MEMO

To:	South Australian Department for Environment and Water
Att.:	Jason Quinn
Cc:	Kia Ly
From:	Méven Huiban
DHI ref.:	43804410
Date:	22 June 2023
Subject:	2023 Update of the sand volume analysis along West Beach

1 Introduction

In 2017, DHI was engaged by the Department for Environment and Water (DEW) to undertake an investigation of the West Beach sediment cell, to identify the causes of long term and ongoing recession of the shoreline, and to evaluate a range of management options for this sediment cell.

During this project, a detailed analysis of bathymetry data, coastal profiles and historical nourishment volumes led to the development of a conceptual model of the coastal processes causing erosion at West Beach. The understanding of the coastal processes allowed the establishment and calibration of a coastal sediment transport model of the West Beach sediment cell.

The results of this assessment were documented in a detailed technical report (Ref. /1/)

Since the completion of the study, DEW has continued the collection of detailed profile surveys in December/January each year. Consequently, the data for additional years can be analysed and used to inform the recent evolution of the sand volumes in the West Beach sediment cell. Ref /2/ to Ref /4/ present the yearly analysis of the data collected from 2018 to 2020, in January 2021 and in December 2021/January 2022.

This document presents the results of the analysis of the profiles collected until January 2023. In addition to the coastal profiling survey, DEW has captured LiDAR data sets covering West Beach in 2022 and 2023. The comparison between the two images is also reported in this document.

2 Analysis of the profiles

2.1 Methodology

To allow direct comparison with the previous results, the same methodology has been applied to the recently collected survey. As a reminder, the littoral volume analysis is based on the following principles:

- For each profile, the volume of sand per metre is integrated from the back of the dune system out to -5 m AHD, which is the estimated depth of closure. The beach volume per metre of beach length has been calculated for all available profiles. In case a measured profile does not extend below -5 m this profile was not included in the analysis. Profiles not extending above 0 m were also excluded.

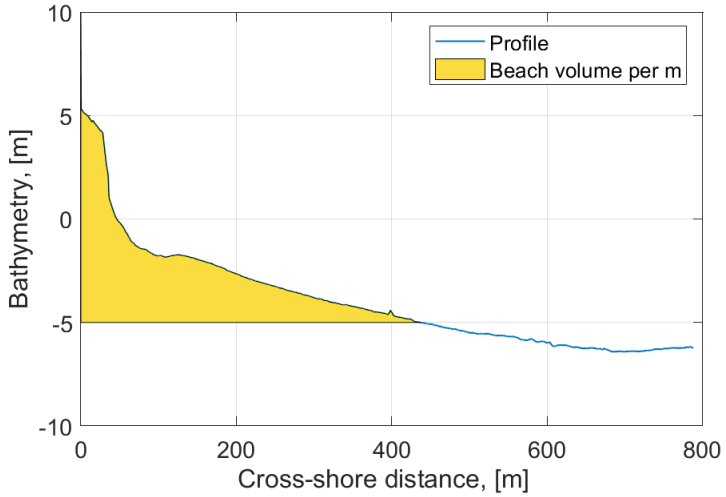

Figure 2-1 Computation of the volume of sand per metre in the surveyed profiles.

- To reconcile the different timings of the surveys throughout the years, the volumes at each profile were interpolated in time, by linear interpolation, to provide an estimated volume on Jan 1st for each year at each profile and facilitate subsequent analysis over the entire cell.
- The total littoral volume is calculated by trapezoidal integration per metre between each surveyed profile, as schematically illustrated in the figure below, where the total volume of sand (in yellow) is integrated from the discrete volume per metre in each profile (in blue).

