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R2140 Rev 1

March 2026

City of Stirling

Mettams Pool Nourishment
Consideration of Alternative Options

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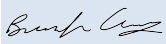
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1. Introduction

The City of Stirling (City) is responsible for approximately 6.5 km of coastline, extending from Watermans Bay in the north to Peasholm Beach in the south. Mettams Pool is a popular beach within the City and is located approximately 14 km north-west of Perth's Central Business District, adjacent to West Coast Drive.

Mettams Pool was identified as a coastal hotspot in Western Australia in 2019 (Seashore, 2019). Following this, the City prepared a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP; Cardno 2022a–2022e) in 2022 for its coastline. The CHRMAP identified Mettams Pool, along with Watermans Bay, as high-priority sites for coastal adaptation and recommended that further detailed investigations be undertaken, as well as adaptation options assessment for both sites.

In 2024, M P Rogers & Associates Pty Ltd (MRA) was engaged by the City, on behalf of the Project Working Team (PWT), which included representatives from the Department of Planning, Lands and Heritage (DPLH) and the Department of Transport (DoT), to develop coastal adaptation options for Mettams Pool. Due to similarities in coastal processes and constraints, Watermans Bay was also included in the assessment.

MRA worked closely with the Mettams and Watermans Reference Group, which comprised two Councillors and six community representatives, along with members of the PWT. The Reference Group was established to represent the broader community and to provide input and direction during the development and assessment of the potential adaptation options.

Four options were assessed using a Multi-Criteria Analysis (MCA) framework based on the key success criteria outlined in the CHRMAP. The MCA identified beach nourishment as the highest-ranking option, and it was recommended that this option be progressed to further evaluation and future design phases.

MRA has since been re-engaged by the City to:

- Investigate further alternative permanent options, including a submerged reef and small-scale retaining wall and/or groyne, which may reduce the volume and / or frequency of beach nourishment.
- Further detail the beach nourishment option, including the preparation of relevant documentation and drawings.

The scope of works presented in this report relates specifically to the investigation of alternative coastal adaptation options and includes:

- A review of recent data and developments.
- Development of an updated conceptual model for the submerged breakwater (reef) option, considering its potential impact on the volume and frequency of beach nourishment along the foreshore.
- Conceptual design and cost evaluation of permanent coastal adaptation options at Mettams Pool.

This report has been prepared in response to Council Resolution 0525/033.



Figure 1.1 Location of the Site

2. Review of Background Information

2.1 General

This work is intended to support the earlier Coastal Adaptation Options Assessment for Mettams Pool (MRA, 2025). This report provides significant context and background information to this work.

In accordance with Council Resolution 0525/033, MRA has been engaged to further investigate the potential use of permanent structures, including a submerged breakwater (reef) and other smaller-scale measures, to reduce the ongoing beach nourishment requirements at Mettams Pool.

It is assumed in all aspects of this works that the base adaptation option is beach nourishment.

2.2 Beach Nourishment

Table 2.1 summarises the historical volume of sand placed at Mettams Pool. In recent years the beach nourishment has typically been undertaken on an annual basis to replace material lost during the preceding year and provide a buffer to storm erosion. These works are generally funded by the City, with assistance from Coastal Adaptation and Protection (CAP) funding.

Beach nourishment was not undertaken in 2023 or 2024 due to concerns regarding the availability of sand at Trigg Beach, which is the primary sand source location. In 2024, the City investigated the option of sourcing sand from Sorrento Beach within the City of Joondalup (CoJ). However, due to timing constraints and a relatively mild summer, during which sea breeze conditions were less prevalent than typical, the beach was assessed as having sufficient sand reserves for the summer period.

The nourishment work is reviewed below with respect to the beach survey data and available online shoreline datasets.

Table 2.1 Beach Nourishment Works at Mettams Pool

Date	Approx. Volume (m3)	Harvest Location
Apr 2021	2,200	Sorrento Beach / Mettams Pool
Nov / Dec 2021	5,000	Trigg Beach / Mettams Pool
Nov / Dec 2022	5,000	Trigg Beach / Mettams Pool
Mar / April 2025	5,000	Trigg Beach / Mettams Pool

2.3 Site Conditions

As part of this work, MRA attended site in November 2025 to review changes to the coastline since the previous works. The photographs presented below were taken in January 2024, November 2025 and January 2026 from the viewing platform above the changerooms, immediately adjacent to the swimming area.

Figure 2.1 shows the northern section of Mettams Pool. The photographs indicate relatively consistent position of the beach berm as well as the overall beach profile.

Figure 2.2 shows the southern section of Mettams Pool, including the designated swimming area. Significantly more calcarenite rock is exposed, and the beach profile is steeper this year when comparing the 2024 and 2026 photographs. The foreshore adjacent to the pool consists of sand perched on rock, which generally responds more rapidly to changing conditions.

Comparing these photographs with the November 2025 image (Figure 2.3), much of the beach width gained from sand placement has been redistributed or lost. The November 2025 photograph was taken approximately six months after the beach nourishment works at Mettams Pool. These works are typically annual however no nourishment occurred in 2023 or 2024 due to limited sand availability at Trigg Beach. The beach berm lost over the summer months also serves as a haul route to provide access to the southern beach, including the swimming area, from the Saunders Street carpark. Consequently, the increased berm observed is largely attributed to the beach nourishment operations.

During the 2025/26 inspections, targeted sand placement was also noted to still be present at the back of the beach in the swimming area.



Figure 2.1 Northern Section of Mettams Pool: (L) January 2024 (R) January 2026



Figure 2.2 Southern Section of Mettams Pool: (L) January 2024 (R) January 2026



Figure 2.3 Northern Section of Mettams Pool: November 2025 – Six Months Following Beach Nourishment

These photographs show a combination of:

- The seasonal changes experienced at Mettams Pool.
- The impact of the placement of sand nourishment.
- The underlying trend of erosion and sand loss.

2.4 Monitoring Surveys

The Northern Beaches Alliance (NBA), comprising the Cities of Nedlands, Cambridge, Stirling, Joondalup and Wanneroo, and the Shire of Gingin, undertakes ongoing coastal monitoring for the member LGAs and extends from Two Rocks in the north to Cottesloe in the south. The information gathered as part of these monitoring activities includes:

- Ground surveys – completed every six months and extended into the water as far as practicable.
- Airborne surveys – completed every six months for the acquisition of Light Detection and Ranging (LiDAR) data and aerial imagery.

MRA has been involved in discussions with the NBA and the surveyor engaged to complete the surveys, MNG Survey (MNG). While the survey coverage is not perfect (the data only captures the foreshore above the waterline), it provides valuable information on shoreline and seasonal change.

Figures 2.4 and 2.5 present heatmap plans of Mettams Pool over a 12-month period for the survey intervals listed below. While not shown in the figures, volume change estimates have also been completed for the different sections of the foreshore depicted above the waterline.

- Figure 2.4 – April 2024 to April 2025 surveys (April surveys).
- Figure 2.5 – October 2024 to October 2025 surveys (October surveys).

The following key observations are derived from the heatmaps and associated cut and fill estimates:

- April surveys:
    - A net volume loss of approximately 2,100 m³ is observed above the waterline at Mettams Pool, with the majority of material lost from between the Saunders Street carpark and the area north of the swimming enclosure.
    - Minor, localised areas of volume increase are evident above the beach berm.
    - No nourishment activities were undertaken by the City during this period.
- October surveys:
    - A net volume increase of approximately 1,500 m³ is observed above the waterline at Mettams Pool, with the majority of material gained south of the Saunders Street carpark, including within the swimming area. The increase is evident at the waterline and across the beach berm.
    - Minor, localised areas of volume loss are visible however these losses are not spatially consistent along the foreshore.
    - Approximately 5,000 m³ of sand was placed by the City during this period. The material was placed above the waterline and is therefore captured by the surveys.

Based on the review of the heatmaps and associated changes in volume above water level, the following conclusions can be inferred:

- The volumes estimated from the surveys do not include the changes below water and need to be treated with caution. They are most likely to underestimate total change.
- Without the placement of sand nourishment, there is an underlying erosion trend.
- The current beach nourishment activities appear appropriate to generally maintain the existing beach position.



Figure 2.4 Mettams Pool Heatmap Plan: April 2024 to April 2025



Figure 2.5 Mettams Pool Heatmap Plan: October 2024 to October 2025

It should also be considered that the metocean conditions vary year to year. Over the past 2 years these conditions have generally been mild in relation to high water level events and storm activity. In "stormier" years we would expect to see increased erosion.

2.5 Shoreline Movement

Among other methods, MRA (2025) assessed changes in the shoreline by reviewing shifts in the position of the Mean Sea Level (MSL). For the section of shoreline between Hamersley Street in the north and Bailey Street in the south, this approach is considered to provide a reliable representation of shoreline change.

Mapping of the MSL position was sourced from the Digital Earth Australia (DEA) Coastlines platform. DEA is an Australian Government initiative, managed by Geoscience Australia, which provides reliable and accessible geospatial information derived from satellite imagery.

Figure 2.6 shows the extent of the available DEA Coastlines data at the time of reporting, with the most recent MSL position (2024) shown in black. The figure also presents annual rates of shoreline change for several locations along Mettams Pool. The data indicates a period of accretion between 2020 and 2022 across several sections of the shoreline, followed by retreat in the subsequent period (eg 2022 to 2023). This behaviour is consistent with the timing of beach nourishment works undertaken in 2021 and 2022 to replace sediment lost through natural littoral drift processes.

The largest rates of shoreline change at Mettams Pool occur at the swimming area to the south. Based on 36 years of recorded data, rates of change in this area vary between 0.4 and 0.6 m/year. Similar rates are observed directly in front of the Saunders Street carpark, whereas other sections of the foreshore have remained either relatively stable or have experienced lower rates of change (up to 0.3 m/year).

Overall, there is no substantive evidence to suggest that shoreline behaviour at Mettams Pool differs from the conclusions reached during the Coastal Adaptation Options Assessment (MRA, 2025). The shoreline continues to exhibit a long-term erosion trend and ongoing beach nourishment is expected to remain necessary to maintain beach amenity and provide a buffer to coastal assets.

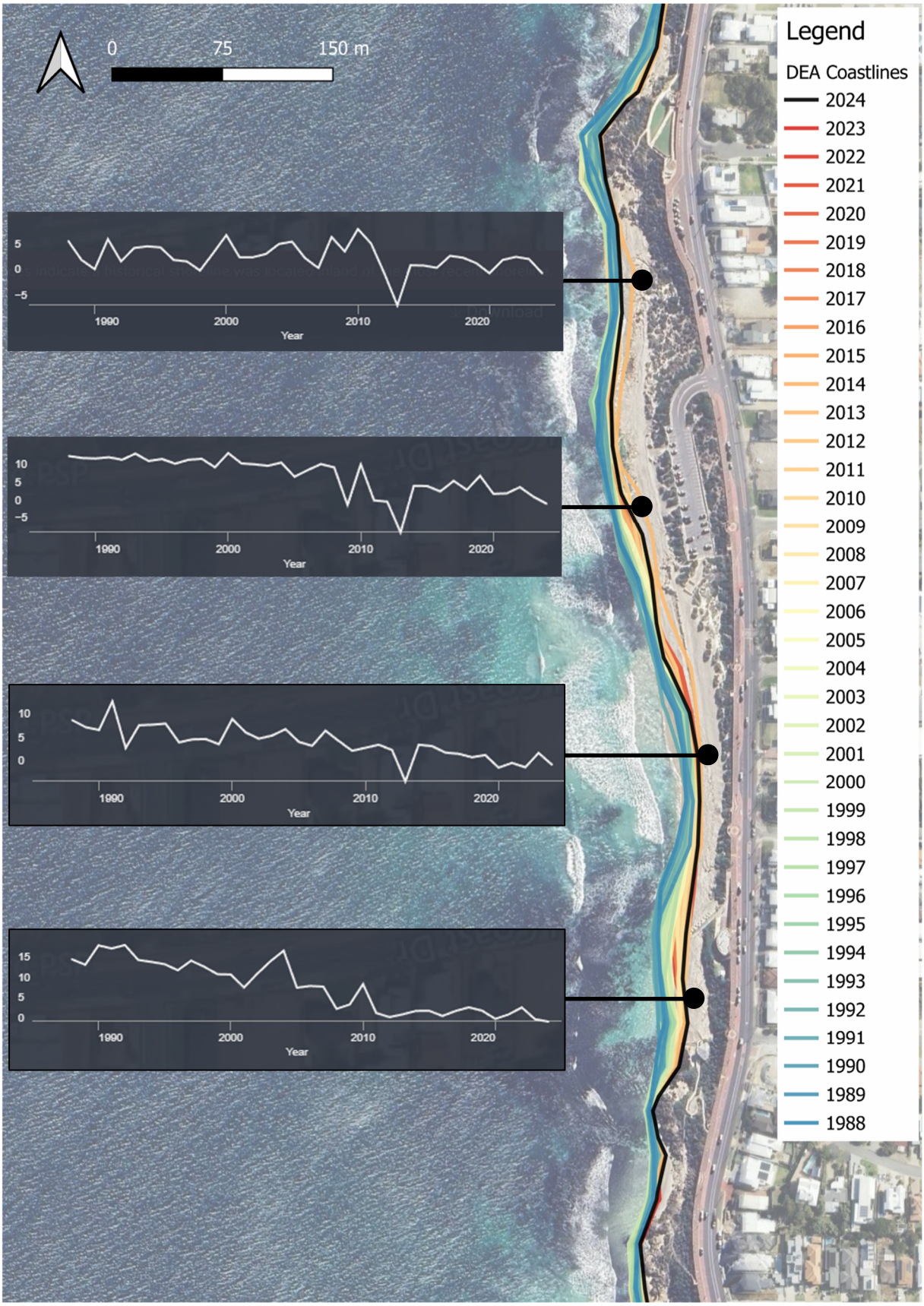


Figure 2.6 DEA Coastlines: MSL Position & Rates of Change Between 1988 to 2024

2.6 Conceptual Model

A conceptual model of sediment movement was developed as part of the Coastal Adaptation Options Assessment (MRA, 2025). This work was based on a review of the coastline, with consideration given to coastal processes, natural and man-made features, and coastal management activities (eg beach nourishment, raking and regrading, revegetation and fencing). The coastline of interest extended from Hillarys Boat Harbour (HBH) in the north to the Cottesloe Groyne in the south.

