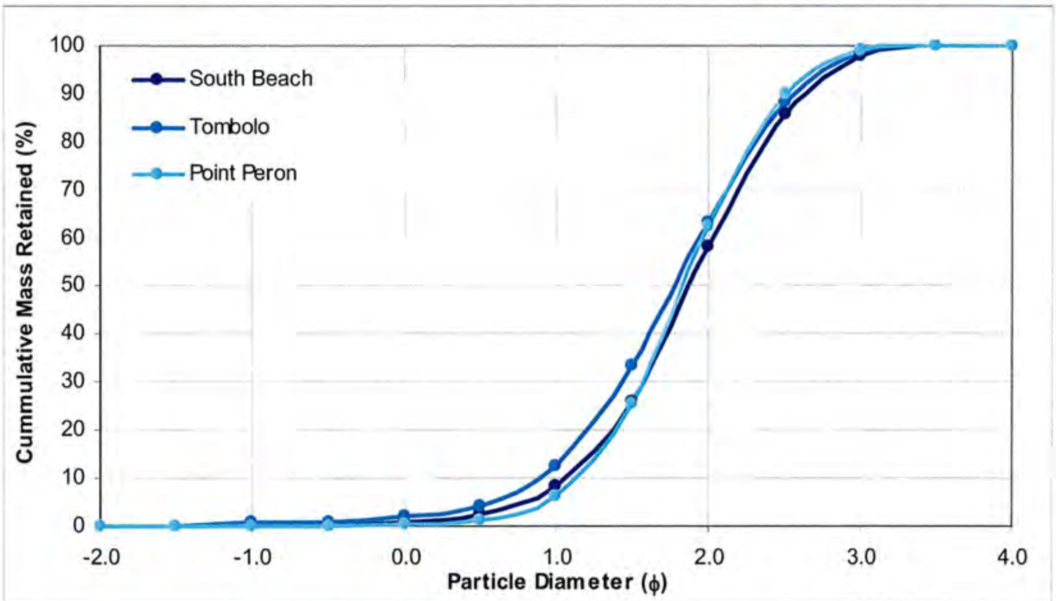


Figure 3.5 Particle size distribution of the average of core samples taken at South Beach, the tombolo and Point Peron

3.4 Overfill and renourishment factors

The sediments from the tombolo and Point Peron have an estimated overfill factor of 1.02 and 1.10 respectively (Table 3.3). Hence, to renourish an equivalent 13,500 m^3 of material on South Beach would require approximately 14,000 m^3 of material from the tombolo or 15,000 m^3 of sediment from Point Peron. The renourishment ratio's are also close to a value of 1, indicating that it is expected that fill material would behave similarly to the natural South Beach sediment.

The overfill and renourishment factors should be considered as indicative estimates of the behaviour of the borrow material. The pattern of erosion on South Beach has been intermittent and associated with severe storm events rather than a gradual erosive cycle (Oceanica 2005). This differs from the 'relatively stable' assumption under which the overfill and renourishment factor relationships were designed (Section 1.1).

Table 3.3 Overfill and renourishment factors for the tombolo and Point Peron

Source	Percentile Grain Size (ϕ)					Sorting, σ	Mean Grain size, M	Average σ	Average M	Factor 1 (F1)	Factor 2 (F2)	Estimated Overfill Factor	Estimated Renourishment Factor
	ϕ_5	ϕ_{16}	ϕ_{50}	ϕ_{84}	ϕ_{95}								
South Beach													
SB1	1.064	1.513	2.014	2.584	2.932	0.579	2.037	0.646	1.864	n/a	n/a	n/a	n/a
SB2	0.519	1.015	1.726	2.383	2.803	0.723	1.708						
SB3	0.843	1.240	1.856	2.444	2.850	0.636	1.847						
Tombolo													
TO1	0.646	1.213	1.922	2.532	2.909	0.707	1.889	0.702	1.762	1.09	-0.16	1.02	0.9
TO2	0.510	0.992	1.651	2.336	2.758	0.711	1.660						
TO3	0.530	1.079	1.770	2.366	2.731	0.689	1.738						
Point Peron													
PP1	1.064	1.409	1.863	2.372	2.712	0.515	1.881	0.595	1.830	0.92	-0.05	1.10	1.2
PP2	0.903	1.278	1.858	2.418	2.809	0.603	1.851						
PP3	0.683	1.125	1.761	2.387	2.795	0.668	1.758						

4. Conclusions

Analysis of the core samples showed that the sediment from both potential source sites show similar grain size characteristics to the natural material found on Penguin Island. The material from the tombolo does contain a proportion of darker particles and shell fragments, however it would be expected that over time, exposure to the sun would bleach this darker material. Hence, it is concluded that sediments from either the tombolo or Point Peron would be appropriate for the renourishment of South Beach.

The following table indicates the approximate volume of material required and renourishment interval for both the alternate rehabilitation options for the southern beach of Penguin Island.