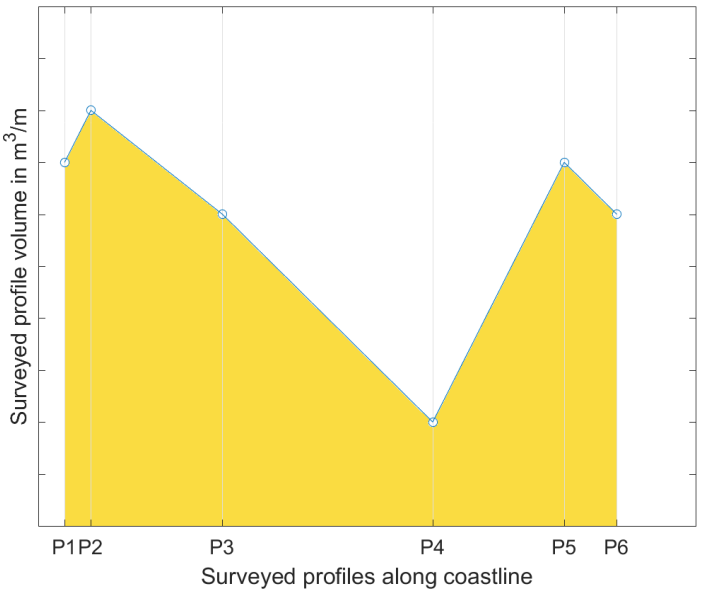

Figure 2-2 Integration of the volume of sand per metre to compute the total littoral volume in the sediment cell.

For the assessment of the West Beach sediment cell, the analysis is based on the five profiles indicated in Figure 2-3.

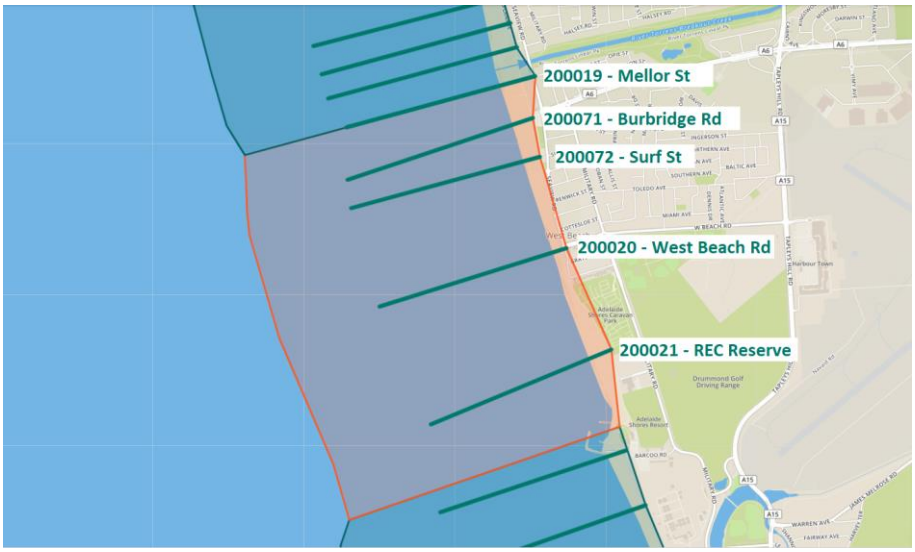

Figure 2-3 Overview of profiles located within the West Beach sediment cell.

2.2 Results

Figure 2-4 presents the results of the analysis in terms of volume of sand in the cell. It is reminded that some adjustments had to be made on the profiles to account for non-representative alterations of the profiles at the REC Reserve profile location (see Ref. /2/) and West Beach Rd. location (see Ref./3/).