Figures 2.7 and 2.8 are extracts from MRA's previous work (MRA, 2025) presented here as the basis for an updated conceptual model. This model will consider the effects of the submerged breakwater (reef) on sediment dynamics to investigate the impacts of beach nourishment.

The shoreline movement rates presented below are generally consistent with those outlined in Section 2.3. There is slight variability however this can be attributed to differences in the timeframes and methods of assessment.

There can be considerable variation in magnitude and direction of the longshore sediment transport from season to season and year to year. Longshore sediment transport in the Perth metropolitan region is typically north in summer and south in winter. The strong sea breezes from the south-west in summer transport sediment to the north. In winter, severe storms generate waves from the north, swinging to the south over their duration. This typically transports sediment to the south (Masselink and Pattiaratchi 2000).

As a result, significant seasonal fluxes can exist along the Perth metropolitan region. For example, the seasonal sediment flux at Sorrento Beach prior to construction of Hillarys Boat Harbour was estimated at 70,000 to 90,000 m³ (PWD 1984). Seasonal sediment transport rates are highly dependent on prevailing weather patterns and can therefore vary significantly.

Notwithstanding this variability, the shoreline is generally subject to a net northerly sediment transport of approximately 10,000 m³/year. This is evidenced by accretion on the southern sides of Trigg Point and HBH, as shown in Figure 2.7. The values presented in Figure 2.7 also indicate that the coastline is subject to an onshore supply of sediment, the full extent of which is unknown and which is likely to vary seasonally and interannually.

Figure 2.7 indicates an average net loss of around 1,200 m³ from Mettams Pool. The shoreline movement assessment indicates that sediment is being lost from both the beach and dune systems, as demonstrated by seaward translation of both the vegetation line and MSL position. Given the greater rate of change in the MSL position compared to the vegetation line, the data also suggest an overall narrowing of the beach due to sediment loss.

The coastal dynamics at Mettams Pool are significantly more complex than those of a typical sandy coastline. Figure 2.8 highlights this complexity, where sediment movement is multifaceted and strongly influenced by metocean conditions.

For the foreshore north of Trigg Point, longshore transport is considered to occur through sediment movement between headlands and shallow tidal reefs, directly seaward of these reefs, or further offshore. In contrast, cross-shore transport involves sediment moving offshore and onshore via beach slopes, gaps and channels in the rock platform, over and across shallow tidal reefs, or along sand ramps connecting beaches with offshore sand banks (BMT JFA, 2016). This indicates that sediment pathways along this section of the foreshore are closely linked to coastal topography.

Furthermore, as Mettams Pool is a perched beach, it is expected to undergo more rapid morphological changes than typical sandy coastlines. Investigations by BMT JFA (2016) concluded that perched beaches may also recover more slowly from erosion associated with daily summer sea-breeze conditions.

Where rock platforms are present, wave energy and elevated water levels during storm events can be attenuated. Wave breaking on reefs can also generate shoreward flows. The effects of these processes on the coastline are complex and vary depending on several factors, including but not limited to spatial extent, permeability, freeboard, and surface roughness.

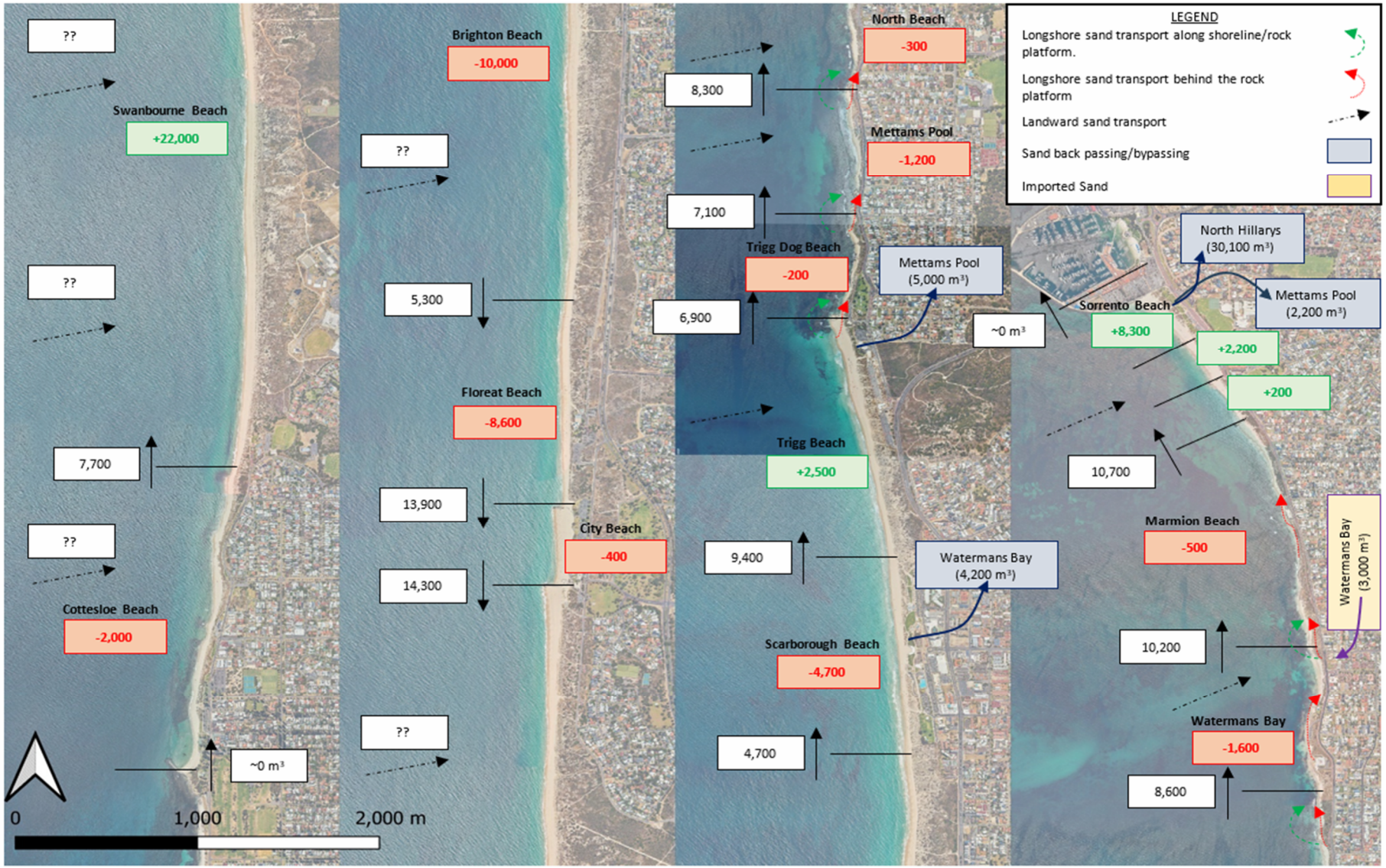


Figure 2.7 Sediment Budget Overview (Hillarys Boat Harbour to Cottesloe Groyne)

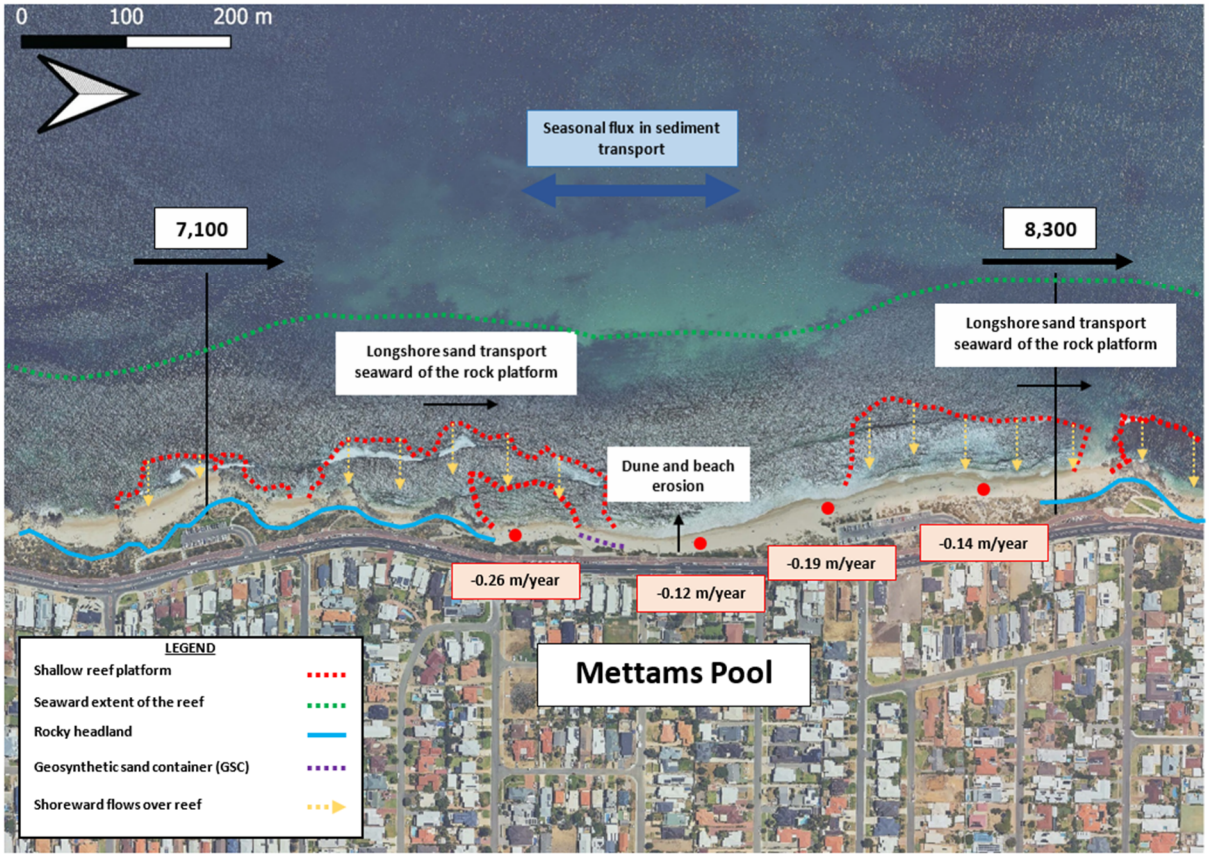


Figure 2.8 Mettams Pool Coastal Dynamics & Sediment Budget

2.7 Marine Parks

Figure 2.9 illustrates the proposed boundary of the Marmion Marine Park, with the proposed extension also shown. The extension is expected to increase the size of the marine park from approximately 9,500 ha to 34,500 ha. The Marine Park extends from the High Water Mark (HWM) to the limit of State Waters.

MRA met with the Department of Biodiversity, Conservation and Attractions (DBCA) in November 2025 to discuss works within marine parks. This included the construction of a submerged breakwater (reef) and other coastal protection measures, such as groynes and seawalls.

DBCA advised that any activity below the HWM must demonstrate a net-neutral or net-positive environmental outcome. This typically requires supporting investigations such as benthic habitat mapping, sediment plume modelling, monitoring programs, and other environmental studies. Marine parks are regarded as significant natural assets and are therefore managed accordingly.

At a high level, and considering the location of Mettams Pool, DBCA indicated that proponents must demonstrate that the proposed works do not:

- impact the lagoon;
- result in the loss or alteration of biota; or
- negatively affect amenity, including snorkelling, fishing, surfing, and swimming.

DBCA also noted that the placement of materials (such as rock) that may increase fish abundance must be assessed holistically to determine whether the outcome is genuinely net-neutral or net-positive. For example, consideration must be given to whether other species are displaced or reduced as a result of the works. A key example in this area is the Weedy Sea Dragon, which is known to inhabit local reef environments.

For activities above the HWM, works are not subject to the same approval requirements however appropriate due diligence is still required where activities may indirectly impact the Marine Park. For instance, beach nourishment may smother nearshore reef habitats, and shoreline structures (such as groynes) may alter nearshore wave conditions.

At present, there is no clearly defined trigger or threshold that specifies when additional environmental investigations must be undertaken for works above the HWM. The annual beach nourishment works currently undertaken at Mettams Pool do not have formal approvals in place, and DBCA has had no direct involvement to date, as sand placement has historically occurred on the beach berm and dune system.

At present, there are no clear recent comparable examples regarding approval for the construction of a coastal protection reef structure or large scale sand nourishment works within a marine park. Large scale nourishment works at Port Beach were completed in recent years to the south of the Cottesloe Reef Fish Habitat Protection Area (FHPA), which is a protected marine area but not a recognised marine park.

For the beach nourishment via rainbowing (ie spraying dredged sand into the nearshore environment) for this work, the project was required to undertake appropriate due diligence of the potential environmental impact, which was submitted to the Environmental Protection Authority (EPA) for their information.

Ultimately, formal assessment was deemed not to be required, which meant the works were not formally reviewed or approved by the EPA. Works within a marine park, such as at Mettams Pool, would likely require formal EPA approval and a more rigorous assessment and review process.

It is recommended that the City undertake further consultation with DBCA to confirm and address any additional requirements associated with proposed works at Mettams Pool. Based on initial conversations, it is likely that works below the HWM will be subject to significant additional investigations and more detailed and extensive environmental approvals process.

