SOUTH WEST COASTAL MONITORING

making space for sand



Making Space for Sand – Harvey's Towans Beach Report

Topographic and LiDAR Data Analysis

SWCM | TBR17 | 17/05/2024

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Document Title	**Making Space for Sand – Harvey's Towans Report**
Reference	**TBR17**
Status	**Final**
Date	**17/05/2024**
Project Name	**Making Space for Sand**
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Cover Photograph: Harvey's Towans, 30 August 2022
Taken by: Miranda Soskin

Summary

This report utilises Light Detection and Ranging (LiDAR, topography and aerial imagery data collected by the South West Coastal Monitoring (SWCM) Programme to analyse beach and dune volume at Harvey's Towans. The aim is to highlight coastal change at Harvey's Towans using SWCM data since 2007, focusing on beach and dune areas categorised into four zones: Beach, Mobile, Fixed, and Developed. Harvey's Towans Beach situated within Hayle Estuary, a north-northwest facing large sandy beach backed by a dune system. Topographic data collected bi-annually along fixed cross-shore profile lines are presented to indicate change of the intertidal beach area over time. LiDAR data is compared from each available flight to show difference models of the intertidal area, to compare volumetric data over time and to show change in Mean Seal Level and Dune Toe contours over time.

Since 2007, 44 topographic surveys were conducted at Harvey's Towans, including 13 full coverage surveys and 31 interim surveys. Analysis of topographic data suggests the survey unit has remained relatively stable between 2007 and 2024. Notable fluctuations were observed in survey results, with two noticeable drops in volume in 2009 and 2017. The survey unit volume was not negatively impacted by the 2013/14 storms but peaked in 2014 as well as 2020. The overall topographic trend between 2007 and 2024 has shown Harvey's Towans to accrete, but it is important to note, the changing river path heavily influences the data.

Volume has been extracted from the Mobile and Beach Zones from 10 LiDAR flights between 2007 and 2023. The Mobile Zone showed some similarities for change when compared to topographic data. The overall trend is for erosion, experiencing a noticeable impact in the 2011 and 2017 surveys, losing 6% and 12% in volume respectively. The 2013/14 storms had minimal effect on both the Beach and Mobile Zones. The Beach Zone also has a trend for erosion, losing 5% in volume between 2008 and 2023 with the lowest volume recorded in April 2017. The Dune Toe contours have retreated by up to 9 m, however to the south the contour has advanced by up to 12 m.

Overall, Harvey's Towans beach has remained relatively stable between 2007 and 2024 despite the area being so dynamic. The dunes to the south have appeared to accrete and build-up, whilst to the north the dunes have experienced a significant loss. The intertidal zone significantly differs with each survey, likely due to the changing river path.

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1.0 Introduction

The aim of this report is to highlight beach and dune change at Harvey's Towans using data collected as part of the South West Coastal Monitoring (SWCM) Programme since 2007. Four zones have been identified to define the beach/dune area and are defined as:

- **Beach Zone** – The wet beach area has been defined using Mean Low Water Spring (MLWS) and Mean High Water Spring (MHWS) contours extracted from all LiDAR data captured by SWCM. The Beach Zone will therefore encompass the area between the MHWS and MLWS contours, with volumes for this area extracted from each LiDAR surface.
- **Mobile Zone** – This area is defined as the active dune face and embryo dune[1] from MHWS +1 m to the back of the mobile area, often distinguished by vegetation depth or urban development. The Mobile Zone has been defined using aerial imagery from 2007 to 2021 and historic OS maps and has been verified through site visits.
- **Fixed Zone** – This area is defined by permanent dune vegetation that may also include scrub or invasive species, effectively denoting vegetation atop sandy soil.
- **Developed Zone** – This is defined as urban development areas (i.e., car parks, unnatural grassy areas, roads, houses etc.) which have been built atop previously present dune systems.

1.1 Study Site

Harvey's Towans, situated within Hayle Estuary, is a north-northwest facing large sandy beach backed by a dune system (Fig.1). A car park is located to the east, within the dune system. The beach has a cross-shore section of ~300 m and longshore distance of ~600 m with an average spring tidal range of 5.8 m.

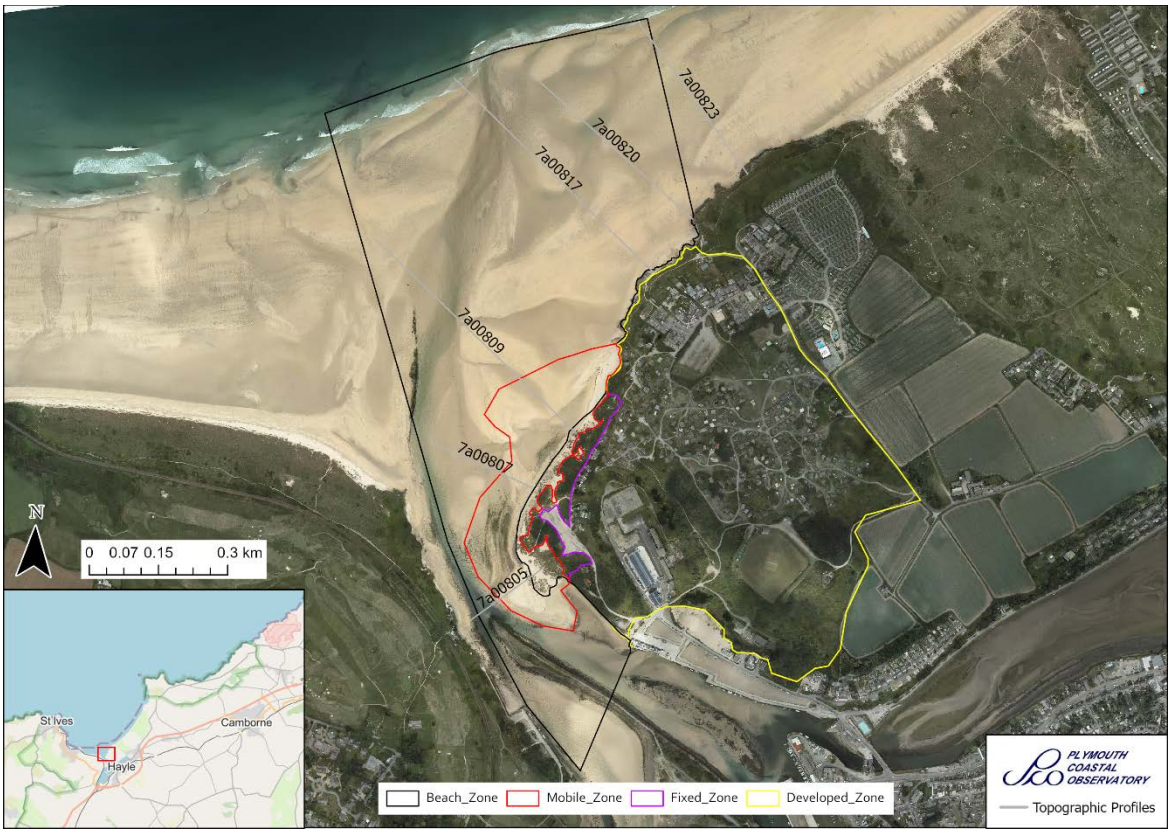


Figure 1 - Location Map of Harvey's Towans Beach and Dune System, indicating the four defined zones outlined in section 1.0. Interim topographic profiles are also overlain to show their location, as detailed in section 2.1

[1] An embryo dune, or yellow dune, is the earliest stage of dune growth, usually found along the seaward extent of a dune system or newly formed dune.

2.0 Methods

Data utilised in this report was collected by SWCM between 2007 and 2024. Information on topographic and LiDAR data collection and specifications can be found on the Website for the National Network of Coastal Monitoring Programmes.

2.1 Topographic Data

SWCM have undertaken routine topographic beach surveys at 34 of the 40 MS4S sites since 2006. All surveys are conducted from the MLWS contour to the backshore. On average, each surveyed beach receives two interim surveys a year and one full coverage survey every 5 years:

- Interim - Conducted twice a year in the spring (conducted between January and April), and autumn (conducted between September and December). An interim survey consists of collecting data points at 5m intervals along pre-defined profiles; these are outlined in Figure 1.
- Full coverage – Conducted once per phase (6 years), or annually at more vulnerable sites (conducted between May and September). Full coverage surveys include a full profile survey at 50 m intervals and continuous spot height data collected across a 5 m grid covering the whole beach.

Analysis of the Cross-Sectional Area (CSA) change is conducted for each individual profile between each separate survey. Changes in CSA are measured relative to the fixed master profile which is defined by a pre-determined stable landward position and the MLWS level in reference to Ordnance Datum.

2.1.1 Topographic Data Analysis

Topographic data is presented as the following, where applicable:

Trend Analysis Plot - The combined profile trend in CSA is presented for each survey unit (example shown in Fig.2). The sum of all interim profile CSA is combined for each survey conducted to date to provide a survey unit with a single 'beach area' value, known hence-forth as the Combined Profile Area (CPA). CPA is compared using linear trend analysis over a temporal scale (Fig.2).