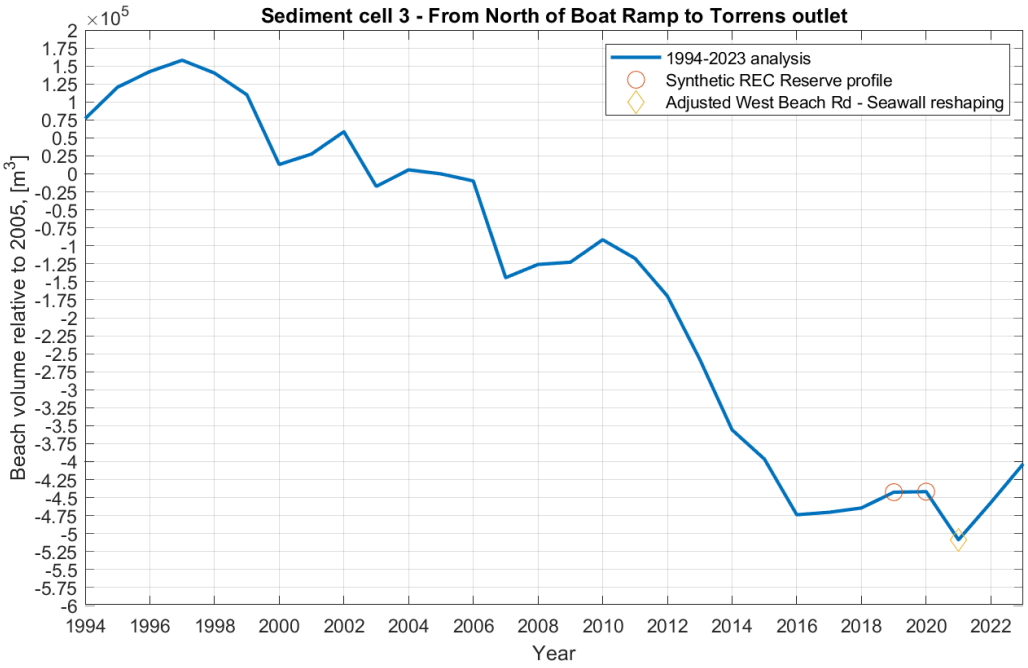

Figure 2-4 Change in West Beach sediment cell volumes relative to the volume in 2005, including 2023 surveys.

Based on the analysis of the profile surveyed in 2023, the estimated volume of sand has increased by ~+55,000 m^3 during the 2022 calendar year. This balance is the result of the combined effect of the natural net littoral drift towards North, which tends to remove sand from the sediment cell, and the addition of sand during nourishment activities.

3 Analysis of LiDAR

The limitations associated with the profile-based methodology are described in the previous updates of the estimated volume (see Ref./2/ to Ref./4/). To complement the profiles, DEW has initiated the capture of regular LiDAR DEM captured by drone. These additional datasets specifically inform the upper part of the cross-shore profile.

At this stage, two datasets have been taken, in January 2022 and March 2023. This section presents a first analysis of these datasets aiming at complementing the profiling surveys in the process of tracking the sand volume evolution in the West Beach Sediment cell.

3.1 Methodology

Figure 3-1 presents the two LiDAR datasets captured by drone on the 8th of January 2022 and 11th March 2023. The table below summarises key characteristics of the provided datasets.

Id	Date of capture	Horizontal projection	Vertical Datum	Resolution
1	January 8, 2022	MGA-54	AHD	20cm
2	March 11, 2023	MGA-54	AHD	25cm

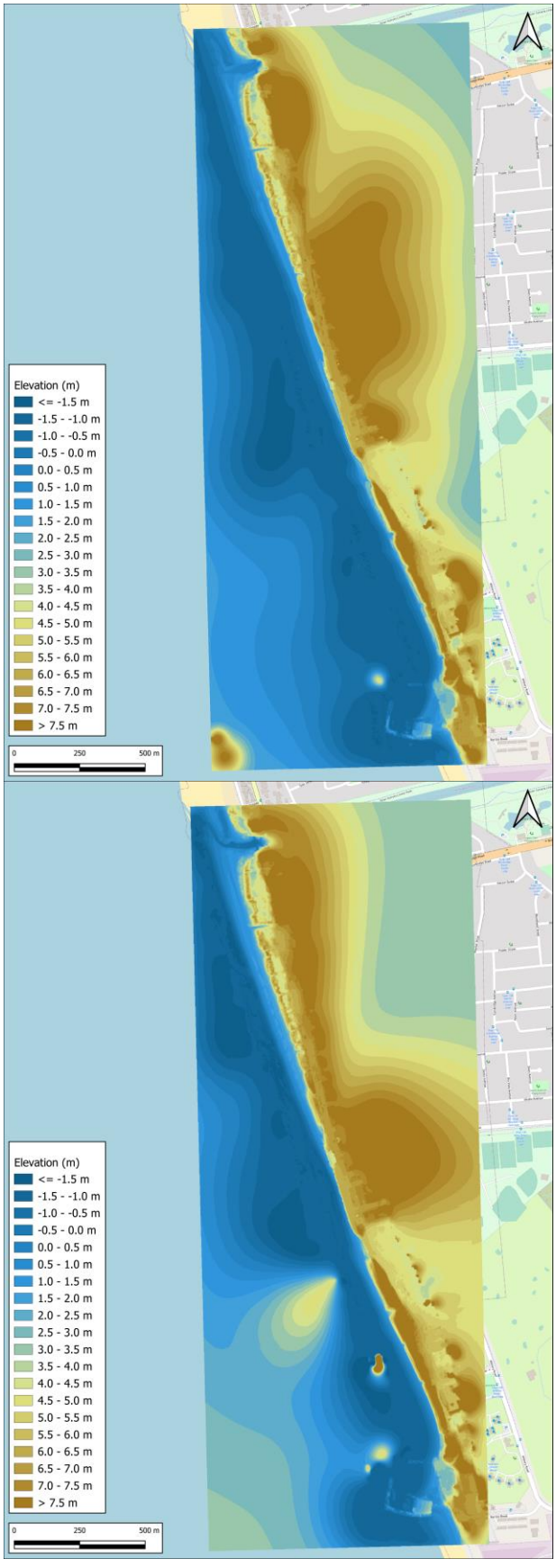

Figure 3-1 LiDAR data captured in January 2022 (upper) and March 2023 (lower), as provided by DEW.

