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R1668 Rev 1

May 2022

City of Joondalup

Joondalup Coastal Monitoring 2021/22 Data Report

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1. Introduction

The City of Joondalup (City) has established a coastal monitoring program for the shoreline within its boundaries. The City's shoreline extends from Marmion in the south, to Burns Beach in the north. The extent and key locations are presented in Figure 1.1.

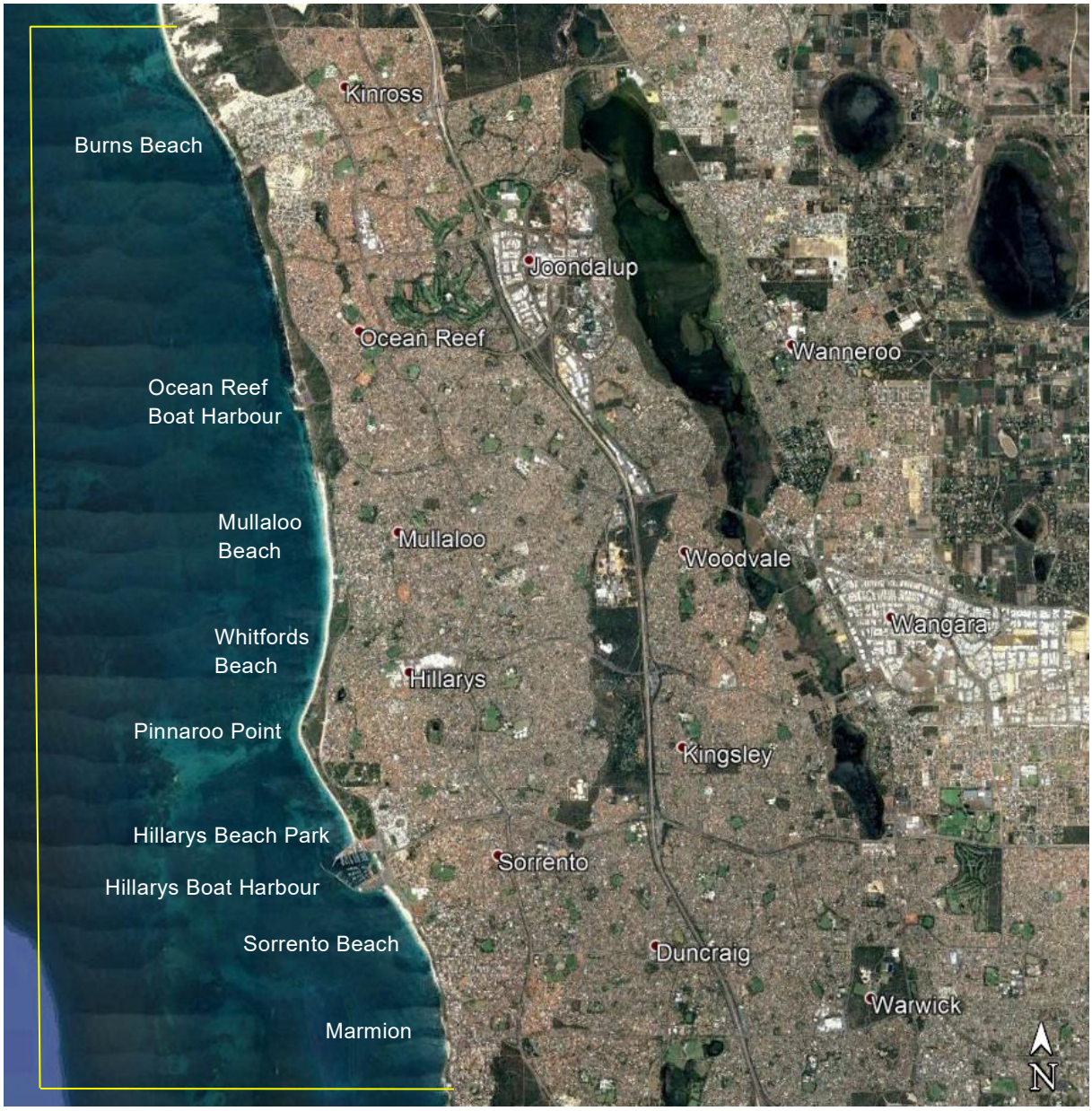

Figure 1.1 Joondalup Coastal Monitoring Study Area

The Joondalup coastal monitoring program has been set up to monitor changes to the shoreline within the study area, and to assist the City in managing their coastal assets. The monitoring program was established under a Coastal Adaptation and Protection grant from the Department of Transport (DoT) in 2015 and includes the following elements.

- Beach and hydrographic surveys conducted every 2 years, from behind the primary dune to several hundred metres offshore. 22 profiles are completed over approximately 15 km.

- Inspections and photographic monitoring of the beaches within the study area every six months.
- Mapping of the shoreline from aerial photographs taken every year.
- Analysis of the monitoring surveys by experienced and professional coastal engineers, identifying areas of accretion or erosion.
- Implementation of a fixed monitoring camera to monitor the shoreline in Marmion (now redundant).
- A report on the monitoring results and analysis each year, highlighting notable variations in shoreline movements and metocean conditions.

The data and assessment is used to identify areas of concern and inform decision making for development and maintenance of coastal assets.

The City has engaged M P Rogers & Associates Pty Ltd (MRA) to complete the coastal monitoring of the shoreline within the study area.

This report presents a summary of the monitoring results from Financial Year 2021/22. Comparative analyses with the monitoring data collected in previous years have also been completed and are discussed in the following sections.

The coastal management works completed within the period are outlined and recommendations for future monitoring and management are provided.

2. Monitoring Activities

The Joondalup coastal monitoring program includes the following monitoring activities.

- Beach profiles (survey).
- Shoreline mapping (coastal vegetation line mapped from aerial photographs).
- Photographic monitoring (seasonal).
- Temporary camera monitoring.

The results of the monitoring are presented in annual Coastal Monitoring Data reports. Table 2.1 presents the recently completed and planned monitoring activities.

Table 2.1 Proposed Monitoring Frequency

Activity	Frequency	2018/19 FY		2019/20 FY		2020/21 FY		2021/22 FY		2022/23 FY	
		October 2018	March 2019	October 2019	March 2020	October 2020	March 2021	October 2021	March 2022	October 2022	March 2023
Beach profiles survey	Biennial			✓				✓			
Shoreline mapping	Annual	✓		✓		✓		✓		✓	
Photographic monitoring	6 monthly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fixed camera monitoring	Continuous (daily)	✓	✓	✓	✓	✓	✓				
Temporary camera monitoring	During Severe Event - Annual									✓	

Notes: 1. Program established in 2015.
2. Completed works have been highlighted in green.
3. Proposed works have been highlighted in blue.
3. FY – Financial year.

The surveyed beach profiles will notionally be completed in October every 2 years, following winter. It is important that they are completed at the same time each period (following winter) to minimise the impact of seasonal changes on the shoreline data.

The shoreline mapping will be completed by mapping the position of the coastal vegetation line from ortho-rectified aerial photography. The shoreline mapping will be used to assess shoreline movement and monitor large scale trends in movement. The mapping should be completed annually and use aerial photographs from consistent times of the year to remove any seasonal variations from the record.

Photographic monitoring will be completed at 21 fixed sites notionally in March (end of summer) and October (end of winter) each year. The photographic monitoring and will assist in highlighting seasonal movements on the shoreline and visually show any changes to beaches, as well as providing a long term reference of shoreline condition.

The monitoring activities carried out in the 2021/22 Financial Year monitoring period will be discussed in the coming sections, including comparisons with the previous year's (2020/21) dataset. This will help to highlight areas of change and to inform future monitoring and management requirements.

2.1 Recommendations of Previous Monitoring

The previous coastal monitoring report (MRA 2021) assessed the changes to the shoreline and made several recommendations to the City. These are outlined below:

- Continue to monitor and actively manage (if required) erosion between and including Hillarys Beach Park and Pinnaroo Point.
- Continue to complete annual sand bypassing around Hillarys Boat Harbour (around 10,000 to 15,000 m^3, depending on budget) to address the recession identified at Hillarys Beach Park and Pinnaroo Point.
- Continue to specifically monitor the shoreline movement at Burns Beach.

These recommendations have been considered in relation to the October 2021 and March 2022 monitoring data captured.

3. Metocean Analysis

An assessment of the metocean conditions experienced in 2021 has been completed by analysing relevant water levels and wave data provided by DoT. Water levels were taken from the Fremantle Fishing Boat Harbour (FFBH) tide gauge, whilst wave measurements were taken from an offshore directional wave rider buoy, located south west of Rottnest.

