Seashore Engineering

Freshwater Bay
Sand Management Plan

Prepared for Town of Claremont

Seashore Engineering

August 2021

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Document Control

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1. Introduction

1.1. BACKGROUND

This Sand Management Plan has been prepared on behalf of the Town of Claremont for the Freshwater Bay foreshore (Figure 1). It has been co-funded by DBCA Riverbank Program, aimed at achieving best practice foreshore management. The plan outlines actions relating to ongoing foreshore monitoring, management of day-to-day change, and responses to events causing erosion or foreshore mobility. The Plan is intended to address existing and potential impacts of foreshore erosion and inundation. It provides a longer-term management framework, which may be applicable for 10 to 25 years, depending on foreshore development and conditions experienced, including sea level change.

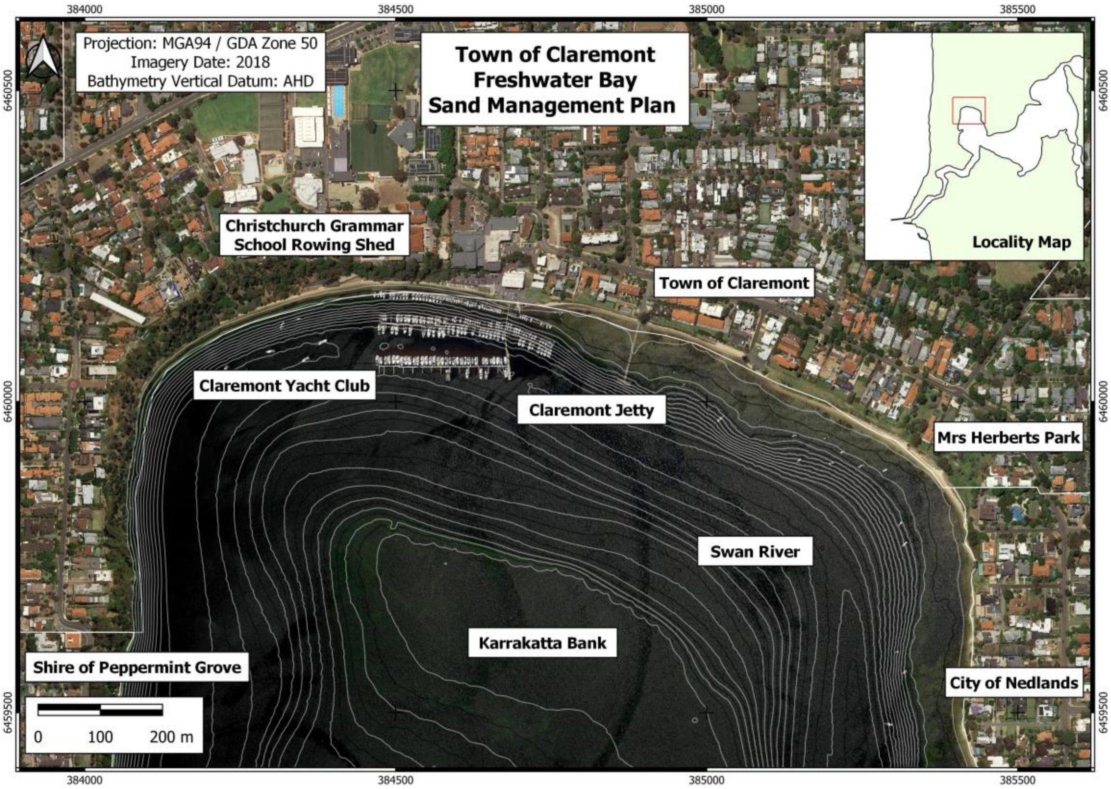

Figure 1: Location Diagram

The need to develop a Sand Management Plan for Freshwater Bay was identified through WESROC Foreshore Management Plan (Seashore Engineering 2016). Specifically, challenges along Freshwater Bay occur because the estuarine beaches are narrow and low lying, with private properties close to the shore. Consequently, episodes of minor erosion or inundation can potentially impact public access and amenity. Management of the foreshore is complicated by the Town of Claremont’s high water mark boundary, and potential for sediment transport along the shore to switch direction both seasonally and episodically.

A description of historic change along Freshwater Bay and further information on foreshore drivers and dynamics is provided in Appendix A.

1.2. OBJECTIVE

This Sand Management Plan (SMP) provides a management framework for the Town of Claremont foreshore along Freshwater Bay, to mitigate existing and potential impacts from foreshore dynamics, including erosion and inundation. Existing management requirements are low; however, more substantial impacts are expected in the longer-term under future projections of rising sea levels and changing weather patterns. Options and recommendations for transition towards long-term foreshore management are also included within this Plan.

Existing foreshore management activities are partly constrained by tenure (Section 2.6), with the high water mark boundary causing an artificial division of management actions. The Town is responsible for maintaining a narrow strip of foreshore, with the Department of Biodiversity Conservation and Attractions (DBCA) responsible for management of the beach and adjacent estuary bed, through the Swan and Canning Rivers Management Act (2006). In practice, this separation is not rigid, with the Town historically undertaking foreshore management works on the beach, subject to permission from DBCA and Department of Planning, Lands and Heritage (DPLH). However, the process of engagement is slow, requiring review and assessment of proposed works before undertaking actions. This SMP aims to reduce this limitation by defining a set of possible activities, that are agreed to by DBCA and DPLH, which may potentially support more effective use of minor works by the Town of Claremont.

The Town of Claremont is responsible for implementation of the Sand Management Plan. Although the Plan is subject to agreement with DBCA, adherence to the SMP does not alter the requirements for the Town to meet Environmental or Heritage regulations.

1.3. SITE DESCRIPTION

The foreshore area considered for the SMP extends roughly 1350m along the northern side of Freshwater Bay from the rocky foreshore downslope from Cliff Road to Watkins Road. West of Claremont Yacht Club, around 550m of foreshore has a narrow fringe of low elevation land in front of a high, sloping scarp, which transitions into rock cliff further west (Figure 2). East of the yacht club, the foreshore is low elevation, and in some locations, private property boundaries are close to shore (Figure 3).

(a) View west from Claremont Yacht Club **(b) View west towards Christchurch Rowing Shed**

Figure 2: Views Along Claremont Foreshore (West)

(a) View east from Claremont Yacht Club (b) View west from Mrs Herbert's Park

Figure 3: Views Along Claremont Foreshore (East)

From west to east along the foreshore, features include:

- Rocky shore downslope from Cliff Road.
- 130m of scarped, steeply graded foreshore, fronted by a narrow beach.
- Christchurch Grammar School Rowing Shed, which includes gabion walling to provide stabilisation along 110m of foreshore.
- 140m of scarped, steeply graded foreshore, fronted by a narrow beach, sheltered by Claremont Yacht Club jetties.
- 60m of narrow sandy beach in front of walling, that retains car parking area. This area is used for dinghy storage. It is sheltered by Claremont Yacht Club pens.
- Claremont Yacht Club hardstand, including boat ramp, walling and jetty abutments.
- 170m of beach, with a 10-25m wide grassed foreshore reserve in front of private properties.
- Claremont Jetty and its abutment, adjacent to which a large stormwater drain discharges.
- 180m of beach, with a 0-15m wide grassed foreshore reserve in front of private properties. The western 85m has had sedges planted, to provide increased foreshore stability.
- Chester Road carpark, contained within a 20m wide foreshore reserve, protected by a limestone revetment for approximately 45m alongshore length.
- Almost 300m of foreshore beach, with a grassed foreshore reserve in front of private properties. The reserve narrows from about 25m at its western end, to less than 15m at its eastern end. Sedges have been planted along the shore, providing discontinuous riparian stabilisation, with areas subject to undermining or trampling. A living stream with rock pitched sides has been constructed toward the eastern end of this section at Alex Prior Park.
- Approximately 100m of beach in front of the grassed foreshore of Mrs Herbert's Park.
- A length of approximately 30m of bioengineering works, providing stabilisation to the access track on the east side of Mrs Herbert's Park.

A generalised characterisation of the Claremont foreshore east of Claremont Yacht Club is a steep rise up from the relict river channel, a ~50m wide terrace with grade ~1:50 and a lower beach grade of ~1:25 (Figure 4). The upper bank is ~1:8 where it is a beach and ~1:3 where sedges are established.

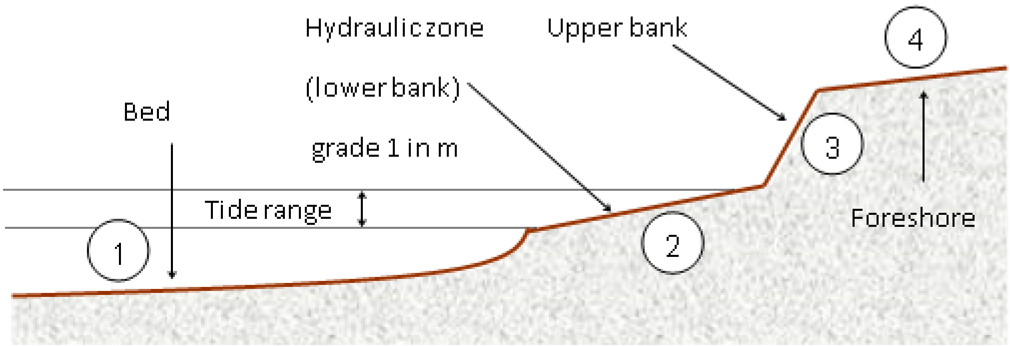

Figure 4: Generalised Foreshore Structure (East of CYC)

1.4. FORESHORE MANAGEMENT VALUES AND PRIORITIES

Foreshore management values of the Town of Claremont were collated as part of the WESROC FMP (Seashore 2016). Previously identified values relevant to foreshore sand management include:

- Maintain existing uses.
- Maintain recreational amenity, with a continuous access track along the foreshore (noting a paved pathway is not suitable along much of the foreshore).
- Low maintenance and sustainable management solutions through increasing foreshore resilience.
- Preference for some vegetation (trees unlikely to be supported) rather than hard structures.
- Whadjuk values (general through the Swan River) are to maintain ecological function, return foreshore to more natural conditions with a reduction in hard walling.
- Foreshore management should not defer erosion/inundation risks to local private property owners. Private property owners should not transfer erosion risk to the foreshore reserve.
- Maintain car parking areas at Chester Road and Jetty Road.

These values provide a broad setting through which foreshore management is undertaken. At a finer detail, priorities for management actions need to be established, and regularly reassessed, typically on an annual basis. Priority should be based upon:

- Immediate Safety Issues
- Foreshore Stability
- Environmental Values
- Heritage Values
- Hazard to Adjacent Landowners
- Public Interest
- Amenity

Conditions observed in July through September 2020 indicated no substantive issues with respect to immediate safety or foreshore stability. Exposed rubble and debris to the east of Chester Road was identified by the Town of Claremont as the most pressing present issue.

2. Key Issues

WESROC Foreshore Management Plan (Seashore 2016) summarised foreshore management stresses experienced by the Town of Claremont. Several issues identified included:

- Inundation.
- Foreshore Erosion.
- Beach and Foreshore Access.
- Local Scour.
- Exposure of Rubble.
- Tenure Constraints.

These issues are each outlined briefly in this Section.

2.1. INUNDATION

A preliminary assessment of inundation hazard to Claremont foreshore has been undertaken through comparison of the water level record from Barrack Street (Perth) tide gauge with foreshore levels derived from LIDAR survey. It is recognised that water levels vary slightly between Claremont and Perth, and that inundation hazard is also influenced by the coincident wave conditions.

The tide gauge record from Barrack Street indicates a distinct seasonal pattern, with high water levels mainly occurring during May to July, when tides, storm surges and seasonal mean sea level can be simultaneously high (Eliot 2012). Annual maxima are consequently always above highest astronomic tide (0.44mAHD), with a relatively ‘flat’ extreme distribution, as there is only ~0.3m between the 1-year average recurrence interval (ARI) level of 0.88mAHD and the 100-yr ARI level of 1.19mAHD.

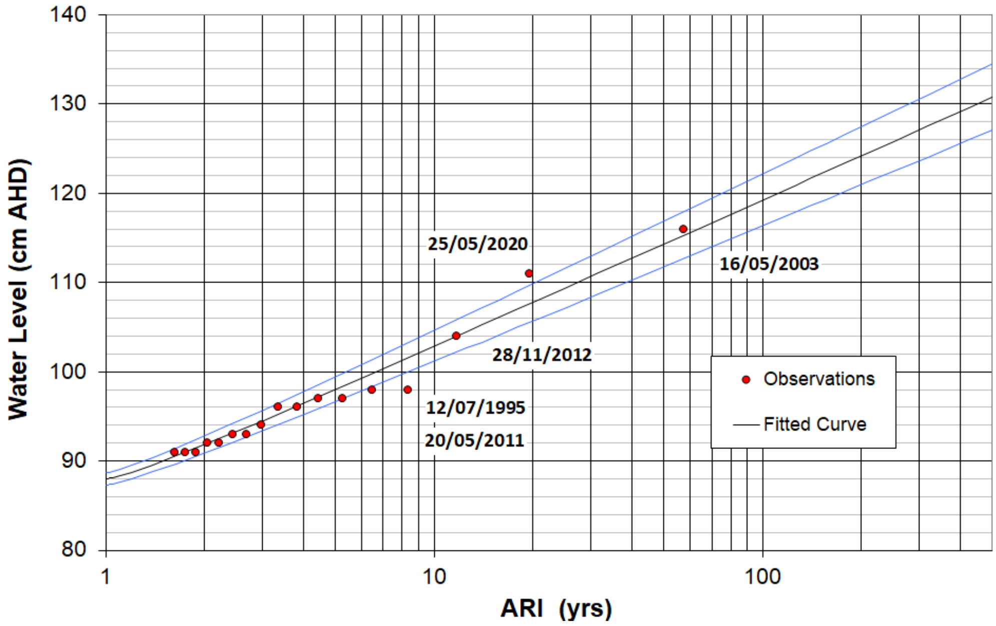

Figure 5: Barrack Street (Perth) Extreme Water Levels

Claremont foreshore is low lying, with levels of 0.7-1.5mAHD identified by LIDAR survey across the grassed foreshore areas (Figure 6).

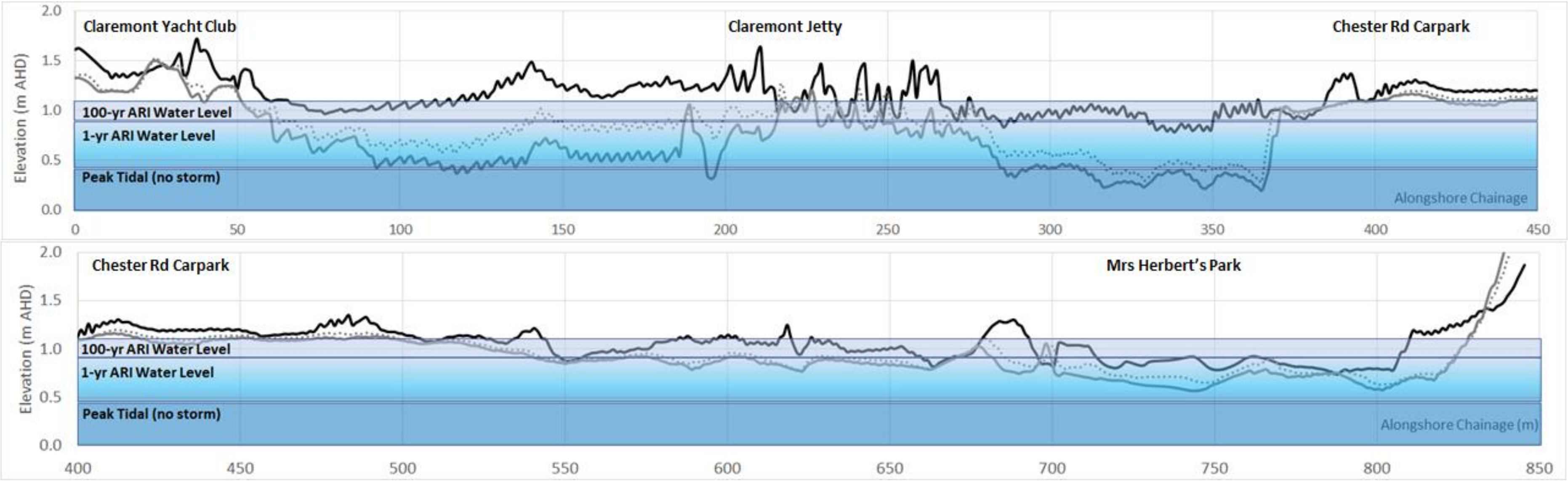

Figure 6: Foreshore and Inundation Levels

(a) Grey solid line is approximately along the vegetation line; (b) Black line is approximately along the property boundary; (c) Grey dotted line is intermediate, giving an indication of slope.