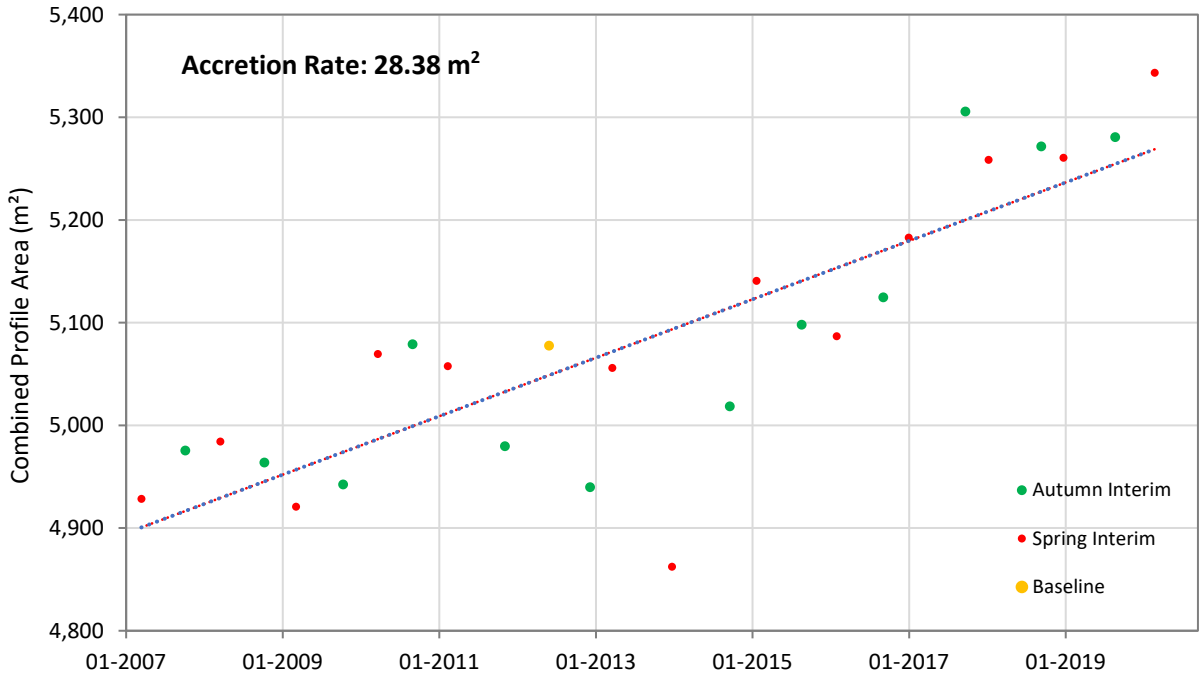


Figure 2 - Example of trend analysis for CPA for each survey with a linear trend rate highlighted at 28.4 m^2 y^{-1} equating to the increase of 0.56% of the average CPA per year.

If a profile has been omitted from a particular survey, for reasons of obstruction or similar, the average CSA of that profile from all available surveys is taken to ensure a consistent 'beach area'; if fewer than 75% of surveys have been conducted for a particular profile, the profile is omitted.

Profile Extremes Analysis - This plot displays the range of CSA values recorded throughout the duration of data collection (2006-2024) for each individual interim profile; the most recent survey is represented as a green dot. An example is given in figure 3. This plot provides the reader with information on how the CSA for each interim profile from the most recent survey corresponds to the entire dataset range.

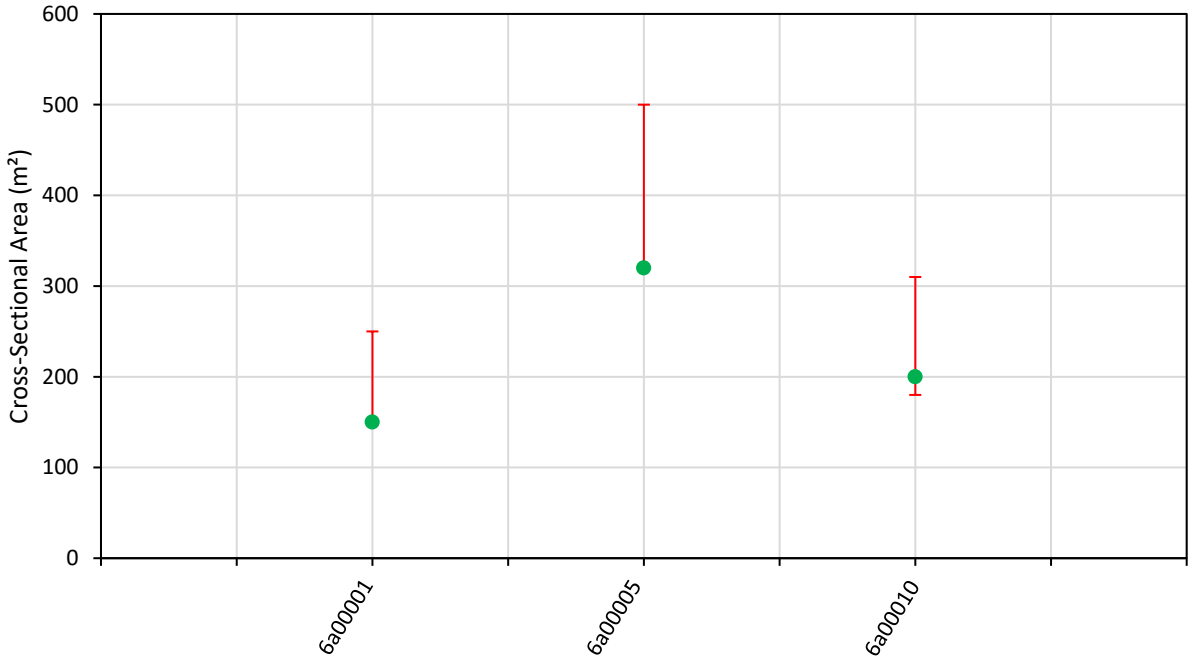


Figure 3 - Example plot showing the most recent CSA value recorded for three separate profile lines (green dots). The error bars represent the range of CSA recorded by each profile throughout the topographic dataset.

CSA Time Series Plot - CSA measurements for each interim profile are displayed on a separate plot representing values from each interim and full coverage survey conducted to date (example shown in Fig.4). This provides the reader with information on each interim profile's CSA evolution through time.

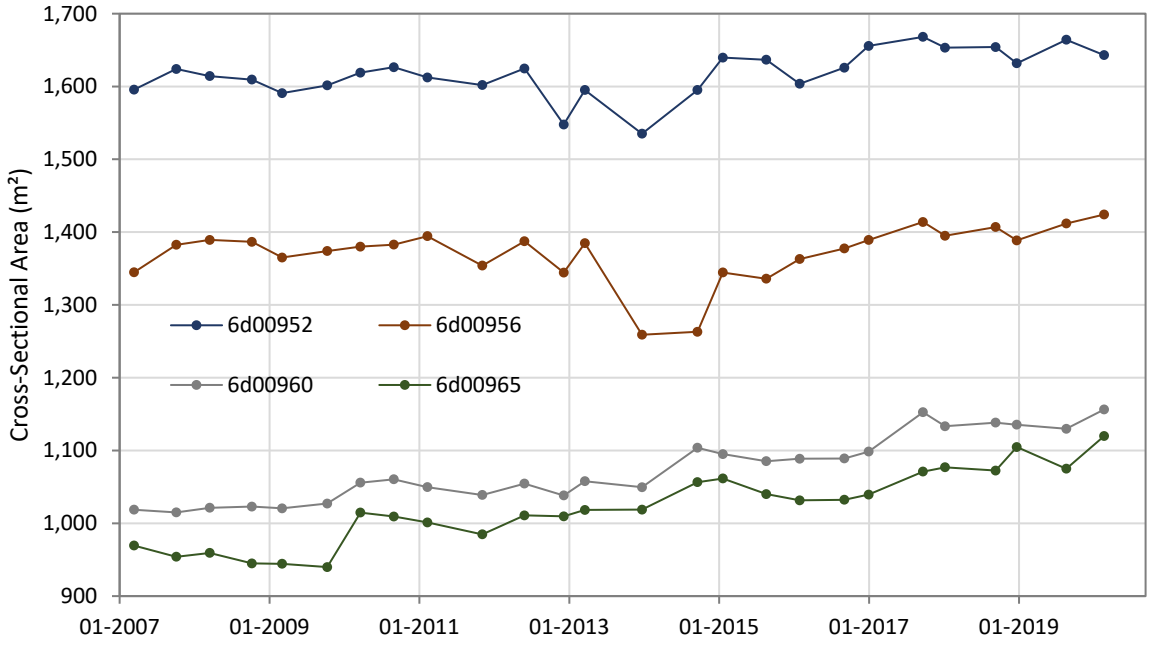


Figure 4 - Example of a cross-sectional area plot showing each of the interim profiles recorded for every survey since the 2007 baseline.

Individual Profile Charts - Each interim profile is portrayed as a cross-sectional profile comparing the most recent spring interim (blue), the previous spring interim (green) and the original full coverage survey (red). Profiles are displayed against the master profile (dotted red line) and are presented in the Appendices.

The 2013/2014 Storms – The winter period between September 2013 and April 2014 was, for many beaches in Cornwall, the most destructive period since SWCM records began in 2007. An abnormal number of significant storms, occurring in quick succession, heavily impacted many beaches, causing the loss of sediment from the intertidal area and dune face. This period is extensively discussed throughout this report and will hereinafter be referred to as the 2013/2014 winter period.

2.2 LiDAR Data

Airborne Light Detection and Ranging (LiDAR) data have been captured as part of the SWCM since 2007. Products include a point clouds, from which filtered and unfiltered 1 m^2 gridded surface models are derived:

- Unfiltered (Digital Elevation Model) representing the earth's surface including natural and artificial features such as trees and buildings.
- Filtered (Digital Terrain Model) representing the bare earth surface, with trees, buildings, cars etc. removed.

LiDAR is captured between September and March to minimise vegetation capture. Data is captured between MLWS and up to approximately 500 m inland. This report utilises "filtered" LiDAR data.

2.2.1 LiDAR Data Analysis

LiDAR data analysis is presented as the following:

Difference Modelling – Separate LiDAR surfaces are compared to produce a difference model of change based on gridded spot height elevations. The raw spot height data is processed into a gridded digital terrain model (DTM) and successive models are subtracted from one another to produce a difference model for the survey unit. Change in elevation is shown for values +/- 0.25 m and is represented by a colour scale bar.

Volume Extraction - Net sediment volume (m^3) is extracted for each LiDAR surface from the Beach Zone above MLWS and Mobile Zone above MHWS for trend comparison over time.