3.1 Water Level Analysis

Water level measurements taken from FFBH were analysed for the entirety of 2021. The mean water level experienced in 2020 was 88.8 cmCD, which was 11 cm greater than the 2019 mean and 6 cm greater than the 2020 mean. This was largely a result of a number of high water level events that occurred from May through August and demonstrates the elevated water levels which may lead to increased erosion to dunes and the rear of the beach.

In particular, each time the water level exceeds 160 cmCD represents an exceedance of the 1 year Average Recurrence Interval (ARI) water level. Where the water level exceeds 180 cmCD is an exceedance of the 5 year ARI water level event (MRA, 2018c). Clearly, 2021 was an above average year in terms of a large number of high water events. This has likely been a major contributing factor to the erosion observed at the City's beaches.

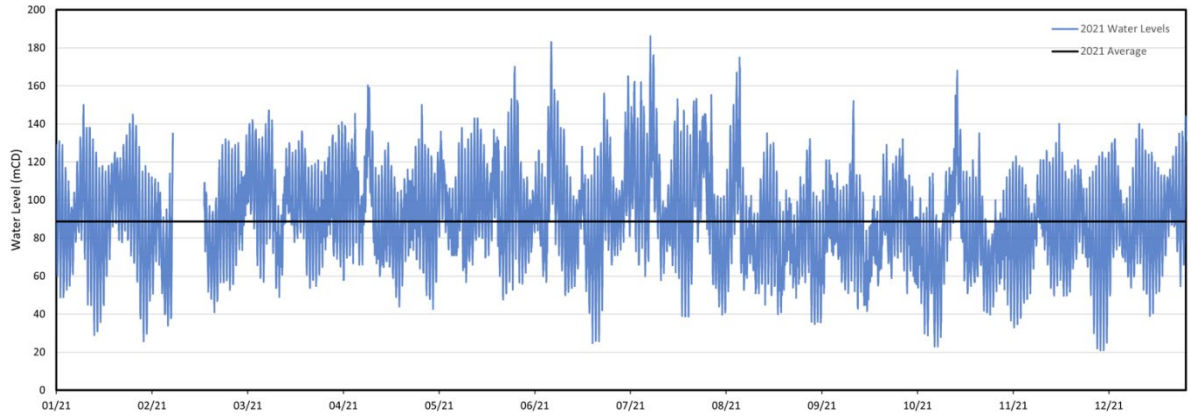

Figure 3.1 Water Levels at FFBH 2021

To assess the long term trends in water levels, MRA have previously plotted mean water levels from FFBH. This assessment has been updated with the 2021 average, and is presented in the figure below.

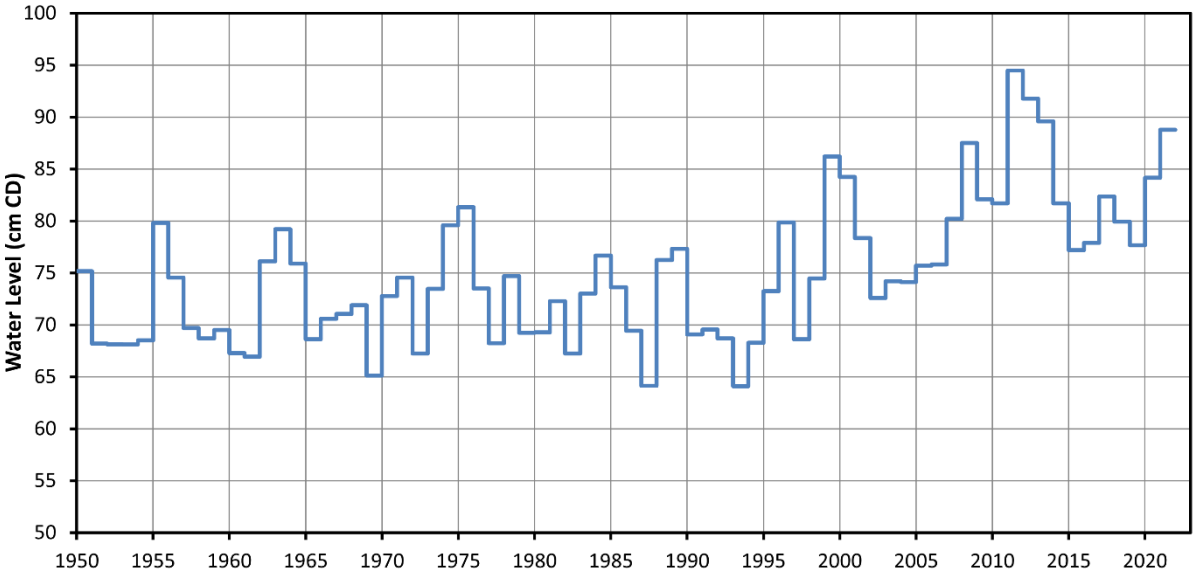

Figure 3.2 Mean Water Levels at FFBH (1950 to 2021)

The figure indicates that since 1995, there has been an upward trend in mean water levels as a result of sea level rise. The figure also shows the increase in mean water levels between 2019 and 2021.

MRA have also previously analysed extreme water level events from 1950, which provides a reliable long-term record. The metocean conditions experienced in 2021 contained 4 of the top 50 highest water levels recorded at FFBH since 1950, as presented in the figure below. The elevated water levels, typically associated with storm surges from severe storm events, indicates that 2021 was a particularly stormy year. The figure also indicates that extreme water level events have occurred more frequently in recent years as a result of longer term sea level rise.

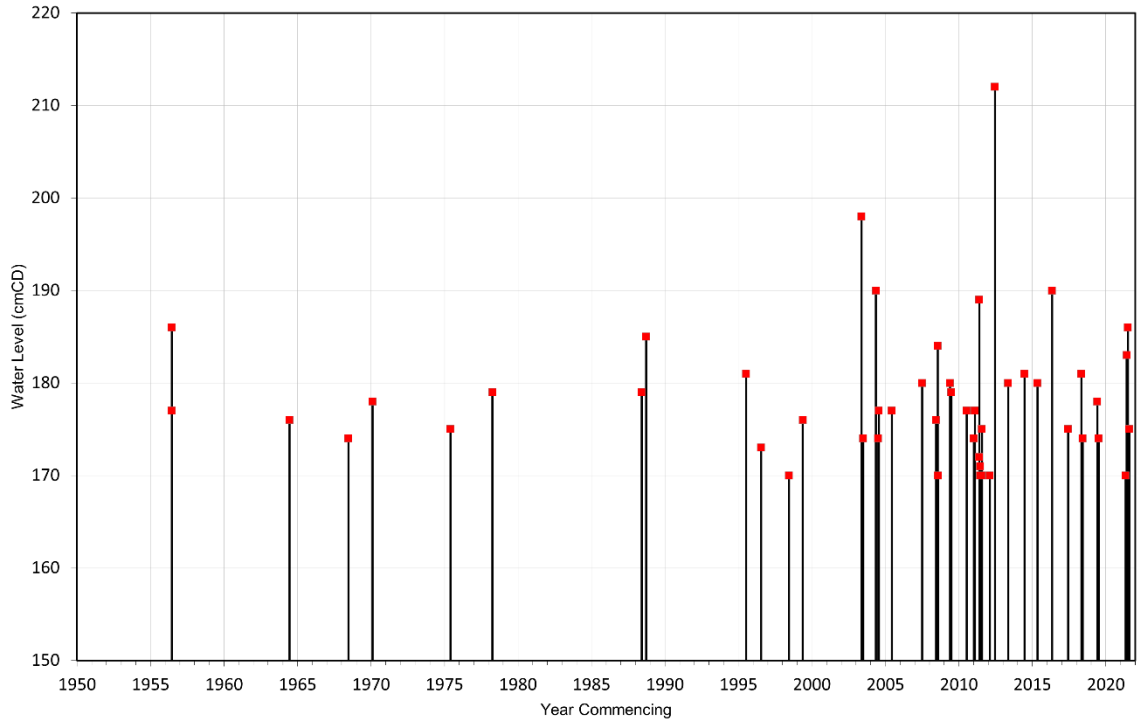

Figure 3.3 Top 50 Water Level Events 1950 – 2021

3.2 Wave Analysis

Wave data from the DoT's offshore wave rider buoy located south west of Rottnest was analysed. Moderate and severe storm events were assessed in the record. Severe storm events, defined as days when the significant wave height is greater than 6 m and associated with strong onshore winds leading to a large sea component, are evident in the figure below. The findings were that:

- 2021 experienced approximately 5 days of severe storm conditions, all in July and August.
- The most severe wave event occurred in August 2021.
- Overall, Rottnest experienced a lengthy winter storm season with sustained moderate to severe wave events.
- The severe wave events typically align with high water events as shown in Figure 3.1. This would exacerbate beach erosion.