The following comments can be made on the captured LiDAR and subsequent analysis of the datasets:

- The provided DEMs are derived from drone flight lines covering a relatively narrow band along the West Beach coastline (See below illustration showing raw data and flight lines). Outside of the flown over area, extrapolation has been applied, leading to erroneous elevation values, both on land and offshore.

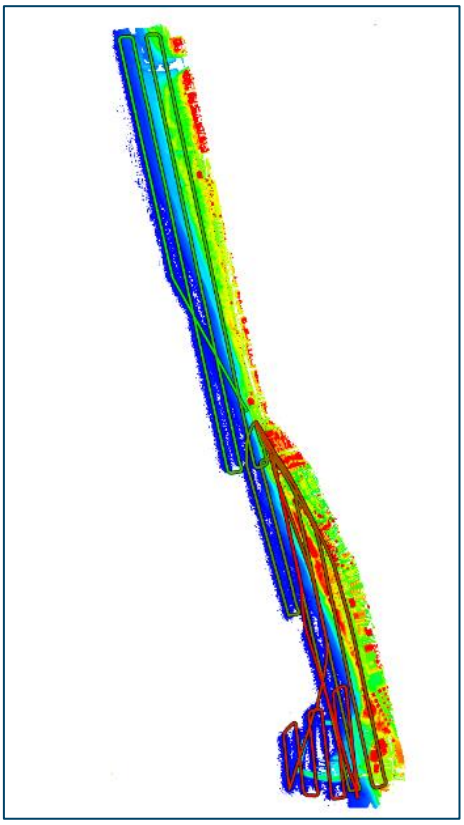

Figure 3-2 Raw flight tracks, as captured by the data provider, prior to interpolation on the provided regular grid.

- The LiDAR data supplier indicated that during the capture in March 2023, some wave run-up could potentially have affected the measurements in the wet part of the profile. However, it is very difficult to assess how the collected data is affected quantitatively.
- The capture of bathymetry using LiDAR technology is depth-limited, due to light penetration limitations and can therefore only inform the upper part of the profile.

To estimate the evolution of the sand volumes in the area covered by the DEMs, the following methodology is applied:

1. The two Lidar DEMs have different horizontal resolutions (8 January 2022: 20cm, 11 March 2023: 25cm). The datasets are interpolated on a common grid, with a resolution of 1m, covering the entire surveyed area.
2. The difference between the two grids is computed for the entire domain.
3. The volume difference is integrated within a defined polygon to filter out unrealistic/unreliable values, as described previously.

3.2 Results

Figure 3-3 presents the difference between the two datasets restricted to the selected integration polygon (in green).