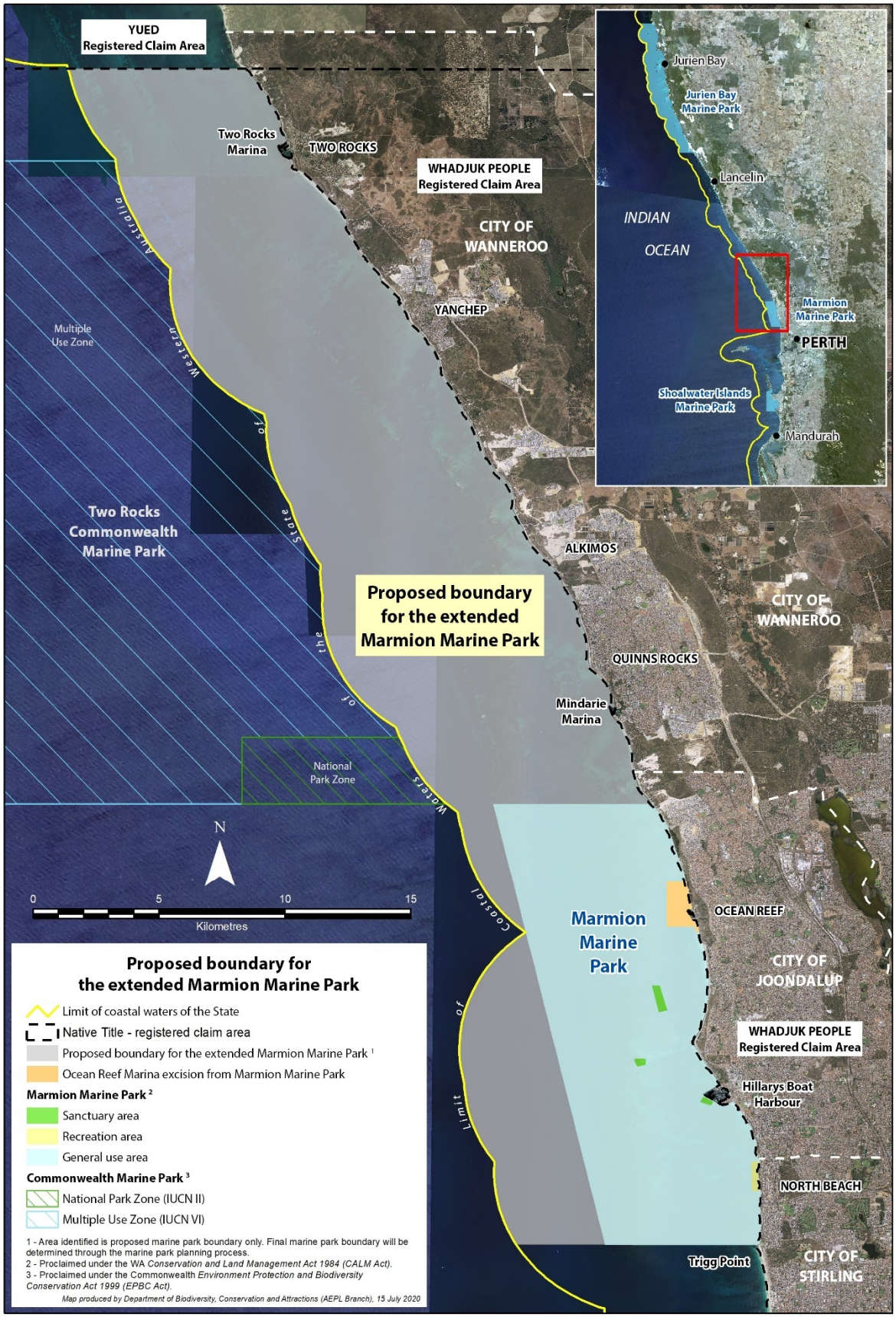


Figure 2.9 Marmion Marine Park & Proposed Extension (DBCA)

2.8 Submerged Breakwater (Reef)

2.8.1 General

This review of submerged breakwaters builds on the work undertaken by MRA (2025). The following section provides additional detail on the coastal processes relevant to the development of a revised conceptual model, with a focus on understanding the influence of submerged breakwaters on littoral sediment transport. It also reviews existing and planned reef projects, including structures designed for specific functions and those classified as multi-purpose reefs (MPRs).

2.8.2 Nearshore Hydrodynamics

Wave Transmission

Submerged breakwaters influence sediment transport in a similar manner to emergent structures by dissipating incident wave energy in the lee of the structure. The proportion of wave energy transmitted past a structure is governed by the amount of energy passing through and over it. Consequently, wave transformation is strongly dependent on the structure's freeboard (ie crest elevation relative to water level) and permeability.

Gent et al. (2023) recently published a study on wave transmission at submerged coastal structures and artificial reefs. This work builds on earlier research by Daemen (1991), who investigated wave transmission for submerged and emergent low-crested rubble mound structures under irregular waves, along with subsequent studies by d'Angremond et al. (1996), Briganti et al. (2003), Van der Meer et al. (2005) and Kurdistani et al. (2022). Collectively, these studies used large experimental datasets and scaled flume testing to derive empirical relationships for estimating the wave transmission coefficient, K_t.

Figure 2.10 presents results from d'Angremond et al. (1996), showing K_t as a function of non-dimensional freeboard ($Freeboard\ (R_c)$/(Wave Height (H_{m0})) for both impermeable and permeable structures.

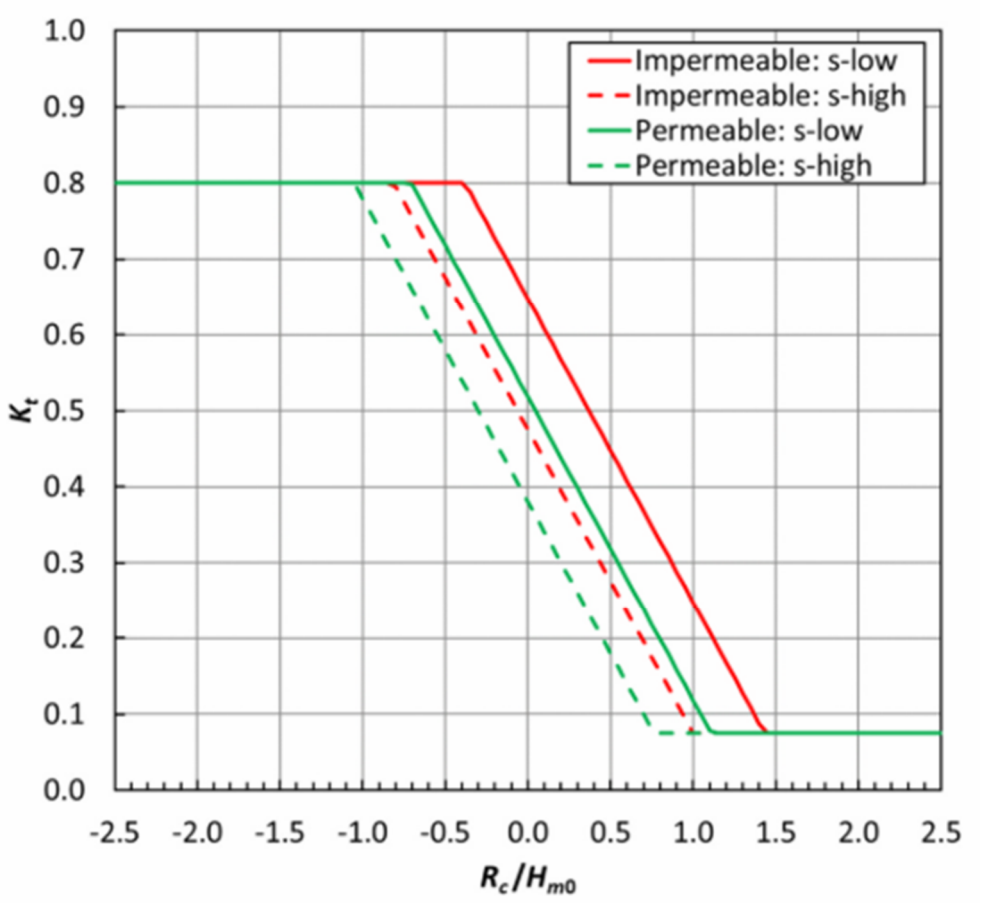


Figure 2.10 Wave Transmission as a Function of Non-Dimensional Freeboard

Gent et al. (2023) specifically addressed the observation that, for very low freeboards, K_t appeared to asymptote towards approximately 0.8 rather than 1.0, as would be expected for negligible or absent structures. To investigate this behaviour, physical model testing was undertaken on five trapezoidal structures with varying permeability but identical geometry (total height h = 0.3 m, 1V:2H side slopes and crest width B = 0.2 m).

The results (Figure 2.11) for impermeable (smooth timber) and permeable (homogeneous stone) structures demonstrate that K_t does asymptote towards 1.0 as the non-dimensional freeboard is significant small (when R_c/H_{m0} = -2.5). The findings also indicate that permeability plays a more significant role when the structure's crest is just below the water surface. The dominant mechanism for energy dissipation is wave breaking rather than surface roughness or internal flow through the structure.

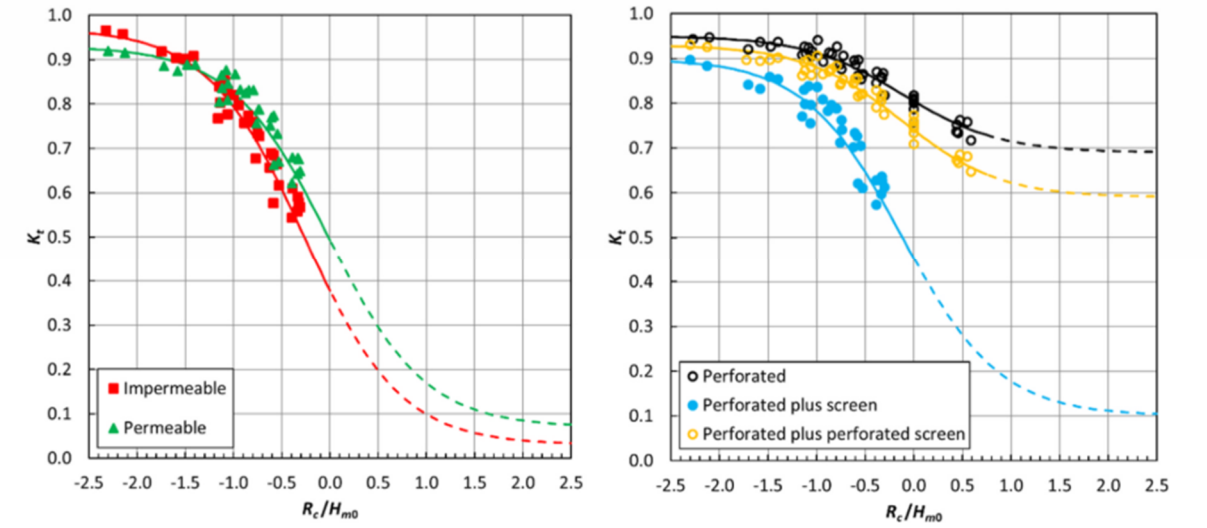


Figure 2.11 Revised Wave Transmission as a Function of Non-Dimensional Freeboard

Gent et al. (2023) proposed a new expression from the works, which is presented below.

$$K_t = c_1 tanh\left(-\left(\frac{R_c}{H_{m0}} = c_2\left(\frac{B}{L_{m-1,0}}\right)^{c_3} + c_4\right)\right) = c_5$$

Where:

$L_{m-1,0} = (g/2\pi)T_{m-1,0}^2$= the spectral wave period

B= Crest width, and

The coefficients for the equation are presented in the figure below and vary depending on the type of structure.

Structure type	c_1	c_2	c_3	c_4	c_5	RMSE
A: Impermeable structure	0.47	3.1	0.75	0	0.5	0.0166
B: Permeable structure (rubble mound structure)	0.43	3.1	0.75	−0.25	0.5	0.0198
C: Perforated structure	0.13	3.1	0.75	−0.15	0.82	0.0149
D: Perforated structure with screen	0.40	3.1	0.75	−0.15	0.5	0.0229
E: Perforated structure with perforated screen	0.17	3.1	0.75	−0.15	0.76	0.0137

Figure 2.12 Coefficients for the Gent et al. (2023) Equation

Overall, the findings of the study concluded that the effects of submerged coastal structures and artificial reefs on wave transmission tended towards 1 for very low freeboards, as hypothesised, rather than 0.8 as suggested in previous literature. Furthermore, the permeability of these structures typically played a more significant role when the non-dimensional freeboard approached zero. These findings reinforce the critical importance of crest depth, which must be appropriately considered in the design of submerged coastal structures and artificial reefs to limit

wave transmission and, therefore, the wave energy reaching the foreshore on the lee of the structure.

In simple terms, these results highlighted that for most effective coastal protection, the submerged structure should be impermeable and with a crest as high as possible. However, rubble mound structures, which are generally considered permeable, only exhibit slightly higher wave transmission than impermeable structures when they are only slightly submerged.

Wave Diffraction & Refraction

Submerged breakwaters introduce a hard structure into the nearshore environment and are therefore likely to alter offshore wave conditions also through diffraction and refraction processes, particularly where structures are discontinuous. Diffraction and refraction describe the spreading or focusing of wave energy as waves encounter an obstruction or change in bathymetry.

In coastal engineering, wave diffraction is particularly relevant when assessing the performance of structures such as submerged reefs and low-crested breakwaters as it allows for wave energy to propagate into the lee of the structure, influencing nearshore wave climates, sediment transport patterns, and shoreline response.

Recent work by da Silva et al. (2022a) indicates that while submerged structures are commonly assumed to promote coastal protection by dissipating wave energy and creating sheltered conditions on their leeward side, this is not always the case. Their review of the meta-analysis by Ranasinghe and Turner (2006) found that, in the majority of documented cases, erosion occurred in the lee of submerged breakwaters.

Nearshore Flows & Wave Runup

Submerged breakwaters modify nearshore hydrodynamics by disrupting the incoming wave field, which in turn alters shoreline flow patterns and water levels in the lee of the structure. Recent work by Silva et al. (2022b) examined how these structures influence circulation patterns and associated shoreline response.