A time series of wave heights recorded in 2021 is presented below. The figure also indicates the sea and swell components of the total combined wave height.

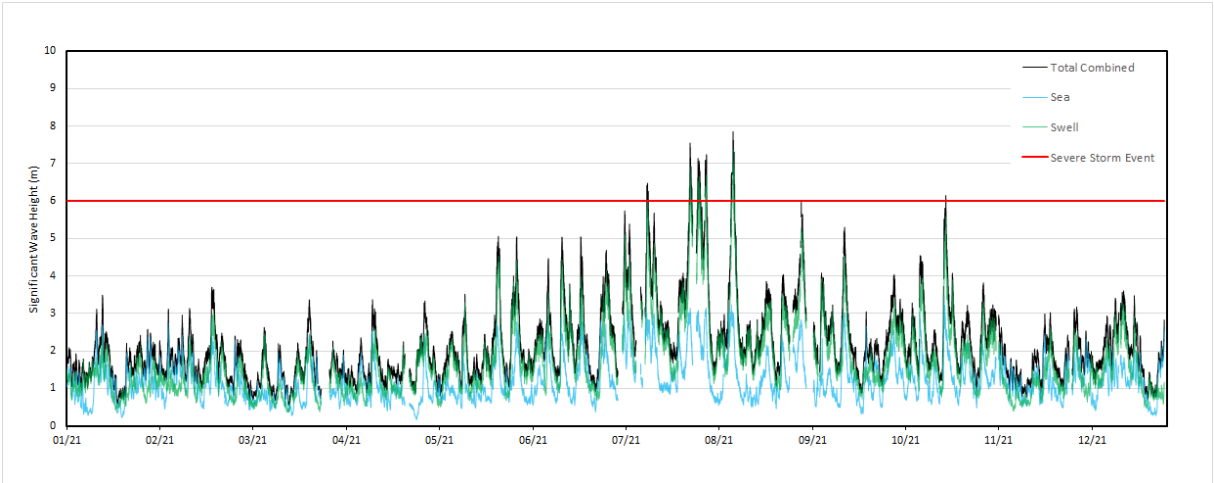

Figure 3.4 Significant Wave Heights – 2021

The combination of sustained large waves coincident with high water levels is expected to have resulted in significant shoreline erosion over the winter 2021 season. High water levels combined with large wave run-up can often erode up to and behind the vegetation line. We would therefore expect to see narrow beaches and erosion of the dune at the rear of the beach in the October 2021 profile surveys.

4. Shoreline Movement

4.1 Mapping

The movement of a shoreline can be estimated through mapping the position of the coastal vegetation line from aerial photography. The vegetation line is a good indicator of the shoreline position, as it generally represents the limit of coastal processes and is less susceptible to short term fluctuations than other markers such as the waterline. By mapping the historical position of the vegetation line, changes to the shoreline can therefore be estimated.

For the Joondalup coastal monitoring program, mapping of the coastal vegetation line provides a continuous estimate of the shoreline position for the study area. This expands upon the beach survey profiles used to represent the various shoreline sectors.

A shoreline movement plan covering the study area was previously prepared and presented in the baseline monitoring data report (MRA 2016). A detailed description of the source of the aerial images used for shoreline mapping has been presented in MRA (2016).

In each subsequent monitoring period, the shoreline movement plan has been updated to include vegetation line mapping from the most recently available ortho-rectified aerial imagery provided by the City. The vegetation line mapping has been completed based on DoT (2009) and has an estimated accuracy within the order of ±5 m, depending on the resolution of the aerial photographs and the rectification process.

The shoreline movement plan has been updated with the October 2021 vegetation line and is presented in Appendix A.

Using the updated shoreline movement plan, the relative movements of the mapped coastal vegetation lines were estimated at 100 m intervals along the shoreline. These chainages are presented in Figure 4.1.

Figure 4.1 Shoreline Movement Chainage Plan

4.2 Shoreline Movement Analysis

The shoreline movements over the past year (August 2020 to October 2021) and between 2015 and 2021 have been generally assessed from the shoreline movement plans.

The net movements were in some cases made up of varying inter-annual changes. The following annual movements were noted in the assessment of shoreline movement.

- There were considerable amounts of erosion (up to 8 m) and areas of accretion along the City's coastline between August 2020 and October 2021.
- The overall change to shoreline position between 2015 and 2021 is generally less than 5 m. The only notable exceptions occurred at the following previously identified sites:
    - Hillarys Beach Park.
    - Pinnaroo Point.
    - The northern end of Burns Beach.

The movement in the shoreline position is presented in the following figure. While historical vegetation lines date back to 1942, significant changes to the sediment movement dynamics in the area were caused by the following developments:

- Construction of Ocean Reef Boat Harbour.
- Construction of Hillarys Boat Harbour (HBH).
- Construction of the Sorrento groyne field.

The current reconstruction of the Ocean Reef Marina will potentially lead to changes in future coastal dynamics and shoreline movements, which will need consideration in future years.

The first available vegetation lines after these developments (1987 and 1996) are therefore used as the baseline for analysis in Figure 4.2. This has been discussed in detail in previous monitoring reports and assessments for the City (MRA 2016, MRA 2017, MRA 2018b and MRA 2019)). It should be noted that the gaps in the shoreline movement plot (Figure 4.2) represent sections of rocky shoreline or coastal structures where this method of coastal monitoring is not applicable.

The shoreline movement for the areas that were previously identified as requiring specific monitoring (Hillarys Beach Park, Pinnaroo Point and Burns Beach) have been assessed in more detail with the updated shoreline movement data. These areas are identified in Figure 4.3. Extracts showing the vegetation lines between 2015 and 2021 for each of the locations are provided below and discussed thereafter.

