Report

Impact Assessment of Moving Sand from Adelaide's Northern Beaches – Phase 1 Assessment: 2020-2021 Sand Movement

Department for Environment and Water

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EXECUTIVE SUMMARY

The Department for Environment and Water aims to truck sand for the 2020-21 financial year in advance of a proposed new sand transfer pipeline being commissioned. The design and construction of the proposed pipeline has been considered separately. This report is an independent review of impacts of trucking on the beaches and has been initiated in response to community concern.

The report summarises the anticipated effects of up to 120,000m^3 sand transportation (via trucking) from the northern beaches to West Beach in order to offset current rates of sand loss from West Beach while a new sand pumping system is planned, designed and constructed from West Beach to the northern beaches.

Scenarios Considered

Three hypothetical sand movement scenarios were considered for collection of different amounts of sand from different areas at different times, for the 2020-21 financial year. The collection methodologies included:

- Movement of up to 120,000m^3 of sand in the 2020-21 financial year to West Beach from beaches between Semaphore Park and Largs Bay.
- Sand to be collected by land plane (scraper) from the beach between the low water mark and 5m from the toe of dune - also noting the requirement in Section 3.3 to consider alternative offset distances from the toe of dune (5m, 10m and 15m).
- Sand to be moved by truck along the beach to the existing beach access point at the Semaphore Surf Life Saving Club (Point Malcolm Reserve), where it will be loaded onto road haulage trucks and transported to West Beach.

Harvesting Assessment

An analysis of past harvesting campaigns and an erosion assessment was undertaken to provide an independent assessment of sand harvesting works on the northern beaches from Semaphore to Largs North. The analysis is focused on long-term impacts rather than short-term impacts that can affect the beaches at any time regardless of the sand harvesting works. In other words, the development of erosion scarps can occur at any time if harvesting is undertaken or not as this is the natural response of the beach to storms. In summary:

- Most northern beaches are accreting, and sand harvesting is therefore possible without significant impact on the dunes.
- Erosion is experienced just north of the breakwater which will need to be managed actively. This area requires ongoing beach nourishment rather than sand harvesting.
- All other beaches will continue to grow despite short term storm impacts and harvesting works.
- Semaphore breakwater has been intensely harvested in 18/19 and 19/20, resulting in increased extent of downdrift erosion at Semaphore Jetty.
- The amount of additional storm erosion on the ‘harvested’ beach profiles is relatively small, especially in comparison to the beach accretion rates, and recovery is expected to occur quickly due to the overall accretion trend.
- From a coastal engineering perspective, sand harvesting has therefore very limited impacts on the harvest area in terms of impacts on the dune/available erosion buffer. Sufficient dune erosion buffers exist with no infrastructure at risk from a significant storm event on the pre- or post-profile.

Recommendations are included in Section 2.9, and include further detail on:

- Future 2020/21 sand harvesting campaigns at Semaphore breakwater should be no more than the natural rate of replenishment

- Future harvesting campaigns at the breakwater should therefore be reduced to be no more than the natural rate of replenishment to limit further downdrift impacts.
- Beach conditions shall always be assessed prior to each campaign to ensure that sufficient volumes are available.
- A maximum quantity of about 60,000 m^3 can potentially be harvested from the area in between Semaphore and Largs Jetty and a maximum of 85,000 m^3 from North of Largs Jetty in 2020/21.
- Detailed discussion of the three 3 scenarios investigated in this report, with preferred recommendations.

Biodiversity

Dune vegetation is a key consideration with respect to sand harvesting impacts, and there is no high value vegetation identified in the foredune area. With only a small amount of dune recession predicted, it was considered that there was no vegetation of significance in the area that could be eroded. Although the vegetation on the dunes will not be physically impacted by machinery in the sand harvesting process, there is the possibility of resultant foredune erosion and therefore displacement of the vegetation on the outermost dune face and crest. Section 3 discusses this in further detail. Mitigation measures include:

- Ensure that all machinery stays off the vegetated dune system.
- Identify and protect nesting sites.
- Limit the number of campaigns, however it should be noted that there is a compromise between harvesting less often and extracting more sand at one time.
- Minimise traffic on beach – If larger dump trucks are used, fewer trips are required. This may also be a compromise as it is unknown whether fewer larger trucks cause greater compaction of the sands.
- Ensure maximum vehicle speeds are adhered to and reduce speed if necessary to avoid contact with any vegetation.
- Minimise distribution of vehicle movements on the beach, preferably operating in the intertidal zone.
- if it is necessary to move seagrass wrack to harvest sand, it should be relocated to the upper beach rather than removing from site.

Other Impacts

Safety considerations form a paramount component of the social assessment, and DEW has a current set of operating conditions of the sand movement works such as truck speed on the beach and give-way rules. It should be noted that in 40 years of operation, there have not been any reported health and safety incidents attributed to the movement of sand.

Other impacts have been considered in this report, and it is recognised that there will be disturbance to local residents, commercial and beach users during the sand movement campaigns.

Current operational hours are:

- 7am to 5pm for the land plane
- 9am to 4pm for the beach trucks
- 7.30am to 5pm for the road trucks

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1 INTRODUCTION

1.1 Purpose of the Report

The Department for Environment and Water is commissioning an independent assessment of the impacts of sand movement activities associated with the *Securing the future of our coastline project* on the northern Adelaide metropolitan beach systems (including the local primary dunes systems). The impacts of two components of the project are to be assessed in separate phases:

- Phase 1: Interim sand management (2020-21): Sand transportation (via trucking) from the northern beaches to West Beach in order to offset current rates of sand loss from West Beach while a new sand pumping system is planned, designed and constructed from West Beach to the northern beaches.
- Phase 2 (Not in Scope): Ongoing sand management: Development of the new sand pumping system, which will deliver annual recycling of sand from the northern beaches to match littoral drift rates out of West Beach.

This report is to assess the impacts of trucking sand for the 2020-21 financial year in advance of the new pipeline being commissioned, which relates to Phase 1 above. It is an independent review of impacts of the project on the beaches and has been initiated in response to community concerns. The community is generally concerned about loss of beach width at the collection point, and a resulting loss of recreational amenity. There are also concerns about the impacts of sand movement logistics, as the continuous trucking operations will partially restrict access to the beach, significantly impacting amenity value during sand movement operations.

The community is also concerned about the loss of primary foredune and potential environmental impacts on coastal flora and fauna. Other concerns have been raised about visual amenity (beach appearance after scraping) including the potential development of erosion scarps. These potential impacts will be assessed as part of this project.

1.2 Background

The Phase 1 works involve the collection of up to 120,000m^3 of sand from the beaches in between Semaphore Park and Largs Bay. Sand is generally collected in between the low water mark and 5m from the front of the toe using a scraper. The sand is trucked to a transfer point (existing beach access) at the Semaphore Surf Life Saving Club, and then is loaded onto road haulage trucks and transported to West Beach for placement. The scope of works is to assess impacts on the beach at the collection point at Semaphore Park to Largs Bay, but not at the place of deposition at West Beach.

Three scenarios have been assessed and are summarised in Table 2-1. Sand is typically moved during Spring and Autumn and outside of school holidays to enable the public to enjoy the beaches over the summer months without disturbance. The impact assessment has considered environmental, social and economic aspects that can potentially arise from the removal of sand at the northern beaches.

1.3 Activity to be Assessed

The following activities will be assessed, which will consider three hypothetical sand movement scenarios detailed in Table 2-1for the 2020-21 financial year:

- Movement of up to 120,000m^3 of sand in the 2020-21 financial year to West Beach from beaches between Semaphore Park and Largs Bay.
- Sand to be collected by land plane (scraper) from the beach between the low water mark and 5m from the toe of dune - also noting the requirement in Section 3.3 to consider alternative offset distances from the toe of dune (5m, 10m and 15m).

- Sand to be moved by truck along the beach to the existing beach access point at the Semaphore Surf Life Saving Club (Point Malcolm Reserve), where it will be loaded onto road haulage trucks and transported to West Beach.
- Sand to be moved under the Semaphore jetty using a mobile conveyor belt system when necessary.

1.4 Northern Beaches Previous Campaigns

DEW undertook sand back-passing campaigns in spring 2019 and autumn 2020, where sand was removed from the northern beaches. As part of those campaigns a number of datasets, such as pre- and post-works surveys, were collected. Additionally, DEW has a long term record of beach profile surveys and sand analysis information. Water Technology has reviewed all data and reports to make informed decisions about any possible impacts from the planned spring 2020 and autumn 2021 campaigns. Other previous studies, such as the DHI 2018 report have also informed the assessment, as this provides detailed data about longshore sand transport rates in the various beach cells. This enables assessment of the short term and long term impacts to estimate the time for ‘recovery’ of the northern beaches.

1.5 Desktop Assessment

Based on the review of previous data, Water Technology has undertaken modelling for the three outlined sand removal scenarios to estimate the:

- Anticipated dune recession and the remaining dune buffer at the borrow site; and
- Anticipated impacts on downdrift and updrift sites from the borrow site.

Impacts of everyday conditions and minor-to-moderate storm events (e.g. 10% AEP) on the pre- and post-works profiles have been assessed and compared.

1.6 Stakeholder Consultation

As part of the ongoing stakeholder consultation process, two workshops were held and presentations of the findings of this report were made:

- Workshop 1 held on 15 September 2020 at the Quest Hotel, Port Adelaide
- Workshop 2 held on 25 September 2020 at the Port Environment Centre, Port Adelaide

A number of additional concerns were raised by the stakeholder group, and these have been addressed in this report where they were in scope. Input was received from stakeholders including:

- Individual local stakeholders
- Port Adelaide Residents Environment Protection Group
- Semaphore Largs Dunes Group
- Save Our Shores (SOS) Semaphore Largs Bay
- Friends of Gulf St Vincent
- Birdlife Australia

2 COASTAL ENGINEERING ASSESSMENT

The coastal engineering assessment analyses the erosion impact of sand harvesting works on the beaches and dunes. Sand harvesting is undertaken in three areas (see Figure 2-1):

- Near Semaphore Breakwater;
- In between Semaphore and Largs Jetty; and
- North of Largs Jetty.

FIGURE 2-1 SAND HARVESTING AREAS

2.1 Coastal Processes

Coastal Processes and sediment movement along Adelaide beaches have been assessed as part of other studies in the past and are utilised for this project:

- CES, 2007: Adelaide's Living Beaches Strategy, Quantifying Adelaide Coast Protection Alternatives, 01 May 2007

- WRL, 2001: Semaphore Park Offshore Breakwater Optimisation and Detailed Design, Nov 2001.
- WRL, 2007: Technical Review of the Semaphore Park Trial Breakwater, South Australia, Oct 2007.
- Department for Environment and Heritage, 2005: Adelaide's Living Beaches, A Strategy for 2005–2025, Technical Report, June 2005
- DHI, 2018: West Beach Coastal Processes Modelling. Assessment of Coastal Management Options, August 2018.

Most relevant findings to this assessment:

- Sediment transport along Adelaide beaches is northwards.
- Sediment longshore rates at the northern beaches have been estimated in the order of 55,000 m³/year at Semaphore (Cell 5) and 0 - 30,000 m³/year at Largs Bay (Cell 6) by CES, 2007.
- As part of the Semaphore breakwater design review (WRL, 2007) it was estimated that sustainable sand yields in the lee of the breakwater range from 28,000 to 45,000 m³/year.
- Longshore sediment transport rate estimates at West Beach were updated by DHI, 2018, stating rates from 50,000 to 150,000 m³/year, with an average of 100,000m³/year. The range of sediment transport is rather large, meaning that in any given year, the longshore transport can be as little as 50,000 m³/year or as much as 150,000 m³/year, depending on the weather conditions in that year. The DHI report did not provide detailed varying longshore sediment transport rates for the various beach cells but estimates the 50,000 to 150,000 m³/year range to be valid for "West Beach and further north".

2.2 2020/21 Harvest Campaign Scenarios

An independent review of data from past harvesting campaigns was undertaken in order to assess the following 2020/21 Harvesting Campaign scenarios (Table 2-1).

TABLE 2-1 HARVESTING SCENARIOS

Location of Sand Collection	Spring 2020 (m³)	Autumn 2021 (m³)	Totals for 2020-21 (m³)
Scenario 1			
Breakwater salient (Point Malcolm)	0	50,000	50,000
Between Semaphore and Largs Bay Jetties	10,000	10,000	20,000
North of Largs Bay Jetty (to Strathfield Terrace)	25,000	25,000	50,000
TOTALS	35,000	85,000	**120,000**
Scenario 2			
Breakwater salient (Point Malcolm)	0	50,000	50,000
Between Semaphore and Largs Bay Jetties	17,500	17,500	35,000
North of Largs Bay Jetty (to Strathfield Terrace)	17,500	17,500	35,000
TOTALS	35,000	85,000	**120,000**
Scenario 3			

Location of Sand Collection	Spring 2020 (m^3)	Autumn 2021 (m^3)	Totals for 2020-21 (m^3)
Breakwater salient (Point Malcolm)	0	50,000	50,000
Between Semaphore and Largs Bay Jetties	20,000	0	20,000
North of Largs Bay Jetty (to Strathfield Terrace)	0	50,000	50,000
TOTALS	20,000	100,000	**120,000**

2.3 Details of Current Operation

Currently harvesting of the northern beaches from Semaphore breakwater to Largs north is undertaken using a land plane (scraper). The contractors are instructed to undertake the operations in the following manner:

- Sand is to be won as far seawards as daily tides permit.
- Sand shall be removed in layers of depth less than 250 millimetres (approximately) in depth over the entire area designated for collection.
- For all excavations, the edge between the natural undisturbed surface and the excavation shall not exceed aforementioned specified depths and a batter of 1:10, perpendicular to the edge, shall be left at the end of each day to remove sharp drops in beach levels which are potentially unsafe to the public.
- No collection shall occur within 6 metres of the toe of any seawall or sand dune or from lower than low water mark unless specified otherwise in the Task Specific Specification or with specific written Principal's approval.

2.4 Methodology

In order to assess the outlined scenarios for the 2020/21 harvesting campaigns the following tasks were undertaken:

1. Review of relevant reports as outlined and summarised in section 2.1 of this report.
2. Analysis of previous harvesting campaigns, locations, quantity and timing (chapter **Error! Reference source not found.**).
3. Analysis of existing beach profile records from 2010 to 2020. A trial breakwater was constructed at Semaphore (Bower Road), consisting of geobags. The breakwater was subsequently replaced with a permanent rock breakwater in 2008. As such, an analysis of historical data was undertaken from 2010 onwards, to fully account for any impacts from the permanent rock breakwater (chapter 2.6).
4. Analysis of 2016 storm event (chapter 2.6.3).
5. Analysis of DEM surveys that were undertaken for some campaigns (chapter 2.6).
6. Analysis of aerial photography (chapter 2.6).
7. Erosion assessment (chapter 2.7).

Details of each task are outlined throughout the following chapters.

2.5 Previous Sand Harvesting Campaigns

Records of previous sand harvesting campaigns by area and per financial year are presented in Figure 2-2.

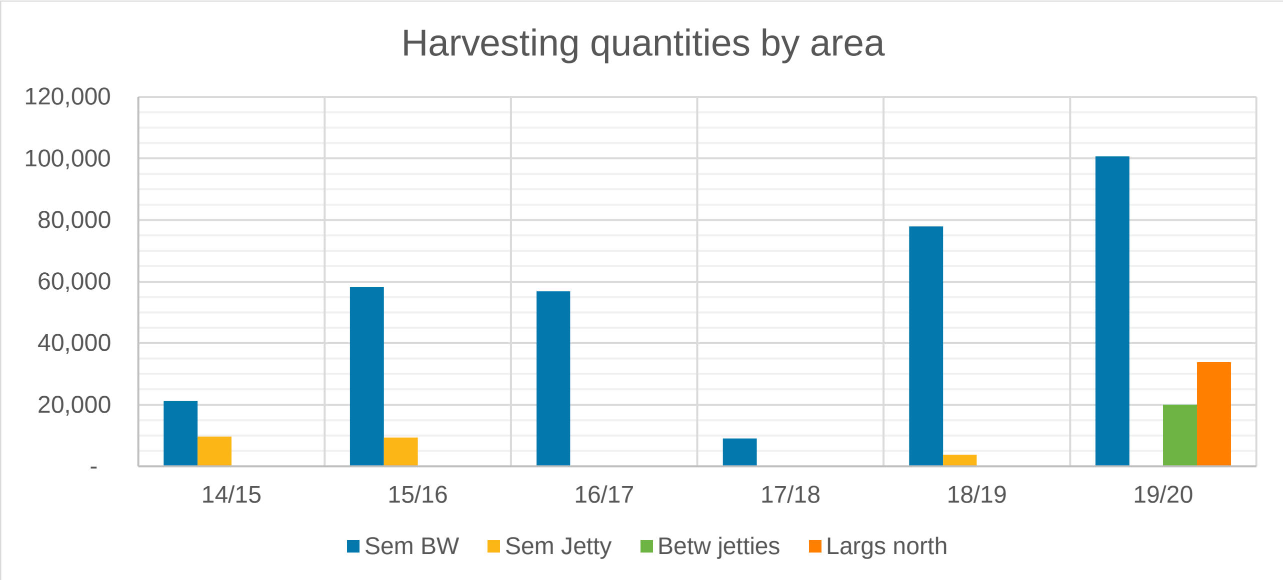

FIGURE 2-2 PAST HARVESTING CAMPAIGNS BY AREA

During past campaigns, most sand was harvested from the breakwater salient ("Sem BW'). Large campaigns were undertaken in 15/16, 16/17, 18/19 and 19/20. Specifically, the last two campaigns in 18/19 and 19/20 are rather large campaigns, undertaken in consecutive years.

The area around Semaphore Jetty was mostly harvested in 14/15 and 15/16 with only a very small quantity taken in 18/19. Sand from in between Semaphore and Largs Jetty as well as north of Largs Jetty was only harvested during the most recent 19/20 campaign.

2.6 Analysis of Surveys

Two types of survey data were available for further analysis, DEMs and profile surveys.

Digital elevation models (DEM) were available for 2018-2020 in the lee of the Semaphore breakwater and a before and after DEM was available for north of Largs Jetty for 2020. DEMs are 3-dimensional models that show the terrain surface. The DEMs were used to create comparison plots of the terrain before and after sand harvesting campaigns. In addition to the DEMs, profile survey data is available along Adelaide beaches. An analysis was undertaken on the profiles within the harvest areas, going back to 2010 to include all impacts from the breakwater, constructed in 2009. **Error! Reference source not found.** provides an overview of where the survey profiles (orange lines) are located and their numbering system as well as the extent of the DEMs shown with the red outline.

