Department of Environment and Water (DEW)

Sand management using dredgers – sand sourcing and other feasibility assessments

Adelaide Beach Management Review Implementation Project

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Report No: P24462_2025DredgingFeasibilityAssessment_R4.00

Executive summary

This report, commissioned by the South Australian Department for Environment and Water (DEW), assesses the long-term feasibility of using dredgers for sand management on Adelaide's northern metropolitan beaches, as an alternative to quarry sand and fixed sand recycling pipelines. It addresses key uncertainties identified in the 2023 Adelaide Beach Management Review (ABMR), including the suitability of external (marine) and nearshore sand sources, environmental constraints, operational feasibility and cost-effectiveness.

The study confirms that West Beach can be restored with external marine sand via dredging. Two viable external borrow areas were identified: EBA1 (north of the port channel) and EBA2 (offshore West Beach). EBA1 contains over 1 million m³ of good-quality clean sand, sufficient for both restoration and future sand top-ups. EBA2, while smaller (~200,000 m³), offers high-quality clean sand within proximity, allowing efficient nearshore placement using cutter suction dredges.

For ongoing sand recycling, four nearshore borrow areas (NBA1–NBA4) were evaluated. Combined, these areas can sustainably supply up to 90,000 m³/year, matching long-term nourishment needs. The sand quality is generally suitable, with low contamination levels and sufficient physical compatibility. Precautionary no-take zones are recommended to avoid downdrift impacts on the beaches including around sensitive dune areas and to maintain storm resilience and beach widths.

Operationally, trailer suction hopper dredges (TSHDs) were identified as the most efficient and flexible dredging method, particularly for external (marine) sources. Cutter suction dredges (CSD) were deemed suitable for nearby sources with good weather conditions. However, CSDs were found not be effective for longer sand transport distances because sailing is more efficient than pumping for distances greater than 3-5km. A similar general rule of thumb would also apply for sand pumping via a land-based pipeline.

Comparative cost estimates show that dredging can deliver sand for \$13–\$32/m³, significantly cheaper than the ~\$63/m³ for trucked quarry sand. These cost rates are summarised as

- **Restore:** most cost effective is to use the nearby external borrow area no. 2 (EBA2) for an estimated rate of \$13.17/m³. However, there is limited sand volume available in EBA2. Using EBA1, which is further way, this estimated cost rate using a small trailer hopper suction dredger (TSHD) is between \$15-19/m³, with the range dependant on the size of the nourishment campaign.
- **Recycle:** the most cost-effective means of delivering sand recycling is by using a very small TSHD and combining the sand recycling from the nearshore with some sand top-up from external sources (i.e. EBA1). This has an estimated cost rate of \$22.44/m³ and would only need to be undertaken once every two years. If only sand recycling is undertaken using a very small TSHD the estimate rates are 32.40/m³ if undertaken annually, or 29.70/m³ in a larger sand recycling campaign is undertaken every 2-years. The higher rates for sand recycling only are due to tidal restrictions on access to the shallow nearshore borrow areas.

The 2024 dredging trial further demonstrated the technical and environmental feasibility of dredging, with minimal turbidity or noise impacts and effective placement outcomes.

The assessment concludes that sand management via dredging is feasible, flexible and cost-effective, with fewer community and environmental disruptions than alternative methods. Key next steps include securing planning approvals, securing suitable contractors for the works components and addressing social license challenges, particularly for nearshore operations. A dredger-based strategy also offers long-term adaptability in the face of climate change and can integrate well with other coastal management initiatives.

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1. Introduction

1.1 About this report

This report assesses the long-term feasibility of carrying out future sand management activities on Adelaide's northern metropolitan beaches using dredgers. It follows on from the Adelaide Beach Management Review (ABMR) which concluded that sand management in the northern management area using dredgers had merit but there were remaining uncertainties (Bluecoast, 2023). A future sand management approach using dredgers was proven to have merit because of the approaches ability to transfer sand to where it is needed is more efficiently (i.e., significantly cheaper), with more flexibility and can be achieved with significantly less community disruption. As a next step, this report seeks to sufficiently resolve these remaining uncertainties and recommend a clear way forward on each of the ABMR Independent Advisory Panel's (IAP, 2023) two key recommendations, which are stated verbatim in Section 1.2, and rephrased here as questions:

1. Can West Beach be restored with 'external'[1] sand using dredging from suitable offshore sand deposits as the preferred alternative to the use of importing quarry sand?
2. Can dredgers be used to recycle sand from nearshore deposits on the northern part of Adelaide's metropolitan beaches as the preferred long-term alternative to the use of a sand recycling pipeline?

The remaining uncertainties surrounding any future implementation of a long-term strategy using dredgers to restore and recycle sand for beach management are summarised below, including how these have been addressed within this report:

- **Sustainable sand sources:** as the main risk to successful implementation, sand sources have been assessed using extensive marine sediment sampling and surveying programs to investigate and identify suitable sand borrow areas. To address sustainability, an analysis of the impacts of sand harvesting on coastal processes, including downdrift effects and storm resilience, has been conducted.
- **Work method and costs:** once suitable sand borrow areas were identified the dredging methodologies and associated cost estimates are crucial for determining the feasibility of a strategy using dredgers. Informed by both site data from the borrow areas and data from a recent dredge nourishment trial, the most suitable work methods and their costs are examined.
- **Planning pathways and environmental assessments:** these issues have been assessed in a separate report being prepared by JBS&G.

1.2 Context of this report

For the past 50 years, the South Australian Government has managed Adelaide's beaches. Metropolitan beaches are managed to safeguard coastal assets from storms while ensuring that the community can continue to enjoy sandy beaches. The main activity has been sand recycling (or backpassing) from northern to southern beaches to counter the natural net northerly coastal sand movements.

In 2023, the Department for Environment and Water (DEW) commissioned the Adelaide Beach Management Review (ABMR) to evaluate current practices and explore future options for addressing the

[1] In this context 'external' means sand sourced from outside the active coastal beach system, which in this study area would typically mean being seaward of the -5m AHD depth contour or otherwise external to the West Beach to North Haven coastal sand system.

long-term sand management strategy. The ABMR's Scientific Review (Bluecoast, 2023) concluded that restoration of West Beach's sandy buffer along with ongoing sand recycling by dredge in the northern management had merit but there were remaining uncertainties that had to be investigated before deciding on the long-term feasibility of the strategy. Given the scope of the ABMR's Scientific Review was limited to desktop work, without scope for field investigations, it was unable to resolve these key uncertainties. The adaptive decision pathway shown in Figure 1 was suggested as a 'no regrets' approach that would rule in or out the feasibility of the sand management using dredgers.

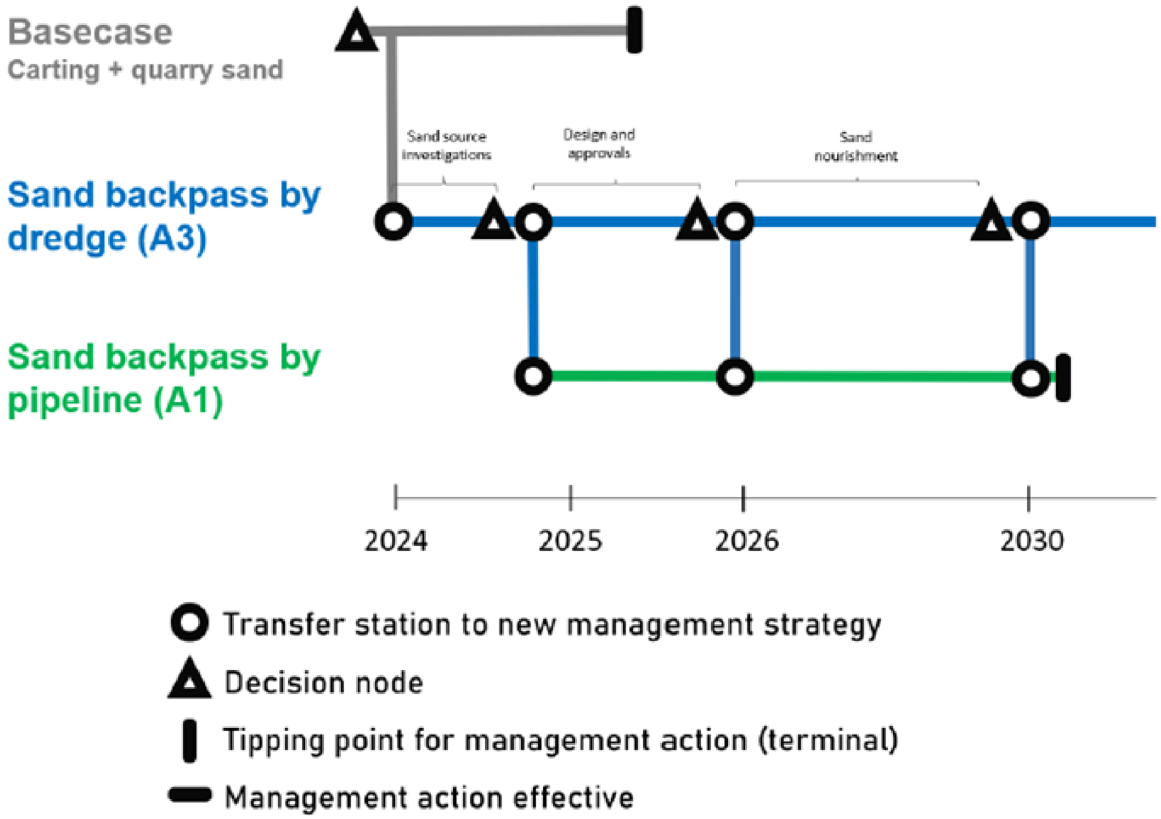


Figure 1: Suggested adaptive management pathway (adapted after Bluecoast, 2023).

The Independent Advisory Panel (IAP) considered Bluecoast's 2023 Scientific Review, along with the outcomes of the community consultation, and provided the SA Government with advice and recommended next steps. Table 1 provides the Panel's recommendations. These:

- tasked DEW to undertake further investigations into the feasibility of offshore dredging for restoring sand to West Beach and nearshore dredging for sand recycling to West Beach
- make it clear that the Panel viewed quarry sand as the next most feasible alternative to dredging to restore West Beach with external sand and the sand recycling pipeline as the next most feasible alternative to sand recycling using dredging.

Along with the marine sediment sampling investigations and the other assessments completed herein, DEW undertook a dredging trial from 3rd October to 30th November 2024. Relevant outcomes of this trial will be used herein to inform the long-term feasibility of sand management using dredgers.

Table 1. Summary of Independent Advisory Panel's advice to government.

Recommendation	Recommended actions
Recommendation 1: **Restore West Beach with external sand within 5 years (by 2030)**	1.1 Investigate dredging using offshore sand, including verifying the availability of suitable sand source/s (volume, grain size and composition), assessment of environmental impacts, and viability of operations and approvals. 1.2 Replenish West Beach with 550,000m^3 of sand using quarry sand, or until restoration using an offshore sand source is found to be viable from an environmental, economic and social perspective.
Recommendation 2: **Recycle sand between northern beaches and West Beach**	2.1 Investigate the feasibility of dredging nearshore or nearby sand deposits as a long-term, sustainable method to deliver sand recycling. This should include verifying the availability of suitable sand in the littoral zone, as well as the operational viability and constraints for environmental approvals. o If viable, assess against sand recycling pipeline option to determine the best long-term, sustainable sand recycling option. o If not viable, seek relevant approvals to implement the sand recycling pipeline. 2.2 In the interim, implement sand recycling via sand carting using trucks to manage the build-up of sand at the northern beaches.

1.3 Study area

This feasibility assessment focuses on the ‘northern management area’ of Adelaide’s Beaches’ stretching from West Beach to North Haven as shown in Figure 2. This 20 km stretch of coastline includes developed residential areas such as Henley Beach as well as more recreational areas with wide dunes such as at Semaphore and Largs. The southern management area has an existing sand recycling pipeline which serves to manage sand in that area. Operation of the southern sand recycling pipeline, when combined with the boat harbours at West Beach and Glenelg, act to cut-off the littoral supply of sand to West Beach and the rest of the northern management area. Therefore, a source of sand to restore and maintain this northern management area is required.

Figure 2: Location of management area for feasibility assessment.

1.4 Scope and structure of this report

The scope and structure of this report is in line with its objectives to resolve the remaining uncertainty regarding the feasibility of sand management using dredgers. The report is structured as follows:

- **Section 2** provides background information regarding nourishment material specifications, restore and recycle volumes required as constraints and metocean climate.
- **Section 3** summarises the field investigations used to identify potential sand sources and assess their suitability.
- **Section 4** provides details of the identified nearshore borrow areas and identifies a sustainable strategy to recycle sand from these borrow areas. This includes an assessment of the impact of sand harvesting on the coastal processes, including downdrift impacts and storm erosion resilience.
- **Section 5** provides details of the identified external borrow areas for restoring sand volumes at West Beach.
- **Section 6** preliminary assessment of the methods and costs associated with backpassing by dredge from the potential borrow areas set out in Section 3

2. Background information

2.1 Northern management area nourishment requirements

Section 4.3.3 of the ABMR scientific review (Bluecoast, 2023) defines the sand quantities needed for the restoration and ongoing nourishment of West Beach to address the current deficit and ongoing replenishment to counter the sand imbalance (i.e. sand losses due to northward sand movements without sufficient sand supply). Since the review the restore quantity has been revised as set-out below:

- **Restore:** 430,00m^3 is the adopted herein as the 'restore' as at the end of June 2025 is based on:
  - The 550,000m^3 'restore' volume to return West Beach sand volumes to pre-1985 levels as calculated in mid-2023. This assumes the sand delivered for the 'restore' component would be over and above the on-going sand losses at West Beach (estimated an annualised rate of 90,000m^3/yr).
  - The ABMR Independent Advisory Panel's Report published in December 2023 recommended that West Beach be restored with 550,000m^3 over a five-year period ending in December 2028.
  - Between December 2023 and 30 June 2025, a total of 300,000m^3 of 'external' quarry sand will have been delivered to West Beach. Accounting for the two years of annual sand losses at West Beach, the remaining 'restore' volume is calculated as: 550,000m^3 (2023 estimate) - 300,000m^3 ('external' quarry sand added as restore) + 180,000m^3 (estimated on-going sand losses) = 430,000m^3 (of remaining 'external' sand should be delivered to West Beach by December 2028, over and above the annual maintenance volume).
  - Other sand placements at West Beach in the last two years were sourced from the nearshore (at West Beach boar harbour and North Haven Marina) but because these nearshore sources were either from updrift of West Beach (i.e. transferring sand from West Beach Harbour was forward passed rather than recycling or backpassing of sand) or was relatively small volume of fine sand (in the case of North Haven source). Being from the active coastal sand movement system, these were not considered in offsetting the restore volume.
  - It is recommended that a reassessment of the restore quantity be recalculated using recent survey data, as this would be more accurate and remove many of the assumptions in the above derivation of the remaining restore volume.
- **Recycle:** 90,000m^3/year ongoing 'recycle' volume would be needed to maintain the West Beach compartment.

These quantities guide the selection of potential borrow areas and their impacts in subsequent sections.

2.2 2024 trial of sand management using dredgers

Following the IAP's report, DEW took the decision to undertake a trial in Spring 2024 to help determine the feasibility of dredging as part of the long-term management strategy. This trial included the dredging of sand from two nearshore borrow areas, one adjacent to North Haven Marina (referred to in the trial as SBA1) and a second adjacent to West Beach boat harbour (referred to in the trail as SBA3), and delivering it to West Beach. This trial began in early October and ceased at the end of November 2024, being the start of seagrass growth window. Following the seagrass growth window, nearshore dredging could recommence in April 2025.

The purpose of this was to gain insight into the:

- effectiveness of this nourishment method on improving the beach
- assess the operational methodology of using this equipment
- assess the environmental impacts from nearshore dredging and placement.

The 2024 ABMRI trial was overseen by DEW, with Hatch and Swash Project Delivery (Swash), along with a range of specialist service provides, responsible for planning, design, oversight of the works and monitoring of the trial. Local marine contractor, Maritime Constructions, were the works contractors.

Swash (2025) provides a factual operational review of the 2024 trial. Key relevant aspects of the trial as summarised as follows:

- Two nearshore sand borrow areas (referred to in the trial as SBA) were used, one adjacent to North Haven Marina (SBA1) and a second adjacent to West Harbour boat harbour (SBA3) were used.
- SBA1 is a 17.6km from the sand placement area at West Beach. The sand size in the borrow area is D50 of 0.11mm with a percentage of fine sediment (silts and clays) of about 8.5%. The work method used was combination of a Cutter Suction Dredge (CSD) to collect the sand from borrow area before pumping the sand a short distance to two non-self-propelled split hopper barges (SHBs) that were towed by tugs to the placement site at West Beach. The placement methods was bottom dumping. An estimate of around 13,680m^3 of sand was placed at West Beach from SBA1, compared to an extraction quantity of 16,800m^3 with the difference between removal and placement of 3,120m^3 due to overflow losses at the SHB loading site (i.e. where the CSD to SHB) (SWASH, 2025). This overall method is considered to have a relatively high potential for loss of fine sediments (and therefore turbidity generation) at the CSD header, at the SHB filling site including the overflow and at the placement site.
- SBA3 is less than 1km from the sand placement area at West Beach. The work method used a simple Cutter Suction Dredge (CSD) to collect the sand from borrow area and pump it directly the short distance to the nearshore with placement via a pipeline and diffuser into the nearshore in a discrete area of West Beach. Some 41,800m^3 was dredged from SBA3 and placed at West Beach (SWASH, 2025). With fewer sources of fines loss, this method is considered to have relatively potential for fine sediment to the loss to the water column. Potential losses of fines to the water column are further reduce by the fact that this SBA3 source has coarser sand with a much lower fines content.

Monitoring the impacts on the placement and borrow areas is an ongoing process and has yet to be finalised, as have the longer-term studies on the impact on seagrass (which involved a baseline study and 12 months post-works). However, the monitoring around operations has been completed. The main outcomes assessed so far are:

- Weather (wind and waves) significantly impacted the operations of the CSD limiting production to 10 of the 18 days (55% operational time).
- Results from water quality monitoring result in levels well below the EPA's trigger levels for 'Alarm' or 'Hold'. It was noted that peak turbidity was associated with natural wind and weather events rather than dredging activities (Epic, 2025).
- No noise impacts to sensitive residential receivers measured at the borrow or placement areas (SWASH, 2025).

The 2024 trial was a step in the process of determining the feasibility of sand management by dredge for the northern management area and examining sand placements at West Beach. Wherever possible information gathered because of the trial has been incorporated into the assessments completed herein.

2.3 West Beach native beach sand characteristics

Understanding the native sand characteristics is crucial for determining the compatibility of sand from potential borrow areas. A recent sampling campaign at West Beach provided the parameters for developing specifications for compatible material, detailed in the technical note '*Advice on the feasibility of dredging based on the results of further investigations undertaken*' (Bluecoast, 2024a), provided in **Appendix A**. Care has been taken in selecting samples and sample locations to ensure that recent quarry sand placements have not influenced the characterisation of native beach sediments, including consistency checks against nearby beaches (e.g. Glenelg North and Henley).

For reference, a summary of the two acceptability criteria is given in Table 2 below. In addition to an ideal beach nourishment criterion, a second set of criteria for the 'beneficial reuse' of material from opportunistic sources (e.g., dredging of North Haven marina) was defined where the ideal minimum standards for material acceptability are justifiably loosened. The justification of the loosening on acceptance criteria is that there are additional benefits, over above the nourishment purpose, generally associated with the extraction of this sand (e.g. navigation access benefits or reducing harbour siltation).

Table 2: Specifications for acceptable beach nourishment[2] material at West Beach.

Acceptability item	Acceptability criteria	
	Beach nourishment (ideal)	Beneficial reuse
Median grain size (D_{50})	Median grain size should be between **0.18mm to 0.25mm**, or slightly coarser.	Median grain size should be between **0.14mm to 0.30mm**, or slightly coarser.
	Material outside of this median grain size range to be considered on a case-by-case basis.	
Fines content **(fines have particle sizes less than 75µm)**	<u>Onshore placement:</u> Fines fraction to be less than 5% by weight. <u>Nearshore placement:</u> Fines fraction to be less than 10% by weight (desirable). However, fines fraction greater than 10% may be acceptable on a case-by-case basis following detailed compatibility assessment considering range of factors.	
Gravel content **(particle sizes greater than 2mm)**	<u>Onshore placement:</u> Gravel fraction to be less than 2% by weight. <u>Nearshore placement:</u> Gravel fraction to be less than 5% by weight (desirable). However, gravel fraction greater than 5% may be acceptable on a case-by-case basis following detailed compatibility assessment considering range of factors.	
Mineralogy	Sand is to be quartz sand with a carbonate content of less than 25%. Shall not contain excessive amounts of organic matter, demolition material or other debris. Seagrass wrack, rhizome mats and or organic matter naturally occurring on Adelaide' beaches is acceptable with preference for nearshore placement for material with high wrack content.	
Uniformity coefficient **$Cu = D_{60}/D_{10}$**	Cu values less than 2.4 are desirable for creating beaches. Cu values substantially above this will compact more and create a beach which is more "concrete" like and will not freely drain when the tide drops, resulting in a "swampy" feel.	

[2] The process of placing sand from elsewhere onto an eroding shoreline to create a new beach or to restore or maintain an existing beach.

Acceptability item	Acceptability criteria	
	Beach nourishment (ideal)	Beneficial reuse
Colour	Onshore placement: The beach nourishment material should have a colour, following placement and exposure to the elements, like the existing beach sand in the placement area. Nearshore placement: Ideally, nourishment material should be of similar colour to the native beach sand. In practice, this may not be achievable (e.g., where nourishment sand is sourced from deeper water). This would not be a significant issue while the sand remains in the subaqueous beach zone where it is not visible but may become noticeable once the sand is transported onto the subaerial beach although this would likely be minor due to mixing with the native sand. Once darker nourishment sand is transported onto the subaerial beach, it may lighten in colour due to bleaching by sun, leaching by rain, wetting/drying and further mixing with the native sand.	
Angularity	Desirable that sand be well rounded, rounded or sub-rounded	
Contamination	Onshore placement: Sand should be free of contaminants in accordance with: • Environmental Protection Authority's Dredge Guidelines 2020 • National Assessment Guidelines for Dredging 2009 (NAGD, 2009) • National Ocean Disposal Guidelines for Dredged Material (Commonwealth of Australia, Canberra, 2002) • Australian Guidelines for Fresh and Marine Waters (ANZECC, 1992 and 2000). Nearshore placement: For sediment to be considered suitable for Adelaide's beaches, the 95% upper confidence limit of the mean concentration of all contaminants must be below the screening levels in the 2009 National Assessment Guidelines for Dredging (NAGD).	

2.4 Distribution of nearshore sediments

The distribution of sand types (i.e. grain size, composition, roundness or angularity and the mix with other sediments and materials) are not uniform along Adelaide coastal system. The distribution of sand types is influenced by the geomorphic structure and a range of coastal processes. Key previous literature that covers sand type distribution include the Adelaide Living Beaches (ALB) report (DEW, 2005) and Bluecoast's 2023 ABMR Scientific Review. Based largely on the 2024 high resolution sediment sampling, the following insights are relevant to the sand sourcing investigation presented herein:

- **Alongshore distribution:** Figure 5 shows the alongshore distribution of median grain sizes (D50) in Adelaide's coastal system (toe of dune to -5m AHD) based on the 2024 high resolution sediment sampling between West Beach and North Haven as well as previous historical data. The analysis shows alongshore gradients in the grain sizes, particularly around Point Malcolm[3] where there is a distinct decrease (fining) of grain sizes. Within Largs Bay, to the north of Point Malcolm, the grain sizes are markedly finer, reducing the effectiveness of use of this material to nourish West Beach. The implications for this are:

[3] Point Malcolm is the name given to the natural point like feature where the coastline changes alignment, the Semaphore breakwater is now located at Point Malcolm.

- Selecting nearshore sand harvesting areas for the most effective sand recycling, the focus should be on areas south of Semaphore breakwater where compatible sand exists (i.e. recycling would intercept sand moving northward before it reaches Largs Bay, where the bulk of the deposition occurs).
- To manage downdrift impacts, the harvesting areas should be either (I) located as close to the deposition areas in Largs Bay or (ii) located in areas were sand has historically been building up and there are sufficient sandy buffers to avoid unacceptable increases in the risk of coastal hazards (storm erosion or inundation).

- **Cross-shore distribution:** Figure 3 shows the cross-shore distribution of median grain sizes across a typical coastal profile (dune to -5m AHD). There is notably finer sand in the most active part of the coastal profile (0m AHD to -2m AHD). It is postulated that this intertidal/surfzone part of the profile has proportional higher rates of alongshore transport, explaining at least in part why we see finer sands in Largs Bay where the alongshore moving sand accumulates. The implications of this are that more suitable sand is found outside of this highly active zone (i.e. being above and landward 0m AHD and below and seaward of -2m AHD contour).

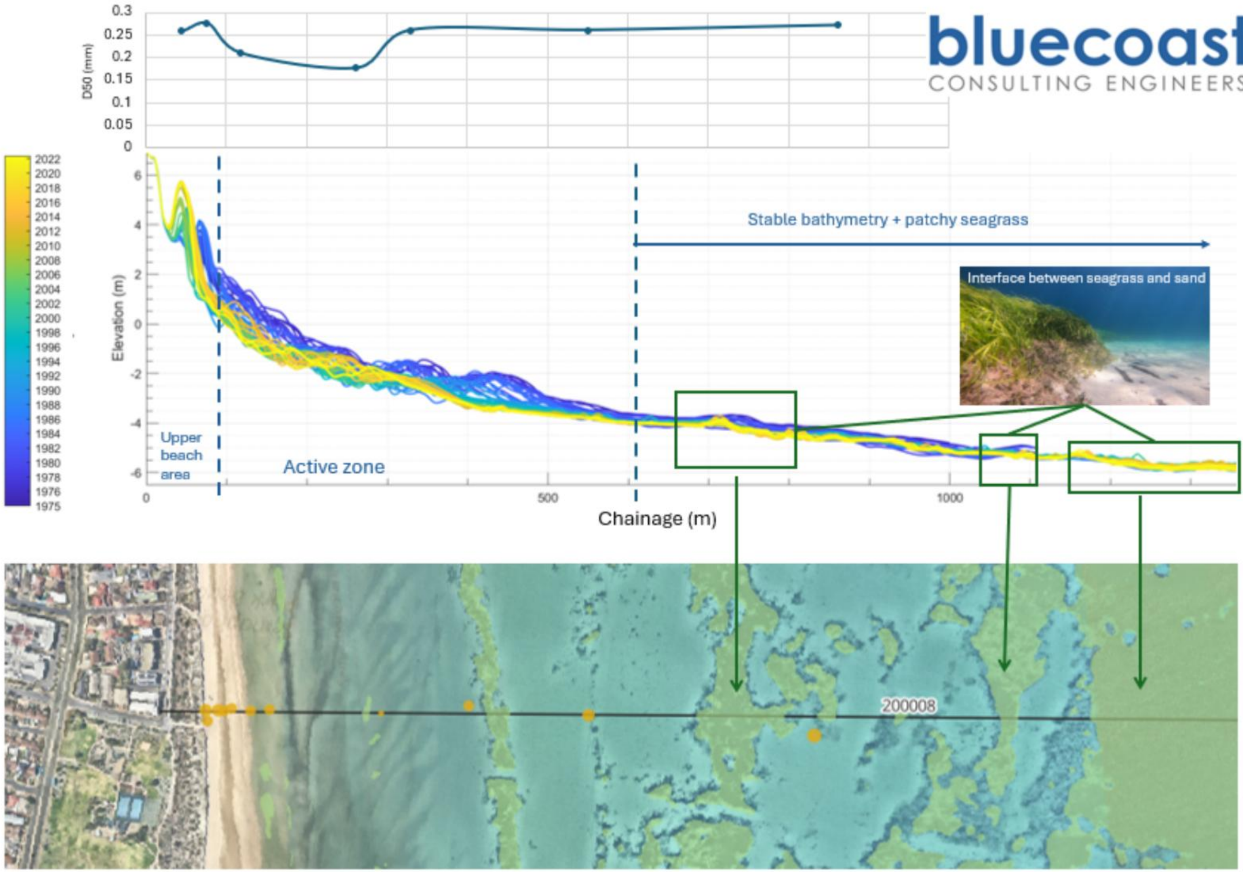


Figure 3. Cross-shore distribution of sand grain sizes (typical example at profile 200008).

- **Vertical distribution:** Early sampling conducted by JBS&G included shallow core samples which were split at 0.5m before homogenisation (i.e. 0-0.5m then 0.5-0.9m). This allowed differences of median grain size with depth to be observed. Comparison of these through the sampling conducted in southern Largs Bay shows very little difference between depths (see Table 3). When combined with Figure 4, which show the envelop of the active coastal profile, the implications of this for future rapid sand sampling campaigns are:

- that it would be appropriate to utilise a surface grab sampler for rapid sediment sampling over a wider areas as these surface samples are likely to be representative of shallow depths (top 1 to 2m or so below the surface) of the 'well mixed' active seabed
- it is possible that the grain sizes and other sand characteristics vary below the active profile but sampling from this area would require deeper (2 to 3m) cores be taken, which can't be achieved with diver-based push core and would require alternative coring techniques.

Table 3. Vertical grain size differences in top 1m from seabed surface.

Sample ID	D50 (mm) at sample depths of:		Relative difference (%)
	0 to 0.5m	0.5 to 1m	
S50	0.107	0.104	3%
S49	0.108	0.107	1%
S47	0.102	0.101	1%
S41	0.101	0.101	0%
S40	0.101	0.101	0%
S39	0.102	0.101	1%
S37	0.103	0.107	4%
S31	0.095	0.123	26%

Note: See JBS&G 2025 for sample locations.

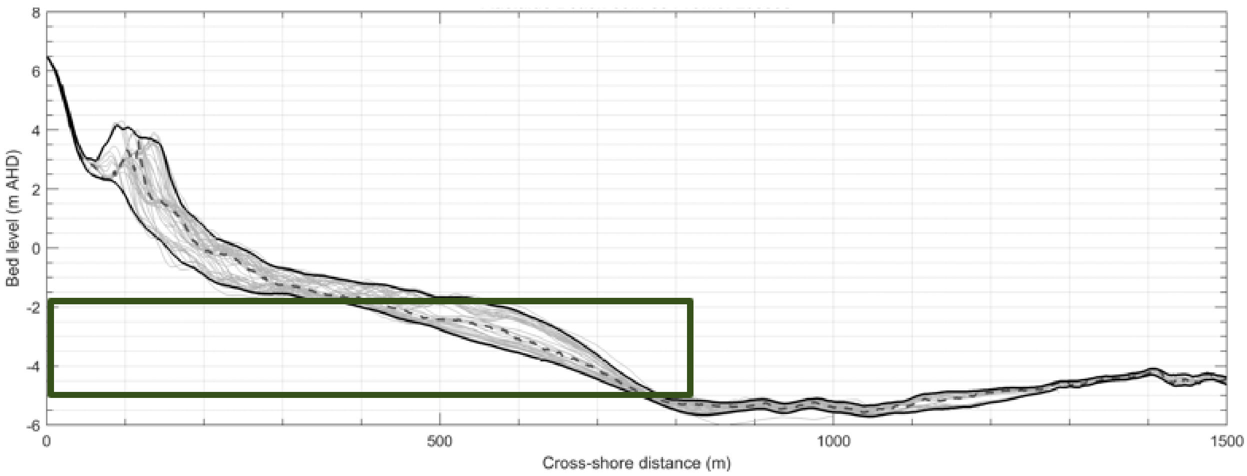


Figure 4. Envelop of active profile defined by the two solid black lines (5% and 95%ile), median profile shown in thick black dotted line and all surveyed profiles as thin grey lines (profile 20006).

Note: Green box shows approximate sand extraction depths.