Table 4.1 Approximate volumes and renourishment intervals for rehabilitation works on South Beach, Penguin Island

Buffer (m)	Volume[1] (m^3)	Tombolo	Point Peron
		Estimated Volume Required [(1)] (m^3)	Estimated Volume Required [(1)] (m^3)
OPTION 1—REVETMENT WALL			
30	13,500	14,000	15,000
20	9,000	9,500	10,000
15	7,000	7,500	7,500
10	4,500	5,000	5,000
OPTION 2—ALONGSHORE GROYNES			
30	7,000	7,500	8,000
20	4,500	5,000	5,000
15	3,500	4,000	4,000
10	2,500	3,000	3,000

Note: 1. Volumes have been rounded up to the next 500 m^3.

5. References

Folk, R.L., and Ward, W.C. 1957, 'Brazos River Bar, A study in the significances of grain size parameters', *Journal of Sedimentary Petrology*, Vol. 27, pp. 3-26.

James, W.R. 1975, *Techniques in Evaluating Suitability of Borrow Material for Beach Nourishment*, Coastal Engineering Research Centre, United States Army, Vicksburg.

Oceanica Consulting Pty Ltd. 2005, *Penguin Island South Beach Rehabilitation, Environmental Referral Document*, Prepared for the Department of Conservation and Land Management, Report 422/1, Australia.

United States Army Corps of Engineers. 1984, *Shore Protection Manual*, Prepared for the Department of the Army, Washington.

6. Acknowledgements

This report has been prepared by **Michelle Carey** (Oceanica) and reviewed by **Bruce Hegge** (Oceanica). Preparation of GIS figures for this report was completed by **Marie Gouteff** (Oceanica).

The core sediment sampling was conducted by **Dave Tunbridge** (Marine and Freshwater Research Laboratory, Murdoch University). The sediment analyses were completed by **Bill Wilson** (University of Western Australia).

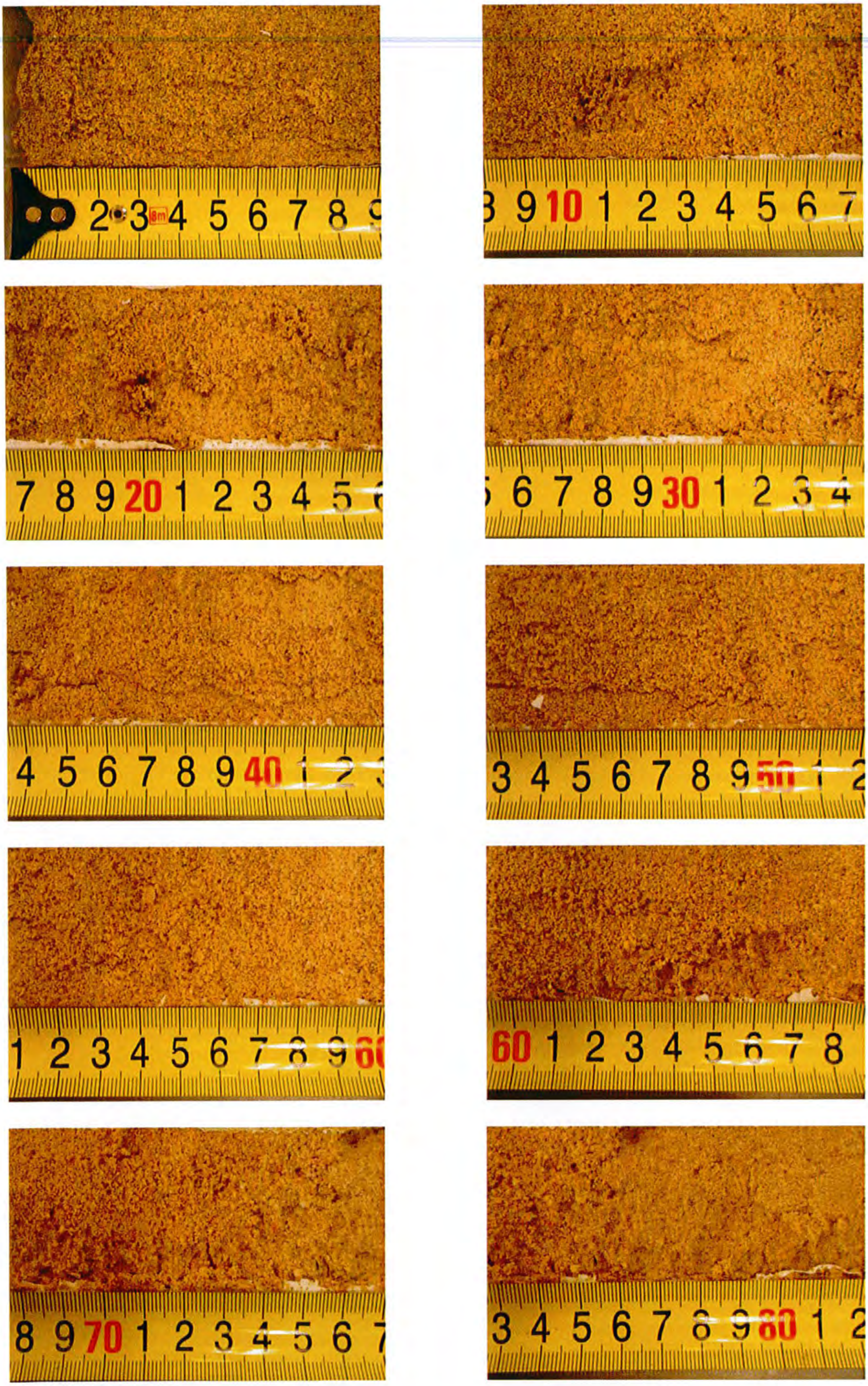
The client contacts for this project are **Alan Robson** (Resolve FM), **Kylie Ryan** and **Ben Tannock** (Department of Conservation and Land Management).