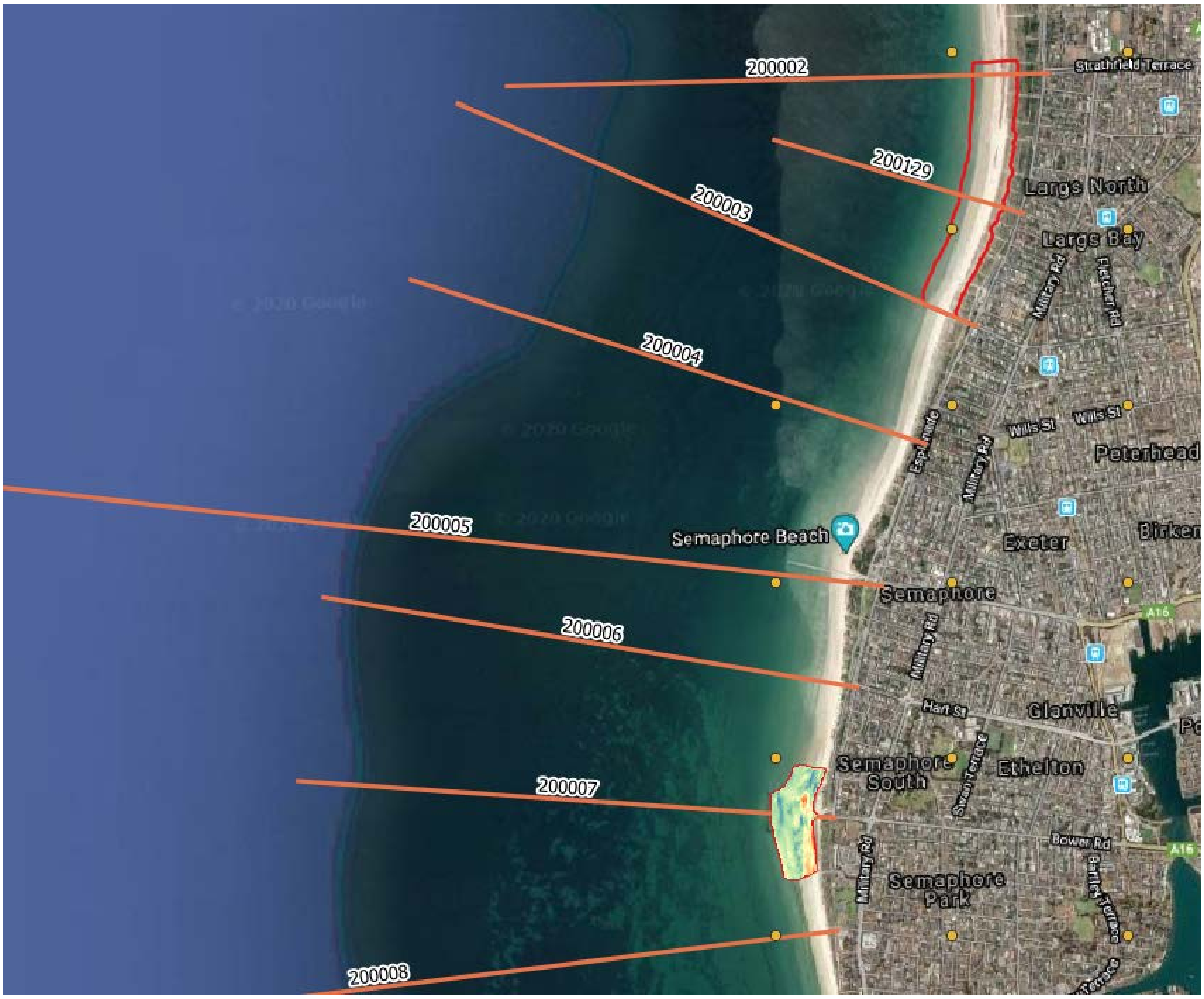

FIGURE 2-3 SURVEY PROFILES ALONG THE HARVEST AREA

The dunes are generally higher and steeper in the south around Semaphore Breakwater and become gentler sloped and reduce in height towards the north to Largs Bay (Figure 2-4).

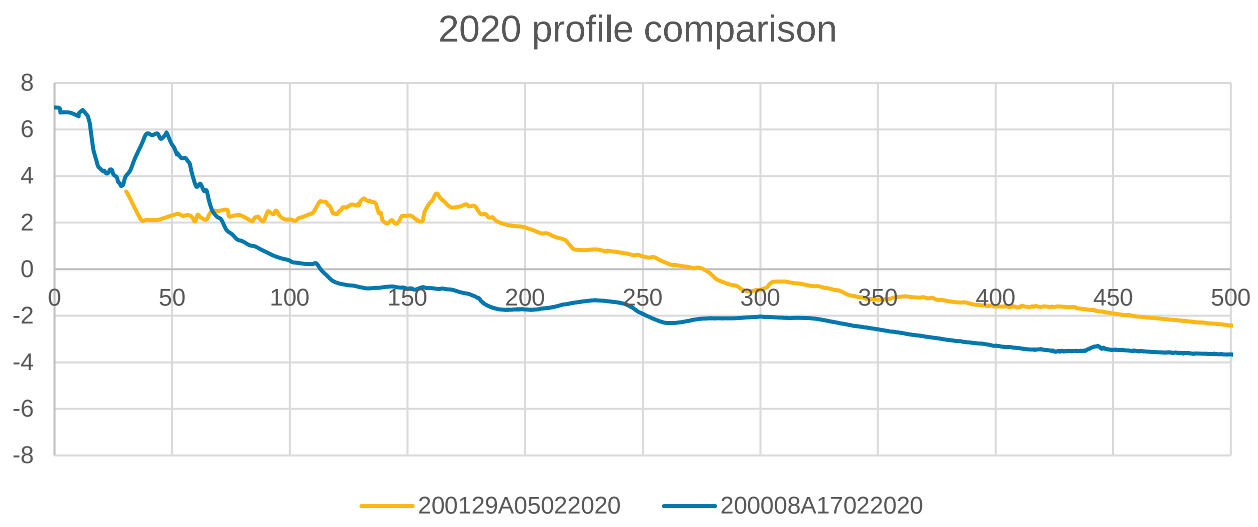

FIGURE 2-4 COMPARISON OF BEACH PROFILES SOUTH OF SEMAPHORE BREAKWATER (BLUE LINE) AND NORTH OF LARGS JETTY (YELLOW LINE)

A detailed analysis of beach profiles was undertaken. Appendix A provides a detailed description of the various profiles and how they evolved over time with Appendix B providing the actual record of beach profiles from 2010 to 2020. A summary of the findings from the profile survey analysis as well as the DEM analysis is provided in the following subchapters, split by harvest area.

2.6.1 Semaphore breakwater area

The semaphore breakwater is designed to protect Semaphore Park and to capture sand for beach harvesting. The breakwater design estimated that a yield of 28,000 to 45,000 m^3/year is sustainable with approx. 33,000 m^3/year naturally bypassing the breakwater (WRL, 2007). The actual sand volumes in the lee of the breakwater will vary every year, depending on the storminess of the year and the resulting longshore sediment transport rates. Bypassed sand will deposit on any of the beaches north of approx. Semaphore Jetty. The breakwater causes a net loss of sand in the immediate downdrift area of the breakwater due to the breakwater and salient[1] shielding that area.

Comparing the past harvesting campaigns in the lee of the breakwater (Figure 2-5) with the sustainable harvesting quantities of 28,000 to 45,000 m^3/year shows that harvesting campaigns have exceeded the sustainable quantities. The two campaigns in 15/16 and 16/17 have been preceded and followed by smaller campaigns though, resulting in an average of 36,000 m^3/year over the 4 years from 14/15 to 17/18. On average the maximum capacity of 45,000 m^3/year has therefore not been exceeded. The last two campaigns however in 18/19 and 19/20 exceeded the maximum capacity.

[1] Salient is the accumulation of sand in the lee of a detached breakwater, causing the beach to be wider in the lee of the breakwater compared to up and downdrift beaches. Tombolo means that the accumulation of sand is so big that a sandbar connects the beach to the breakwater.

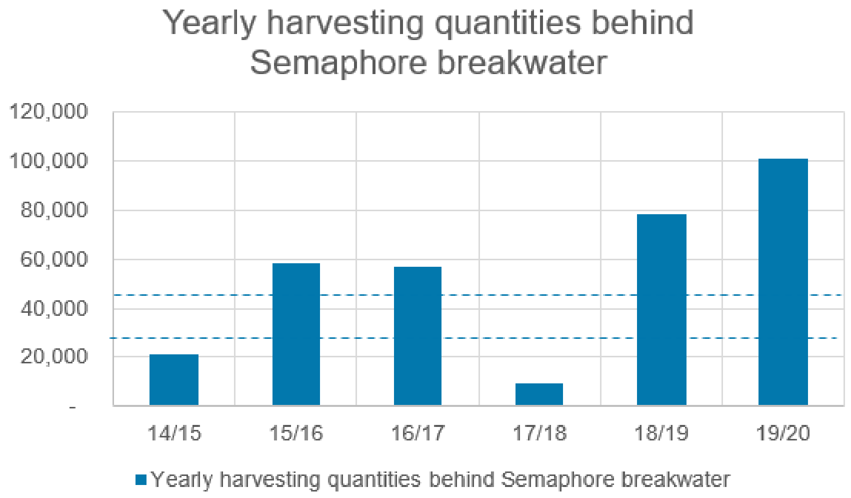

FIGURE 2-5 RECORD OF SAND HARVESTING AT SEMAPHORE BREAKWATER

The impact of one harvesting campaign in 2018 is well captured on google earth aerials. Figure 2-6 shows the aerial captured on the 17/11/2018 displaying localised depressions in the sand from the harvesting campaign. Figure 2-7 is captured on 23/12/2018, so only one month later and the sand has already been smoothed out from the longshore sediment transport and tides. While impacts are clearly visible after one campaign, they do seem to be temporary in nature due to the breakwater fulfilling its purpose and capturing the longshore sediment transport.

Further analysis of aerial photography showed that a salient has formed most years with the exception of August 2016 which coincides with a harvesting campaign and no salient forming December 2018 to March 2020 due to the intensive harvesting works occurring at that time. The latest aerial from June 2020 showed the salient is starting to form again (Figure 2-8).

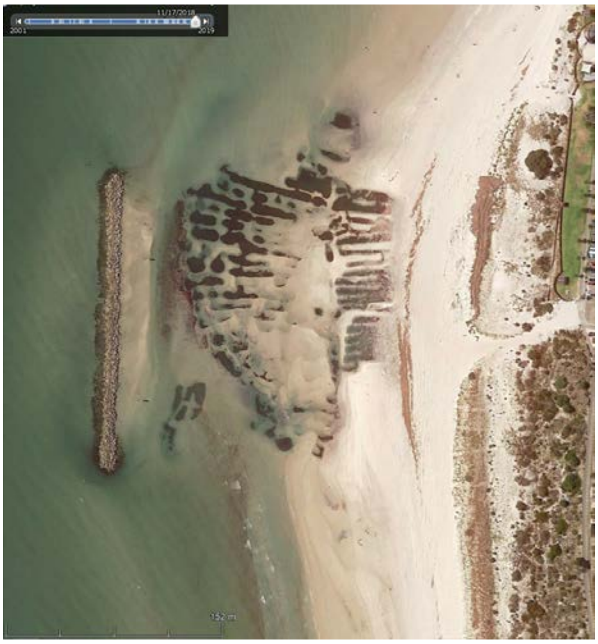

FIGURE 2-6 17/11/2018

FIGURE 2-7 23/12/2018

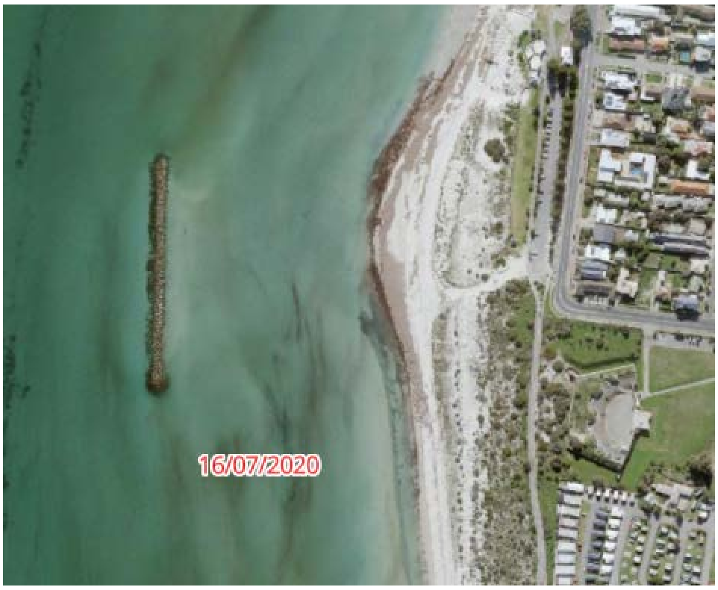

FIGURE 2-8 AERIAL FROM 16/07/2020 SHOWING SALIENT

A comparison of the DEM from 10/2018 to 10/2019 is shown in Figure 2-9. The red area represents a lowering of the beach, with the blue areas representing an increase in beach levels. Over that period 100,000m^3 of sand was harvested from the area. Sand was mostly taken from the salient.

Comparing the 10/2019 and 01/2020 DEMs (Figure 2-10), over which time 70,000 m^3 were harvested, clearly shows that harvesting was mostly undertaken south of the breakwater because there was insufficient sand availability in the breakwater salient. This is likely caused by the disproportionate harvesting campaign undertaken in 18/19 and not allowing sufficient time afterwards for the beach to rebuild. Beach lowering is most noticeable in the upper beach area next to the dunes south of and directly in the lee of the breakwater. Figure 2-11 and Figure 2-12 below show the aerials from 10/2019 and 01/2020 and it can be seen that insufficient sand was available in the lee of the breakwater in the salient. Moving the sand harvest area to south of the breakwater, exceeding the maximum sustainable harvesting quantity and the coincidence with a small storm event shortly after the 19/20 harvesting campaign resulted in erosion of the foredune after the Oct-Dec 2019 campaign.

FIGURE 2-9 DEM COMPARISON 10/2018 TO 10/2019

FIGURE 2-10 DEM COMPARISON 10/2019 AND 01/2020

FIGURE 2-11 AERIAL FROM 10/2019

FIGURE 2-12 AERIAL FROM 01/2020

Despite the large harvesting campaigns in 18/19 and 19/20, the profile analysis showed that the long-term trend (2010 to 2020) is beach accretion, which means that the beaches in the lee of and south of the breakwater are growing. The front of the dunes extended by +10m in the lee of the breakwater (Figure 2-13) and +8m south of the breakwater. This long-term trend includes the harvesting campaigns that were undertaken during that time as well as the 2016 storm event, which equates to approx. a 50-year ARI event. The 2016 storm is further discussed in chapter 2.6.3.

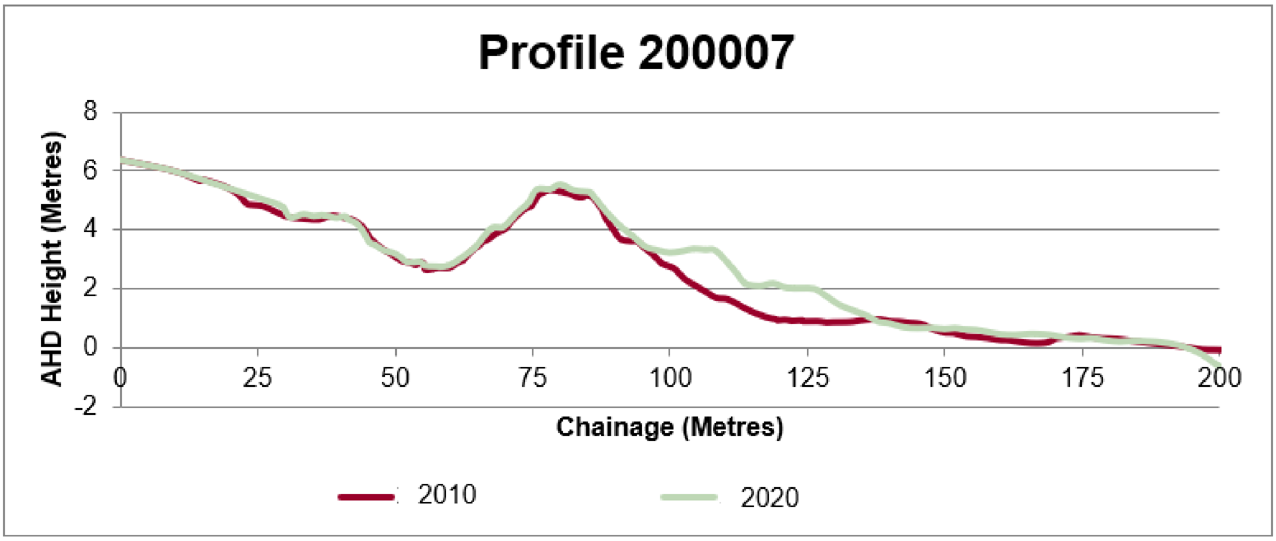

FIGURE 2-13 PROFILE COMPARISON 2010 AND 2020 AT SEMAPHORE BREAKWATER

The beach north of the breakwater is receding. This was to be expected due to the downdrift effect of the breakwater and has been analysed during the design stages of the breakwater. The beach north of the breakwater (profile 200006) has receded by a total of -27m from 2010 to 2020. The maximum amount of erosion was -40m, however, beach nourishment campaigns undertaken throughout the years reduced that to a total of -27m over the 10 years.

Erosion due to the breakwater should ideally be limited to south of Semaphore Jetty. However, analysis of the Semaphore Jetty profile provided the following insights:

- Accretion of +14m from 2010 to 2016;
- Erosion of -7m from 2016 to 2020. This change in trend from accretion to erosion has started around the same time of the 2016 storm event. The 2016 storm had similar impacts on most beaches, however most other beaches recovered quickly and started accreting, exceeding the 2016 pre-storm profile again in 2017 or 2018 (depending on exact location). This profile however continued to erode. It is suspected that the large harvesting campaigns in 18/19 and 19/20, which exceeded the recommended maximum sustainable harvesting quantity of 45,000m^3, caused the net deficit of sand availability at that location.
- While the net impact is +7m beach accretion at that profile, the beach is experiencing ongoing erosion since 2016. Further erosion can be expected until such time that a new equilibrium is reached and the salient in the lee of the breakwater had time to recover.
- Any future campaigns at the breakwater should therefore not exceed the amount of sand that has accumulated within the breakwater salient during that year (expected range to be within 28,000 to 45,000 m^3/year), provided that sufficient time has passed for the area to fill up again after the 18/19 to 19/20 campaigns.

The net dune accretion/recession rates from 2010 to 2020 are summarised in Figure 2-14. During the profile analysis it became evident that it is difficult to determine the 'toe of dune' in the field. Based on the data from the last 10 years the toe of dune has been generally assessed as being further towards the ocean. As a result, collection has occurred further away from the toe of dune than the currently nominated 6m offset. Harvesting works were therefore focused on the intertidal areas, causing the dunes to grow further despite harvesting being undertaken.