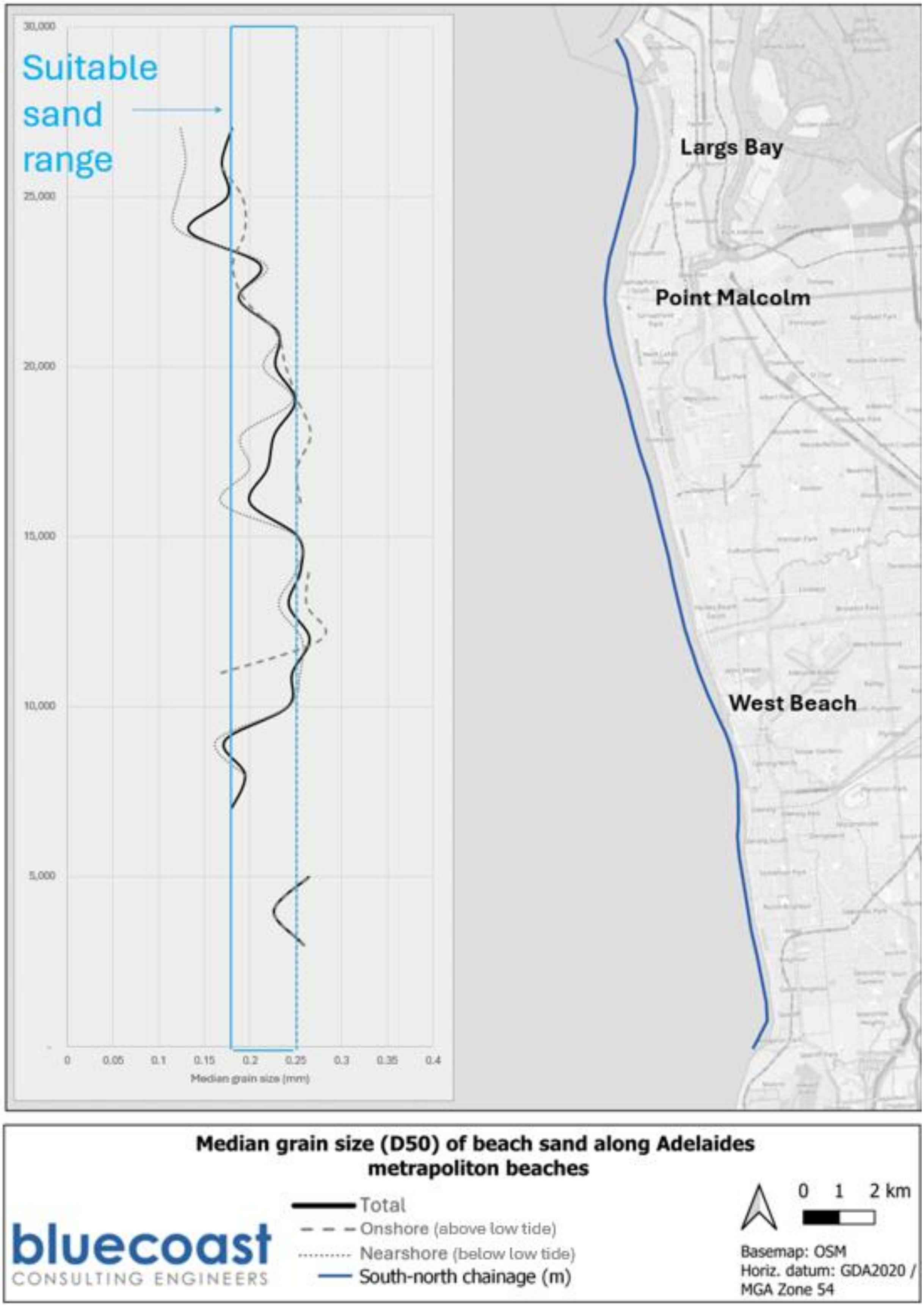


Figure 5. Alongshore distribution of median grain size distribution (D50) along Adelaide's beaches.

2.5 Known constraints

The AMBR scientific review (Bluecoast, 2023), ALB report (DEH, 2005), and other similar reports detail the geological and environmental settings of Adelaide's beaches and their implications for accessing sand for management strategies. The following summarises the constraints:

- **Seagrass:** Extensive seagrass meadows exist in Adelaide's nearshore waters. Protected under the *Native Vegetation Act 1992* and the *Environment Protection (Water Quality) Policy 2015*, consultation with the EPA and Native Vegetation Council is required for dredging in these areas.
- **Geological constraints**: Sand formations along the Adelaide coastline are generally a thin veneer, increasing in thickness northward toward the Port River estuary, with similar physical properties to existing beach material (Golders, 2014). Offshore sources are less documented.
- **Shipwrecks and heritage**: Various shipwrecks, particularly around the Outer Harbour, are protected under the *Heritage Places Act 1993* and the *Historic Shipwrecks Act 1976*. Several recorded shipwrecks between Tennyson and Semaphore require consideration during dredging. Upon finalisation of the dredging strategy and target borrow areas magnetometer surveys should be conducted to determine exact extents of any historical shipwrecks.

2.6 Metocean conditions

2.6.1 Wave climate

The nearshore wave climate was assessed using the following data:

- Nearshore wave buoy at Brighton. Wave and wind data available from 13 August 2021 to 21 November 2024. This wave buoy is in water depths of around 18m relative to AHD.
- Nearshore wave buoy at Semaphore. Wave and wind data available from 13 August 2021 to 14 May 2023. This wave buoy was deployed in water depths of around 19m relative to AHD.

Nearshore wave roses for total, swell (swell waves, Tp >8s) and sea (local sea, Tp <8s) are provided in Figure 6, while average wave statistics for Brighton and Semaphore wave buoys are provided in Table 4. It is noted that spotter wave buoys have more recently been deployed at North Haven and West Beach, in addition to the ones at Brighton and Semaphore (DEW, 2025).

Adelaide's metropolitan beaches are exposed to waves from the south-west sector dominated by low energy and low period sea waves. Sea waves are predominant around the 75% of the time in Brighton and 66% in Semaphore. Sea waves reaching the metropolitan beaches are mostly generated by west-south-west winds. The wave roses show a narrow band of incoming wave directions. The location of Adelaide 100km into the Gulf together with the blocking effect of Kangaroo Island across the Gulf's entrance results in ocean swell being generally of low amplitude when it reaches Adelaide's beaches.

Table 4: Wave measurement statistics derived from Brighton and Semaphore wave buoys.

Parameters	Statistics	Brighton 4-year record	Semaphore 3-year record
Significant wave height (Hs) [m]	Mean	0.55	0.60
	20%ile	0.25	0.29
	50%ile	0.44	0.51
	75%ile	0.68	0.76

Parameters	Statistics	Brighton 4-year record	Semaphore 3-year record
	90%ile	1.06	1.08
	99%ile	1.93	1.81
	99.5%ile	2.15	2.02
	Maximum	5.35	4.27
Peak wave period (Tp) [s]	Mean	6.3	7.1
	20%ile	3.1	3.4
	50%ile	4.4	4.6
	75%ile	8.5	12.8
	90%ile	12.8	14.6
	99%ile	20.5	17.0
	% of time sea (Tp<8s)	75	66
	% of time swell (Tp>8s)	25	34
Peak wave direction (Dp) [ºN]	Weighted average	252	226
	STD	44	44

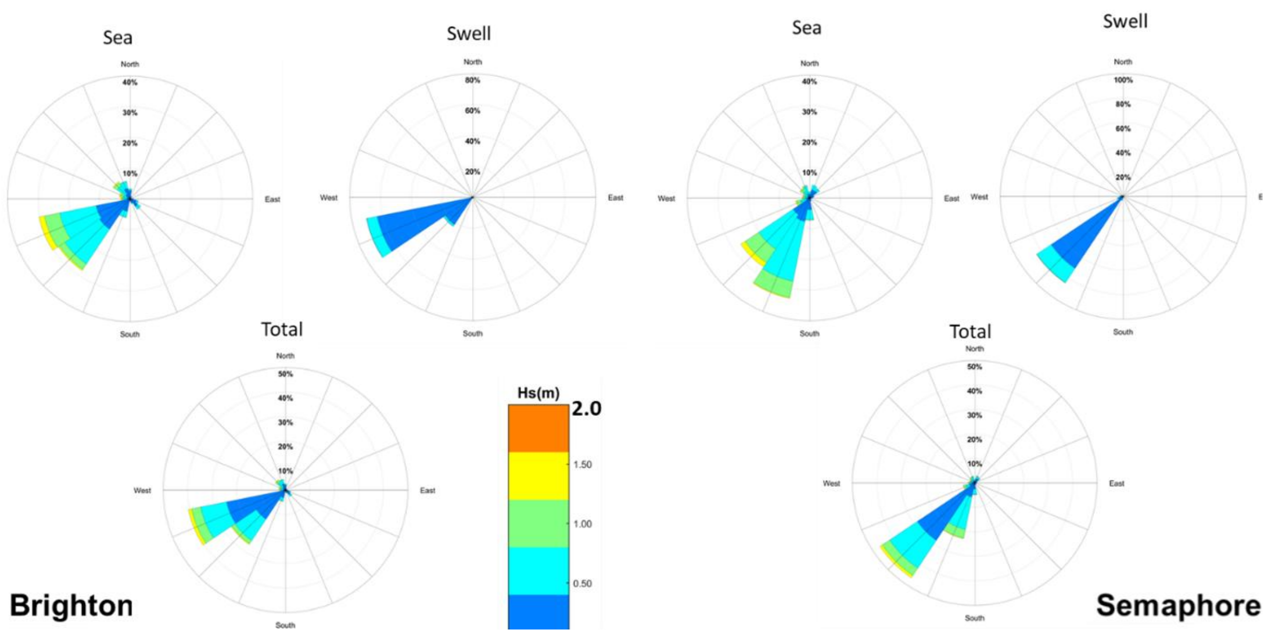


Figure 6: Total, swell and sea wave height and direction roses at Brighton (left) and Semaphore (right).

2.6.2 Water level

The tidal range on the Adelaide coast varies from about 2.4m at spring tides to near zero at neap tides. Tidal planes based on the latest 18.6-year tidal cycle at the Port Adelaide Outer Harbour tide gauges are provided in Table 5.

The water level exceedance curve shown in Figure 7 shows the total range of water level variation measured at Port Adelaide tide gauges. This is based on long-term water level data from the 82-year period (1940 to 2022) at the Outer Harbour site and the 87-year period (1932 to 2019) at the Inner Harbour site. The highest recorded water level at the Port Adelaide Outer Harbour of 2.348m AHD occurred on 9 May 2016 during the passage of a deep low-pressure system (approximately 980hPa). This was during a storm that caused widespread coastal erosion, particularly at West Beach. The highest recorded water level at the Port Adelaide Inner Harbour of 2.327m AHD occurred on 3 July 1981.

Table 5: Tidal planes for Adelaide (Outer Harbour gauge).

Tidal plane	Outer Harbour (m AHD)
High High Water Solstice Springs (HHWSS)	1.531
Mean High Water Springs (MHWS)	0.937
Mean Sea Level (MSL)	-0.079
Mean Low Water Springs (MLWS)	-1.095
Indian Spring Low Water (ISLW)	-1.519

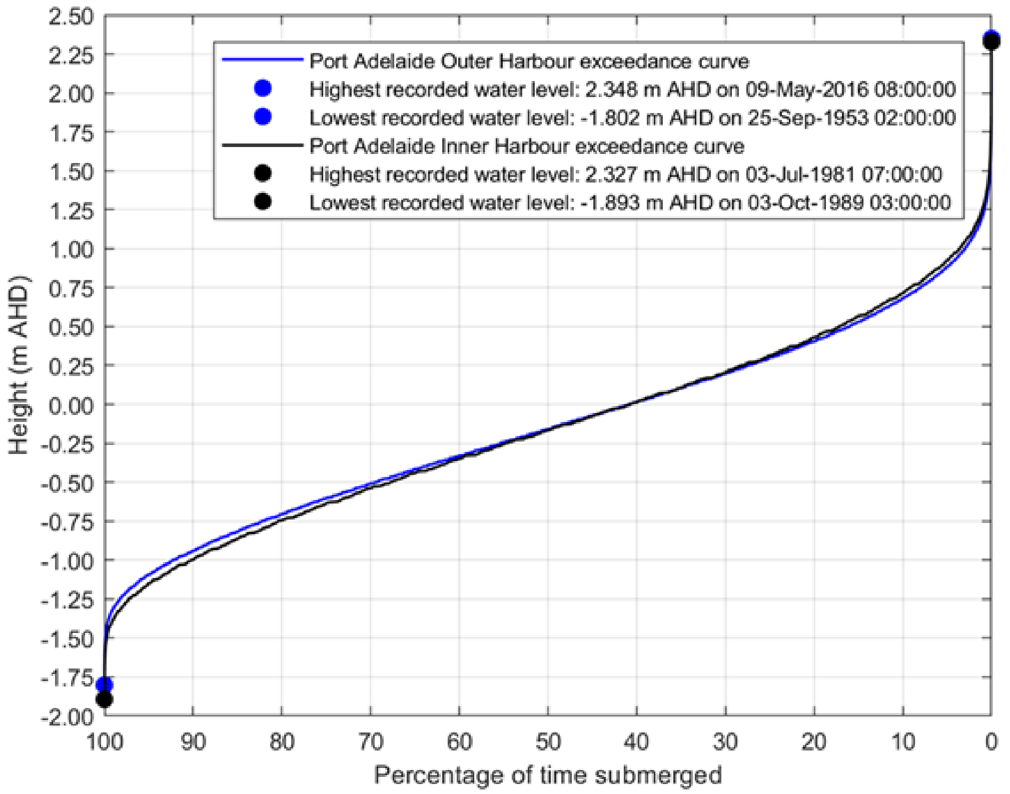


Figure 7: Water level exceedance curve for Port Adelaide tide gauges.

3. Sand source investigations

3.1 What makes a suitable sand source?

In the search for suitable sand sources to restore and maintain Adelaide's beaches it is important to consider the factors that are important in selecting suitable areas for sourcing sand. The selection criteria used to guide the search for sand are summarised in Table 6.

Table 6: Summary of factors used to select suitable sand sources.

Criteria	Selection parameters
Sand compatibility (quality) – see Table 2	• **Grain size** and uniformity • Fines (silts and clays) content • Gravel content • Minerology • Colour
Volumes and sustainability	**Restore:** • Remaining restoration volume: 430,000m^3 (see Section 2.1) • External to littoral zone being offshore of the -5m AHD contour or otherwise external to the West Beach to North Haven coastal sand system **Recycle:** • Annual sand demand: 90,000m^3/yr • From littoral zone being inshore of -5m AHD contour • No unacceptable impacts on Adelaide's beaches and dunes
Accessibility	• Proximity to beach nourishment site (West Beach) • Water depth and thickness of sand layer • Dredging, transport and placement feasibility • Cost and economic viability
Avoidance of environmental harm	• Benthic habitat (seagrass, razor fish, shellfish and POMS) directly in the investigation areas as well as nearby sensitive receptors • Turbidity and water quality • Protected areas and protected species

3.2 Overview of field investigations

Following the completion of the ABMR scientific review in late 2023, field investigations of sand sources were identified as a key next step to reducing the uncertainty in the long-term feasibility of sand management for the northern management area. Figure 8 provides a map of all sediment sampling locations considered in this analysis of suitable sand sources. Table 7 and Table 8 provides a summary of the scope of each field task completed to-date and laboratory analysis completed on the samples collected. **Appendix C** provides more details on each of these recent (post-ABMR) sediment sampling as well as recent historical sampling efforts.

The following is a summary of the relevant field investigations completed since late 2023:

- March to August 2024 (Stages 1 to 4): completed by JBS&G, these sediment sampling investigations covered areas offshore of Largs Bay as well as nearshore areas between North Haven and Point Malcolm. Diver cores, which are shallow cores, with recovery depths of up to 1m. This dive coring, sediment sampling and laboratory analysis was conducted prior to the 2024 dredge trial for the primary purpose of identifying feasible long term sand sources for more detailed investigations (and for use in the trial). More details on these investigations are given in JBS&G 2024a, 2024b, 2024c and 2024d.
- October to November 2024: in this second round of sediment sampling, Bluecoast collected grab samples from Point Malcolm to Henley Beach as well as additional samples on areas offshore of Largs Bay. These were primarily intended to inform the long-term feasibility of sand management using dredgers as a rapid and initial scan to identify areas for more detailed investigations (i.e. ‘investigation areas’). Grab samples are collected from the surface of the seabed.
- January 2025: DEW collected benthic observations in investigation areas offshore of Largs Bay. These observations involved camera drops to ground truth backscatter surveys and aerial image as well as identify seagrass species and percentage coverage as well as other benthic habitats. It is further noted that all the recent subaqueous samples collected included benthic observations at the sample site. In the nearshore areas, the observations aligned well with the seagrass coverage observable from recent satellite imagery. For the offshore areas, this is used to help provide a more detailed description of the benthic habitat which helps identify the viability as a harvest area.
- January and February 2025: Revelare and Flinders Ports undertook multibeam echo sounder (MBES), backscatter, and sub-bottom profiler (SBP). High resolution bathymetric survey and acoustic backscatter within four (4) offshore and one nearshore investigation areas. Revelare also completed sub-bottom profiling in three (3) of these offshore and the nearshore investigation area. The purpose of these investigations was to collect bathymetric data and information on the sediment thickness in these investigation areas. Revelare’s detailed survey report is provided in **Appendix B**. Flinders Ports undertook multibeam echo sounder (MBES) and backscatter survey in an area of interest north of the port’s navigation channel and were not requested to provide a survey report.
- February 2025: Bluecoast lead a team including Seas Offshore and Maritime Constructions to undertake vibrocoring. This critical work is aimed at confirming sand thicknesses and sand properties across the full sand extraction depths. Collecting these sediment cores is ultimately required to establish suitable sand borrow areas for use in beach nourishment activities. Vibrocoring was initially focused on previously identified investigations areas but expanded to include other investigation areas when suitable sand was not found. Simultaneous to vibrocoring efforts, additional diver cores were collected in the nearshore between Grange and Semaphore by East West Dive & Salvage. **Appendix C** provides a *Sampling and Analysis Plan (SAP) Implementation Report* which sets out the methodology and factual results from this important coring, sampling and analysis work.

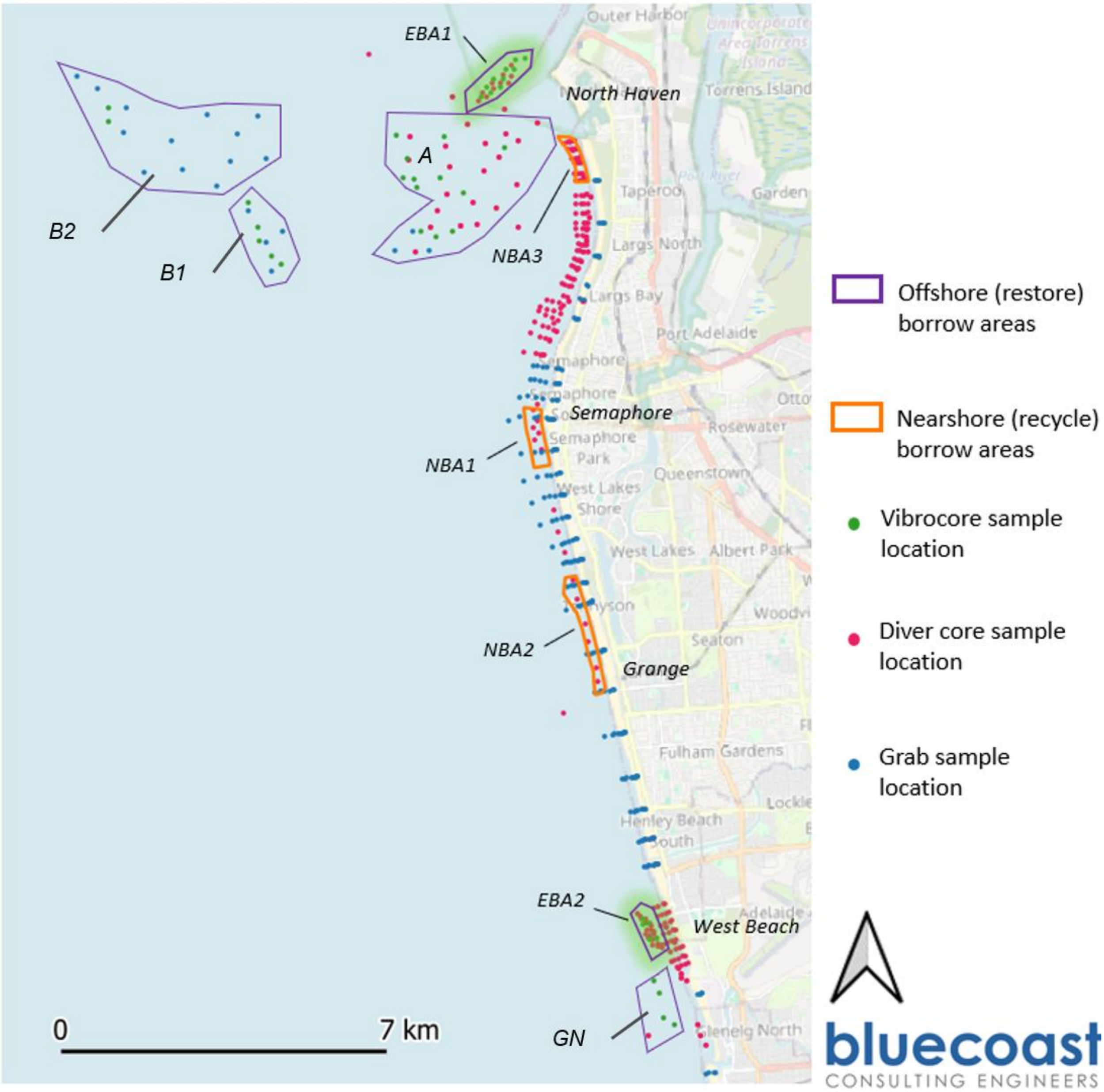


Figure 8: Map of sediment sampling investigations.

Table 7: Summary sand source field investigations.

Fieldwork task	Overall scope completed
Sediment sampling and coring	Five (5) offshore (restore) borrow areas and four (4) nearshore (recycle) borrow areas • 235 grab samples • 248 shallow diver cores • 38 vibrocores

Fieldwork task	Overall scope completed
Surveys	• High resolution bathymetric survey and acoustic backscatter at four (4) offshore and one nearshore area. • Sub-bottom profiling completed at three (3) offshore and in one nearshore area.
Benthic habitat	• 113 towed video drops with species identification and coverage classification.

Table 8: Summary of laboratory analysis of sediment samples collected.

Laboratory analysis of sediment samples	No. of samples tested
Grain size analysis (PSD)	624
Carbonate content	259
Metals and Total Organic Carbon (TOC)	222
Full chemical suite **(Organotins, pesticides, TRH and BTEX) and PFAS**	88

3.3 Investigation areas taken forward

This section describes the process undertaken to identify investigation areas that should be taken forward for further consideration as potential sand borrow areas. The definitive investigations and selection criteria vary between sand recycling from the nearshore and beach restoration from external sources meaning the selection process, as set out below, was also different.

The details of each of the borrow areas taken forward is provided in Section 4.

3.3.1 External investigation areas

Informed by the initial and rapid sediment sampling using surface/shallow penetration depth sampling (phase 1), compatibility assessments were completed to help identify external sand sources for further detailed investigations. For further details on this initial screening process, see **Appendix C**. Informed by this initial screening, more detailed vibrocoring and surveying tasks were undertaken at the planned investigation areas. During the critical vibrocoring activities, when coring activities showed unfavourable substrata in the planned investigation area, additional unplanned areas were cored (i.e. the fieldwork adapted to conditions encountered). Table 9 outlines the investigation areas that were ruled out during the detailed (phase 2) site investigations, including the reasons why they were not considered further as a source of sand of Adelaide's beaches. As determined by the critical vibrocoring activities the external sand sources taken forward were:

- EBA1: Sand deposit north of the port's approach channel, which is north of and external to the West Beach to North Haven littoral sand movement system.
- EBA2: Sand deposit located just offshore of West Beach. This sand deposit is located offshore of the -5m AHD depth contour and outside the active sand movement system.

Table 9: External investigation areas that were not taken forward and why.

Investigation area	Reason why it was ruled out
A **[A3, A2]**	Vibrocores within this area generally show a thin (0.4 to 0.8m) sheet of sand overlying stiff clay. The sand thicknesses are too thin to be extracted effectively using dredging equipment. The underlying clay also posed risks for sediment plumes of disturbed when dredging the thin layer of overlying sand.
B1	Vibrocores showed a thin layer of variable sand (high fines and gravel content) overlaying a shelly layer and clay. The upper layer of sand was unsuitable for use as nourishment material due to the incompatibility of sand properties.
B2	Vibrocores showed that the substrata was highly variable, both spatially and vertically, with pockets of sand interspersed with clay and/or gravel/cobble layers. The pockets of sand that were analysed for physical characteristics were unsuitable for beach nourishment.
GN	Vibrocores shows that while this area had promising sand properties, the sand layer was too thin (0.1 to 0.3m) and underlain by dense organic matter and stiff clay.

3.3.2 Nearshore investigation areas

Nearshore areas between Torrens Outlet and the North Haven Marina have been investigated for suitability as sand borrow areas for recycling. Between these alongshore extents, nearshore areas being subtidal but inshore of the -5m AHD contour have been assessed for suitability as nearshore sand borrow areas. It is also noted that most seagrass beds are offshore of the -5m AHD depth contour, however, the shoreward extent of seagrass beds does vary alongshore.

This step involved filtering alongshore zones within the nearshore investigation area into areas to be taken forward for further consideration. Guided by the selection criteria set out above in Table 6 a multi-criteria analysis (MCA) type approach was adopted. Importantly, the process provides justification for why certain area were not selected for further consideration herein. To ensure an evidence-based and data-driven approach was utilised:

- the results of the sand sourcing investigations completed to-date
- the sustainable sand recycling strategy informed by the sand budget and movement (see Section 5)
- a review of seagrass extents and associated benthic habitat datasets (see **Appendix D**)
- Table 10 sets out the assessment criteria, scoring system and data analysis used to make evaluate the criteria.

The results of the MCA-based filtering process for the nearshore investigation areas are presented in Table 10 and mapped in Figure 9.

Table 10. Assessment criteria and scoring system used to filter investigation areas.

Rating (score)	Sand compatibility[1]	Volumes and sustainability	Accessibility	Avoidance of environmental harm[2]
Go (3)	Sand is generally conforming with beach nourishment compatibility requirements.	Area has healthy sandy buffer and no significant downdrift impacts expected from sand harvesting.	Sediment thickness is sufficient (>1.5m) and water depths are accessible for very small TSHD at least 75% of the time.	Seagrass coverage is less than 5%.
Slow (2)	Sand is generally conforming with beneficial reuse compatibility requirements.	Area has sufficient sandy buffer and manageable downdrift impacts expected from sand harvesting.	Marginal sand thickness (1.0 to >1.5m) and/or water depths are accessible for very small TSHD around 25% of the time or more.	Seagrass coverage is between 5% to 15%.
Stop (1)	Does not meet sand compatibility requirements.	Unacceptable risk with insufficient sandy buffer and/or significant downdrift impacts expected if sand harvested for recycling.	Sand layer too thin and/or water depths inaccessible for dredging equipment.	Seagrass coverage is greater than 15%

Note: 1. Sand compatibility has been assessed using all sediment data collected between 2022 and 2025. Samples within each investigation area were averaged and assessed against the physical parameters in the sand specifications. The results of this analysis are provided in **Appendix G**.

Note: 2. An important potential environmental impact will be the direct removal/impact on the benthic habitat within dredging areas. Along the Adelaide's northern management area, seagrass is the most common high valued benthic habitat in the nearshore zone, hence this criterion is assessed based on the extent of seagrass within each investigation area using the 2022 benthic habitat mapping (DEW, 2023). The results of this analysis are also provided in **Appendix G**.

Table 11: MCA-based filtering assessment results for nearshore investigation areas.

Nearshore investigation area	Sand compatibility	Volumes and sustainability	Accessibility	Environmental (seagrass)	Overall outcome and main justification for being carried forward or not
NBA4 (Torrens)	Go	Go	Go	Go	**Carried forward.** Sand compatibility based on limited sampling. High gravel content in single sample ignored as unlikely to be representative.
E8 (Henley to Grange)	Go	Stop	Go	Slow	**Not carried forward.** This area has been subject to long-term erosion trends (2008 to 2024) and is not a sustainable sand harvest area due to potential downdrift impacts and inadequate sandy buffer against storms.
NBA2 (Grange to Tennyson)	Slow	Go	Go	Go	**Carried forward.** This coastline has a long-term (2008 to 2024) accretion trend and adequate sandy buffer. Sand compatibility meets beneficial reuse specifications.
E6 (West Lakes Shores)	Slow	Stop	Slow	Go	**Not carried forward.** This area was not carried forward as it has a low sandy buffer volume. The coastline is stable (i.e. neither eroding or accreting) but given low sandy buffer it was not carried forward.
NBA1 (Semaphore Park)	Go	Go	Slow	Slow	**Carried forward.** This coastline has a long-term (2008 to 2024) accretion trend, has historical been a significant source of sand for beach management and has an adequate sandy buffer. Sand compatibility meets beach nourishment specifications. Seagrass coverage and accessibility are considered manageable constraints.
E4 (Semaphore South)	Slow	Go	Slow	Slow	**Not carried forward.** This area was not carried forward as it has significant erosion trends (2008 to 2024) and a relatively low sandy buffer volume.
E3 (Semaphore/Largs)	Slow	Slow	Go	Stop	**Not carried forward.** Relatively high seagrass coverage. Much of this coastline has observed long-term erosion trend (2008 to 2024).
E2 (Largs Bay)	Stop	Slow	Slow	Stop	**Not carried forward.** Relatively high seagrass coverage. Sand is too fine and does not meet beneficial reuse specifications.
B3-A (Largs North)	Stop	Stop	Go	Stop	**Not carried forward.** Relatively high seagrass coverage. Sand is too fine and does not meet beneficial reuse specifications.
NBA3 (North Haven)	Stop	Slow	Slow	Go	**Carried forward.** While the sand here is too fine and does not meet beneficial reuse specifications, this area is carried forward because it offers significant benefit in terms of the dredging reducing harbour maintenance requirements for the marina.

Legend	Stop	Slow	Go
	(red)	(yellow)	(green)

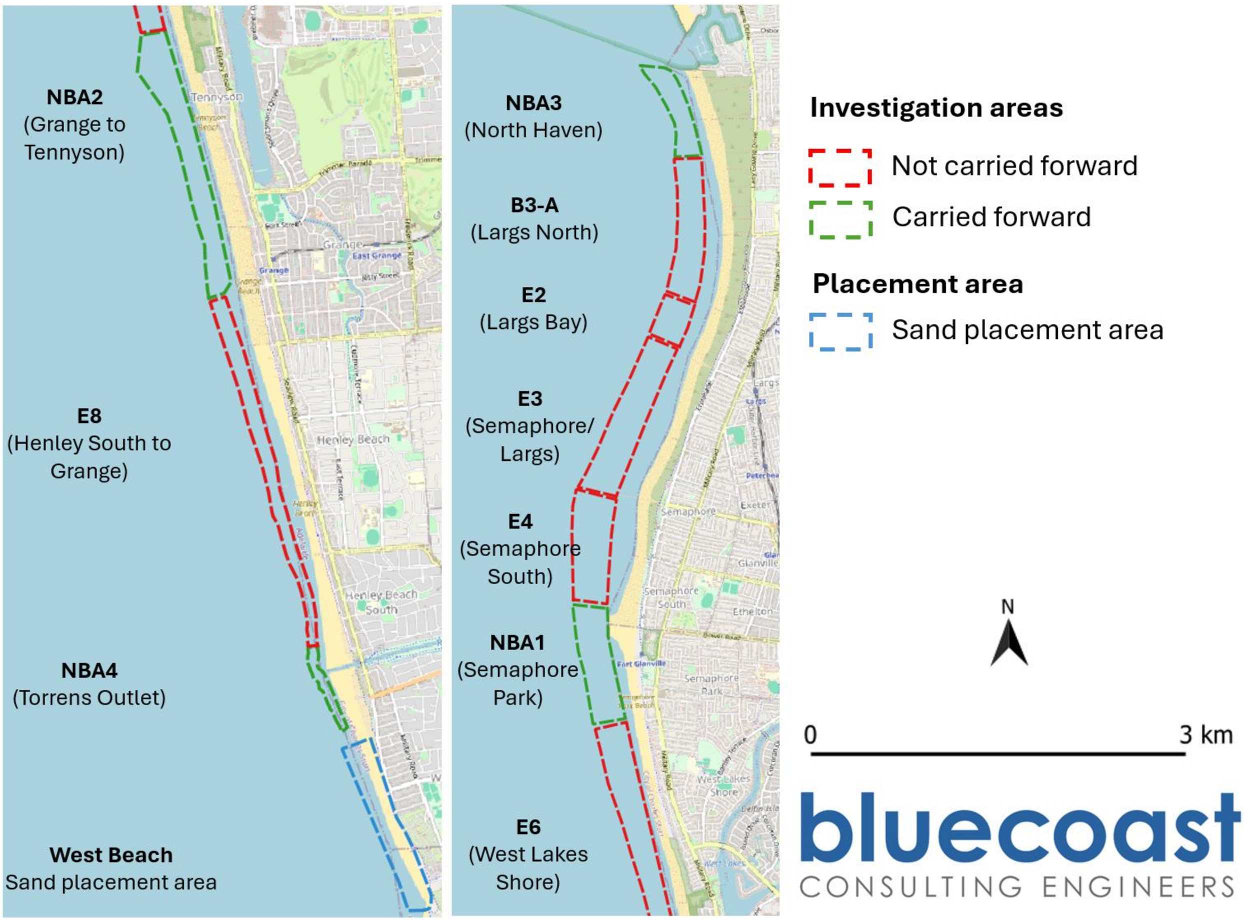


Figure 9: Mapped results of investigation areas taken forward and those that were not taken forward.