Comparison of inundation levels with foreshore levels suggests that about 50% (by length) of the foreshore area will experience inundation during a 1-yr ARI water level event of 0.88mAHD, but that most floodwaters will be contained within the foreshore reserve, as less than 10% of the property boundary is inundated. For a 10-yr ARI water level event of 1.04mAHD, approximately 70% of the foreshore vegetation line will be flooded and 30% of the property boundary will be inundated. During a 100-yr ARI water level of 1.19mAHD, approximately 90% of the foreshore vegetation line will be flooded and 50% of the property boundary will be inundated. Waves will typically add to flood hazard, although the occurrence of southerly winds and onshore waves is infrequently coincident with high water levels.

Photographs from the severe flooding event of May 2020 are included in Appendix C.

2.2. FORESHORE DYNAMICS

Changing waves and water levels cause beach sediments to be redistributed, including both cross-shore and alongshore sediment transport. Review of historic information (Appendix A) indicates that major changes have been caused by human activities, particularly reclamation works and installation of structures. Subsequent adjustment has been relatively gradual, due to the low energy setting and the relative shore alignment to modal wave conditions, with short-term foreshore movement due to variability of wave direction or water levels.

Short-term foreshore change is mainly caused by storm events, which typically cause beach flattening. During high energy or high water level events, there are two typical modes of change (Figure 7), with extension of the lower bank / beach gradient causing erosion, or deposition as an overwash berm (Figure 8).

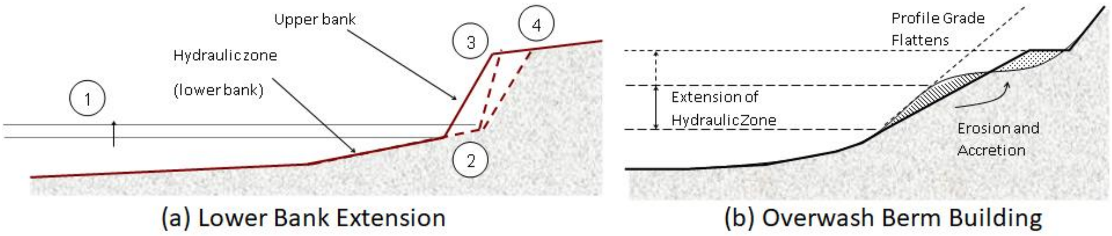

Figure 7: Typical modes of foreshore response to storms

Figure 8: Photograph of Overwash Berm

For typical grades occurring along Claremont foreshore, a storm event that extends the hydraulic zone by 0.1m can expand the beach 2.5m landward. Where the foreshore is fronted by a beach, this can cause a small (0.2m) cut. Where sedges are present, erosion can typically be resisted. However, if the sedge protection is ineffective, such as when they are undercut, there is potential for rapid shoreline retreat and scarp formation, up to 0.8m height.

Seasonal behaviour includes movement of prevailing and dominant (strongest) wind directions (Appendix A), causing wave directions to switch and potentially producing oscillatory sediment transport along the beach. This interacts with seasonal beach change caused by fluctuating water levels.

Over the longer-term, Claremont foreshore has gradually evolved, with net sediment movement in either direction away from the Chester Road revetment, accumulating to the east of Claremont Yacht Club (Figure 9) and in front of Mrs Herbert's Park (Figure 10). The rate of loss has been slow, with limited change in vegetation line (Appendix A). However, conversion of the upper beach slope to a sedged foreshore includes steepening, which is equivalent to 3 to 5m landward movement of the beach face.

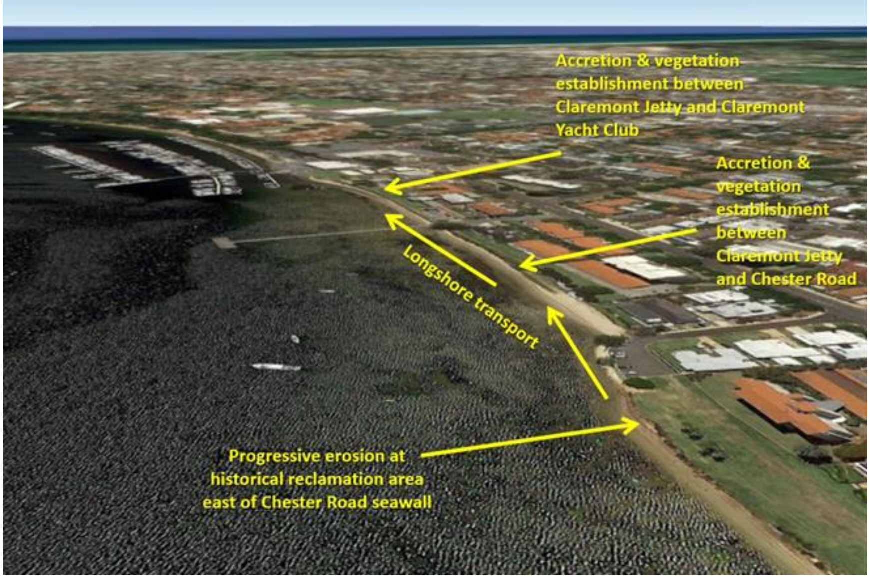

Figure 9: Claremont foreshore looking west (image source Google Earth)

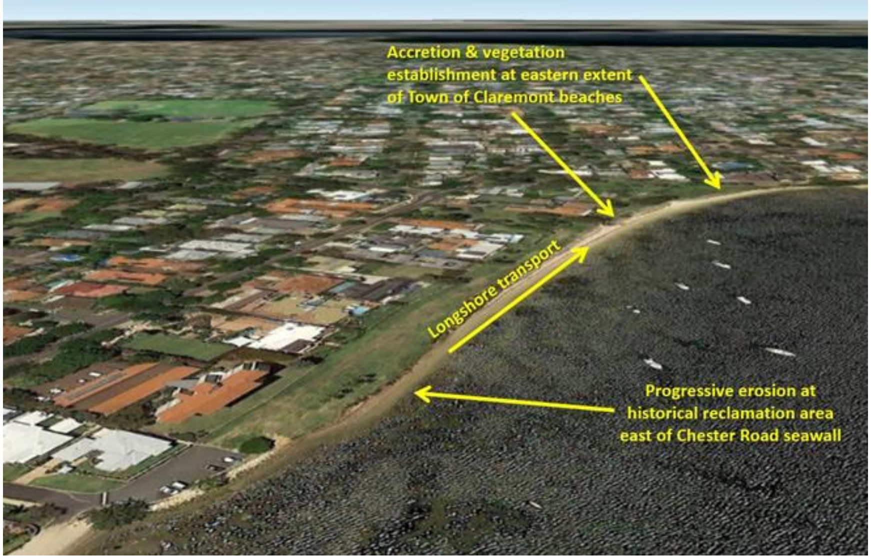

Figure 10: Claremont foreshore looking east (image source Google Earth)

Foreshore dynamics on the west side of Claremont Yacht Club include gradual loss from the area west of Christchurch Rowing Shed and deposition on the west side of CYC hardstand in the lee of CYC pens. This has had relatively low impact due to the small volumes of net transport but has created scarping west of Christchurch Rowing Shed, sand deposition on the CYC ramp area and apparently causes some shallowing in pens close to shore.

A model of foreshore dynamics has consequently been developed (Figure 11), based on information summarised in Appendix A. Claremont Yacht Club, through its armoured hardstand and shelter from mooring pens, divides the foreshore and provides a focal point for deposition. Transfer from west of Christchurch Rowing Shed towards CYC has not been consistent historically, with the Christchurch boat ramp providing a partial (above mean tide) barrier to alongshore sediment transport between 2004 and 2018.

Figure 11: Conceptual Model of Claremont Foreshore Dynamics

2.3. ACCESS

Pedestrian access is a key amenity for foreshore users east of Claremont Yacht Club, including access along Claremont foreshore reserve, access along the beach and access between the reserve and the beach.

Alongshore continuity of foreshore access is crucial, with approximately 4m required to provide good pedestrian access, although pinch points of 2m width may be tolerable for short sections. For the area east of Claremont Jetty, the width is minimal, which limits the capacity for expansion of the sedge zone (Figure 12). Areas where there is a loss of grass such as adjacent to Chester Road, can be considered lowered amenity.

Alongshore beach access does not need to be continuous, but longer sections are preferred. These typically require foreshore to beach access at several points, particularly at each end of the beach section. Beach access is constrained where the foreshore edge is steeper, with low-mid tide access in front of sedges and low tide access only in front of Chester Road revetment.

Access between the beach and foreshore reserve can occur at discrete points. Where sedges are planted, uncontrolled access can cause a breach, which can possibly undercut the vegetation.

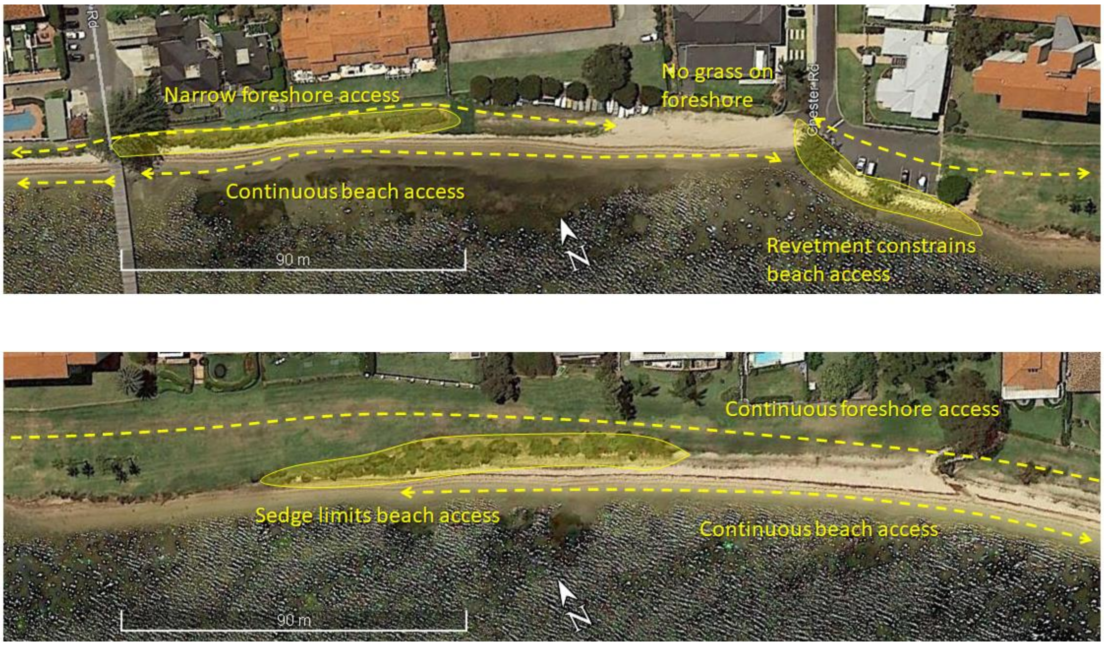

Figure 12: Illustration of beach and foreshore access

Pedestrian access to areas west of Claremont Yacht Club is required for discrete sections along the area used for dinghy storage and in front of Christchurch Rowing Shed. The latter is partly restricted where beach lowering has occurred and rock toe mattress has become exposed due to its low embedment. Continuous access along the foreshore is limited to low tides, with scarping progressively reducing accessibility under higher tides.

2.4. LOCAL SCOUR AND DEPOSITION

The large stormwater drain outlet adjacent to Claremont Jetty (Figure 13) provides a point of local scour and deposition due to variable stormwater flows. The cyclic pattern of scour and then infill, drawing from its surrounds, provides a local point of foreshore erosion pressure. Sediment in the vicinity of the drain may be mildly polluted from road runoff and therefore should not be used as a sand resource.

Figure 13: Stormwater Outlet

2.5. EXPOSURE OF RUBBLE

The foreshore area including Chester Road carpark was reclaimed, using fill of mixed quality, apparently including rubble and debris. Foreshore erosion, including retreat after Chester Road revetment was shortened, has exposed the rubble including rusting metal (Figure 14). The extent and volume of rubble and debris located along the foreshore is unknown.

Figure 14: Rubble, debris and undercut sedge adjacent to Chester Rd revetment

2.6. TENURE

The Town of Claremont and DBCA have shared management responsibility for Claremont foreshore under the Swan and Canning Rivers Management Act (2006). The foreshore is within the Swan-Canning Development Control Area and therefore under planning control of DBCA Statutory Assessments Unit.

Claremont foreshore has a high water mark tenure boundary, with a narrow foreshore reserve area mainly managed by the Town of Claremont, abutted by privately owned freehold lots (Figure 15). There are two areas of unallocated crown land within the foreshore reserve, and Claremont Yacht Club holds a seabed lease, with land ownership behind the foreshore reserve. This tenure arrangement determines the following foreshore managers:

- DBCA (Estuaries Branch) are responsible for management of the foreshore below high water mark.
- The Town of Claremont are responsible for management of the foreshore above high water mark, except the areas of unallocated crown land. This responsibility includes road reserves that provide access to the foreshore reserve.
- Department for Planning, Lands and Heritage are responsible for management of the crown land.
- Private land-owners are responsible for management of their land, subject to regulatory approval by the Town of Claremont.

- As seabed lease holders, CYC are not directly responsible for foreshore management, with the foreshore reserve separating the seabed lease from the privately owned land. However, in practice, CYC coordinate works to manage their lease area that affect the foreshore such as construction of walling or dredging, subject to regulatory approval by the Town of Claremont.