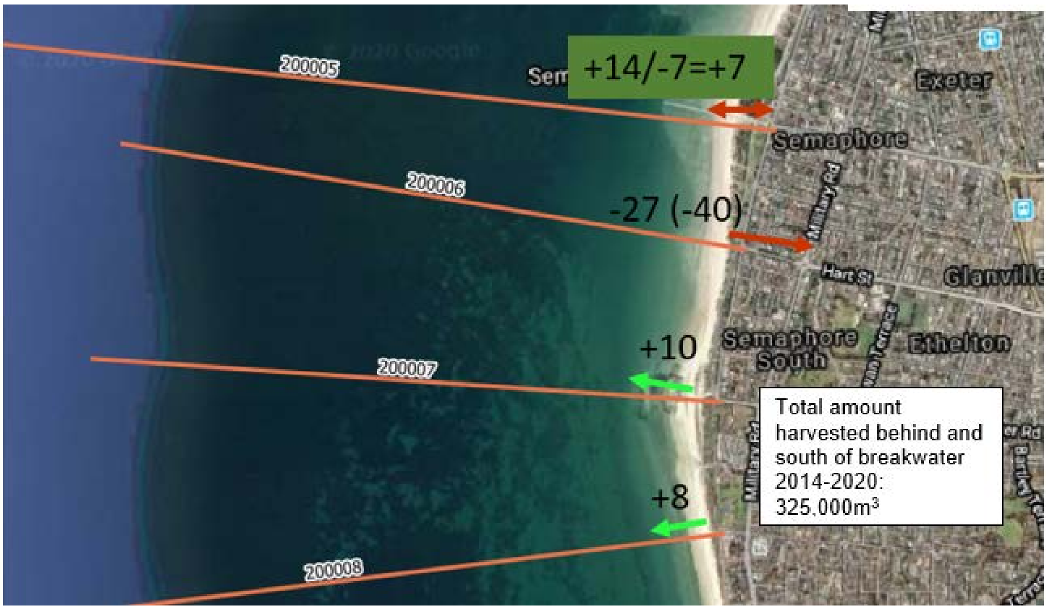

FIGURE 2-14 NET ACCRETION/RECESSION RATES AROUND SEMAPHORE BREAKWATER

Conclusion

The following conclusions can be drawn for the Semaphore breakwater area:

- Large quantities harvested at Semaphore breakwater in 2018/19 and 19/20 exceeded natural replenishment rates.
- It is likely that the intense harvesting at Semaphore breakwater caused the ongoing erosion trend since 2016 at Semaphore Jetty. In other words, if no or reduced harvesting would have occurred at Semaphore Breakwater in 18/19 and 19/20 (equal or less than natural rate of replenishment) it is possible that the profile would be in a state of accretion rather than ongoing erosion.
- Future harvesting campaigns at the breakwater should therefore be reduced to be no more than the natural rate of replenishment to limit further downdrift impacts.

2.6.2 North of Largs Jetty

The area north of Largs Jetty has only been harvested in 2019/20, but not in previous years. A before and after DEM is available from that campaign. A comparison plot is shown in Figure 2-15 with the red areas showing lowering of the beach and blue areas an increase in beach levels. It can be seen that more sand was harvested from the area closer to the jetty, it is understood that this was due to beach wrack on the beach in the northern section at the time of harvesting. Sand was mostly taken from the upper beach area with less sand taken from the lower intertidal area. It can also be seen that sand harvesting activities were undertaken in strips.

FIGURE 2-15 COMPARISON PLOT OF BEACH LEVELS BEFORE AND AFTER BEACH HARVESTING (APRIL – JUNE 2020)

The profile analysis showed that all beaches are in a state of accretion, with accretion rates of the dunes increasing towards the north. This is in line with the reduced sediment transport rates that are experienced in that area, with the longshore sediment transport reducing to nil at North Haven as shown in CES, 2007. In total, from 2010 to 2020, dunes grew by +9m in between the jetties and by +30 and +35m north of Largs Jetty (Figure 2-16).

The profile at Largs Jetty (200003) has been excluded from the analysis because the profile sits immediately adjacent to the Jetty and has been influenced by beach access clearing activities (removal of sand within the area under and each side of the jetty). It is therefore not representative of natural processes.

FIGURE 2-16 DUNE ACCRETION NORTH OF SEMAPHORE JETTY

Conclusion

The following conclusions can be drawn for the area north of Largs Jetty:

- Beaches are accreting north of Semaphore Jetty.
- Sand harvesting of those areas is therefore possible with minimal impact on the dunes.

2.6.3 2016 storm event

Generally, profile surveys are undertaken once a year. This means that short term impacts and formation of erosion scarps from small events are not detectable in the analysis. In 2016 two surveys were undertaken due to the severe storm event that occurred that year. It is estimated that the 2016 storm approximates to a 50-year ARI storm event which has a 2% chance of occurring in any given year. The two surveys enable the analysis of the impacts of the storm on the beaches.

The analysis showed that the beaches from south of Semaphore breakwater to Largs Jetty experienced dune erosion in 2016. Beaches generally started to accrete again in 2017 and exceeded their pre-2016 storm profile in 2018. One exception is the area just north of the breakwater which is impacted by downdrift effects from the breakwater and has been discussed in more detail in chapter 2.6.1.

The beaches north of Largs Jetty did not experience any dune erosion from the 2016 storm event, only some minimal erosion on the beach itself in the intertidal area. This resulted in those northern dunes continuing to accrete sand, despite the significant storm event. It can therefore be anticipated that impacts from sand harvesting activities are less north of Largs Jetty compared to the area south of the jetty due to the reduction in longshore sediment transport resulting in increased sediment deposition. This results in those northern beaches recovering more quickly than the southern beaches around Semaphore.

2.6.4 Summary

A summary of the dune accretion and recession from 2010 to 2020 is provided in Table 2-2. Most dunes are growing, and sand harvesting is therefore possible with minimal impact on the dunes. However, no sand harvesting activities should be undertaken in between Semaphore Breakwater and Semaphore Jetty. Instead ongoing beach nourishment will be required north of the breakwater.

Sand harvesting activities should not exceed the natural rate of replenishment to avoid direct impacts on the beach and also indirect downdrift impacts on other beaches.

TABLE 2-2 SUMMARY OF ACCRETION AND EROSION

Profile	Description	Average 2010 to 2020 dune growth (+) or recession (-) [front face] in m	Comment
200008	South of Semaphore breakwater	+8	Dune grew in height and overall thickness landwards and seawards.
200007	Semaphore breakwater	+13	Lower front dune established in front of existing dune.
200006	North of Semaphore breakwater	-27 (2020) -40 (2017/18/19)	Dune recession due to breakwater downdrift effects. Beach nourishment campaign undertaken in 19/20. Largest amount of recession was experienced in 2017/18/19.
200005	Semaphore Jetty	+14 (2010-2016) -7 (2016-2020) +7 (2010-2020) TOTAL	Dune grew in height 0.8m. Dune accretions 2010 to 2016 followed by dune recession 2016 to 2020. In total there is dune accretion, however, the existing trend is recession.
200004	In between Semaphore and Largs jetty	+9	Dune grew in height 1.2m.
200003	Largs Jetty	N/A	Profile excluded due to anthropogenic impacts.
200129	Approx. 700m north of Largs Jetty	+30	Steady growth, new foredune forming
200002	Approx. 1.5km north of Largs Jetty	+35	Steady growth, new foredune forming

2.7 Erosion Assessment

In order to assess erosion impacts on the beach before and after sand harvesting activities an erosion assessment was undertaken. This is done by exposing the beach profile to a storm event. A 1-year and 10-year ARI event were selected. The impact of the harvesting works was assessed by analysing storm impacts on the pre-harvested beach profile and the post-harvested beach profile. The following data was used in the analysis:

2.7.1 Sediment size

Sand grain analysis has been undertaken in the past and the median grain size (D_{50}) from the Semaphore Breakwater to Largs Jetty ranges from 0.2 to 0.22mm ("Semaphore Sand Suitability Investigation – Summary"). Further north, towards North Haven, the sediment characteristics change to a slightly finer sand and the sand is therefore less suitable to be used for sand back passing as larger quantities of sand would be required to achieve the same level of protection that the coarser sand can provide. The sand grain analysis showed that 6m^3 of sand would be required from North Haven to provide the same level of protection as 1m^3 of sand from Semaphore breakwater due to the varying grain size. A D_{50} of 0.2mm has therefore been adopted in the analysis.

2.7.2 Water levels

When considering coastal processes, it is necessary to consider water levels that prevail on site on a daily basis such as astronomical tides and extreme water levels that can be experienced during storm events, so called storm tides.

Astronomical tides are the 'normal' rising and falling of the ocean water levels in response to gravitational forces from astronomical bodies, mainly the sun and moon. The effects are predictable and can therefore be forecast with confidence. Table 2-3 outlines the tidal levels at Adelaide Outer Harbour (2020 Tide Tables, DPTI).

TABLE 2-3 TIDAL PLANES AT ADELAIDE OUTER HARBOUR

	mLAT	mAHD
Highest Astronomical Tide (HAT)	2.91	1.46
Mean High Water Springs (MHWS)	2.41	0.96
Mean Sea Level (MSL/MHWN)	1.39	-0.06
Australian Height Datum (AHD)	1.45	0
Lowest Astronomical Tide (LAT)	0.08	-1.37

A storm tide is the combined action of the astronomical tide and the storm event as presented in Figure 2-17. During a storm event surface winds push the water against the shoreline and changes in atmospheric pressure result in a rise of water levels. This rise in water levels is called the storm surge. The strong winds during a storm event also result in the generation of waves. As the waves approach shallow nearshore water they start to break. The dissipation of wave energy during the wave breaking process induces a localised increase in the ocean water level shoreward of the breaking point which is called wave setup. Wave setup can be experienced for a sustained time and therefore should be considered in the total storm tide component.

Wave runup is typically not included in the total storm tide component because it is very dependent on local foreshore type and characteristics. Wave runup is the vertical height above the local water level up to which incoming waves will rush when they encounter the land/sea interface.

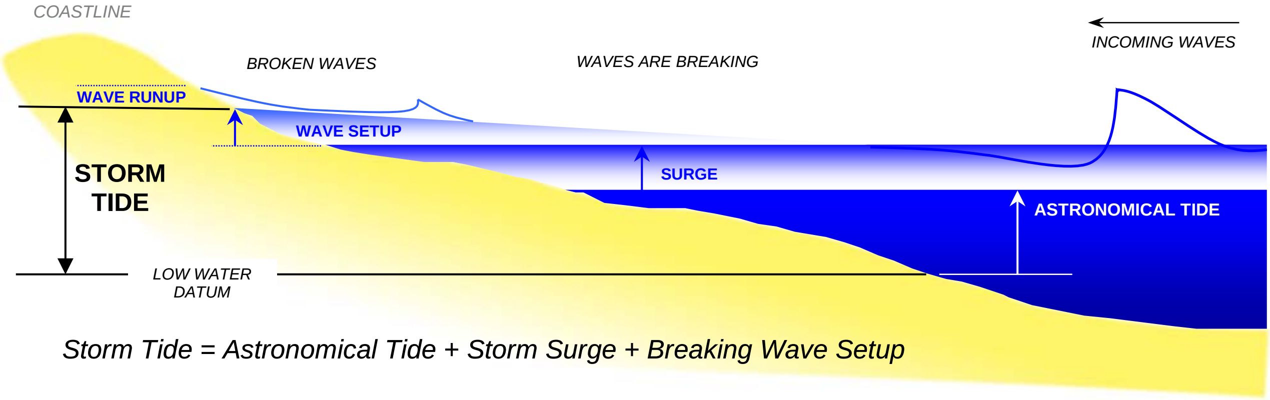

FIGURE 2-17 COMPONENTS OF A STORM TIDE EVENT

Several previous studies asses the storm tide levels at the Adelaide Beaches and are outlined in the design report for the Semaphore Breakwater (WRL, 2001). The same storm tide levels are adopted in this study and are outlined in Table 2-4. It must be noted that the presented water levels have been derived from a joint probability analysis that considers the joint occurrence of extreme waves and water levels.

TABLE 2-4 STORM TIDE LEVELS FOR ADELAIDE

ARI event	Water level in mAHD
1 year	1.5
5 year	1.95
10 year	2.05
20 year	2.15
50 year	2.30
100 year	2.35

2.7.3 Waves

The wave heights at the project site are also adopted as per WRL, 2001 and are listed in Table 2-5 below.

TABLE 2-5 WAVE HEIGHTS

ARI event	offshore H_s	offshore $H_{10\%}$	Corresponding water level in mAHD
1 year	2.1	2.7	1.5
5 year	2.4	3.0	1.95
10 year	2.7	3.4	2.05
20 year	2.9	3.7	2.15
50 year	3.1	3.9	2.3
100 year	3.4	4.3	2.35

2.7.4 Results

An example of the results is shown in Figure 2-18. The initial beach profile is shown in solid yellow. The 1-year storm event results in erosion of the dune front of 5m (green solid line). Exposing the beach to the same storm event but applying the harvested beach profile (yellow dashed line) results in an additional 3m of erosion (green dashed line).

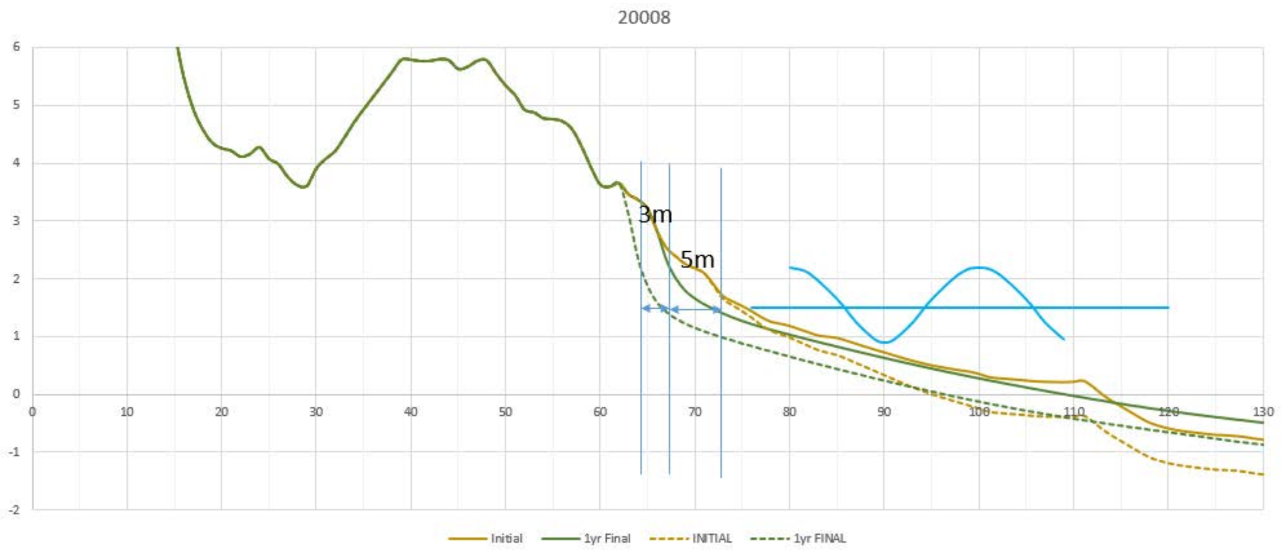

FIGURE 2-18 EROSION IMPACT ON PRE AND POST HARVESTED BEACH PROFILE

Two profiles were tested, one south of the breakwater (the area in the lee of the breakwater will not be impacted by erosion due to the protection of the breakwater) and north of Largs Jetty. The actual harvested profiles were used from the last 19/20 campaign. Additionally, artificial post-harvest profiles were investigated to assess the impacts from harvesting depth and distance to toe of dune. The results of the analysis are provided in Table 2-6.

TABLE 2-6 EROSION INCREASE DUE TO HARVESTING WORKS

Storm event ARI	Recession of dune front before harvesting (m)	Recession of dune front after harvesting (m)	Erosion increase due to harvesting works (m)
South of Semaphore jetty			
1	5	7	2
10	11	14	3
North of Largs Jetty			
1	0	0	0
10	0	5	5

Periodic erosion of the dunes will be experienced regardless of sand harvesting works for the beaches from south of Semaphore breakwater to Largs Jetty. This means that erosion scarps are likely to be experienced regardless of sand harvesting works as it is natural for sandy beaches to respond that way to storms. While dune scarps are natural, to be expected and not critical, they can generate a nuisance to beach goers and can generate a negative perception amongst the local community regarding the impact of the works. Should that be the case, active management of occurring erosion scarps by means of smoothing them out can be considered, however, this also comes at an additional cost and should only be considered for significant erosion scarps that can pose a public safety risk (e.g. scarps larger than 1 m drop).

The dunes north of Largs Jetty are not affected by erosion, with only the lower beach experiencing minor erosion in the intertidal area. This is also consistent with the analysis of the 2016 storm, where the dunes north of Largs Jetty were not impacted by erosion. Larger events (e.g. 100-year ARI event) however will cause erosion of the foredune due to the higher water levels experienced in a more significant storm event. The higher water levels cause waves to directly impact on the dunes, resulting in erosion. However, the existing erosion buffer is ample and only the foredune will be affected in a significant event.

The amount of erosion of the dune front increases after harvesting was undertaken, with up to 3m of additional erosion experienced south of Semaphore breakwater and up to 5m north of Largs Jetty in a 10-year ARI event. Experiencing increased erosion on the post-harvested beach profile is to be expected. It is important to note however, that impacts will vary with time, with the maximum impacts as outlined in Table 2-6 to be experienced directly after harvesting was undertaken. Impacts can be expected to be reduced after a few months due to the longshore sediment transport re-filling the beaches.

The remaining dune buffers in all locations (except north of Semaphore breakwater) are substantial and the dunes can easily accommodate the additional erosion should a storm occur shortly after sand harvesting. No infrastructure is at risk from a 100-year storm event, neither on the pre-harvest nor the post-harvest profile.

Conclusion

- The amount of additional erosion on the ‘harvested’ profile is relatively small, especially in comparison to the beach accretion rates.
- The additional erosion will only be experienced if a storm event occurs shortly after the harvesting campaign. If the storm occurs a few months after the campaign the beach would have already had time to re-fill.
- Erosion after a storm event is generally a short-term impact. In the long-term beaches will start growing again after a few months.
- The exact amount and location of erosion is highly dependent on water levels during the storm and the existing height, shape, and slope of the dune.

2.8 Summary

An analysis of past harvesting campaigns and an erosion assessment was undertaken to provide an independent assessment of sand harvesting works on the northern beaches from Semaphore to Largs North. The analysis is focused on long-term impacts rather than short-term impacts that can affect the beaches at any time regardless of the sand harvesting works. In other words, the development of erosion scarps can occur at any time if harvesting is undertaken or not as this is the natural response of the beach to storms.

In summary:

- Most northern beaches are accreting, and sand harvesting is therefore possible with minimal impact on the dunes.
- Erosion is experienced just north of the breakwater which will need to be managed actively. This requires ongoing beach nourishment rather than sand harvesting.
- All other beaches will continue to grow despite short term storm impacts and harvesting works.

- Semaphore breakwater has been intensely harvested in 18/19 and 19/20, resulting in increased extent of downstream erosion at Semaphore Jetty.
- Amount of additional storm erosion on the 'harvested' beach profiles is relatively small, especially in comparison to the beach accretion rates, and recovery is expected to occur quickly due to the overall accretion trend.
- From a coastal engineering perspective, sand harvesting therefore has very limited impacts on the harvest area in terms of impacts on the dune/available erosion buffer. Sufficient dune erosion buffers exist with no infrastructure at risk from a significant storm event on the pre- or post-profile.

2.9 Recommendations

Based on the analysis the following recommendations can be made:

- Future 2020/21 sand harvesting campaigns at Semaphore breakwater should be no more than the natural rate of replenishment (e.g. harvesting should be focused on the salient. If no salient has formed sand harvesting should be avoided or heavily limited in quantity). No spring 2020 campaign should be undertaken at the breakwater to allow sufficient time for the salient to re-built. A maximum of 40,000m^3 should be harvested in autumn 2021 to limit further downdrift effects, even if more sand is available in the salient (Table 2-7). A pre-works survey shall confirm exact quantities available at that point in time (it is possible that less than 40,000m^3 will be available).
- Beach conditions shall always be assessed prior to each campaign to ensure that sufficient volumes are available. In other words, if there was a stormy season, harvesting depth shall be reduced further than what is recommended in the following slides.
- Harvesting operations should be optimised to achieve the following profile for South of Semaphore Breakwater and in between Jetties (Figure 2-19):
  - Min distance of 5m offset from toe of dune recommended (some short-term impacts will be observed, however, due to the natural replenishment and existing dune buffer and growth rate, this is considered acceptable);
  - Increase of 'transition slope' from 1:10 to 1:20;
  - Harvesting depth shall be kept above MLWS;
  - Harvesting depth shall not exceed 0.5m;
  - Natural beach features such as ~MSL berm shall be maintained; and
  - Majority of sand harvesting to be undertaken in the intertidal area.
- For the area north of Largs Jetty the same recommendations apply, with the exception that harvesting depth shall not exceed 0.6m.