4. Sand borrow areas

4.1 Introduction

This section sets out a description of the quantity and quality of the sand that has been tested and found to be available with external and nearshore borrow areas. This includes a detailed compatibility assessment as well as an assessment of the level of certainty and further considerations for each borrow area and each selection criteria for what makes a suitable sand source.

4.2 External sand borrow areas

The details of the two external sand borrow areas identified as having suitable sand for use on the management of Adelaide's beaches are:

- **External borrow area 1 (EBA1)**: Sand deposit north of the port's approach channel, which is north of and external to the West Beach to North Haven littoral sand movement system.
- **External borrow area 2 (EBA2)**: Sand deposit located just offshore of West Beach. This sand deposit is located offshore of the -5m AHD depth contour and outside the active sand movement system.

Figure 10 provides a series of maps providing an overview of borrow areas EBA1 and EBA2.

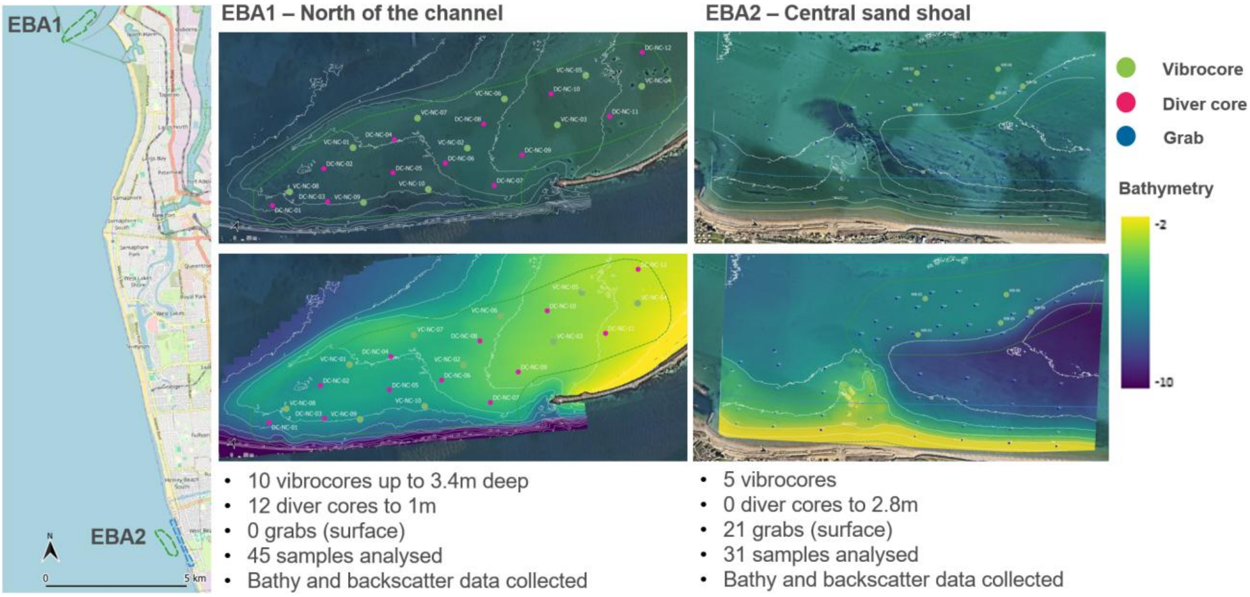


Figure 10: Overview maps of two external sand borrow areas.

4.2.1 Compatibility assessment

Table 12 and Table 13 provide details on the quantity and quality of sand in EBA1 and EBA2, respectively. The compatibility assessment considers the suitability of each borrow area for use to supply material for beach nourishment on Adelaide's northern beaches.

Table 12: Quantity and quality of nourishment sand available in EBA1.

Type	Parameter	Values, commentary and outcome
Quantity	Average sand thickness:	**2.8m** Some cores (3 of 10) were bottomless sand meaning there is potential for greater quantity of sand being extracted should it be proven with further testing in the future.
	Underlying substrata:	Sandy organic matter (believed to be rhizome mats)
	Size of borrow area:	460,000m^2 Opportunity to expand slightly subject to benthic classifications data, this would result in a greater volume of sand being available for use.
	Sand volume available:	**1,080,000 m^3** [1,030,000 to 1,130,000 m^3 as lower and upper bound assuming a 0.3m to 0.5m tolerance to underlying substrata. This volume considered the 100m exclusion around the unknown shipwreck location.]
	Outcome:	**Quantity of proven sand in this borrow area is sufficient to <u>restore</u> the beaches in the northern management area. Moreover, give the volume in greater than what is needed, EBA1 could also provide <u>maintenance sand 'top-ups'</u> (i.e. residual volumes if sand recycling by dredging, or other**

Type	Parameter	Values, commentary and outcome
		means, were less than the 90,000m³/yr). It's longevity as a source for on-going sand top-ups depends on how much is recycled from the nearshore borrow areas, with options available for 100% recycling. EBA1 could also be used as source for renourishing other vulnerable areas (e.g. Glenelg North).
Quality (physical)	No. of samples: 47 D50: 0.181mm [0.12–0.29mm] Cu: 0.19 Fines: 3.7% Gravels: 1.2% Carbonate: 18% Colour: Light grey	The values of each parameter presented here are averages across the 47 samples tested for PSD for grain size-based parameters and across the 18 samples tested for carbonate content. As such they are represent the bulk material properties as intended by the sand specifications. **All parameter values indicate the source meets the 'beach nourishment' (ideal) acceptance criteria for either onshore or nearshore placement.** (Pass)
	Overfill ratio (Ra)[4]: Renouishment factor (Rj):	1.20 1.25
	Outcome:	**Meets 'beach nourishment' (ideal) specification for onshore or offshore placement. No further sediment testing is required.**
Quality (geo-chemical)	Metals and metalloids: (Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Vanadium, Zinc)	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 46 samples tested. (Pass)
	BTEXN & TRH (Benzene, Toluene, Ethylbenzene, Xylene (total) and C6-C10)	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 15 samples tested. (Pass)
	Organochlorine, PCBs, PAH, Organotin	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 15 samples tested.

[4] Overfill ratio is an engineering feasibility parameter determined by the overlap in the grain size distribution between native beach and borrow area sand. It is not a specification but provided herein as provides a mean to calculate the 'effective nourishment' volume for sand placed from this source on West Beach.

Type	Parameter	Values, commentary and outcome
	(4,4-DDE, gamma - BHC, Dieldrin, Cis-chlordane, Trans-chlordane, 4,4-DDT, 4,4-DDD, Endrin, Heptachlor epoxide, Total PCBs, Tributyltin as Sn and Benzo(a)pyrene)	✓ (Pass)
	Outcome:	**Sand is clean and uncontaminated as confirmed by testing in accordance with NAGD guidelines.**

Table 13: Quantity and quality of nourishment sand available in EBA2.

Type	Parameter	Values, commentary and outcome
Quantity	Average sand thickness:	**1.0 to 1.8m** This borrow area consists of a boarder flatter area, with a sand thickness of about 1.0m and a sloped area with a sand thickness up to 1.8m.
	Underlying substrata:	Thick organic matter (believed to be rhizome mats)
	Size of borrow area:	300,000m^2 Opportunity to expand slight subject to benthic classifications data.
	Available sand volume:	**200,000 m^3** [170,000 to 230,000 m^3 as lower and upper bound]
	Outcome:	**Quantity of proven sand in this borrow area could either contribute to the <u>restoration</u> the beaches in the northern management area or to any <u>maintenance sand 'top-ups'</u>.** There is insufficient sand volume for the restore volume to be delivered solely from this source, however, given its proximity to West Beach is considered a useful supplementary sand source. This borrow area would benefit from additional vibracoring or sub-bottom profiling to better map the substrata to avoid risks associated with sand removal.
Quality (physical)	No. samples: 31 D50: 0.256mm [0.24–0.30mm] Cu: 0.17 Fines: 1.1% Gravel: 0.4% Carbonate: 4%	The values each parameter presented here are averages across the 31 samples tested for PSD for grain size-based parameters and across the 29 samples tested for carbonate content. As such they are represent the bulk material properties as intended by the sand specifications. **<u>All parameter values indicate the source meets the 'beach nourishment' (ideal) acceptance criteria for either onshore or nearshore placement.</u>**

Type	Parameter	Values, commentary and outcome
	Colour: Beige	✓ (Pass)
	Overfill ratio (Ra)[5]: Renouishment factor (Rj):	1.00 0.70
	Outcome:	**Meets 'beach nourishment' (ideal) specification for onshore or offshore placement.**
Quality (geo-chemical)	Metals and metalloids: (Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Vanadium, Zinc)	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 14 samples tested. See Appendix F for more details. ✓ (Pass)
	BTEXN & TRH (Benzene, Toluene, Ethylbenzene, Xylene (total) and C6-C10)	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 12 samples tested. See Appendix F for more details. ✓ (Pass)
	Organochlorine, PCBs, PAH, Organotin (4,4-DDE, gamma - BHC, Dieldrin, Cis-chlordane, Trans-chlordane, 4,4-DDT, 4,4-DDD, Endrin, Heptachlor epoxide, Total PCBs, Tributyltin as Sn and Benzo(a)pyrene)	All individual sample concentrations along with their 95% upper confidence levels were well below NAGD screening levels. 12 samples tested. See Appendix F for more details. ✓ (Pass)
	Outcome:	**Sand is clean and uncontaminated as confirmed by testing in accordance with NAGD guidelines.**

[5] Overfill ratio is an engineering feasibility parameter determined by the overlap in the grain size distribution between native beach and borrow area sand. It is not a specification but provided herein as provides a mean to calculate the 'effective nourishment' volume for sand placed from this source on West Beach.

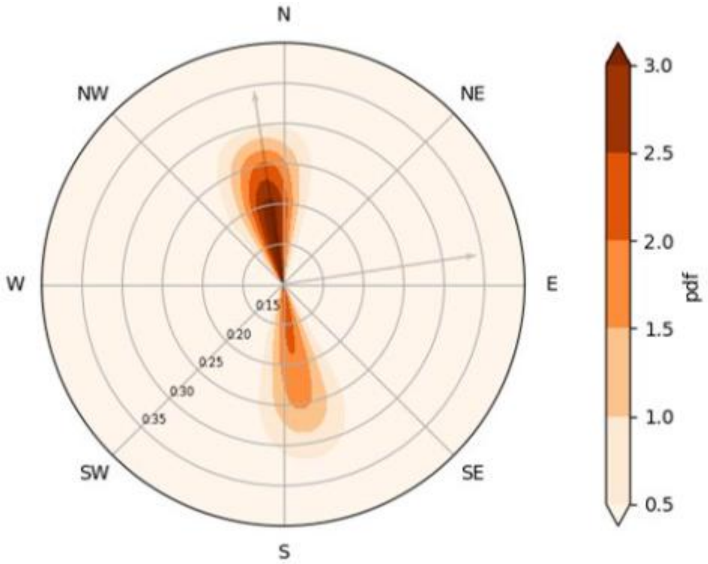
4.2.2 Level of certainty and further considerations

An important objective of this report is to resolve, to a sufficient level of certainty, uncertainty around sustainable sand sources for the on-going management of Adelaide's beaches using dredgers. With respect to external sand sources, Table 14 provides a summary of:

- What we now know about these potential external sand sources and to what is the level of certainty?
- What don't we know but is critical to find out before being able to put a source forward in tender for dredging works?

Table 14: Summary of level of certainty and further considerations for external borrow areas (EBA1 and EBA2).

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
Sand compatibility (quality)	**EBA1:** 10 deep vibrocores and 12 diver cores were recovered from EBA1, with detailed laboratory analysis demonstrating that this deposit contains clean and compatible sand that could be used to restore West Beach. Sample densities and testing was in accordance with guidance in NAGD (2009). No further sediment sampling or testing is considered warranted. One remaining concern is the colour of EBA 1 sand, which is slightly darker and more grey and less beige compared to the native West Beach sand, see Figure 12. As suggested in the sand specifications, this could be addressed with a preference for nearshore placement because of the reasons stated in Table 2 (i.e. nearshore placement provide opportunity for natural 'washing' of material by wave and tidal actions and mixing with native material before bleaching).	✓ [95%]
	EBA2: While only five (5) vibrocores were collected, an additional 26 grab samples together with detailed laboratory analysis demonstrated that the EBA2 sand deposit contains 'premium' quality sand with which to restore West Beach. The sand colour, as seen in Figure 12, is very similar to the native beach sand. Sample densities and testing was in accordance with guidance in NAGD (2009) and any further sediment sampling would only be considered warranted as part of any additional vibracoring aimed at better map sand/rhizome interface (see below).	✓ [100%]
Volumes and sustainability	**EBA1:** Vibrocoring has confirmed this area to be a relatively thick (average thickness of 2.8m) deposit of sand with a minimal extractable volume of 1,050,000m^3. The overfill ratio (Ra) of the EBA1 sand is 1.2. This means to provide the adopted restoration volume of say 430,000m^3, the total volume required from EBA1 would be 516,000m^3. <u>This means the available sand in EBA1 is at least 500,000m^3 over and above that required for the adopted restoration volume.</u> Located north of the port's entrance channel and breakwaters, EBA1 is clearly external to the West Beach to North Haven coastal sand system. Sand movements and the expected infilling rate in this area have not been considered as they are not critical to the suitability of this source. However, it's suspected that this sand deposit has been formed by wave action in combination with tidal and fluvial flows and	✓ [100%]

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
	their combined interaction with the port channels breakwaters. These processes will continue after extraction and it is expected that the borrow area would be infilled with sand, likely coming from the areas immediately north of the borrow area.	
	EBA2: Vibrocoring has confirmed this area to be a useful supplementary external sand borrow area with a minimal extractable volume of 170,000m^3. The sand in this borrow area is highly suitable to nourish West Beach and its proximity makes it various dredging methods, including Cutter Suction Dredgers (CSD) possible. The sand thicknesses, in some area, are marginal and additional vibracoring would be recommended to map the sand isopaches (i.e. thicknesses) in more detail. This is because dredging over thin layers of sand carries risks around disturbing the underlying material which is believed to be dense rhizome mats. CSD would offer a more precision dredging approach but a very small or small TSHD may also be viable by optimising to control the draghead depth (e.g. draghead with a visor, adjusting suction power, use of GPS and real-time dredge management software and/or shallow pass techniques). Based on a recent review of bathymetric surveys and DEW's coastal profile survey, this sand deposit is currently accreting at a relatively slow rate of around 3,150m^3/yr (Bluecoast, 2024). The source of the sand accumulating in the areas is believed to be the sand sheets to the south. This hypothesis is supported by recent nearby ADCP measurements (see Figure 11) which show net northward alongshore directed currents, with a northward bias velocity asymmetry (i.e. swifter northward flow currents when compared to southward flowing currents). Along with wave-driving action on the seabed, these currents provide a mechanism by which sand may be transported to and deposited in this area.  **Figure 11: Surface velocity distribution from recent ADCP deployment nearby the site (source: Hatch, 2025).**	✓ **[70%]**

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
Accessibility	**EBA1:** • EBA1 is 10.2NM from the West Beach placement area. • A recent high-resolution bathymetric survey was completed over the borrow area and show the water depths to be sufficient for accessing with a very small or small TSHD • The thickness of sand layer is considered sufficient for TSHD or higher precision dredging methods. • A TSHD will be the most efficient means of undertaking the beach nourishment works with a larger hopper providing more efficiency (subject to under keel clearance). TSHD is noted as also having the advantage of flexible sand placement methods, likely to be a combination of pump to-the-nearshore and bottom dumping. Using such a method is expected to result in good value and economic viability (see Section 6).	✓ **[95%]**
	EBA2: • EBA2 is 0.3NM from the West Beach placement area. • A recent high-resolution bathymetric survey was completed over the borrow area and show the water depths to be sufficient for accessing with a very small or small TSHD. A CSD could also access this area and given it's proximity, could pump sand directly for placement in the nearshore of West Beach (i.e. in a similar manner to that used in the 2024 dredge trial. • The thickness of sand layer is considered relatively thin for TSHD work, suggesting higher precision dredging methods such as CSD may be more effective. • The recent dredge trial demonstrated that the use of CSD at nearby sites pumping directly to West Beach's surfzone or nearby is an efficient method, even in the marginal wave climate, and could be similarly expected to result in good value and economic viability from this source (Swash Project Delivery, 2025).	✓ **[95%]**

Avoidance of environmental harm	**EBA1:**
	• Given the material is clean dan with low fines contents, direct impacts from dredging in this borrow area are expected to be a key potential impact significant (i.e. removal of seagrass and other benthic organisms by dredging). Aerial photography and high-resolution bathymetric survey indicate that there is only limited seagrass in the area. DEW recently completed benthic field surveys in EBA1, with the results mapped in Figure 13. These show the area, conservatively, can be described as:
	  ○ 81% bare sand seabed habitat, likely to contain infauna (marine invertebrate) species.
	  ○ 19% containing seagrasses with the majority being spare density coverage with some isolated or medium density coverage with species including: Halophalia, Posidonia and Zostera.
		✓
		[60%]

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
	○ Possible dumped items or wrecked artefacts identified in one discrete area. • Water quality monitoring during the dredge trial in 2024, including 6-day and 15-day rolling median turbidity measurements remained below the adopted trigger values during all working periods (Epic, 2025). Epic (2025) reported that there was no discernible signal of dredge plumes in the turbidity data. The dredging trial included operations in NBA3 (North Haven) area, where the sand is finer (D50 = 0.11mm) and the fines (silts and clays) component is 8.5%. Given the sand in EBA1 is coarser (D50 = 0.18mm) and the fines content is 3.7% (i.e. less than half the fines in the dredge trial area) the potential of impacts related to turbidity and water quality are expected to be minimal (albeit subject to difference in sediment splits from relevant work methods). This implies that indirect impacts on seagrasses and other nearby benthic habitats from turbidity plumes is also likely to be minimal. • Pacific Oyster Mortality Syndrome (POMS) is a herpes virus effecting Pacific oysters in the Port Adelaide River. There is a potential risk that any bivalve organisms relocated by the nourishment works may spread this virus to other areas (e.g. West Beach). Mitigating factors are likely to include: ○ EBA1 is outside the bivalve shellfish closure area (PIRSA, 2023). ○ Limiting works to periods when the water temperature is less than 18°C or very low risk and less than 16°C for no risk. • The South Australian government maintains a database of shipwrecks, which are mapped in Figure 13. Unknown wreck (Id 605) is mapped as being within EBA1, but the actual resting place of this wreck is uncertain and there is no information about its vessel or it's wrecking. It is currently not protected. As a result, it seems unlikely that there would be any historic shipwrecks located in the area immediately north of the Outer Harbor breakwater, however, the following is recommended: ○ Magnetometer survey of the area and/or side-scan sonar survey of the area to double check for any possible shipwrecks or other heritage items. ○ Exclusion zones around any proven wrecks with a buffer distance of 100m (approximately one vessel length for a small TSHD). This has been applied to the unknown wreck (Id 605) with the sand volume excluded from the estimated available quantities. ○ Further discussions with the SA government's Maritime Heritage Officers with respect for the need for additional heritage impacts assessments and/or the development of an unexpected finds protocol. • Long-nosed fur seals (*Arctocephalus forsteri*) and Australian sea lions (Neophoca cinerea) have been observed on the Outer Harbour breakwaters, including the tip of the northern breakwater	

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
	(Shaughnessy et al, 2018). These species are not threatened but most native wildlife is afforded protection under State and federal laws and nearby dredging will need to consider the management of the works to be non-harmful to these seals. • As noted in the introduction of this report, environmental approval pathways are not addressed in this report. However, it is noted that following a DA approvals pathway dredging approvals were gained from the port's channel widening project in 2017/2018 and that this site is (i) adjacent to this projects footprint and (ii) requires much lower dredging volumes with lower production rates in material with much lower fines content. • The configuration of the dredge cut could be checked for any potential impact of wave transformation and any implication for littoral sand movements. As dredging would be on the leeward (shore facing) slope no significant effect on wave transformation is expected, and this may be net positive, but it should be checked.	
	EBA2: • The D50 in EBA2 is 0.27mm and fines content is 1.1%. Following the rational provided for EBA1, turbidity plumes and water quality are expected to be minimal. Despite this water quality monitoring would likely form part of the mitigation measures. • Like EBA1, aerial photography, high-resolution bathymetric survey and benthic observation indicate that there is only very limited seagrass in the area. • This area is well outside the bivalve shellfish closure area and not expected to subject to POMS risk. • Approval pathways are a remaining risk to implementation but nor addressed herein. • Social considerations are important for EBA2, with community concerns raised regarding this sand sourcing being perceived as being within the littoral zone and therefore not external to the coastal barrier system of West Beach.	✓ **[60%]**

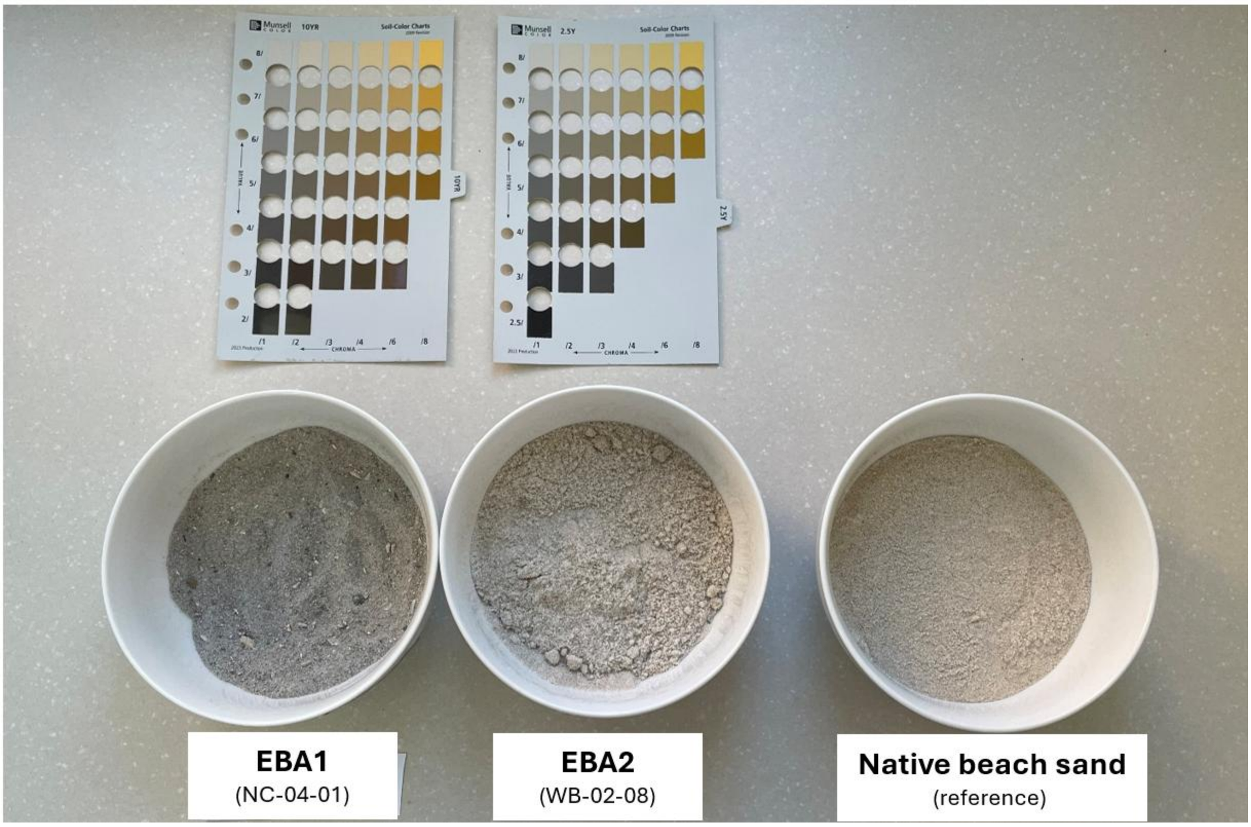


Figure 12: Sand colour comparison based on typical samples from EBA1 and EBA2 compared to native beach sand.

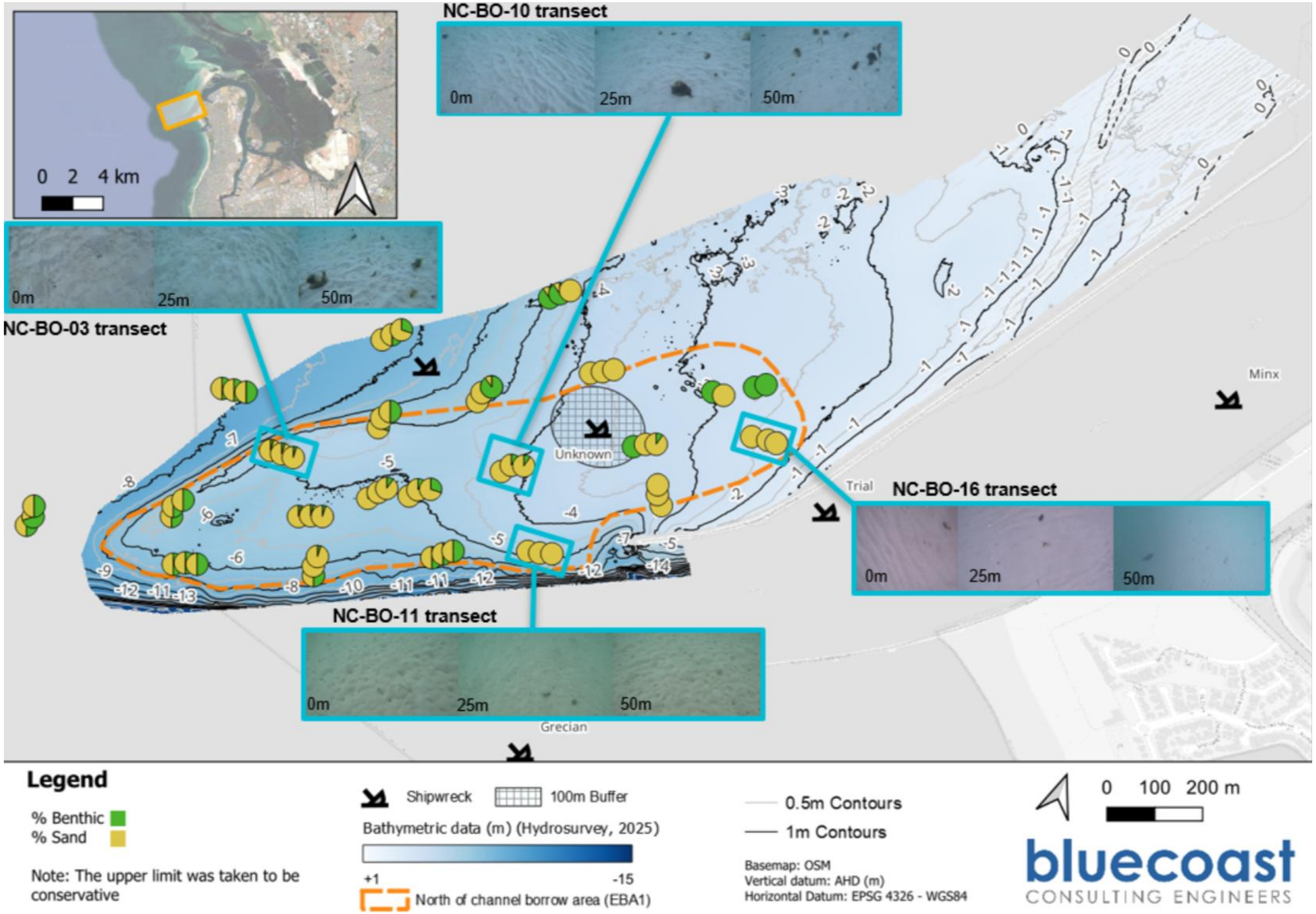


Figure 13: Benthic habitat and shipwrecks mapped for EBA2.

4.3 Nearshore sand borrow areas

Section 5.4 outlines how a sustainable sand recycling strategy, along with other constraints, were used to identify four (4) discrete nearshore borrow areas from the sand recycling investigation area between Torrens Inlet and North Haven. Figure 14 provides a series of maps and other details for three of these nearshore borrow areas (NBAs) identified for sand harvesting for sand recycling, all four described as:

- **Nearshore borrow area 1 (NBA1)**: This Semaphore borrow area around the breakwater would act as the main source of sand for recycling.
- **Nearshore borrow area 2 (NBA2)**: in the Grange to Tennyson nearshore area this borrow area would act as a supplementary source of sand for recycling.
- **Nearshore borrow area 3 (NBA3)**: just south of the North Haven Marina this would act as a supplementary source of sand for recycling. This area is known to have fine sand that is not well suited for nourishment at West Beach, however, removal of sand in this area has the benefit of reducing sedimentation in the marinas and its entrance area.
- **Nearshore borrow area 4 (NBA4)**: located to the north of West Beach, Torrens Outlet has been observed to accumulate sand and been used extensively in the past as a source for sand management. It has therefore been utilised as part of the recycle strategy to spread the sand harvesting areas and ensure a sufficient overall volume can be collect from each area in sustainable quantities.

4.3.1 Compatibility assessment

Table 13 provide details on the quantity and quality of sand in the four nearshore sand borrow areas, which are mapped in Figure 14. The compatibility assessment considers the suitability of the each borrow area to be used to harvest sand for recycling of sand along Adelaide's northern beaches.

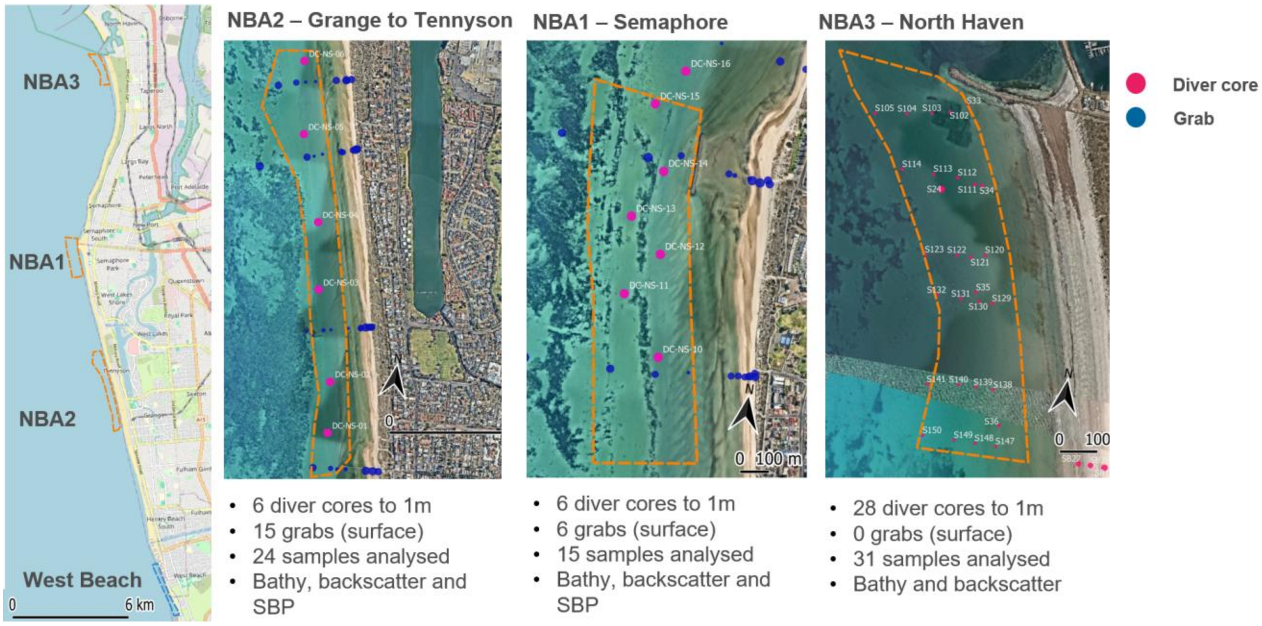


Figure 14: Overview maps of three (3) nearshore sand borrow areas.

Note: NBA4 (Torrens Outlet) not shown.

Table 15: Quantity and quality of nourishment sand available in nearshore borrow areas.