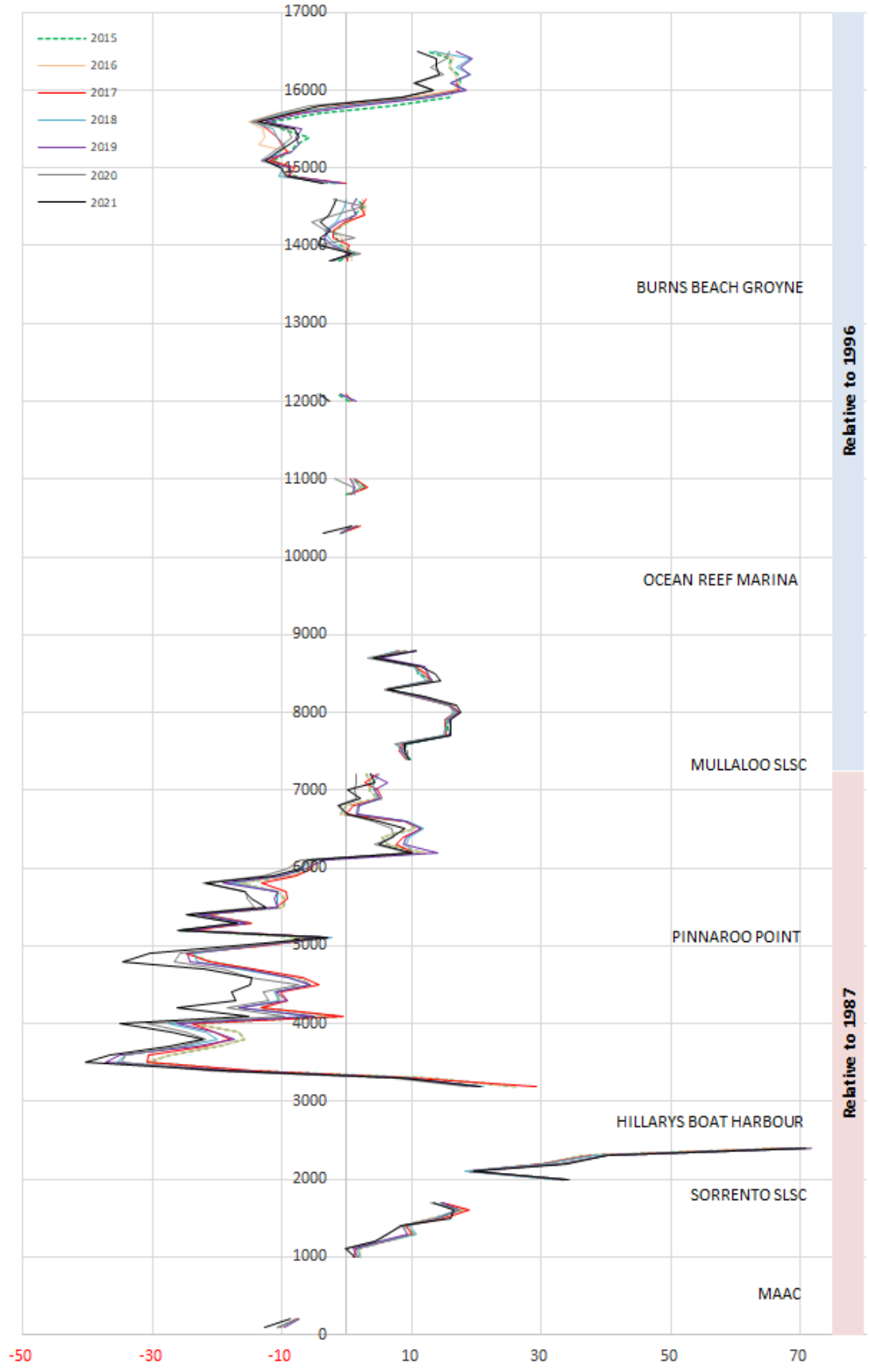

Figure 4.2 Shoreline Movement to 2021

Figure 4.3 Previously Identified Sites for Further Investigation

4.2.1 Hillarys Beach Park

Figure 4.4 Recent Shoreline Movement at Hillarys Beach Park

The shoreline fronting Hillarys Beach Park, north of Hillarys Boat Harbour, experienced recession of up to 8 m between August 2020 and October 2021. This was recognised as the continuation of a previously identified erosion trend. However, the almost 8 m recession recorded in this period is considerably more than in previous years (MRA 2020a, MRA 2021). Overall, the vegetation line at Hillarys Beach Park has receded more than 40 m since 1987.

Multiple severe storm events impacted the City's coastline throughout Winter 2021. The increase in water levels during these events allow waves to reach high levels on the beach, which cause erosion into the dune system and recession of the vegetation line. These storms contribute to the increase in yearly recession of the vegetation line at Hillarys Beach Park.

The sand bypassing works completed in November 2021 have also influenced the shoreline fronting Hillarys Beach Park. This will be discussed further in Section 7.

4.2.2 Pinnaroo Point

Figure 4.5 Recent Shoreline Movement at Pinnaroo Point

The shoreline at Pinnaroo Point has receded considerably since 2020. The vegetation line within 500 m either side of Pinnaroo Point experienced changes of up to 8 m between August 2020 and October 2021. This is notably more than the recession experienced in recent years. At chainage 4800 m, 100 m south of Pinnaroo Point, the shoreline has receded 35 m since 1987.

Similar to Hillarys Beach Park, the metocean conditions experienced in 2021 and the sand bypassing works are likely to have influenced the Pinnaroo Point shoreline. This is discussed in more detail in Section 7 of this report.

4.2.3 Burns Beach

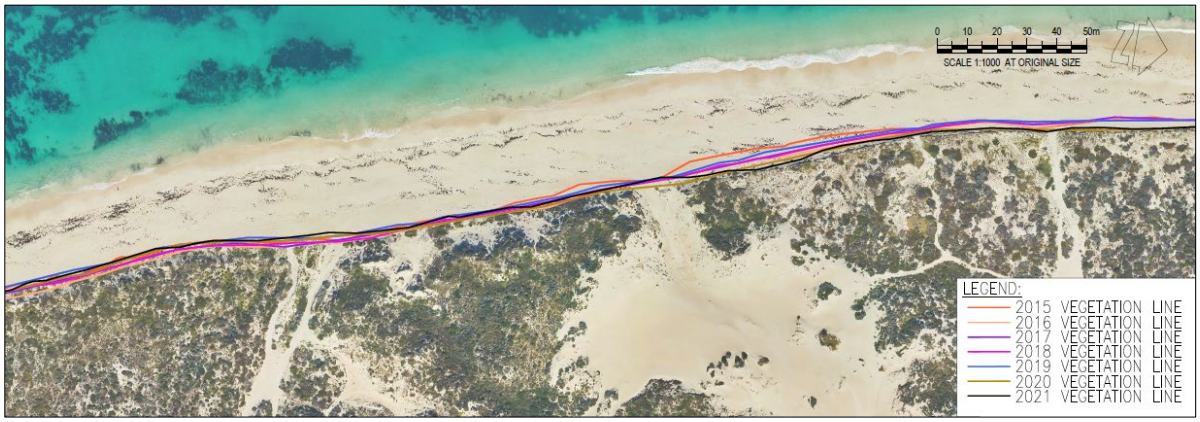

Figure 4.6 Recent Shoreline Movement at Northern End of Burns Beach

The shoreline along Burns Beach generally experienced mild accretion of up to 2m between August 2020 and October 2021. This is notably in contrast to the recession of up to 7 m between August 2019 and August 2020. The severe storm conditions and high-water levels experienced in 2020 are likely to have influenced the recession of the vegetation line. It is apparent from the periodic photographic monitoring at this site that the beach profile exhibits considerable seasonal variation. The severity of the seasonal metocean conditions and timing of the aerial imagery are likely to have an impact on the annual position of the vegetation line at this location. This observation is supported by the Photographic Monitoring discussed later in this report and included in Appendix D.

5. Beach Survey Profiles

A beach monitoring program has been established to monitor the shoreline within the City's boundaries. Beach and hydrographic surveys are collected and analysed to allow long-term changes in shoreline position and coastal processes to be monitored.

The beach monitoring program consists of 22 profiles across the full extent of the City's coastline. Survey profiles 8, 9 and 10 were unable to be captured during the October 2021 round of monitoring as a result of the construction of the Ocean Reef Marina. The locations of the profiles are shown in Figure 5.1.

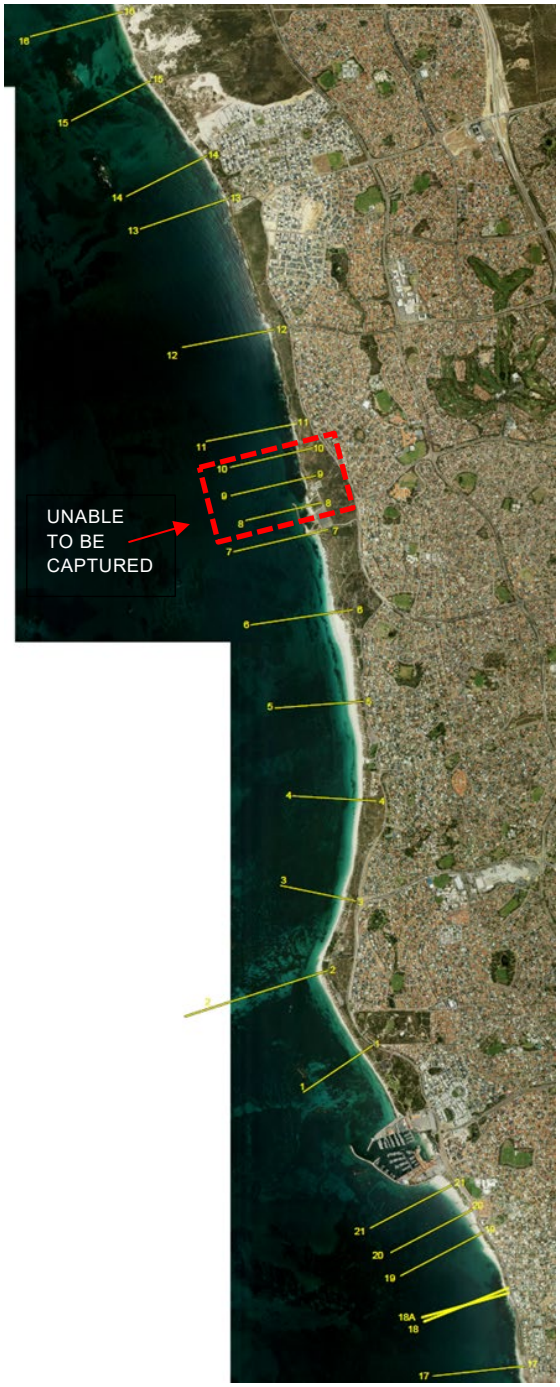

Figure 5.1 Location of Beach Monitoring Survey Profiles

The locations of the profiles are also provided in more detail in Appendix B. The beach survey profiles are provided in Appendix C.

All of the surveyed profiles extend from behind the coastal dune to approximately 1 km offshore to capture the extent of sediment movement and accurately assess the shoreline changes and coastal processes.

5.1 Investigation Triggers

The trigger values for investigation of shoreline recession in the area were set at:

- 5 m recession of the Mean Sea Level (MSL), approximated as the 0 mAHD contour.
- 5 m recession of vegetation line, approximated as the +3.5 mAHD contour.