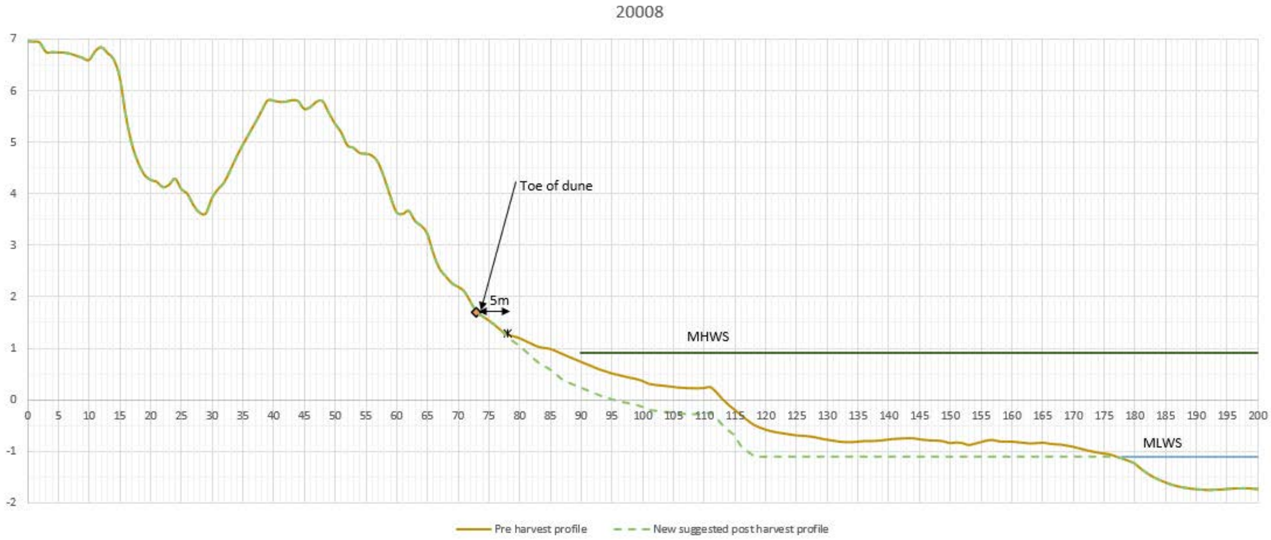

FIGURE 2-19 RECOMMENDED HARVESTING SPECIFICATIONS

- Working towards the recommended harvested beach profile would result in a maximum quantity of about 60,000 m^3 that can potentially be harvested from the area in between Semaphore and Largs Jetty and a maximum of 85,000 m^3 from North of Largs Jetty in 2020/21. However, lesser quantities shall be envisaged to minimise adverse impacts on beach usability during and after a campaign. Therefore the suggested quantities of the three scenarios of maximum 35,000 m^3 and 50,000 m^3 for the area in between Semaphore and Largs Jetty and North of Largs Jetty respectively are acceptable (Table 2-7).
- While generally all 3 scenarios are acceptable with the outlined optimisations, Scenario 3 is the least desirable. This is because the scenario 3 campaigns are focused on one time of the year rather than spread out over two campaigns over the year. Harvesting large quantities at one time will result in increased impacts such as the development of erosion scarps. Scenario 1 and 2 are therefore preferred.

TABLE 2-7 REVISED SCENARIOS FOR 2020/21 CAMPAIGN OPTIONS

Location of Sand Collection	Spring 2020 (m^3)	Autumn 2021 (m^3)	Totals for 2020-21 (m^3)	Recommended revised quantities
Scenario 1 - recommended				
Breakwater salient (Point Malcolm)	0	~~50,000~~ 40,000	~~50,000~~ 40,000	Max 40,000m^3 in autumn 2021. Possibly less if that quantity is not available within the salient.
Between Semaphore and Largs Bay Jetties	~~10,000~~ 20,000	10,000	~~20,000~~ 30,000	Acceptable. Should an additional 10,000 m^3 be required that cannot be harvested from the breakwater area they should be harvested from this area.
North of Largs Bay Jetty (to Strathfield Terrace)	25,000	25,000	50,000	Acceptable.
TOTALS	~~35,000~~ 45,000	~~85,000~~ 75,000	**120,000**	
Scenario 2 - recommended				
Breakwater salient (Point Malcolm)	0	~~50,000~~ 40,000	~~50,000~~ 40,000	Max 40,000m^3 in autumn 2021. Possibly less if that quantity is not available within the salient.
Between Semaphore and Largs Bay Jetties	17,500	17,500	35,000	Acceptable.

Location of Sand Collection	Spring 2020 (m³)	Autumn 2021 (m³)	Totals for 2020-21 (m³)	Recommended revised quantities
North of Largs Bay Jetty (to Strathfield Terrace)	~~17,500~~ 27,500	17,500	~~35,000~~ 45,000	Acceptable. Should an additional 10,000 m³ be required that cannot be harvested from the breakwater area they should be harvested from this area.
TOTALS	~~35,000~~ 45,000	~~85,000~~ 75,000	**120,000**	
Scenario 3 – not recommended				
Breakwater salient (Point Malcolm)	0	~~50,000~~ 40,000	~~50,000~~ 40,000	Max 40,000m³ in autumn 2021. Possibly less if that quantity is not available within the salient.
Between Semaphore and Largs Bay Jetties	~~20,000~~ 30,000	0	~~20,000~~ 30,000	Acceptable. Should an additional 10,000 m³ be required that cannot be harvested from the breakwater area they should be harvested from this area.
North of Largs Bay Jetty (to Strathfield Terrace)	0	50,000	50,000	Acceptable.
TOTALS	~~20,000~~ 30,000	~~100,000~~ 90,000	**120,000**	

3 BIODIVERSITY CONSIDERATIONS

This section considers the potential impacts of sand extraction on biodiversity values in the vicinity of project area. This desktop review was undertaken to consider the potential environmental impacts of the proposed 2020-2021 campaign and to identify some potential impact mitigation practices to help minimise those impacts. Four key environmental assets have been considered.

- Dune Flora – native vegetation (presence and quality of vegetation on the foredune as this was the main area potentially impacted)
- Beach and dune Fauna – beach nesting birds as the most vulnerable
- Wrack – this is important as it provides an important link between land and sea, and provides food and shelter
- Intertidal ecosystems living in the sand under the sea or tidal zones.

3.1 Potential Impacts from Sand Harvesting

There are a number of activities that can impact the environment, and these are identified in the following sub-sections. These impacts on the four key environmental assets are then discussed in Section 3.2.

3.1.1 Physical removal or exposure of intertidal ecosystems

There is generally a poor understanding of the abundance and diversity of intertidal ecosystems along Australian beaches, and also worldwide, and the impact of sand harvesting and beach nourishment on these is identified as a knowledge gap. Any depletion of intertidal ecosystems is also expected to have a putative effects on fish and birds, but again this is an identified knowledge gap.

Intertidal ecosystems are almost certainly present within the sands being harvested and removed from the site and deposited on beaches elsewhere. Where the sand has been removed from the surface, ecosystems deeper in the sands may be left exposed or at least temporarily displaced.

3.1.2 Compaction of sands

Where scrapers, excavators and dump trucks are travelling, a level of compaction of the sands is anticipated.

There is evidence that long term vehicle movement on beaches increases sediment compaction, and this relates to beaches that are open to large numbers of vehicles year round, and not to short term access for sand movement referred to in this report. Compaction of sediments could have the following detrimental effects (FR3cE 2008):

- More compacted sands have slower rates of water movement within them. Invertebrate animals called meiofauna live between these sand grains and these animals are responsible for processing organic materials dissolved in seawater and act as a water-filtering system. Reduced flows through compacted sands results in less favourable conditions to these organisms.
- Compaction of sands also reduces the ability of larger invertebrates to burrow. Affected animals include cockles, worms, snails and small crustaceans.
- Compaction, in combination with vehicles impacting wrack, can lead to fewer and less diverse macroinvertebrates in wrack and impair the beaches ability to function as an ecosystem

The movement lines and compaction of sands in different locations is also considered a compromise. There is known to be less infauna present below the dryer, upper beach sands. However, the upper part of beach below the foredune is most susceptible to vehicle impacts as the soft sands are easily rutted by tyres and wrack accumulates at the high tide mark (FR3cE 2008). These ruts can trap young birds and lead to crushing if vehicles retrace the movement path. Movement along the areas already scraped, or along the areas planned to be scraped on that day, might be the path of least impact. Where practical, consideration should be given to trucks following a consistent line that will be scraped last at the end of day.

3.1.3 Wrack loss

Wrack is the term for the seaweed, marine vegetation and other organic materials that wash ashore on the beach. Wrack is a key component of beach ecosystems (Duong 2008). It provides an important link between the marine and terrestrial environments via the transfer of nutrients and organic matter. It interacts with and influences beach morphology and sediments, provides habitat for macrofauna, re-mineralises nutrients through decomposition and provides the basis for a complex trophic web that helps support important native fauna.

Wrack provides food and shelter for a variety of beach inhabitants. Wrack and the fauna it supports can be lost through physical removal during sand harvesting or crushing by scrapers or dump trucks.

3.1.4 Scraper and truck movement keeping fauna from swash zone

The physical movement of vehicles along the beach can discourage fauna from approaching the swash zone. It is important for shorebirds to be able to feed near the water's edge and amongst the wrack.

3.1.5 Noise and activity disturbance

General noise and activity of machinery on the foreshore can deter fauna from utilising the beach.

3.1.6 Dune erosion and steepening

As explained in Section 2, sand harvesting, particularly if closely followed by a storm event, can cause erosion to the foredune and steepen the face of the dune or create a scarp (a steep slope).

Substantial erosion and recession of the dune system could result in the physical loss of vegetation. This could in turn result in the influx of invasive dune seed (e.g. sea wheat grass) which, once established, can bind the crest dune sands and lead to a steep dune slope when high tides and storms erode the toe. Furthermore, the development of a tall scarp may impede the movement of humans and possibly dogs, but a steep foredune also impedes movement of fauna to and from the swash zone. Allowing this movement is especially critical to beach nesting birds and their chicks and is discussed further in Section 3.2.2.

3.2 Key Environmental Assets and Impact Mitigation

3.2.1 Flora

Dune vegetation is a key asset to be considered with respect to sand harvesting impacts. Although the vegetation on the dunes will not be physically impacted by machinery in the sand harvesting process, there is the possibility of resultant foredune erosion and therefore displacement of the vegetation on the outermost dune face and crest.

The Department for Environment and Water had recently commissioned T&M Ecologists to undertake a Flora survey of the dunes from Semaphore South to Largs North (T&M Ecologists 2020). This report described the vegetation present across the dune system. Vegetation was mapped into 20 different vegetation types/units which were individually described by species cover and diversity, and the overall condition was also described. This vegetation mapping was then re-classified and mapped into three condition categories:

- High quality vegetation (mapped as red, see Figure 3-1)
- Moderate quality vegetation - slightly degraded or weedy vegetation (mapped as yellow)

- Poor quality vegetation - very sparse native, heavily degraded or exotic vegetation (mapped as green)

The most seaward foredune and its vegetation was of greatest interest as it was this dune that may be impacted by the works. The consistent trend was that the condition improved with distance inland from the foredune and nearly all of the foredune was in poor condition with exotic species dominating, particularly Sea Wheat-grass (*Thinopyrum junceiforme*) and Sea Rocket (*Cakile maritima*). Figure 3-1 shows the reclassified vegetation mapping at the northern end of the project area. Note that all the foredune area within this section has poor quality vegetation (shaded green).

FIGURE 3-1 RECLASSIFIED DUNE VEGETATION CONDITION MAPPING (ORIGINAL MAPPING FROM T&M ECOLOGISTS 2020)

If additional foredune retreat does occur due to sand harvesting, it is likely to only impact the poor quality vegetation. It is highly unlikely that there will be any impact to high or medium quality vegetation from the harvesting campaign. Loss and growth of the foredune is coastal process that occurs naturally and this part of the beach/dune system is dynamic and the ecology has evolved to cope and respond.

Impact mitigation:

- Ensure that all machinery stays off the vegetated dune system.

3.2.2 Fauna

There are a number of transient and resident fauna that utilise the dune system and upper beach zone. For the purposes of this review we have looked at the potential impact on beach nesting birds as they are considered most sensitive to the proposed sand harvesting activities. Plovers (Red-capped and Hooded) have been adopted as the key fauna species when considering potential impacts and mitigation strategies. At the time of preparing this review (Sept-Oct 2020), there were no known Plovers nesting sites on the beach or dunes within the project area, however, there had been no formal surveys undertaken.

Key attributes and requirements of beach-nesting birds are as follows (Cuttriss et al. 2015) (Schlacher et al. 2016):

- Birds appear to select breeding habitat sites with more food to meet the increased energetic requirements associated with breeding.
- Biparental care and low reproductive success mean that adult plovers have limited mobility for long periods when breeding (30 days incubation, 35 days brood-rearing) and breeding territories are used for up to eight months per year.
- Plover chicks must feed themselves for five weeks before they can fly. The chicks require food resources to sustain growth and survival across that five week brood rearing phase. The adults too have increased energy requirements associated with breeding and coincidental moult of primary feathers. To sustain this demand for prey, adults and chicks need access to the swash zone and wrack.
- Most beach-nesting bird species rely on invertebrates (e.g. insects, small crustaceans) as an irreplaceable food source, foraging primarily around the strandline and amongst wrack on the upper beach near the dunes.
- Chicks must be able to move from the nesting site, typically high on the beach or foredune, to the swash zone to feed and back again. If the dune slope is too steep the birds cannot make their way back up the beach and a scarp may prevent return movement. Therefore, beaches with steep foredunes or scarps will either deter birds from selecting that beach for nesting or will likely cause chicks to starve or be stranded.

Speybroeck et al. (2006) suggests that the preferred season to undertake works is entirely site specific, depending upon the area's location, shorebird community and other environmental interests. The guidelines for ecologically good practice when undertaking beach nourishment are also relevant to sand harvesting. When aiming to minimise impacts on beach nesting birds only, activities should ideally be undertaken within the winter period. However, since a number of organisms spend the winter months in the shallow infralittoral zone, this timing is not without impact. It is suggested that activities be undertaken during periods of low beach use by birds and other migrating or mobile organisms.

Potential impacts:

- Increased dune slope – sand harvesting can lead to an increase in foredune slope or scarping.
- Loss of wrack/food – removal or damage to wrack (this is discussed in Section 3.1.3).
- Noise and movement – The movement of scrapers and dump trucks along the beach may discourage birds or discourage birds from feeding within the swash zone.
- Crushing – flightless chicks have the potential to be run over by scrapers and dump trucks moving near the swash zone or hiding within tyre ruts.

Impact mitigation:

- Identify and protect nesting sites – Using trained personnel so as not to cause more disturbance and/or crushing of eggs, undertake a targeted beach-nesting bird survey of the project area dune system prior to commencement of works. If a nest site is identified, rope off the nesting area and develop a site specific impact mitigation strategy. This should include not harvesting within a certain distance of the site, driving machinery further down the beach at that location and moving more slowly and carefully to limit the likelihood of disturbance to the birds.

- Timing of works – There are compromises for fauna regarding the timing of works and there are also social and operational needs to consider. One campaign mid-winter would be ideal for beach-nesting birds however, it has been reported that there are fewer opportunities for sand removal due to tides, weather and shorter daylight hours. Compromise has previously been made to move sand by articulated dump trucks in the middle of the day (9am – 5pm) to avoid walkers before and after work. There is also the need to harvest during the lower tide periods.
- Limit the number of campaigns – There is a compromise between harvesting less often and extracting more sand at one time. If only one campaign is undertaken per year, more sand needs to be extracted and the potential impacts on intertidal ecosystems (due to digging deeper), dunes (more erosion potential), vegetation (loss with dune erosion) and fauna (steeper foredune) is greater. The current practice is therefore to extract broad and shallow twice per year in spring and autumn. The current 2020-2021 campaigns are unlikely to be changed but consideration should be made for a single winter campaign if smaller volumes are required and the impact on the foredune is expected to be minor.
- Minimise traffic on beach – If larger dump trucks are used, fewer trips are required. The overall compaction of sands resulting from many small trucks versus fewer large trucks is unknown. The potential for noise disturbance and crushing is likely to be less with fewer trips by a large truck. Overall, it is suggested that larger trucks with broader tyres, making fewer trips, is likely to deliver the least impact to fauna.
- Limit the speed of trucks – Fauna will have a greater chance of being seen by drivers, and a greater chance of moving out of the path of trucks if speed is reduced. Ensure maximum speeds are adhered to and reduce speed if necessary to avoid contact with any vegetation. If nesting sites are identified, a much slower speed should be set in the vicinity to avoid disturbance and to reduce noise.

3.2.3 Wrack

As indicated in the previous sections, wrack is important for physical and biological processes on beaches. The primary source of wrack on Adelaide beaches is seagrass.

Impact mitigation:

- Minimise distribution of vehicle movements on the beach, preferably operating in the intertidal zone. This will help to minimise the crushing of wrack and the invertebrates that live within, while also providing some certainty of path for beach users.
- if it is necessary to move seagrass wrack to harvest sand, it should be relocated to the upper beach rather than removing from site. The presence of wrack on the upper beach can significantly increase the abundance and diversity of invertebrates, and therefore food supply for beach nesting birds and the high energy demands of their chicks (Schlacher et al. 2017). If wrack is limited or likely to be removed or crushed by machinery movement, consideration should be given to moving wrack to the upper beach. This would need to be done regularly because as soon as the wrack is no longer connected to the tide it dries out very quickly and many of the prey items associated with the wrack die. Ideally the wrack would be placed higher on the beach but still connected at high tide, so it becomes wet again.

3.2.4 Intertidal Ecosystems

The physical removal of these, and compaction of sands within which they live, has been identified as the main potential impacts. The literature review has revealed a scarcity of information on how to manage intertidal ecosystems and how to mitigate disturbance during harvesting. There is much literature about the effects and biological processes occurring at nourishment sites (where the sand is deposited), with far less research available about the effects on infauna at harvest sites. One study of relevance that was undertaken on a beach on the northern New South Wales Coast (Smith et al. 2011). This study involved the scraping of sand to a depth of 0.5m and relocating that sand to the upper beach (not removed from the site). The study confirmed suggestions from other research that beaches are highly dynamic do have the ability to rapidly recover from physical disturbance. However, the study also revealed that most beach animals (at this site) inhabit the upper layer of the beach (top 0.1m or so) and this would have resulted in complete defaunation of the scraped area. The study then states that the un-impacted lower beach/very shallow subtidal region, which generally has a higher diversity (Hacking 1998) may provide a source of highly mobile infauna recruits capable of rapidly colonising the scraped areas. Generally, beach infauna species are abundant and mobile, where species either move vertically up and down through the sand or up and down the beach profile with tide and water level (marinespecies.org).