Contour Analysis – Contours are mapped from four LiDAR epochs spanning from 2007 to 2023, representing Mean Sea Level (MSL) and dune toe (calculated using the Stockdon equation by UoP, 2023[2]).

2.3 Accuracy Statement

Topographic Data – All survey points recorded along profiles have a measurement accuracy of +/- 0.03 m RMSE[3] in the horizontal and +/-0.03 m RMSE in the vertical.

LiDAR Data – Each LiDAR point cloud dataset has an average point density of 1.5 points per square metre. The digital terrain surfaces provide a minimum accuracy in elevation data of +/- 0.10 m RMSE with a minimum horizontal standard deviation as < 0.05 m. Please note that while every endeavour has been made to capture LiDAR as far seaward as MLWS, tidal and weather restrictions may in some instances have precluded this and coverage may be slightly reduced.

[2] Please refer to the following for Dune Toe elevation calculation: UoP, 2023. MS4S: Contemporary Dune Evolution and Future Predictions, Report, University of Plymouth, 33 pp.

[3] RMSE – Root-Mean-Square Error

3.0 Results

3.1 Topographic Data Analysis

There has been a total of 44 topographic surveys at Harvey's Towans since 2007, 13 are full coverage surveys and 31 are interim surveys. Exact dates of each survey for Harvey's Towans are available to view on our survey record. Analysis of the CPA indicates the survey unit has been accreting at 5.5 m^2 y^{-1} equating to 0.11% of the average beach area per year (Fig.5). The lowest recorded combined area was during the 2017 autumn interim (4,587 m^2); however the beach gained its highest recorded combined area, 3 years later, during the spring interim of 2020 (5,549 m^2).

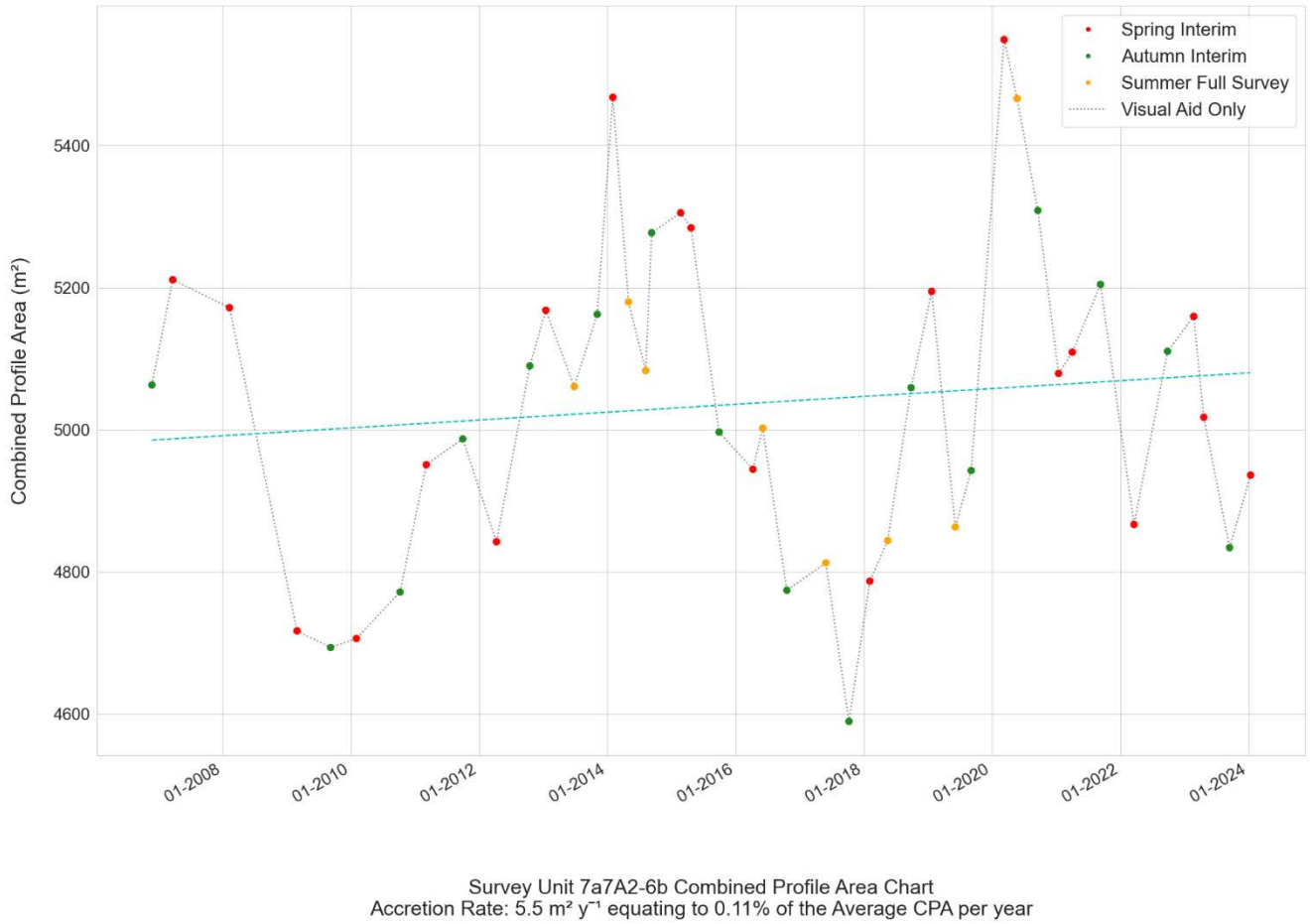


Figure 5 - The Combined Profile Area (CPA) for Harvey's Towans, including every spring (red), summer (yellow) and autumn (green) survey completed between 2007 and 2024.

When comparing to the entire dataset (Fig.6), during the 2024 spring interim there are a mixture of above and below average CSA values at Harvey's Towans. Profiles 7a00807, 7a00809, and 7a00823 are displaying lower than average CSA values, whilst the remaining profiles have suggested an average to higher-than average area values to date.

When comparing profile cross-sectional areas to the entire time series (Fig.7), all profiles again have displayed minimal seasonal variation, but a peak in area is apparent in most of the profiles in the spring 2020 survey. Noticeably, the majority of profiles do not appear to have been impacted by the 2013/14 storms.

Profile Charts for Harvey's Towans can be found in Appendix 1, these display the cross-sections of each profile for the initial baseline survey conducted in 2007 along with the two most recent interim surveys. All the profiles show a lot of variances, due to the river course flowing along the majority of the profiles. Profile 7a00805 has seen almost a 3 m gain in beach elevation, whereas profile 7a00807 has seen dune face erosion, since 2007, as well as a loss of up to 2 m in beach elevation.

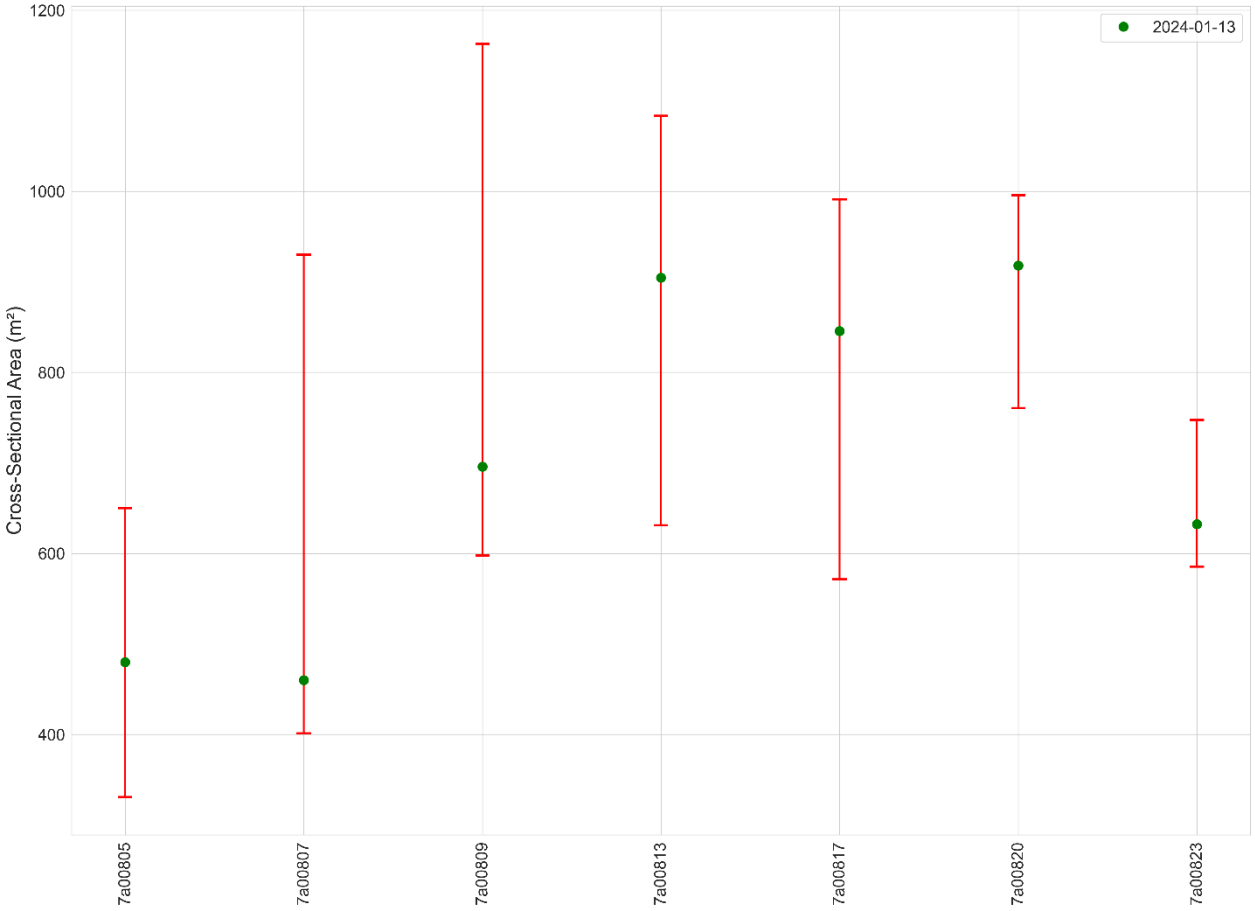


Figure 6 - Cross-sectional area of each interim profile, comparing the current area of the profile (green dot), with the maximum and minimum values (red error bar) recorded between 2007 and 2024.