These are referenced to the baseline position (2015).

The MSL contour or waterline is a short-term indicator of shoreline change, but is susceptible to fluctuations and short-term movements. The vegetation line is a commonly used indicator of longer term change and trends. Discussion of these triggers is presented in MRA (2016).

5.2 Movement of MSL Contour (0 mAHD)

Table 5.1 presents the positions of the shoreline at the end of winter (October). Profiles where the MSL contour has receded by more than the trigger value are highlighted grey in the table. Figure 5.2 presents the change to the MSL since 2015 graphically.

Table 5.1 Position of the MSL

Survey Profile	Nov 2015	Oct 2017	Oct 2019	Oct 2021	Change from 2019 to 2021 (m)	Change from Baseline (m)
16	66.9	73.7	70.7	70.9	0.2	4.0
15	46.9	58.3	48.3	55.2	6.9	8.3
14	56.5	56.9	54.9	56.2	1.3	-0.3
13	34.2	32.2	31.4	30.4	-1.0	-3.8
12	75.2	71.8	73.1	75.5	2.4	0.3
11	55.1	53.3	54.9	54.1	-0.8	-1.0
10	183.7	184.6	181.0	OCEAN REEF MARINA		
9	146.9	147.2	148.4			
8	OCEAN REEF BOAT HARBOUR					
7	N/A	N/A	233.3	231.8	-1.5	N/A
6	201.8	N/A	195.1	195.4	0.3	-6.4
5	141.3	127.5	139.9	137.6	-2.3	-3.7
4	187.4	192.5	192.8	187.4	-5.4	0.0
3	170.3	163.3	162.7	160.8	-1.9	-9.5
2	108.8	100.1	101.4	90.1	-11.3	-18.7
1	142.2	137.4	138.9	138.6	-0.3	-3.6
21	80.6	80.0	85.8	74.9	-10.9	-5.7
20	93.6	100.5	97.8	96.6	-1.2	3.0
19	44.8	43.2	45.8	40.4	-5.4	-4.4
18	33.2	33.0	33.6	34.6	1.0	1.4
17	38.0	36.3	37.2	43.4	6.2	5.4

Notes: 1. Values in table are position in metres, relative to a nominal baseline.
2. Positive values indicate accretion, negative values (in red) indicate recession
3. The MSL is approximated by the 0 mAHD contour.
4. Changes that have exceeded the trigger value have been highlighted in grey.

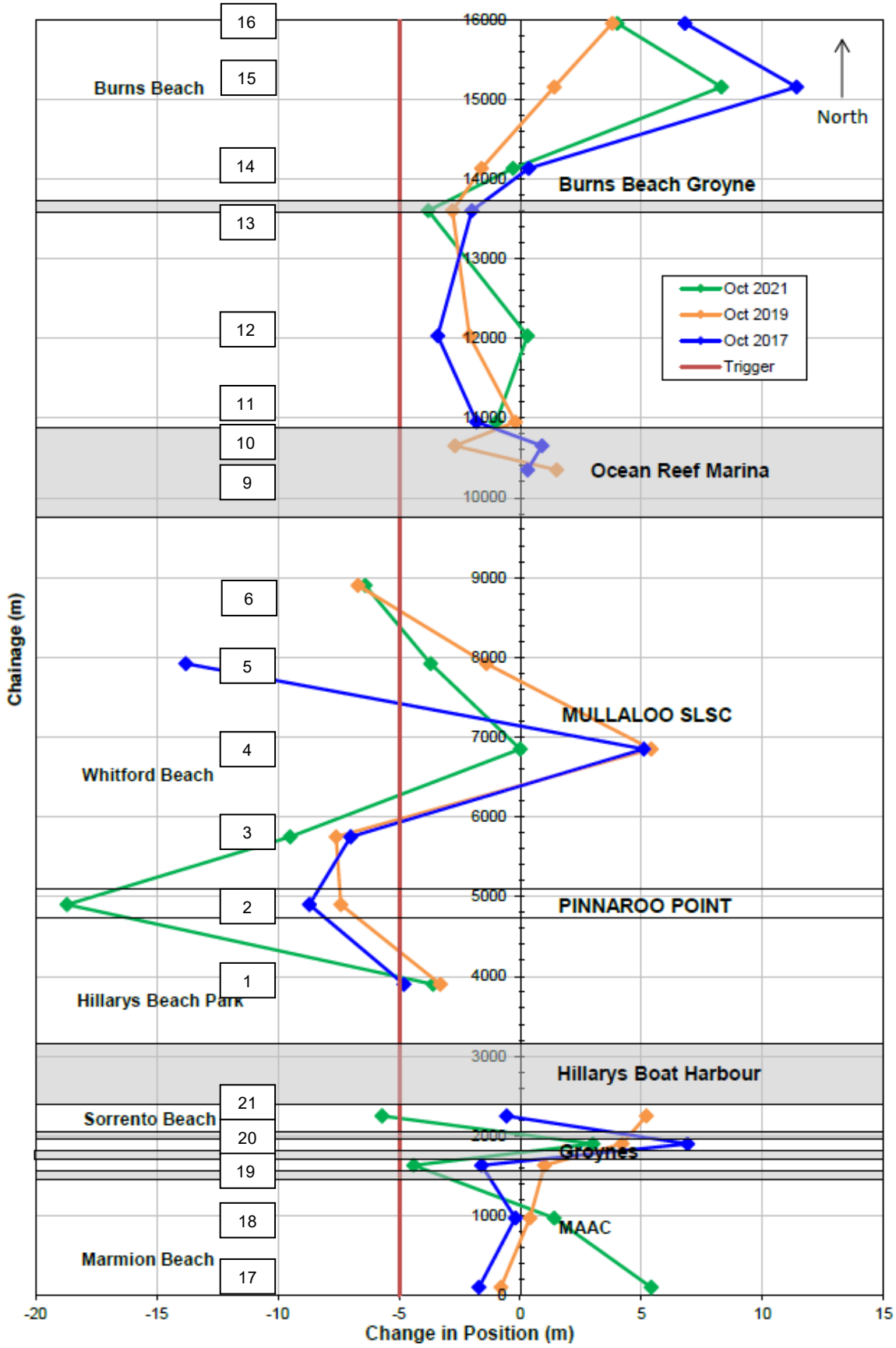

Figure 5.2 Position of 0 mAHD Relative to 2015 Baseline

The following observations are noted for the past 2 years.

- The shoreline at Profile 2 at Pinnaroo Point has eroded a substantial amount since 2019. The MSL has receded 18.7 m since the baseline, which is considerably larger than the investigation trigger value of 5 m.
- Profile 3 at Whitfords Beach has undergone minor erosion since 2019. The position of the MSL relative to the baseline is greater than the investigation trigger value.
- Profile 6, south of Ocean Reef Marina, has been stable since 2019, however the position of the MSL relative to the baseline is still greater than the investigation trigger value.
- Profile 21 at Sorrento Beach has eroded over 10 m since 2019. The MSL has receded over 5 m since 2015, greater than the trigger. It should be noted that between the 2019 and 2021 surveys, two rounds of sand bypassing have removed approximately 8,700 and 8,000 m^3 from Sorrento Beach. This removal of sand is a contributor to the change in the position of the MSL contour.
- All profiles north of Burns Beach groyne have accreted since 2019.
    - Profile 14 has accreted 1.3 m over 2 years, and has receded 0.3 m over 6 years.
    - Profile 15 has accreted 6.9 m over 2 years, and has accreted 8.3 m over 6 years.
    - Profile 16 has accreted 0.2 m over 2 years, and has accreted 4.0 m over 6 years.

5.3 Movement of the Approximated Vegetation Line (+3.5 mAHD)

Table 5.2 presents the position of the vegetation line contour at the end of winter (October). The +3.5 mAHD contour is used as a representation of the coastal vegetation line from the surveys.

Figure 5.3 presents the change to the vegetation line since 2015 graphically.