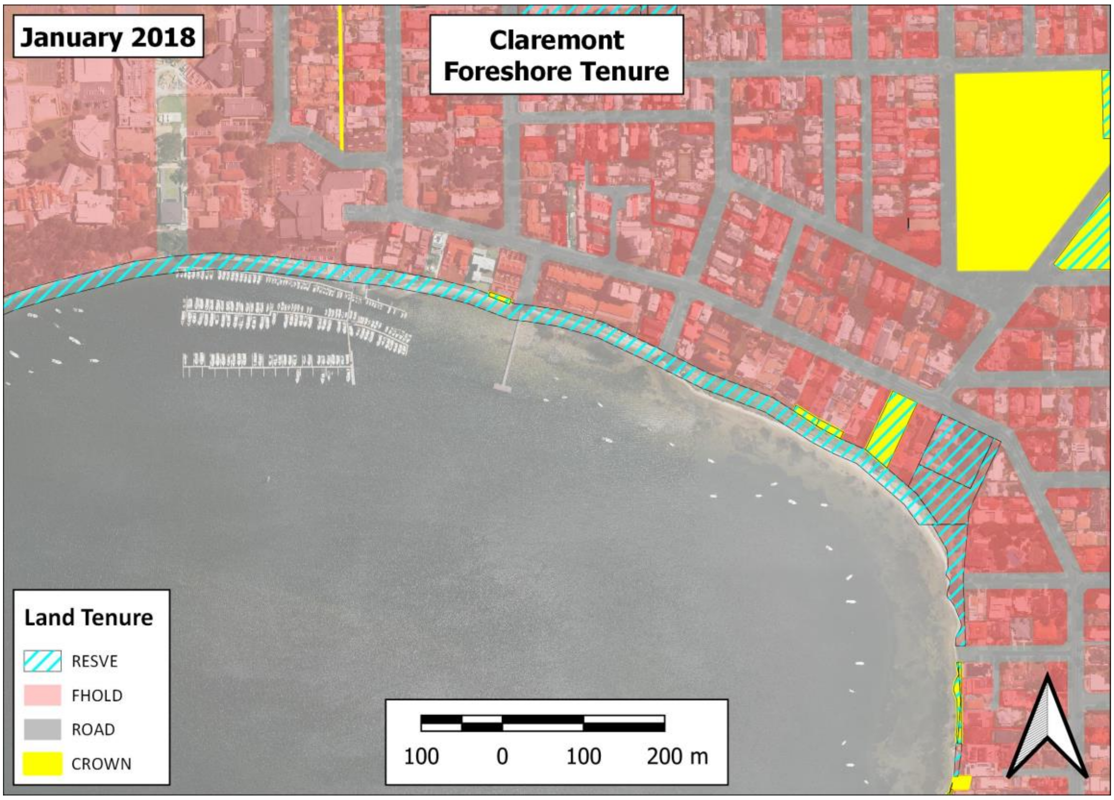

Figure 15: Tenure Map for Claremont Foreshore

Existing foreshore management activities are partly constrained by tenure, with the high water mark boundary causing an artificial division of management actions. Although activities crossing over tenure boundaries can often be easily agreed between parties, the effort to negotiate collaboration and required documentation for regulatory approvals provide a barrier to undertaking minor works that cross over. This barrier can be reduced through development of a management plan, agreed to by all parties. This would support more effective foreshore management, with focus on use of targeted, low impact works.

2.7. LONG TERM FORESHORE CHANGE

Long-term change, including projected sea level rise, is expected to modify the relative significance of the key issues. Unless otherwise managed, the overall expected response is progressive movement of the foreshore profile to landward (Figure 16), with increasing occurrence and severity of inundation. Vertical growth of the overwash berm will occur on the shoreward margin, but may not extend landward, creating a basin that is subject to intermittent flooding.

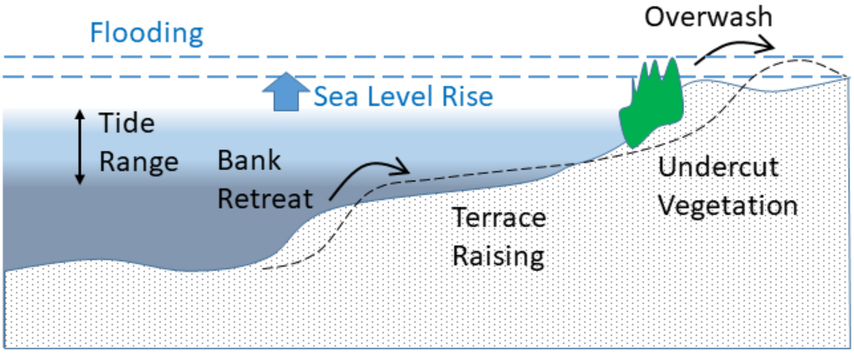

Figure 16: Long-term foreshore response to sea level rise (schematic)

3. Sand Management Considerations

3.1. SAND RESOURCES AND REQUIREMENTS

Available accumulations of sand along Claremont foreshore are resources that may be used to address some of the foreshore management issues:

- Ongoing accumulation of approximately 50 m^3/yr east of Claremont Yacht Club (Figure 17a) may be considered a sustainable source for the next 10 years. This was previously used as a resource by the Swan River Trust, who (anecdotally) undertook local backpassing. Over longer time frames, this rate of deposition will slow as the foreshore continues to erode and due to effects of sea level rise, effectively ceasing by 2070.
- Existing deposition to the east of Claremont Yacht Club has been estimated at up to 650m^3. This is a non-sustainable sand resource.
- Deposition west of CYC hardstand has been occurring at roughly 20-30m^3 over the last 65 years (~1600m^3). Land created by this deposition provides a narrow and low-lying foreshore buffer in front of the Claremont Yacht Club carpark extension, built in 2015. Capacity to extract sediment from this area is limited by its existing role as a buffer and dinghy storage area, with approximately 100m^3 considered presently available (Figure 17b). Extraction of the low and shallow volumes of deposited material would best be undertaken using beach scraping, with at least 5 years before further extraction.

(a) Deposition Lobe east of Claremont Yacht Club **(b) Deposition area west of Claremont Yacht Club**

Figure 17: Existing Points of Deposition

- Deposition on either side of Claremont Yacht Club potentially suggests there has been deposition within the yacht club seabed lease. This may be partly 'managed' by dispersion via propeller scour, with incidental scour holes where pens are close to shore. However, due to the historical nature of the yacht club site, there is high potential for contamination of deeper deposits or in areas within the pre-2000 yacht club footprint. Any material removed from the yacht club area should be subject to an appropriate chemical assessment before re-use.
- Although there are no identified plans for expansion of the yacht club pens, any development dredging may provide a large volume of sediment. Geotechnical and chemical testing is required to confirm its suitability for use (Section 3.2).
- Beach scraping may potentially be undertaken as a supplementary source, relocating sand from a beach area to a location of local stress, such as undercut sedges. Approximately 70m^3 could be harvested from a 100m length of beach offshore from Mrs Herbert's Park, approximately once every 5 years.

- External sand resources may be required if there is insufficient locally available material. These sources should be appropriately tested and require matching of size and colour to in-situ material (Section 3.2).

Estimated volumes of sediment needed to address some of the key issues are:

Issue	**Option**	**Required Sediment**
Inundation	Raise foreshore area mid-line to +0.84mAHD (1-yr ARI) and landward level to +1.11mAHD (100-yr ARI)	
	- West side of CYC	100 m^3
	- CYC to Claremont Jetty	100 m^3
	- Claremont Jetty to Chester Rd	500 m^3
	- Chester Rd to Mrs Herbert's Park	300 m^3
Foreshore Dynamics	Balance out approximate historic rates of loss	
	- CYC to Chester Road	60 m^3/yr
	- Chester Rd to Mrs Herbert's Park	25 m^3/yr
Exposure of Rubble	Cover rubble with sand	40 m^3/yr
	Excavate rubble and replace with sand	1200 m^3
Sea Level Rise	Balance overwash deposition on foreshore area for 0.2m SLR (2050)	
	- West side of CYC	120 m^3 (4 m^3/yr)
	- CYC to Chester Rd	170 m^3 (6 m^3/yr)
	- Chester Rd to Mrs Herbert's Park	150 m^3 (5 m^3/yr)
	Balance overwash deposition on foreshore area for 0.5m SLR (2070)	
	- West side of CYC	310 m^3 (9 m^3/yr)
	- CYC to Chester Rd	900 m^3 (44 m^3/yr)
	- Chester Rd to Mrs Herbert's Park	750 m^3 (37 m^3/yr)

Comparison of sand resources potentially required and available suggests there is likely to be insufficient sand to address all the foreshore management issues.

Time Frame	**2020-2030**	**2030-2050**	**2050-2070**
West side of CYC	100 m^3 required 100 m^3 available	4 m^3/yr required 25 m^3/yr available	9 m^3/yr required 25 m^3/yr available*
CYC to Chester Rd	1500 m^3 required 1150 m^3 available	66 m^3/yr required 50 m^3/yr available	104 m^3/yr required 50 m^3/yr available*
Chester Rd to Mrs Herbert's Park	650 m^3 required 140 m^3 available	30 m^3/yr required 14 m^3/yr available	62 m^3/yr required 14 m^3/yr available*

* Historically available rates may decline with accelerating SLR.

The deficit between potential required and available sand suggests a need to either prioritise available sand for specific uses, or cover the deficit using imported sand. Interpretation of an appropriate strategy is complicated by variability in the amount of sand required (on a year-to-year basis) and uncertainty associated with estimation of sediment volumes. Consequently, an adaptive sand management plan has been developed, that includes assessment of sand resources, needs and priorities.

3.2. ASSESSING SAND SUITABILITY

For any potential source of sand, whether obtained locally or externally, it is required that the sand be determined as suitable for placement. This shall include assessment of key biophysical characteristics of the source material, with varying requirements based on the history of the source site (Table 1). This generally follow relevant parts of the National Assessment Guidelines for Dredging (Commonwealth of Australia 2009), the Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) and WA Contaminated Sites Management series (DEC 2010).

Table 1: Sand Source Assessment

Source Origin	**Assessment Requirements**
Local, surface source: Source and placement site within the same local area of sediment circulation and extracted from the near surface (<1m depth).	Confirm the source site is free of debris, organic matter or odour. Undertake a minimum of 5 particle size distributions using sieve, settling tube or other graduate methods. Confirm median source particle size (D50) exceeds that of the placement site, or D50>0.6mm. Confirm there is less than 2% of fine sediment (smaller than 0.12mm) Confirm the source material has a matching colour to the placement site or can be cleaned to provide a match.
External source with existing sediment sampling demonstrating no contamination.	As above.
Local source with source from >1m depth.	As above plus evaluation of: • Tributyltin (TBT) which is an organotin. • Polycyclic aromatic hydrocarbons (PAHs). • Total petroleum hydrocarbons (TPHs). • Chromium reducible sulphur (refer to DEC 2013).
External source with no existing sediment sampling.	Development and implementation of a Sediment Sampling and Analysis Plan (SAP) to identify potential contaminants of concern and assess comprehensively. At minimum, this will be as above, plus: For sites with upstream riverine origin: • Organochlorine pesticides. For sites potentially exposed to industrial pollution: • Polychlorinated biphenyls (PCBs). • Benzene, toluene, ethylbenzene, xylene (BTEX).

3.3. INVESTIGATIONS

Decision-making regarding sand management along Claremont foreshore may require two investigations to be conducted:

1. Investigation of the sand lobe on the east side of Claremont Yacht Club
2. Evaluation of the distribution of rubble east of the Chester Road revetment and determination of appropriate longer-term management.

The sand lobe has previously been used as a local sand source by the Swan River Trust and the volume which has been deposited since it was last used is highly likely to be suitable for use. However, it is unclear how much has previously been removed, and whether any of the lobe's volume contains rubble or other material unsuitable for sand renourishment. Investigation options may either be undertaken prior to excavation, with a truck-mounted bore ($7,500-$10,000 hire per day), or as part of sand management works, where material is assessed as it is excavated, and operations are stopped if unsuitable material is reached.

Existing knowledge of the rubble east of Chester Rd revetment suggests that it is mainly inert material and therefore it creates no adverse issues when buried. However, it is acknowledged that a series of partial removals as different areas become exposed is likely to provide ongoing poor amenity. Consequently, it is necessary to evaluate the total distribution of rubble and develop an achievable strategy for rubble management. An investigation combining ground penetrating radar with vacuum excavation (cost estimate $5,000) is recommended as a first step, with subsequent options assessment by a geotechnical professional.

3.4. CLASSIFICATION OF SAND MANAGEMENT ACTIONS

Sand management activities required for effective management of Claremont foreshore range in scope, with different levels of project controls (and consequent regulatory approval) required to ensure acceptable outcomes. A provisional classification of sand management actions is presented (Figure 18), which separates the activities into minor, intermediate or major actions, each with associated levels of permitting.

MINOR ACTIONS	All of the following: • Volume of sand <150m^3/yr • Claremont foreshore sand source • No pollutants • Excavation < 0.2m	Notification by Town of Claremont
INTERMEDIATE ACTIONS	All of the following: • Volume of sand <600m^3/yr • Claremont foreshore sand source or Certified clean sand source • Excavation < 0.2m	Written permission from DBCA and DPLH
MAJOR ACTIONS	Any of the following: • Volume of sand >600m^3/yr • Uncertified foreshore sand source • Potential for pollutants • Excavation > 0.2m	Formal Environmental & Heritage submissions

Figure 18: Classification of Sand Management Actions

Minor actions are those for which the Town of Claremont provides notification to DBCA and DPLH, without requiring formal permission to proceed. This may include activities such as sand placement on the beach area or small-scale beach scraping, where turbity issues are managed through small scale and timing of works during low tide and non-winter conditions. Endorsement of this Sand Management Plan by DBCA is intended to provide enduring permissions for the Town of Claremont to conduct small scale works below the high tide mark (i.e. within DBCA's management area). This will streamline the permissions process and increase effective use of minor actions for foreshore management.

Intermediate actions are those where written permission is required from DBCA and DPLH. A project outline shall be provided by the Town of Claremont to seek this permission, outlining scope, timing and controls to limit adverse impacts.

Major actions are those where formal environmental and heritage submissions will need to be prepared, demonstrating the adequacy of project controls to limit adverse impacts. Due to the presence of pollution and the estimated volume of excavation required, remediation of the exposed debris to the east of Chester Road revetment is a major action.

3.5. WEST OF CLAREMONT YACHT CLUB

West of Claremont Yacht Club, foreshore dynamics suggest net movement from the foreshore west of Christchurch Rowing Shed to the east, where they accumulate west of CYC hardstand, in the shelter of the yacht club pens (see Appendix A for additional description). Progressive scarping of the foreshore west of the rowing shed and accumulation in the yacht club area are acknowledged as adverse impacts, occurring at a relatively slow rate. However, because erosion of the scarp involves activation of the foreshore material, moving deposited sediment back in front of the scarp will provide limited protection and would not substantially slow foreshore change. Consequently, sediment management is not considered a primary tool for management along this section of foreshore.

Treatment via stabilisation preferred, as this will reduce both scarp formation west of Christchurch Rowing Shed and sedimentation west of CYC hardstand. However, due to limited assets along this section and slow rates of change, there is limited economic justification for stabilisation works, unless scarps are large and steep enough to threaten geotechnical instability. An alternative reason to undertake stabilisation is to provide safe low-tide beach access, however west of the rowing shed has very low use, and safety risk could be effectively managed by prohibiting access. In this setting, it is recommended to use local scarp management, until there is significant slip risk (Table 2).

Table 2: Local Scarp Management Monitoring, Triggers and Actions

Monitor:	Inspect Foreshore every 5-10 years, assessing scarp height & looking for signs of instability (scarp collapse). Inspect in during low tides in October-November to maximise access.
Trigger:	Active scarp height >1.5m for <25m lengths
Action:	Local scarp knock-down, pending accessibility
Trigger:	Active scarp height >1.5m for >25m lengths
Action:	Undertake geotechnical assessment of slip risks, to identify suitable actions & determine setback trigger

Christchurch Rowing Shed is the only asset for which foreshore dynamics may strongly impact amenity, particularly through exposure of shallow buried rock toe mattresses (see Appendix A for observed behaviour). As the structure is only recently constructed, it is unclear is this is short term response or a long-term trend. Ongoing inspection of the beach should be undertaken, to help identify potential mechanisms for change (Table 3), assess foreshore access and confirm adequate structural integrity. Structural adaptation may include addition of a short groyne to the east of the structure (which has the benefit of reducing sediment transfer towards Claremont Yacht Club), or construction of a more deeply embedded toe if the mattress fails.

Table 3: Potential Mechanisms, Behaviour & Responses Near Rowing Shed

Potential Mechanism	Behaviour	Possible Response
Reduced control on foreshore position	High rates of eastward sediment transport continue for 3+ years	Stabilisation structure near centre of gabion walling (reduces beach access)
Response to pushing beach forward	High rates of eastward transport end in < 3 years	Not required
Local scour due to wave reflection	Beach locally lowered in front of gabions	Locally baffle waves
Local scour due to downdrift erosion	Beach seasonally lowers on east side of rowing shed	Stabilisation structure on east side of gabion walls
Gabion mattress constructed too high	Undermining causes damage to mattress	Lower mattress

Table 4 outlines a preliminary monitoring framework for the foreshore immediately adjacent to the Christchurch Rowing Shed. Actions are presently noted as investigative, as the cause of erosion is uncertain. Quarterly monitoring is recommended, as it is unclear whether beach conditions will be worst under peak seasonal conditions, or at the end of winter or summer.