There is evidence that long term vehicle movement on beaches increases sediment compaction, and this relates to beaches that are open to large numbers of vehicles year round, and not to short term access for sand movement referred to in this report. It is shown that beaches open year round to larger numbers of vehicles have significantly fewer species and abundance. Macrobenthic assemblages on off-road vehicle impacted beaches had significantly fewer species at substantially reduced densities, resulting in marked shifts in composition and structure (Schlacher et al. 2008). The ecological consequences of vehicles on sandy beach ecosystems is largely speculative and there is a knowledge gap in the putative effects on fishes and birds.

Impact mitigation:

- Strip harvesting - It has been recommended (Rosov et al. 2016) to utilise shallow cuts in strips while leaving unexcavated sand between cuts (striped dredging) to promote recolonisation from the un-impacted refuge areas. However, this approach is likely to be difficult to implement and is unproven. If this approach is to be implemented, appropriate monitoring should be established to determine if it improves recolonisation of the harvested strips. There are also public safety considerations by leaving a rutted / lumpy intertidal area that is potentially unsafe until it is naturally smoothed by water forces.
- Minimising sand compaction – the movement of vehicles should be minimised, and consistent movement paths should be established and adhered to. This may compact a particular line but minimise the overall impacts. Consideration should be given to the one path that can be utilised under the operational range of tide heights (i.e. establish one path adjacent to the highest scrape line).
- Continue to use shallow and broad harvesting – Again there is a knowledge gap regarding the species present and the depth at which they live. However, there are other potential impacts if harvesting is too deep and therefore shallow extraction is recommended. Given the consensus that infauna is mobile, burrows and moves up and down the beach with the movement of tide/ water line, shallow scraping would be the best approach to avoid damage to infauna.

4 TRAFFIC MOVEMENTS

4.1 Current Traffic Movements

An assessment has been made of possible impacts of the sand movement works on the beach, including as a result of heavy vehicles operating in the intertidal zone and as a direct result of the removal of sand.

DEW has historically limited operations to a window to enable the public to enjoy the beaches in the morning and afternoon (outside of common work hours). However, limited operating hours impact on the total duration of each campaign and this needs to be balanced carefully. The vehicles access the beach from a single access point at the Surf Lifesaving Club at Point Malcolm Reserve, as shown in Figure 4-1. Current operational hours are:

- 7am to 5pm for the land plane
- 9am to 4pm for the beach trucks
- 7.30am to 5pm for the road trucks

FIGURE 4-1 SAND ACCESS AND COLLECTION ROUTES

4.2 Trucking Movements

Existing access to the beach will be via the ramp adjacent to Semaphore SLSC at Point Malcolm. The approximate number of truck movements were assessed by looking at the capacity of the typical truck used by DEW for sand carting works, which is a Caterpillar 740 Articulated Truck.

Although the specifications say this truck is typically 24 cubic metres capacity, the actual volume moved by each truck is also dependent on the loader/ excavator used and the number of "swings" they use to load. A calibration is made of each loader/ excavator bucket used by each contractor to determine a "deemed" bucket capacity. Consequently, depending on the contractor, the deemed volume moved by each truck can vary from between 20 to 25 cubic metres per truck (loose sand).

During this report, sand volumes for a campaign refers to the "solid" or "in-situ" volume of the sand e.g. "20,000m^3 from between the jetties" means the solid volume before removal. As the contractors measure the "loose" (bulked) volume, a conversion factor of 1.13 from loose to solid is applied. On this basis, the "worst case" number of vehicle movements was calculated as follows:

- Volume of sand to be removed annually up to 120,000 m^3
- 20-25 m^3 per truck = 17.5-22 m^3 actual sand
- Number of yearly truck movements around 6,000 (between spring and autumn) – it should be noted that this refers to return movements (full truck one direction, empty truck the other). This translates to up to 12,000 journeys over the year.

The possibility of having one longer sand movement campaign has been considered, and the success of this would be highly dependent on good weather and tide conditions to avoid there being fewer opportunities to remove the sand. Two campaigns allows more flexibility to allow some regeneration of sand before more is removed. The following has been developed following other sand movement campaigns in Adelaide's southern beaches, and disruption is minimised through:

- Use of a single beach access point
- Timing of removal to avoid:
  - School holidays
  - Early mornings and after work
- Balance between truck movements and size of truck
  - Larger vehicles would result in fewer movements
  - Smaller vehicles will result in more journeys over a longer period of time
  - Noise
  - Vibration
- Single winter campaign
  - Weather issues
  - Fewer opportunities for effective working
  - Potentially more disruptive short term to sand regeneration

4.3 Operational Requirements

To minimise the potential negative impacts on adjoining and nearby residences and business premises particularly from dust, odour and noise, the following requirements are in place during every operation to undertake maintenance or relocate sand:

- All machinery and equipment involved in sand management activities are scheduled to occur on weekdays, and not on weekends or public holidays.
- Speed limits are 40 km/h, but these are reduced in the proximity of other beach users
- Heavy vehicles and machinery are generally not stored overnight on the beach, which ensures the equipment is safe from overnight water movement and interference.
- Contractor's methods are set out in their contractual documentation, which includes hours of working, speed limits, access points, routes and areas for sand removal.

5 OTHER IMPACTS

In addition to traffic movements, some of the other impacts likely to be encountered by beach users are discussed below and include:

- Safety of beach use whilst sand carting movements are ongoing, for all beach users, especially children and dogs
- Speeding or dangerous driving by truck drivers
- Loss of dunes which will affect flora and fauna, but also stormwater quality which is currently filtered by the dunes
- Loss of amenity, including visual and noise disturbance
- Impact on local businesses

5.1 Health and Safety

Safety considerations form a paramount component of the social assessment, and DEW has a current set of operating conditions for the sand movement works, which includes constraints such as truck speed on the beach and give-way rules.

It should be noted that in 40 years of operation, there have not been any reported “notifiable” health and safety incidents attributed to the movement of sand. The following operational requirements are currently in place and will be maintained through effective management:

- Sand is collected at times that minimise public interaction
- The trucks and other plant operate on an approved route only
- Access for sand movement is via a single point, which is currently in use for this purpose for sand transfer to the south
- Sand is left in a safe condition at the end of each working day, (i.e. no steep slopes or overhangs)
- Information/ warning signage, site supervision and public safety measures
- Safe operation through vehicle drivers’ contractual arrangements

5.2 Social and Amenity

It is recognised that as on any sand campaign, noise and disruption is to be expected, however management practices are already in place to limit impacts to the public. Water Technology have reviewed current practices and the resulting impacts, for example reduced working hours or reduced work area extents.

Beach replenishment activities to date have usually required the presence of trucks and earthmoving equipment on the beach. Earthmoving equipment is loud, especially when reverse warning alarms are in use, and affect nearby beach users and residents. Although these activities are mostly carried out during months and times of day when there are fewer people on the beach, the work still poses a risk of injury, disturbs beachside residents and deters visitors from using the beaches, and these need careful management.

Another concern about beach replenishment activities to date has been the amount of disturbance and traffic congestion created when trucks cart sand along suburban roads for replenishment activities further south.

In the meantime, a significant but short term effect on beach amenity will be experienced.

5.3 Impact on Local Businesses

Semaphore Road and other local roads are part of a major business activity centre, with significant dependence on day-tripper trade from Adelaide's northern suburbs and the Barossa Valley. There may be a measurable effect on local shops and businesses during the campaigns if fewer people are using the beaches. A large number of local businesses are not solely dependent on beach trade, as the section of Esplanade adjacent to the proposed campaign mostly comprises residential properties.

Business owners were surveyed by local group Save Our Shores which indicated significant concerns by business owners on their trade, and this has not been quantified as part of this report. It should also be noted that this area is known for other activities and events including the Semaphore Kite Festival, and other organised beach sports.

5.4 Stormwater Quality

A qualitative assessment has been made of the potential impacts of dune recession on stormwater quality, as some stormwater is discharged behind the dunes, and one of the concerns raised by stakeholders is that an element of filtration could be lost.

Along the metropolitan coast, most stormwater is directed straight onto the beach, and a limited number of the discharges points have enough stable dune width to facilitate a basin.

The assessment of sand movement earlier in this report has demonstrated that with appropriate management the dunes will not be eroded to the point they don't provide a level of filtration.

The dunes do not form part of a formal stormwater treatment facility, although this could be a potential opportunity, but would require a constructed treatment facility, and is not covered under the scope of this report.

5.5 Dune Vulnerability

One of the concerns raised by the stakeholder group is the potential incursion of high sea levels through dune gaps into low lying areas behind the fore dune.

A low lying area has been identified where seawater incursion could occur in a local area opposite Koowarra Terrace (south of Strathfield Terrace towards the northern extent of proposed sand carting). This shows a potentially vulnerable lower point through the primary dune to the rear, although water incursion has not been observed.

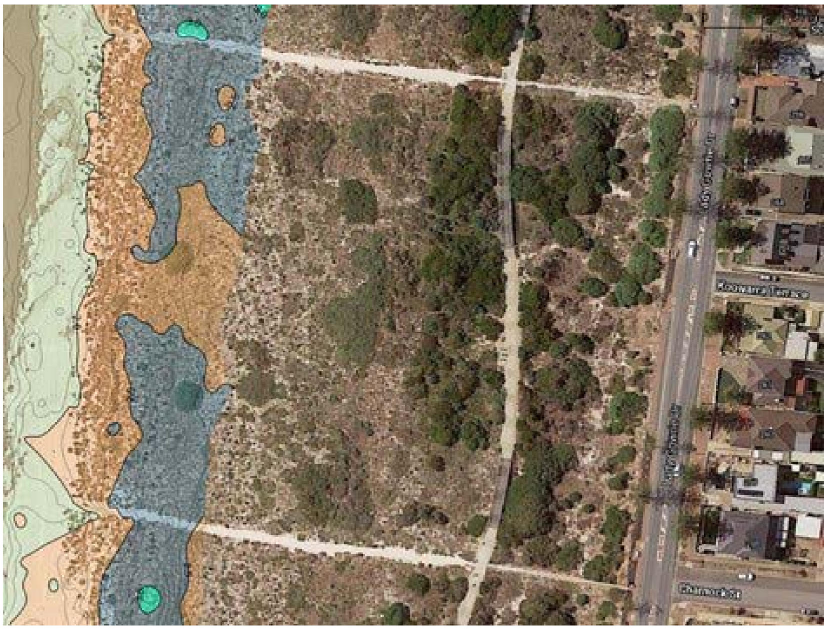

FIGURE 5-1 LOW LYING DUNE AREA AT KOOWARRA TERRACE

The Digital Elevation Model is limited in its easterly extent but indicates that the dune width at this point is around 190 m. Other areas between the Largs and Semaphore jetties are much narrower, and the concern is that an incursion may be significant.

Further survey would be required to be able to model this to provide greater certainty. Use of higher resolution Digital Elevation technology could well clarify the processes happening, however use of profiles is still valid, particularly given length of historical data set, and these do not indicate an elevated risk.

5.6 Other Mitigation

There is a nominated contact at the Department for Environment and Water for any questions regarding the coastline. Copies of these cards are distributed locally and can be found in libraries and cafes etc. and a copy of this card is included in 6Appendix C.

5.7 Economic Assessment

An economic assessment was discussed for this report, which comprised utilisation of a combination of LiDAR and beach surveys to assess the impact on the coast from coastal hazards such as storm tide inundation and erosion.

A 10% annual exceedance probability (AEP) storm event was used for the analysis and is generally described as a ‘rare’ event (for comparison, a 20-50% AEP is considered ‘frequent’, 50-100% AEP ‘very frequent’, 0.1-1% AEP ‘very rare’).

A more extreme storm event was not used for this analysis because it is anticipated that the reduced beach width is only a temporary state, with the beach naturally re-building over time due to the natural longshore sand transport.

The risk of erosion to infrastructure behind the dunes is dependent on substantial dune recession and the likelihood of this was discussed earlier in the report.

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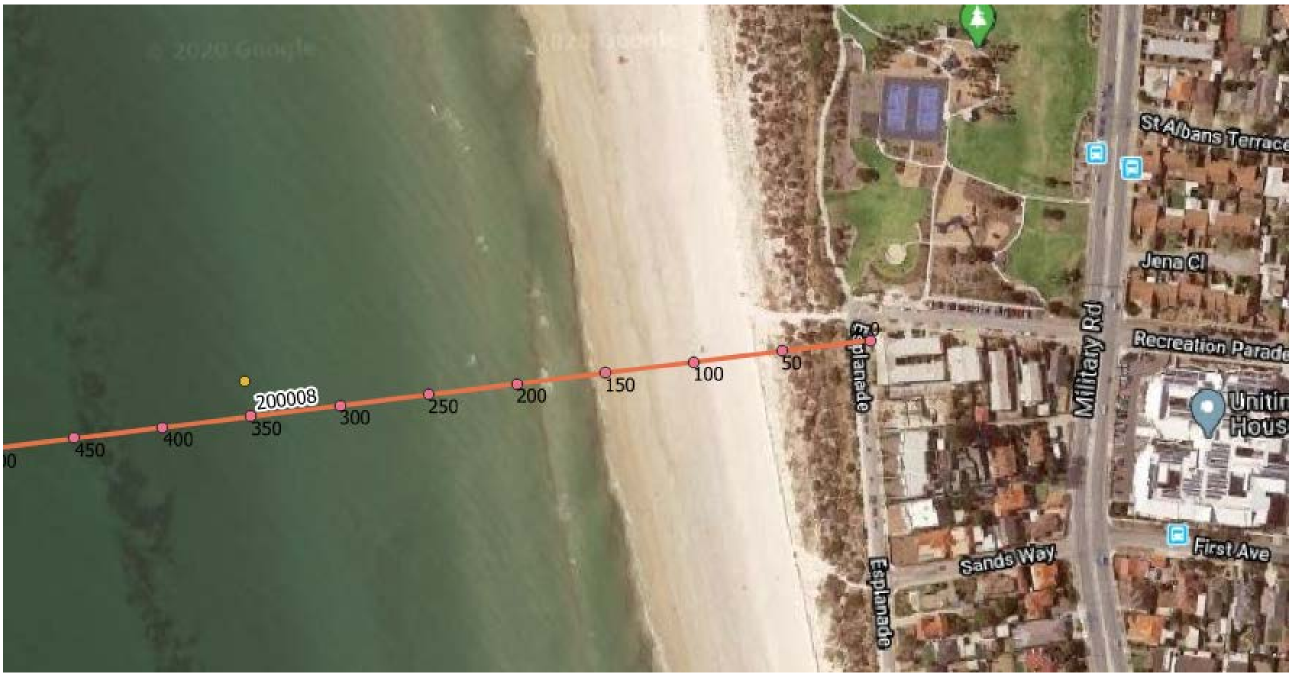
APPENDIX A
PROFILE ANALYSIS – DETAILED DESCRIPTION

A-1 Location and chainages of profiles

A-2 Profile discussion

Profiles are discussed in the order of south to north.

200008



- The dune has grown in height and width from 2010 to 2020. The dune height increased by over 1m to +5.8mAHD and grew almost 20m in thickness, resulting in a volume change of about 65m^2 at the profile location. Most of this dune growth has occurred from 2010 to 2014, with the dune being stable with only minimal change from 2014 to 2020.
- This profile location is further south than the harvest area, so no direct conclusions can be drawn on the impacts of the sand harvesting. However, due to the observed substantial dune growth in between 2010-2014 it is possible, however unconfirmed, that the erosion observed after the 19/20 campaign south of the breakwater (FIG DEM COMPARISON) did not exceed beyond the 2010 dune profile.
- There is minimal change observed in the beach and intertidal areas with natural fluctuations and movement of sand, but no long term trend to be observed.

200007

- The 2010 and 2020 profile is very similar with less than 1m erosion at chainage 195-245 on the 2020 profile.
- The foredune has accreted and extents further offshore in the 2020 profile than in 2010 with the dune toe pushed out from chainage 95 to 135. This accretion of the foredune has started after 2010 and steady increase of the foredune is noted, especially from 2018 - 2020 even though the most amount of sand was harvested during those years. It is suspected that the constant growth of the foredune is a result of the operations practises to maintain at least 6m clearance from the dune toe. Because the dune toe is not a fixed location it is reasonable to assume that the dune toe assessment was erred on the side of caution, resulting in a net foredune growth over the years.
- This resulted in sand harvesting areas to be pushed further down the beach towards the ocean, resulting in an overall steepening of the profile. This is not a concern in itself because the breakwater creates an offshore limit to potential oversteepening and sand will naturally replenish in lee of the breakwater due to the natural longshore transport in between campaigns.
- During the 18/19 and 19/20 campaign large amounts of sand were harvested in the lee of the breakwater, in excess of the 28,000 to 40,000 m^3/year that are considered sustainable. This resulted in the beach lowering of a large area (from chainage 130 to 280) of over 1m in height in some locations when comparing the 2018 to the 2020 profile. It is expected that the breakwater area will refill relatively quickly (see **Error! Reference source not found.** and **Error! Reference source not found.**) due to the natural longshore sand transport and the protection from the breakwater. However, the area just south of the breakwater that has been highlighted during the DEM analysis above (FIG) is not protected from coastal processes in the same way that the breakwater area is and impacts have been observed in the form of an erosion scarp following the works. It could not be determined if the localised erosion occurred due to the harvesting works themselves or as a consequence due to natural processes acting on the lowered beach profile.

- Due to the slight shift in harvest area and based on the large harvest quantities of the last 2 years it is less likely for a tombolo to form in the short term.
- The area in between the breakwater and the dunes fluctuated up and down in response to natural longshore sediment transport and sand harvesting campaigns.

200006

- The dune receded by about 38m from 2010 to 2017. The profile 200006 is located north of the area of the most recession (which is experienced in between Arthur St and Hart St) and therefore does not represent the maximum recession rate.
- No movement (neither recession nor accretion) has been observed from 2017 to 2019.
- Small nourishment campaigns have been undertaken over the years (data is available from 2014 onwards), ranging from as little as 1,500m³/year to 20,000m³/year, with a total of 41,500m³ placed from 2014-2019.
- A larger beach nourishment campaign of almost 35,000m³ was undertaken in 2020, resulting in accretion of the dune by about 10m, almost reaching the 2016 profile extent.
- Recession downdrift from the breakwater is to be expected and has been addressed in the breakwater design report (REF). Active management of downdrift erosion is continuously required.

200005

- Dune grew in height (0.8m) and grew seawards (6m) 2010-2020.
- Increase in height occurred slow and steady over the years.
- Dune seaward extent increased 2010 – 2016 by 14m, followed by 7m dune recession from 2016- 2020 . Resulting in a net accretion rate of +7m.
- It is not entirely clear what exactly caused a change from accretion to recession in 2016. Sand harvesting of a total of 19,000m³ has occurred in 14/15 and 15/16 at the jetty which would have resulted in recession of the profile during those years. Ongoing recession after 2016 could be caused by the cumulative impact of increased sand back passing from the breakwater salient in 15/16, 16/17, 18/19 and 19/20, leaving less sand to be transported to the northern beaches.

200004 * when there is no description of the changes in beach levels it is because they fluctuate naturally and no trend observed. applies to all profile discussions.**

- The dune increased in height from 3.4 to 4.6 mAHD and the front of the dune moved about 9m seawards from 2010 to 2020. This process occurred relatively steadily over the years.
- 20,000m^3 were harvested in between the jetties in 19/20. This impact might be seen when the next profile survey will be undertaken. No impact is visible on the current 2020 profile because the sand was taken either side of profile 200004. This was done to limit any impact on the middle section in between the two jetties where the dune buffer is the smallest, compared to the available dune buffer closer to the jetties.