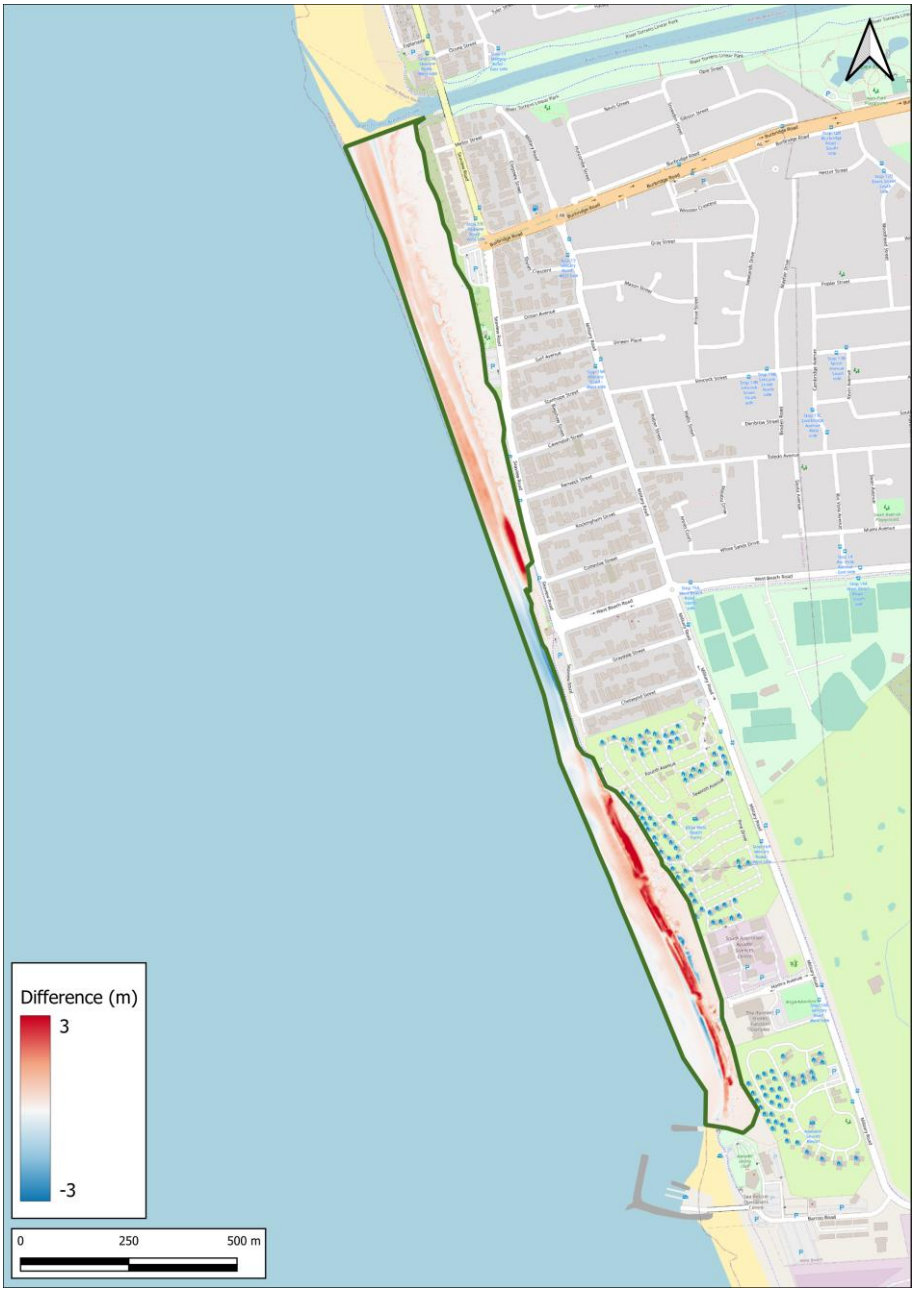

Figure 3-3 Evolution of the elevation between January 2022 and March 2023. Red indicates accretion.

Comparing the 2023 dataset to the 2022 dataset, the estimated volume variation within the polygon represents an increase in sand volume of approximately ~+45,000 m^3. Erosion is seen along the West Beach seawall (elevation loss reaches -2.5 m locally) whereas an accumulation of sand is seen along the rest of the coast, especially on the upper part of the profile. This is a function of the initial large replenishment volume along the seawall rapidly eroding due to wave action. Subsequent replenishment has targeted the dunes south of the seawall and immediately to the north of the seawall (see Section 4.1).

The variation observed between the two LiDAR DEMs also highlights the importance of having more than 5 profiles to capture the longshore evolution. As an example, the significant volume increase North of the seawall seen in the LiDAR is not captured by the 5 surveyed profiles analysed in Section 2.

4 Discussion

4.1 Nourishment activities in 2022

This section provides an overview of the nourishment activities conducted along West Beach in 2021 and 2022. Figure 4-1 presents the various zones targeted by the nourishment activities as summarised in Table 4-1.

Figure 4-1 Delineation of the nourishment zones along West Beach for the 2021/2022 nourishment campaign.

As indicated in the table below, a total 131,000 m^3 of quarry sand was added to the West Beach Sediment cell. Based on the reported volume, Zone 5 benefitted from the largest total nourishment volume amongst all zones. This, however, corresponds to 80 m^3/m - below the average of 93 m^3/m considering the nourishment per unit beach length.

Table 4-1 Summary of the nourishment activities along West Beach in 2021 and 2022.