Table 4: Local Scarp Management Monitoring, Triggers and Actions

Monitor:	Inspect foreshore every 3 months, to evaluate foreshore access and structural integrity. Inspect in June-July (mid-winter), September-October (end of winter), December-January (summer recovery) and April (before winter). Collect photographs at fixed locations.
Summer or Autumn Trigger:	No dry / safe pedestrian access along the gabion walling
Action:	Assess options for improved accessibility
Winter or Spring Trigger:	Damage to or undermining of gabion toe mattress
Action:	Assess options for improved structural performance

4. Existing Vegetation and Revegetation Works

Effective sand management integrally relates to the presence and functions of foreshore vegetation. This is a two-way consideration, with vegetation potentially providing sediment retention and affecting sediment redistribution, and sediment deposition or loss potentially causing smothering or undercutting.

Previous planting of riparian vegetation has focused on use of *juncus kraussi*, which preferentially occupies the upper intertidal zone (0.3 – 0.7 m AHD). For the prevailing structure along Claremont foreshore, there is a narrow niche which can be occupied, generally resulting in a narrow fringe of riparian vegetation (Figure 19). This fringe can be fragile, subject to undercutting during storm events, or it may actively trap sediment, helping to build a foreshore berm.

(a) Juncus kraussi fringe in moderate health **(b) Remnant juncus kraussi fringe**

Figure 19: Examples of riparian fringes in fair and poor states

Greater health and thickness of the riparian fringe will improve resilience of the foreshore to disturbance events. This requires a wider band of riparian vegetation, typically 4-5m. As the existing foreshore is towards the upper limit of *Juncus kraussi*, a robust band of riparian vegetation may require either (i) slight lowering of the foreshore behind the existing sedges and planting with mature juncus from >140mm pots, or (ii) raising of the foreshore behind the existing sedges and planting with *Ficinia nodosa* and further away from the waterline *Lepidosperma gladiatum* (preferably above 1.5mAHD), as these species have good soil stabilisation properties.

Opportunity for greater species diversity to improve ecological function may include sporadic planting of samphire (*Sarcocornia quinqueflora*) and seablite (*Suaeda australis*) among the juncus. However, these species do not have substantial root structures and therefore are reliant on the juncus for soil stabilisation, and hence juncus must remain the main floral element.

Other salt tolerant species that can be blended to landward with the *Ficinia nodosa* and *Lepidosperma gladiatum* include *Atriplex spp*, *Sporobolus virginicus*, *Threlkeldia diffusa, Tetragonia tetragonoides*, *Tecticornia spp*, *Samolus junceus* and *Frankenia pauciflorus*.

Melaleuca cuticularis and *Casuarina obesa* shrubs provide useful soil retention and high salt tolerance. However, it is recognised that there is likely to be limited appetite for vegetation that affects sight lines, so any planting should be limited, at carefully selected locations and in small clumps of two or three shrubs.

Planting locations should preferably be:

- Along the more stable sections of foreshore (i.e. away from scarps or areas of widely fluctuating foreshore beach). When used in less stable areas, riparian planting will be subject to occasional disturbance, and should be considered as requiring active maintenance.
- Placed in continuous lengths of more than 25m, with gaps aligned with preferred access points between the foreshore area and the beach. General alignment should be parallel with the existing vegetation line.
- When more broadly spaced, the capacity for a length of riparian vegetation to create a point of alongshore control should be recognised. The key implication is increased capacity for erosion on the downdrift side (Figure 11).
- Fenced off from the landward side during an establishment phase of at least 1-2 years.
- Riparian planning should typically be supported through placement of a sand buffer in front, to support vegetation during a period of establishment.

Foreshore vegetation should be monitored regularly (approximately monthly), with appropriate seasonal planting to replace damaged or lost plants. Overall performance of foreshore vegetation should be reviewed at a minimum every 3-5 years. There is a potential need to adjust species composition over time, with appropriate supplementary planting to ensure dense growth and foreshore stabilisation.

5. Sand Management Plan

Sand management actions for Claremont foreshore east of Claremont Yacht Club are presented. As discussed in Section 3.5, sand management is not considered a primary tool for foreshore management west of Claremont Yacht Club, although accumulated sand may be a supplementary source for sand management to the east.

5.1. INSPECTIONS

Twice annual inspection of the foreshore by a Town of Claremont representative shall be undertaken in September and March. Photographs should be taken to support recommended actions. Inspection shall identify:

- Areas of sedge undercutting or root exposure by more than 0.2m. This represents a situation with potential for rapid foreshore erosion and should be addressed as a priority.
- Scarping of more than 0.3m height. This represents a potential trip hazard but may also be indicative of erosion.
- Exposure of rubble or debris.
- Loss of accessible foreshore grass coverage or width.
- Indications of inundation across the foreshore reserve such as wave debris lines.

Inspections shall be reported to the Town of Claremont Foreshore Committee.

5.2. IDENTIFICATION OF MAJOR SAND REQUIREMENTS

Two issues have been identified for Claremont foreshore requiring major sand management activities, being (i) infilling to reduce inundation hazard; and (ii) management of the exposed rubble east of Chester Road revetment. These projects are expected to require formal project planning and appropriate permissions. The quantity of sediment required to address these issues may affect the availability of sand for minor foreshore management activities.

5.3. IDENTIFICATION OF SHORT-TERM SAND REQUIREMENTS

Evaluation of sand requirements shall be undertaken, based on the foreshore length of undercutting, scarping or rubble exposure (i.e. addressing erosion), plus an estimate of the area exposed to inundation.

An estimate of the sand required to address erosion shall be based upon 0.5m^3 per metre of foreshore experiencing undercutting, scarping or rubble exposure (Figure 20a). This quantity shall be reviewed on an annual basis, after observing performance of placed material.

The need to address inundation requires consideration of the severity of events experienced since the previous inspection:

- If foreshore inundation has occurred due to a flood event exceeding the 10-yr ARI water level (1.04mAHD or 1.80mCD), based upon the Department of Transport’s Barrack Street tide gauge record, then sand placement is not considered necessary.
- If inundation has been caused by a lower event, then 1m^3 of sand per metre of foreshore should be placed and spread on the foreshore (Figure 20b).

Sand placed to address erosion is considered to have a higher priority than that required to address inundation.

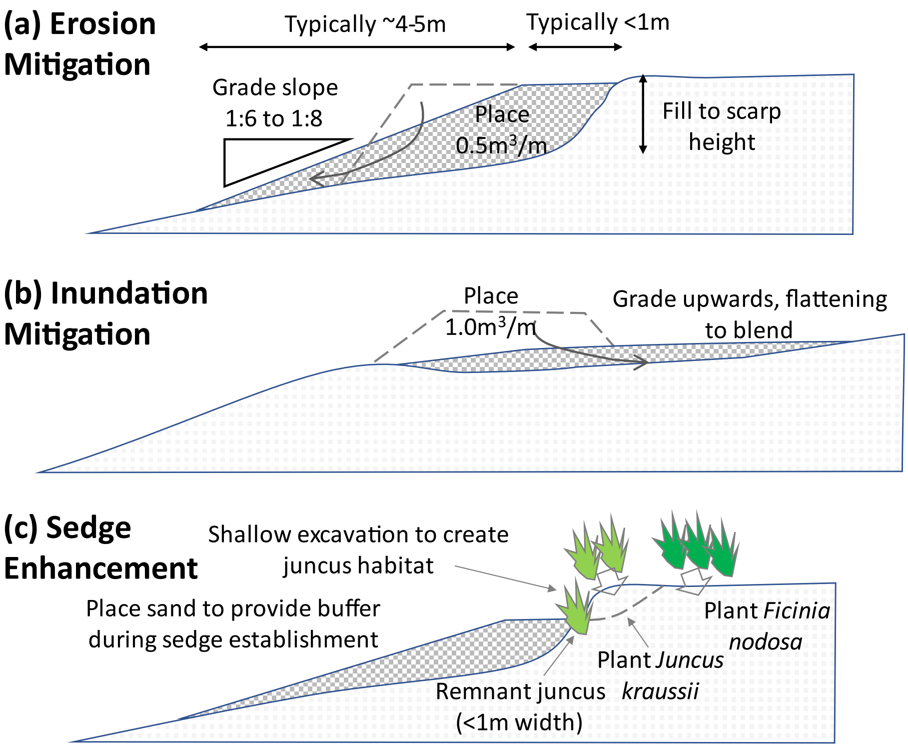

Figure 20: Indicative placement by cross-section

Calculating sand requirements from an inspection involves multiplying the lengths of scarping or inundation by typical placement rates. For the example presented in Figure 21, a total length of 90m scarping (0.5m^3/m), 25m of exposed rubble (1 m^3/m) and 95m of inundation hazard (1m^3/m), has a sand requirement of 165m^3. If only 120m^3 of sand was available, then 70m^3 would be placed on the scarped areas and only 50m^3 placed at the inundation sites.

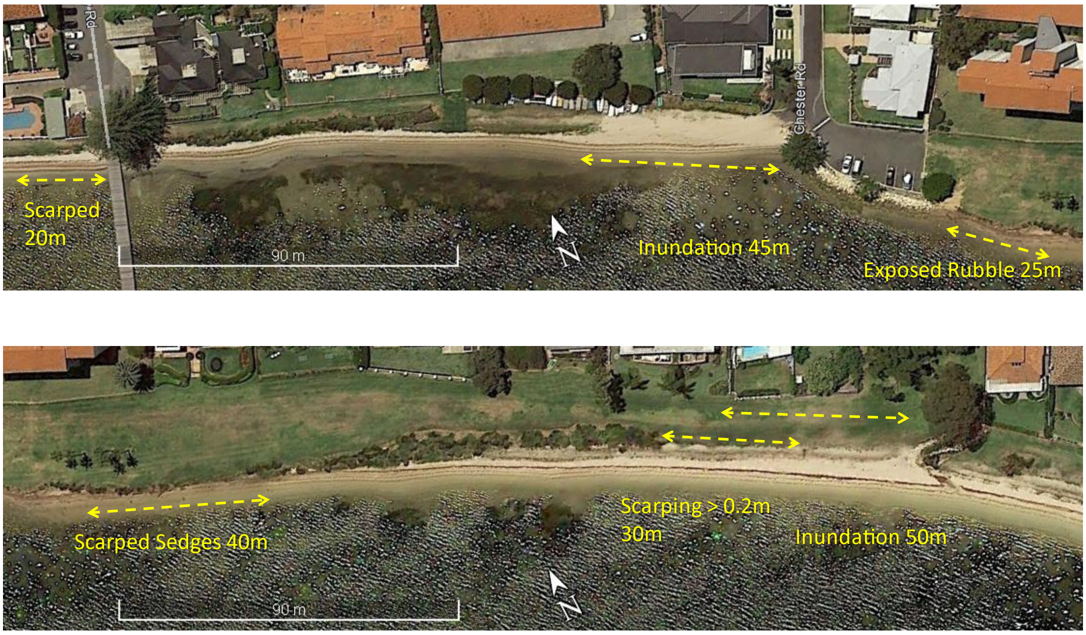

Figure 21: Example of inspection outcome

5.4. CONFIRMATION OF SAND RESOURCES

Availability of sand resources to address the sand requirements shall be undertaken as part of inspections. This shall include:

- Identification of approximate sand volumes available adjacent to CYC on the beach. This requires that the beach is not 'concave' (steep adjacent to vegetation), with a clear beach ridge and no scarping (see Figure 17a for an example). An estimate of available volume shall be based upon 0.1m times the width and length of the beach. It is anticipated that sand harvesting from this beach can be achieved every 1-2 years.
- Estimation of sand volume remaining in the grassed area east of CYC, based upon previous extractions.
- Identification of approximate sand volumes available from the beach in front of Mrs Herbert's Park. This requires that the beach is not 'concave', with a clear beach ridge and no scarping. An estimate of available volume shall be based upon 0.1m times the width and length of the beach. It is estimated that sand harvesting from this beach can be achieved every 3-5 years.
- Identification of approximate sand volumes available from the beach west of CYC hardstand. This requires that the beach is not 'concave'. An estimate of available volume shall be based upon 0.05m times the width and length of the beach. It is estimated that sand harvesting from this beach can be achieved every 5-10 years. Due to the low wave energy on this beach, disturbance by plant (likely a bobcat) may result in a boggy beach. Consequently, it is important to undertake works during low tide, providing the best opportunity for beach material to settle under tidal wash.

5.5. BALANCING OF SAND REQUIREMENTS AND RESOURCES

Estimated volumes of sand required and available shall be compared.

- If there is sufficient supply to address the requirements, the volume of sand necessary for placement shall be used to classify sand management actions as minor, intermediate or major (Figure 18).
- If there is an overall deficit of material, an external source of clean, coarse sand shall be identified, to supplement the available material.

Where there is a small deficit, and some of the sand requirements are caused by scarping, an option to knock down a section of scarp shall be considered. This reduces the volume of sand required, but reduces the width of the foreshore reserve, and consequently should be undertaken only where there is a wide (>10m) foreshore reserve.

5.6. FORESHORE TREND ASSESSMENT

The recommended approach of using observations of scarps and evidence of inundation to guide sand management needs provides a simplified, flexible method to cater for year-to-year variability of pressure on the foreshore. However, longer-term success of sand management also requires a more quantitative evaluation, to support adaption of the foreshore management approach.

The overall slow rate of change occurring along Claremont foreshore supports infrequent assessment of the foreshore. Once every 5 years, trends of foreshore change shall be assessed. This shall involve:

- Collection of a field-based photographic record, corresponding as much as practical to sites previously photographed (Department of Transport 2013).

- Collation of management records over the preceding 5 years, including identification of how much sand has been extracted from non-sustainable sources (i.e. east of CYC hardstand).
- Obtaining recent high-quality aerial imagery from Landgate or an alternative provider (e.g. Nearmap).

This information shall be collated in a short report, identifying apparently trends and evaluating the efficacy of the management efforts to address foreshore management issues. This evaluation should identify rates of horizontal foreshore movement (m/yr), but it will be important to place these values in the context of weather and tide conditions experienced between assessment periods. Recommendations for variation of the sand management approach shall be identified.

It is noted the 5 yearly time scale of trend assessment is not indicative of foreshore management time scales. Episodic change (e.g. impact of a severe storm) is typically rapid and may require urgent response. More typically, response should be undertaken when seasonally appropriate.

6. Action Summary

Actions to be undertaken as part of the Sand Management Plan are summarised by Table 5.

Table 5: Summary of SMP Actions

Initial Actions (2021-2022) • Investigate the sand lobe on the east side of Claremont Yacht Club. • Evaluate of the distribution of rubble east of the Chester Road revetment. • Establish a foreshore baseline, suitable for trend assessment.
Sequential Actions (2022 onwards) • Geotechnical options assessment for rubble east of Chester Rd revetment. Determine and implement the appropriate management.
Annual Actions (ongoing) • Undertake sand demand and resource assessment to determine annual sand management. Undertake placement, preferably in October-December.
Irregular Actions (ongoing) • Assess sand resource on beach in front of Mrs Herbert’s Park (every 3-5 years). • Assess sand resource on beach west of CYC hardstand (every 5-10 years). • Foreshore trend assessment (every 5 years).

The SMP deliberately does not lead to a fixed volume of sand management but combines evaluation of sand requirements and resources to determine the actions required on an annual basis. Based on historic patterns of shoreline change, it is anticipated that approximately 125 m^3/yr (on average) will be required to address erosion pressure, with further sand required to address inundation hazard. This quantity exceeds the estimated 70m^3/yr average rate of sand supply, indicating there is a need to extract sediment from areas where it has accumulated historically.