200003

- Whole dune moved seaward with the dune crest moving about 23m from 2010 to 2020
- The dune front face moved out by about 16m 2010-2020
- Totally flat in 2013- check with James

200129

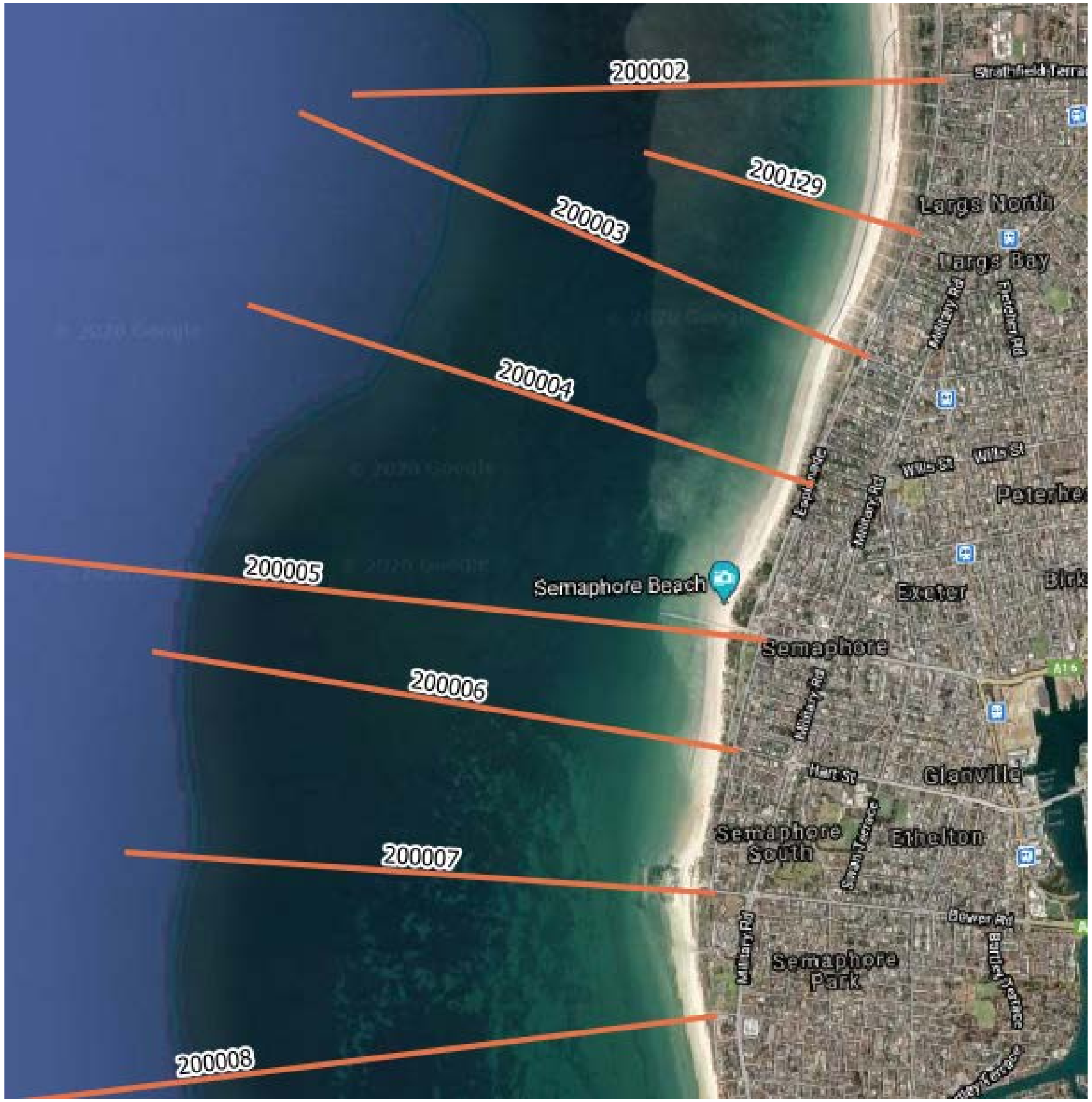
- Growth in height 0.9m 2010-20, biggest grow 2010-2014
- Grew seaward on average 30m, relatively steady over years
- New foredune forming

200002

- 35m seaward growth 2010-20 steady
- ‘new foredune forming in front of 2010 dune

APPENDIX B
RECORD OF PROFILES FROM 2010 TO 2020

1 PROFILE OVERVIEW



Profile list from south to north:

200008 – south of Semaphore Breakwater

200007 – Semaphore Breakwater

200006 - North of Semaphore Jetty, approx.. halfway to Semaphore Jetty

200005 – Semaphore Jetty

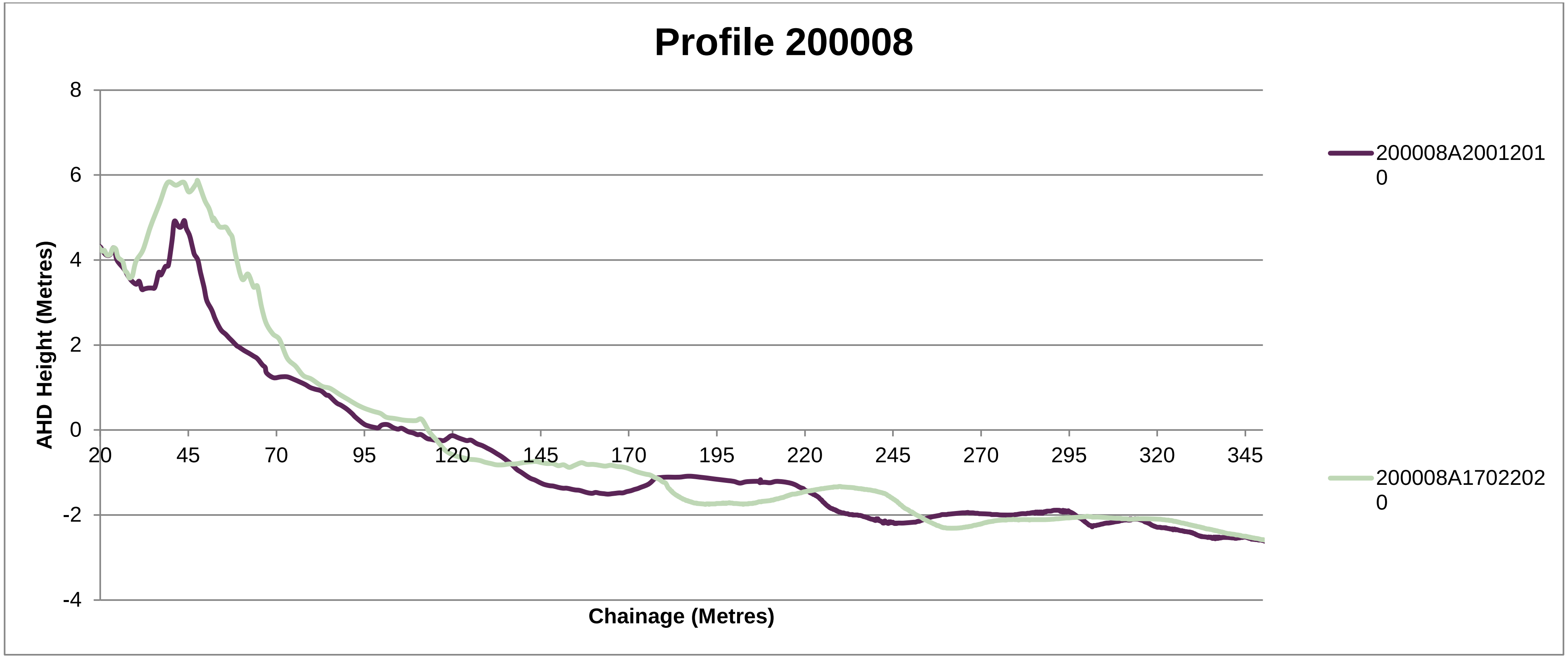
200004 – approx. central in between Semaphore and Largs Jetty

200003 – Largs Jetty – excluded from this analysis: The profile line sits on top of the beach access which is maintained by taking sand out of the dune. Not representative of natural processes and impact of harvesting works.

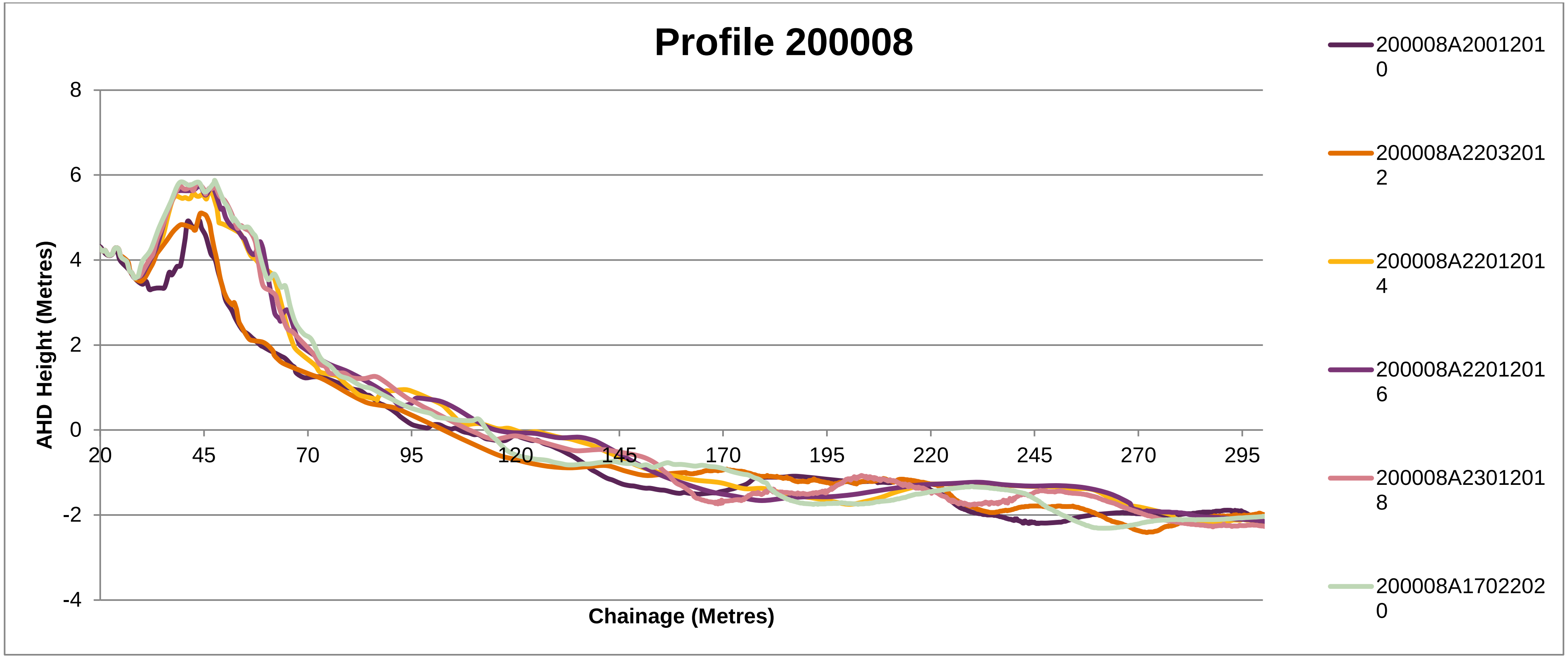
200129 – approx. 600m north of Largs Jetty

200002 – approx. 1.4km north of Largs Jetty

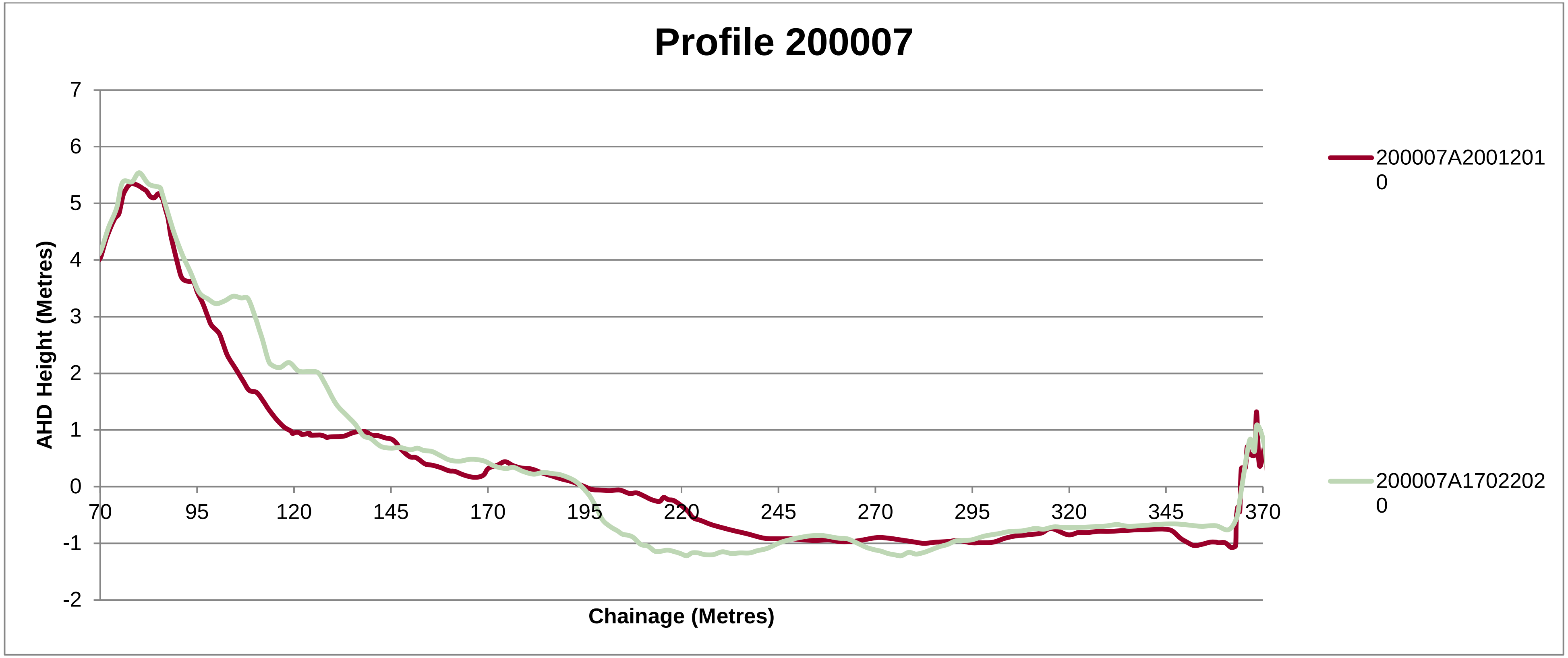
1.1 Profile 200008

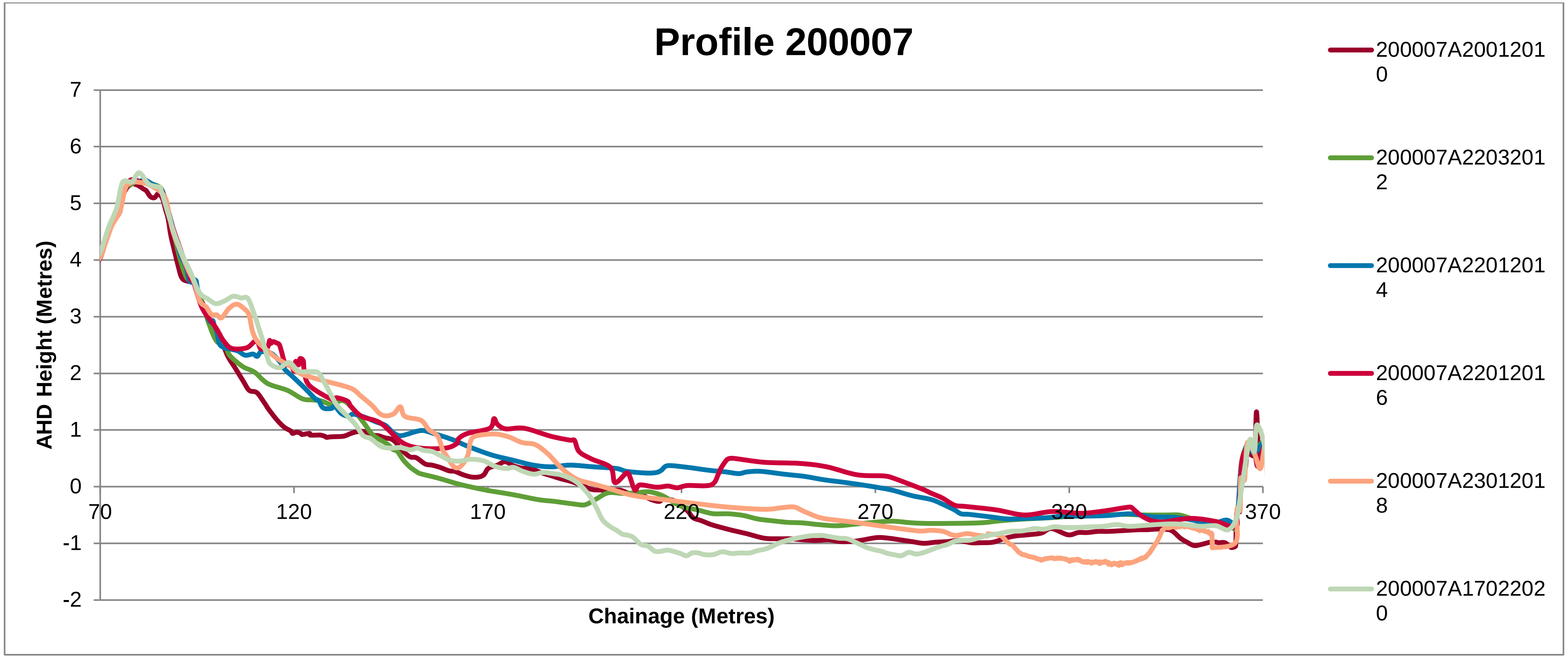


Profile 200008
8
6
4
2
0
-2
-4
AHD Height (Metres)
20
45
70
95
120
145
170
195
220
245
270
295
320
345
Chainage (Metres)
200008A20012010
200008A17022020


Profile 200008
AHD Height (Metres)
8
6
4
2
0
-2
-4
20
45
70
95
120
145
170
195
220
245
270
295
Chainage (Metres)
200008A20012010
200008A22032012
200008A22012014
200008A22012016
200008A23012018
200008A17022020

1.2 Profile 200007


Profile 200007
AHD Height (Metres)
7
6
5
4
3
2
1
0
-1
-2
70
95
120
145
170
195
220
245
270
295
320
345
370
Chainage (Metres)
200007A20012010
200007A17022020