Modelling results indicated that where nearshore flows diverge (ie 2-Cell Circulation (2CC)), erosion is likely to occur in the lee of the structure, refer to Figure 2.13. Conversely, where flows converge near the shoreline (ie 4-Cell Circulation (4CC)), accretion is expected. The development of 2CC or 4CC was shown to depend on incident wave height, structure crest elevation, and distance to the shoreline (water depth at the structure). While the study demonstrated that circulation patterns could be predicted under controlled conditions, the authors noted that in real-world settings, where wave climate and water levels vary seasonally and spatially, circulation types are likely to alternate, resulting in variable shoreline responses.

Although sediment transport was not explicitly modelled, intrawave velocities, water levels and bed shear stresses were used to derive proxies for mean sediment transport. Comparison of mean currents and inferred sediment transport vectors showed similar directional trends, with convergence and divergence patterns evident in both (Silva et al., 2022b), refer to Figure 2.14.

With respect to wave runup, the authors concluded that the submerged breakwater had a relatively limited influence (approximately 15%) across a range of beach slopes (1V:20H to 1V:200H). This resulted in comparable shoreline water levels both with and without the structure present.

These findings suggest that, given the minimal effect on overall water levels, the primary coastal protection mechanism provided by submerged breakwaters is not a significant reduction in runup,

but rather the increased beach width that may develop as a result of the induced circulation patterns and associated sediment redistribution.

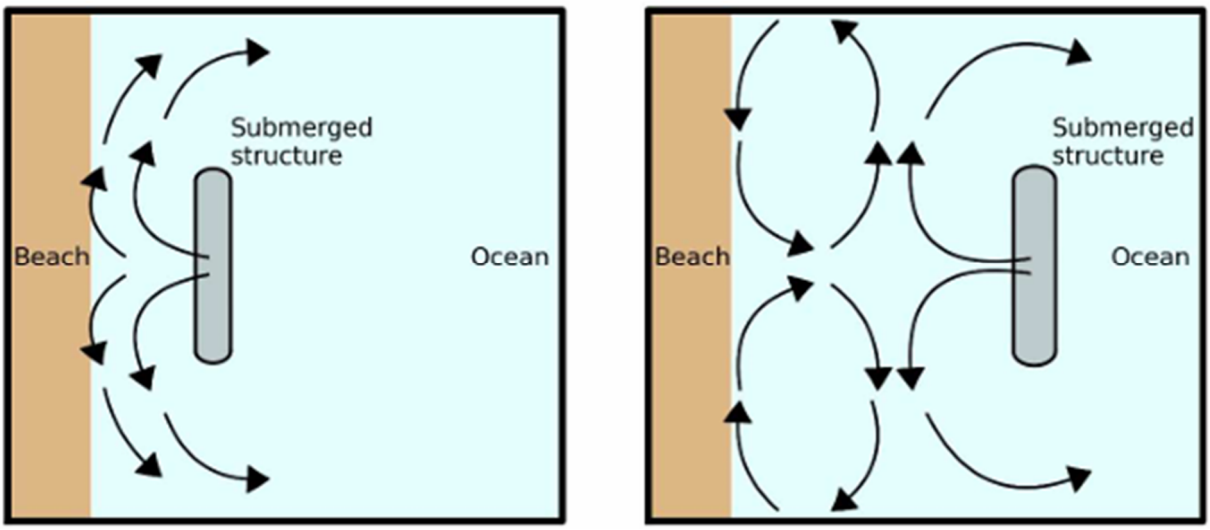


Figure 2.13 (L) 2-Cell Circulation (2CC) (R) 4-Cell Circulation (4CC) Patterns Cause by Waves Interacting with a Submerged Structure

In other words, the protection offered by submerged reefs relies on a buffer of sand accumulating and remaining behind the structure. This likely requires an active sediment supply, or ongoing placement of sand nourishment.

Further, while the flow regime is influenced by several key parameters, its position relative to the shoreline appears to be the strongest predictor of the resulting circulation pattern. The further offshore the reef is located, the more likely a 4CC pattern is to develop, which is associated with converging shoreline flows (ie accretion).

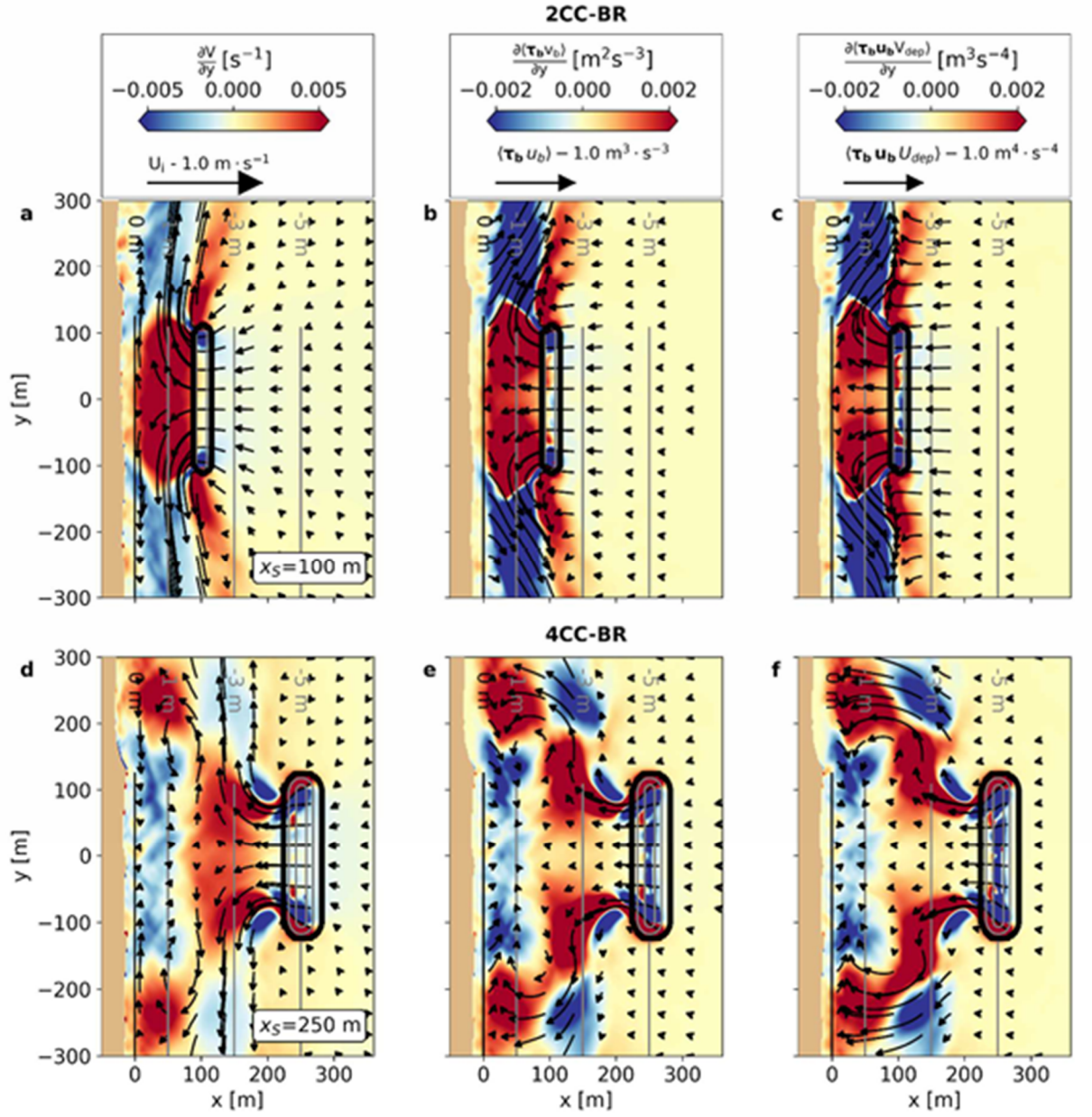


Figure 2.14 Map View of Predictors of Sediment Transport – Red & Blue Gradients are Likely Consistent with Erosion & Accretion Respectively

2.8.3 Fringe Reef – City of Cockburn

The City of Cockburn (CoC) has implemented a modular engineered fringing reef trial off C.Y. O'Connor Beach near North Coogee. The reef is constructed from precast concrete bombora modules, shown in the figure below, which were installed in the nearshore zone (approximately 100 m offshore). The first stage, commencing in 2021, comprised of 135 modules installed in reef array designed to attenuate wave energy and reduce the erosive forces acting on the beach. In late 2024, the reef was expanded to 270 modules in a second stage.

With respects to project costs, the first stage was delivered at around $565,000, partly funded by the City and a State Government Coastal Adaptation Protection (CAP) grant, while the second stage expansion cost approximately $802,000, supported by the Coastal and Estuarine Risk Mitigation Program (CERMP) grant and contributions from the CoC.

The fringing reef trial is not the only form of coastal protection implemented along this section of foreshore. A buried seawall is also installed directly behind the reef and in front of existing assets and infrastructure, and the coastline is subject to beach nourishment works. This typically involves the placement of approximately 15,000 to 20,000 m³ of sand on the foreshore to maintain beach amenity.

MRA has consulted with the CoC on this project, with the following outcomes noted:

- Preliminary performance data indicates that the engineered fringing reef has contributed to an approximate 5-10% reduction in wave height, which is understood to equate to around a 10-20% reduction in wave energy reaching the shoreline.

- Environmental surveys have identified that construction of the fringing reef has resulted in a substantial increase in species diversity and abundance compared to pre-reef conditions, including colonisation by macroalgae, mussels, and other biota.

- The reef has delivered multiple co-benefits, including improved snorkelling opportunities and enhanced recreational amenity.

The modest reduction in wave height is considered to result from the bombora modules being hollow (ie not solid) and highly permeable, allowing the motion of water to pass through the modules with minimal impedance.

Due to the depth and geometry of the units, as well as the wave climate in this area, wave breaking induced by the structure is likely to be inconsistent. Under ambient conditions, waves are likely to pass over and through the structure with minimal impedance, whereas during storm events the units would promote wave shoaling and breaking.

Anecdotal evidence suggests that there has been no discernible change to the shoreline in the lee of the structure (ie no visible signs of salient formation). Since installation of the second stage, aerial photographs have suggested minor formation of a salient in the lee of the structure at some times, although ongoing and persistent erosion has continued around the structure. Furthermore, the City's requirement to place beach nourishment has remained unchanged since installation of the reef, suggesting that there has been no noticeable alteration to littoral drift and that beach amenity must continue to be maintained through beach nourishment.

One of the key takeaways from the trial relates to reef geometry. It has been suggested that the crest level of the structure could have been higher, for example, emergent at low tide, to further reduce the wave energy reaching the shoreline. Additionally, extending the overall length of the structure would have been favourable, as protection would have been afforded to a greater extent of the coastline.

In conclusion, it is noted that:

- The fringe reef is supplementary to other coastal protection measures along the coastline, including the seawall and ongoing beach nourishment.

- Only a modest reduction in wave height, and therefore wave energy at the foreshore, has been observed. To date, this has not resulted in any discernible change in shoreline position.

- Construction of the fringe reef has not reduced the volume of beach nourishment placed on the foreshore, and the foreshore remains subject to ongoing erosional issues.

While the reef does offer other benefits, it does not appear to have significantly improved the coastal protection for the foreshore behind.



Figure 2.15 Fringing Reef Trial at C.Y. O'Connor Beach, North Coogee (Courtesy of City of Cockburn)

2.8.4 Great Southern Surf Reef – City of Albany

The Southern Ocean Surf Reef (SOSR) at Middleton Beach within the City of Albany (CoA) is a purpose-built submerged artificial reef designed to enhance surf quality and frequency. The project involved the construction of a rock reef approximately 140 m offshore, with a footprint of roughly 165 m by 110 m and a crest level around 1 m below mean water level. The structure comprises approximately 62,800 tonnes of quarried rock, placed in graded layers (belly, core and armour rock).

The total project cost is reported at approximately $11.75 to 13 million, funded through a combination of Commonwealth and State Government grants, CoA contributions, and minor community funding. A cost-benefit analysis demonstrated a strong economic justification, with a reported benefit to cost ratio of approximately 6.7. Benefits are considered to include tourism, events, and flow-on spending in the local economy, as well as health and wellbeing benefits associated with increased recreational use.

The site (Middleton Beach) and the reef location were selected to mitigate shoreline impacts. This was considered a key success criterion for the project, along with surf amenity, environmental impacts and safety. Investigations into shoreline response included site-based data collection, numerical modelling, physical modelling, and development of a quantified conceptual model.

MRA issued correspondence to the CoA to consult on the project. At the time of reporting, no response had been received. Notwithstanding this, the Submerged Breakwater (reef) Option (Option 4b), as proposed in MRA's Coastal Adaptation Options Assessment (MRA, 2025), was conceptually assessed based on the available online information relating to the SOSR.

In conclusion, it is noted that:

- The SOSR is a purpose-built submerged artificial reef designed to enhance surf quality and frequency.

- One of the key success criteria of the works was to mitigate shoreline impacts. The investigations indicate that the reef will result only in localised wave shadowing in the lee of the structure.

To date no monitoring data has been made available to confirm any impacts on the shoreline.

2.8.5 Ocean Reef Surf Reef – City of Joondalup

MRA has consulted with the City of Joondalup (CoJ) regarding the pre-feasibility study for the proposed surf reef as Ocean Reef Marina (ORM). At the time of reporting, this study is considered confidential and is not available for external distribution until it has been presented to CoJ Council and the wider community.

Similarly to the above, the Submerged Breakwater (reef) Option (Option 4b) was assessed based on our discussion with the CoJ.

2.8.6 Updated Conceptual Model

The figure below presents a revised conceptual model of Mettams Pool that considers the construction of the submerged breakwaters. The general nearshore processes acting along the coastline are expected to remain largely unchanged, as they are governed by the offshore metocean conditions to which the coastline is exposed to. Specifically:

- Seasonal sediment transport rates are of the order of 100,000 m³, driven by sea breezes during summer and storm events in winter.

- The shoreline is subject to a net northerly sediment transport, with Mettams Pool receiving approximately 7,100 m³ of sediment from the south.

However, when considering Mettams Pool in a local context, the inclusion of submerged breakwaters as part of the nearshore morphology is expected to introduce fundamental changes to nearshore dynamics. As identified in the literature, these changes include:

- Reductions in wave energy in the lee of the structure associated with depth-limited breaking, increased surface roughness and porosity of the reef system, as well as wave diffraction and refraction.