Type	Parameter	NBA1 (Semaphore)	NBA2 (Grange)	NBA3 (North Haven)	NBA4 (Torrens Outlet)5
Quantity	Average sand thickness:	1.3m	2.5m	>2.5m	Unknown
	Underlying substrata:	Stiff clay (TBC)			Unknown
	Size of borrow area:	595,000m²	435,000m²	245,000m²	
	Available sand volume:	1,000,000m³	950,000m³	>650,000m³	Unknown
	Outcome:	**Sufficient sand thickness in each of these three areas to allow sustainable sand harvesting.**			**TBC**
Quality (physical)	No. of samples:	15	22	31	3
	D50:	0.21mm	0.16mm	0.11mm	0.20mm
	Cu	2.1	2.0	1.3	1.9
	Fines:	4.5%	7.8%	8.5%	1.7%
	Gravels:	1.0%	0.9%	0.6%	3.7%
	Carbonate:	10.7%	10.6%	0.1%	7.0%
	Overfill ratio (Ra):	1.0	1.5	6.0	1.0
	Renouishment factor (Rj):	0.8	1.5	NA	0.7
	Outcome:	**Sufficient sand thickness in each of these three areas to allow sustainable sand harvesting.**		**Sand finer than West Beach.**	**Additional sampling warranted**
Quality (geo-chemical)	Metals and metalloids: (Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Vanadium, Zinc)	✓ (Pass)	✓ (Pass)	✓ (Pass)	✓ (Pass)

Type	Parameter	NBA1 (Semaphore)	NBA2 (Grange)	NBA3 (North Haven)	NBA4 (Torrens Outlet)5
	BTEXN & TRH (Benzene, Toluene, Ethylbenzene, Xylene (total) and C6-C10)	✓ (Pass)	✓ (Pass)	✓ (Pass)	✓ (Pass)
	Organochlorine, PCBs, PAH, Organotin (4,4-DDE, gamma - BHC, Dieldrin, Cis-chlordane, Trans-chlordane, 4,4-DDT, 4,4-DDD, Endrin, Heptachlor epoxide, Total PCBs, Tributyltin as Sn and Benzo(a)pyrene)	✓ (Pass)	✓ (Pass)	✓ (Pass)	✓ (Pass)
	Outcome:	**Sand is clean and uncontaminated as confirmed by testing in accordance with NAGD guidelines.**			

4.3.2 Level of certainty and further considerations

An important objective of this report is to resolve, to a sufficient level of certainty, uncertainty around sustainable sand sources for the on-going management of Adelaide's beaches using dredgers. With respect to nearshore sand sources, Table 14 provides a summary of:

- What we now know about these potential nearshore sand sources and to what is the level of certainty?
- What don't we know but is critical to find out before being able to put a source forward in tender for dredging works?

Table 16: Summary of level of certainty and further considerations for nearshore borrow areas (NBA1 to NBA4).

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
Sand compatibility (quality)	**NBA1 to NBA4:** Sand quality in three of these four nearshore borrow areas has been confirmed by a detailed sampling and testing program. While it is not considered critical to feasibility, additional shallow coring in NBA4 would be useful to provide more certainty on this borrow areas, as only two samples have been collected in this zone.	✓ **[85%]**

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]
Volumes and sustainability	**NBA1 to NBA3:** Sub-bottom profiling (SBP) and diver coring in NBA1, NBA2 and NBA3 confirmed these areas to be of sufficient thickness to maintain sustainable sand harvesting. Deeper vibrocoring in NBA1 maybe warranted to ground truth SBP data prior to implementing the works. An assessment of coastal processes (see Section 5) has been completed to inform the sustainability of sand recycling from the nearshore. When combined, these four borrow areas can be expected to provide the required 90,000m^3/yr sand recycling rate. This includes consideration of the overfill ratios (Ra's) which has been calculated for each nearshore borrow area. A remaining uncertainty is the rate of sand infilling that could be expected in each of these borrow areas and the quality of the material infilling the dredged holes. While it is considered too early to adequately evaluate, initial analysis of the survey results from the recent dredge trial suggest: • NBA3: infilling rates of around 20m^3/day with extrapolated infilling time of 2.3 years. • West Beach Harbour sand bypassing pathway (SBA3): infilling rates of around 160m^3/day with extrapolated infilling time of 0.7 years. It is recommended that: • these infilling rates be reevaluated using subsequent monitoring surveys planned for borrow areas used in the trial (particularly after larger wave conditions/events have occurred) and • once the dredged holes are sufficiently infilled, coring and testing of infilling sediments be used once establish the sand (and organic content) properties infilling these holes.	✓ **[80%]**
	NBA4: Much of that discussed above applied to NBA4, however, it has been separated here as this area has not been subject to coring or sub-bottom profiling. Therefore, there is greater uncertainty until this is completed. Based on the build-up of sand at Torrens Outlet as well as other nearby factual data on the seabed substrata, we believe the sand layer thickness in this area will be sufficient but factual data should be used to check this expectation.	✓ **[65%]**

Criteria	Description of results and further considerations	Pass/ fail [level of certainty]

Accessibility	• The distances between the nearshore borrow areas and the West beach placement areas are:
	  ○ NBA4 (Torrens Outlet) is approximately 1.1NM
	  ○ NBA2 (Grange to Tennyson) is approximately 3.8NM
	  ○ NBA1 (Semaphore Park) is approximately 6.1NM
	  ○ NBA3 (North Haven) is approximately 9.5NM.
	• High-resolution bathymetric surveys have been completed for all four of the nearshore borrow areas. Due to their location within the -5m AHD depth contour, these shallows borrow areas have limited accessibility for TSHD equipment, which requires sufficient water depth for operation. The effectiveness of working within tidal windows for very small TSHDs. There are a limited number of very small TSHDs currently available in Australia to undertake this work.
	• The thickness of sand layer in three of these nearshore borrow areas has been confirmed as considered sufficient for TSHD or higher precision dredging methods. As noted above additional vibracoring or sub-bottom profiling in NBA4 (Torrens Outlet)
	• Work methods are examined further in Section 6.
		✓
		[75%]

Avoidance of environmental harm	**NBA1 to NBA4:** • A similar logic on turbidity and water quality impacts will also apply to the nearshore borrow areas. The highest fine component of these nearshore borrow areas is NBA3, which was also showed no discernible turbidity plumes over the rolling averages monitored during the 2024 dredge trial. • Direct impacts from dredging in these borrow area requires more detailed environmental assessment. Working with the EPA will be a key component of this with reference to their guidelines for dredging works as well as in relation to seagrass restoration sites. The known seagrass restoration sites relative to the defined nearshore borrow areas are mapped in **Appendix C**. • From the work completed on the Development Application for the sand recycling pipeline, there are known and legitimate community concerns that relate to the impacts of sand recycling on the northern beaches. While the work completed herein has assessed the impacts the beaches, it will be important that further assessment work be completed with the potential for further refinement and improvement of this flexible and adaptive approach. • As noted in the introduction of this report, environmental approval pathways are not addressed in this report.	✓ **[60%]**

5. Sustainable sand recycling

5.1 Introduction

Recycling sand (or backpassing) from an active coastal barrier (i.e. a beach and dune system) with significant alongshore sand movement (or littoral drift) needs careful consideration. If sand is removed excessively in the littoral zone it can lead to downdrift areas experiencing sediment starvation which in turn can lead to beach narrowing and the loss of an adequate sandy buffer to protect landward assets from short-term storm erosion. From a coastal processes' perspective, the principal concern is determining sustainable rates of sand recycling from harvesting areas that are selected to manage downdrift impacts within acceptable limits.

Concerns around the potential for impacts on coastal processes and the coast were highlighted in DEW's previous engagement on the proposed sand recycling pipeline. Most of the communities' concerns related to the proximity of the proposed sand collection infrastructure to residential dwellings at Grange and concerns with regards to noise, safety and visual amenity (i.e. impacts related to the pipeline infrastructure and method of sand collection on public beaches that are not directly relevant to sand recycling using dredgers) (DEW, 2022). However, concerns were also expressed regarding the potential for long-term impacts on the coast. According to Salients' 2021 report these include:

- loss of usable beach width and potential reduction in width of dunes
- lower sandy buffer against storm erosion.

This section examines the sustainable harvesting capacity of designated area to support sand recycling efforts. By analysing the relationship between sand extraction practices and coastal dynamics, the assessment aims to address the above concerns while ensuring the long-term sustainability of harvesting.

The assessment includes a detailed evaluation of the area required to sustainably extract the necessary sand volumes, considering infilling rates to maintain equilibrium. It also explores the potential effects of sand harvesting on coastal processes, such as downdrift sediment transport, storm resilience, and the reshaping of beach profiles. To support this analysis, the section leverages a comprehensive sand budget for the borrow areas and applies numerical modelling to simulate storm erosion.

5.2 Sand budget and coastal sand movements

Being refined from the metro-wide coastal sand budget developed as part of the ABMR Scientific Review (Bluecoast, 2023), a more detailed sand budget and conceptual coastal sand movement model was developed for the northern management area (West Beach to North Haven). The development of this detailed sand budget is documented in the relevant supporting information in **Appendix D**, while Bluecoast (2023) provides more details on the original sand budget developed for the ABMR.

Figure 15 provides key outcomes of the sand budget analysis completed from 2008 to 2024, for each analysis cell including:

- Annual rates of net alongshore sand movement (in m^3/year) showing the rate at which sand moves to the north.
- Observed trends in sand gains or losses (erosion or accretion) within each analysis cell (also in m^3/year).
- Annualised rate of net sand management quantities either removed or added to each analysis cell.

Figure 16 provides a graphical overview of the quantified conceptual model of sand movements (quantified model) across the Adelaide's northern management area.

The results of this analysis have been used to develop the sustainable sand recycling strategy presented in Section 5.4.

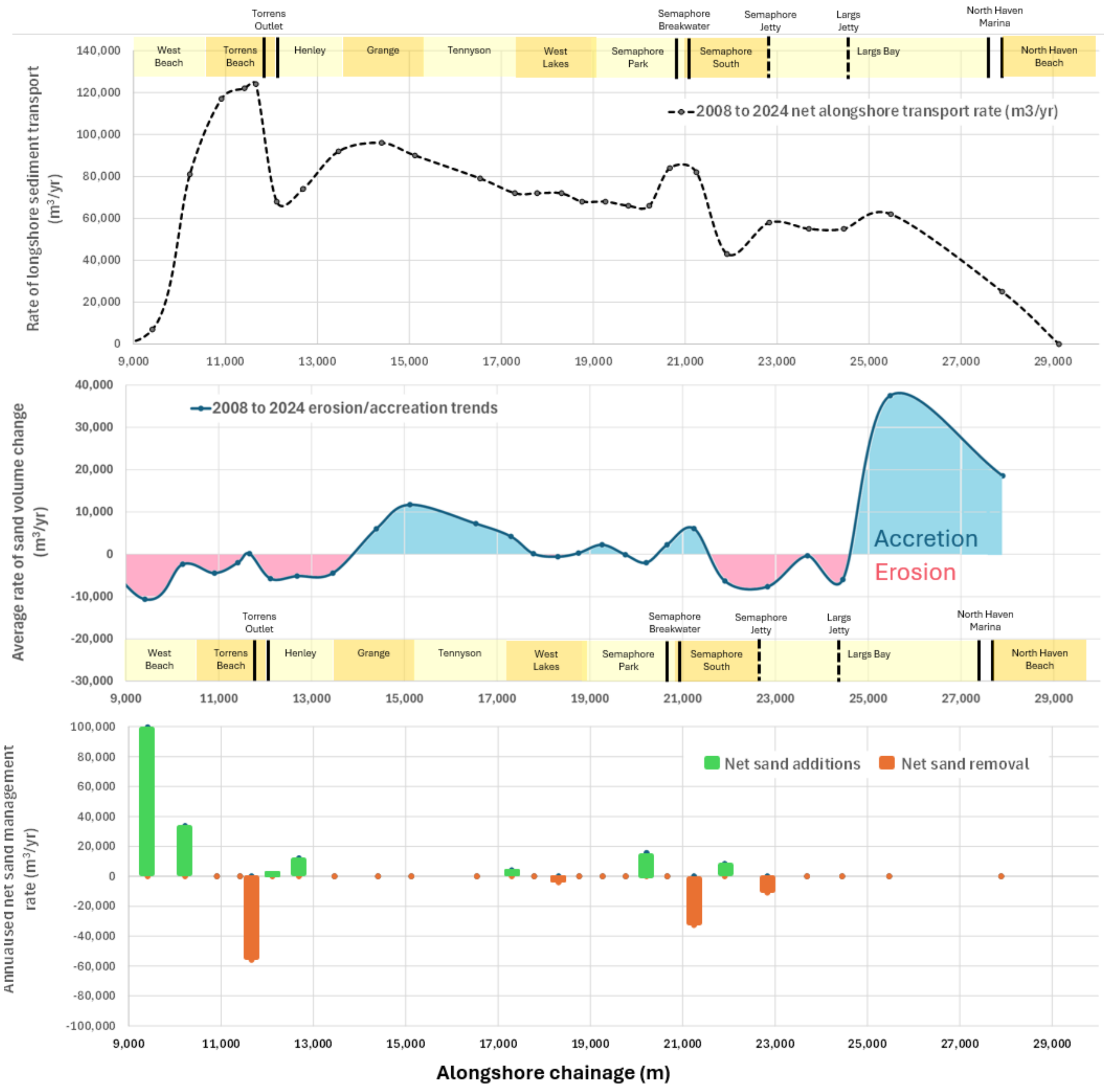


Figure 15: Alongshore sand movement rate (top), erosion or accretion trends (middle) and annual sand management volumes (bottom) between 2008 and 2024 for northern management area.

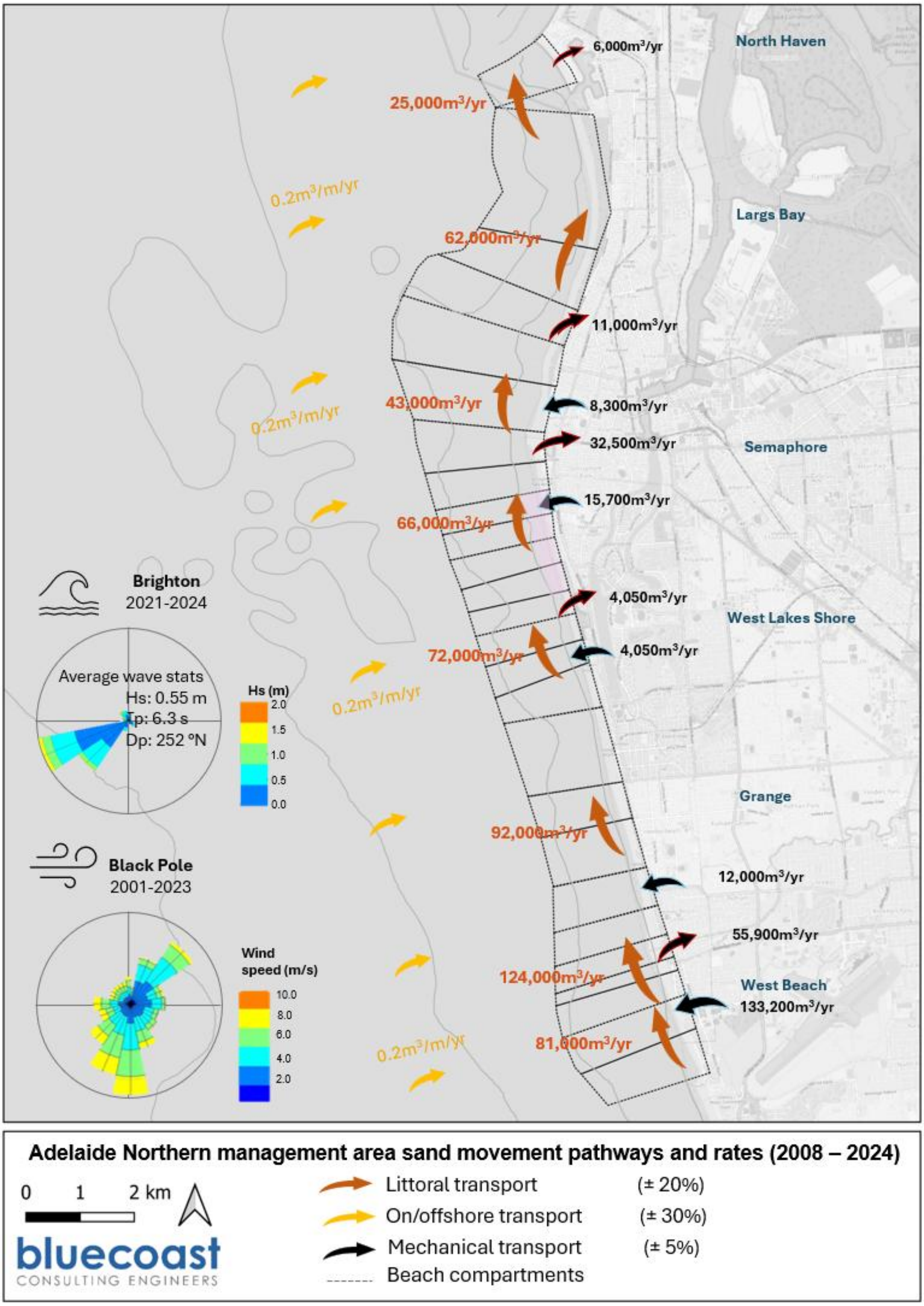


Figure 16: Quantified conceptual model of sand movements along Adelaide's Northern management area.

5.3 Storm resilience

5.3.1 Available sandy buffer

Resilience to storm erosion and therefore protection of landward assets is provided by a healthy beach and dune system. Figure 17 presents an overview of the areas proposed for nearshore sand harvesting, showing the elevations of the beach and dune system, historical erosion scarps, coastal assets and other relevant information. This map shows that:

- Grange, much of Tennyson, West Lakes and most of Semaphore all have coastal assets set back from the active beach system with sufficient sandy buffer protection.
- West Lakes Shores and two isolated areas at Tennyson, being along Seaview Road between Hillview Ave and Bournemouth Street, and in Semaphore at the southern end of Esplanade (corner with Third Ave) are relatively narrow with coastal assets in closer proximity to the active beach system.

The upper beach volume (above 0m AHD) is commonly used as a measure of the sand buffer available to protection against erosion. To examine the vulnerability of the proposed sand harvesting area upper beach sand volumes were calculated from the DEW profiles. These were calculated as the volume of sand above 0m AHD and seaward of a back beach reference line. The reference line was defined as being 15-meter seaward of the closest coastal assets (e.g. roads, footpaths, residential properties) to the beach. The 15-meters buffer distance was adopted as a trigger, which if exceeded would, in most cases, allow time for intervention. Figure 6 displays the box plots of these volumes.

A conservative sand buffer of 80 m^3/m above 0 m AHD was adopted after the Coastal Protection Board's management policy as well as based on observed profile volume changes and findings from Coastal Engineering Solutions (2004) (see Section 5.3.2). All upper beach volumes are significantly above the established sand buffer, except for the section at profile 20009. At profile 20009, while the observed mean beach volume is well above the acceptable sandy buffer, a minimum of 70m^3/m was recorded in 1994.

Storm resilience is defined as the required sand buffer to provide protection against two 1-in-100-year average return interval storms. This approach aligns with the Coast Protection Board's policy and ensures the maintenance of a dry sandy beach amenity. Historically, the sand buffer target has been set at 80m^3/m, measured above a level of 1.0m AHD (Coastal Management Section, 1995).

The Coastal Engineering Solutions (2004) model results, along with volume changes from DEW profiles, indicate that the erosion potential within the sand harvesting area is considerably lower than the design buffer of 80 m^3/m. In comparison, higher storm erosion rates have been recorded at more southern beaches, such as West Beach, where Coastal Engineering Solutions (2004) reported erosion of 70 m^3/m. However, from Tennyson northward, the gentler offshore profile likely causes greater wave energy dissipation compared to areas with steeper foreshore slopes.

A conservative sand buffer of 80m^3/m above a level of 0m AHD was adopted for the harvesting area (from Grange to Semaphore) based on measured profile volume changes and Coastal Engineering Solutions (2004) results.

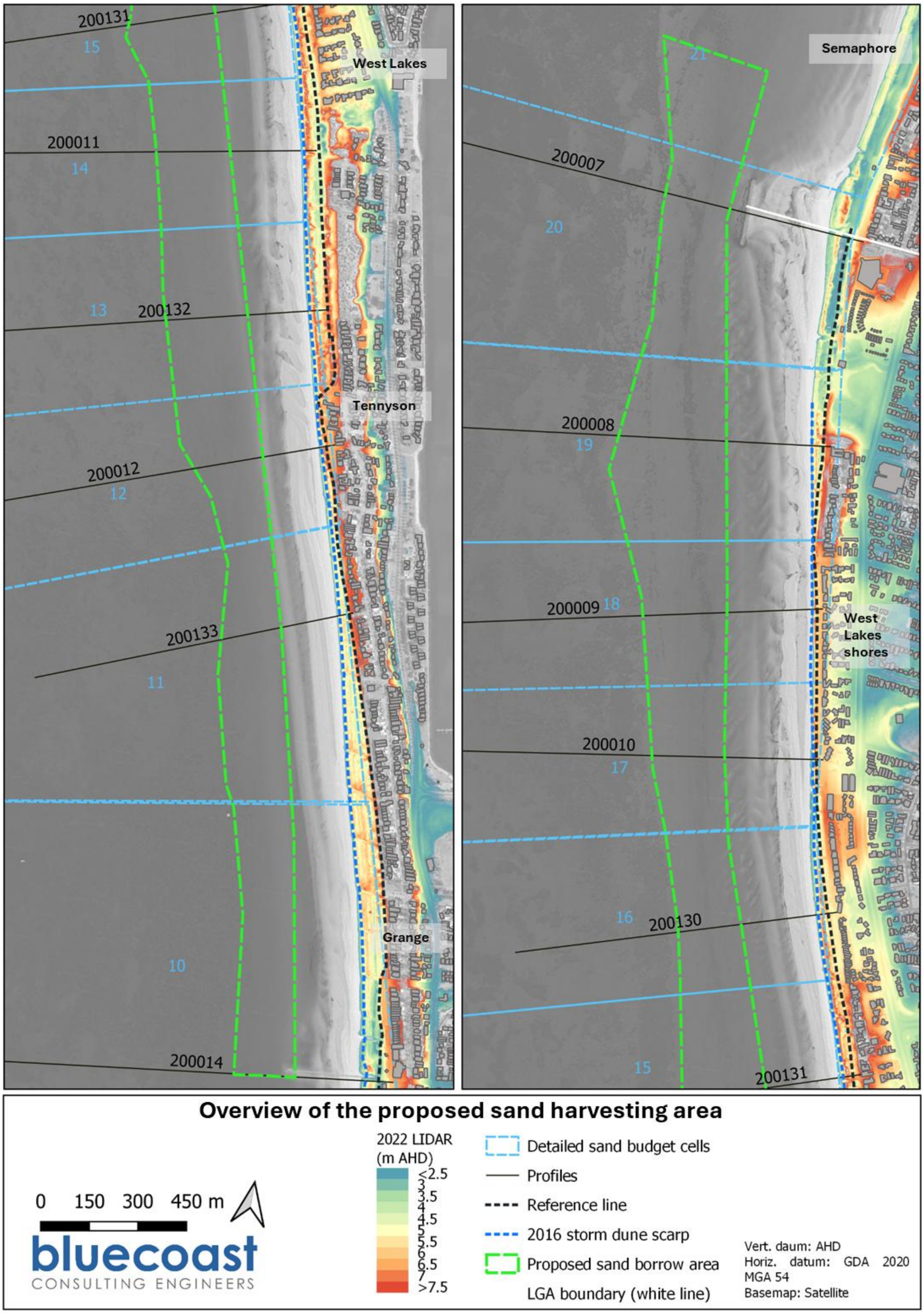


Figure 17. Detailed map of the proposed nearshore sand harvesting area.

Table 17: Summary of upper beach volume analysis.

Profile ID	Upper beach volume (m^3/m) – above $0m^3$ AHD		
	Mean	Min	Max
200014	386	264	518
200133	263	183	338
200012	256	188	401
200132	325	297	356
200011	245	164	314
200131	255	237	286
200130	216	171	262
200010	207	149	263
200009	137	70[1]	185
200008	194	123	259
200007	258	165	3662

Note: 1. This minimum value was surveyed in June 1994 following a major coastal storm (i.e. it is not representative of the upper beach sand volume typically available to buffer against storm erosion).

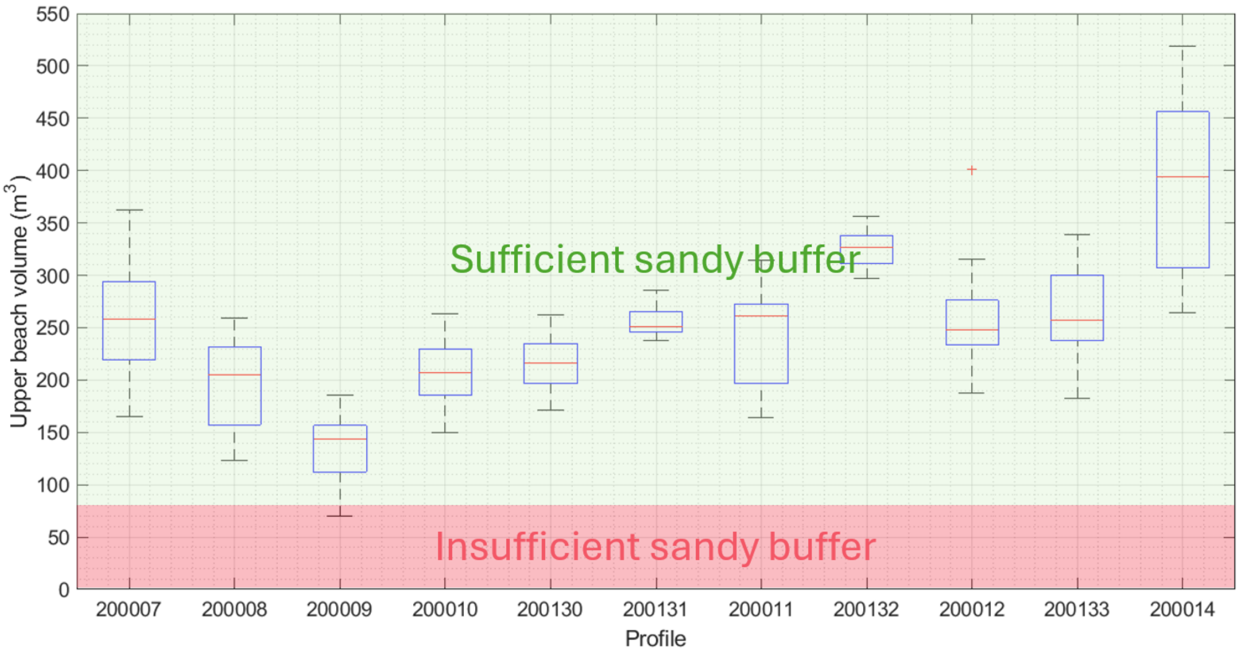


Figure 18: Upper beach volumes for the profiles located along the investigation area.

5.3.2 Storm erosion volumes

Changes in beach profile volumes before and after storm events can help quantify the "storm bite" of a given beach section. The DEW profiles are typically surveyed annually; however, additional surveys are conducted following significant storm events to assess their impact.

In 1994, a severe storm event resulted in a significant reduction of upper beach volume at profile 20009. Analysis of pre-storm and post-storm surveys results in an erosion volume of 23.9 m³/m (Figure 19). Similarly, during storm events in 2016, substantial erosion was recorded along the Adelaide coastline, particularly at Semaphore South (Figure 20). Surveys conducted a few months before and after the storms indicated a volume loss of only 11.0 m³/m (Figure 19). It is important to note that partial recovery of the beach profile may have occurred before the post-storm survey.

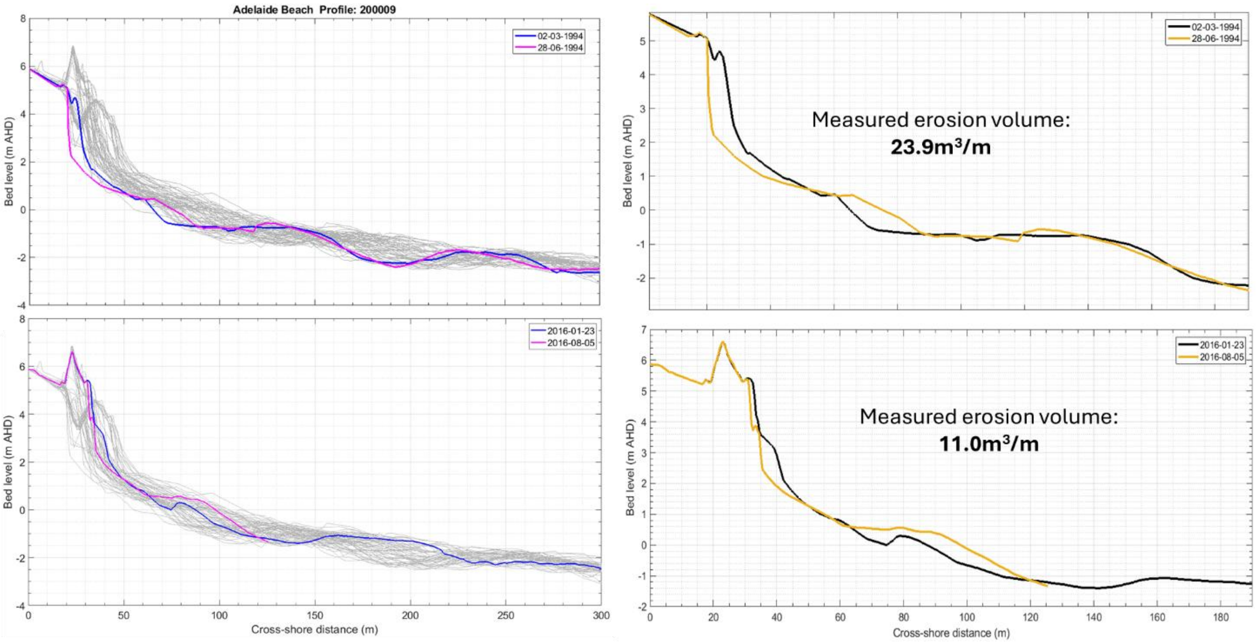


Figure 19: Pre-storm and post-storm profiles for 1994 and 2016 storms and measured erosion volume.

Figure 20: Photographs from West Beach and Semaphore during May 2016 event (Source: DEW website)

Storm bite modelling using XBeach, as reported in Appendix D, was undertaken with the key outcomes:

- Comparing the modelled storm bite with the above measured storm bites, the model was considered conservative, predicting storm bites 2-3 times that observed.

- When comparing a base case (i.e. existing conditions) and a post-sand harvesting scenario, there was a negligible effect on storm erosion predicted by the XBeach model (see Figure 21).

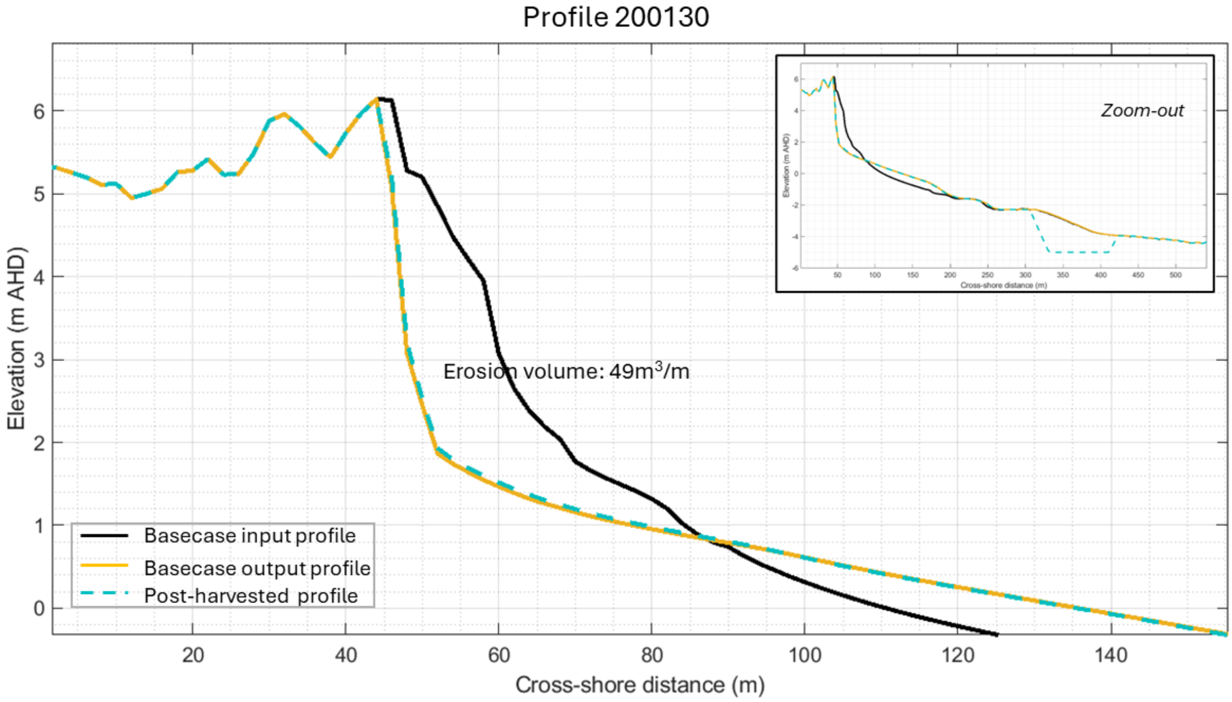


Figure 21: Example of Xbeach storm erosion results for profile 200130.