This report was formatted by **Charlotte Tuckerman** (Oceanica).

Appendix A

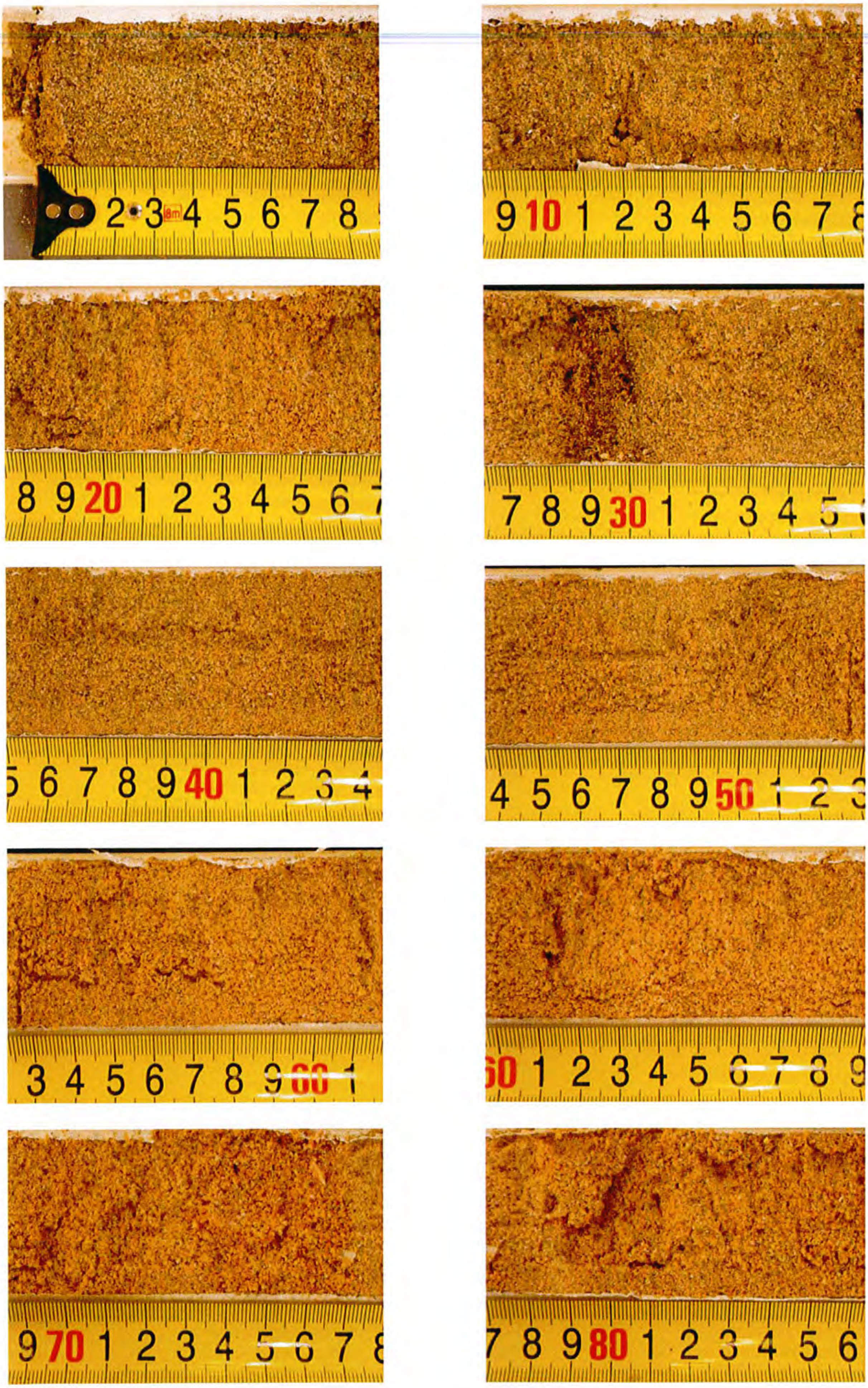
Photographs of Sediment Cores

South Beach—SB1




0 1 2 3 4 5 6 7 8 9