- Introducing nearshore flow patterns in the lee of the structure. These flows may be divergent or convergent at the shoreline and may therefore exhibit erosional or accretional tendencies respectively.

These changes are expected to alter sediment transport processes until a new equilibrium condition is established. Consequently, the previously estimated sediment loss from Mettams Pool would change. Any variation in these volumes would introduce downstream effects along the adjacent coastline.

At a conceptual level, only high-level estimates can be made regarding reductions in wave height in the lee of the structure, and the resulting shoreline response. To develop a more detailed understanding of the shoreline response, further investigations would be required, which may include physical and numerical modelling.

Notwithstanding this, when the proposed reef geometry is reviewed in the context of the findings of Gent et al. (2023), the submerged breakwaters have the potential to reduce transmitted wave heights to approximately 0.6 times the incident wave height for a structure with a non-dimensional

freeboard of zero, and up to approximately 0.8 under more extreme conditions (ie winter storm event with elevated water levels).

As a result, it has been assessed at a conceptual level that the rate of loss has been similarly decreased from 1,200 m^3 to approximately 700 m^3 per year, with increased retention of sand behind the structure. This reduction was estimated by considering the decrease in wave energy in the lee of the proposed structure. It should be noted that these transport rates, like the rest of the coastline, are highly dependent on prevailing weather patterns and can therefore vary significantly season to season and year to year.

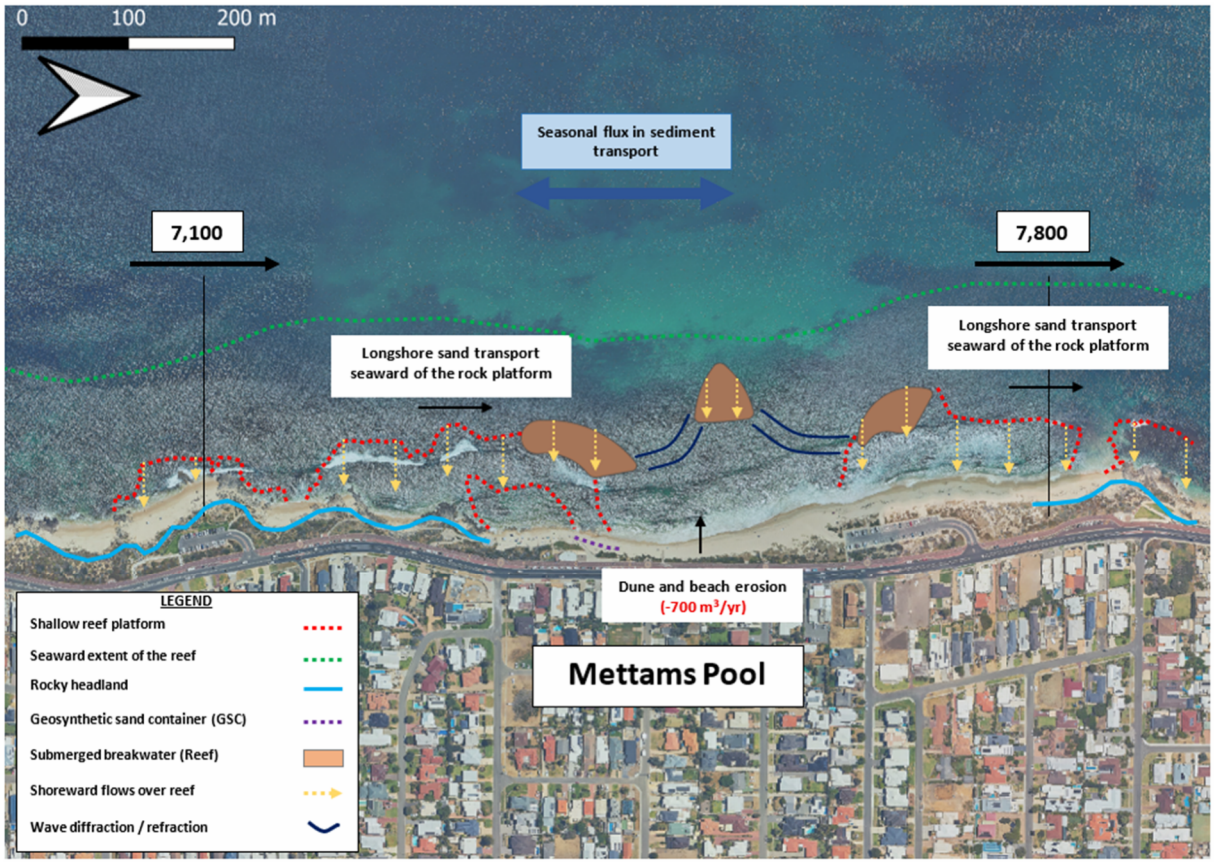


Figure 2.16 Updated Conceptual Model

2.9 Groyne

There have been several occasions where sand placed as part of the annual beach nourishment works has filled the swimming area. For this reason, the City has requested that MRA review the option of constructing a groyne to the north of the swimming area to prevent infilling.

Groynes are shore-perpendicular structures that interrupt longshore sediment transport. In this instance, the structure is intended to limit the amount of sand transported south during winter storm events. Fundamentally, this would compartmentalise the Mettams Pool swimming area from the remainder of the beach, allowing the beach nourishment placed within the swimming area to be retained for a longer period, while preventing the nourished sand placed for further north from infilling the pool.

As is the case with all groynes, updrift and downdrift effects would be expected. At Mettams Pool, given the net northerly sediment transport, accretion would be expected to the south of the

structure and erosion to the north. Notwithstanding this, beach morphology would also continue to be influenced by seasonal rotation of the beach, driven by prevailing weather patterns.

MRA (2025) previously reviewed the option of groynes in combination with beach nourishment as an option. It was determined that this option (Option 3 of the Coastal Adaptation Options Assessment) did not fully satisfy the key success criteria due to its significant impacts on beach amenity and recreational use.

Subsequently, a groyne is still not considered to adequately meet the success criteria developed as part of the community consultation process.

2.10 Vertical Seawall

Like the groyne option, the City has also requested that MRA review the option of constructing a small-scale vertical wall at the rear of the swimming area, to reduce the volume and / or frequency of beach nourishment required within the swimming area.

Vertical seawalls are designed to protect landward assets from coastal erosion and wave attack. Their protective effects are localised to their footprint, providing targeted protection where required.

Other forms of seawalls, such as sloping rock revetments, have previously been assessed in earlier stages of this project and previous works at Mettams. Due to their larger footprint and increased impact on the dunes, they were not supported by the community. A buried seawall may be one way to maintain beach width, but would require increased clearing of remnant dune vegetation and is therefore not consistent with the key project objectives. For this assessment only vertical walls were therefore assessed.

MRA (2025) previously reviewed the option of a seawall in combination with beach nourishment as an option. While this option (Option 2 of the Coastal Adaptation Options Assessment) was considered to adequately meet the success criteria, it received the equal lowest rating of all five options with respect to the economic and environmental criteria of the Multi-Criteria Analysis (MCA). It was the preferred option with respect to the social criteria.

3. Alternative Treatment Options

The alternative treatment options align with the basis of design requirements developed as part of MRA's previous works. The basis of design outlines the high-level approach adopted during the development of all alternative treatment options. For further detail, please refer to the Coastal Adaptation Options Assessment (MRA, 2025).

Alternative Treatment 3 was considered as part of MRA's previous works. This updated assessment reviews this option in further detail, including recent research and an updated assessment of the impact of the submerged breakwaters on sand nourishment requirements.

3.1 Vertical Wall & Beach Nourishment (Alternative Treatment 1)

Due to the inclusion of the vertical wall landward of the swimming area, the beach can be considered as two distinct zones, rather than compartments. While the zones are not separated by a "hard" coastal structure such as a groyne, they have differing coastal protection requirements. These are defined as a Northern Zone and a Southern Zone, with the approach for each outlined below.

Northern Zone

To the north, coastal protection is provided through beach nourishment volumes comprising both of a "Sand Buffer" and "Beach Maintenance", consistent with MRA's previous work and as detailed below:

- Sand Buffer – Additional sand added to the upper beach profile to protect upland infrastructure from storm events and wave action. High-level beach nourishment volumes were estimated using SBEACH a software developed by the Coastal Engineering Research Centre to simulate beach profile evolution in response to storm events. The results from the modelling indicated that during the 100-year storm event approximately 20 m^3/m of erosion could be expected.

- Beach Maintenance – A beach nourishment regime that considers both longshore transport and sea level rise. Longshore transport quantities were estimated via the shoreline movement analysis. Sand loss due to sea level rise was estimated using DoT's recommended sea level rise allowances (DoT, 2010).

Biennial beach nourishment was considered appropriate to ensure that seaward translation of the shoreline does not smother the nearshore reef, that the beach berm height is maintained, and that the beach profile remains within the operational reach of land-based heavy machinery.

Southern Zone

To the south, coastal protection will be provided through a combination of a vertical wall and beach nourishment.

Consistent with the Coastal Adaptation Options Assessment (MRA, 2025), a vertical L-wall is proposed. In this instance, the wall is a smaller-scale structure terminating at a reduced crest level of +3.5 mAHD, compared to the previously proposed +6.0 mAHD. The primary function of the wall is to provide back of beach protection and reduce the volume of beach nourishment required within the swimming area. At this reduced height, the wall will not provide absolute protection during all storm events, and overtopping is expected to occur under more extreme conditions.

Rock levels informing the wall design have been derived from investigations undertaken by GBGMAPS (2018) and DTE Geotechnical (2019). This data was used to establish the wall depth. The geophysical investigations were found to generally overestimate rock levels by approximately 1 m. Accordingly, where rock levels were estimated to be less than +2.0 m AHD, the wall footings were founded at +0.5 m AHD. Where rock levels were estimated to be greater than +2.0 m AHD, the footings were founded at +2.0 m AHD.

The wall height was determined using SBEACH modelling to assess beach erosion response under storm conditions. The adopted height reflects performance during a 100-year storm event combined with a 1-year still water level.

The wall is proposed to tie into the existing vertical wall in the south, adjacent to the gazebo, and the beach access ramp in the north, thereby removing any risk of flanking erosion. As is often the case with these types of structures, the beach in front of the structure may be prone to accelerated scouring and slightly increased erosion rates through reflections. However, as the structure is founded on rock, structural integrity will be maintained.

Given the adopted wall height, beach nourishment within the Southern Zone will comprise both a “Sand Buffer” and “Beach Maintenance”. The required sand volumes for Beach Maintenance are consistent with those identified above. In contrast, Sand Buffer volumes have been reduced due to the landward positioning of the vertical wall. The total reduction in sediment resulting from the construction of the vertical seawall is estimated to be 2,000 m³, associated with the capital works.

The beach berm is proposed to have an as-constructed slope of 1V:4H and an elevation of +2.0 mAHD, consistent with existing berm heights. The native and borrowed sediments are considered to be consistent, therefore the final beach berm profile is expected to closely resemble the existing profile, with only a minor seaward translation.

The figures below illustrate the proposed vertical wall and beach nourishment works to be undertaken as part of the capital works.

3.1.1 Concept

The layout and section for this option are illustrated in Figure 3.1 and included at a larger scale in Appendix A.

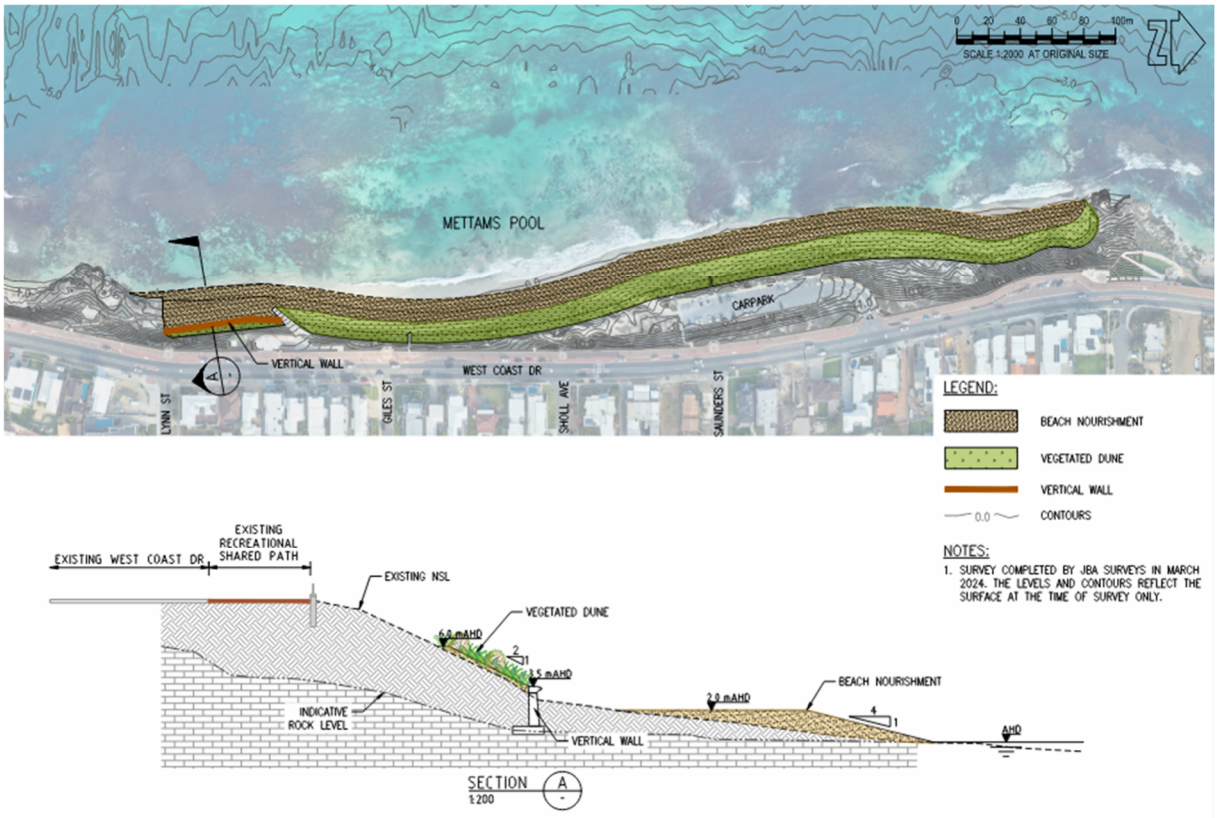


Figure 3.1 Alternative Treatment 1 – (Top) Layout (Bottom) Section

3.1.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for this option. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 3.1 and 3.2 respectively.