Stage	Date		Area						
	Start	Finish	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Total
Stage 1&2	19/08/2021	5/10/2021	13,762	10,662	10,264	13,301			**47,988**
Stage 3	5/10/2021	10/12/2021					61,417	9,546	**70,963**
Stage 4	31/01/2022	14/04/2022			9,139	12,312	37,288	12,184	**70,923**
Stage 5	2/05/2022	17/05/2022	5,863	4,797					**10,659**
Stage 6	18/07/2022	5/09/2022	9,751	9,751	10,548	11,045	2,748	6,152	**49,995**
Total Zone (m^3)			**29,375**	**25,210**	**29,952**	**36,657**	**101,454**	**27,881**	**250,530**
Total Zone in 2022 (m^3) Stages 4-6			15,614	14,548	19,687	23,357	40,036	18,336	**131,578**
Zone longshore length (m)			250	140	135	230	500	150	**1405**
Volume per lineal meter of beach (m^3/m)			**62.5**	**103**	**146**	**101.5**	**80**	**122**	**93.5**

4.2 Weather climate in 2022

Based on information provided by DEW, 2022 was generally stormier than recent past years, with many Adelaide beaches affected by erosion through winter and spring. It has also been indicated that Henley Beach has not yet recovered (in April 2023).

Between May and November 2022, the Outer Harbour Tide Gauge located in North Haven (approximately 17 km North of West Beach) recorded 20 events with a peak water level above or higher than 3.0 m CD (1.55 m AHD). This water level is approximately equivalent to a 1:1 annual occurrence event. Based on DEW observations, the cumulative impact of 20 such events last year appeared to result, at least anecdotally, in similar erosion to one or two severe events.

Water levels were particularly high in May and June 2022, with 9 days recording peaks as below:

Date	Recorded Peak Water Level (m CD)
2 May	3.1
3 May	3.1
16 May	3.1
17 May	3.1
30 May	3.5
31 May	3.1
3 June	3.1
5 June	3.2
15 June	3.3

4.3 Conclusion

This technical memo presents the results of two different methods to assess the evolution of the volume of sand in the West Beach sediment cell in 2022, based on cross-shore profile surveys and LiDAR DEM captured by drone. The two methods are not directly comparable as they cover different spatial and temporal extents. However, the two methods are complimentary on informing the trends observed in the area.

The profile analysis indicates an increase of the sand volume present in the West Beach Sediment cell. The estimated increase in volume is ~+55,000m^3 for the entire cell in 2022.

The LiDAR analysis focuses on the establishment of the evolution of the sand volume (between January 2022 and March 2023) in the upper part of the profile (~-1.5 m and above) and the analysis led to an estimated increase of +45,000 m^3 within the polygon of integration.

Nourishment activities brought approximately 130,000m^3 of sand to the area in 2022. Based on the estimated volume changes for 2022, this would indicate that the annual littoral drift was in the order of 80,000 m^3. This estimate is significantly lower than the estimated typical littoral drift derived from the long-term analysis completed in 2018 (100,000 m^3/yr in average +/- 50,000 m^3/yr), see Ref. /1/.

Given the relatively energetic and stormy climate experienced in 2022, this below-average estimated littoral drift is unexpected and additional investigations should be made to confirm this result. However, the following comments can be made at this stage:

- Based on information provided by DEW, the quarry sand delivered between 18/08/2021 and 05/09/2022 is coarser (d_{50} = 0.305 mm) than the native marine sand present in the area (d_{50} = 0.169 mm, based on sample taken south of West Beach Harbour, see Ref. /6). Mobilisation and transport of this material is more difficult than the natural marine sand.
- Numerical modelling considering quarry sand only and an artificial equilibrium profile was conducted in 2022 (considering d_{50} = 0.37 mm, see Ref. /5/) and led to an estimated reduction of the littoral drift of approximately 35%, compared to similar simulation conducted considering d_{50} = 0.18 mm, see Ref. /1/).
- With the introduction of quarry sediment through the nourishment campaign, a mixture of natural and quarry sands is present in the West Beach sediment cell. A detailed assessment, in the form of sampling and numerical modelling, could inform on the littoral drift affecting this mixture of sediments.

5 References

/1/ DHI, August 2018, *West Beach Coastal Modelling Processes, Assessment of Coastal Management Options.* Technical report prepared for DEW.

/2/ DHI, August 2020, *Analysis of the 2018 to 2020 profiles along West Beach.* Technical memo prepared for DEW.

/3/ DHI, February 2021, *2021 revision of West Beach Sediment cell sand volume estimation.* Technical memo prepared for DEW.

/4/ DHI, April 2022, *Analysis of the 2022 profiles along West Beach,* Technical memo prepared for DEW.

/5/ DHI, March 2022, West Beach Fine Sediments and Nourishment Modelling, Report prepared for DEW.

/6/ DEW, March 2022, *Metro Coastline Sand Sampling.*