Profile 200007
AHD Height (Metres)
7
6
5
4
3
2
1
0
-1
-2
70
120
170
220
270
320
370
Chainage (Metres)
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200007A22032012
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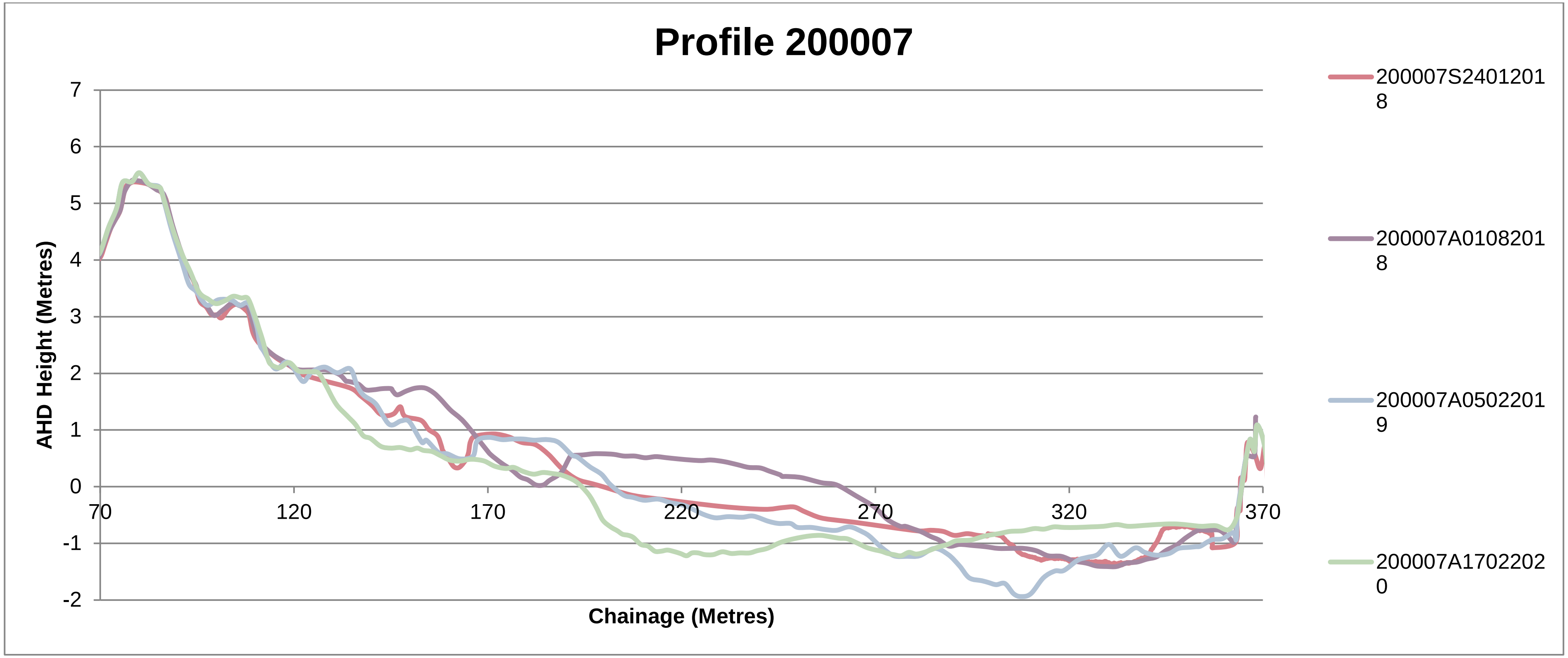
200007A22012016
200007A23012018
200007A17022020



Profile 200007
AHD Height (Metres)
7
6
5
4
3
2
1
0
-1
-2
70
120
170
220
270
320
370
Chainage (Metres)
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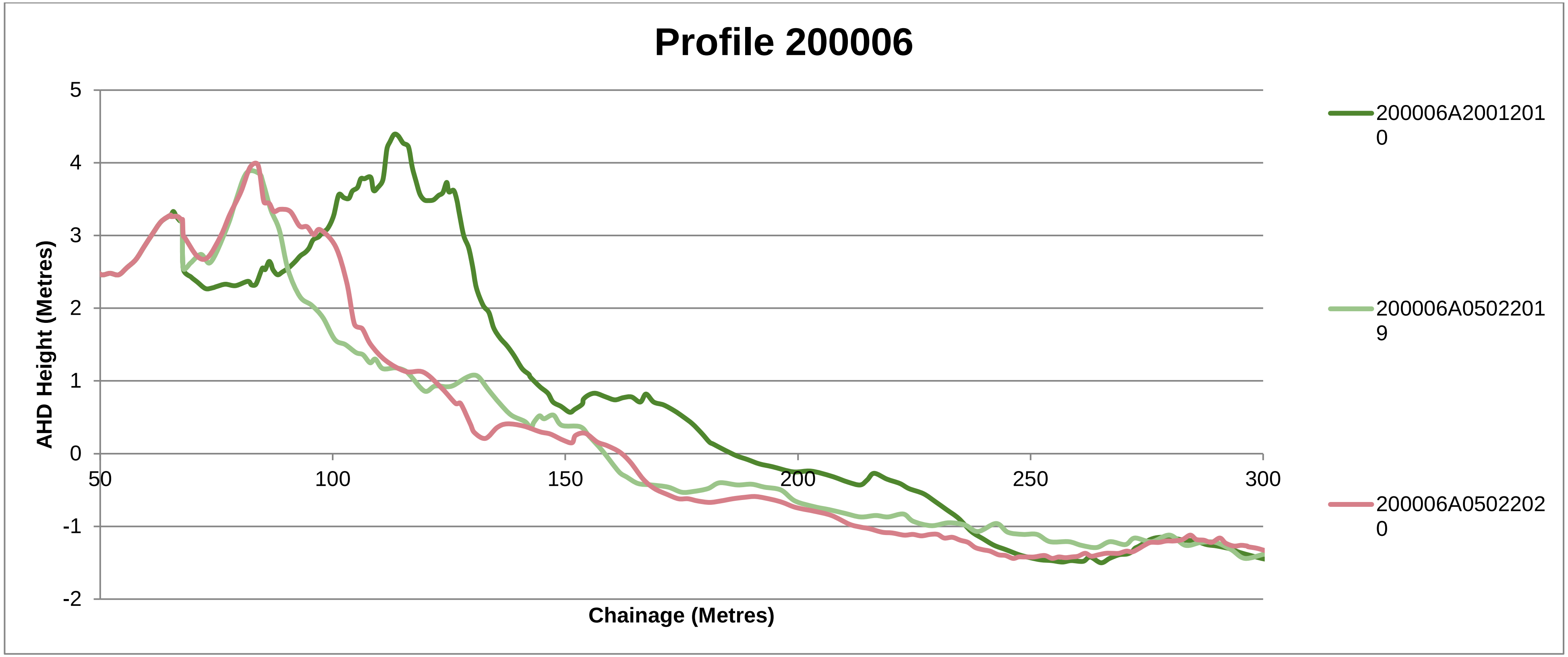
200007A01082018
200007A05022019
200007A17022020

1.3 Profile 200006



Profile 200006
AHD Height (Metres)
5
4
3
2
1
0
-1
-2
50
100
150
200
250
300
Chainage (Metres)
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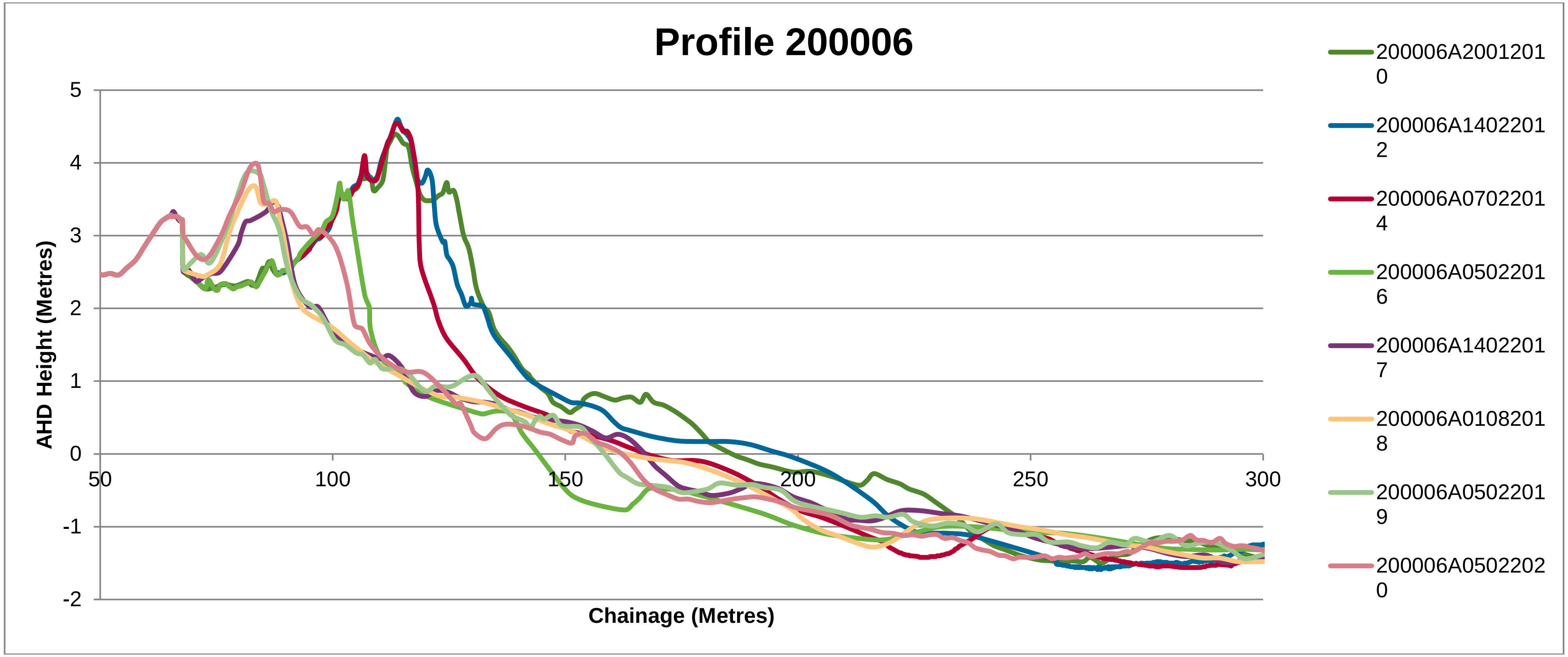
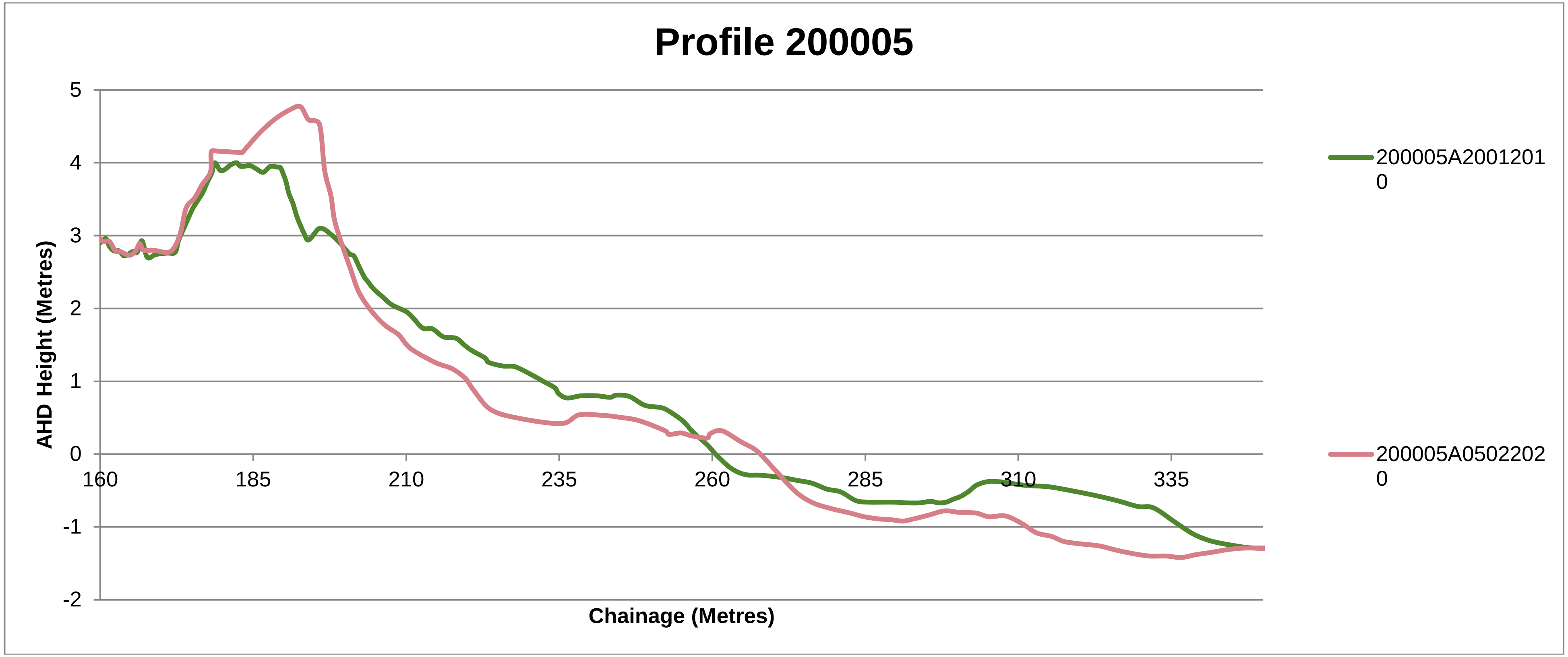
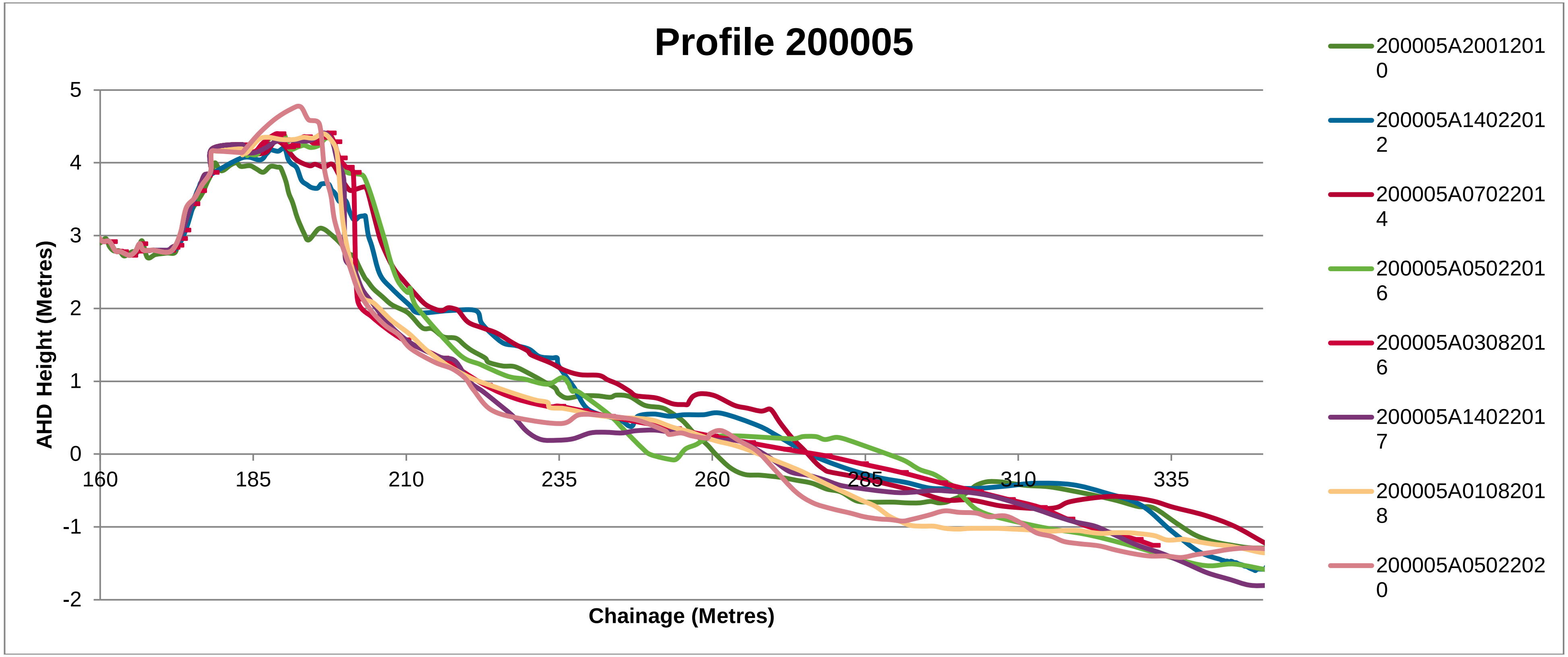
200006A05022019
200006A05022020


Profile 200006
5
4
3
2
1
0
-1
-2
AHD Height (Metres)
50
100
150
200
250
300
Chainage (Metres)
200006A20012010
200006A14022012
200006A07022014
200006A05022016
200006A14022017
200006A01082018
200006A05022019
200006A05022020

1.4 Profile 200005



Profile 200005
AHD Height (Metres)
5
4
3
2
1
0
-1
-2
160
185
210
235
260
285
310
335
Chainage (Metres)
200005A20012010
200005A05022020


Profile 200005
AHD Height (Metres)
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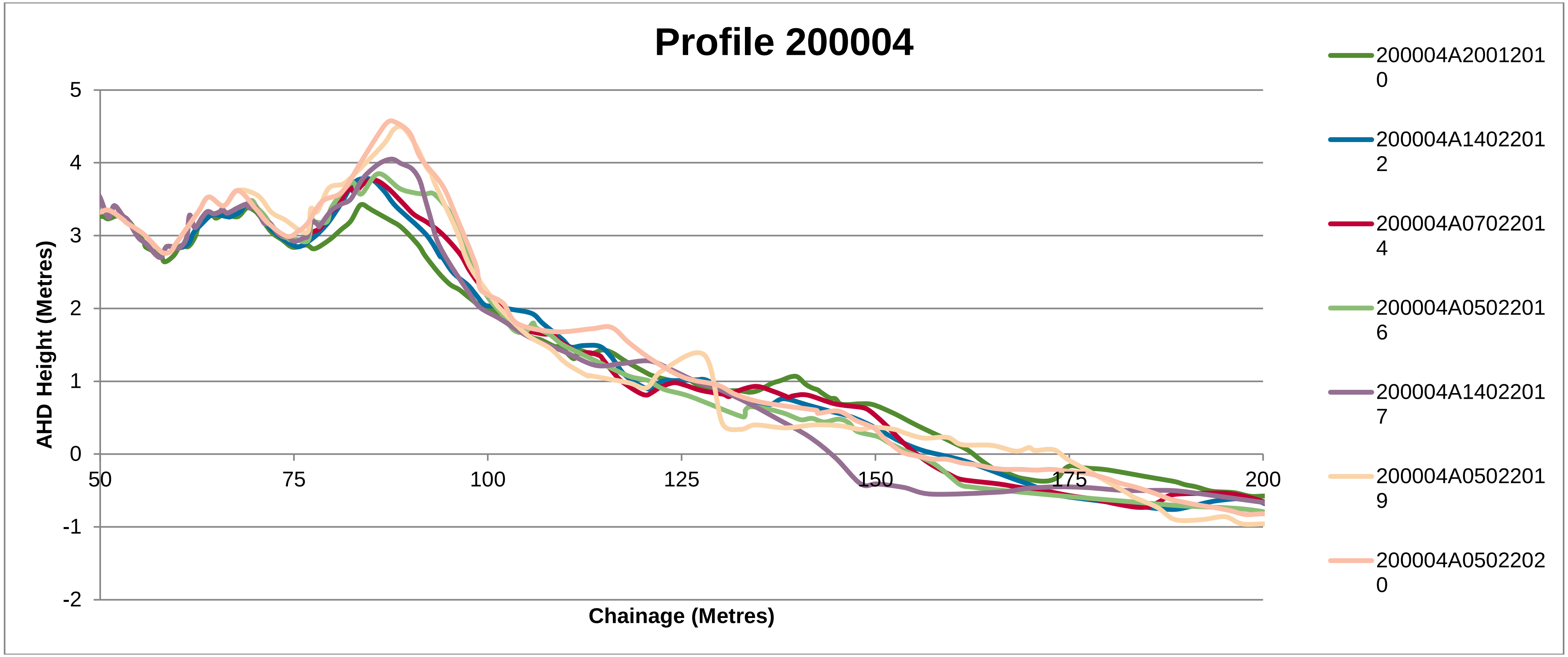
3
2
1
0
-1
-2
160
185
210
235
260
285
310
335
Chainage (Metres)
200005A20012010
200005A14022012
200005A07022014
200005A05022016
200005A03082016
200005A14022017
200005A01082018
200005A05022020