For Alternative Treatment 1, the only change compared with the base case is that placement of the Sand Buffer behind the swimming area is not required however biannual Beach Maintenance is still required. Further, a vertical wall will be constructed behind the swimming area. When considered in the context of the overall cost of the works, the following is noted:

- Capital cost – An increase of approximately $600k to the overall construction cost if a vertical wall is constructed instead of constructing a Sand Buffer behind the swimming area.
- Maintenance cost – An increase of approximately $340k to the overall maintenance cost due to the additional requirement for seawall maintenance.

The maintenance costs for "hard" engineered structures are estimated at 1% per annum of the structure's initial cost, which over a 50-year period equates to 50% of the structure's cost.

Table 3.1 Alternative Treatment 1 – Opinion of Probable Capital Cost

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Capital - Seawall & Nourishment**					$ 2,306,900
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc	1	Item	$ 250,000	$ 250,000	
1.2	Source, transport and construct high-grade, reinforced concrete seawall	48	m	$ 4,300	$ 206,400	
1.3	Source, transport and construct deep founded seawall	27	m	$ 11,500	$ 310,500	
1.4	Source, transport and place beach nourishment from terrestrial sources	22,000	m^3	$ 70	$ 1,540,000	
	Subtotal 1				$ 2,306,900	$ 2,306,900
	Contingencies	20	%		$ 461,380	$ 461,380
	Subtotal 2				$ 2,768,280	$ 2,768,280
	Goods & Services Tax				$ 276,828	$ 276,828
	Total Estimated Cost				$ 3,045,108	$ 3,045,108

Table 3.2 Alternative Treatment 1 – Opinion of Probable Maintenance Cost Over 50 Years

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Maintenance Over 50-year Horizon (Biennially)**					$ 9,658,450
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc	25	Item	$ 40,000	$ 1,000,000	
1.2	Beach nourishment to replace lost material	120,000	m^3	$ 70	$ 8,400,000	
1.3	Seawall maintenance	50	%	$ 516,900	$ 258,450	
	Subtotal 1				$ 9,658,450	$ 9,658,450
	Contingencies	20	%		$ 1,931,690	$ 1,931,690
	Subtotal 2				$ 11,590,140	$ 11,590,140
	Goods & Services Tax				$ 1,159,014	$ 1,159,014
	Total Estimated Cost				$ 12,749,154	$ 12,749,154

3.1.3 Advantages & Disadvantages

The table below lists the advantages and disadvantages associated with this option. Note, this review is in respect to the swimming area only, as the base case scenario "Beach Nourishment" (Option 1) was reviewed within the Coastal Adaptation Options Assessment (MRA, 2025). It attempts to provide relative advantages and disadvantages between these alternative treatments and may not cover all aspects of the total project.

Table 3.3 Alternative Treatment 1 – Advantages & Disadvantages

Advantages	Disadvantages
■ Maintains a usable beach width and beach amenity. ■ Maintains continuity of the beach space, as no shore-normal structures are required. ■ Beach nourishment at Mettams Pool will increase the sediment feed to the northern beaches (including Watermans Bay). ■ Introduce additional sand into the system, which is likely to result in an increase in offshore sandbanks. ■ The wall limits sand nourishment requirements, reducing the likelihood of sand infilling the swimming pool. ■ Provides redundancy to landward assets if sand nourishment is lost, reducing the need for emergency works between biennial nourishment campaigns. ■ Requires no direct encroachment into the Marmion Marine Park, thereby minimising the need for DBCA approvals.	■ The wall will have a visual impact on the foreshore. ■ Beach nourishment causes beach disturbance. ■ Increases the overall cost of the works, including both capital and ongoing maintenance costs. ■ Risk of nearshore reef smothering. ■ Environmental approvals will be required for vegetation clearing. ■ Beach disturbance is likely to be prolonged during construction of the vertical wall. ■ May result in increased localised erosion when wall is exposed.

3.2 Small Scale Groyne & Beach Nourishment (Alternative Treatment 2)

The construction of a small-scale groyne is considered directly north of the beach access ramp. The groyne would only extend out into the nearshore regions to prevent the seasonal changing in beach morphology and minimise the likelihood of the pool infilling with sand following the winter months. Because of this, as well as the shallow nearshore reef system, the construction of the groyne could result in larger shore normal flows in the vicinity of the structure.

Further, due to stakeholders' previous preference against rubble mound structures, Geotextile Sand Containers (GSCs) are proposed for the construction of the groyne. Larger GSCs (2.5 m^3 containers) have been shown to offer improved stability under severe conditions however they can still be dislodged or damaged, similar to rubble mound structures, and will therefore require maintenance. It is assumed that the containers will be filled with imported beach fill required for the works.

A crest height of +2.0 mAHD has been adopted for the design, having regard to the existing elevations of the surrounding area while seeking to minimise impacts on visual amenity. The toe depth is shown to be founded at or below the Natural Seabed Level (NSL), and the structure is designed with side slopes of 1V:2H.

The works consider Mettams Pool to be compartmentalised by the groyne located to the north of the beach access ramp, forming a northern and southern compartment. The following outlines the approach for each compartment with respect to beach nourishment.

North Compartment

Beach nourishment volumes to the north comprises of a "Sand Buffer" and "Beach Maintenance", consistent with the approach described under the Alternative Treatment 1 (Section 3.1).

Biennial beach nourishment was considered appropriate to ensure that seaward translation of the shoreline does not smother the nearshore reef, that the beach berm height is maintained, and that the beach profile remains within the operational reach of land-based heavy machinery.

South Compartment

Beach nourishment to the south is consistent with the requirements for "Beach Maintenance", as described above. However, there is no requirement to construct a "Sand Buffer" behind the swimming area. The total reduction in sediment resulting from the construction of the groyne is estimated to be 4,000 m^3, associated with the capital works.

The beach berm is proposed to have an as-constructed slope of 1V:4H and an elevation of +2.0 mAHD, consistent with existing berm heights. The native and borrowed sediments are considered to be consistent, therefore the final beach berm profile is expected to closely resemble the existing profile, with only a minor seaward translation.

The figures below illustrate the proposed groyne and beach nourishment works to be undertaken as part of the capital works.

3.2.1 Concept

The layout and sections for this option are illustrated in Figure 3.2 and included at a larger scale in Appendix A.

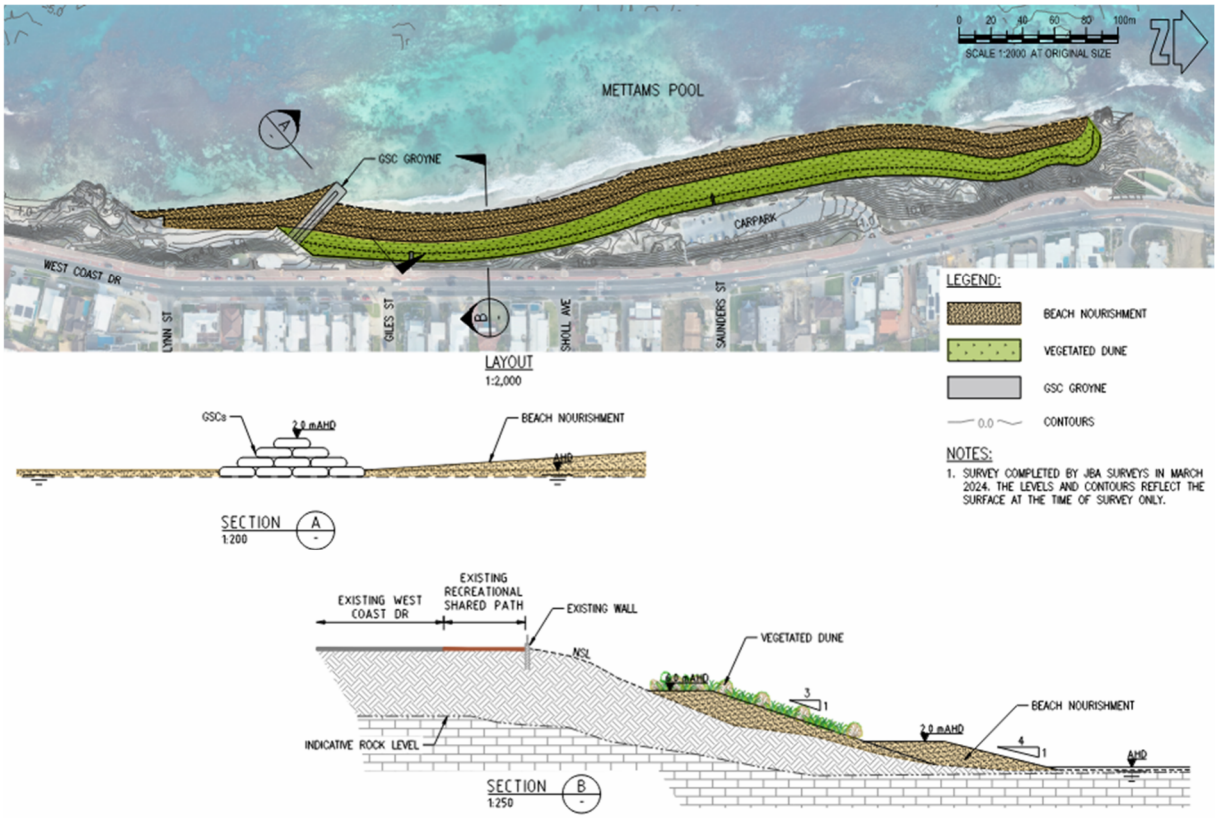


Figure 3.2 Alternative Treatment 2 – (Top) Layout (Bottom) Sections

3.2.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for this option. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 3.4 and 3.5 respectively.

For Alternative Treatment 2, the changes relative to the base case include the removal of the Sand Buffer behind the swimming area and construction of a small-scale groyne. When considered in the context of the overall cost of the works, the following is noted:

- Capital cost – An increase of approximately $3.3k in overall construction costs where a groyne is constructed in lieu of a Sand Buffer behind the swimming area.
- Maintenance cost – An increase of approximately $130k in overall maintenance due to the additional requirement for groyne maintenance.

The maintenance costs for "hard" engineered structures are estimated at 1% per annum of the structure's initial cost, which over a 50-year period equates to 50% of the structure's cost.

Table 3.4 Alternative Treatment 2 – Opinion of Probable Capital Cost

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Capital - Groyne & Nourishment**					$ 1,852,500
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc.	1	Item	$ 250,000	$ 250,000	
1.2	Source, transport and place beach nourishment from terrestrial sources	20,000	m^3	$ 70	$ 1,400,000	
1.3	Source, transport and construct a GSC groyne.	45	m	$ 4,500	$ 202,500	
	Subtotal 1				$ 1,852,500	$ 1,852,500
	Contingencies	20	%		$ 370,500	$ 370,500
	Subtotal 2				$ 2,223,000	$ 2,223,000
	Goods & Services Tax				$ 222,300	$ 222,300
	Total Estimated Cost				$ 2,445,300	$ 2,445,300

Table 3.5 Alternative Treatment 2 – Opinion of Probable Maintenance Cost Over 50 Years

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Maintenance Over 50-year Horizon (Biennially)**					$ 9,501,250
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc	25	Item	$ 40,000	$ 1,000,000	
1.2	Beach nourishment to replace lost material	120,000	m^3	$ 70	$ 8,400,000	
1.3	Groyne maintenance	50	%	$ 202,500	$ 101,250	
	Subtotal 1				$ 9,501,250	$ 9,501,250
	Contingencies	20	%		$ 1,900,250	$ 1,900,250
	Subtotal 2				$ 11,401,500	$ 11,401,500
	Goods & Services Tax				$ 1,140,150	$ 1,140,150
	Total Estimated Cost				$ 12,541,650	$ 12,541,650

3.2.3 Advantages & Disadvantages

The table below lists the advantages and disadvantages associated with this option. Note, this review is in respect to the swimming area only, as the base case scenario "Beach Nourishment" (Option 1) was reviewed within the Coastal Adaptation Options Assessment (MRA, 2025).

As outlined earlier, this option is NOT considered to appropriately meet the success criteria of the City's CHRMAP however has still been reviewed in terms of advantages and disadvantages.

Table 3.6 Alternative Treatment 2 – Advantages & Disadvantages

Advantages	Disadvantages
■ Maintains or increases the existing beach width and beach profile slope. ■ Introduce additional sand into the system, which is likely to result in an increase in offshore sandbanks. ■ Beach nourishment at Mettams Pool will increase the sediment feed to the northern beaches (including Watermans Bay).	■ Was not previously supported by Reference Group. ■ Reduces beach continuity due to the introduction of shore-perpendicular structures. ■ Beach nourishment causes beach disturbance. ■ Risk of nearshore reef smothering. ■ Results in a significant and visually unappealing impact on the foreshore ■ Directly encroaches into the Marmion Marine Park, requiring DBCA approvals. ■ Interrupts longshore sediment transport as it reduces the wave energy reaching the coastline. ■ May alter nearshore coastal processes and inhibit water-based activities such as surfing, windsurfing, swimming and snorkelling. ■ Provides no redundancy to landward assets if sand nourishment is lost, potentially necessitating emergency works. ■ Increases the overall cost of the works, including both capital and ongoing maintenance costs.

3.3 Submerged Breakwaters (Reefs) & Beach Nourishment (Alternative Treatment 3)

Beach Nourishment Quantities

The sand volumes for the Sand Buffer are consistent with the requirements detailed in the vertical wall option (Section 3.1).