5.4 Sustainable sand recycling strategy

The nearshore areas between Torrens Outlet and North Haven Marine inshore of the -5m AHD contour has been considered for sand harvesting for sand recycling using dredgers. The key factors influencing the sustainable volume of sand that can be extracted from this active nearshore area are:

- **Downdrift impacts:** assessment of vulnerability of certain beach sections (notably Semaphore South and Semaphore Park) when considering how the removal of the longshore supply of sand will affect these areas. Through analysis of the areas of accretion and analysis of the historic management volumes there is opportunity to recycle sand while limiting downdrift impact within acceptable bounds.
- **Storm buffer reduction:** An analysis of the available beach volumes indicates that much of the area has a sufficient sandy buffer for natural resilience against storms. However, the dunes around Semaphore Park are more vulnerable to storm erosion due to their smaller size. Although storm erosion modelling with a reduced sand volume showed minimal differences, a conservative 'no-take zone' around this area (sand cells 17 to 19) is recommended to maintain storm resilience

Based on the above factors and considering the outputs from the detailed sand budget given in Section 5.2, Table 18 gives the sustainable borrow volumes for the nearshore harvest area.

Table 18: Sustainable borrow volumes for nearshore harvest area.

Nearshore borrow area	2008 to 2023 sand budget rates (m^3/year)			Recycle scenarios (m^3/year)	
	Change in sand volumes	Net sand transfer volumes	Total	Conservative Retains 2024 shoreline	Maximised
NBA4 Torrens Outlet	+140	55,800 (removed)	+55,940	30,000[1]	30,000[1]
No take zone Henley to Grange	-15,400	12,800 (added)	-28,200	0	0
NBA2 Grange to Tennyson	+25,261	0	+25,261	15,000	20,000
No take zone Semaphore South	-393	15,688 (added)	-15,526	0	0
NBA1 Semaphore Park	+6,078	32,577 (removed)	+38,654	35,000	44,000[2]
NBA3 North Haven	+37,500	18,000 (removed)	+55,500	20,000[3]	20,000[3]
Overall sand harvest volumes(m^3/year) – being up to this value				**100,000**	**114,000**

Note: 1. Prior to 2018, significant annual volumes (typically > 50,000m^3) of sand were removed from Torrens Outlet for recycling after which extraction basically stopped. When averaged between 2008 and 2024 the annualised removal was 55,940m^3/yr, yet the coastline over this time was relatively stable (as demonstrated by the small change in sand volume). A future extraction of 30,000m^3/yr has been conservatively selected as being significantly less removal than historic volumes. **2.** The shoreline just south of the Semaphore breakwater has accreted since construction of the breakwater in 2008. This maximised scenario assumes that over 15-years the shoreline would be allowed to slowly recede to the pre-breakwater position, after which the volume of recycling would be reduced. **3.** This annual sustainable quantity is based on reducing sand borrow from this area to the smallest volume possible because it is considered inefficient to recycle the fine sand in this area as well as limits defined due to blending the fine sand in NBA3 with other areas to best match native material at West Beach. While it is not recommended, this volume could be increased to match the net alongshore supply or around 40,000m^3/yr.

This detailed analysis indicates that while there is a slightly higher volume of sand available for recycling, under the lower scenarios and due to grain size difference between borrow and native sand there may be a need to supplement recycling with external sand (referred to herein as a ‘sand top-up’). Sources for sand top-ups could include:

- External sand sources identified in Section 4.2, with an estimated 570,000m^3 available after an effective restore volume of 450,000m^3 had been delivered from these EBA's.
- Additional sources not yet investigated (e.g. area north of EBA1 and southern prospects reported in ABMR (Bluecoast, 2023).

6. Work methods and cost estimates

6.1 Introduction

This section seeks to confirm the feasibility of long-term management by dredge by considering viable work methods, and their associated costs, for the proposed sand recycling and restore volumes identified in the previous sections. The assessment looks at ruling out possibilities and identifying constraints involved with different work methods. The methods discussed in this section are not intended to be exhaustive, with the intent only to demonstrate that there are economically viable methods to restoring and recycling sand on Adelaide's northern beaches (West Beach to North Haven). Dredging contractor may propose different approaches and ultimately, if a long-term sand management strategy using dredger was implemented, the actual work methods used would be the responsibility of the persons delivering these activities.

6.2 Beach nourishment work methods

6.2.1 Dredging equipment

A review of dredging equipment was undertaken to inform the approach to harvesting and placement. Given there are two potential locations with differing limitations (external and nearshore), different vessels (or combinations) could be used to achieve a target nourishment volume. The following vessel types are a non-exhaustive list that could be suitable.

Trailer Suction Hopper Dredge (TSHD)

- suitable for dredging and transporting material (within hopper)
- suitable for placement via pipeline, bottom dumping or rainbowing
- range of operating water depths depending on vessel size (smallest TSHD require >3.0m depth)
- relatively high mobilisation cost (if suitable local dredge not available)
- good productivity relatively low unit rate for dredging/placement

Cutter Suction Dredge (CSD)

- requires relatively sheltered location for operation or has limited operability
- requires the installation of a pipeline to transport and place material at destination (i.e. with supplementary equipment, CSD is restricted to short transport distances, say 2-3km)
- relatively low unit rate for dredging/placement when sites are nearby
- can dredge in relatively shallow depths (-2.5m AHD achieved in dredge trial)

Backhoe Dredge (BHD)

- dredging depth is typically limited to 20 to 30m
- requires relatively sheltered location for operation but larger BHD less weather restricted than smaller CSD's
- typically requires support barges for transport of material
- relatively high unit rate for dredging/placement

6.2.2 Placement methods

Table 19 provides a summary of the ways sand may be placed for beach nourishment and the typical work methods used to place material in each area of the coastal profile at Adelaide's northern beaches. A combination of these methods could be used to ensure nourishment of the full coastal profile.

Table 19: Placement options for beach nourishment with excavated material.

Placement option	Example
Pumping to the nearshore to nourish the visible beach Pumping sand the nearshore aims to broaden the existing beach and the existing dune systems. The process would involve also pumping sand into the surf zone using floating pipe outlets. A typical approach may consist of: • Pump sand slurry directly from dredge moving pipe outlets progressively along the beaches. Sand could be pumped from either a TSHD or CSD working in a nearby borrow area	

Placement option	Example
• Require additional equipment (e.g., pipeline, earth moving equipment on the beach, floating pipe outlet, slurry booster pumps for pumping beyond 1.5km) – pipeline may be buried and kept in place for future nourishment campaigns. Use of a diffuser is uncommon and certainly optional but worth noting it was recently used in the 2024 trial. • May cause disruption on beach usage during operations	 Pump ashore operations for large scale beach nourishment in the USA.
Rainbowing to nourish the surf zone Some TSHD's have 'rainbow' capabilities. This involves a sand slurry being jetted from the bow with the vessel positioned bow-in as close to the shore as possible. The objective is to widen the visible beach by moving the wave breaking zone seaward. The "losses" occur slowly and in a manner more consistent with a natural beach. For Adelaide's beaches, a typical approach may consider: • the shallow profile of Adelaide's beaches would be restrictive to all but the shallowest (smallest) TSHD's to transport material to the site and rainbow, but this still may prove to be too distance from the active beach fluctuation zone. • rainbowing to the surf zone provides some washing out of fines/ mixing with native sediment prior to arriving on the visible beach.	 A medium sized TSHD rainbowing on the Gold Coast (source: City of Gold Coast).
Bottom dumping to nourish the nearshore Bottom dumping of nourishment material is suitable in the outer surf zone and nearshore area depending on vessel draft. After the dredge (or barge) has filled its hopper, it sails to the sand placement area it either opens hopper doors located at the bottom of the vessel or splits its hull (split-hopper). Split hopper is generally preferred as it allows for shallower placements. Nearshore placement aims to emulate a natural storm bar formation. If a storm arrives soon after beach nourishment, wave breaking may be triggered and thereby help protect the coast. However, if no storm arrives, the waves will redistribute the sand onshore. For Adelaide's beaches, a typical approach may consider: • the method provides cost-efficient placement and cycle times, however draft restrictions would mean the sand was placed well offshore and take some time to work onshore under the action of waves and currents. • placed material would be 'washed' and efficiently sorted by the natural coastal processes with source material mixing with native material and likely to be virtually undetectable at the visible beach.	 Split hopper placing material during the ABMRI dredge trial.

Placement option	Example
• where this technique has been used in other Australian locations the beach response has been positive and there are additional recreational benefits if pattern placement is used.	

6.3 Key factors to consider in selecting work methods

6.3.1 Operability

Due to the high daily costs of the equipment involved in beach nourishment, operations tend to take place seven days a week, 24 hours per day. However, there are limits on the workable sea-state conditions for which dredging, and placement operations can be safely carried out. Should unfavourably marine weather conditions (principally wind and waves) be encountered during the execution period there is a risk that the dredgers cannot work, and sand delivery is compromised.

Limiting wave conditions for TSHD, CSD and BHD equipment are vessel and operation specific. Wave direction, wave period, wind direction, currents, water level and a combination of these will influence the limiting sea states significantly. Whether a vessel can work in a particular set of conditions is a decision for the Master of the vessel. As a first pass look at the operability for different methodologies the limiting wave conditions for operations have been selected as shown in Table 20.

Table 20: Limiting wave conditions by work method.

Operation	Limiting wave conditions (Hs)			
	TSHD (offshore)	TSHD (nearshore)	CSD	BHD
Dredging	1.5m (offshore)	1.0m (nearshore)	0.4m	1.2m
Placement (limited to pump ashore and bottom dumping)	1.5m	1.5m	1.5m[1]	1.5m

Note: 1. Assumes SHB, however, in practice placement can only occur when CSD is operating so the wave height limit of the CSD becomes limit for overall operations.

Using the record from the Brighton wave buoy (Section 2.6.1), the monthly operability limits for the limiting wave conditions are shown in Figure 22. There is a more active wave climate over the winter period resulting in less favourable conditions however operability is stable outside of this time.

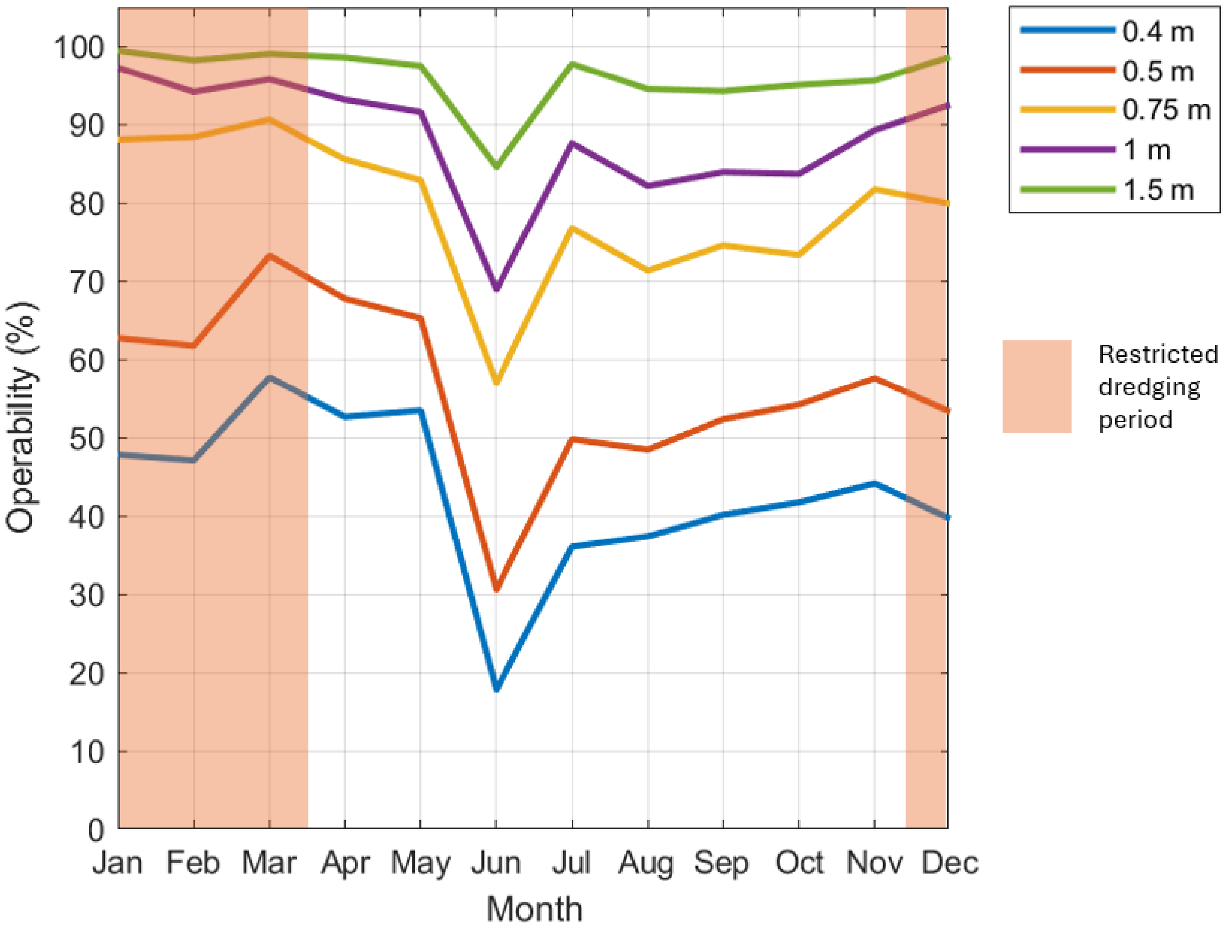


Figure 22: Monthly operability based on limiting wave height.

They typical limiting conditions for dredging and placement for a THSD result in operability above 90% (except for June) which would be applicable for all placement activities and dredging in the offshore areas. Using a TSHD in the inshore area in wave conditions is dependent on the vessel's Master but considering a limiting wave condition of 1.0m would be appropriate to maintain UKC in the deeper areas of the identified nearshore harvest area. A more conservative approach could adopt a limiting Hs of 0.5m and consider utilising offshore areas when UKC becomes an issue.

Data collected during the dredge trial indicated **a limiting significant wave height for CSD operations of approximately 0.4m**. Records from a wave buoy deployed near the harvesting area at North Haven during the trial is plotted against recorded SHB loading times and volumes at the harvest area in Figure 23. This shows the operability limitations of the CSD dredging method. For best operability periods this method should only be considered for months outside of winter.

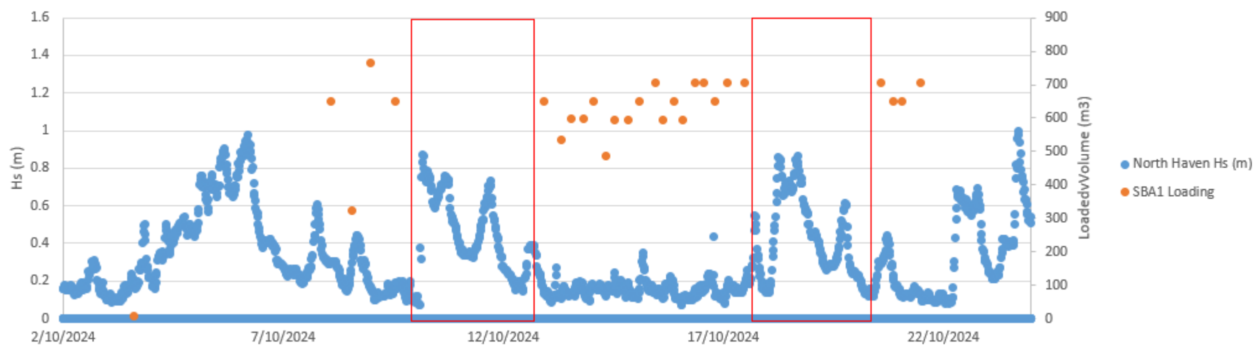


Figure 23: Time series of SHB loading and recorded Hs during dredging trial.

6.3.2 Borrow area water depths

Water depths in EBA1 and the nearshore borrow areas are important to selecting work method:

- Figure 24 shows the areas of EBA1 that are accessible for a small TSHD (1,000 t0 5,000m^3 hopper capacity). 36% of EBA1 is accessible under all tides, with a further 51% accessible by working with the tides (i.e. would be accessible when tidal water levels are higher than the Lowest Astronomical Tide (LAT).
- A very small TSHD could be used in the nearshore borrow areas with the limiting factor being the underkeel clearance (UKC). Noting water levels and expected wave heights, a limiting depth could be calculated for potential vessels. Utilising a TSHD presents a flexible option that allows harvesting from multiple areas allowing opportunities for dredging in some areas when unsuitable in others (e.g. nearshore to offshore, or reverse).
- EBA2 is deep enough for all tide access for very small, small TSHD or CSD.

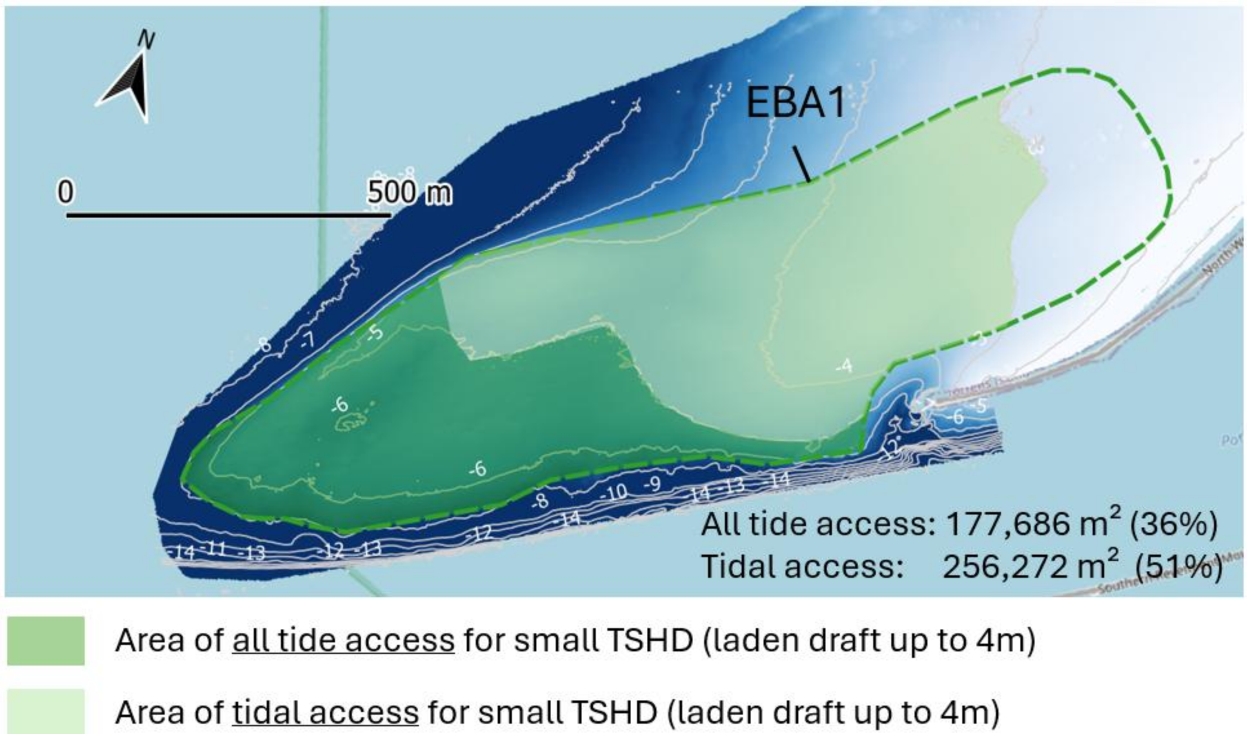


Figure 24. Areas of EBA1 with all tide access and access restricted to tidal levels above LAT.

6.3.3 Proximity of borrow area to placement site

- EBA1: 12NM (22km) – too far to pump sand, sand must be sailed.
- EBA2: less than 1km – ideal for direct pumping, sailing could also be used.
- NBAs: 1.1NM (2km) to 9.5NM (17km) – too far to pump, sand must be sailed.

6.4 Work methods by borrow area

Table 26 provide an overview of potential work methods for the retore and recycle beach nourishments proposed along Adelaide's northern management area. Based on the important factors at each of the borrow areas, Table 21 then sets out a review of the suitability of these work methods at each of the borrow areas (with the NBAs considered collectively).

Figure 25. Summary of advantage and challenges associated with beach nourishment work methods.

Method [placement type]	Description

TSHD
[pump-out to nearshore + bottom dumping]
	Advantages
	• Highly mobile and self-sufficient vessel: TSHD is a self-propelled dredging vessel which can dredge sand and sail it to the placement site without the need for long pipeline or boosters.
	• Efficient transport over long distances: Highest production rates for distances greater than 3km.
	• High operability: Can operate in wave heights (Hs) of up to 1.5 – 2.0m limiting downtime due to weather.
	• Flexible placement methods: bottom dump, rainbowing or pump-out to nearshore/shore.
	• Most prevalent beach nourishment work method used around the world including Europe, USA, Australia and the Middle East.
	Challenges
	• Requires sufficient depth in borrow area to maintain underkeel clearance. Depth required is a function of the draft of the vessel and wave climate:
	  ○ Very small TSHD (hopper capacity less than 1,000m^3): 3 to 5m
	  ○ Small TSHD (1,000 to 5,000m^3): 5 to 7m
	  ○ Medium TSHD (5,000 to 10,000m3): 6 to 9m

CSD **[pump to nearshore]**	**Advantages** • Can dredge in shallow water • Continuous and efficient sand transfer over short distance • Can pump sand directly to the nearshore/beach **Challenges**

<table>
<tr><th>Method [placement type]</th><th>Description</th></tr>
<tr><td></td><td><u>Low operability:</u> Small CSD can only operate in wave heights (Hs) of up to 0.4m, which limits the operability time along the Adelaide coastline which is not sheltered.
<u>Short distances:</u> pumping distances limited to 1-2km without multiple booster stations and extensive floating/submerged pipelines that increase costs, fuel consumption and complexity.
Moderate prevalence in the use of this method for beach nourishment works around the world.</td></tr>
<tr><td>CSD + SHB
[bottom dumping]</td><td>Advantages
Can dredge in shallow water
<u>SHBs can transport sand over long distances:</u> Reduces/eliminate the need for extensive pipelines and multiple booster stations.
Challenges
<u>Low operability:</u> Small CSD can only operate in wave heights (Hs) of up to 0.4m, which limits the operability time along the Adelaide coastline which is not sheltered.
<u>Large spread of equipment</u>: method required CSD, at least 2 x SHBs with accompanying tugs and other work vessels. With the operations dependent on the CSD, which is very limited in the wave conditions it can operate in, when the CSD is not operating all the equipment goes on stand-by rates.
<u>Limited placement options:</u> without added a pump-out station at the placement site, only bottom dumping is possible. A pump-out to nearshore/shore would add placement flexibility but also adds complexity and additional equipment to the operation.
<u>Loss of material:</u> due to double handling and overflow when filling the SHBs material can be lost.
Very low prevalence in the use of this method for beach nourishment works around the world. Limited to small or remote contracts where TSHDs are not available.</td></tr>
<tr><td>BHD + SHB
[bottom dumping]</td><td>Advantages
Can dredge in shallow water
SHBs can transport sand over long distances
Challenges
Higher operability with a wave height limit (Hs) of up to 0.8m when dredging, however, when dredging with a SHB moored alongside the BHD this is likely to be substantial reduces.
<u>Large spread of equipment</u>: method required BHD, at least 2 x SHBs with accompanying tugs and other work vessels.</td></tr>
</table>

Method [placement type]	Description
	• Limited placement options: without added a pump-out station at the placement site, only bottom dumping is possible. A pump-out to nearshore/shore would add placement flexibility but also adds complexity and additional equipment to the operation. • Very low prevalence in the use of this method for beach nourishment works around the world.

Table 21. Selecting most suitable work by borrow area.

Method [placement type]	EBA1	EBA2	On-going sand recycling NBA1 to NBA4
TSHD [pump to nearshore + bottom dumping]	**Most suitable** • 12NM (22km) distance between borrow and placement areas make TSHD method most suitable. • Depths in EBA1 borrow area lend themselves to use of a small TSHD which would have access to 87% of this area (36% all tide or unrestricted access and 51% restricted to working with tides).	**Suitable** • Due to the proximity of EBA2 to West Beach a CSD pumping directly to the nearshore is more efficient at sand transfer. However, as the TSHD has better operability it may be competitive to CSD.	**Most suitable** • The four nearshore borrow areas are up to 9.5NM (17km) away, making TSHD the most efficient method to recycle the sand. • Depths in nearshore borrow areas are shallow, restricting access to use of very small TSHD which would have access net access, working with the tide, across all NBAs of around 75%.
CSD [pump to nearshore]	**Not suitable** • 12NM distance to placement site is too far for a pipeline.	**Most suitable** • Proximity of EBA1 enables direct pump to nearshore for efficient beach nourishment	**Not suitable** • 12NM distance to placement site is too far for pipeline.
CSD + SHB [bottom dumping]	**Not recommended** • This method would be inefficient and provide poor sand placement options.	**Not suitable** • The proximity of EBA means SHB's are not required.	**Not recommended** • While the trial showed this method could work, it also proved that is was inefficient because (i) double handling and loss of material when filling SHBs (ii) poor operability of small CSD (iii) large spread of equipment often on standby (iv) placement limited to bottom dumping.
BHD + SHB	**Not recommended**	**Not suitable**	**Suitable**

Method [placement type]	EBA1	EBA2	On-going sand recycling NBA1 to NBA4
[bottom dumping]	• This method would be inefficient and provide poor sand placement options.	• The proximity of this EBA means SHB's are not required.	• Despite being able to access shallow water, this method is unlikely to match a very small TSHD because of the large spread of equipment required, low operability when dredging because the SHBs need to be alongside the BHD and limited placement options.

In summary:

- Given the distances between the sources, a cost-effective method for dredging and transporting sand to West Beach from any wave exposed areas (e.g., offshore areas) would be employing a small TSHD (EBA2) or very small TSHD (NBAs). TSHD's are often used in beach nourishment projects as they are highly efficient to moving sand over can dredge in varying wave climates and can place the sand in multiple ways (bottom dumping, rainbowing or through a bow connection and a floating pipeline (i.e., pump ashore or pump near-to-the-shore)).
- CSD pumping directly to West Beach is likely to be the most suitable method for EBA2, with a very small or small TSHD also competitive.
- The ABMR Implementation dredging trial utilised a CSD and split hopper barge (SHB) to dredge sand from the Nearshore area immediately south of the North Haven Marina in depths of approx. -2 to -4 m AHD. The sand was pumped to a SHB in a designated mooring area nearby from which it was then transported to the placement area to be bottom dumped. This method was shown to be effective in collecting sand from the nearshore area and placing in the nearshore at West Beach however the operations are susceptible to weather delays with only approximately 55% of operating time during the trial due to weather (this is discussed further in Section 6.3).
- Using a BHD has similar limitations to the CSD method used during the trial, requiring good weather, additional equipment for transport and placement and having limited placement opportunities.

6.5 Nourishment strategy

An effective nourishment strategy has been developed that addressed the two main components, restore and recycle, as shown in Figure 26, and described as:

- **Component 1:** restore volume is delivered by dredge from external sand sources
- **Component 2**: maintenance sand placement at West Beach to replace the on-going sand losses of 90,000m^3/yr, a strong preference that this sand be delivered by recycling from the nearshore littoral sand movement system (i.e. from the beaches north of West Beach and inshore of -5m AHD depth contour).

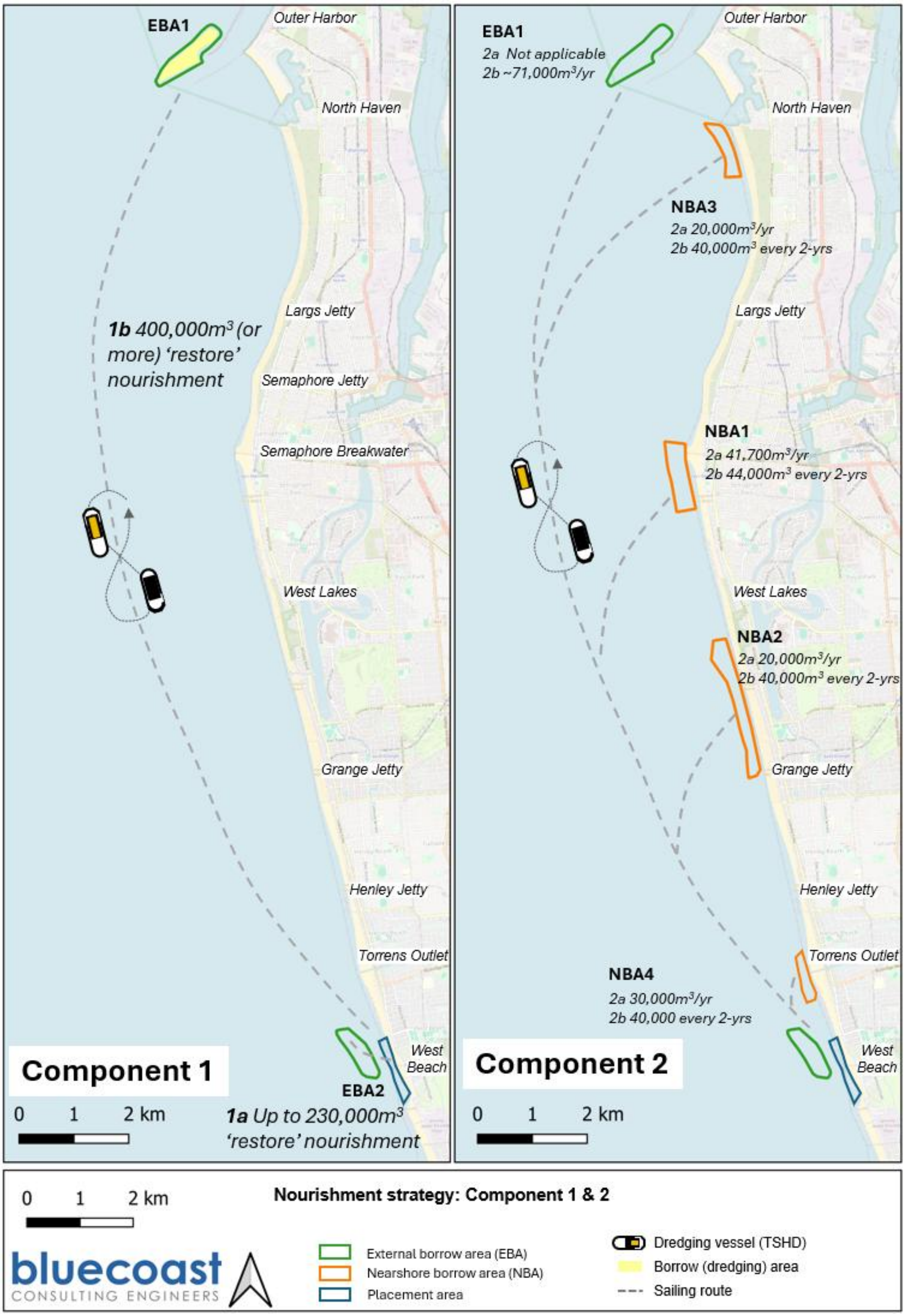


Figure 26: Plan showing nourishment strategy including restore (component 1) and recycle (component 2).

In developing an efficient nourishment strategy for the purpose of developing production and cost estimates, the following factors were considered:

- Our review of nourishment work methods as described above.
- Assumed requirements around planning approvals noting it is assumed that for either pathway the level of environmental assessment would be similar (i.e. all specialists assessments would be completed to similar levels):
  - Shorter (DMP) pathway: like the approvals used for the 2024 dredge trial this would be via a Dredge Management Plan (DMP) with the EPA being the key planning authority. Seeking approval via this pathway can be relatively short (less than 6 months) for areas such as EBA2.
  - Longer (Crown Development Assessment or DA) pathway: this would be a more involved planning approvals process with a development application lodged with the State Commission Assessment Panel who would refer to various government agencies with additional consultation requirements (JBS&G, 2025). This pathway is assumed to take between 12 to 24 months.
- The sustainable volumes of sand that could be recycled (as outlined 5.4) as well as the 'effective nourishment volume' accounts differences in the sediment properties of the native beach material (at West Beach) and that of the respective borrow areas (i.e. for borrow area sand that is finer more is required to achieve the equivalent native material volume). Table 22 gives the sustainably available volumes of sand in each borrow area derived above and the effective nourishment volume at West Beach. This gives:
  - Up to 90,700m^3/yr as an annual effective ongoing 'recycling' nourishment rate at West Beach
  - 1,172,500m^3 of effective nourishment material available for 'restore' campaign(s) or to supplement ongoing recycling volumes.

Table 22: Available and effective volumes for nourishment at West Beach.