Table 5.2 Position of the Approximated Vegetation Line Contour

Survey Profile	Nov 2015	Oct 2017	Oct 2019	Oct 2021	Change from 2019 to 2021 (m)	Change from Baseline (m)
16	28.6	28.1	28.0	24.4	-3.6	-4.2
15	15.0	16.0	15.7	13.0	-2.7	-2.0
14	22.0	21.8	20.5	19.5	-1.0	-2.5
13	7.4	8.0	6.1	5.3	-0.8	-2.1
12	49.3	49.8	47.9	44.6	-3.3	-4.7
11	35.2	36.5	35.3	34.9	-0.4	-0.3
10	165.0	165.5	165.9	OCEAN REEF MARINA		
9	122.8	122.6	122.2			
8	OCEAN REEF BOAT HARBOUR					
7	140.3	140.2	141.5	137.9	-3.6	-2.4
6	187.8	187.9	188.1	188.1	0.0	0.3
5	90.8	91.3	92.5	94.9	2.4	4.1
4	159.5	162.8	164.2	161.7	-2.5	2.2
3	135.8	135.9	132.6	127.8	-4.8	-8.0
2	71.5	71.3	70.1	63.4	-6.7	-8.1
1	121.0	116.0	116.1	111.4	-4.7	-9.6
21	6.7	16.2	16.8	16.7	-0.1	10.0
20	SORRENTO SLSC					
19	16.0	17.8	18.2	16.2	-2.0	0.2
18	7.6	8.6	8.7	9.4	0.7	1.8
17	16.5	17.1	17.3	15.1	-2.2	-1.4

Notes: 1. Values in table are position in metres, relative to a nominal baseline.
2. Positive values indicate accretion, negative values (in red) indicate recession
3. The MSL is approximated by the 0 mAHD contour.
4. Changes that have exceeded the trigger value have been highlighted in grey.

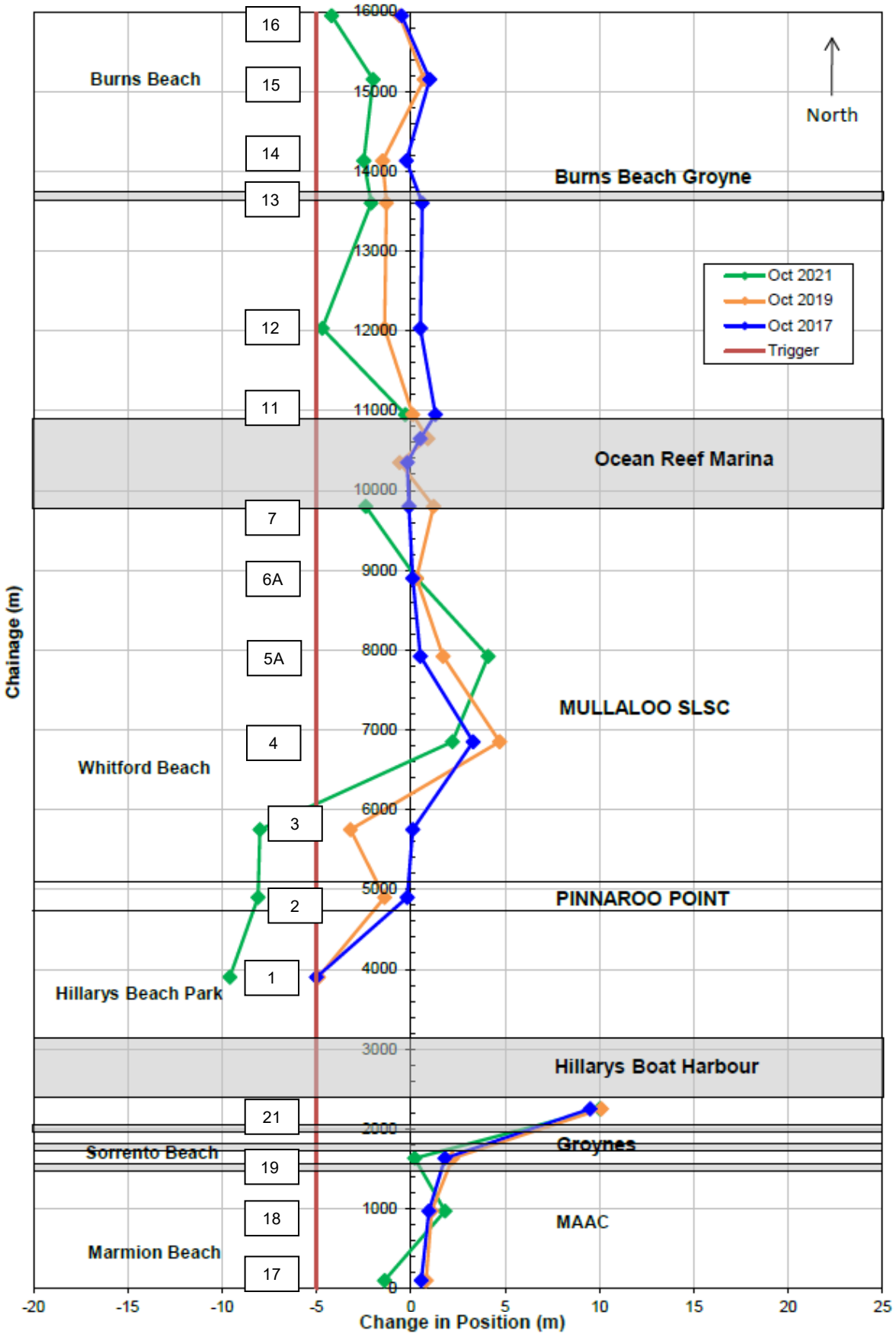

Figure 5.3 Position of Vegetation Line Relative to 2015 Baseline

As expected, changes to the +3.5 mAHD (approximate vegetation line) contour are not as large as the MSL, as it is a longer-term indicator of shoreline change and less susceptible to fluctuation and short-term changes. However, Profiles 1, 2 and 3 are above the trigger value for erosion. These profiles have all eroded more than 4.5 m since 2019.

Sand bypassing operations have been completed annually since 2018 around Hillarys Boat Harbour to address the recession identified at Hillarys Beach Park and Pinnaroo Point. This is further discussed in Section 7 of this report.

At Sorrento Beach (profile 21) the survey data shows that the 0 mAHD contour (MSL) has receded by 5.7 metres since baseline monitoring began, this is in contrast to the accretion of the +3.5 mAHD contour (vegetation line) by 10 metres relative to baseline. While this initially appears contradictory, the sand by-passing supply area is close to the waterline of Sorrento Beach which is why a recession has been noted in the MSL. The recorded recession may be to do with timing and layout of the survey with respect to the sand removal works. The sand-passing volume is considered to be less than the sediment arriving onshore at Sorrento, the accretion of the vegetation line is considered to be a resultant of the anticipated surplus of material which is likely wind blown and is contributing to dune growth and vegetation line accretion.

The changes to the approximate vegetation line contour approximately align with the changes to the vegetation line assessed from aerial photography.

6. Photographic Monitoring

6.1 Periodic Photographic Monitoring

The coastal monitoring program includes seasonal (March and October) photographic monitoring of specific locations within the study area. Through the use of a specific field of view (FOV), photographic monitoring programs can be used to obtain visual estimates of the changes occurring on the coast. Erosion and accretion trends can be observed, while photos taken at more frequent intervals can capture seasonal movements or the changes due to storm events. Figure 6.1 presents the location and orientation for all the points used in the photographic monitoring program.