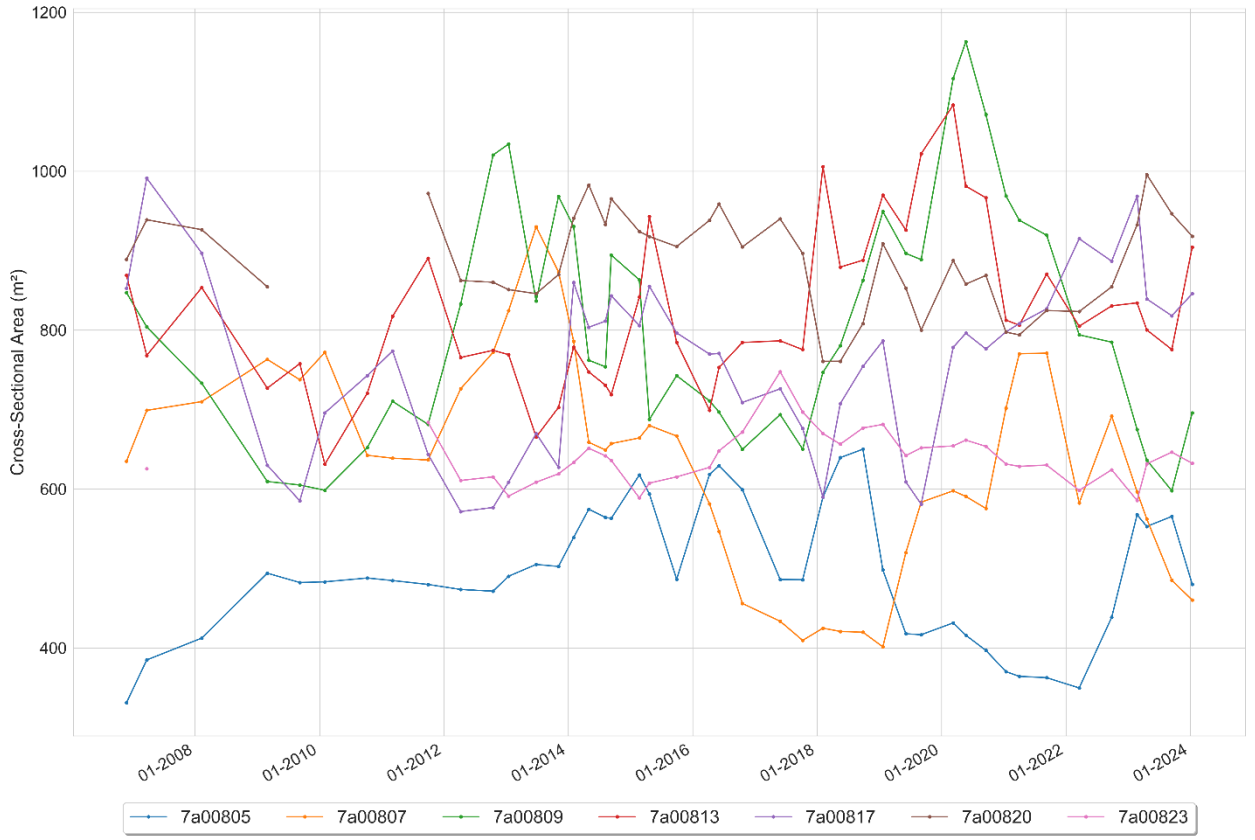


Figure 7 - Cross-sectional area of each interim profile, comparing the values recorded during each interim and baseline survey between 2007 and 2024.

3.2 LiDAR Data Analysis

There has been a total of 10 LiDAR flights captured at Harvey's Towans since 2007, by the SWCM Programme.

3.2.1 Difference Models

Difference models between each epoch of LiDAR data are presented here. Accretion and erosion values observed behind the dune system can be attributable to noise in the filtered LiDAR data or man-made changes in elevation and should be dismissed as such.

Figure 8 shows the difference in elevation between the first filtered LiDAR data from March 2008 compared to the most recent, captured in January 2023. There is considerable erosion present along the dune system, losing >3 m in some areas, followed by a band of accretion on the beach face. Whereas the dune and beach face on the inner section of the estuary suggests acute accretion, followed by erosion. The bend of the river path, at the entrance of the estuary, has seen material to deposit, followed by a large area of erosion. The intertidal zone has experienced a mixture of erosion and accretion, likely due to the moving path of the river.

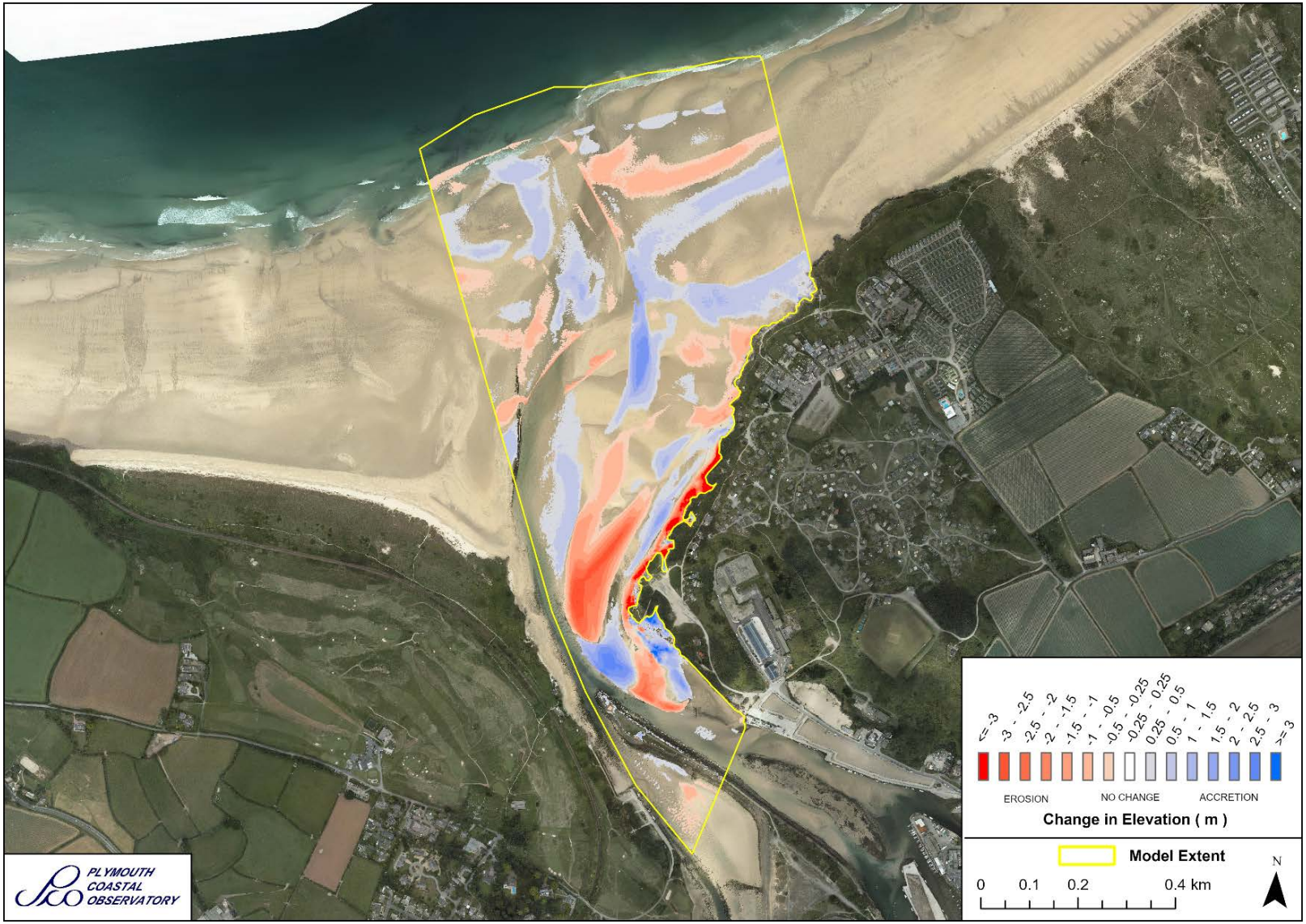


Figure 8 – Difference model indicating the changes in elevation observed between the March 2008 and January 2023 filtered LiDAR datasets within the yellow model extent.

Figure 9 shows differences in elevation between filtered LiDAR data from March 2008 compared to March 2009. A lot of change took place over 1 year, suggesting a large trough feature developing along the beach face, lowering down to 3 m at the very centre. The southern half of the beach face, however, has experienced a build-up of material, continuing round to the mouth of the estuary. Similarly, the eastern side of the river back has also seen a deposition of material, building up to ~2 m. The dune face has seen least amount of change, suggesting small patches of both erosion and accretion along the length of the dune system, with some areas of acute erosion at the peak of the dune blowouts. The intertidal zone has seen a lot of movement, with large areas losing and gaining sediment, likely due to the changing river course.