7. References

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Appendix A: Freshwater Bay Foreshore Drivers and Dynamics

FORESHORE DRIVERS

Claremont foreshore is subject to hydrodynamic forcing by waves, currents, and water level variability. These processes cause constantly changes to the distribution of stresses on the beach and foreshore, which can lead to adjustment of the foreshore shape through sediment transport.

There are no direct measurements of meteorologic or oceanic data available from Freshwater Bay. Consequently, behaviour has been interpreted based upon nearby water level and wind records:

- Barrack Street tide gauge record, maintained by the Department of Transport, has been evaluated, including the available modern record from 1988-2020 and previous historic record from 1930-1977 (Scott 1977). Due to the relative widths of Perth Water and Melville Water compared to the narrow channel between Fremantle and Freshwater Bay, the Barrack Street record is considered a fair representation of water levels along Claremont foreshore – although minor differences will occur because of local wind setup due to winds across different basins.
- Melville Water wind record, from the Bureau of Meteorology weather station AWS9091, is available from 1999-2020. The wind record indicates the capacity for wave generation across the surface of Freshwater Bay, although this is modulated by the effective fetch (Figure 22), increasing waves generated by southeast winds on the west side of the bay and increasing waves generated by southwest winds on the east side of the bay.

This evaluation neglects the potential influence of boat wakes, which provide another source of wave energy. These typically provide a much smaller contribution of nearshore wave energy on a gently sloped beach compared to wind waves, but have the capacity to produce higher individual wave crests and more acute angles, increasing their relative impact.

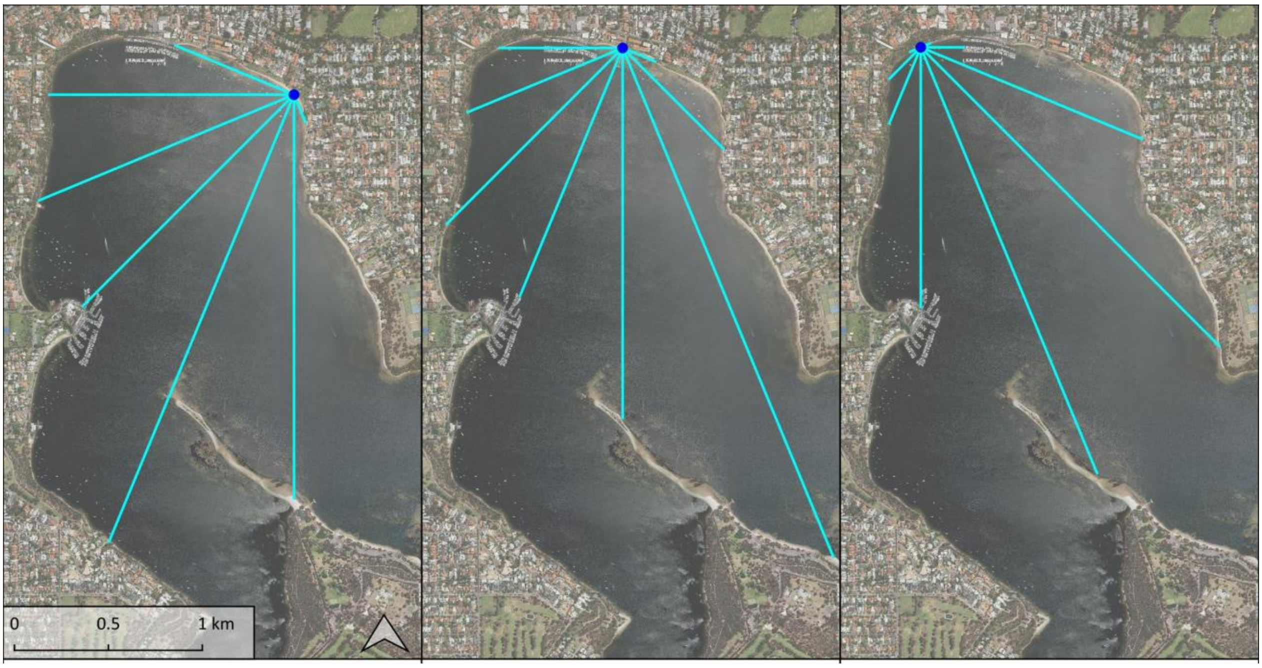


Figure 22: Freshwater Bay Indicative Wind Fetches

Water Level Variability

Water levels inside Melville Water and Perth Water are dominated by marine influences, including tides, surges, and mean sea level fluctuations (Eliot 2012). Although riverine flooding historically demonstrated the capacity to cause extreme water levels within Melville Water (Fraser 1905), the scale of the estuarine basins causes significant damping of runoff flooding, with further reduction over the 20th Century due to catchment modification (Middelmann *et al.* 2005).

Long-term water level measurements from Barrack Street (Perth) tide gauge (Figure 23) show historic annual maximum-minimum water levels digitised from tide traces (1930-1977), and hourly digital observations (1988-2020) from the Department of Transport tide gauge. The record reflects:

- Microtidal conditions, which are mainly diurnal, with one high tide per day.
- An overall rise, which corresponds well to the 20th Century trend observed at Fremantle (~1.7mm/yr), which reasonably matches estimates of global mean sea level rise (Douglas 2001).
- Inter-annual mean sea level variability, which is strongly linked to global-scale climate fluctuations, which contributed to a rapid rise from 1990 to 2011 (White *et al.* 2014).
- Seasonal and episodic variability, with high water levels mainly occurring in May to July. The highest water levels are all associated with extreme storm surges, although storm type and surge processes may vary through the year (Eliot 2012, Pattiaratchi & Wijeratne 2014).

Notably, since 2000, 7 of the 10 highest recorded water level events have been observed, indicating increased recent stress. It is notable that this period is a result of several different phenomena, including a period of sustained high mean sea level in 2011-2013.

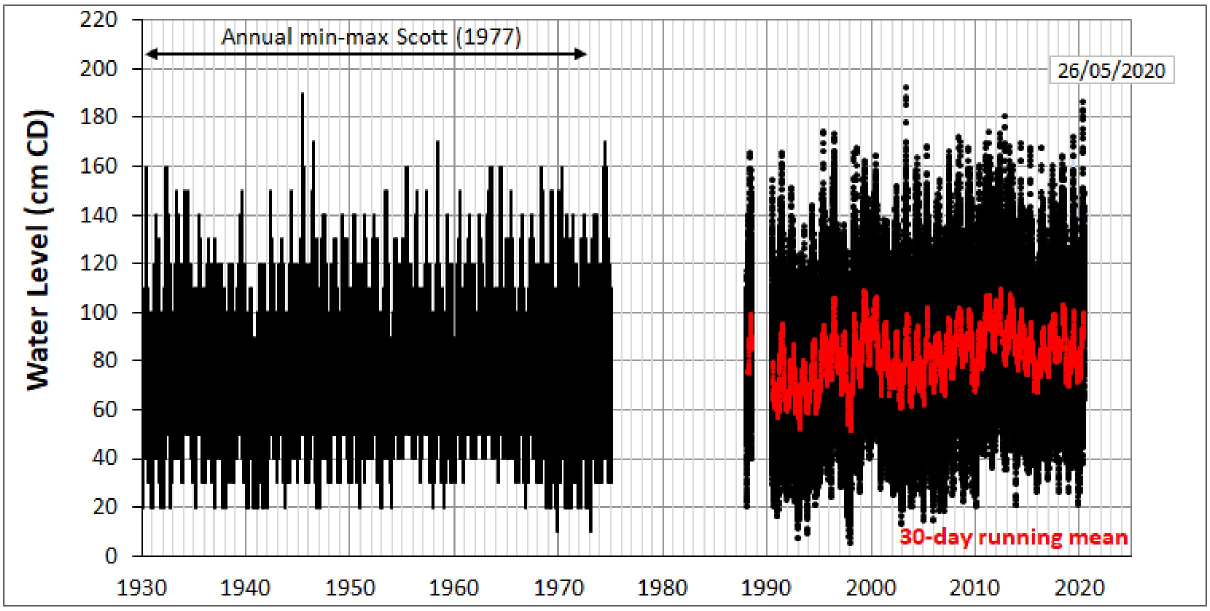


Chart Datum (CD) is approximately 0.76m below Australian Height Datum (AHD), which roughly corresponds to mean sea level.

Figure 23: Barrack St Tide Gauge Entire Historic Water Level Record

The modern water level record from 1988-2020 (Figure 24) more clearly illustrates the 'spiky' nature of high water level events, with most water levels above 1.4mCD (0.84mAHD) lasting for <12 hours. Below this approximate threshold, there is a significant increase in water level occurrence, as levels can be reached by a combination of high tide with small surge, or high surge with moderate tide.

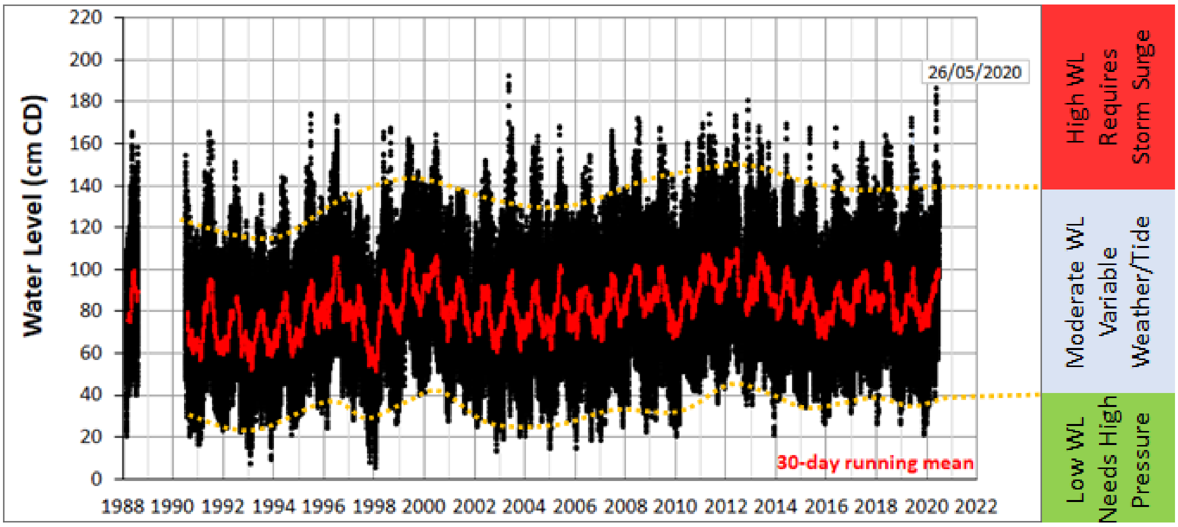


Chart Datum (CD) is approximately 0.76m below Australian Height Datum (AHD), which roughly corresponds to mean sea level.

Figure 24: Barrack St Tide Gauge Modern Water Level Record

Seasonal variation in high water level events is contributed to by tide, surge and mean sea level fluctuations (Figure 25), which all have seasonal patterns:

- Tide has two peaks per year in June-July and December-January.
- Storm surge typically peaks in May-June, but there is capacity for large events all year around, including the effects of occasional southward travelling tropical cyclones and ex-tropical cyclones. TC Alby (April 1978) caused extreme water levels for much of southwest Western Australia.
- Mean sea level varies by 0.2-0.3m over each year, with a peak typically occurring in May-Jun. This variation is strongly tied to large scale weather and oceanographic variations.

Coincidence of peaks for these processes in May-July provides a narrow seasonal window in which extreme water levels most frequently occur.

The significance of different processes contributing to high water level events for foreshore management is illustrated by time series of annual threshold exceedance rates and annual maxima (Figure 26). As inundation of the Freshwater Bay foreshore commences at approximately 1.55mCD (0.79mAHD), a relative indication of foreshore stress is suggested by exceedance around this threshold. Exceedance varies substantially from year to year, corresponding poorly to annual maxima. It is noted that the period of greatest exceedance was 2011-2013, which corresponded to high mean sea level conditions during the 'marine heatwave' caused by a severe La Niña climate phase (Bureau of Meteorology 2012).

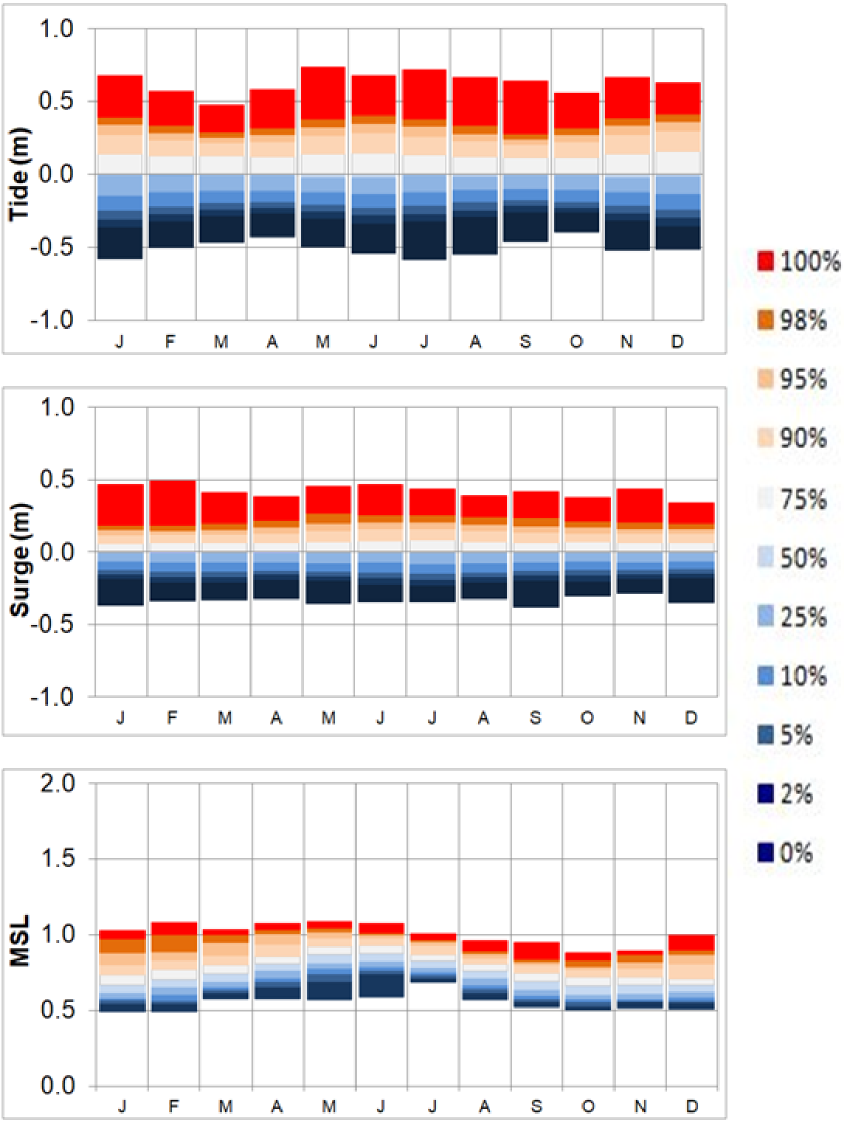


Figure 25: Seasonal Variability of Water Level Components

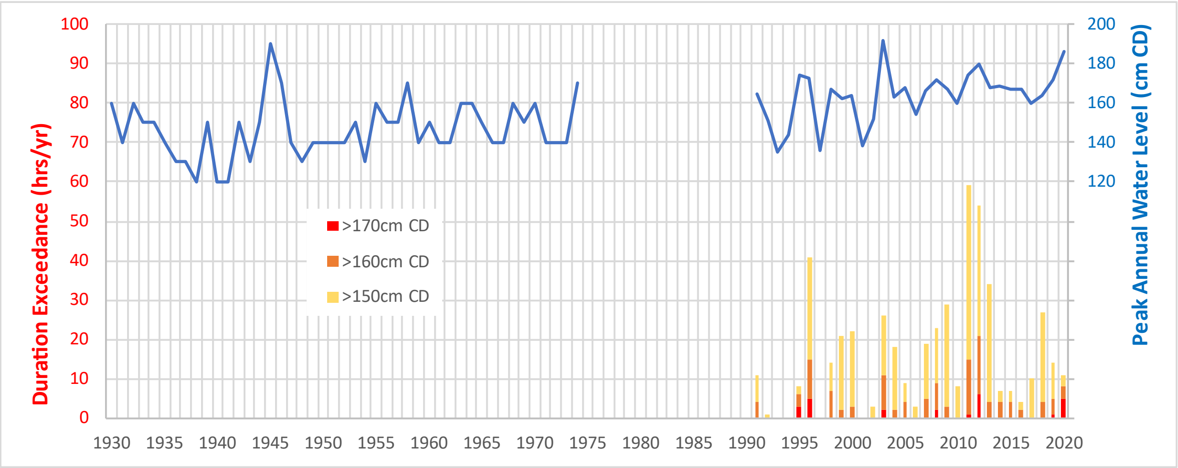


Figure 26: Barrack Street Annual Exceedance Rates and Maxima

Wind Conditions

Winds affecting Freshwater Bay are developed through a combination of prevailing regional winds, weather systems and land-sea breezes. These components all vary spatially due to terrain and distance from the coast, and consequently require interpretation from a point of observation to a site of interest. Bureau of Meteorology site AWS9091 was selected as a likely best available representation of winds across Freshwater Bay due to its location near the centre of Melville Water, on a pylon 400m east of Pelican Point, Crawley.