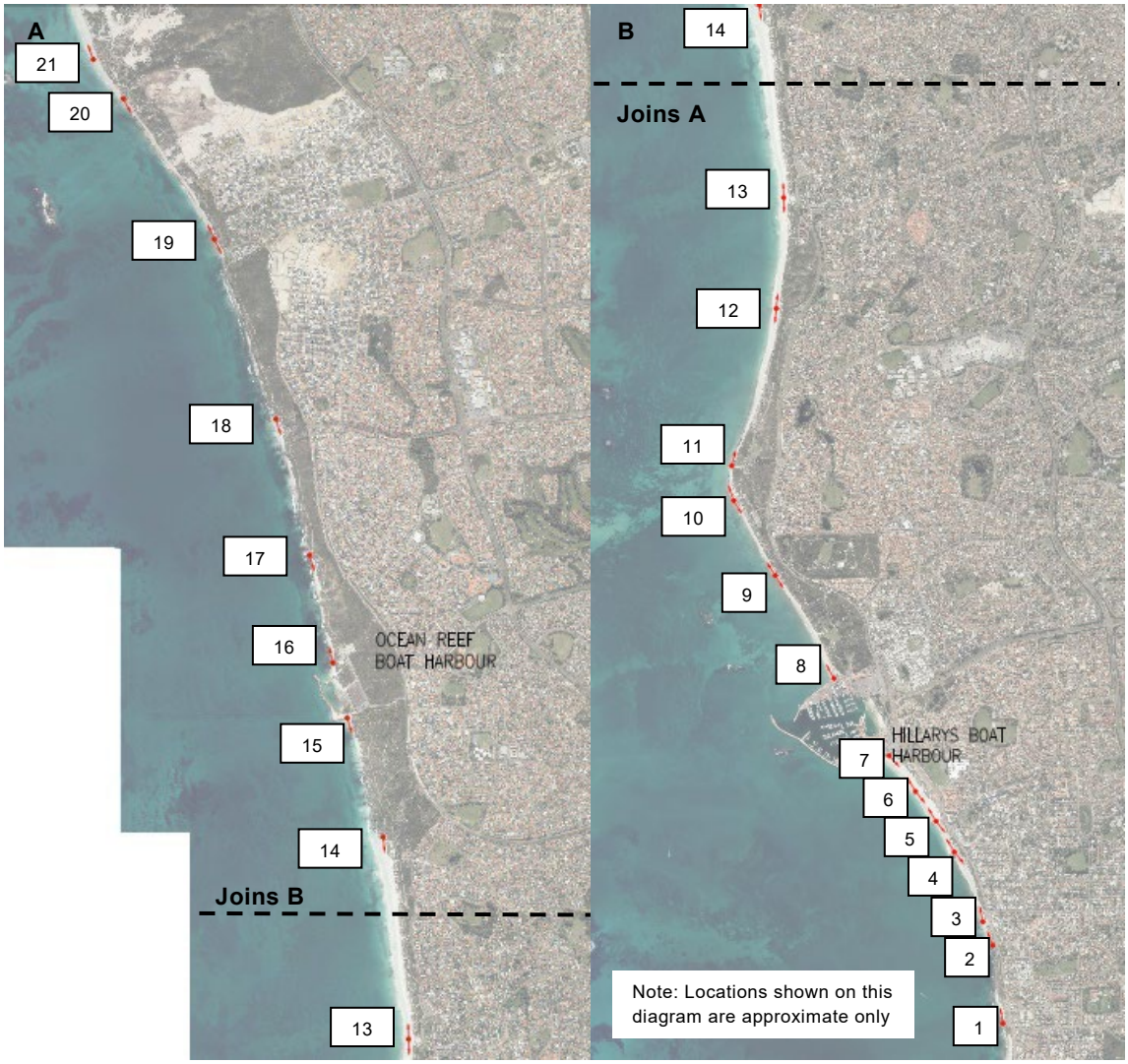

Figure 6.1 Photographic Monitoring Locations

A drawing presenting the photographic monitoring locations, with the survey profile locations, is included in Appendix B.

A summary of the photos taken at each monitoring location are included as Appendix D.

The photographs collected from the 21 photographic monitoring locations were inspected and compared to the photographs from previous monitoring periods. This shows both seasonal and

inter-annual changes to the beach at a number of locations. The photographs show erosion of the primary foredune and recession of the vegetation line at and around Pinnaroo Point. This is consistent with observations from the shoreline mapping. The beach at Hillarys Beach Park also to be receding, despite the annual sand bypassing campaign around Hillarys Boat Harbour.

Locations 20 and 21 (the northern end of Burns Beach) appear to be characteristic of shorelines that exhibit large seasonal variability. In March (following the summer season) the beaches appear receded and steep, often with an erosion scarp. In October (following winter) the beaches appear flatter and wider. This is likely due to the sediment dynamics of the area, with summer weather patterns removing material, and winter weather depositing material on the shore and/or removing material from the primary dune and depositing it on the beach face. The large seasonal variability of this area is an example of why seasonal weather severity and timing of shoreline mapping and surveying can impact the results of the coastal monitoring.

Analysis of the periodic photographs at Location 1 (Marmion) shows a slight recession of the vegetation line and the formation of an erosion scarp in the foredune. This is mostly noticeable at the southern end of the beach and is consistent with mapping of the vegetation line in the Shoreline Movement Plan shown in Appendix A.

There were no additional significant areas of change identified from the monitoring photographs. Many of the sites exhibit seasonal changes in beach profile which varies in magnitude based on the severity of the seasonal weather pattern. The periodic photographic monitoring has been completed twice annually since 2015 and trends are becoming emergent in the seasonal variations of the City's beach profiles. This is useful for the management of coastal erosion risks as well as adaptive planning for coastal assets. It is recommended this monitoring practice is continued going forward, so that all sites can continue to be inspected for trends in movement and changes in key areas.

6.2 Fixed Camera Monitoring

The coastal monitoring program initially involved the use of a fixed monitoring camera that captured daily photographs at the Marmion Angling Aquatic Club (MAAC). This location was chosen because of an identified risk to the carpark asset (upgraded in 2016) if severe erosion were to occur. However, the fixed camera was stolen in May 2021, prompting a re-evaluation of whether a fixed monitoring camera at this location is the most appropriate to capture change.

Since the setup of the camera in 2017, the shoreline and dune in front of the carpark and MAAC has not experienced any significant long term erosion or accretion. The dune face that provides a foundation for the carpark has exhibited an increase in vegetation over the past 4 years which appears to be stabilising the dune as seen in Figure 6.2. There is also the presence of cobble-size rocks at the base of the slope which appear to be acting as scour protection during moderate to high water events. While there is still a risk to the carpark if the dune were to be eroded, particularly in extreme weather events, minimal net change in the beach profile and dune face was recorded throughout the duration of the fixed camera monitoring program. It was therefore decided to not install another fixed camera at this location. This location will continue to be monitored via surveying and periodic photo monitoring.

Figure 6.2 L) 2017 Commencement; R) 2021 Conclusion

In previous annual monitoring reports completed for the City, the photos captured by the fixed monitoring camera were analysed for movement to quantitatively measure changes over time. This was intended to be completed again this year, however, due to the theft of the camera is not possible and has subsequently been omitted.

Instead, the utilisation of a temporary camera at a point of interest (Hillarys Beach Park, Pinnaroo Point, Burns Beach) to capture a severe storm event is being investigated. This will provide the City useful data in helping to manage coastal assets that are located in areas that have historically eroded or are at risk from erosion due to severe weather events.

7. Coastal Management Works Completed

The City undertakes active coastal management works as part of their routine operations. This includes items such as the following.

- Management of sand accumulation.
- Management of dune and beach fencing.
- Management of beach access ways, including following storm events.
- Sand bypassing.

The following sections outline the larger scale coastal management works completed within the City over the past 4 years. Coastal management activities can have a significant influence on coastal dynamics and movements and need to be considered in assessing the monitoring data.

7.1 Sand Bypassing

MRA (2018) recommended that sand bypassing be completed around Hillarys Boat Harbour to assist with the following:

- Reducing the continued erosion trend observed north of Hillarys, including at Hillarys Beach Park and Pinnaroo Point.
- Assist with sand accumulation issues at the accreting Sorrento beach.

MRA (2021) recommended that the sand bypassing volume be increased (10,000 to 15,000 m^3) to address the continued recession identified at Hillarys Beach Park and Pinnaroo Point. The 2021/22 bypassing was undertaken in October/November 2021 and is shown in the following figures.

Figure 7.1 Extraction Area Looking South

Figure 7.2 L) Disposal Area Looking North; R) Graded Disposal Area

Pre and post works surveys were completed by JBA Surveys and are provided in Appendix E. These survey plans show the pre and post works contours as well as the areas, depths and volume differences determined between the two surveys.

Based on these surveys and the Contractor's measured truck volumes, the bypassed volume was estimated and summarised in Table 7.1. The estimated volumes bypassed in previous operations are also provided for information.

Table 7.1 Estimated Sand Bypassing Volumes

Date	Approximate Sand Bypassing Volume (m^3)
December 2018	8,400
March/April 2020	8,700
March 2021	8,000
October/November 2021	8,000

A summary of the bypassing works and potential impacts are outline below.

- The 8,000 m^3 bypassed is less than the 10,000 m^3 target recommended for the works. This is significantly less than the amount of sediment movement out of these areas in recent years and some recession would still be expected.
- A significant amount of material was extracted from the waterline, which was intended as per the Drawings and Specification for the works (MRA 2020) and will assist the beach at Sorrento in naturally accreting.
- The grading in the disposal area appears to adhere to the requirements given in the Drawings.

Observations from the most recent round of monitoring indicate that the vegetation line at Hillarys Beach Park is still receding, although there appears to be more sand accumulation on the beach face close to the Hillarys northern breakwater which is indicative that the sand bypassing program

may be helping to slow the recession. The recession of the vegetation line has been likely been contributed to by the metocean conditions encountered in 2021.

It is important to note that the most recent sand bypassing operations were completed following the October 2021 surveys, photo monitoring and vegetation line mapping. This means that the effectiveness of the most recent bypassing is not evident in that data.

Nevertheless, the overall erosion seen at Hillarys Beach Park and Pinnaroo Point has continued since the commencement of the bypassing. This is because the volume bypassed does not offset the amount of sand being lost along and cross-shore at these locations. Without meeting the designated targets, it is expected that the shoreline at these locations is going to continue to recede.