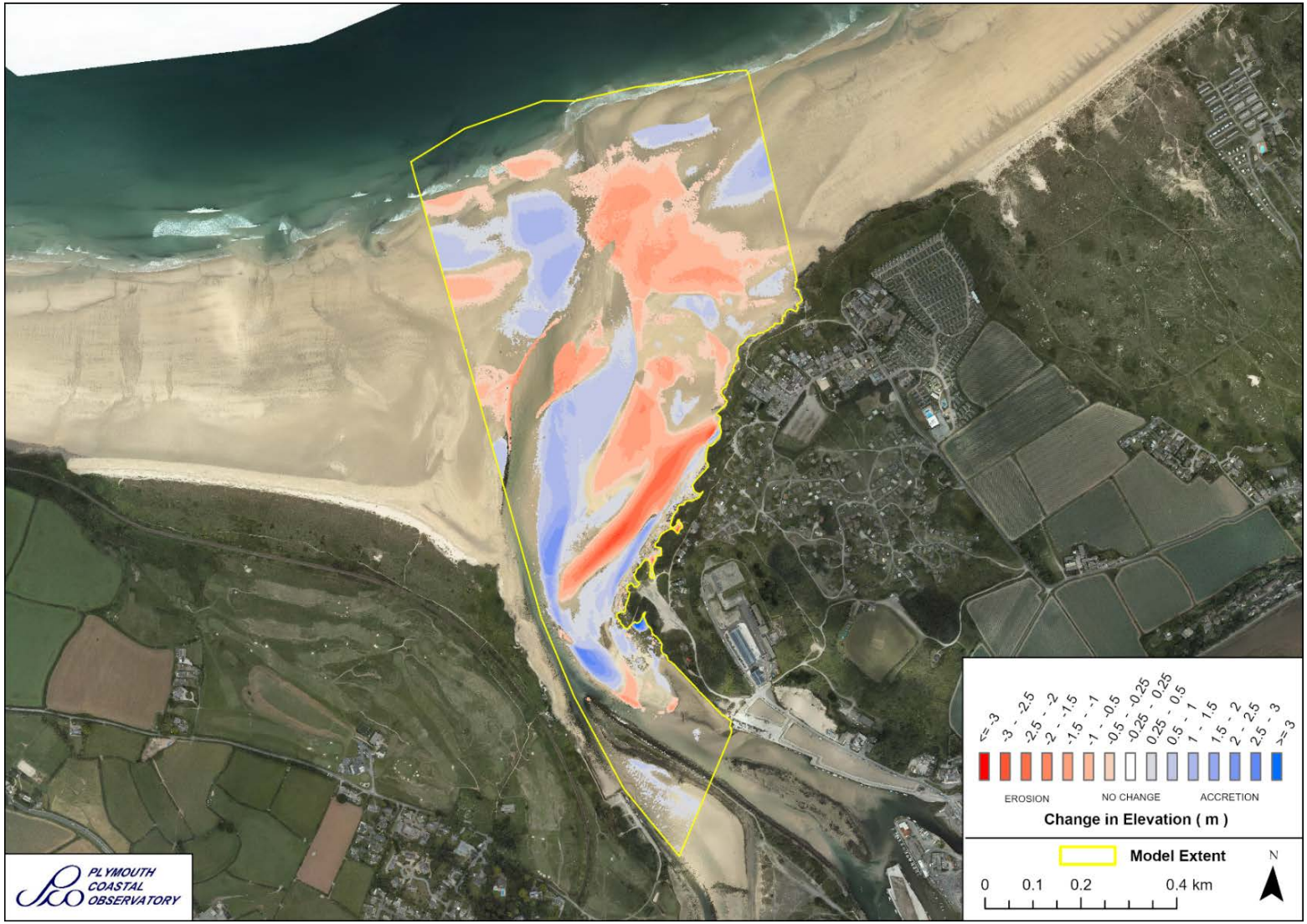


Figure 9 - Difference model indicating the changes in elevation observed between the March 2008 and March 2009 filtered LiDAR datasets within the yellow model extent.

Figure 10 shows differences in elevation between filtered LiDAR data from March 2009 compared to September 2009. In contrast to that of Figure 9 the eastern bank of the river has seen a trend for erosion, losing up to 2.5 m in elevation. The beach face suggests a lowering of elevation, followed by an intertidal bar or berm feature. Again, little change has been observed along the dune face with the dominant trend of patches of low-level accretion experienced and minor pockets of erosion to the south. The intertidal zone has experienced a lot of sediment movement around the unit, which is to be expected from such a dynamic area.

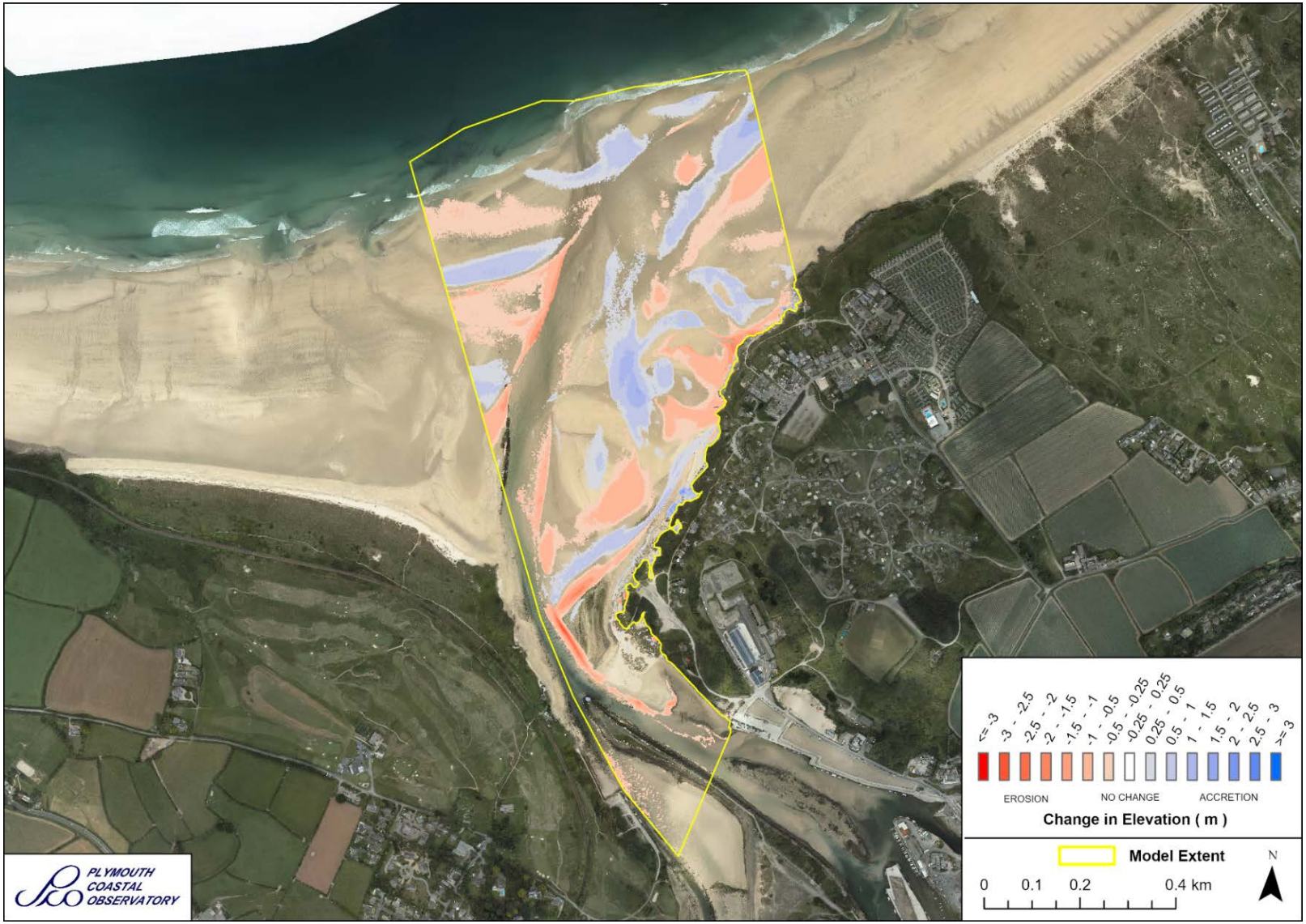


Figure 10 - Difference model indicating the changes in elevation observed between the March 2009 and September 2009 filtered LiDAR datasets within the yellow model extent.

Figure 11 shows differences in elevation between filtered LiDAR data from September 2009 compared to March 2011. Large change has been observed between this epoch, measuring acute erosion along the dune and beach face in the centre of the dune system and continuing south to the river. To the north, however, acute accretion has progressively built-up along the beach face, whereas to the south only patches of low-level accretion can be seen on the dune face. The intertidal zone has experienced a dominant trend for accretion, with pockets of low-level erosion.