The overall wind record suggests a generally bimodal pattern of easterly and south-southwest winds (Figure 27), which is characteristic of the land-seabreeze cycle prevailing for much of the year in Perth.

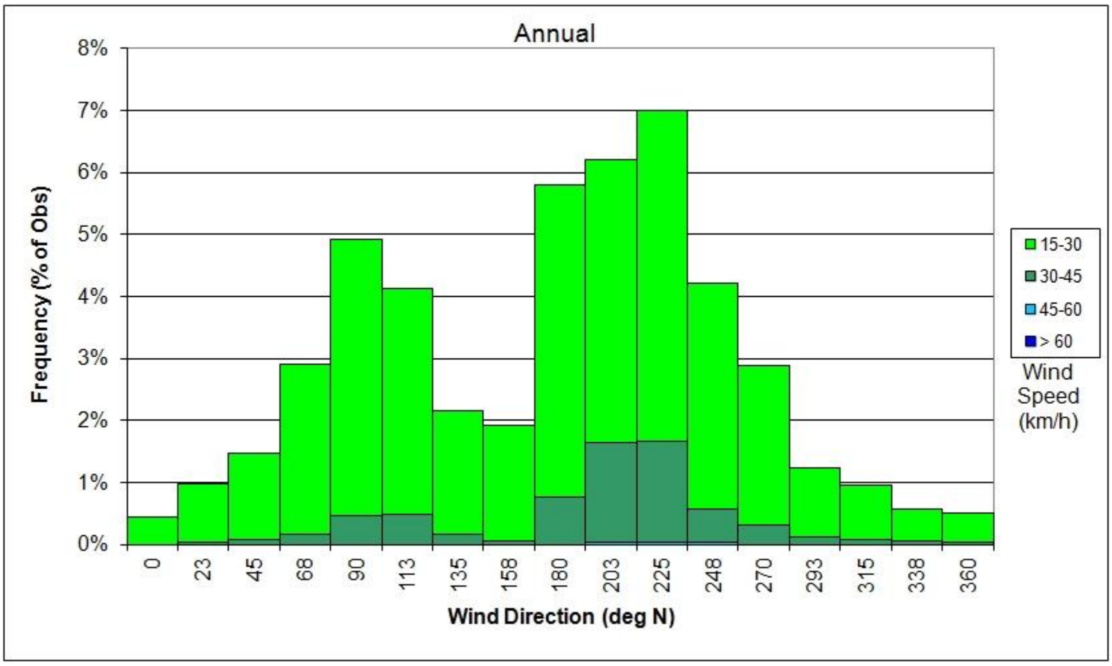


Figure 27: Annual Average Wind Speed and Direction Distribution

Seasonal variation of the wind distribution (Figure 28) occurs in response to changing weather conditions, particularly the increased incidence of mid-latitude storms and reduced effect of diurnal heating and cooling over winter months. This causes weakening of the land-seabreeze system from April to August and increased occurrence of westerly (SW through NW) winds between June and September.

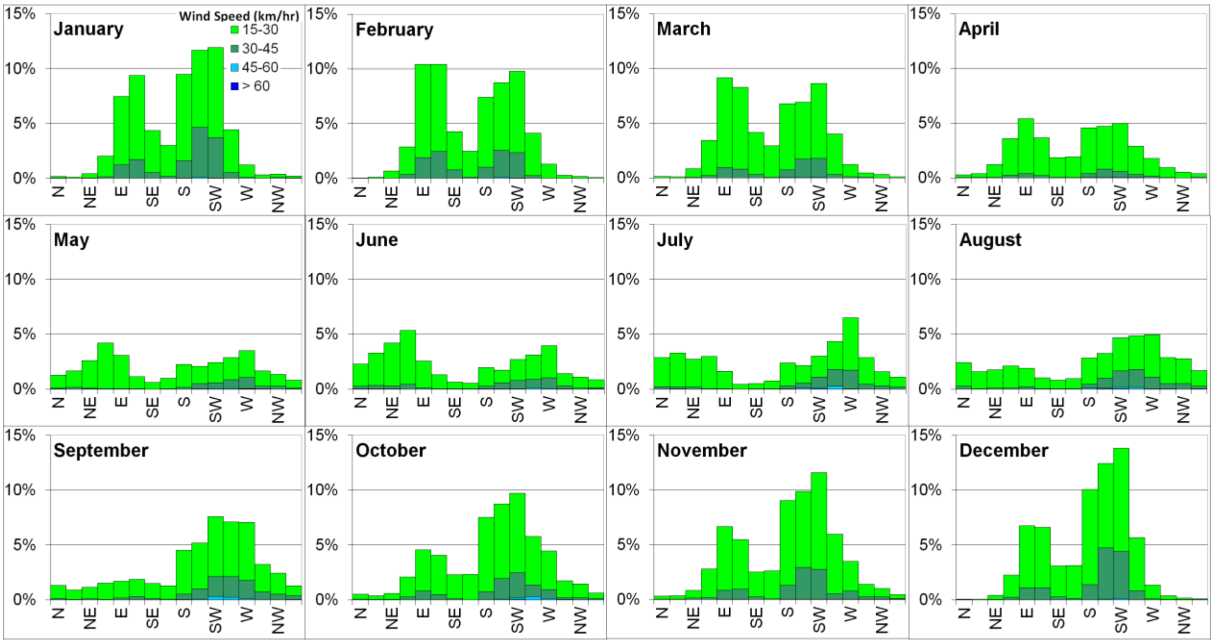
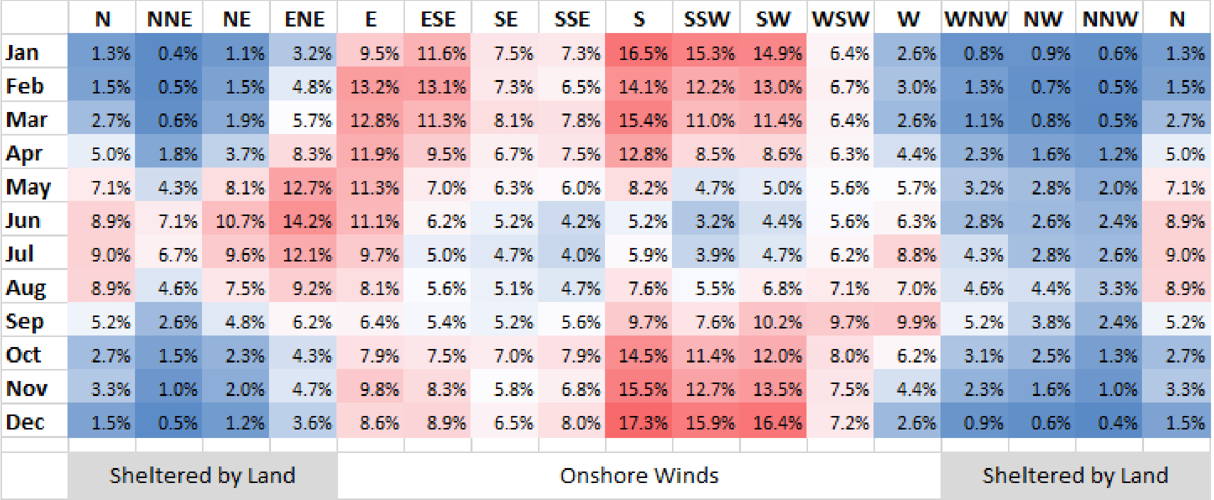


Figure 28: Monthly Wind Speed and Direction Frequency at Melville Water

Presentation of the wind directional distribution per calendar month (Figure 29) also shows the bimodal wind pattern, further highlighting ‘drift’ of the land breeze from east-southeast in November-March to an east-northeast direction in May-August. South to southwest winds prevail from September to March. Winter winds are more evenly spread, with low occurrence of southerly winds during this period.



	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
Jan	1.3%	0.4%	1.1%	3.2%	9.5%	11.6%	7.5%	7.3%	16.5%	15.3%	14.9%	6.4%	2.6%	0.8%	0.9%	0.6%	1.3%
Feb	1.5%	0.5%	1.5%	4.8%	13.2%	13.1%	7.3%	6.5%	14.1%	12.2%	13.0%	6.7%	3.0%	1.3%	0.7%	0.5%	1.5%
Mar	2.7%	0.6%	1.9%	5.7%	12.8%	11.3%	8.1%	7.8%	15.4%	11.0%	11.4%	6.4%	2.6%	1.1%	0.8%	0.5%	2.7%
Apr	5.0%	1.8%	3.7%	8.3%	11.9%	9.5%	6.7%	7.5%	12.8%	8.5%	8.6%	6.3%	4.4%	2.3%	1.6%	1.2%	5.0%
May	7.1%	4.3%	8.1%	12.7%	11.3%	7.0%	6.3%	6.0%	8.2%	4.7%	5.0%	5.6%	5.7%	3.2%	2.8%	2.0%	7.1%
Jun	8.9%	7.1%	10.7%	14.2%	11.1%	6.2%	5.2%	4.2%	5.2%	3.2%	4.4%	5.6%	6.3%	2.8%	2.6%	2.4%	8.9%
Jul	9.0%	6.7%	9.6%	12.1%	9.7%	5.0%	4.7%	4.0%	5.9%	3.9%	4.7%	6.2%	8.8%	4.3%	2.8%	2.6%	9.0%
Aug	8.9%	4.6%	7.5%	9.2%	8.1%	5.6%	5.1%	4.7%	7.6%	5.5%	6.8%	7.1%	7.0%	4.6%	4.4%	3.3%	8.9%
Sep	5.2%	2.6%	4.8%	6.2%	6.4%	5.4%	5.2%	5.6%	9.7%	7.6%	10.2%	9.7%	9.9%	5.2%	3.8%	2.4%	5.2%
Oct	2.7%	1.5%	2.3%	4.3%	7.9%	7.5%	7.0%	7.9%	14.5%	11.4%	12.0%	8.0%	6.2%	3.1%	2.5%	1.3%	2.7%
Nov	3.3%	1.0%	2.0%	4.7%	9.8%	8.3%	5.8%	6.8%	15.5%	12.7%	13.5%	7.5%	4.4%	2.3%	1.6%	1.0%	3.3%
Dec	1.5%	0.5%	1.2%	3.6%	8.6%	8.9%	6.5%	8.0%	17.3%	15.9%	16.4%	7.2%	2.6%	0.9%	0.6%	0.4%	1.5%
	Sheltered by Land				Onshore Winds									Sheltered by Land			

Figure 29: Average Monthly Wind Direction Distributions (Melville Water AWS 9091)

Note that Figure 28 conveys wind occurrence above 15km/h and Figure 29 shows wind direction regardless of wind speed, which means they are not directly comparable.

The effect of seasonal changes to wind direction is modified by the sheltering provided by land and the relative capacity for wave generation across Freshwater Bay (Figure 22). Consequently, only winds from the southerly half of the compass have been considered when looking at year to year variability.

The directional distribution of summer winds, presented as a percentage of winds from east through west, from September to March (Figure 30) shows inter-annual variability. Occurrence of westerlies displays cyclic tendency, but easterlies are more variable on a year-to-year basis. Note that behaviour in 2003-2004 is possibly a local instrument issue.

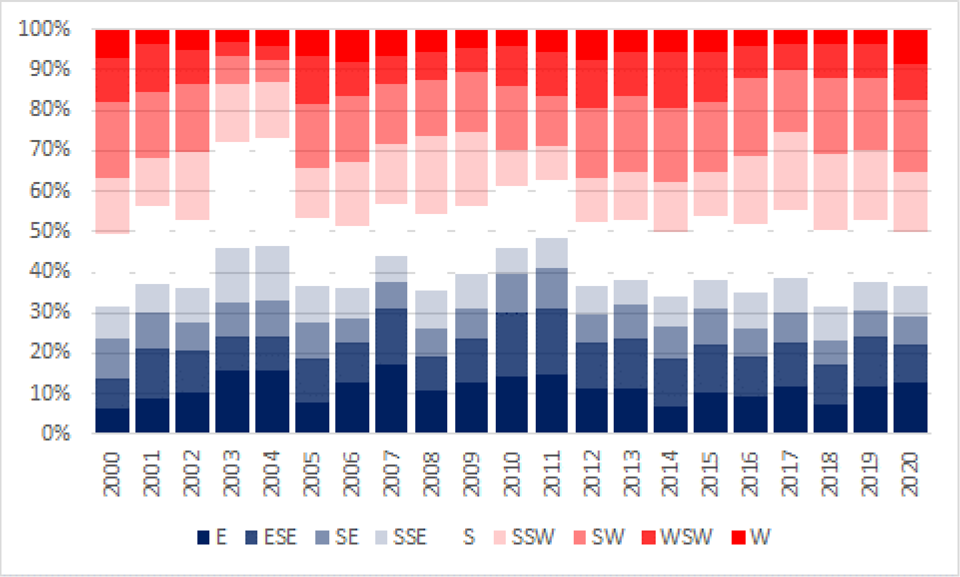


Figure 30: Interannual Variability of Summer Onshore Wind Distribution

The directional distribution of winter winds, presented as a percentage of winds from east through west, from May to August (Figure 31). Both easterlies and westerlies are variable on a year-to-year basis, although a higher occurrence of easterlies is apparent from 2005-2015 than the periods before and after.

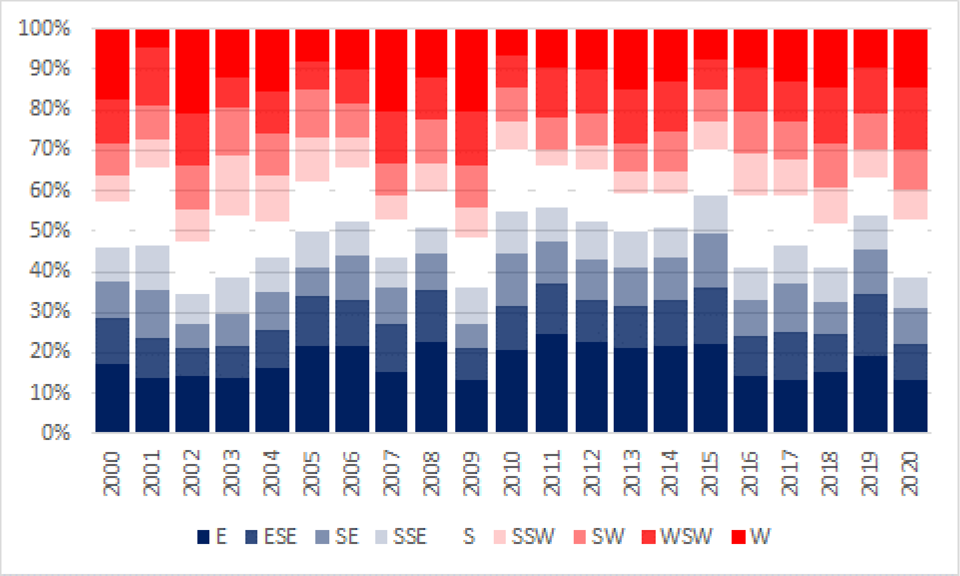


Figure 31: Interannual Variability of Winter Onshore Wind Distribution

Available fetches (Figure 22) have been combined with the wind distribution (Figure 29) using a vector sum of $\sum_{\theta=0^o}^{360^o} F_\theta\, f_\theta$ where F_θ and f_θ are fetch length and wind occurrence corresponding to direction θ. For a fetch-restricted shore, monthly vector sums (Figure 32) indicate wave climate variation over the year, with deviation from the mean direction suggesting a tendency for alongshore transport. Note that wind directions do not directly correspond to wave directions, particularly due to the process of refraction as the waves approach the shore, which is modulated by water level.