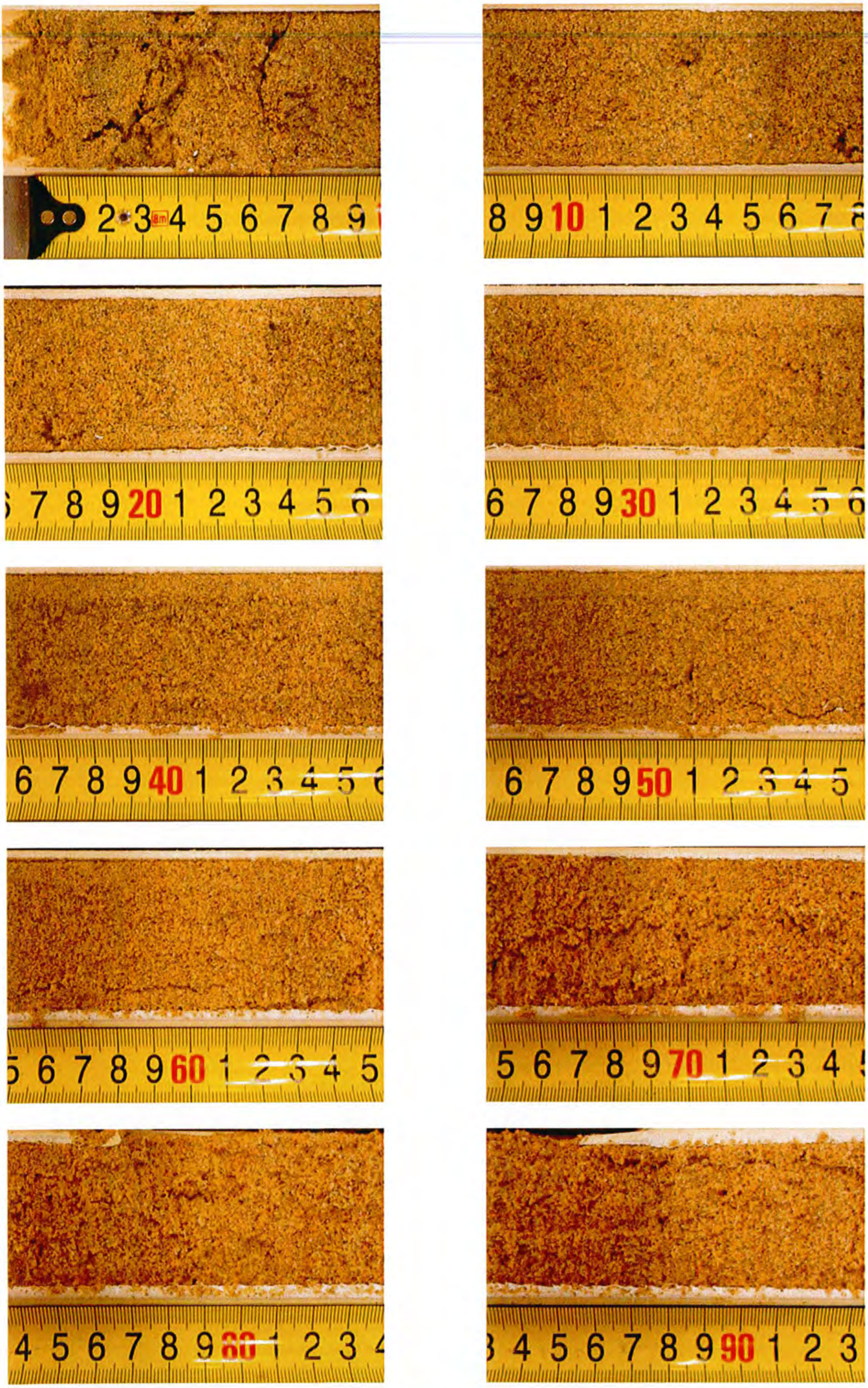
South Beach—SB2




5 6 7 8 9 90 1 2 3 4


9 90 1 2 3 4 5 6 7 8

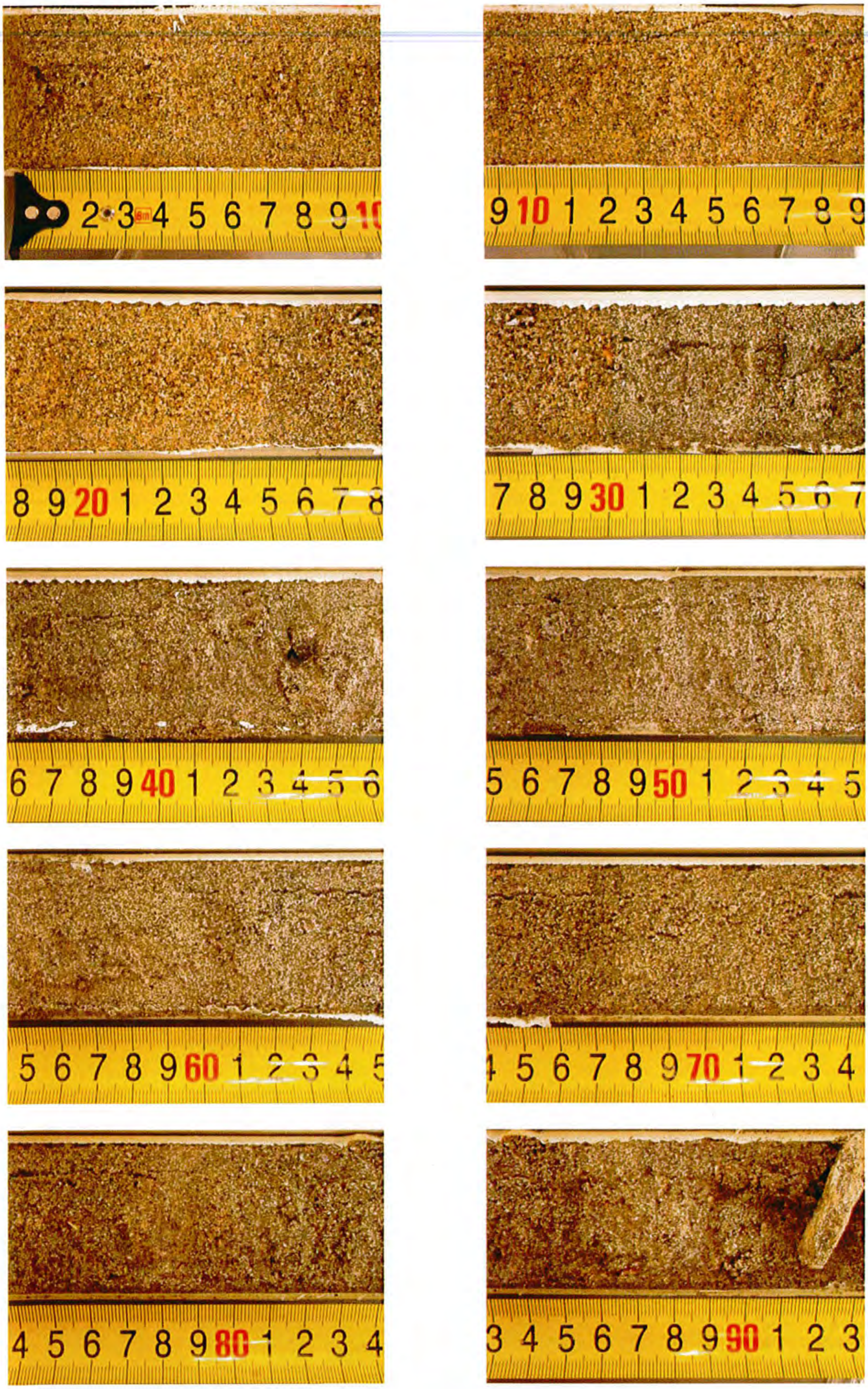
South Beach—SB3




2 3 4 5 6 7 8 9 100 1 2