Conversely, beach maintenance requirements are expected to decrease within the sheltered area in the lee of the submerged breakwaters. Based on the literature, sediment transport volumes may be rationalised from approximately 1,200 m³/year (as previously estimated from shoreline movement analysis) to around 700 m³/year. The total reduction in sediment resulting from the construction of the submerged breakwaters (reefs) is estimated to be 28,000 m³, associated with the maintenance works.

Frequency of Nourishment

Biennial beach nourishment was considered appropriate to ensure that seaward translation of the shoreline does not smother the nearshore reef, that the beach berm height is maintained, and that the beach profile remains within the operational reach of land-based heavy machinery.

Key geometrical features

- Submerged Breakwaters (reefs) –
    - A crest height of 0 mAHD has been adopted for the submerged breakwater (reef) design, assuming that the primary role of the structure is coastal adaptation. As a result, the focus is solely on dissipating nearshore wave energy.
    - Given that the structure is at or below 0 mAHD, it is considered that there will be little to no impact on amenity. Like the adjacent reef it ties in to, rocks will be exposed periodically and during lower water levels.
    - The toe depth is shown to be founded at or below NSL, with the structures having a slope of 1V:4H.
- Beach Nourishment –
    - The sand buffer is designed with a slope of 1V:3H and is intended to be planted and stabilised to enhance durability and resistance to erosion. In contrast, the beach berm will feature a constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with the current berm heights.
    - As the borrowed sediment closely matches the native material, the final beach berm profile is expected to closely resemble the existing one, with only a minor seaward shift.

The figure below illustrates the proposed submerged breakwaters (reefs) and beach nourishment to be undertaken as part of the capital works.

3.3.1 Concept

The layout and section for this option are illustrated in Figure 3.3 and included at a larger scale in Appendix A.

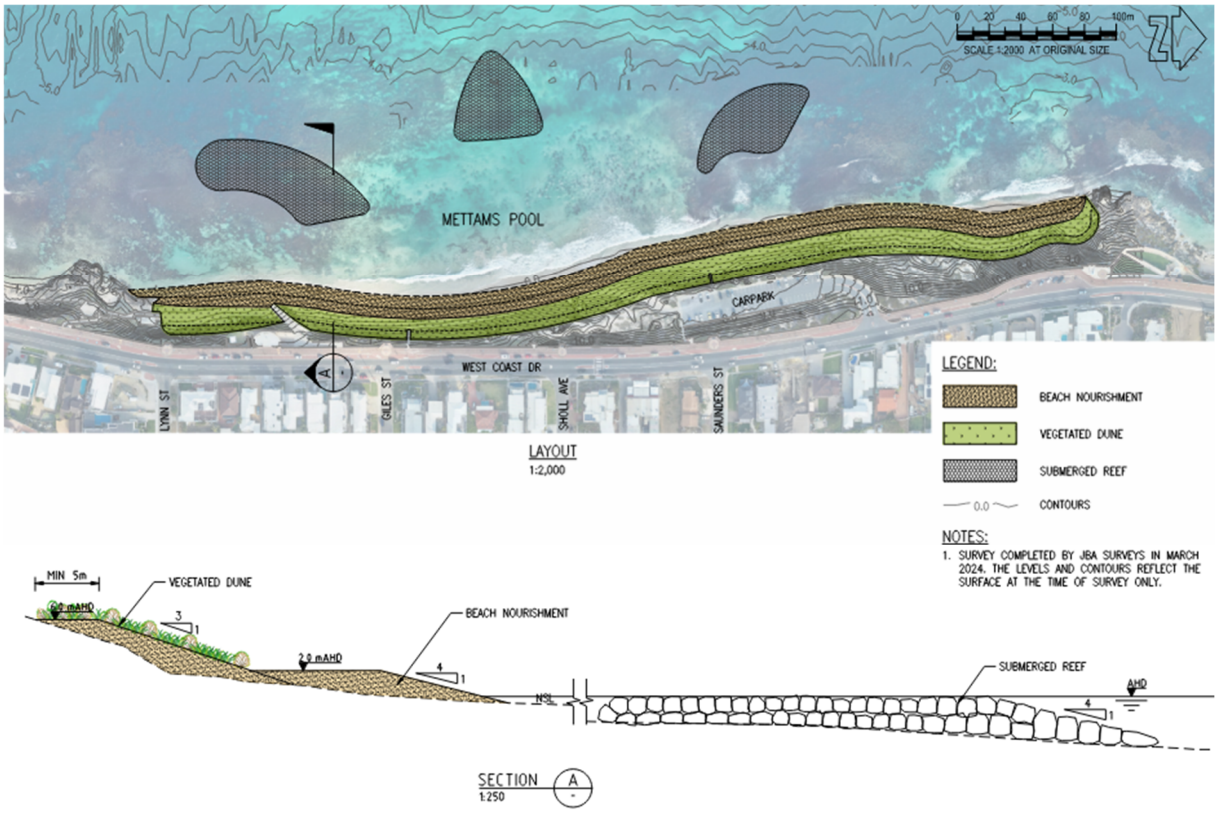


Figure 3.3 Alternative Treatment 3 – (Top) Layout (Bottom) Section

3.3.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for this option. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 3.7 and 3.8 respectively.

For Alternative Option 3, the only change compared with the base case relates to beach maintenance, which has been reduced to reflect the anticipated effects of the submerged breakwater (reef). When considered in the context of the overall project costs, the following is noted:

- Capital cost – Increased to approximately $9.2M due to the increase in costs of basic raw materials over recent years, which is $6.8M higher than the base case.
- Maintenance cost – An increase of approximately $1.2M, due to the maintenance costs of the structure, but also a reduction in the beach maintenance volumes.

The maintenance cost for maintaining the submerged breakwaters (reef) are greater than the previous two options due to the costs associated with accessing the structures but also the fact that in order to be most effective, the crest is to be founded at 0 mAHD. Therefore, additional rock needs to be added to the crest of the structure to account for sea level rise. Maintenance costs for Alternative Option 3 over a 50-year period equates to 63% of the structure's cost.

Table 3.7 Alternative Treatment 3 – Opinion of Probable Capital Cost

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Capital - Submerged Reefs & Nourishment**					$ 6,985,000
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc	1	Item	$ 650,000	$ 650,000	
1.2	Source and transport sand from terrestrial sources	23,000	m^3	$ 60	$ 1,380,000	
1.3	Placement of sand for reef construction as well as beacl nourishment	8,100	m^3	$ 20	$ 162,000	
1.4	Beach nourishment	14,900	m^3	$ 10	$ 149,000	
1.5	Source, transport and construct submergent limestone reefs	25,800	Tonne	$ 180	$ 4,644,000	
	Subtotal 1				$ 6,985,000	$ 6,985,000
	Contingencies	20	%		$ 1,397,000	$ 1,397,000
	Subtotal 2				$ 8,382,000	$ 8,382,000
	Goods & Services Tax				$ 838,200	$ 838,200
	Total Estimated Cost				$ 9,220,200	$ 9,220,200

Table 3.8 Alternative Treatment 3 – Opinion of Probable Maintenance Cost Over 50 Years

Item	Activity	Quantity	Units	Unit Rate	Subtotal	Total for Item
1	**Maintenance Over 50-year Horizon (Biennially)**					$ 10,365,720
1.1	Preliminaries including site establishment, mobilisation, insurances, management plans etc	25	Item	$ 40,000	$ 1,000,000	
1.2	Beach nourishment to replace lost material	92,000	m^3	$ 70	$ 6,440,000	
1.3	Reef maintenance and adaptation	63	%	$ 4,644,000	$ 2,925,720	
	Subtotal 1				$ 10,365,720	$ 10,365,720
	Contingencies	20	%		$ 2,073,144	$ 2,073,144
	Subtotal 2				$ 12,438,864	$ 12,438,864
	Goods & Services Tax				$ 1,243,886	$ 1,243,886
	Total Estimated Cost				$ 13,682,750	$ 13,682,750

3.3.3 Advantages & Disadvantages

The table below lists the advantages and disadvantages associated with this option.

The table is generally consistent with MRA's previous work however considers the protection offered by the submerged breakwater (reef) option. While beach nourishment is still required, this approach alleviates the following disadvantages:

- Reduced overall beach nourishment volumes.
- Less beach disturbance.
- Lower risk of smothering the nearshore reef.

Table 3.9 Alternative Treatment 3 – Advantages & Disadvantages

Advantages	Disadvantages
■ Protects infrastructure through nourishment of dune and providing storm buffer. ■ Maintains continuity of the beach space. ■ Structures can be designed to improve water-based activities such as surfing and snorkelling. ■ Structures can be designed to provide habitat opportunities. ■ Minimal visual impact. ■ Reduced maintenance nourishment requirements compared to other alternative treatments. ■ Beach nourishment at Mettams Pool will increase the sediment feed to the northern beaches (including Watermans Bay).	■ Direct impact from structures on nearshore reef and habitat. ■ Beach nourishment causes beach disturbance. ■ Higher capital and maintenance costs. ■ Risk of nearshore reef smothering. ■ Potential loss of buffer during severe or consecutive storm events, requiring additional nourishment – less guarantee. ■ Logistical challenges with in-water construction. ■ Directly encroaches into Marmion Marine Park, requiring additional environmental approvals. ■ Interrupts longshore sediment transport as it reduces the wave energy reaching the coastline.

4. Recommendations & Conclusion

This report has been prepared in response to Council Resolution 0525/033 and focuses on investigating alternative coastal adaptation options. The scope includes:

- A review of recent data and developments.
- Development of an updated conceptual model for the submerged breakwater (reef) option, including consideration of its potential influence on the volume and frequency of beach nourishment along the foreshore.
- Conceptual design and cost evaluation of alternative small-scale permanent coastal adaptation options at Mettams Pool.

The key findings and recommendations are summarised below:

Beach Nourishment (Base Adaptation Option)

Beach nourishment remains the preferred adaptation option for Mettams Pool. It is recommended that the design be progressed, with sand volumes carefully managed to avoid infilling of the pool and smothering of the nearshore reef. This will likely require a reduction in capital nourishment volumes. A key advantage of this option is its adaptability to observed shoreline response. Importantly, beach nourishment can commence while alternative options continue to be assessed.

Vertical Wall

A low-crested vertical wall at the rear of the swimming area is considered a viable option, providing redundancy for landward assets. In the event of severe or consecutive storm events resulting in sand loss, the wall would provide asset protection without the need for emergency works. This option would significantly reduce nourishment volumes required behind the swimming area while maintaining usable beach width. However, it involves higher capital cost and construction-related beach disturbance when compared to the base option.

Small-Scale Groyne

Shore-perpendicular structures are a proven method for interrupting longshore sediment transport. While there is merit in installing a groyne north of the swimming area to reduce pool infilling, this option does not meet key success criteria due to its likely impacts on beach amenity and recreational use. Should the key success criteria change in the future, the groyne could be considered a viable alternative option.

Submerged Breakwater (Reef)

The submerged breakwater (reef) option has been considered primarily as a coastal adaptation measure. Recent literature suggests there is merit in using such structures to reduce nourishment volumes however further investigations would likely be required, including physical and numerical modelling, given the complexity of nearshore processes. This is particularly relevant for multi-purpose reefs intended to both protect the foreshore and enhance beach amenity (eg surfing).

It is also important to note that the alternative option detailed herein represents a single approach, where the primary objective is coastal protection via nearshore reef enhancement. A reef constructed solely to enhance beach amenity (eg surfing) would likely require a revised shape, location, or form, which would affect project costs. To effectively evaluate such an option, further design development and investigations would be required.

Preliminary advice from DBCA was based on high-level discussions only. Should this option be progressed, formal confirmation would be required regarding its potential acceptability within the marine park and the studies needed to support environmental approvals. The approvals pathway is likely to be lengthy. Additionally, there is a significant capital cost associated with constructing a submerged breakwater (reef).

It is recommended that a revised beach nourishment scheme be progressed and implemented while the City continues to consider alternative options. Although several options have merit, they are associated with increased capital costs and additional approval requirements.