The quantity of sand bypassed has consistently been lower than the targets. This is not due to a supply issue, with Sorrento Beach having a significant reserve capacity compared to the amount required for the works. We understand this has largely been due to difficulties experienced by the Contractor's in accurately measuring and recording the volumes by-passed and bulking factors which may not have been properly accounted for in some of the works.

It is evident that the sediment volumes that have been bypassed are not significant enough to completely offset the observed shoreline retreat at these locations. The City could look to increase future sand bypassing targets or look to progress the longer term adaptation options for this section of coastline. The City is currently preparing a Coastal Hazard and Risk Management Plan (CHRMAP) to inform future decision making about the management of coastal assets in areas experiencing erosion. The erosion experienced at Hillarys Beach Park and Pinnaroo Point will need to be considered in the City's future adaptation planning.

7.2 Dredging at Ocean Reef Boat Harbour

The DoT has historically managed the Ocean Reef Boat Harbour and dredged sand from the entrance of the harbour to maintain navigability. The dredge spoil was generally disposed of on the southern side of the harbour in winter, to encourage transport to the south over winter months.

The historical dredging operations are presented in the table below. The construction of the new Ocean Reef Marina began in 2021 and no further dredging has been undertaken in the period since 2019.

Table 7.2 Historical Dredging at Ocean Reef Boat Harbour

Year	Volume Dredged (m^3)	Volume Bypassed (m^3)
1982 to 2010	76,985	Nil
2011	3,542	1,087
2012	-	2,645
2013	6,031	3,030
2014	3,000	3,350
2015	5,660	5,960
2016	-	5,200
2017	-	-
2018	6,000	-
2019[1]	4,350	4,350

Notes: 1. No maintenance dredging has been carried out since 2019.

The table shows that between 2011 and 2019 approximately 3,600 m^3 was removed from the entrance channel and harbour each year and approximately the same amount has been deposited off the southern breakwater.

7.3 Construction of Ocean Reef Marina

The construction of the Ocean Reef Marina (ORM) commenced in February 2021 and is currently underway. The breakwaters are set to stretch for two kilometres and reach heights of up to 18.5 m above the ocean floor. The construction progress of the northern breakwater is presented in Figure 7.3.

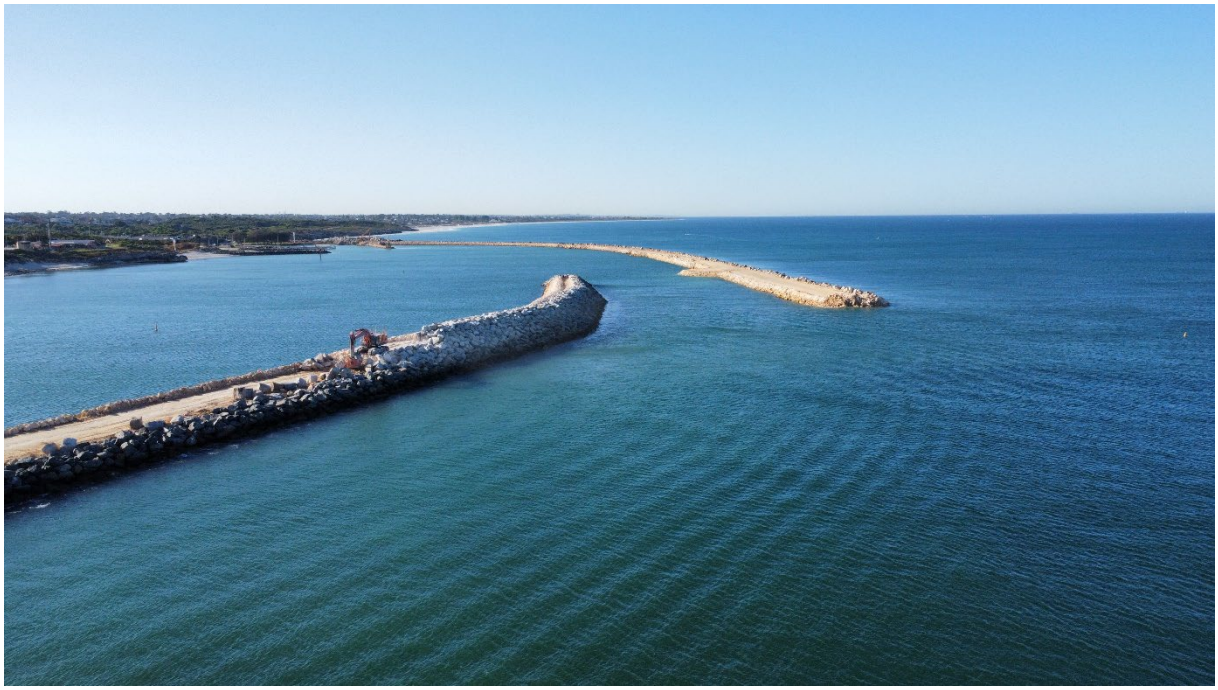

Figure 7.3 ORM Breakwaters – February 2022

It is expected that there may be some changes to the sediment movement dynamics in the area. However, rocky coasts make up the coastline to the immediate north and south of the breakwater, and it is expected that the changes in sediment movement will not be as significant as the changes from the initial construction of Ocean Reef Boat Harbour. The changes due to construction of the Ocean Reef Marina are being monitored in a separate and specific monitoring program by the Proponent (Development WA). Any significant changes identified from this program will be communicated to the City.

Both new breakwaters are now built out to full length and the historical boat harbour breakwaters have been removed. The construction of the new northern breakwater to full height is anticipated to be completed by mid-2022 and the southern to be completed by early 2023. The timing of any internal dredging works is yet to be confirmed, but likely to commence mid to late 2022. This will be undertaken to achieve navigability requirements within the marina. Dredge spoils are likely to be used for reclamation purposes within the marina and should not impact the shoreline adjacent to the marina.

8. Summary & Discussion

Based on the review and analysis presented in previous sections, the key observations are summarised and discussed below:

- There were significant changes (up to 8 m of recession and 3 m of accretion) to the vegetation line over the last year seen in the shoreline mapping. The areas identified as requiring specific monitoring are discussed below. The increased recession identified along the City's coastline was likely caused by sustained moderate to severe weather experienced in Winter 2021.

- The vegetation line at Hillarys Beach Park receded by up to 6 m over the last year. This was recognised as a continuation of the previously identified trend, however was more than the 2 m recorded in previous years.

- The vegetation line at Pinnaroo Point receded substantially (changes up to 10 m) over the last year. Similar to Hillarys Beach Park, the recession previously identified in places at Pinnaroo Point has worsened since the previous period.

- There were no significant areas of change identified from the photographic monitoring, however seasonal trends are becoming emergent as the dataset expands.

- Approximately 8,000 m^3 of sand was extracted from Sorrento Beach, bypassed around Hillarys Boat Harbour and disposed on the beaches to the north in November 2021. This is completed to help replenish the shoreline fronting Hillarys Beach Park and Pinnaroo Point. The sand bypassing program has not significantly reduced the rate of recession of the shoreline at these locations, however, without any bypassing the recession observed is expected to have been far larger in magnitude. It is expected that the target volume for the campaign will need further reviewing prior to the next round of bypassing. The effectiveness of the bypassing program will continue to be assessed in conjunction with monitoring data collected in future monitoring campaigns.

9. Conclusions & Recommendations

This annual report presents the monitoring data collected in the 2021/22 Financial Year, the seventh year of the Joondalup coastal monitoring program, and the changes that have occurred since the baseline monitoring data was collected in 2015/16. The data collected in this monitoring period includes.

- Metocean (water level & wave) data.
- Shoreline mapping and monitoring.
- Photographic monitoring (seasonal).
- Biennial survey profiles.
- Pre and post sediment bypassing surveys.

Based on the monitoring data and assessment, it is recommended that the City:

- Continue to monitor and actively manage (if required) erosion between and including Hillarys Beach Park and Pinnaroo Point.
- Continue to complete annual sand bypassing around Hillarys Boat Harbour (around 10,000 to 15,000 m^3, depending on budget) to address the recession identified at Hillarys Beach Park and Pinnaroo Point. The bypassed amount should be increased from recent operations.
- Progress long term adaptation options for Hillarys Beach Park.
- Continue to monitor the shoreline movement at Burns Beach.

10. References

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MRA 2022. *Joondalup Coastal Monitoring – Interim Data Report, R1631 Rev 1*. Prepared for City of Joondalup.

11. Appendices

Appendix A **Shoreline Movement Plan**

Appendix B **Photographic Monitoring & Survey Locations**

Appendix C **Beach Survey Profiles**

Appendix D **Photographic Monitoring**

Appendix E **Bypassing Surveys**