1 2 3 4 5 6 7 8 9 110 1

Tombolo—TO1

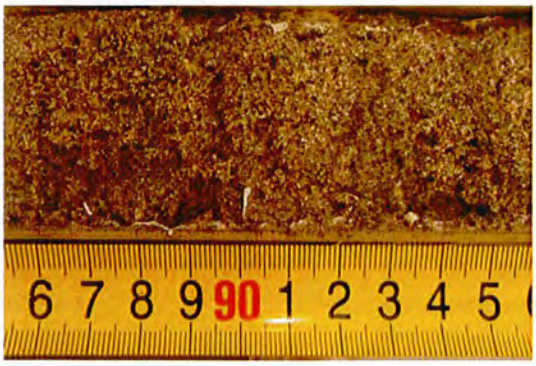



3 4 5 6 7 8 9 100 1 2 3

2 3 4 5 6 7 8 9 110 1 2

9 110 1 2 3 4 5 6 7 8 9

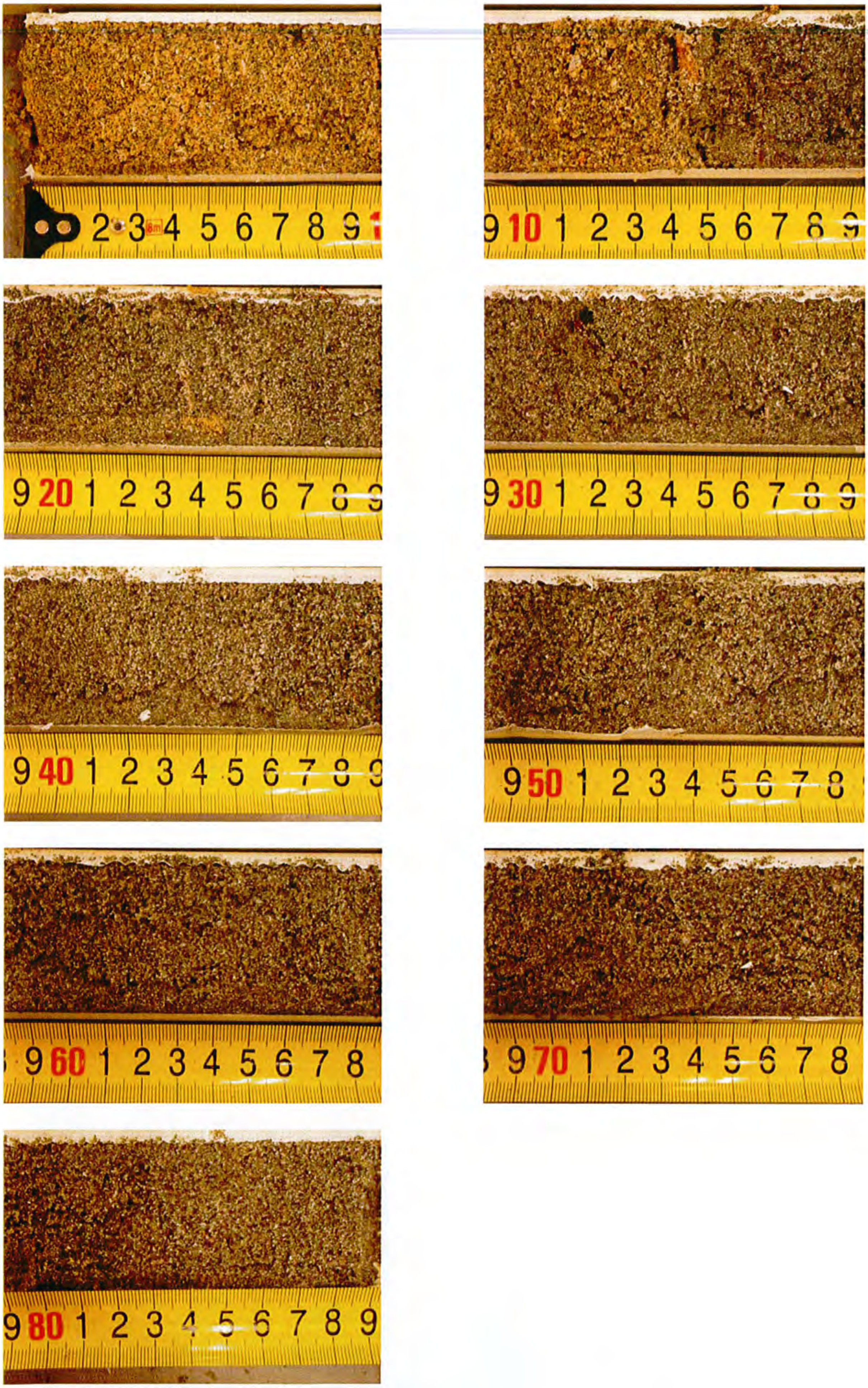
Tombolo—TO2




5 6 7 8 9 100 1 2 3 4

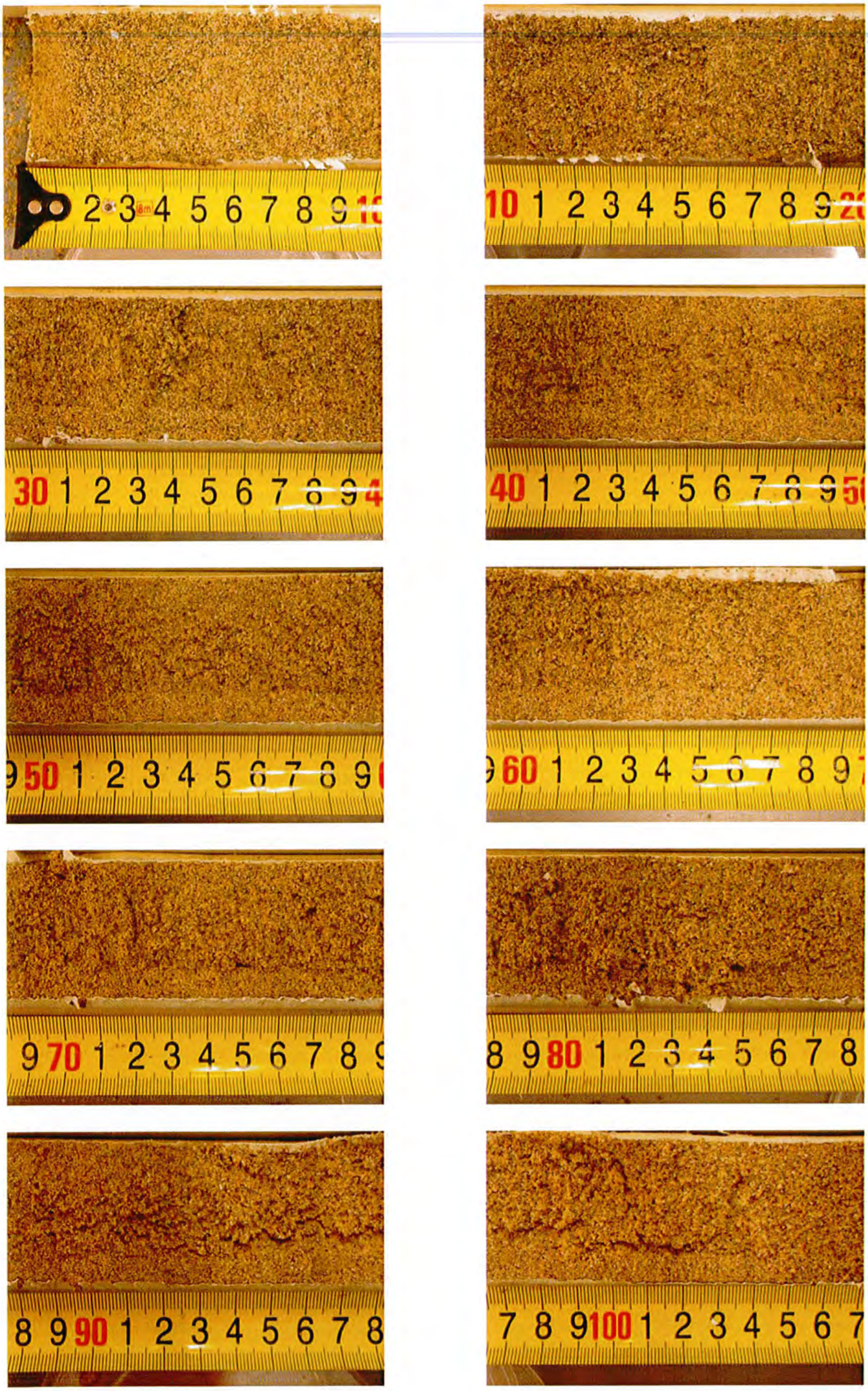

4 5 6 7 8 9 110 1 2 3

Tombolo—TO3



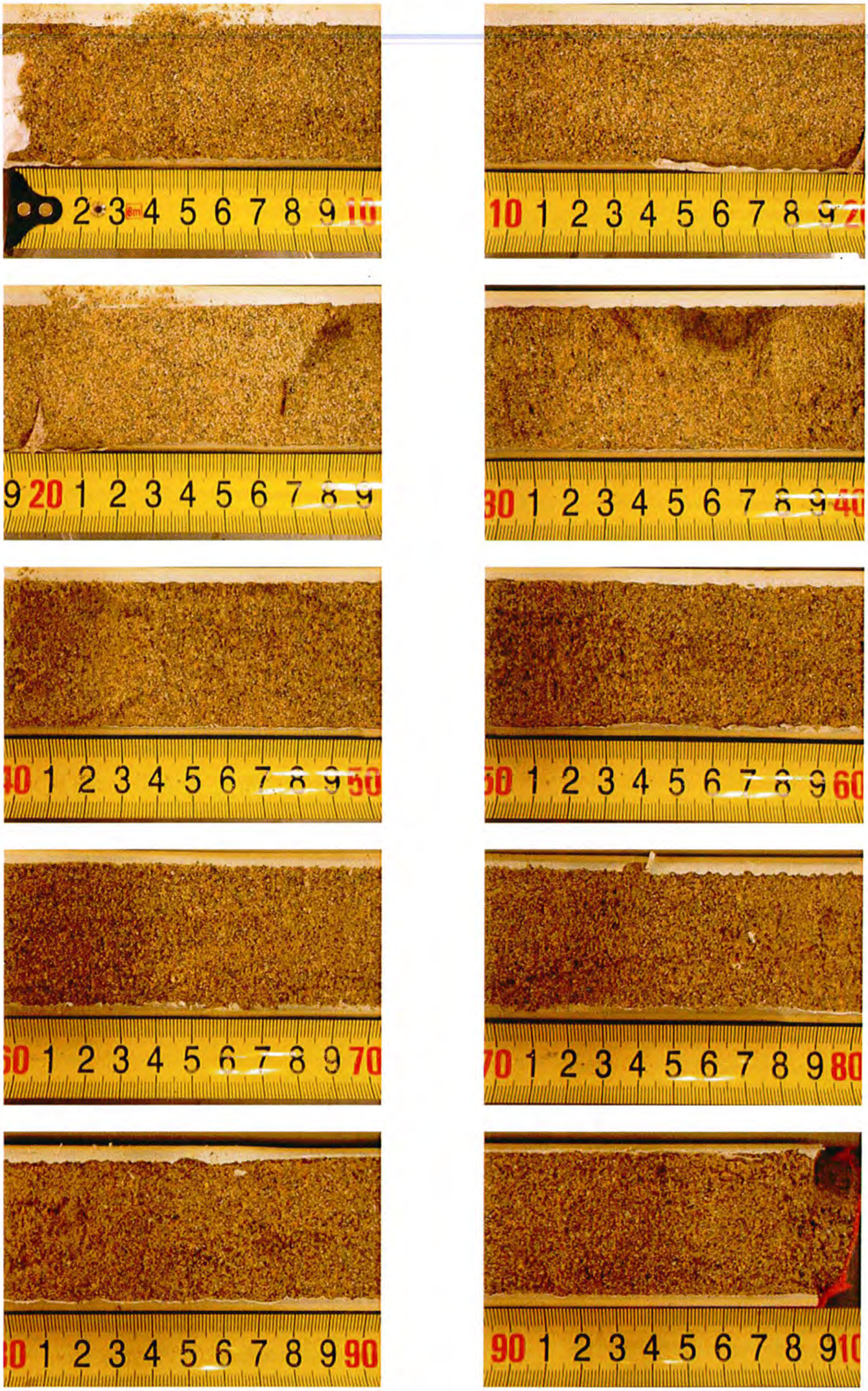
2 3 4 5 6 7 8 9
9 10 1 2 3 4 5 6 7 8 9
9 20 1 2 3 4 5 6 7 8
9 30 1 2 3 4 5 6 7 8 9
9 40 1 2 3 4 5 6 7 8
9 50 1 2 3 4 5 6 7 8
9 60 1 2 3 4 5 6 7 8
9 70 1 2 3 4 5 6 7 8
9 80 1 2 3 4 5 6 7 8 9