Borrow area	Available sand volume at dredging site	Overfill factor (Ra)[1]	Renourishment factor (Rj)[1]	Effective nourishment volume
Recycle				
NBA1 (Semaphore Park)	44,000 m^3/yr	1.0	0.8	44,000 m^3/yr
NBA2 (Grange to Tennyson)	20,000 m^3/yr	1.5	1.5	13,350 m^3/yr
NBA3 (North Haven)	20,000 m^3/yr	-	6.0	3,350 m^3/yr
NBA4 (Torrens Outlet)	30,000 m^3/yr	1.0	0.7	30,000 m^3/yr

Borrow area	Available sand volume at dredging site	Overfill factor (Ra)[1]	Renourishment factor (Rj)[1]	Effective nourishment volume
			Recycle effecting nourishment rate (up to):	**90,700 m³/yr**
Restore[6]				
EBA1 **(North of Channel)**	1,155,000m³	1.2	1.3	942,500 m³
EBA2 **(Central sand deposit)**	230,000m³	1.0	0.7	230,000m³
			Restore quantity (tested and proven so far):	**1,172,500m³**

Note: 1. These factors were calculated using the methods outlined in the Shore Protection Manual (US Army Corp., 1984) using the recently collected sediment data.

- Understanding that the southern sand pipeline is likely to require significant upgrades in about by around 2038 (13-years from 2025) and that this should trigger a review of the sand management practices in both the northern and southern management areas.
- The nourishment strategies are considered for costing considering the above available volumes. These strategies are not exhaustive and have been considered only as possible options. Other factors effecting the implementation of these strategies could include contractor availability, timing and public sentiment.

6.5.1 Component 1: Restore West Beach using sand from external sources

The component would involve delivering mass nourishment to West Beach using external sand. While there is a broad range in the number of ways West Beach could be restored using dredgers, considering the above factors, we have considered the following options for implementation:

- **Component 1a:** sand from EBA2 would be used to provide a rapid and short-term nourishment (i.e. because there is only 230,000m³ of material available) of West Beach while approvals for the EBA1 borrow area are sort. This is included because it already has dredging approvals and could therefore be implemented much quicker than sand from EBA1. However, it is acknowledged that there is a lack of social licence to address prior to use of the borrow are for nourishment works. This may well be possible given there is also a lack of social licence for on-going quarry sand placements and that by using EBA2 in instead of quarry sand the SA Government could save up to $11.5M of sand management cost.
- **Component 1b:** sand from EBA1 would be used to fully restore West Beach, potentially over nourishing slightly to allow for any delays in establishing sand recycling.

[6] These volumes are given with a 0.3m dredging tolerance to the underlying unsuitable layer (clay or organic matter).

Ideally, these components would take place over the period of high operability between August and early December to take advantage of the favourable sea state conditions. If these programs were to take place over the months of June and July, the production rate may decrease, increasing costs.

Component 1a

From this nearby source, a CSD pumping sand directly to West Beach could be used in a similar way to the second phase of the 2024 dredge trial. Key estimates of productive, works duration and cost estimates for a range of restore volumes are given in Table 23. Assumptions used in these estimates are given below the table. However, due to its proximity to the nourishment site, the production rate would increase reducing the unit rate (depending on project size).

Table 23: Production rates and project costs for component 1a from EBA2.

Parameter	Restore volume scenario	
	115,000m^3	230,000m^3
Effective nourishment volume	115,000m^3	230,000m^3
Production rate (m^3/week)	40,350	
Works duration (weeks)	2.9	5.7
Unit rate (per m^3 of sand delivered)	$13.17	$13.17
Sand delivery costs	$1,515,000	$3,029,000

Assumptions used in calculating the costs of the restore campaign are given below:

- Use of a small CSD, equipment which can be sourced locally.
- Cost and production rates are based on the recent 2024 dredging trial as report in SWASH, 2025. The actual rate of sand delivery of just under 42,000m^3 was around $13.17/m^3, excluding management, supervision and survey costs.
- Assumes pumping to nearshore
- Weather delay assumed to be the same as that encountered in the 2024 dredging trail, during which there was 22 working days from a 32-day operational duration (around 31% downtime).
- Allowance of $65,000 for mobilisation and demobilisation costs.

Component 1b

From EBA1, a small TSHD would be used to undertake the nourishment works. Key estimates of productive, works duration and cost estimates for a range of restore volumes are given in Table 24. Assumptions used in these estimates are given below the table.

Table 24: Production rates and project costs for component 1b from EBA1.

Parameter	Restore volume scenario		
	400,000m³	600,000m³	800,000m³
Effective nourishment volume	333,333m³	500,000m³	666,667m³
Production rate (m³/week)	53,820		
Works duration (weeks)	7.8	13.1	15.7
Unit rate (per m³ of sand delivered)	$19.13	$16.67	$15.44
Sand delivery costs	$8,190,000	$10,800,000	$13,425,000

Assumptions used in calculating the costs of the restore campaign are given below:

- Use of a small TSHD (approximately 1,800m³ hopper volume)
- EBA1 to be used as the borrow area with sailing time calculated based on this
- Assumed 25% of volume would be delivered by bottom dumping and 75% by pumping to nearshore
- Weather delay assumed to be 10% based on limiting significant wave height of 1.0m
- Allowance of $2.2M for mobilisation and demobilisation costs and $750,000 for other costs (surveys, monitoring, project management etc.)

6.5.2 Component 2: Maintain sand supply to West Beach using sand recycling

The component could be implemented used full (100%) sand recycling (from nearshore sources) or a combination or sand recycling and extra sand top-ups (from external sources) from with both implementation approaches using dredgers. These implementation approaches are described as:

- **Component 2a:** The scenario for the delivery is that only sand from the identified nearshore borrow areas is used to meet the requirement of 90,000m³ of effective volume delivered to West Beach annually.
- **Component 2b:** The scenario combines sand recycling from nearshore sources with additional volumes from an external source (EBA1). This scenario is included as it allows more efficient sand deliver because downtime due to lack on underkeel clearance with a very small TSHD is reduce.

Like the restore beach nourishment work, ideally these works would take place over the period of high operability between August and early December to take advantage of the favourable sea state conditions.

Component 2a: 100% sand recycling using dredgers

The main assumption used is that of a very small TSHD to access the shallow parts of the nearshore borrow areas. The depth limitation of these areas means that the operator would have to work with the tides to allow access to areas between the -3 and -4m AHD contour. In estimating the costs set out in Table 25 the following approach was used:

- Annual campaigns have been assumed but these could also be every two years or so (i.e. double the quantities to reduce mobilisation/demobilisation costs).
- The source volumes used in achieving the target effective nourishment volume are:
  - NBA1 (Semaphore) 41,700m^3/campaign
  - NBA2 (Grange to Tennyson) 20,000m^3/campaign
  - NBA3 (North Haven) 20,000m^3/campaign
  - NBA4 (Torrens Outlet) 30,000m^3/campaign
- Shallow depths of NBA1 (Semaphore Breakwater) result in the example vessel only being able to operate ~22% of the time. Due to underkeel clearance requirements, this is the limiting condition in terms of workable time for this strategy.
- When the dredge is unable to work in this area due to the lower tidal water levels, it will harvest the other nearshore harvest areas. This leaves a remainder of ~6 weeks of downtime due to water level/underkeel clearance limitations.
- For this downtime, a standby rate discount is applied as it is assumed that the dredge will not be working.

Table 25: Production rates and project costs for component 2A (full sand recycling).

Parameter	Value
Production rate (m^3/week)	12,705 – 33,845 (dependent on borrow area location)
Works duration (weeks) (inclusive of downtime)	12.2
Effective nourishment volume delivered (with consideration of sand grain size differences)	90,000m^3
Total sand delivered (without consideration of sand grain size differences)	111,700m^3
Unit rate (per m^3) (note this unit rate is for the 111,700m^3 of total sand delivered)	$32.40
Total project cost	**$3,620,000**

Assumptions used in calculating the costs of each annual recycle campaign are given below:

- Use of a very small TSHD (around 350m^3 hopper volume).
- Assumed 25% of volume would be delivered by bottom dumping and 75% by pumping to nearshore.
- Weather delay assumed to be 10% based on limiting significant wave height (Hs) of 1m.
- Allowance of $600,000 of mobilisation and demobilisation costs included.

- Does not include any monitoring, project management or other costs not directly associated with the delivery of sand.

Component 2b: 'Recycle' sand from nearshore with sand top-ups from external sources

The same underkeel clearance limiting condition component 2a applies here (i.e. tidal access restrictions in NBA1 dictate the works durations). However additional volume from EBA 1 is sought to achieve an effective volume of 180,000m^3. This means that this scenario would be delivered biannually. The detailed cost breakdown for this scenario is given in Table 26 with the volumes to be taken from borrow areas given below:

- NBA1(Semaphore) 44,000m^3
- NBA2 (Grange to Tennyson) 40,000m^3
- NBA3 (North Haven) 40,000m^3
- NBA4 (Torrens Outlet) 40,000m^3
- EBA1 (North of Channel) 71,280 m^3

Table 26: Production rates and project costs for a scenario with sand recycling with external sand top-ups.

Parameter	Value
Production rate (m^3/week)	12,705 – 33,845 (dependent on borrow area location)
Works duration (weeks)	13.4
Effective nourishment volume delivered (with consideration of sand grain size differences)	180,000 m^3
Total sand delivered (without consideration of sand grain size differences)	235,280m^3 (164,000m^3 recycled and 71,280m^3 top-up from external sources)
Unit rate (per m^3) (note this unit rate is for the 235,280m^3 of total sand delivered)	$22.44
Total project cost	**$5,280,000**

Assumptions used in calculating the costs of the restore campaign are given below:

- Use of a very small TSHD (350m^3 hopper volume)
- Assumed 25% of volume would be delivered by bottom dumping and 75% by pumping to nearshore
- Weather delay assumed to be 10% based on limiting significant wave height of 1m

- Allowance of $600, 000 of mobilisation and demobilisation costs included.
- Does not include any monitoring, project management or other costs not directly associated with the delivery of sand.

While delivery from EBA2 (Central Sand Deposit) has not been costed here, due to its proximity to the nourishment site, the production rate would increase reducing the unit rate.

7. Summary and other substantive issues

7.1 Summary

The Adelaide Beach Management Review (ABMR) concluded that sand management in the northern management area using dredgers had merit relative to the other options investigated (Bluecoast, 2023) but there was remaining uncertainties to implementation. The assessments reported herein, including the extensive sand sourcing field investigations, have resolved the key remaining uncertainties and proven, with sufficient certainty, the long-term feasibility of carrying out future sand management activities on Adelaide's northern metropolitan beaches using dredgers. It has been proven with a sufficient level of certainty, that:

- West Beach can be restored with 'external' sand using dredging from suitable external sand deposits.
- Dredgers can be used to recycle sand from nearshore deposits on the northern part of Adelaide's metropolitan beaches.

Should the South Australian government choose to proceed with such a direction, planning approvals and procuring suitable dredging contractors are the next steps to provide final confirmation prior to rolling out the implementation of the strategy. Key benefits of a sand management approach using dredgers are the greater more efficiently (i.e., significantly cheaper), greater flexibility with limited community disruption.

Based on the findings of this feasibility assessment, the key remaining technical challenges to implementation are:

- Due to the shallow nature of the nearshore sand sources for recycling, suitable shallow draft TSHD's are limited. In the longer-term, and to ensure availability, this may long-term contracts with contractors to allow for them to acquire specialist/bespoke dredging equipment or for the equipment to be purchased.
- Obtaining planning approvals.

Another non-technical challenge is related to social licence and working with communities along the coast in the further planning and delivery of these works.

7.2 Other substantive issues

There are several other issues that warrant consideration in decision-making around coastal management along Adelaide's metropolitan beaches. These substantive issues are discussed in Table 27, with a focus on the approach sand management using dredgers.

Table 27: Summary of considerations on other substantive issues.

Issue	Considerations in relation to sand management using dredgers
Glenelg North Beach	The Glenelg North Beach between the two boat harbours has been largely ignore as it falls outside the northern management area (West Beach to North Haven). This beach has been receding at its southern end adjacent to North Esplanade while being stable following a period of accretion at its northern end adjacent to the treatment plant. A rock revetment seawall provides terminal protection along much of this section of coast, however, the beach widths at the southern end are narrow. Sand has been actively placed in this cell in the past, mostly sourced from the maintenance of West Beach harbour. Should a sandy beach be desired along this frontage in the future, sand management using dredgers offers the most adaptable and flexible approach as placements could also occur along Glenelg North Beach. Sand carting may also be a practical solution if access allows.
The southern backpassing pipeline	A sand recycling pipeline between Glenelg and Kingston Park was commissioned in 2013. Key hydraulic and mechanical elements of this sand pumping system have a 25-year design life, while some of the structures have a 50-year design life. Some of the rotating and wearing parts have a 10-year design life. The operation of this sand pumping system and the sand volumes recycled have recently been compromised by maintenance issues. Given the high sand pumping costs (around $25/m^3 in 2024) and assuming some major renewals being needed towards the end of the 25-years of operation (i.e. 2038), it is recommended that the SA government considers its options regarding sand management in this southern area. If sand management by dredgers proves successful in the northern management area, this approach could be extended to cover the entire Adelaide metropolitan area. Under a metro-wide approach: • sand would be recycled, using dredgers, from the four nearshore borrow areas (NBA1 to NBA4) and placed at Brighton (instead of West Beach) • sand would be bypassed around the two boat harbours, likely using a similar CSD work method as per the 2024 dredging trial, which had an actual cost rate of around $13/m^3 While analysis of such a metro-wide system has not been completed herein, it is likely to be the lowest cost outcome with a range of other benefits.
Sand accretion in Largs Bay and North Haven	Due to the trapping effect of the Outer Harbour breakwater, Largs Bay and North Haven have undergone ongoing accretion of the shoreline and shoaling of the nearshore profile. While this has created new low lying dune systems the sand ingress has caused siltation issues for the North Haven Marina, making it more challenging to maintain navigation the marina's entrance. As set out in the above, inclusion of NBA3 with sand extraction for between 20,000 to 40,000m^3/yr could be undertaken in this area with the sand recycled to the southern beaches.

Issue	Considerations in relation to sand management using dredgers
Climate change including sea level rise	Climate change is expected to have an influence on the Adelaide coastline, with possible effects ranging from increased storm intensity, changes in wave climate, changes in rates of alongshore sand movement and a rise in the mean sea level. Sand management using dredgers, with its much-reduced capital investment requirements and ultimate flexibility in sand placement locations, will perform well in adapting to future changes in the local climate. In response to sea level rise, new (or imported) nourishment sand may be needed, with the use of dredging equipment and the proven external sand sources making this a most effective mechanism to deliver this.
Management of Torrens Outlet	Sand accumulates at Torrens Outlet, having the potential to cause issues with water quality and drainage. Sand collected from NBA4 using dredger can either be recycled south to West Beach or ‘bypassed’ north, with both placement areas likely to be beneficial depending on the state of the beaches. This flexibility will be beneficial in the management of Torrens Outlet.
Integration with complementary coastal management options	Dredging options would be expected to perform best with each of these complementary management options, including seagrass restoration and dune stabilisation and revegetation. Beneficial reuse of dredged material is a standout example of this.

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Appendix A: Bluecoast's 2024 nourishment feasibility to inform dredge trial

Appendix B: Relevare's 2025 survey report

Appendix C: Phase 1 – rapid sediment sampling and assessments – supporting details

Sediment sampling details

Table 28 provides details of recent and relevant sediment sampling field sediment sampling. These investigations are further detailed in the associated reports, listed in our reference list. The sampling reports provide details of the sampling methods, laboratory analysis completed as well as benthic observations. The following maps show the sampling locations and associated sediment sampling locations and some map some of the results.

Table 28: Summary of sediment investigations reviewed for this sand compatibility assessment.

Investigation[1]	Areas covered	Samples and analysis	Sampling method
2022 beach sampling Environmental Projects, January 2022	Dry and intertidal beach (toe of dune to intertidal zone) from Kingston Park to North Haven (these are not mapped herein but were used for reference in determining suitable areas)	• 88 x PSD • 88 x Carbonate	Shallow samples collected directly from the beach.
Stage 1 JBS&G, March 2024	Largs offshore (A1-5, B1-2, C), scattered Largs Bay nearshore (Area identified in ABMR report)	• 50 x PSD • 39 x heavy metals • 11 x full geochemical suite	Diver hand core (0-0.5m and 0.5-0.9m samples taken at each site)
Stage 2 JBS&G, June 2024	B3, E2, E3	• 26 x PSD • 26 x Carbonate • 26 x heavy metals • 7 x full geochemical suite	Diver hand core (0-0.5m and 0.5-0.9m samples taken at each site)
Stage 4 JBS&G, August 2024	B3, E2, E3 (Located in Largs Bay on the -3, -4, -5, -6m AHD contours)	• 100 x PSD	Diver hand core (0-0.5m depth)
Nearshore Semaphore – Torrens Outlet Bluecoast, October 2024	Located between Semaphore Jetty and Torrens outlet from toe of dune to -5m AHD contour along DEW defined transects.	• 64 x PSD • 34 x Carbonate • 3 x full geochemical suite	Grab
Offshore Largs Bluecoast, October 2024	BO and A3	• 22 x PSD • 22 x Carbonate • 2 x Geochemical	Grab

Note: 1. See factual data reports for each sampling investigation below.

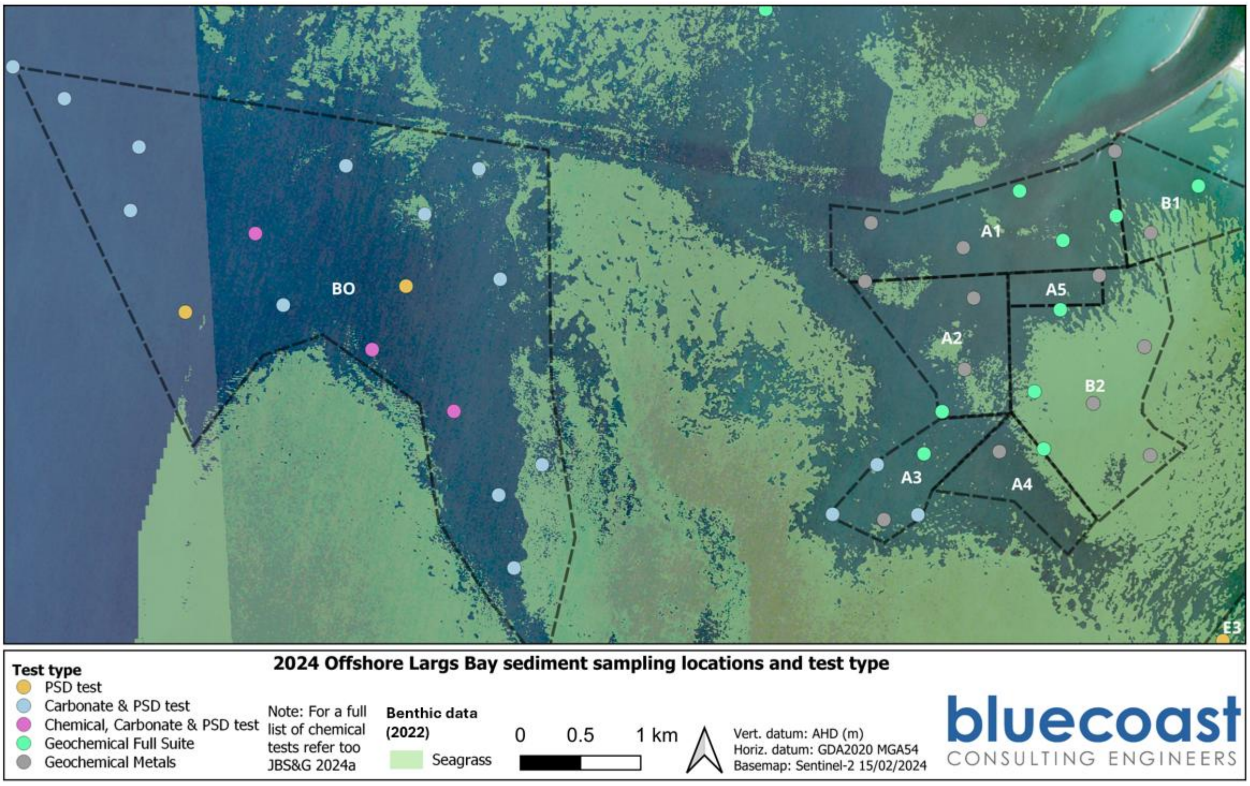

Figure 27: Offshore sampling locations and type of analysis conducted.

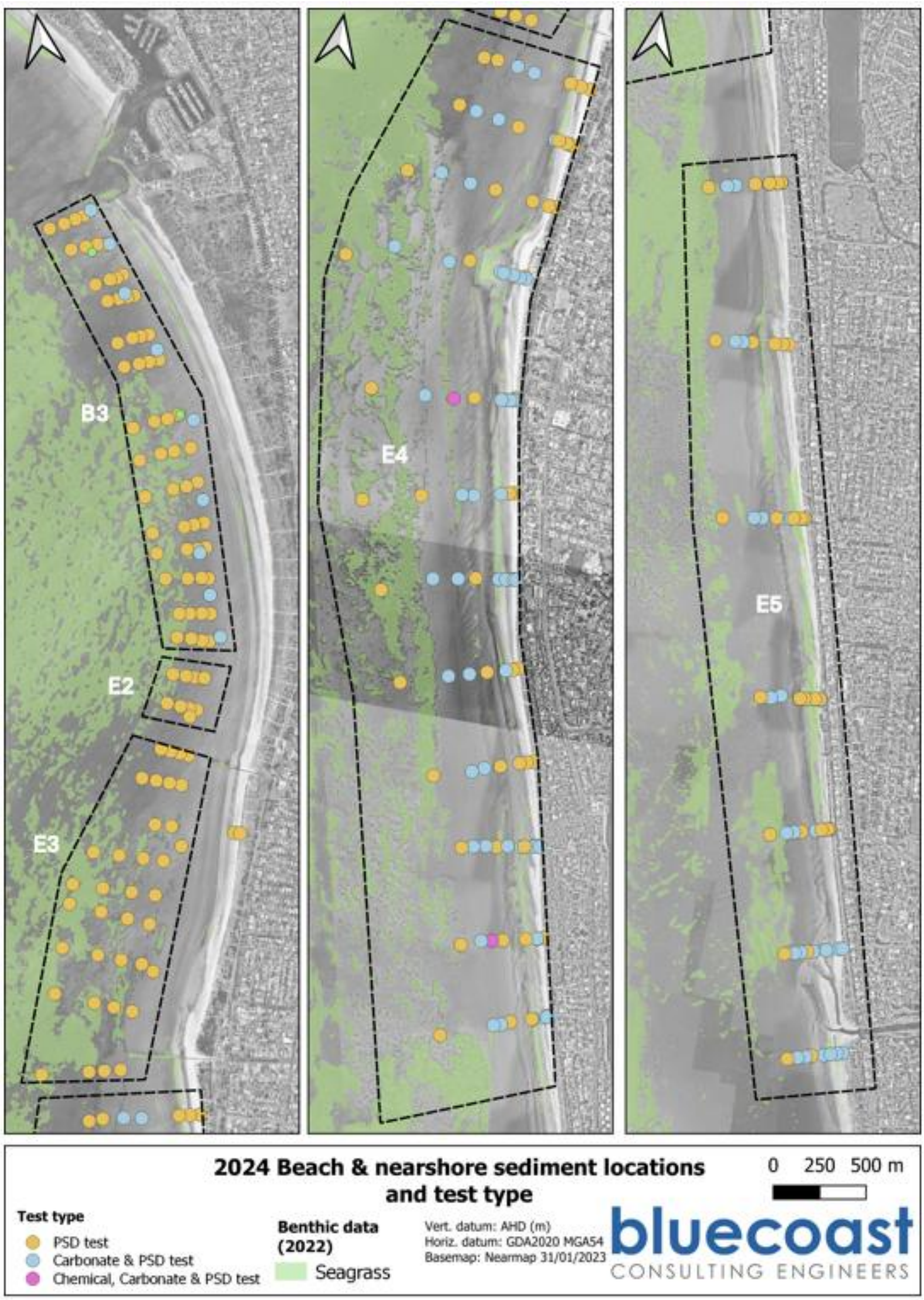

Figure 28: Nearshore sediment sampling locations and corresponding analysis.

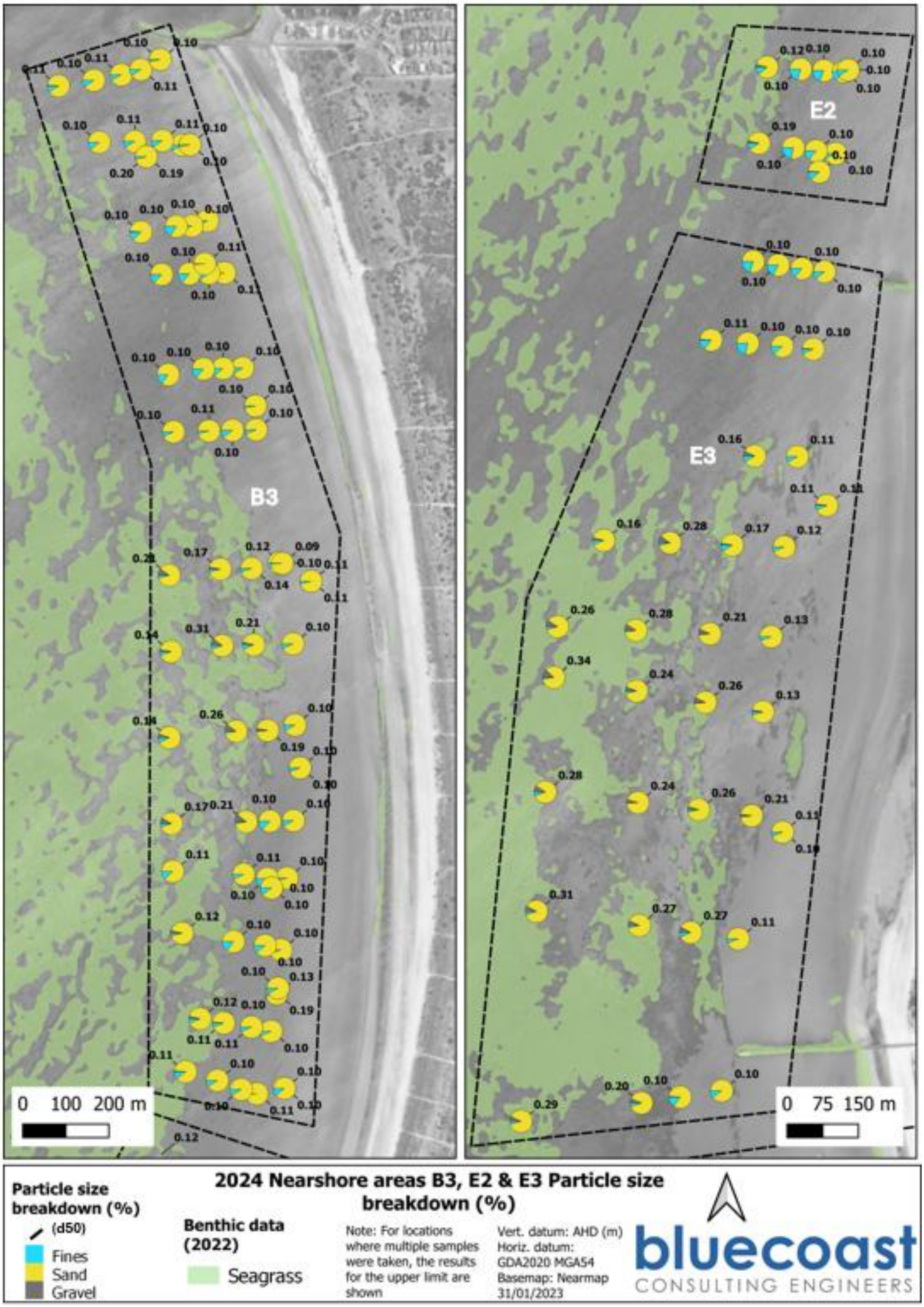

Figure 29: Sediment composition of nearshore areas within Largs Bay.

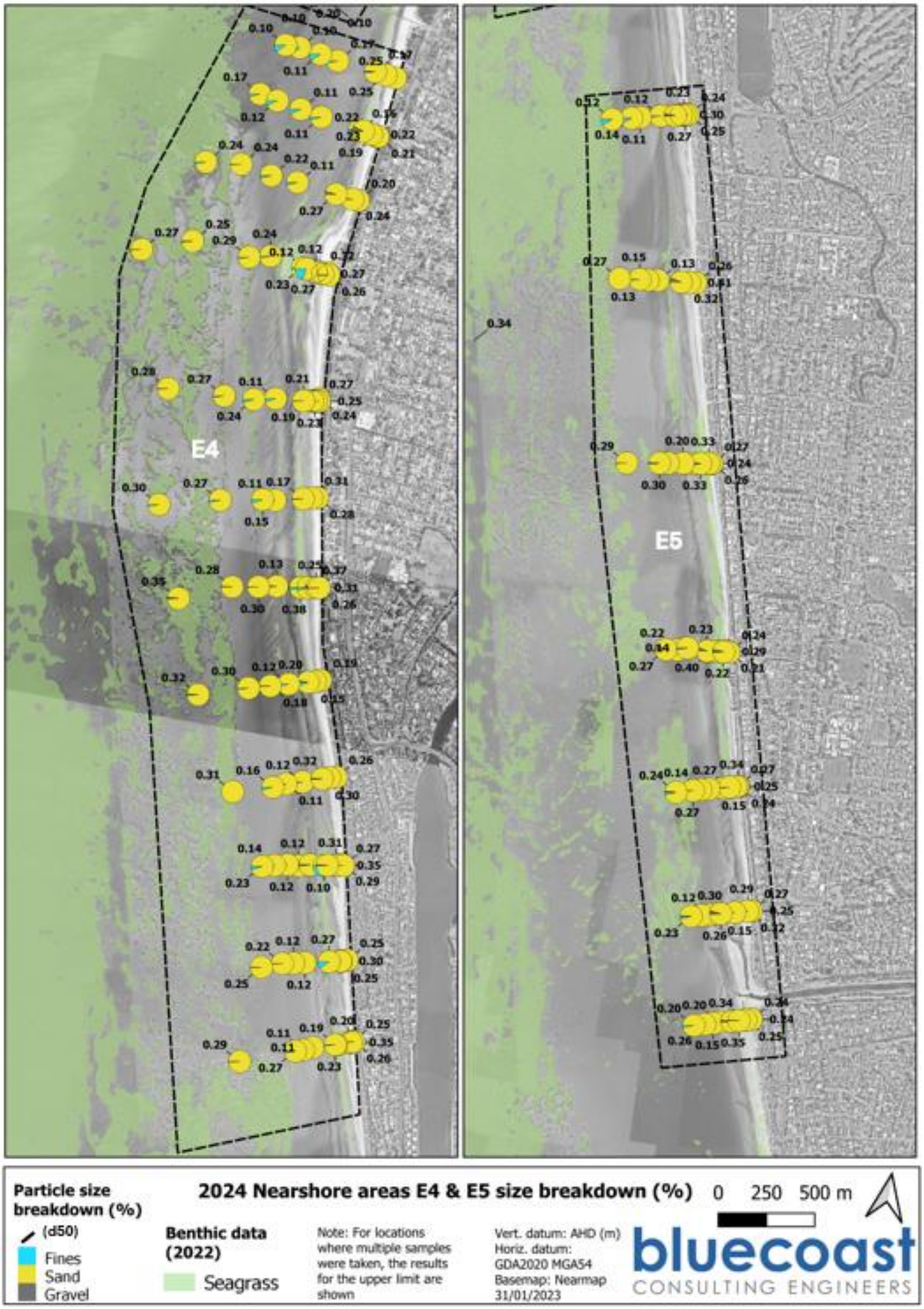

Figure 30: Sediment composition of nearshore areas between Semaphore and Torrens Outlet.

Rapid nearshore sand source investigations

Compatibility assessment

Adopting and extending the zones from JBS&G's sampling reports (JBS&G, 2024a, b, c and d) sets out a compatibility assessment against the sand suitability criteria in Section 2.3. This has been done for the three zones defined in JBS&G's reports (i.e. B3, B3, E2) as well as two additional areas (i.e. E4 and E5) defined herein, as shown in Figure 29 and Figure 30, respectively. This compatibility assessment concludes:

- Areas within Largs Bay (B3, B3, E2) contained sand that was too fine to meet compatibility requirements. A section of coarser sediment between Largs and Semaphore jetties (southern part of E3) was identified but excluded due to dense seagrass coverage.
- The nearshore components of E4 and E5 (south of Semaphore) are suitable areas for harvesting sand for recycling to West Beach. Sampling south of the Semaphore breakwater showed more favourable grain sizes with less fines and/or gravel content. The E4 and E5 zones are defined inshore of dense seagrass with suitable sandy benthic seabed inshore of the -4m AHD contour increasing to around -5m AHD near Tennyson Dunes.

Table 29: Sediment compatibility assessment results for nearshore areas.