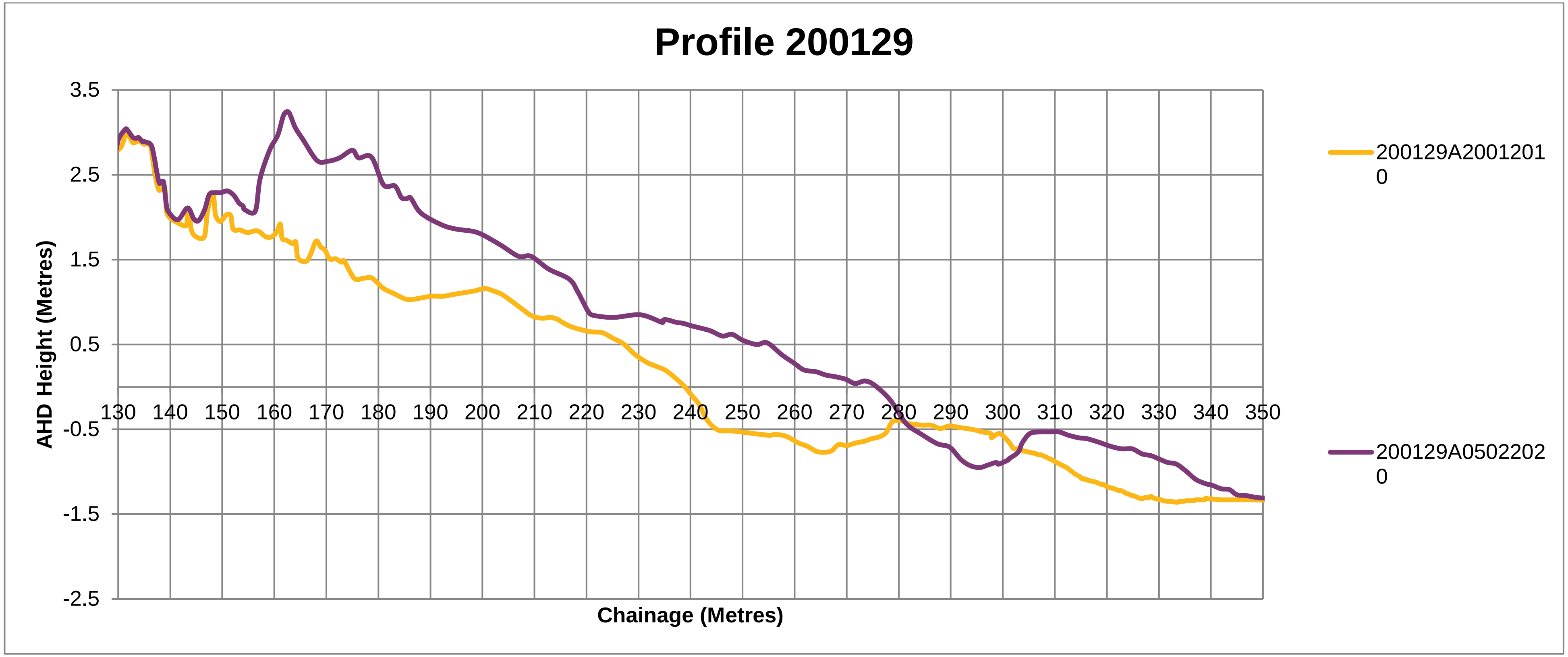
1.5 Profile 200004

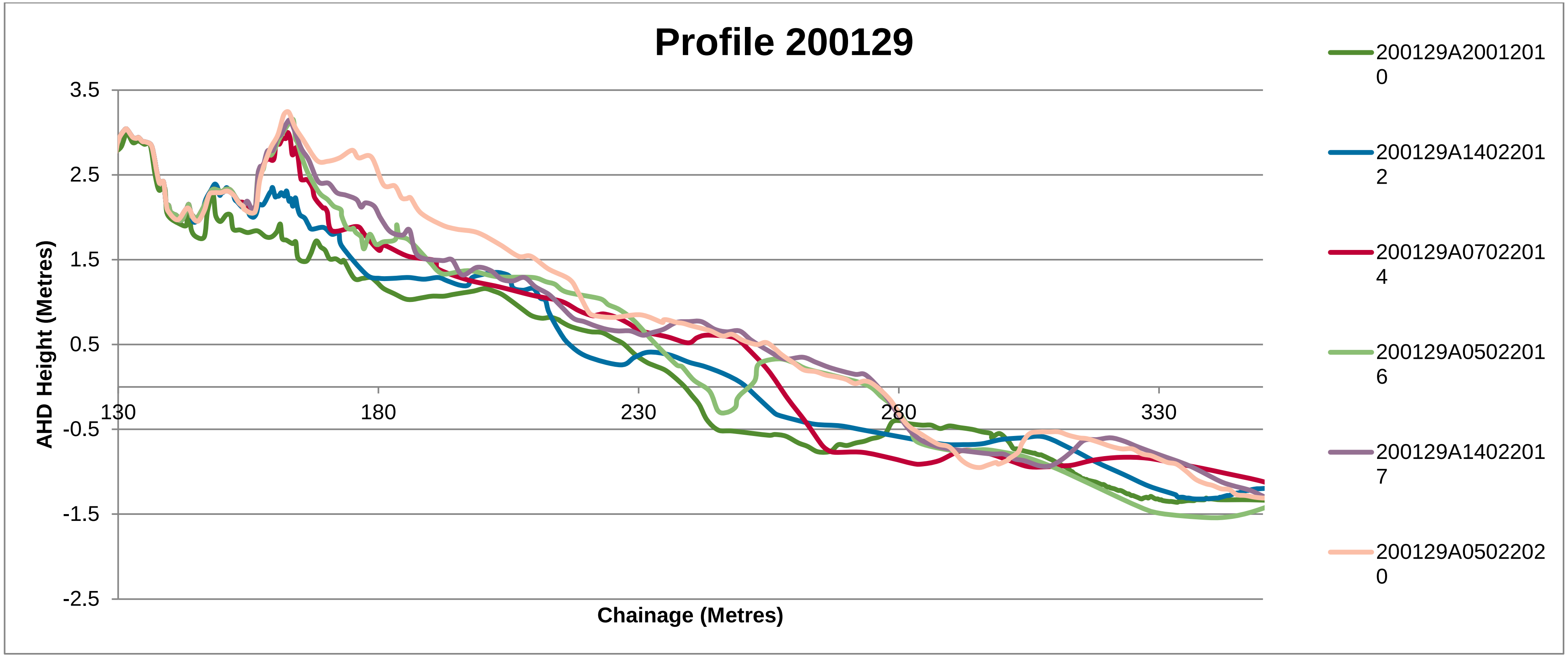
Profile 200004
AHD Height (Metres)
5
4
3
2
1
0
-1
-2
50
75
100
125
150
175
200
Chainage (Metres)
200004A20012010
200004A05022020



Profile 200004
AHD Height (Metres)
5
4
3
2
1
0
-1
-2
50
75
100
125
150
175
200
Chainage (Metres)
200004A20012010
200004A14022012
200004A07022014
200004A05022016
200004A14022017
200004A05022019
200004A05022020

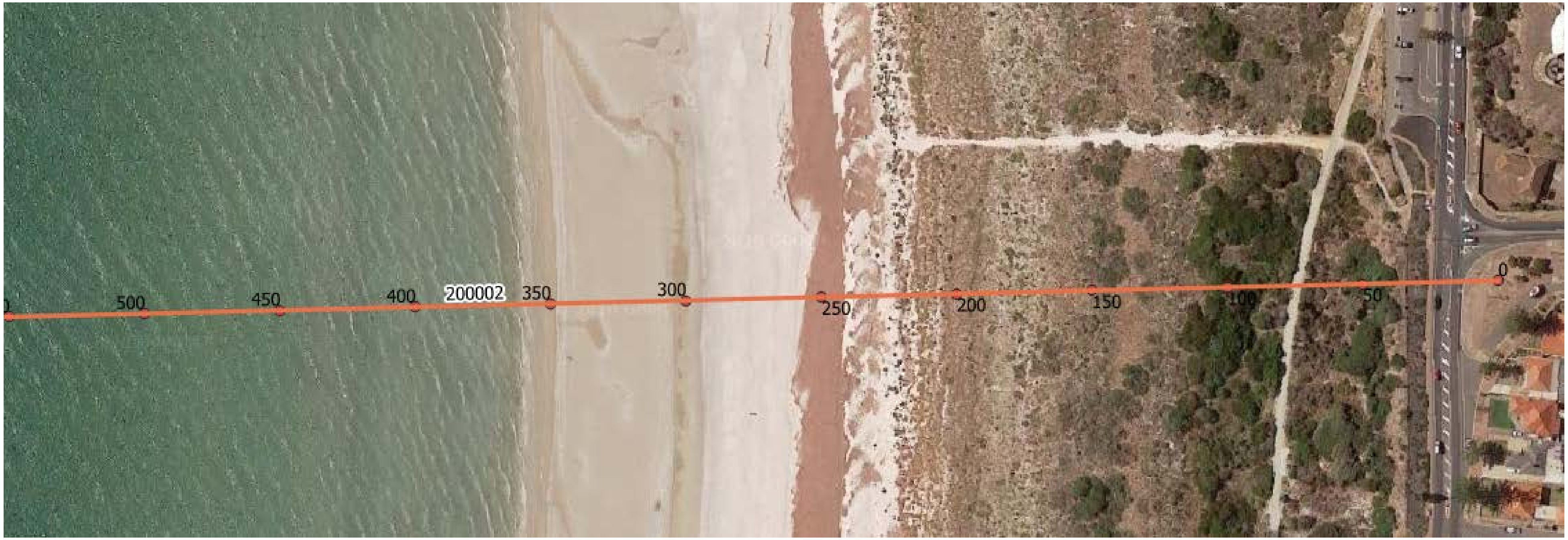
1.6 Profile 200129

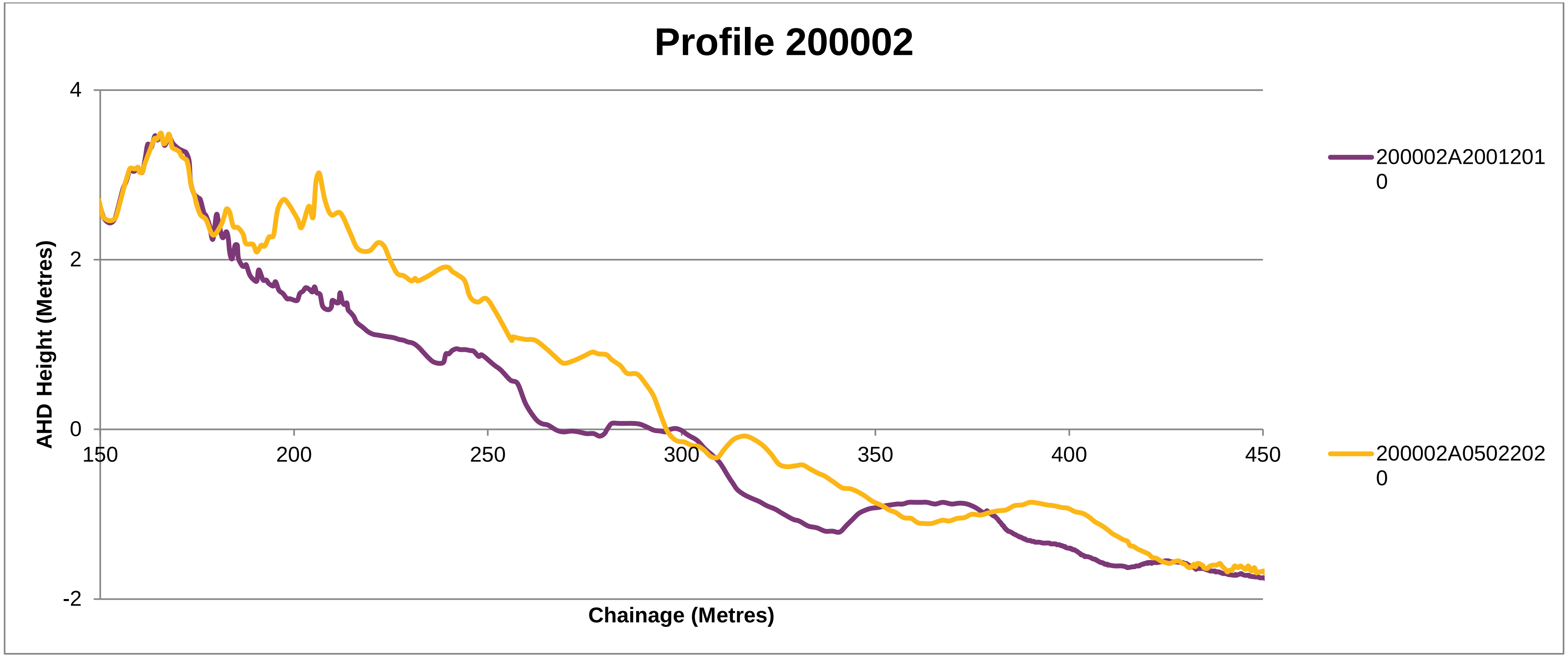

Profile 200129
AHD Height (Metres)
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
Chainage (Metres)
200129A20012010
200129A05022020

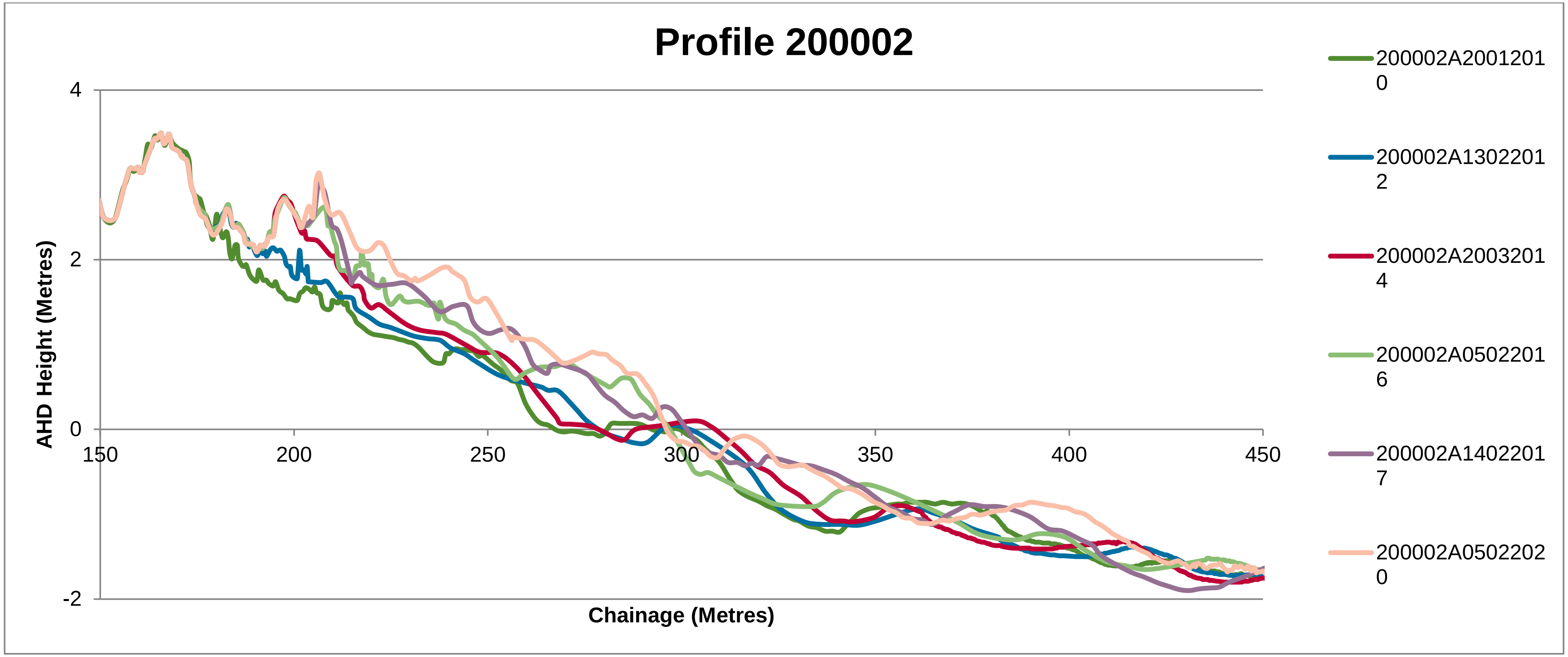


Profile 200129
AHD Height (Metres)
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
130
180
230
280
330
Chainage (Metres)
200129A20012010
200129A14022012
200129A07022014
200129A05022016
200129A14022017
200129A05022020

1.7 Profile 200002

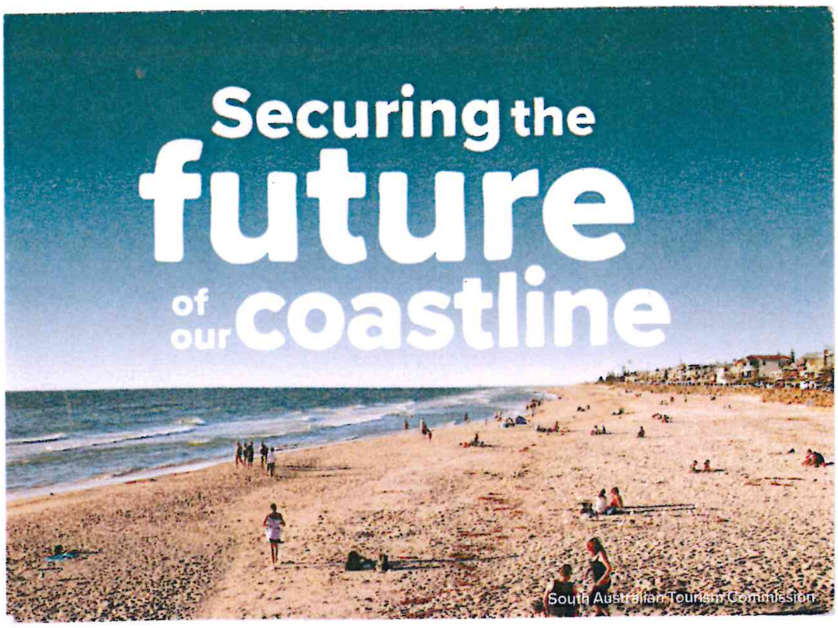



Profile 200002
AHD Height (Metres)
4
2
0
-2
150
200
250
300
350
400
450
Chainage (Metres)
200002A20012010
200002A05022020



Profile 200002
AHD Height (Metres)
4
2
0
-2
150
200
250
300
350
400
450
Chainage (Metres)
200002A20012010
200002A13022012
200002A20032014
200002A05022016
200002A14022017
200002A05022020

APPENDIX C
DEW'S COASTAL TEAM CONTACT CARD



Any questions?

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