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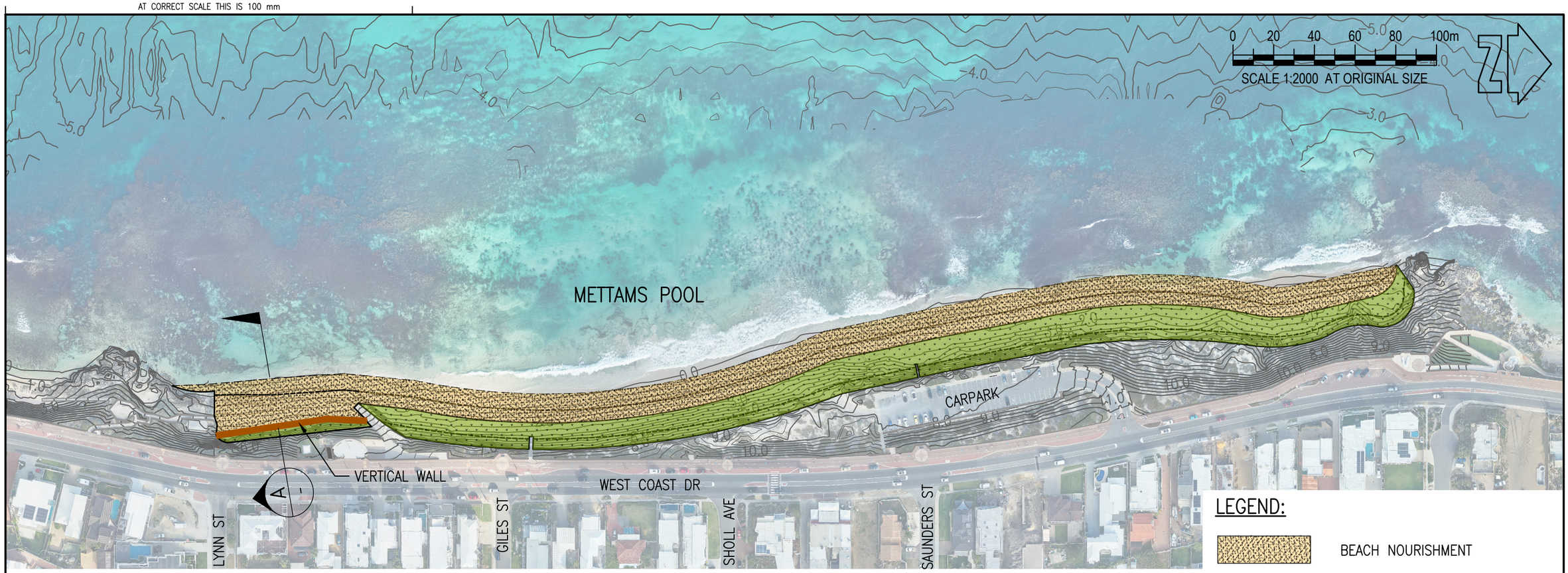
Van Gent, M. R. A., Buis, L., van den Bos, J. P., & Wüthrich, D. 2023. *Wave transmission at submerged coastal structures and artificial reefs*. Coastal Engineering, 184, Article 104344. https://doi.org/10.1016/j.coastaleng.2023.104344

6. Appendices

Appendix A Alternative Treatment Options

Appendix A Alternative Treatment Options

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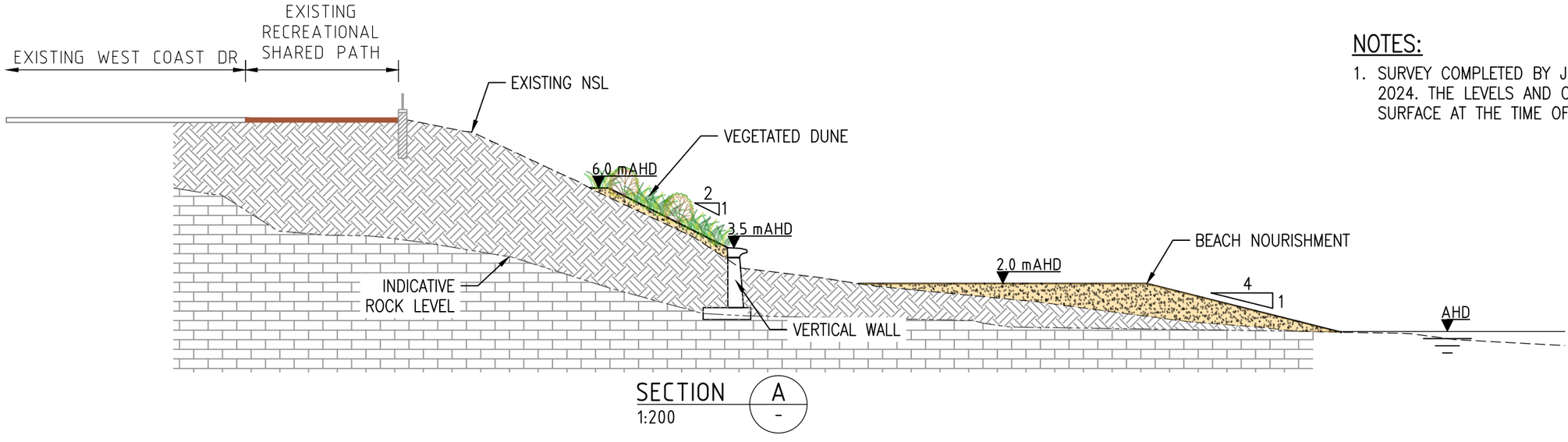


LEGEND:

- BEACH NOURISHMENT
- VEGETATED DUNE
- VERTICAL WALL
- 0.0 CONTOURS

NOTES:

1. SURVEY COMPLETED BY JBA SURVEYS IN MARCH 2024. THE LEVELS AND CONTOURS REFLECT THE SURFACE AT THE TIME OF SURVEY ONLY.



SECTION A - 1:200

AT CORRECT SCALE THIS IS 100 mm

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ALTERNATIVE TREATMENT 1 - VERTICAL WALL AND BEACH NOURISHMENT

METTAMS POOL

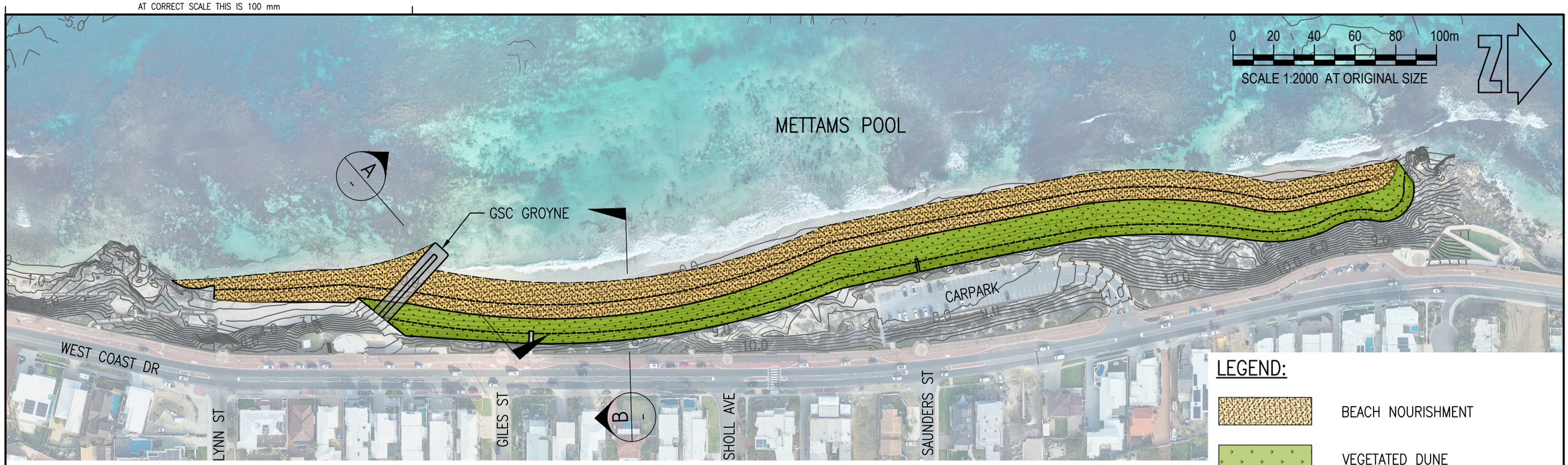
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FEBRUARY 2026

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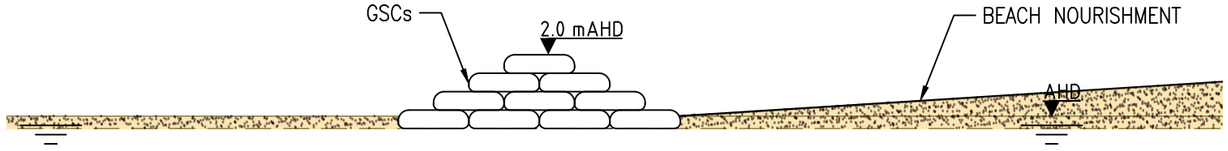
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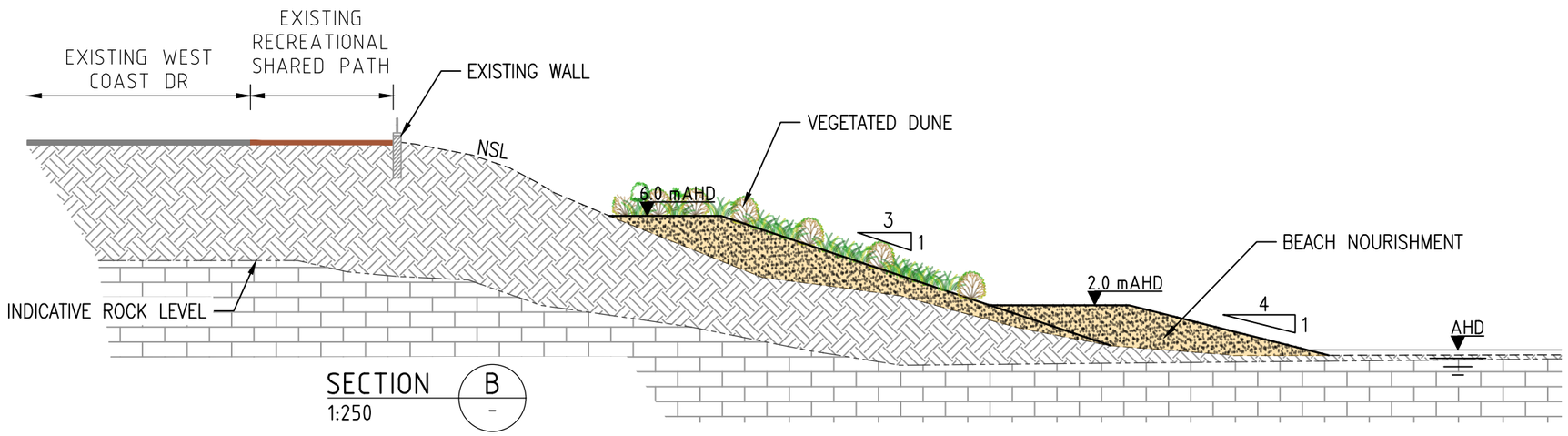
- BEACH NOURISHMENT
- VEGETATED DUNE
- GSC GROYNE
- 0.0 CONTOURS

NOTES:

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SECTION A - 1:200



SECTION B - 1:250

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ALTERNATIVE TREATMENT 2 - GROYNE AND BEACH NOURISHMENT

METTAMS POOL

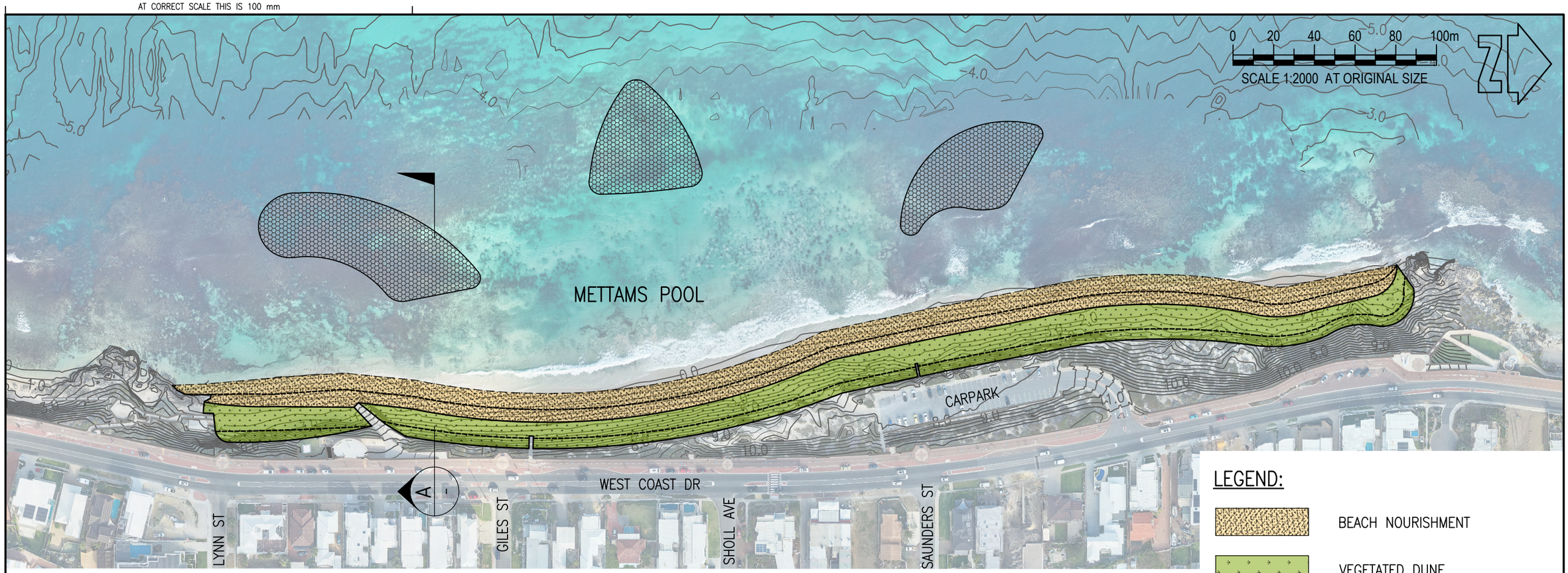
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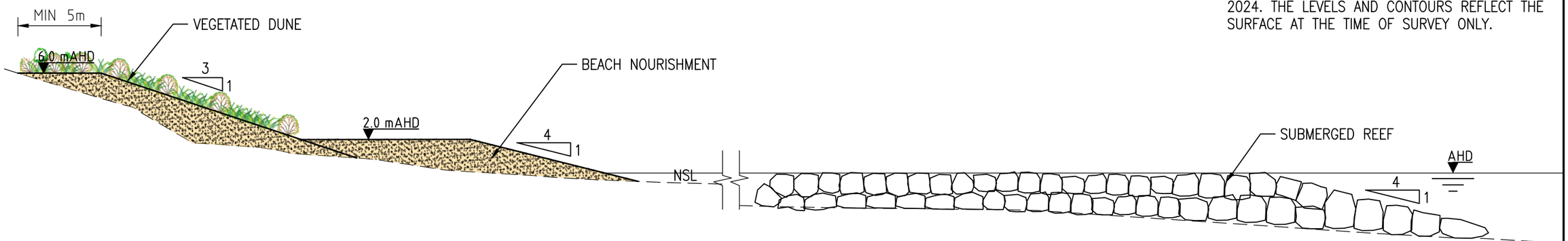
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LEGEND:

- BEACH NOURISHMENT
- VEGETATED DUNE
- SUBMERGED REEF
- 0.0 CONTOURS

NOTES:

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SECTION A -
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ALTERNATIVE TREATMENT 3 - SUBMERGE REEF AND BEACH NOURISHMENT

METTAMS POOL

SCALE AT A3 AS SHOWN

FEBRUARY 2026

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