Location (Investigation area)	D50 (mm)	% Fines (Onshore <5% Nearshore <10%)	% Gravel (Onshore <2% & Nearshore <5%)	Uniformity (<2.4)	Carbonate content	Suitability comment
B3	0.12	7.3	1.2	n/a	16.3	• B3 sand is not suitable, it is too fine. • There is an isolated area in B3 where the D50 exceeds 0.13mm. However, this area has a significant seagrass cover and is therefore not suitable.
E2	0.11	13. 6	0.6	1.4	n/a	• Grain size to fine and fines content is too high to be suitable.
E3	0.18	6.8	4.8	2.6	n/a	• While this area has a suitable grain size for beneficial reuse (BR) it has a significant seagrass cover and is therefore not suitable.

Location (Investigation area)	D50 (mm)	% Fines (Onshore <5% Nearshore <10%)	% Gravel (Onshore <2% & Nearshore <5%)	Uniformity (<2.4)	Carbonate content	Suitability comment
E4[7]	0.21	3.3	0.3	1.8	8.0	• Suitable grain size, composition and carbonate content.
E5[4]	0.23	2.3	1.3	1.9	8.4	• Suitable grain size, composition and carbonate content.

Defining nearshore investigation areas to take forward for detailed investigations

Based on the nearshore distribution of coastal sediments, the results of the compatibility assessment as well as other factors, investigation areas have been defined. The other factors considered in defining this nearshore investigation areas include:

- The presence of seagrass patches which are visible in aerials, benthic mapping and on DEW surveyed profiles. In identifying suitable areas, the change in profile elevation can be consulted to determine if these seagrass patches are persistent or transient. Figure 31 shows an example profile (200009) in which the main features are identified. For all profiles, the pattern of grain size decreased from the subaerial beach to the shallow inshore area before increasing again with depth. The recent benthic habitat mapping of Law et al, 2023 was used to assist in determining suitability of the cross-shore locations. Benthic habitat and seagrass are discussed further below in Section Appendix E:.
- Avoiding or managing impacts on coastal processes, which are discussed further below in Section 5 of the main report.

[7] For areas E4 and E5 only the nearshore samples are included in the averaged results presented.

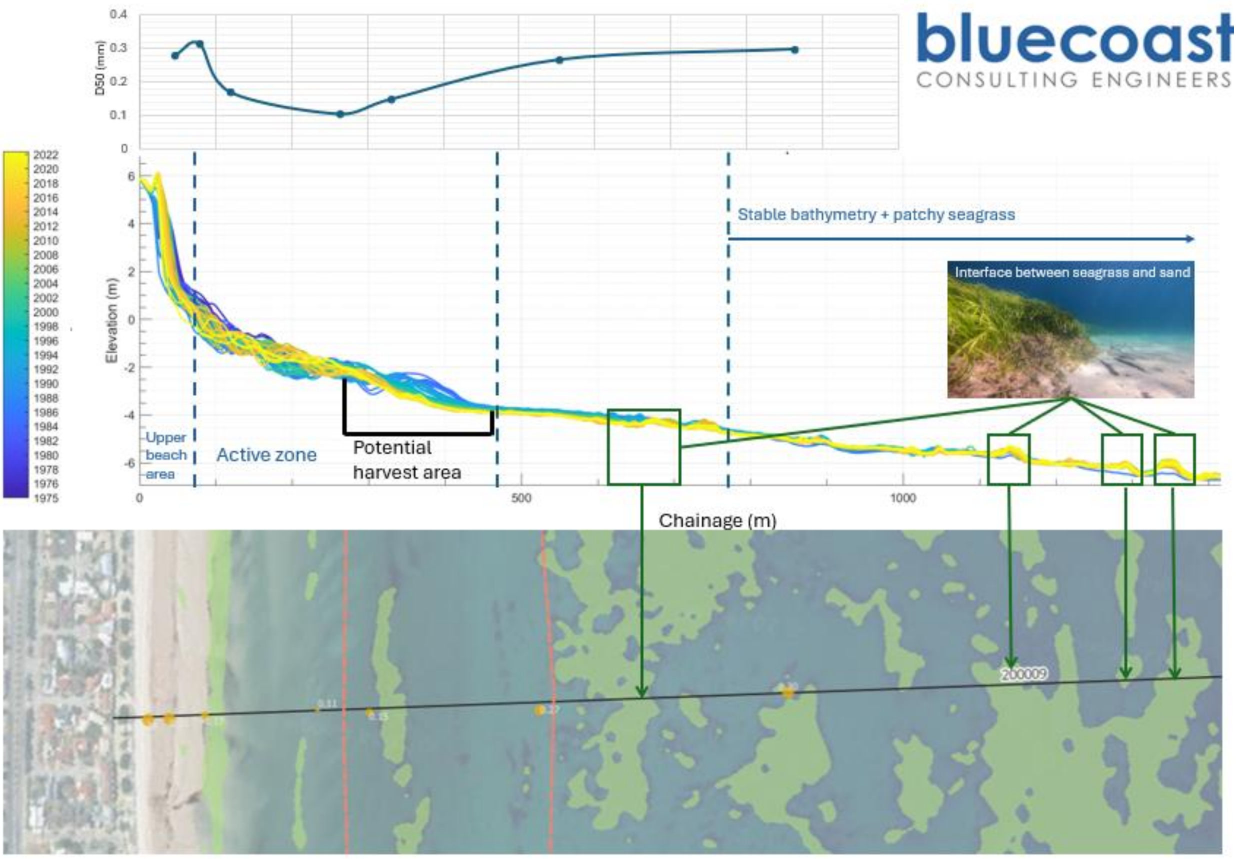

Figure 31: Representative cross-shore profile features.

Figure 32 shows the identified preliminary nearshore investigation area which stretches from Semaphore to Grange. This area is inshore of all mapped dense seagrass areas (however there are some mapped patches within this area particularly toward the north) and targets depths between -2.5 and -5m AHD. This seagrass coverage is shown as a percentage within Table 30 as well as the total available harvest area given. For the development of a long-term strategy this area could be broken up into smaller longshore zones which could be targeted based on previous nourishment campaigns and results of detailed site investigations.

Table 30: Available area of identified nearshore harvest location.

Parameter	Nearshore borrow area
Area	1,474,216 m^2
% of seagrass identified (based on 2022 benthic dataset with 25m buffer)	9%
Approx. usable area (m^2)	1,346,285 m2

While considerable effort and care has already been expended in defining these nearshore investigation areas, they are considered preliminary until such time as more detailed geophysical and vibracoring investigations, environmental assessments and community consultation is completed.

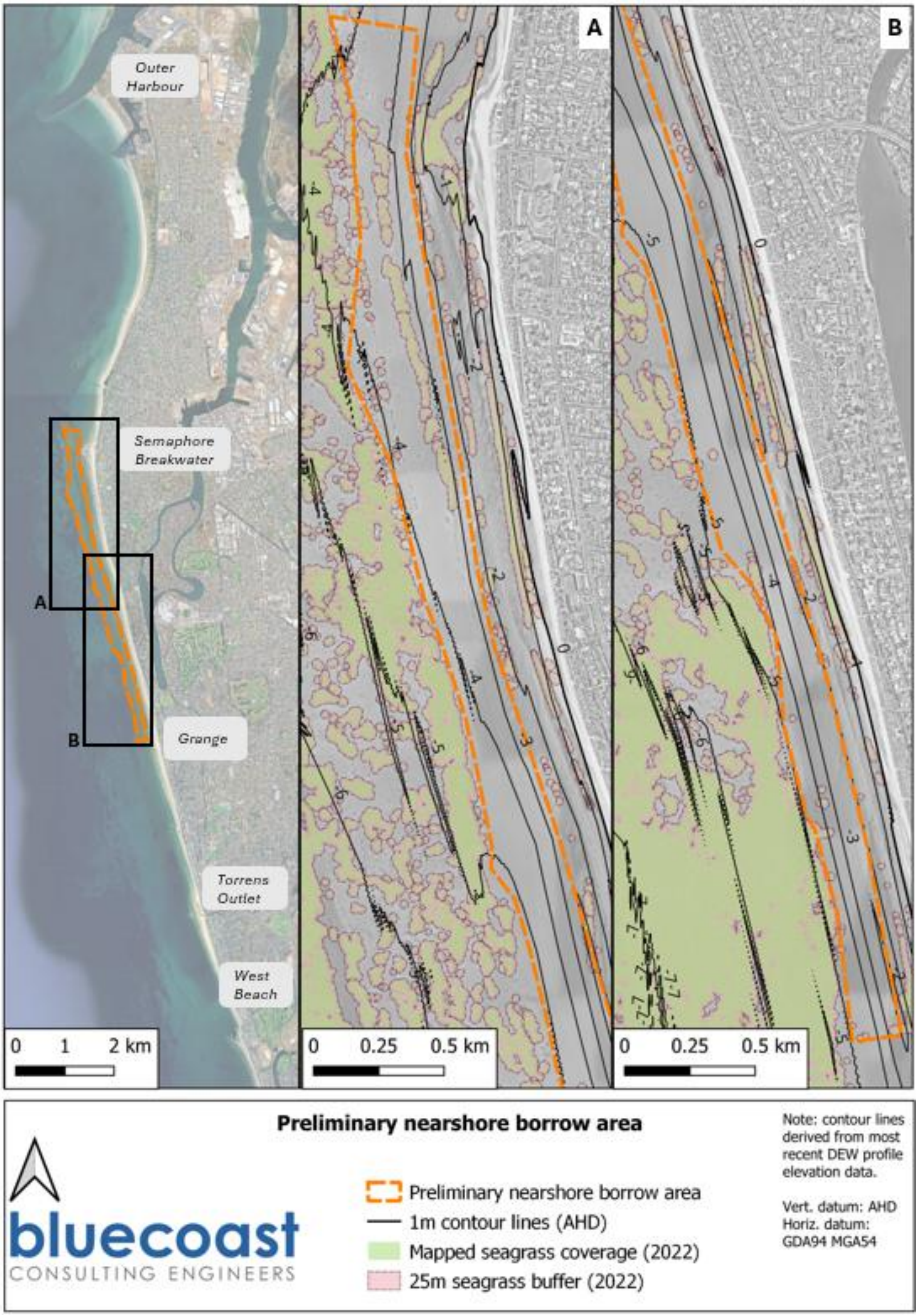

Figure 32: Preliminary nearshore borrow areas.

Rapid external sand source investigations

Compatibility assessment

Investigation into the physical and geochemical properties and benthic habit of external areas were conducted to determine if there were any suitable areas for nourishment of West Beach. This follows a significant review of offshore sand sources in the ABMR scientific review including: Port Stanvac, Section Banks, Murray Mouth and external Largs Bay. This assessment of sand compatibility focusses on the area offshore of Largs Bay as the closest and most practical source of external sand.

There were two main areas offshore of Largs Bay investigated for nourishment compatibility which were those identified in the ABMR scientific review (A1-A5, B1-B2) and an additional area further offshore (BO) which was identified through review of new seagrass coverage datasets and historical borehole sampling results.

Chemical sampling from the Stage 1 areas (A1-A5, B1-B2) shows that all geochemical results were below the NAGD screening levels (JBS&G, 2024a). The sediment composition derived from the particle size distribution (PSD) analysis for each sample location is shown in Figure 33. It should be noted that there were limited PSD sieve sizes used it the Stage 1 sampling which may reduce the accuracy of the median grain size (d50) calculation as well as limit the accuracy of the d10 and d60 values used to calculate the uniformity coefficient (Cu). Figure 33 shows that for the Stage 1 sample area (A1-A5, B1-B2), there is either a high fines or gravel content while in area BO it is mostly sand with gravel.

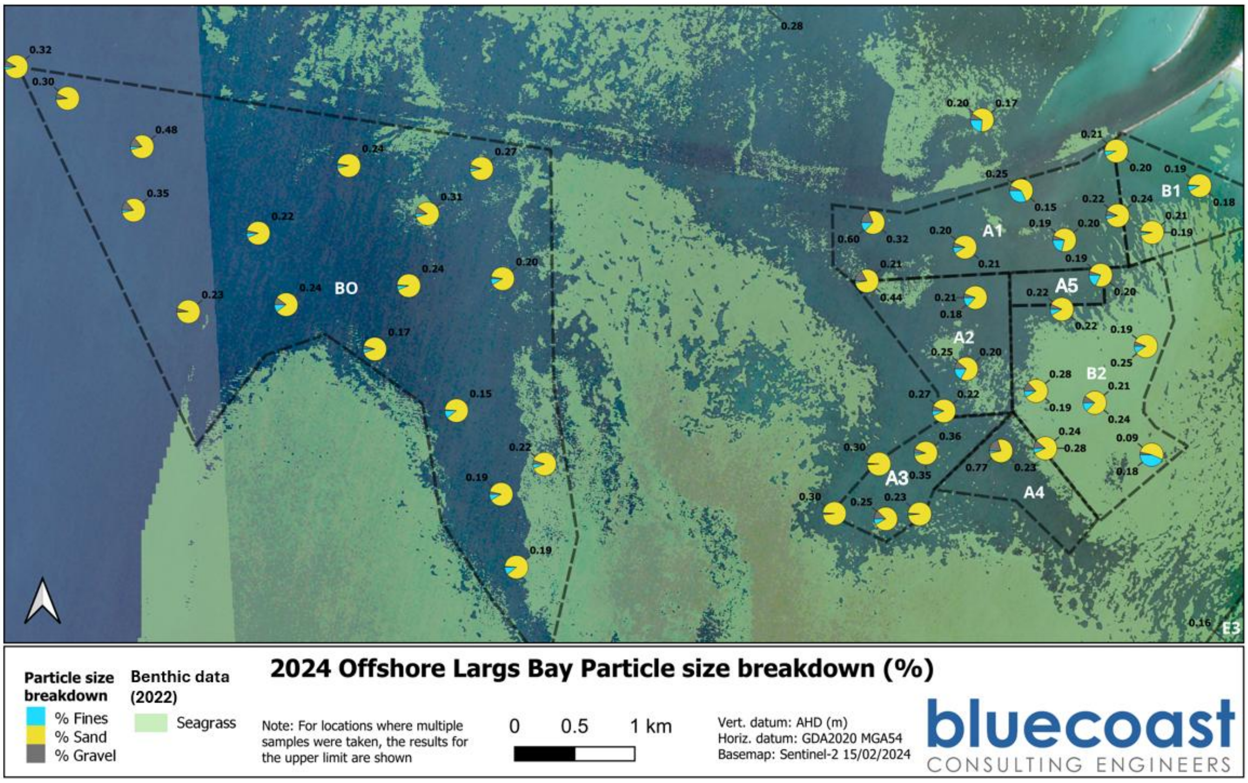

Figure 33: Sediment composition of external areas.

It was found that while some of the Stage 1 areas had suitable d50s, the fines and gravel content mostly precluded them from suitability, with the exception of Area A3. Additional surface sampling was conducted in area A3 (Bluecoast, 2024b) and found that the median grain size, fines and gravel content, uniformity coefficient and carbonate content were all within the suitability limits. Results for the sampling conducted in BO are described in detail in Bluecoast, 2024b and highlight that there is a range of benthic habitats and sediment composition types. The samples collected around the southern and northwest corners of BO had promising composition qualities as well as being mostly bare substrate around the sample site. These would warrant further investigation through core samples and towed benthic video capture. Table 31 gives the average of the compatibility criteria for each area.

Table 31: Sediment compatibility assessment results for external areas.

Location (Borrow Area)	D50 (mm)	% Fines (Onshore <5% Nearshore <10%)	% Gravel (Onshore <2% & Nearshore <5%)	UC	Carbonate content	Suitability comment[8]
BO	0.25	6.65	7.06	3.31	24.67	• Relatively high gravel and Carbonate content for most samples in area however this may be due to sample collection method (surface grab from vessel) collecting surface shells. Some seagrass meadows identified however some identified areas of bare substrate that should be mapped further to define constraint in area.
A1	0.26	13.86	9.80	3.78	n/a	• High fines and gravel content with large areas of seagrass observed
A2	0.25	12.39	8.13	5.32	n/a	• High fines and gravel content with spares areas of seagrass observed
A3	0.28	4.38	4.71	3.71	18.33	• Median grain size slightly higher than target but suitable fines, gravel and Carbonate content. Seagrass observed in some areas, more detailed mapping required
A4	0.34	16.85	12.75	7.73	n/a	• High fines and gravel content.
A5	0.20	14.70	3.50	2.79	n/a	• High fines content. Sparse seagrass but predominantly bare sand.
B1	0.20	6.19	0.83	2.42	n/a	• Sparse seagrass and some razor clams observed.
B2	0.22	14.33	7.75	3.83	n/a	• High fines and gravel content. Sparse seagrass and some razor clams observed.

8 For detailed comments on each site, refer to JBS&G, 2024a and Bluecoast, 2024b.

Defining external investigation areas to take forward for detailed investigations

Based on the above analysis and available benthic data, three external areas have been identified for further detailed site investigations, listed in Table 32 and shown in Figure 34.

Table 32: Identified preliminary external harvest areas.

Area	Area (m^2)	Comment	Further information required
A3	1,050,000	Shown to be suitable sand with patches of seagrass not well defined by mapping.	
BO1	1,075,000	Shown to have favourable physical characteristics with benthic observations showing minimal seagrass	Additional detailed benthic survey and core sampling should be conducted to finalise borrow area capacity and constraints.
BO2	2,375,000	Shown to have favourable (slightly shelly, gravelly) physical characteristics with benthic observations showing minimal seagrass.	

-
- A detailed breakdown of the sediments from sampling results within the preliminary areas is shown in Figure 35. The summary of the sediment compatibility is shown in Table 33. These areas were identified as the areas were free (or partially free) of benthic coverage and had sediment characteristics that are favourable for nourishment.

Table 33: Sediment compatibility assessment results for external areas.

Location (Borrow Area)	D50 (mm)	% Fines (Onshore <5% Nearshore <10%)	% Gravel (Onshore <2% & Nearshore <5%)	UC (<2.4)	Carbonate content	Suitability comment[9]
A3	0.28	4	4	3.7	18	Median grain size slightly higher than target but suitable fines, gravel and Carbonate content. Seagrass observed in some areas, more detailed mapping required
BO1	0.18	10	3		24	Median grain size on the low end of the target size with fines approaching the limit of
BO2	0.31	4	9	3.1	24	Higher gravel content than guidelines however this may be due to sample

[9] For detailed comments on each site, refer to JBS&G, 2024a and Bluecoast, 2024b.

Location (Borrow Area)	D50 (mm)	% Fines (Onshore <5% Nearshore <10%)	% Gravel (Onshore <2% & Nearshore <5%)	UC (<2.4)	Carbonate content	Suitability comment[9]
						collection method (surface having a layer of gravelly shells)

Figure 34: External areas taken forward for detailed site investigations.

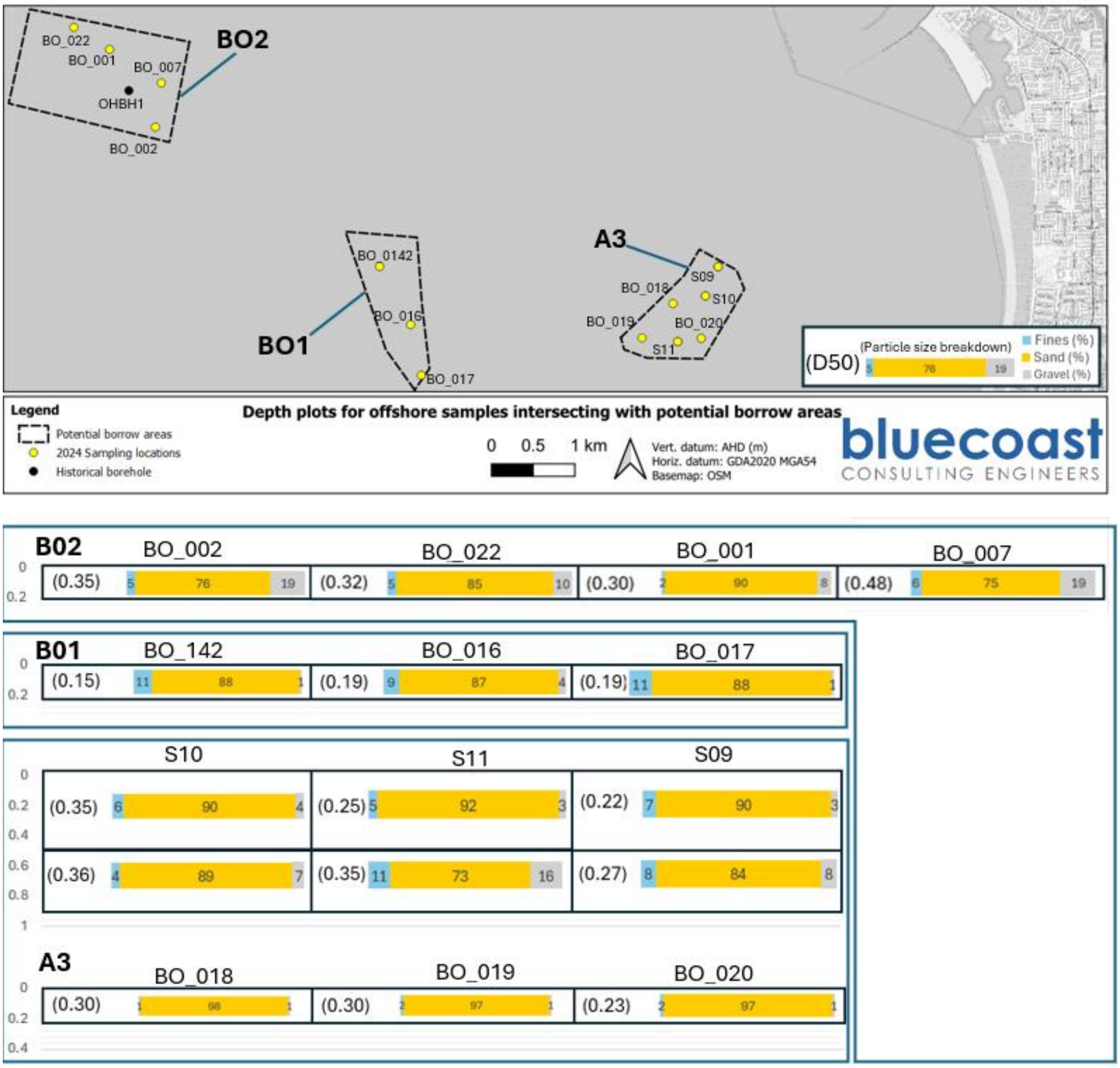

Figure 35: Composition breakdown of samples collected from the external areas taken forward.

To support the feasibility of external borrow area BO2, historical data from investigations conducted by the port were consulted to assist with the determination of potential sand source thickness. The *Outer Harbor Channel Widening Project Development Application Report* (Arup, 2017) contains a geological interpretation along the approach channel to Outer Harbour including nearby the identified area BO2 (shown in Figure 36). This, combined with the data from the borehole log for OHBH1 shown in Figure 35, indicates that there is a layer of unconsolidated sand of approx. 1.5m depth in this area. This gives confidence to the area as a potential source for a substantial quantity of nourishment material.

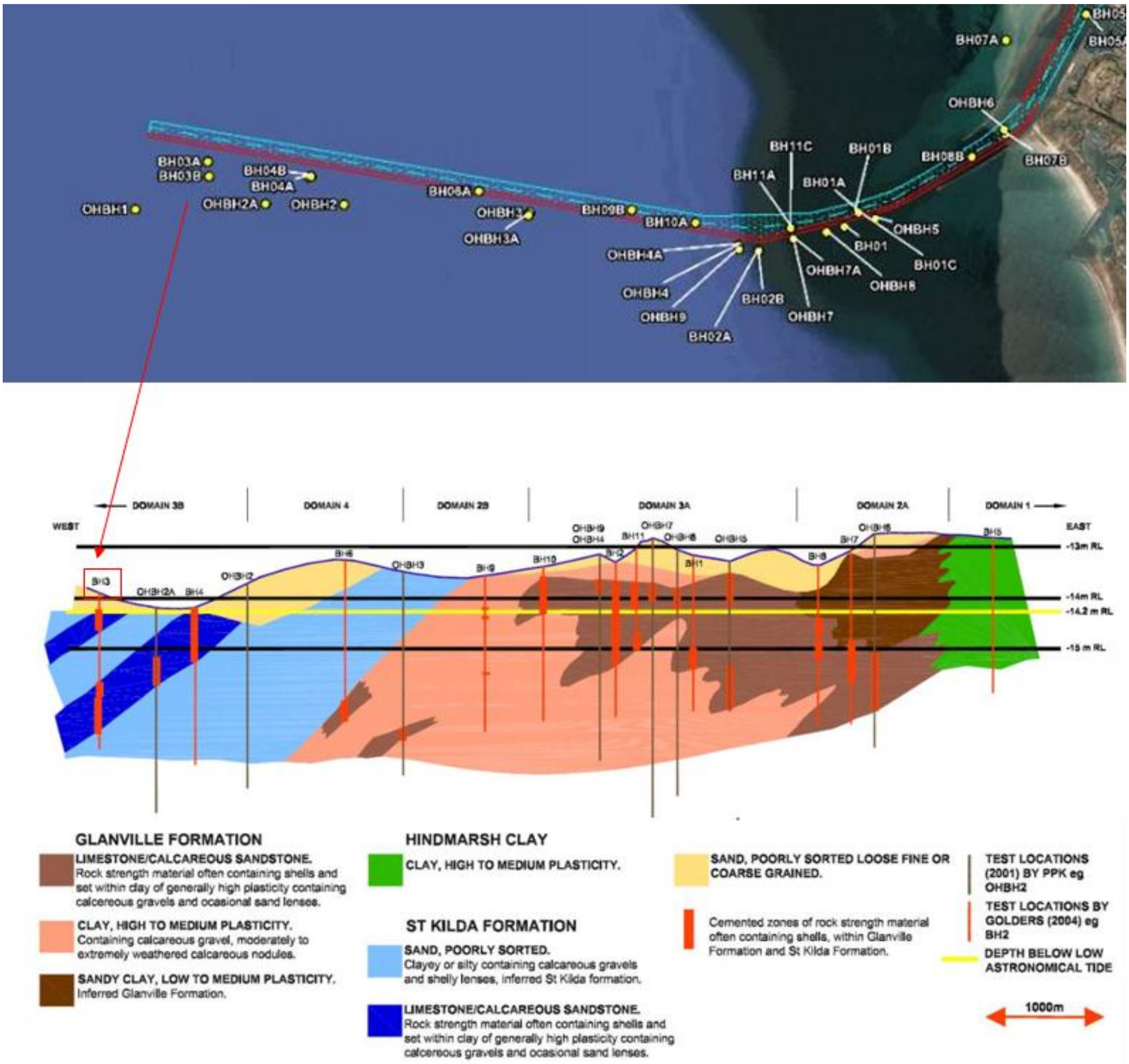

Figure 36: Inferred geological section (adapted after Arup, 2017).

Appendix D: Supporting information on detailed sand budget and storm resilience

Detailed sand budget of the target areas

Observed changes 2008 to 2024

A detailed assessment of the change in the sand volumes focused on the northern management area was undertaken adopting 29 analysis cells from West Beach up to North Haven (see Figure 19). The alongshore extents and division of the cells were defined based on the DEW profiles (each cell is defined by one or at most two profiles). Cross-shore extents of the cell were defined according to the beach profile length from the top of the dune down to around -5 to -6m AHD.

Table 34 provides a summary of the profiles used in each beach compartment and the rate of change observed from 2008 to 2024. Figure 37 illustrates the adopted cells alongside the profiles utilized in the volume change analysis, with colours representing the observed rate of change over this period. The rates of DEA shoreline change are also included for comparison, allowing for cross-checking of trends across different datasets.

Sand management volumes (i.e. sand placed or removed in each cell) for each of the cells were calculated based on detailed information provided by DEW for carting and pumping activities between 2008 and 2024. Table 34 gives the resulting net sand management rates for each cell where positive values are sand added while negative values correspond with areas where sand was removed.

Table 34: Summary of the volume rate of change of each beach cells.

Cell ID	DEW profiles	Alongshore length (m)	Rate of change (m^3/year) 2008 to 2024	Net sand management volumes (m^3/year)
1	200021	813	-10,607	63,511
2	200020	686	-2,366	33,603
3	200072	503	-4,455	-
4	200071	250	-1,996	-
5	200019 & 200070	452	143	- 55,858
6	200018	574	-5,752	768
7	200017	771	-5,161	12,030
8	200016	940	-4,465	-
9	200015	723	6,027	-
10	200014	1,420	11,714	-
11	200133	755	7,247	-
12	200012	485	4,205	4,047
13	200132	528	144	-
14	200011	447	- 581	- 4,047

Cell ID	DEW profiles	Alongshore length (m)	Rate of change (m^3/year) 2008 to 2024	Net sand management volumes (m^3/year)
15	200131	507	289	-
16	200130	501	2,244	-
17	200010	452	- 104	-
18	200009	449	- 1,984	15,688
19	200008	578	2,250	-
20	200007	917	8,356	- 32,577
21	200006	660	- 4,539	8,331
22	200005	861	- 7,641	- 10,939
23	200004	761	- 351	-
24	200003	1,020	- 5,974	-
25	20002 20001	2,424	37,489	-
26	200122 200123	1,235	18,557	- 6,238

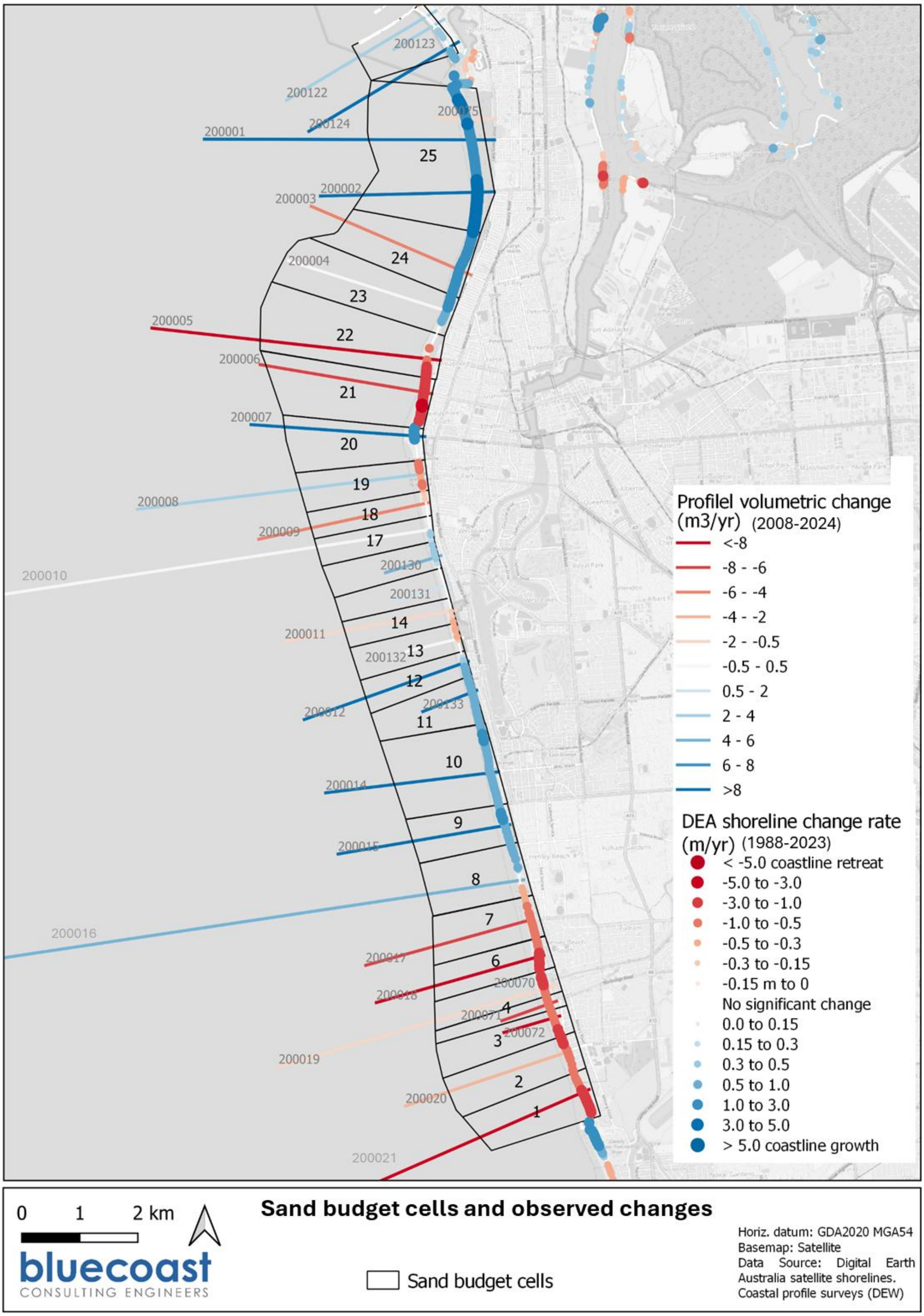

Figure 37: Adopted beach cells and profiles in the sand budget analysis. Profile colours representing the observed rate of change from 2008 to 2024 and DEA shoreline rates shown along the coastline.