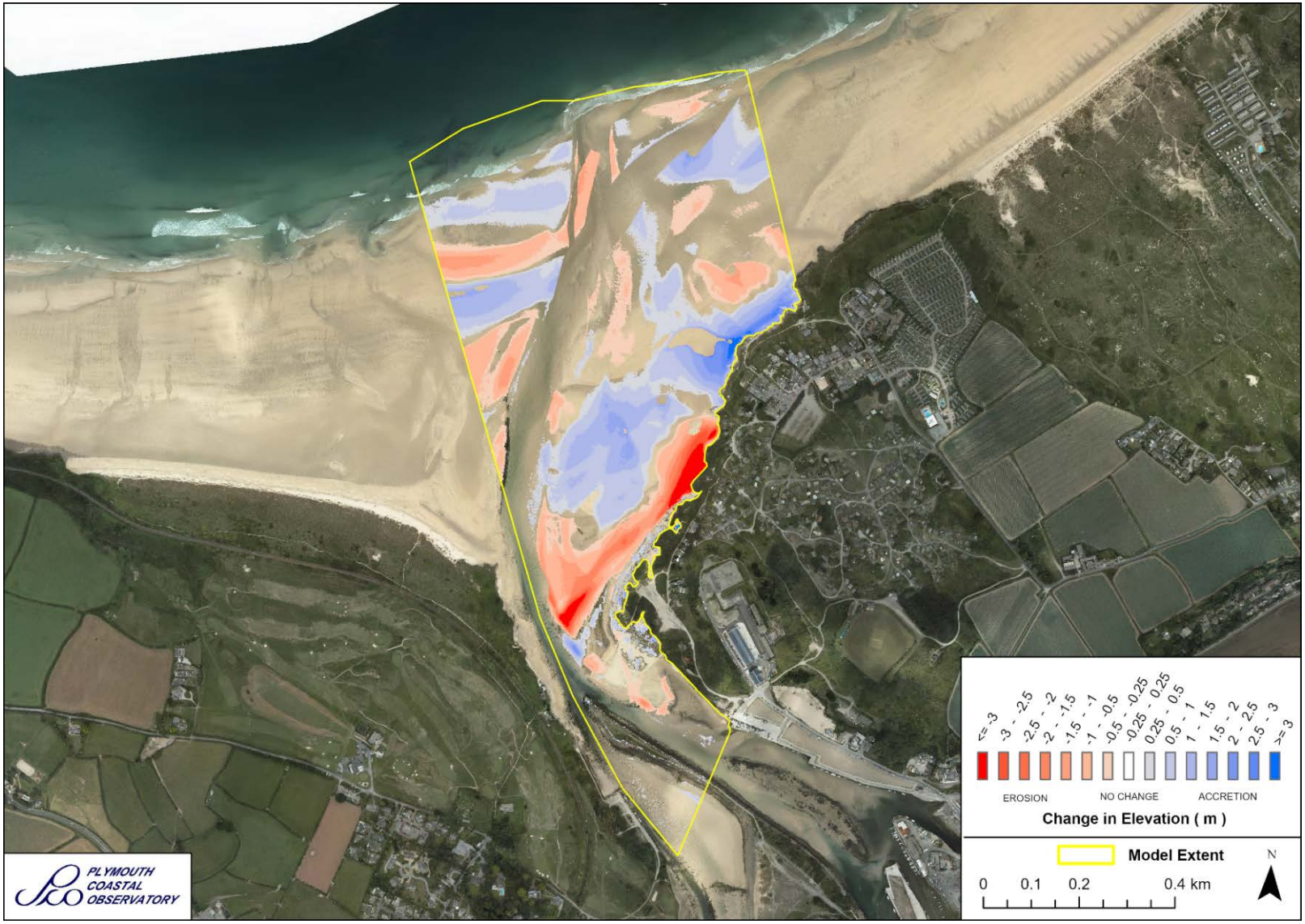


Figure 11 – Difference model indicating the changes in elevation observed between September 2009 and March 2011 filtered LiDAR datasets within the yellow model extent.

Figure 12 shows differences in elevation between filtered LiDAR data from March 2011 compared to April 2012. Again, large areas of change can be indicated within this epoch. However, the change here is more linear, experiencing a lowering in elevation towards the seaward extent and along the MSL mark, whilst an intertidal bar has built-up. The upper beach has observed a dominant trend for accretion, gaining up to 3 m in some areas, whereas the beach face has observed the opposite effect, losing >3 m of elevation. The dune face has experienced some change, with a mixture of patches of erosion and accretion.

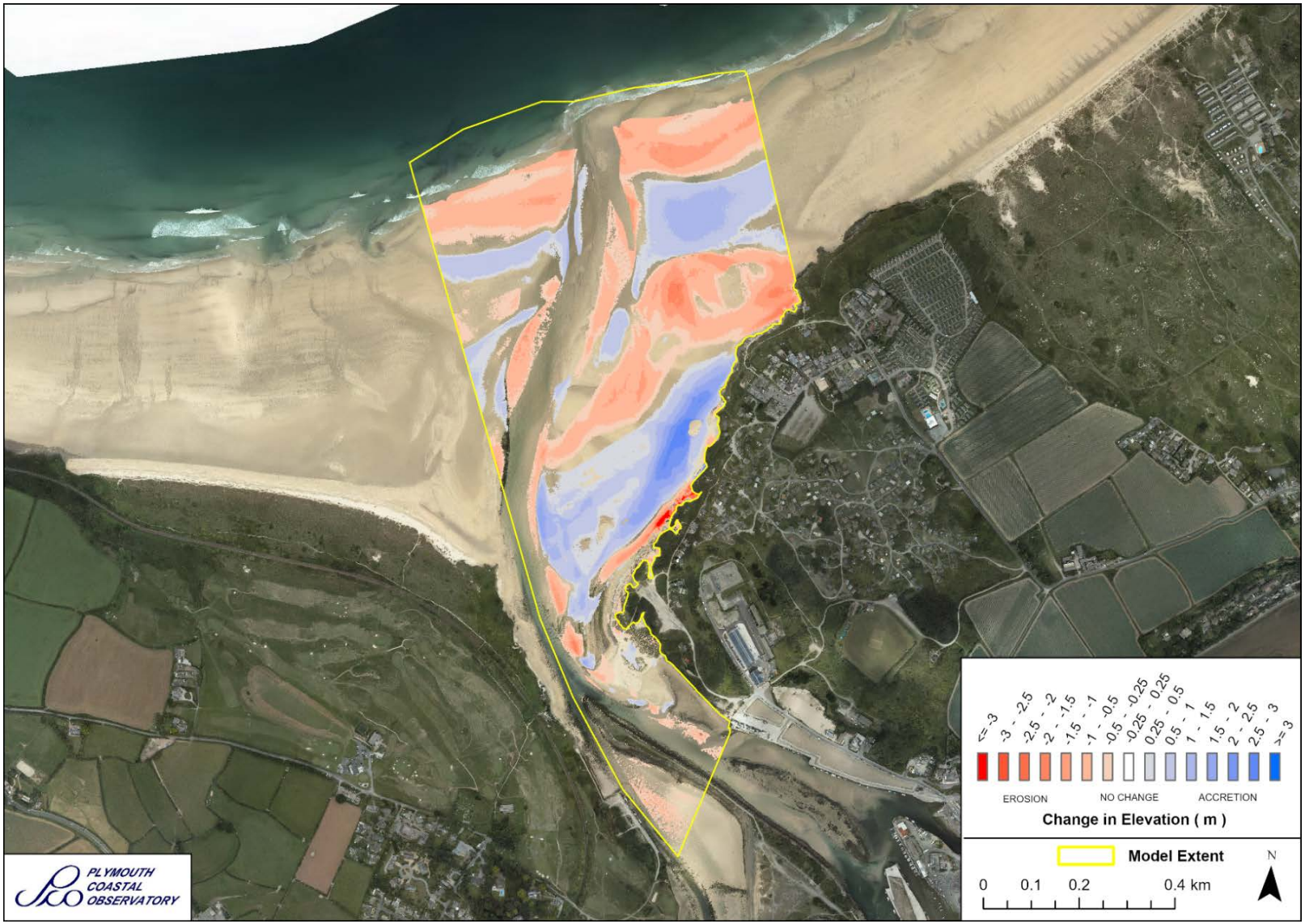


Figure 12 - Difference model indicating the changes in elevation observed between March 2011 and April 2012 filtered LiDAR datasets within the yellow model extent.

Figure 13 shows differences in elevation between filtered LiDAR data from April 2012 compared to April 2014. Despite the impact of the 2013/14 winter storms, Harvey's Towans has experienced large areas of accretion. Acute accretion is observed along the upper beach and beach face, continuing round to the mouth of the estuary, whilst small pockets of erosion and accretion are indicated along the dune face. A large erosional dip is suggested along the MSL mark, losing >3 m towards the north of the shoreline. The rest of the intertidal zone has seen a dominant trend for accretion gaining between 0.25 and 2 m in elevation.