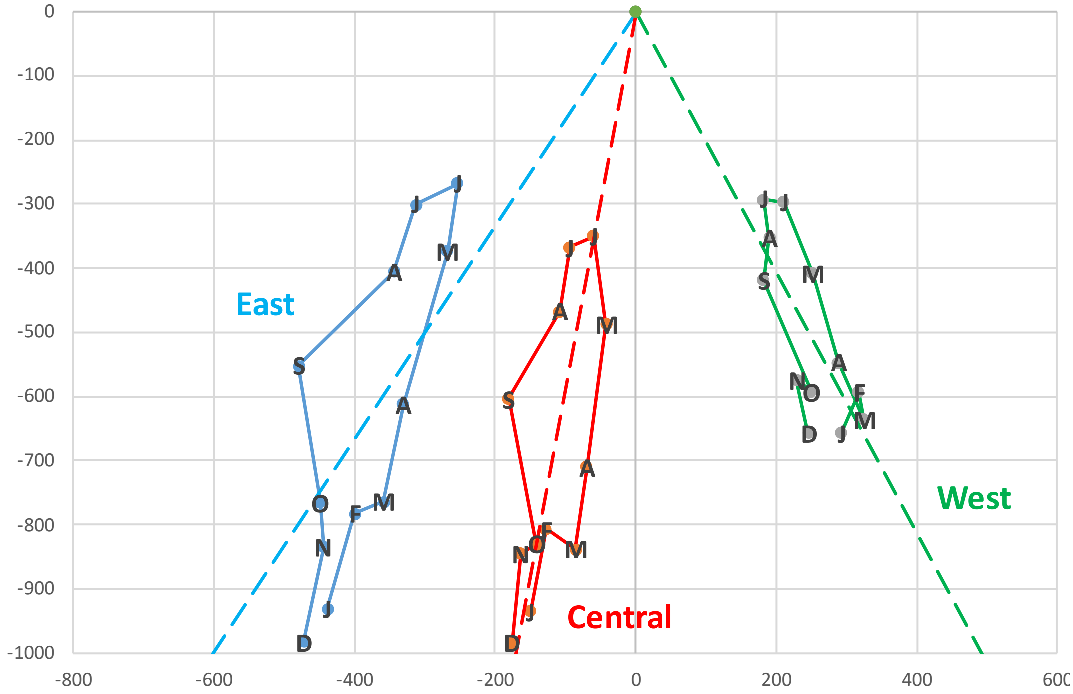


Figure 32: Seasonal Variation of Wind-Fetch Alignments

Monthly vector sums developed for three points along northern Freshwater Bay suggest different annual sequences:

- Average wave conditions west of Claremont Yacht Club tend to be from the south-southeast, with winter conditions (April to August) tending to have a small increase in easterly component (i.e. beach sediments will generally move westward during winter and east during summer). This interacts with seasonal sea level variability, such that the foreshore beach near Christchurch Rowing Shed is likely to be narrow over winter.
- Average wave conditions for the central section of Claremont foreshore are approximately straight on to the shore, being slightly west of south. Fluctuations in direction occur during March to May, when westward transport is likely and July to September, when eastward transport is likely. This is out of phase with seasonal fluctuations in sea level and therefore foreshore behaviour may appear erratic.
- Average wave conditions east of Alex Prior Park tend to be from the south-southwest, with winter (May to September) tending to increase the westerly component. This is expected to cause a seasonal oscillation, in the opposite direction to the beach west of Claremont Yacht Club. Combined with seasonal sea level change, this is likely to cause large beach width variation between Alex Prior Park and Mrs Herbert's Park.

OBSERVED FORESHORE DYNAMICS

Change to Claremont foreshore has been assessed using vertical aerial photographs from 1953 onwards, sourced from the Department of Biodiversity, Conservation and Attractions (DBCA). Key changes are demonstrated by figures showing four tiled photographs from selected dates along distinct shoreline reaches. Present-day foreshore dynamics are apparently dominated by relative exposure to wind waves, ongoing redistribution of historic reclamation, wave attenuation by Claremont Yacht Club, and local sediment capture by CYC Hardstand and Chester Road revetment, with lesser roles by Christchurch Rowing Shed and Claremont Jetty abutment. Relative exposure to easterly and westerly winds shifts alongshore, resulting in a tendency for net eastward transport west of CYC, net westward sediment transport between CYC and Chester Road, and net eastward transport along the eastern foreshore. This creates a tendency for gradual erosion from the centre of northern Freshwater Bay.

Cliff Road to Claremont Yacht Club

This section of foreshore has a relatively narrow low beach in front of a scarp, which is steep and rocky towards Cliff Rd, becoming less steep and increasingly sand covered to the east. Adjacent land has been occupied by Methodist Ladies College, Christchurch Grammar School and Claremont Yacht Club since around 1910 and Bethesda Hospital since the 1950s.

The foreshore has historically had relatively low use, including boat sheds and jetties (Figure 33). Key changes including installation of CYC hardstand before 1965, sequential yacht club jetty extensions in 1974, 1995, 2010 & 2015, CYC carpark extension in 2015 and redevelopment of Christchurch Rowing Shed facilities in 2018.

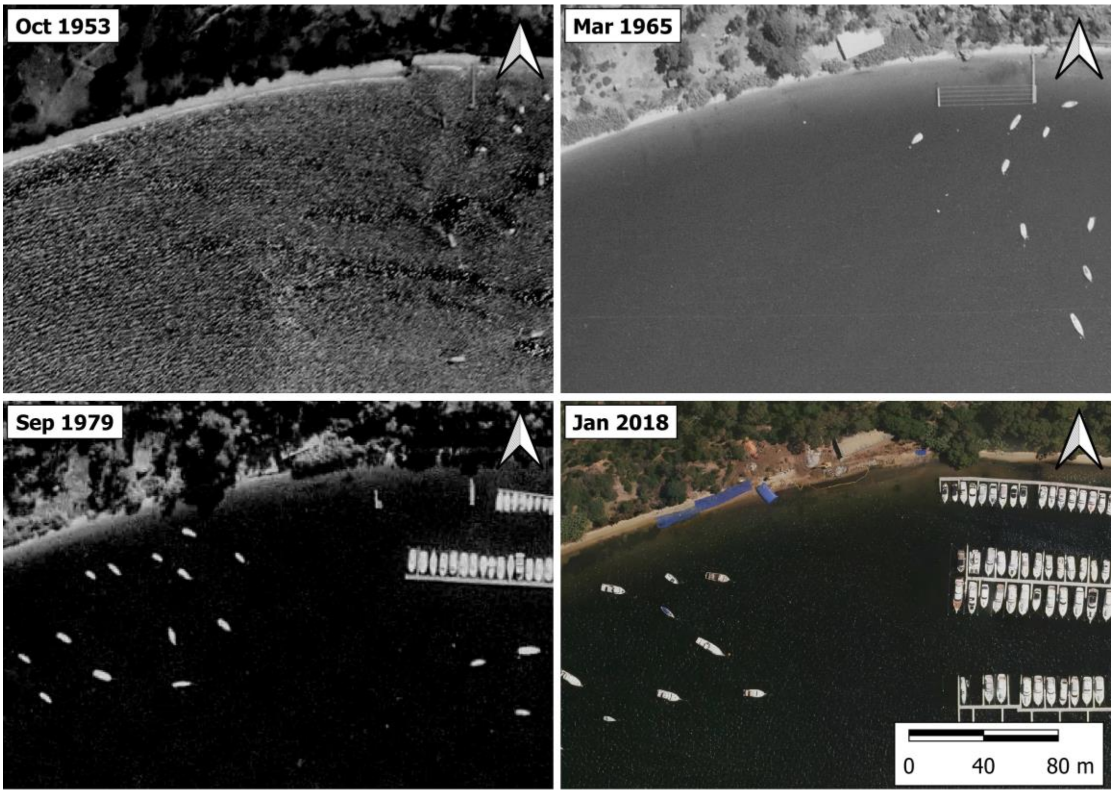


Figure 33: Cliff Rd to Claremont Yacht Club, historical change 1953 to 2018

Construction of yacht club facilities caused the expected division of the estuarine beach along northern Freshwater Bay. The hardstand provided a direct barrier to alongshore sediment transport and the pens provided an area of wave shelter, which has expanded with growth of the facilities. Sand trapping on the west side of the hardstand has occurred, however, it has developed slowly (10-15m over 65 years), with an almost straight beach structure. Sheltering from the yacht club pens determines that there is limited wave forcing on the beach, with scour holes caused by boat propellers able to persist for a long time (Figure 34).

Figure 34: Scour holes caused by vessels in yacht club pens

West of Claremont Yacht Club, there have been three distinct phases of foreshore condition (Figure 35). Prior to 2003, the beach was continuous from Cliff Rd to CYC hardstand. From 2004, the beach became disconnected, with Christchurch Rowing Shed ramp and an outlying rock apparently providing partial foreshore control. This change followed from an extreme storm in May 2003, and a program to remove giant bamboo from the foreshore, however, neither has been established as contributing to the beach change.

Redevelopment works at Christchurch Rowing Shed were undertaken in 2018 (Figure 36), including removal of the previous concrete ramp and construction of gabion walling, fronted by rock toe mattresses. After these works there has been increased foreshore continuity, potentially allowing increased sediment to move toward Claremont Yacht Club. Anecdotally, the beach in front of the Rowing Shed has lowered, occasionally exposing rock toe mattresses. These changes may reflect the following processes:

- Slightly increased incidence of westerly winds during recent years (Figure 30 and Figure 31).
- Removal of the concrete ramp may have removed a partial foreshore control, allowing greater movement of the beach (west of the Boat Shed) towards the east.
- If the beach was rebuilt ‘further out’ than its original position, then it is expected that the extra material will be dispersed in both directions.
- Layout of the gabions does not parallel the foreshore, with a ‘point’ near the eastern end of the walling, which is subject to more frequent exposure to wave action.
- Gabion walls cause greater wave reflection than a sandy foreshore, which will result in local flattening of the beach profile when the gabions are reached by waves under high water level events. This potentially causes local lowering of the beach.
- The toe mattresses have been placed with limited embedment.

Figure 35: Changing shoreline connectivity near Christchurch Rowing Shed

Figure 36: Reconstruction Works at Christchurch Rowing Shed

Claremont Yacht Club to Claremont Jetty

Interruption of sediment transport and increased wave attenuation associated with the CYC hardstand and jetty marine structure, has encouraged the accretion of sediments at the beach on the eastern side of the CYC. This is evident in photographs of 1953, 1965, 1995 and 2018 (Figure 37).

The sand build-up adjacent to the CYC reclamation hard stand occurred a relatively high rate initially following the 1960's works and has continued more gradually over time, including further riverward and eastward progression over the past decade 2010 to 2020. The beach between CYC and Claremont Jetty has also progressed riverward over the 60 year timeframe since the reclamation of the CYC hardstand area. It has increased in width from 7.5m at the Claremont Jetty end of the beach to 17m at the CYC end of the beach. Again, the sand contributing to this gradual beach widening is likely to have redistributed from the eroding historically reclaimed shoreline immediately to the east of the Chester Road seawall.

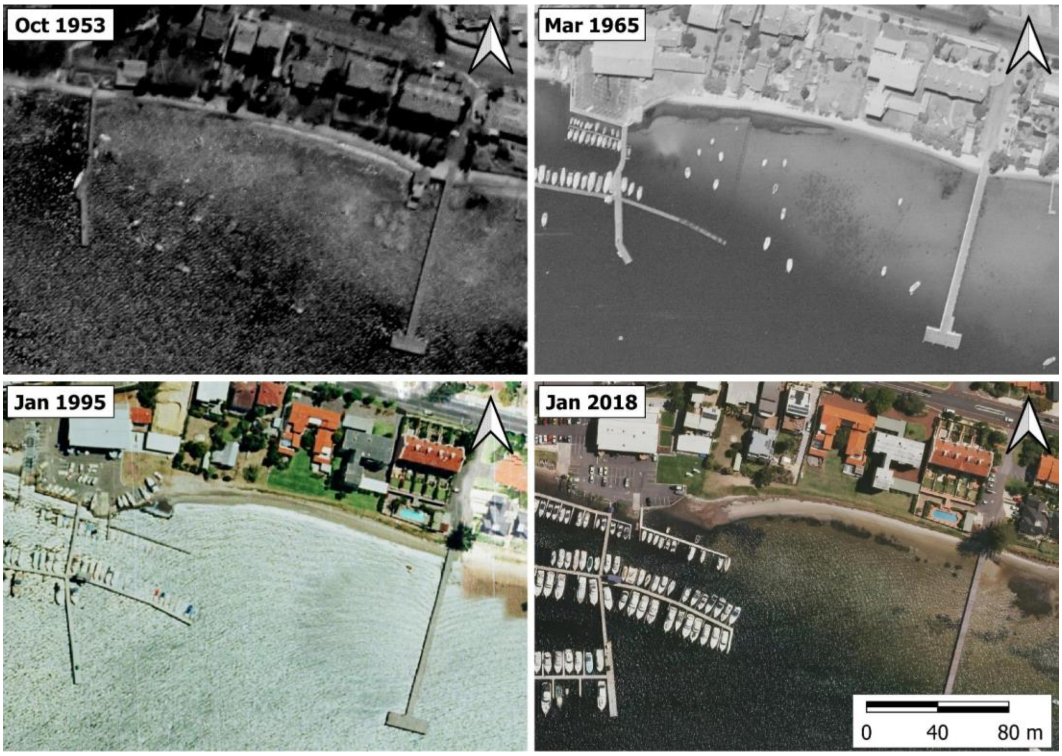


Figure 37: Claremont Yacht Club to Claremont Jetty, historical change 1953 to 2018

It is understood that removal of the sand build-up, and redistribution of this sand along the beach between CYC and the Claremont Jetty abutment, was a regular exercise undertaken by the DBCA (previously the Swan River Trust - SRT). This is known as *sand back-passing* and was undertaken to improve beach amenity. However, this activity has not been undertaken after 2015.

Anecdotal advice from CYC staff is that sedimentation of the nearshore navigation areas of the yacht club, has occurred in an increasing manner with ongoing expansions of the CYC's jetty network since the 1960s.

Claremont Jetty to Chester Road

Chester Road revetment was initially constructed in 1980, to protect the riverfront carpark, which was under increasing erosion pressure with realignment of the reclaimed foreshore to the east. Prior to its construction, the beach west of Chester Road had a curved shape as the net westward sediment redistribution under prevailing conditions occurred unimpeded. Further reclamation of the beach area occurred with housing developments along this reach being built closer to their riverward property boundaries, this has had a significant straightening effect upon the beach. This is evident from looking at the 1979 and 2018 aerial photographs of Figure 38, in which the vegetated shoreline in the centre between Claremont Jetty and Chester Road has progressed 9m riverward over 40 years. The Chester Road revetment contributed to increased sediment retention to the east, but also formed an erosion hotspot forming directly west of the rockwall, with approximately 5m of localised erosion and retreat since 1980.