Sand budget analysis

Full coastal survey profiles (i.e., both subaerial and subaqueous part) were analysed to examine sand volume changes along the northern management area. The observed changes detailed above were used to quantify the rates of sediment transport and beach volume changes. A summary of how these observed changes are used for the sand budget analysis is shown in Figure 38.

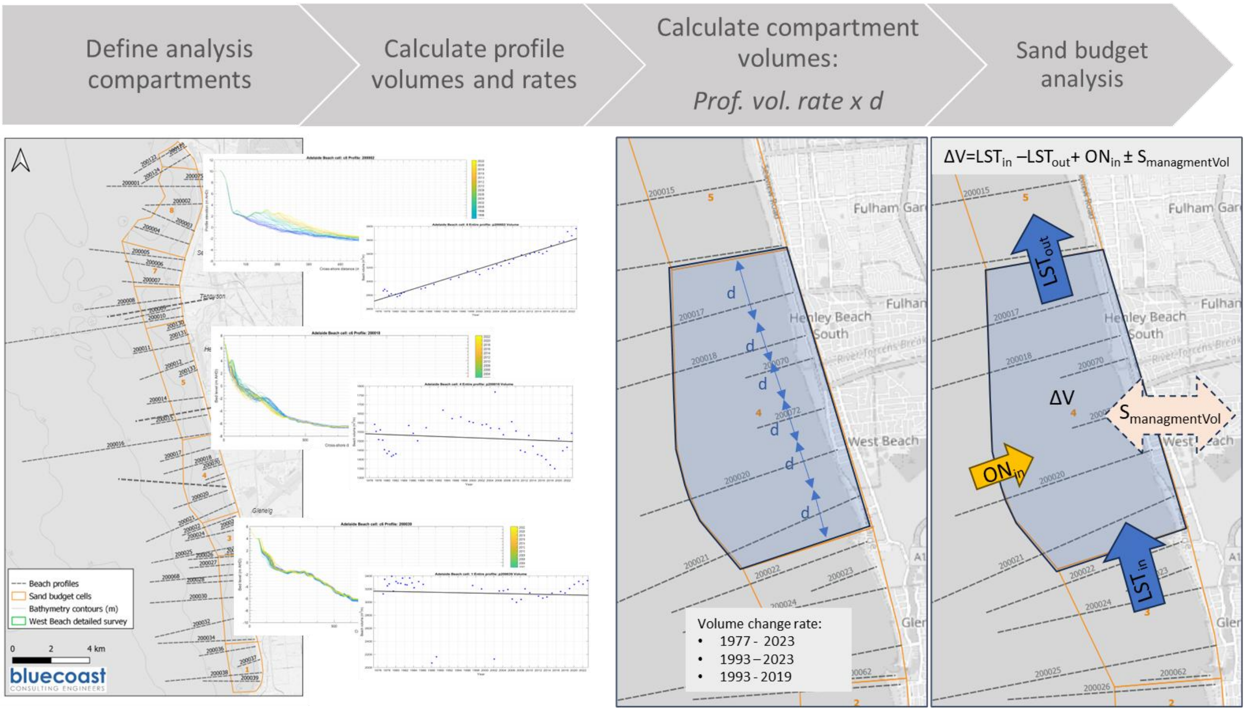

Figure 38: Summary of the sand budget analysis approach (Bluecoast, 2023).

The cells selected for the analysis were selected based on available profile location, data coverage and shoreline behaviour (based on satellite derived shoreline rate shown in Figure 37). These cells are much higher fidelity compared to those used in the ABMR scientific review. This results in sensitivity of the longshore transport rate due to sand management volumes (either placing or removing sand). Due to some uncertainty regarding the boundaries of the removal or placement area in each cell it was necessary to 'smooth' some of the volumes (i.e. spread over adjacent cells) to ensure that the resulting longshore transport rates were reasonable.

In the calculation of these rates, it was assumed that there was no sand leaving the system at the Northern end (Outer Harbour). As such, this was used as the boundary condition in calculating the longshore transport along the system. Figure 39 shows the longshore transport rates using the detailed cells for the northern management area with comparison to the rates calculated in Bluecoast (2023). Of note is the significant increase in rates between Glenelg North and Torrens Outlet (i.e. West Beach) as well as the increase around Semaphore Park, immediately south of Semaphore Breakwater.

The main outcomes of the conceptual model are:

- There is approx. 7,00m^3/yr entering the system from Glenelg North. This is less than was calculated in the ABMR scientific review (41,000m^3/yr) however given this analysis covers only then time after the West Beach Harbour was built and the Cell 1 backpassing pipeline implementation, it is reasonable to assume that transport rates into West beach have reduced
- The transport rate between West Lakes Shores and Semaphore breakwater is fairly stable around 70,000 m^3/yr. This area makes up part of the nearshore harvest area.

- The rate of transport into Semaphore is around 58,000 m³/yr. This rate aligns with previous studies summarised by Water Technology (2020) in the assessment of 2020-21 harvesting capacity for sand carting.
- The average transport rate along the West Beach compartments is approximately 80,000 m³/yr, aligning well with recent studies (Salients, 2021).

Figure 39: Longshore sand movement rates along Adelaide's beaches.

Storm resilience

Coastal Engineering Solutions (2004) identified a series of severe storms that occurred between 1948 and 2002 and assessed their impact on the Adelaide foreshore. The study utilized the SBEACH model to simulate offshore sediment transport and evaluate beach response to these storm events. For the analysis, ten representative locations along the Adelaide foreshore were selected. The study modelled the response of each beach profile to eight severe storms within the identified period. To ensure consistency, the 1999 surveyed beach profiles at each site were used as the baseline condition prior to the onset of each storm. A summary of the results is presented in Table 35 for the profiles located at harvested area. While the 1948 storm resulted in the greatest dune cuts across all profiles, the 1956 storm caused the largest erosion volume.

Table 35: Results of the SBEACH modelling undertaken in Coastal Engineering Solutions (2004).

Location	Storm erosion (m^3/m)	Comment
Tennyson	45 (1956 storm)	• The 1948 storm would have eroded the full width of the high berm on the front face of the dune. • Sand move offshore to fill in the swales between the bars rather than all moving offshore.
Tennyson Dunes	40 (1956 storm)	• The 1948 storm totally removed the foredune and started to erode the primary dune due to the high water level. • The sand eroded from the dune does not move offshore into deep water.
Tingira Ave, Semaphore Park	35 (1956 and 1994 storms)	• The 1948 storm has the highest cut in the dune. • The sand eroded from the dune does not move offshore to any great extent but rather fills the swales between the nearshore bars.
Semaphore Jetty	25 (1956 storm)	• The 1948 storm has the highest cut in the dune.

Storm resilience is influenced not only by the upper beach volume but also by the total volume across the full coastal profile. The upper beach volume provides the immediate buffer against wave action during storm events, helping to absorb energy and reduce erosion impacts on coastal infrastructure. However, the resilience of the beach system as a whole is heavily dependent on the volume stored within the entire coastal profile, including the nearshore and offshore zones.

The offshore volume plays a critical role in storm recovery and sediment dynamics. During a storm, sand is often transported from the upper beach to the offshore region, where it forms bars or accumulates as temporary storage. This sand can then be naturally recycled back to the beach during calmer wave conditions, facilitating beach recovery and restoring its protective function.

A sufficient volume across the full coastal profile ensures that there is an adequate sediment supply available to support this natural recovery process, reducing the long-term impacts of erosion and enhancing the beach's ability to withstand future storms.

Impact of sand harvesting on storm erosion

To evaluate the influence of sand harvesting on beach erosion, the XBeach 1D model was employed. XBeach is a process-based model commonly used to simulate nearshore morphological changes during storm events.

A calibration exercise was conducted to ensure the model could replicate observed coastal responses during storm events. The calibration focused on the May 2016 storm in South Australia (Figure 20) and documented through pre- and post-storm profile surveys by the DEW. Calibration was focused on the profile shape rather than the exact erosion volume. The 14-hour simulation used tide data from the Outer Harbour gauge and a synthetic wave height series as inputs.

The calibrated model was applied to profiles within the sand harvesting area (200008, 200009, 200010, 200130, 200131, and 200132). Erosion volumes and 2% run-up values were computed for basecase and post-harvested beach profiles (Table 36). The results indicated that sand harvesting had no discernible effect on storm-induced erosion across all profiles. An example of the XBeach input profile and post-storm profile for the basecase and harvesting scenario are shown in Figure 40.

Table 36: Xbeach storm erosion and run-up results for base profiles and harvested profile along harvested area.

Profile ID		Erosion volume (m^3/m)	2% run up height (m AHD)
200008	Basecase profile	47	2.87
	Post-harvested profile	47	2.86
200009	Basecase profile	60	2.91
	Post-harvested profile	61	2.90
200010	Basecase profile	58	2.92
	Post-harvested profile	56	2.88
200130	Basecase profile	51	2.91
	Post-harvested profile	49	2.91
200131	Basecase profile	54	2.87
	Post-harvested profile	52	2.84
200132	Basecase profile	55	2.88
	Post-harvested profile	53	2.87

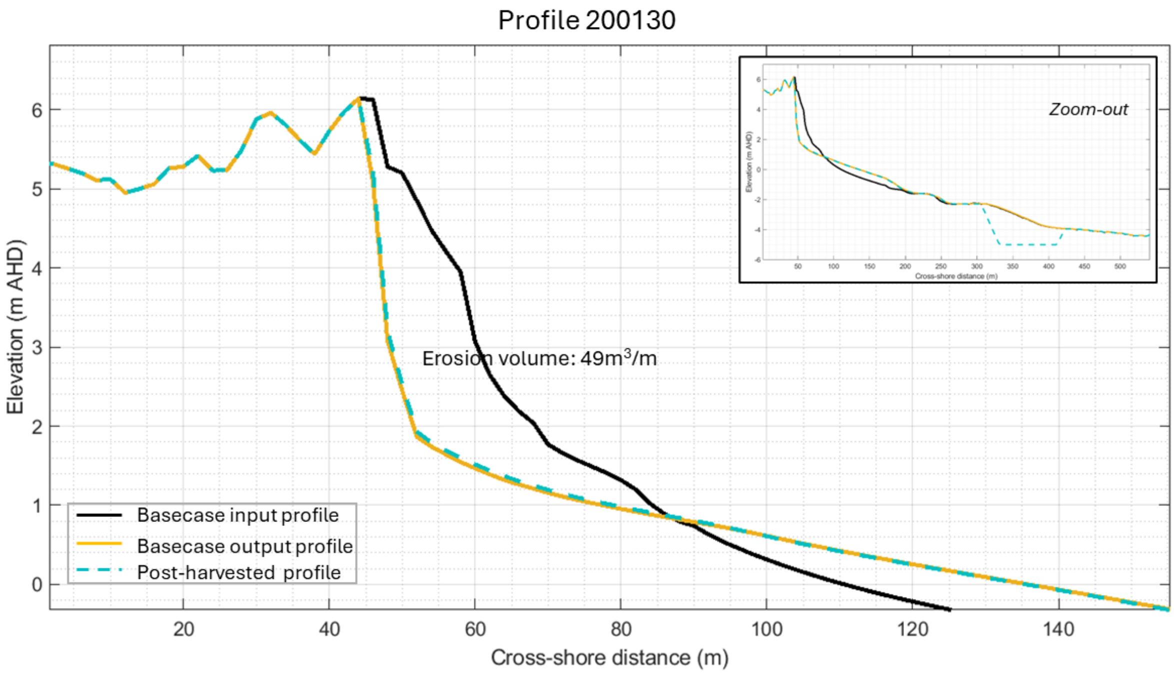

Figure 40: Example of Xbeach storm erosion results for profile 200130.

Beach width

Beach width is a key physical parameter for analysing trends in beach vulnerability to erosion, influencing recreational activities and coastal protection strategies (de Paula et al., 2022). Along the sand harvesting area, beach width was assessed using DEA shorelines data from 1988 to 2023. This was calculated as the distance between DEA shoreline positions and the vegetation line at DEW profile locations. The DEA shoreline dataset provides annual snapshots of shoreline positions, making it a valuable tool for representing instantaneous beach width variations over time.

Table 37 presents a summary of the beach width analysis at each assessed DEW profile and Figure 41 shows the boxplot of these beach widths. The smallest beach widths were recorded along Tennyson (profiles 200133 and200012), with mean widths ranging between 25 and 28 meters. The greatest variability in beach width was observed at profile 20007, located near the offshore detached breakwater at Semaphore (the greatest beach width following construction of the breakwater).

Table 37: Summary of beach width analysis.

	Beach width (m) 1988 to 2023		
Profile ID	Mean	Min	Max
200014	40	20	55
200133	28	11	47
200012	25	12	36
200132	40	30	52

	Beach width (m) 1988 to 2023		
200011	34	27	47
200131	38	29	51
200130	33	18	50
200010	36	23	42
200009	39	21	48
200008	47	34	67
200007	56	14	154

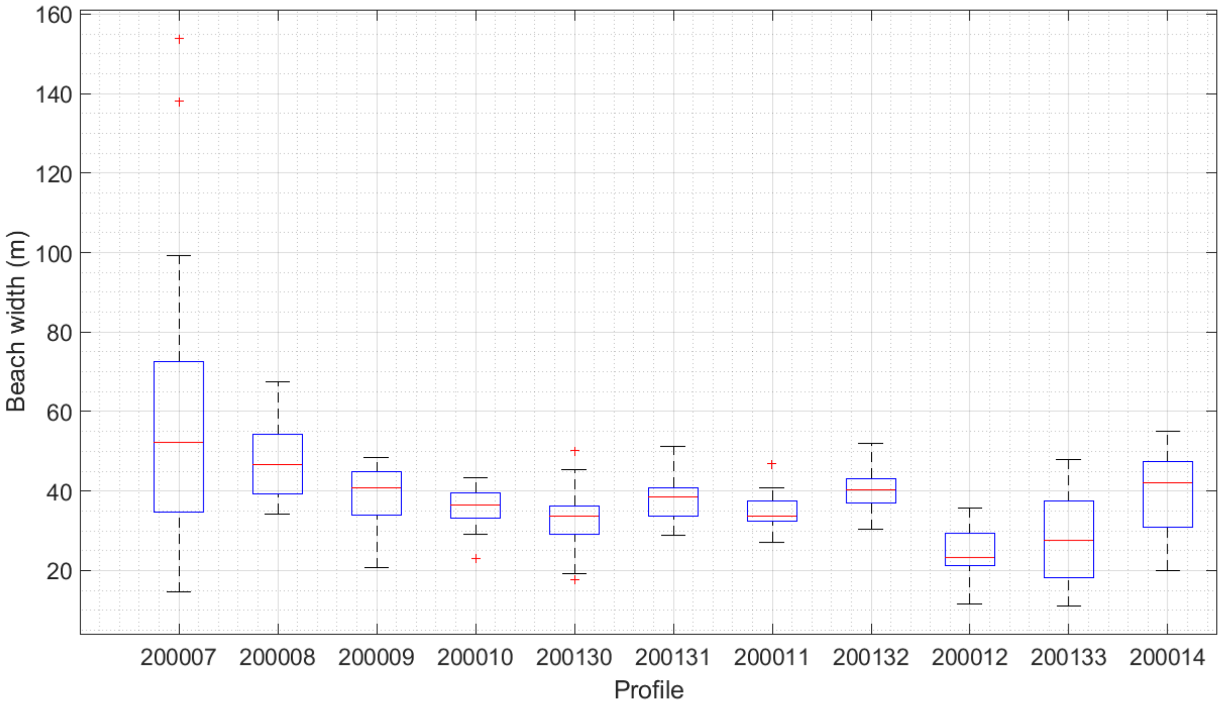

Figure 41: Beach width from DEA shorelines to vegetation line along harvesting area.

Appendix E: Review of seagrass constraints

Introduction

Within the northern management area are extensive seagrass meadows which have been subject to coverage gain and loss over the last century. Monitoring, protection and restoration efforts over more recent years show areas where seagrass is stable, in active recovery or active decline. This information is relevant to this assessment as the feasibility nourishment by dredge is dependent on the environmental constraints (seagrass) in the target harvest areas. This section details the following:

- Temporal changes in seagrass coverage
- Restoration campaigns
- Offshore coverage and mapping

It is noted from a review of the available literature that the typical seagrass genus contained alongside sand and algae within the nearshore and offshore borrow areas consists of; *Posidonia*, *Amphibolis*, *Halophila* and *Heterozostera*.

Temporal change in seagrass coverage

Over three decades of Landsat data (remote satellite data), the seagrass boundary in the potential harvest areas (predominantly E4, A3 and BO in **Figure 42**) remained relatively stable, with seagrass expansion primarily in deeper waters (>10 m) and at the seaward edge of the existing coverage (Fernandes et al., 2022). It should be noted that the area of seagrass loss from 1988-1997 off Semaphore is associated with a sludge outfall while no reason is given for the loss near the port shipping channel from 1988-2007 (Fernandes et al., 2022).

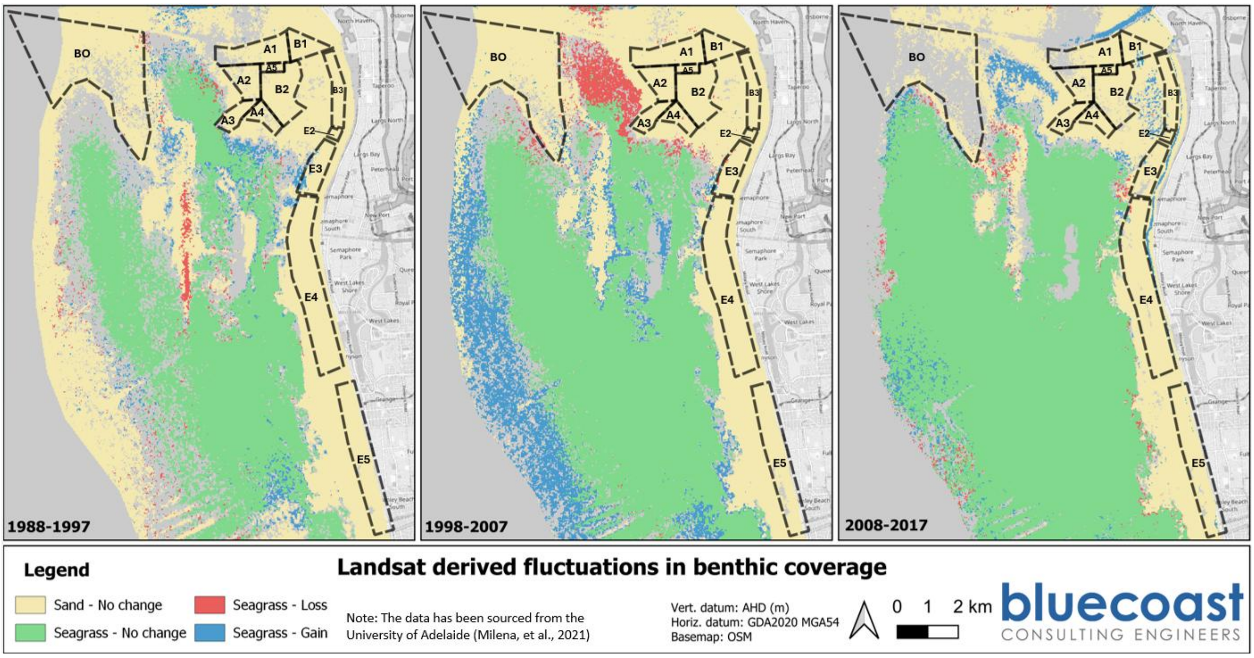

Figure 42: Landsat derived benthic data detailing the fluctuations in seagrass coverage between three successive decades.

More recent benthic mapping utilising hyperspectral imagery conducted by Clarke et al (2021) estimated both the seagrass coverage (bare vs. non-bare substrate) as well as genus level classification to identify areas of *Posidonia* and *Amphibolis*. Maps of the outcomes of this are shown in **Figure 43**. It should be noted that the accuracy attributed to the coverage mapping and the genus classification were 98% and

85% respectively when compared to the field data. This shows a defined band of bare substrate in the nearshore area starting at Point Malcolm and travelling south as well as in the offshore 'A' and 'BO' areas. The benthic coverage in the nearshore areas (typically -5m AHD) is able to be viewed in high quality aerial imagery (such as those available from Nearmap) and any mapping product should be compared to them. Hyperspectral mapping resulting from processing of 2022 imagery by Law et al (2022) provides good correlation with nearshore observed coverage and is used in Section 3 to identify contemporary areas of coverage.

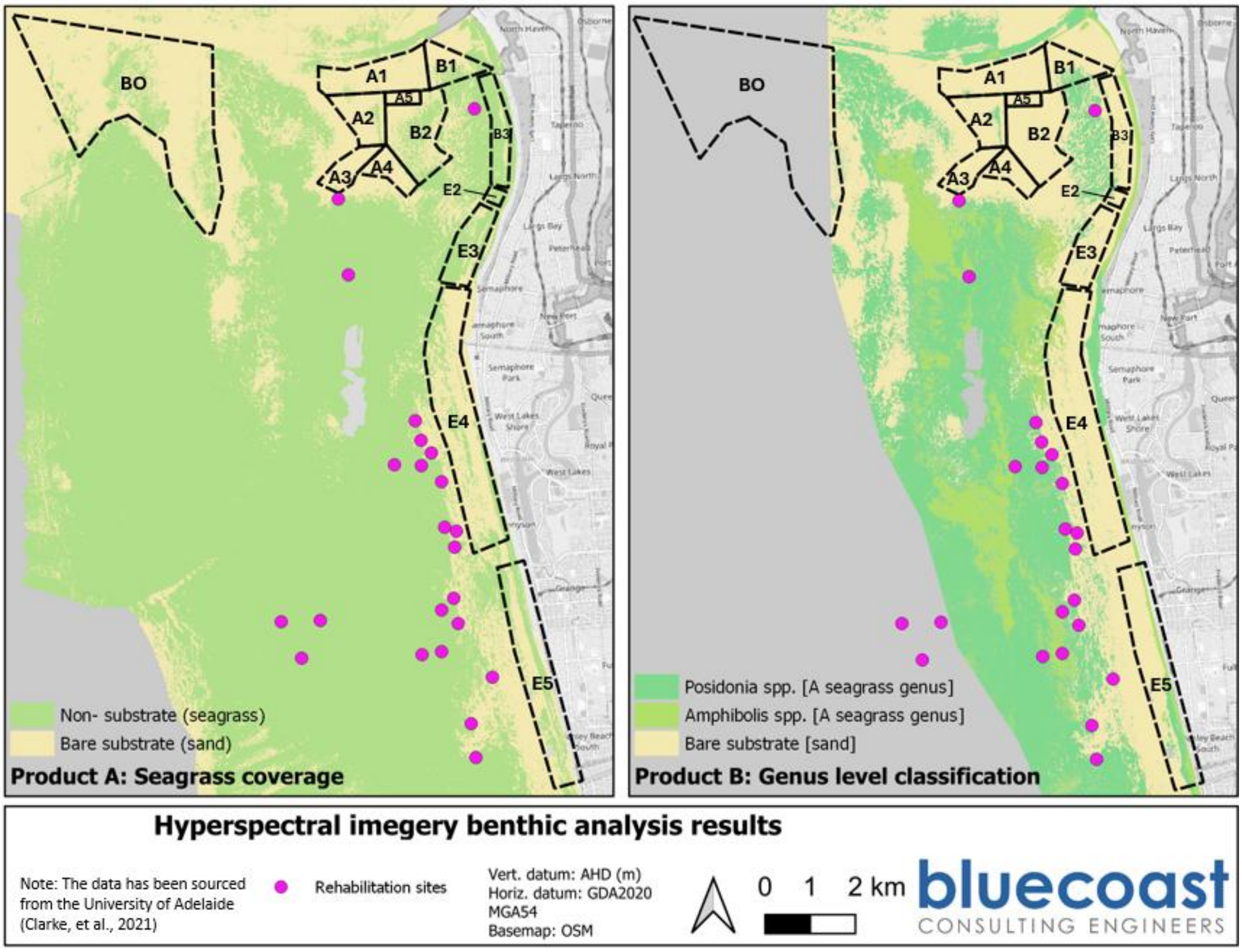

Figure 43: Identification of seagrass species within Adelaide metropolitan coastline.

Seagrass restoration campaigns

Seagrass restoration campaigns along Adelaide's metropolitan coast have been conducted since the early 2000's to restore areas of recession or anthropogenic loss. A summary of the campaigns conducted from 2003 to present was provided by DEW and is mapped spatially in **Figure 43**. It should be noted that these restoration sites are outside of the proposed nearshore or offshore borrow areas.

In addition to the mapped rehabilitation sites, there has been further work to understand the mechanisms in which these species reproduce by Tanner et al (2021) with the intention of increasing the success rate of restoration projects. Surveys conducted over a 2-year period to better understand the reproduction cycle of the Zostera species. As a result of these surveys, there is a better understanding of the distribution of seagrass genus along the metro coast, shown in **Figure 44**. Specifically, the study noted that it Zostera restoration presents difficulty along the metro coast due to the timing of seed release.

Across all 37 sites shown in Figure 23 (left) the mean coverage for the following species was *Posidonia* (10%), *Amphibolis* (3%), *Zostera* (2%) and *Halophila* (0.6%).

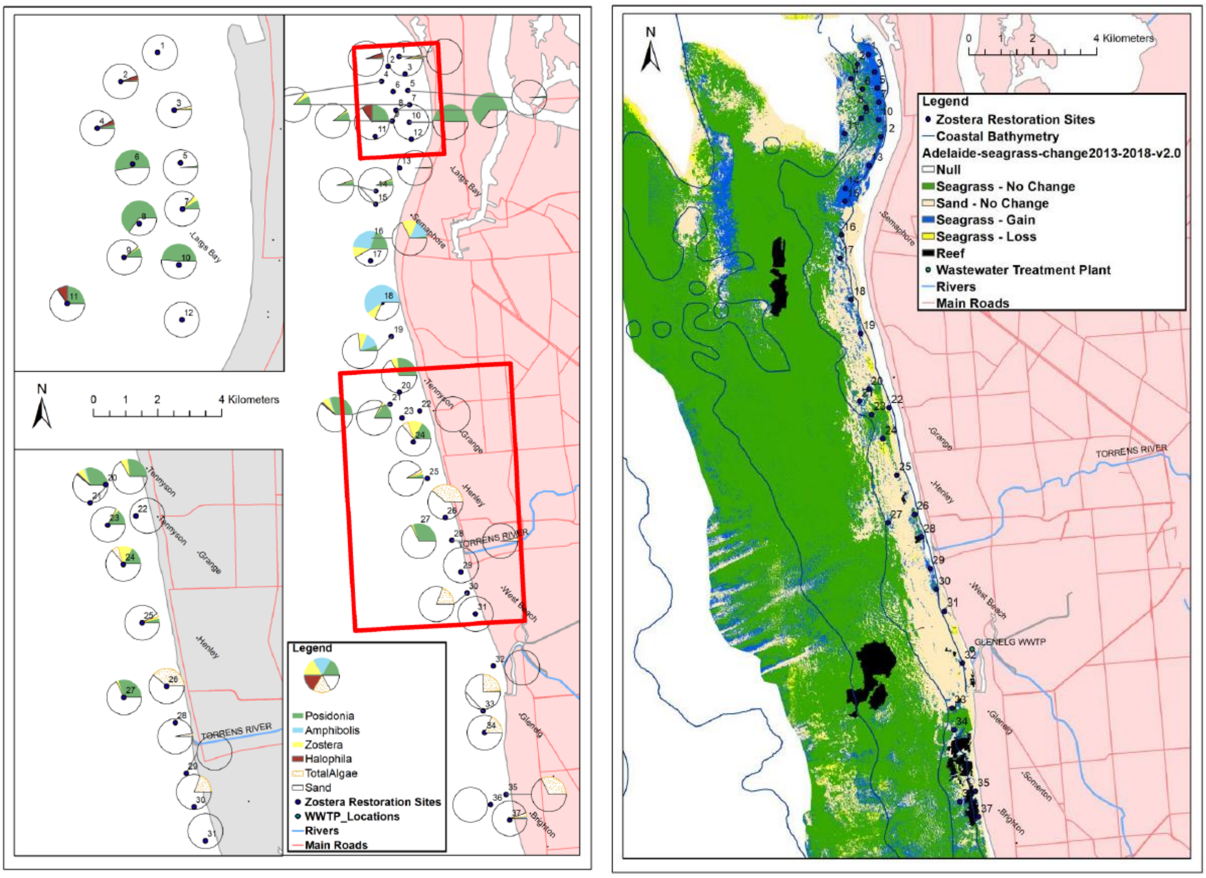

Figure 44: Composition of Zostera restoration sites (left) and Seagrass change between the period of 2013 to 2018 (right) (Tanner, 2021).

The review of available information on the recovery and restoration efforts of seagrass show that the identified borrow sites (nearshore and offshore) avoid areas with active regrowth or restoration efforts and that there has been little change in coverage due to these efforts.

Coverage in offshore areas

Coverage data in offshore areas is less detailed and accurate due to limitation is penetration of light at deeper water depth limiting the use of remote sensor monitoring (i.e. satellite imagery). However there have been studies that have used field observations to calibrate mapping outputs. A recent monitoring study conducted as part of the Outer Harbour Channel Widening project in 2019 provided pre and post-works seagrass mapping using video drops for calibration and ground-truthing. The species outlined in the report are consistent with other studies highlighting that *Posidonia* and *Amphibolis* dominated the meadows with lower concentrations of *Halophila* and *Zostera* also present.

Benthic surveys were conducted by DEW in 2023 to inform identified borrow areas as part of the ABMR scientific report (Bluecoast, 2023) as well as additional observations as part of the sediment sampling campaign described in Section 3 by JBS&G (2024a) and Bluecoast (2024b). These observations are mapped in Figure 45. There is variability in the coverage for A3 and BO2 with only limited coverage in BO1.

For further investigations to determine the feasibility of these regions, the benthic mapping requirements should be defined so that the mapping can align with a resulting outcome. The available data indicates that these sites are likely suitable with low seagrass coverage but additional coverage surveys should be conducted.

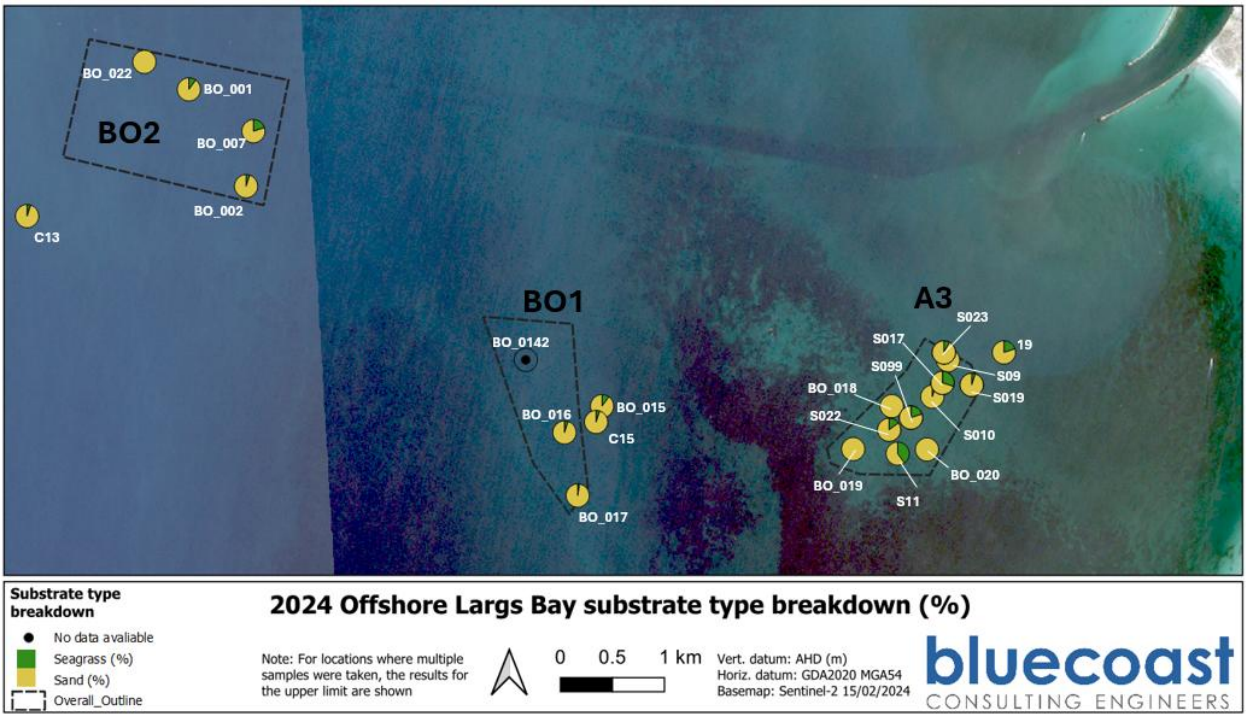

Figure 45: Benthic observations in identified offshore borrow areas.

Appendix F: Sampling and analysis plan (SAP) implementation report

Appendix G: Supporting information – sand compatibility and seagrass coverage assessment results