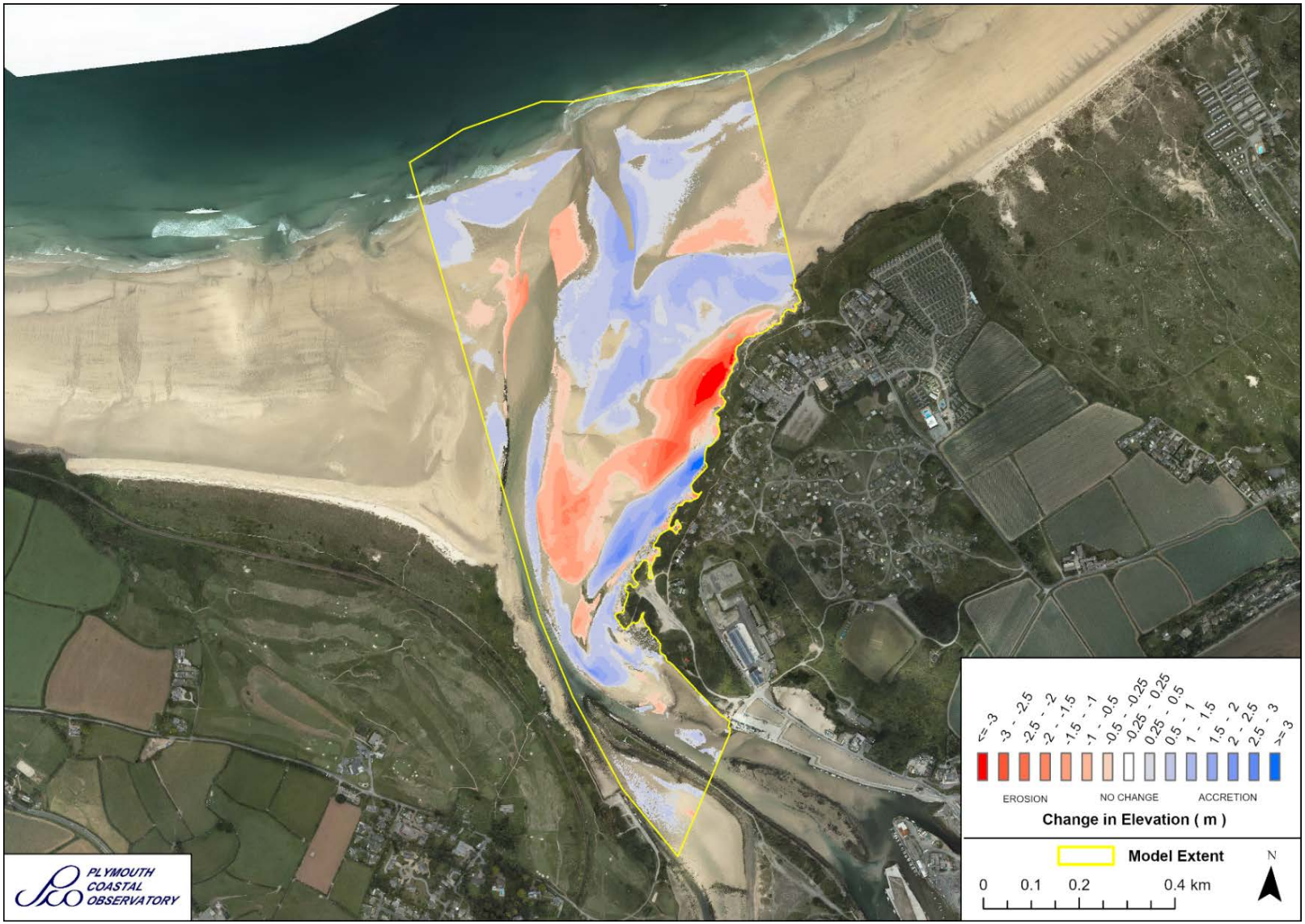


Figure 13 - Difference model indicating the changes in elevation observed between the April 2012 and April 2014 filtered LiDAR datasets within the yellow model extent.

Figure 14 shows differences in elevation between filtered LiDAR data from April 2014 compared to February 2016. Again, this epoch has seen a lot of sediment movement, with the intertidal zone seeing a dominant trend for erosion. An intertidal bar can be observed in the middle of the beach, whilst the upper beach has experienced accretion to the east but erosion to the west. The beach face has however accreted along the width of the beach, whereas the dune face has remained relatively stable, losing some elevation at the peak of the dune blowouts. The dune in the south has remained stable.

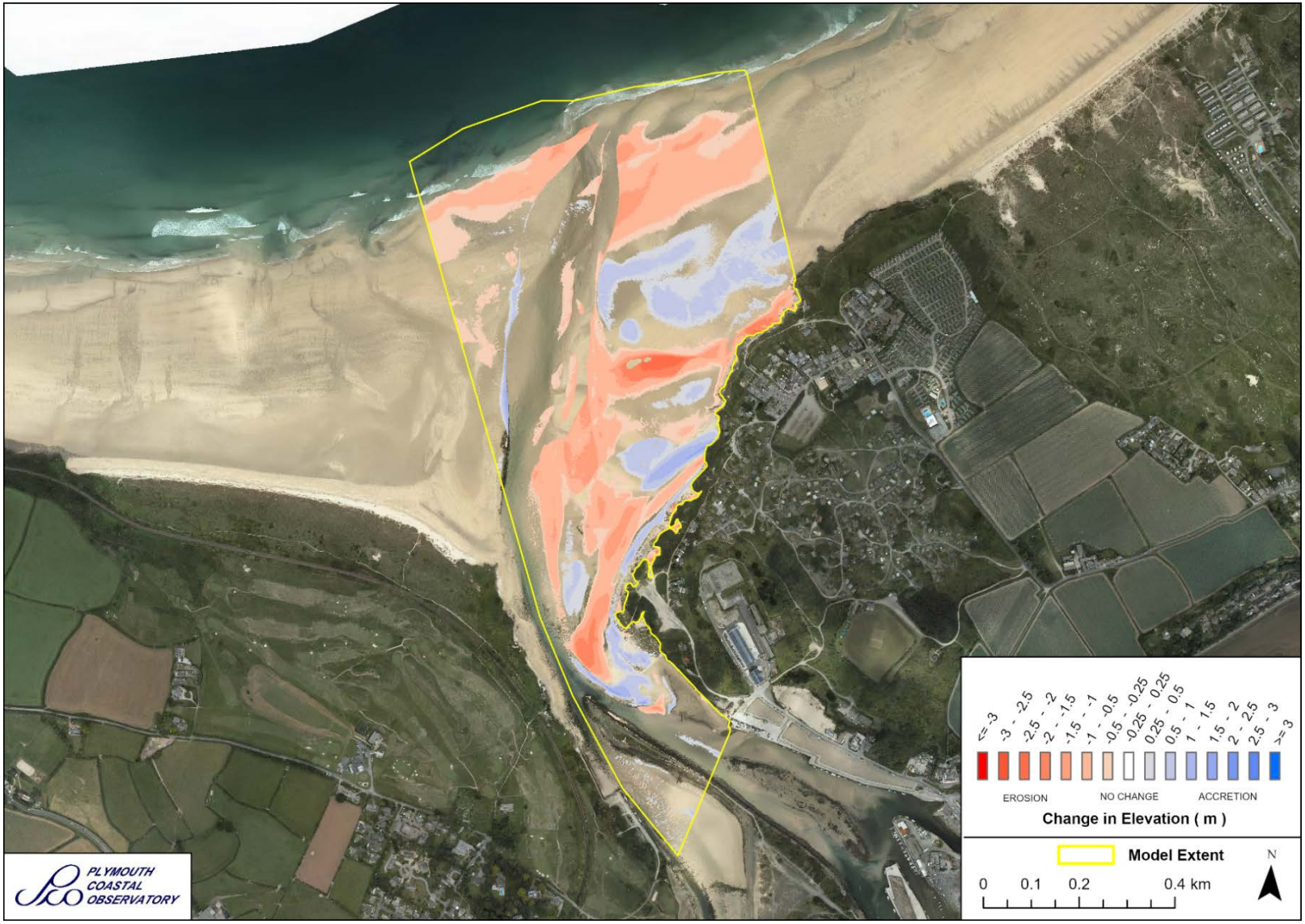


Figure 14 - Difference model indicating the changes in elevation observed between April 2014 and February 2016 filtered LiDAR datasets within the yellow model extent.

Figure 15 shows differences in elevation between filtered LiDAR data from February 2016 compared to April 2017. Acute erosion can be observed along the upper beach, the dune face, and this continues south towards the mouth of the estuary. The intertidal zone has seen a mixture of erosion and accretion due to it being such a dynamic system.

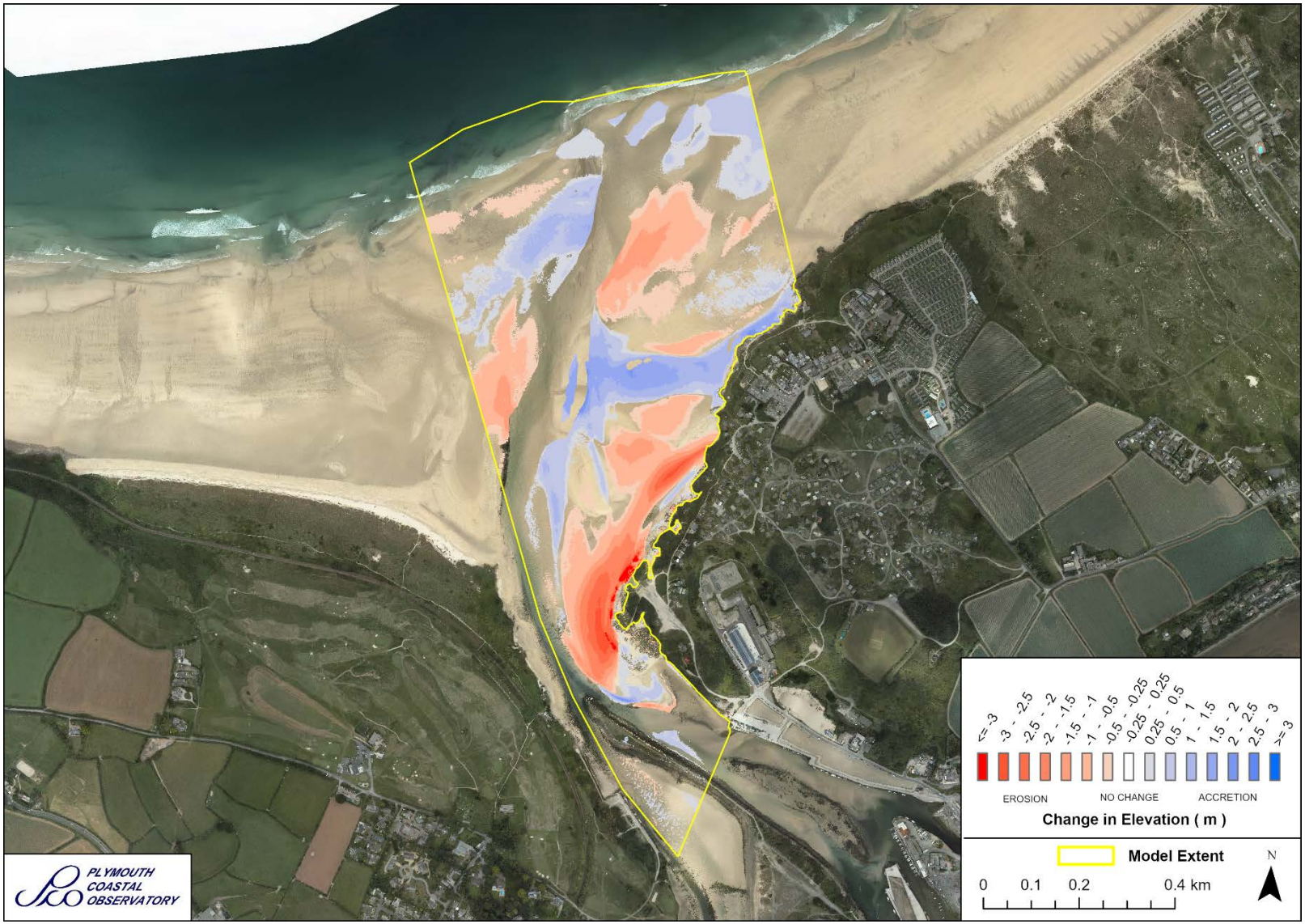


Figure 15 - Difference model indicating the changes in elevation observed between February 2016 and April 2017 filtered LiDAR datasets within the yellow model extent.