The revetment was upgraded in late 2017 to increase hydraulic smoothness, including truncation of the eastern end and adding a more gradual tie-in to the east.
There is a large water drain outlet located directly to the east of the Claremont Jetty abutment. During times of high rainfall, this drain mobilises sediments locally from the beach into a nearshore delta structure next to Claremont Jetty, which can be seen in the 1953, 1979 and 2018 photographs of Figure 38.

Figure 38: Claremont Jetty to Chester Road, historical change 1953 to 2018

Redistribution of Reclamation East of Chester Road

The shoreline protrusion inherited from historic reclamation east of Chester Road, has played a key role in the sediment dynamics along the wider Claremont foreshore since 1953. This reclaimed area has been progressively eroding (Figure 39), with this section of Freshwater Bay realigning to a straighter shoreline over time, as can be observed in the photographs of Figure 39. This has involved sediment redistribution both to the west and east, contributing to ongoing accumulations evident at the CYC and eastern foreshore, respectively. It is recognised that the potential for sediment transport to the east was likely increased following removal of the Claremont Baths in 1971, which permitted more locally generated westerly wave energy to reach the shoreline.

Figure 39: Retreat of historic reclamation area, east of Chester Road seawall

The rate of shoreline realignment was relatively high in early imagery from 1953 to 1979 and has apparently declined as the shoreline has straightened with influence control being provided by the Chester Road revetment.

Eastern Foreshore

This section of shoreline has been accreting since the 1950s. Further eastwards, the City of Nedlands extended Watkins Road and installed bioengineering foreshore treatment with a rock toe on the foreshore in 2015. This resulted in a hard-engineered control structure functioning at the eastern extent of Town of Claremont's beaches. The structure appears to be trapping sand and preventing it from travelling further south towards Point Resolution. Along the entirety, the eastern foreshore is accreting, with sediment supplied from the realignment of the large reclamation area east of Chester Road, refer Figure 40.

Figure 40: Eastern foreshore, historical change 1953 to 2018

ANALYSIS OF SURVEYS

Historical survey data for the Claremont Foreshore site, dated 1912, 1971 and 2012 was reviewed for this investigation. This review indicated that the nearshore bathymetry of Freshwater Bay has changed very little in the past 100 years, with significant changes to the beach alignment being due to reclamation activities, which not been adequately documented to conclude volumes of material imported to the foreshore.

MORPHODYNAMIC INTERPRETATION

Foreshore behaviour at the Town of Claremont's beaches has been significantly influenced by reclamation and installation of marine structures over time. The major reclamation that occurred in the late 1920s created a bulging feature east of Chester Road, that has been eroding and redistributing its sediments since the removal of the Claremont Baths in 1971. Reclamation accompanying housing development has also attributed to a general straightening of the shoreline from its previously curved shape. The staged reclamation of the CYC hardstand area in the early 1960s and early 1980s, and the ongoing expansion of the yacht club's jetty with vessel wet storage pens positioned parallel to shore from the 1960s has also influenced the sediment transport regime. The eastern side Freshwater Bay is experiencing accretion, and the bioengineered hard-engineered structure installed by the City of Nedlands in 2015 is encouraging sediment accretion at the south-easterly municipal boundary between the two councils.

Overall behaviour of the site is indicative of gradual foreshore change due to locally generated wind waves, with redistribution of sediments influenced by the dominant wave direction at the time. Exposure to wind waves is influenced by the attenuation effects of the CYC jetty and vessel storage pen marine structures, and also topography. Sediments from the beaches on the western side of Chester Road tend to be pushed in a westerly direction and accumulate at the CYC hardstand reclamation area, while sediments from the beaches to each side of Chester Road tend to be pushed in an easterly direction and accumulate in the area between Mrs Herberts Park and Watkins Road bioengineering. In summary:

- Foreshore position in 1912 was mostly landwards of today's shoreline (Figure 41). Claremont Baths and Claremont Jetty marine structures had been installed.
- A major reclamation activity took place to the east of Chester Road in the late 1920s, presumedly to provide vehicle parking and an increased recreational foreshore reserve adjacent to Claremont Baths. This reclamation activity was not specifically documented in PWD records, so it is assumed that material for the reclamation was sourced from nearby surplus road construction fill and construction waste material.
- The reclamation of CYC's hardstand area in the early 1960s formed a hard-engineered structure which reduced the sediment transfer to and from the western side of Freshwater Bay. This protruded into the river approximately 20 m from the original shoreline and encouraged sediment accretion at its eastern side.
- Ongoing expansion to the CYC jetty facilities, along with increasing wet vessel storage pens had a wave attenuation effect, also encouraging sand accretion at the eastern side of the CYC reclamation area.
- Removal of Claremont Baths in 1971 also removed its wave attenuation impact on the adjacent foreshore east of Chester Road. Erosion of the bulging section of the reclamation area east of Chester Road increased and the sediments released by this erosion began travelling in both east and west directions.
- Between the 1950s and 1990s, undocumented reclamation has taken place between CYC and Chester Road, on both sides of Claremont Jetty. This has taken place with residential development gradually progressing further riverward towards the property boundaries, and additional foreshore reserve being reclaimed over a 40-year timeframe.

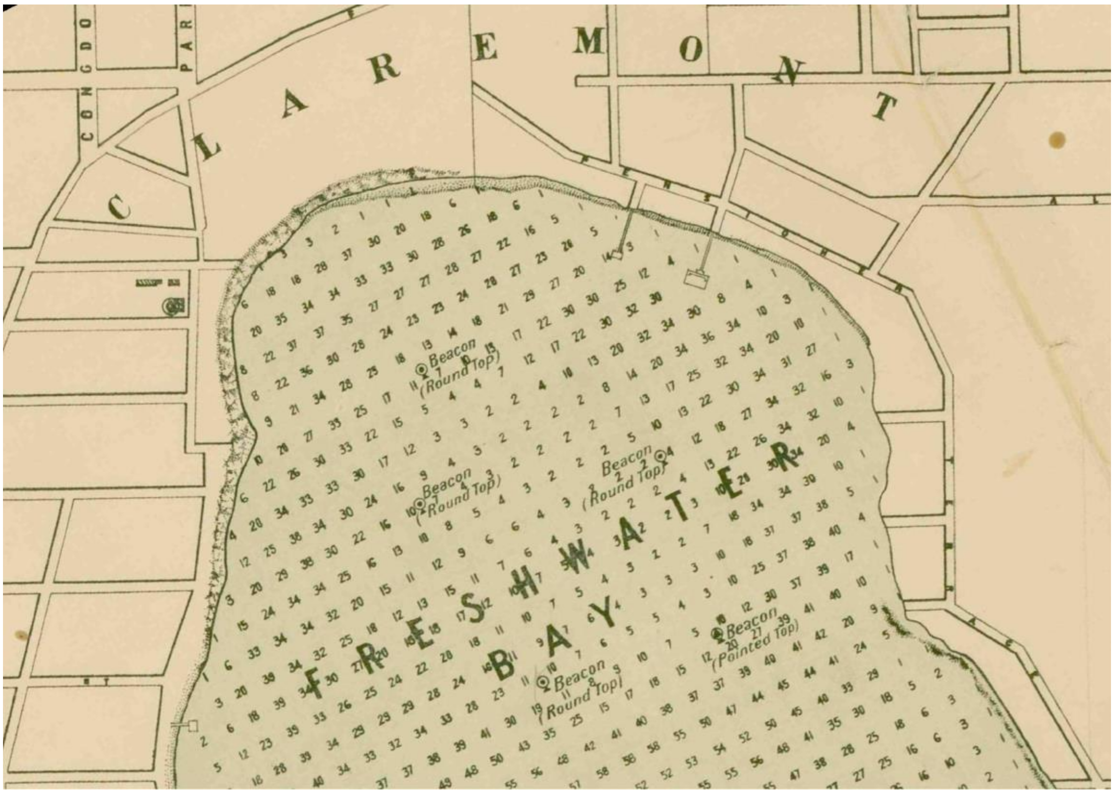


Figure 41: Extract from PWD Bathymetric Survey 1912

- Sediment accretion has also been occurring at the eastern side of Freshwater Bay, with a bioengineering hard-engineered structure installed at the riverward end of Watkins Road in 2015.
- Up until 2015 sand backpassing was undertaken at CYC by the DBCA, redistributing sediments towards Claremont Jetty.
- In 2017 Chester Road seawall was refurbished with new armour stones. Its eastern end was truncated and tied into the adjacent foreshore to improve hydraulic smoothness and encourage sediment bypassing between the beaches to the east and west sides of Chester Road.
- Ongoing erosion of the reclamation area east of Chester Road has exposed rubble, indicating that the historic reclamation at this site utilised construction waste material.
- The small locally generated wind waves within Freshwater Bay tend to push sediments to the upper section of the beach and over its crest onto the elevated, landward top of beach platform above the high tide level. The sediments are then trapped by grass and other establishing vegetation, resulting in a steepening of the foreshore over decades. The steep grade of the sedges provides constraint to access, with the accessible area narrowed during high tides, which is amplified by beach erosion. This can reduce the visual amenity of the beach and constrain recreational use to lower tidal levels.

CONCEPTUAL MODEL

Foreshore dynamics within the Town of Claremont' beaches are consistent with a slow-moving bi-directional sediment transport due to locally generated wind waves. There are six distinct foreshore reaches (Figure 42), each of which is subject to a different orientation, profiles and structural control, affecting rates of sediment transport.

Figure 42: Conceptual model and foreshore reaches at Town of Claremont beaches

For a balanced system, rates of sediment supply into and out of each reach are equal, with the structural control limiting the influences of local differences in transport; typically this is accommodated by shoreline rotation or profile adjustment such as scarping or flattening.

Most of the reaches along the Town of Claremont foreshore have not displayed stability since significant reclamation works were undertaken in the late 1920s, with erosion of the reclamation area east of Chester Road, ongoing reclamation and riverward foreshore progression between 1950 and 1990, and historic alterations to features that act as structural controls. Several human activities have provided a significant influence on these dynamics. In summary:

- Prior to reclamation and marine structure installation, the shoreline of Freshwater Bay was representative of a relatively continuous arc, with fairly uniform sediment transport between the eastern and western beaches.
- Construction of Claremont Jetty and Claremont Baths introduced minor wave attenuation to the original shoreline position, through weak control.
- The original large reclamation east of Chester Road, carried out in the late 1920s has modified the original shoreline position of the Town of Claremont foreshore, pushing it 30m riverward and introducing a major source of erodible sediment supply.

- Construction of the weak controls of Claremont Jetty and Claremont Baths caused the foreshore to evolve into a series of arcs (refer Figure 42), specifically between CYC and Claremont Jetty (Reach 3), Claremont Jetty and Chester Road (Reach 4) and Alex Prior Park and Watkins Road (Reach 6). Reach 5 is a protruding foreshore in the lee of Claremont Baths.
- Ongoing reclamation between Chester Road and CYC from 1950 to 1990, along with the hardstand area reclamation at CYC in the early 1960s, has pushed the shorelines of Reaches 3 and 4 further south from its original position, by an average of 10m. This progressive reclamation was assisted by the removal of Claremont Baths in 1971, exposing the bulge at Reach 3 to erosion and redistribution of sediments. The bulge at Reach 5 has had sedges planted on it to assist with its stabilisation, the sedges are currently undermined and in poor condition, with the erosion scarp reaching the grass landward of the sedges. There is also exposed construction rubble at this location.
- Construction of the Chester Road seawall in the early 1980s created a hard point on the shoreline, slowing the westerly transfer of sediments from the Reach 5 towards Claremont Jetty. The refurbishment and shortening of the Chester Road seawall in 2017 encouraged the transfer of sediments from Reach 5 towards Claremont Jetty, nourishing the beaches at Reaches 3 and 4.
- The hardstand reclamation area at Claremont Yacht Club is trapping sand, that is travelling alongshore from Reaches 3, 4 and 5 in a westerly direction. It is estimated that up to 50m^3/year of sediment is being trapped at this location.
- Due to the lack of foreshore level survey data between 1950 and 1990, there is uncertainty regarding the volume of sand that is being pushed over the top of the upper beach by storm waves and trapped above the high tide level in the foreshore crest by grass and vegetation.
- With no sand backpassing being undertaken at CYC's eastern sediment accretion area at the western end of Reach 1 since 2015, an estimated 650m^3 of sediment is available for extraction along the 70m stretch from CYC seawall heading east towards Claremont Jetty. This would also decrease the risk of sedimentation of the CYC nearshore berths.
- This 650m^3 of extracted sediment could be redistributed along the remaining 280m of foreshore between CYC and Chester Road, which would push the beach profile approximately 5m further south into the river, with a 1:7 slope.
- Extraction of the rubble from within Reach 5 reclamation area may require the excavation of a large trench of the following dimensions:
    - Cross-shore excavation width of 7.5 m,
    - Excavation depth to elevation -0.5 m AHD
    - Length of 160 m
    - Volume of material to be removed is estimated to be 1,200m^3
    - 1,200m3 of certified clean sand would need to be imported to site from a quarry to replace the extracted rubble material, which would greatly improve visual and recreational beach amenity.

Clean sand may erode at a faster rate than the currently present rubble material, this will need to be monitored by Town of Claremont.

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Appendix B: Sand Accumulation Next to Claremont Yacht Club

Sand has accumulated on the east side of Claremont Yacht Club hardstand area. This area is well grassed, with spillover use from the yacht club, although the area is Town of Claremont foreshore reserve.

The volume of sediment that is contained adjacent to the CYC hardstand reclamation has been assessed for possible re-use. Up to 650m^3 of sand could be extracted from this location if the top of beach is realigned approximately 10m north and the beach reprofiled to a 1:7 slope. This would reduce the size of this grassed area, affecting amenity. There may be some reduction in volume due to the quantity of established grass at the top of the accreted sand, which will need to be disposed of at an approved green waste disposal facility.

The proposed extraction footprint will approximately reinstate the foreshore at this location to its 1974 shoreline position, as can be observed in the aerial imagery Figure 43. Note that this is still further riverward than the 1965 shoreline position, indicating that the historical riverbed will not be excavated. Neither indigenous nor European heritage artifacts will be disturbed during the sand extraction process.

Figure 43: Historic shoreline position comparison 1965 – 2018
Proposed sand extraction zone next to CYC

Due to the slow rate of sediment transport along the Town of Claremont foreshore, high level monitoring of sand accretion at the edge of the reclamation area could be undertaken using photographic records. Additionally, sedimentation within the CYC could easily be undertaken as part of the post-nourishment campaign monitoring efforts using probes. This would provide ongoing depth data to assist with determination of the rate of sediment transport and accretion within the CYC's nearshore wet vessel storage pens.

Quantities of seagrass and algal wrack are pushed towards the northern sections of Freshwater Bay in late autumn/early winter each year due to seasonal changes and an associated increase in sea-state conditions within the Swan River estuary. This wrack accumulates on the eastern side of the CYC hard stand reclamation area and deteriorates in late winter. Seasonal timing of sand extraction would need to be considered to prevent additional unnecessary effort in moving wrack.

Appendix C: Photographs from May 2020 Inundation Event

Flooding of parts of Claremont foreshore occurred in May 2020, developed through the coincidence of high tide, a mid-latitude storm system and the remnants of ex-tropical cyclone Mangga. Photographs of the 25 May 2020 event have been supplied by DBCA and Town of Claremont.

Figure 44: High water levels on 25 May 2020 - looking east from Claremont Jetty

Figure 45: High water levels on 25 May 2020 - looking west from Claremont Jetty

Figure 46: High water levels on 25 May 2020 - looking west from Mrs Herberts Park

Figure 47: High water levels on 25 May 2020 - looking west across Mrs Herberts Park