Point Peron—PP1

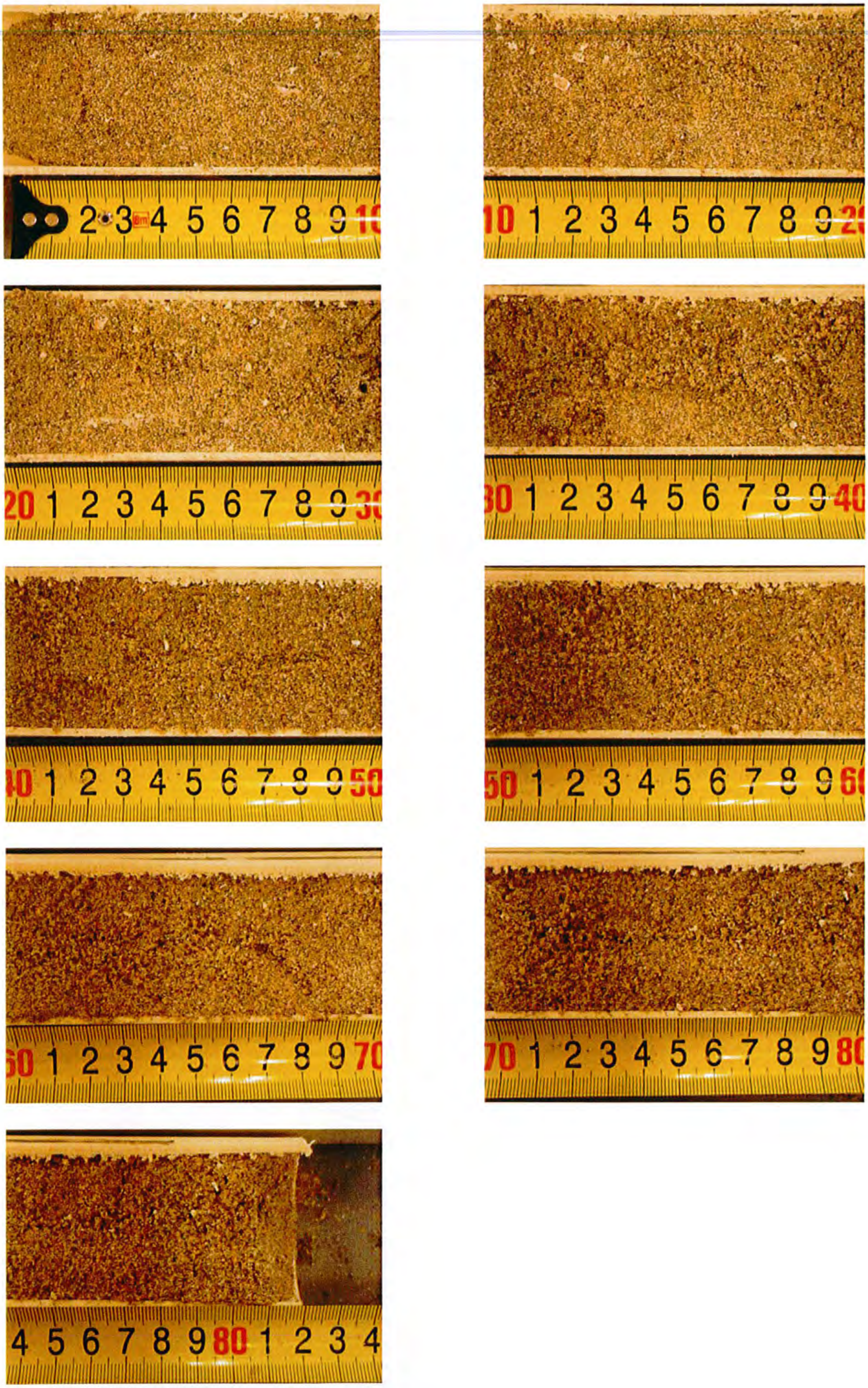



2 3 4 5 6 7 8 9 110 1 2

Point Peron—PP2



Point Peron—PP3



Appendix F

Pro-forma for Visual Monitoring of Plume Extent

South Beach Shoreline Management Works
Visual Monitoring of Plume Extent

For week ending: ___/___/___

During each day of shoreline renourishment works the extent of the turbid plume shall be monitored via photograph taken from viewing platform on the southern hill of Penguin Island between 13:00 and 15:00.

DATE/TIME AND CONDITIONS

Details	Monday	Tuesday	Wednesday	Thursday	Friday
Date					
Time					
Wind speed (knots)					
Wind direction					
Photograph No(s)					
Surveyors initials					

Further Comments:

CALM Representative (or nominated agent) ____________________

Signed ____________________ Date __________

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