Figure 16 shows differences in elevation between filtered LiDAR data from April 2017 compared to April 2019. Considerable change can be observed across the entire upper beach area, with acute erosion seen along the dune face (>3 m) followed by a large area of accretion. Whilst the remaining intertidal zone has seen a mixture of erosion and accretion. The dunes to the south have remained stable, whilst the dune face to the west has observed acute erosion whereas low-level accretion is indicated to the east.

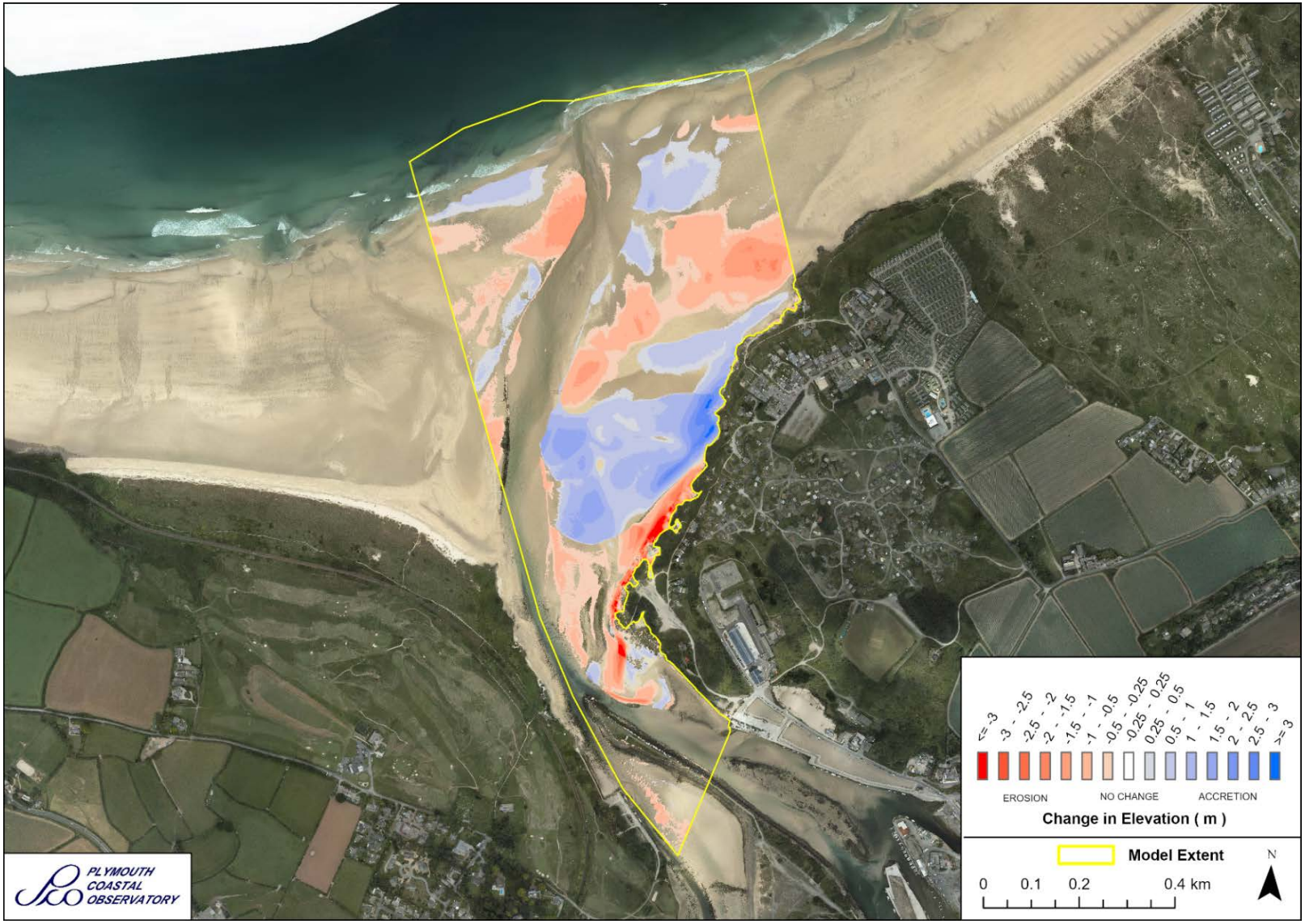


Figure 16 - Difference model indicating the changes in elevation observed between the April 2017 and April 2019 filtered LiDAR datasets within the yellow model extent.

Figure 17 shows differences in elevation between filtered LiDAR data from April 2019 compared to September 2020. The upper beach indicates a split in elevation change gaining >3 m of material towards the south, whilst the northern half of the beach has experienced up to 3 m of elevation loss. The dune face has measured patches of erosion and accretion, whereas the southern dunes have only seen small pockets of accretion.

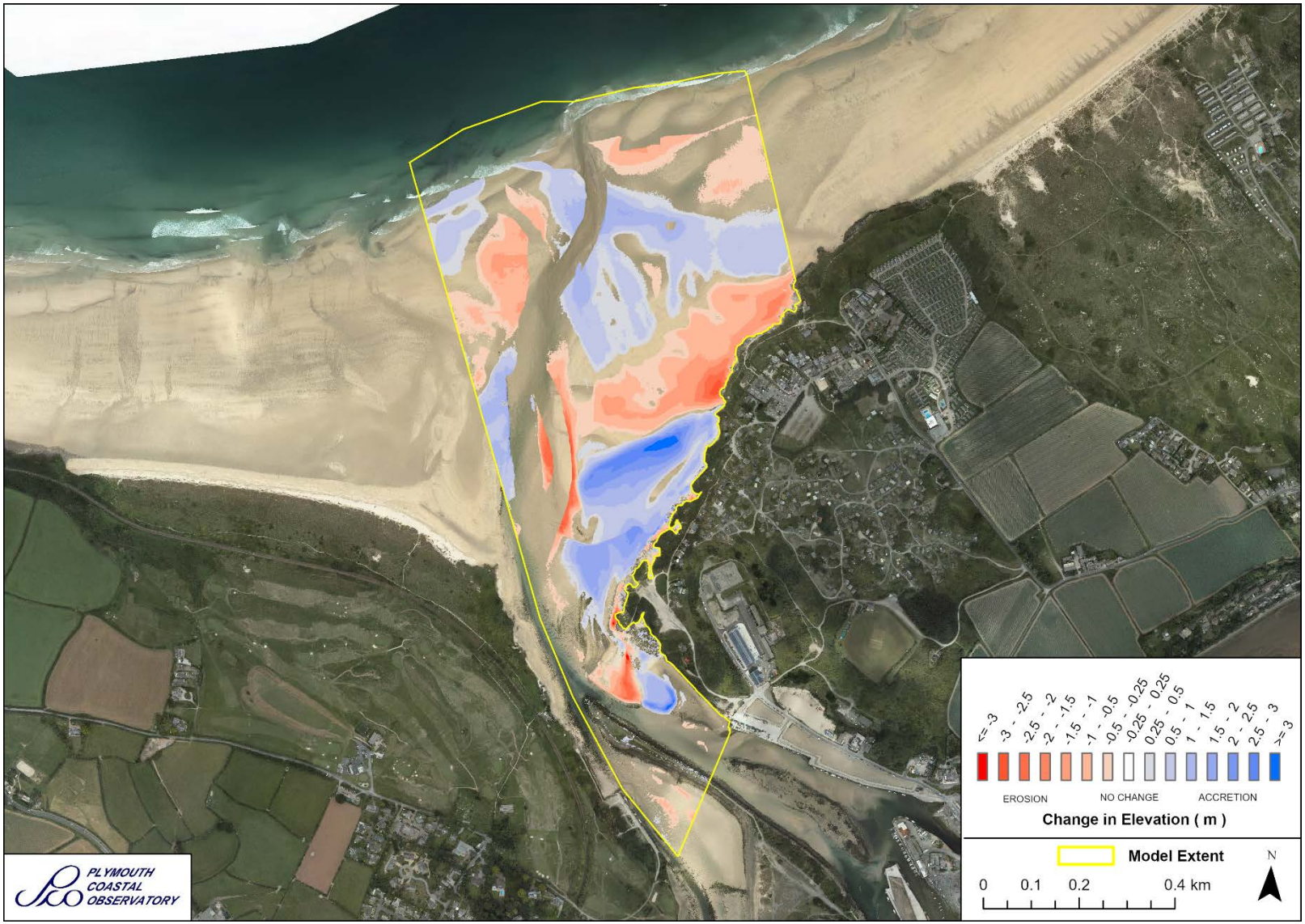


Figure 17 - Difference model indicating the changes in elevation observed between the April 2019 and September 2020 filtered LiDAR datasets within the yellow model extent.

Figure 18 shows differences in elevation between filtered LiDAR data from April 2020 compared to January 2023. The dune system has remained relatively stable; however patches of erosion can be seen along the width of the dune. Whereas the dune and beach face has seen a build-up of material, reaching >3 min elevation towards the south of the beach. This is followed by a section of acute erosion heading up the estuary. A significant amount of erosion (>3 m) can be indicated along the MSL mark, whilst the rest of the intertidal zone has experienced both erosion and accretion between the 3-year epoch.

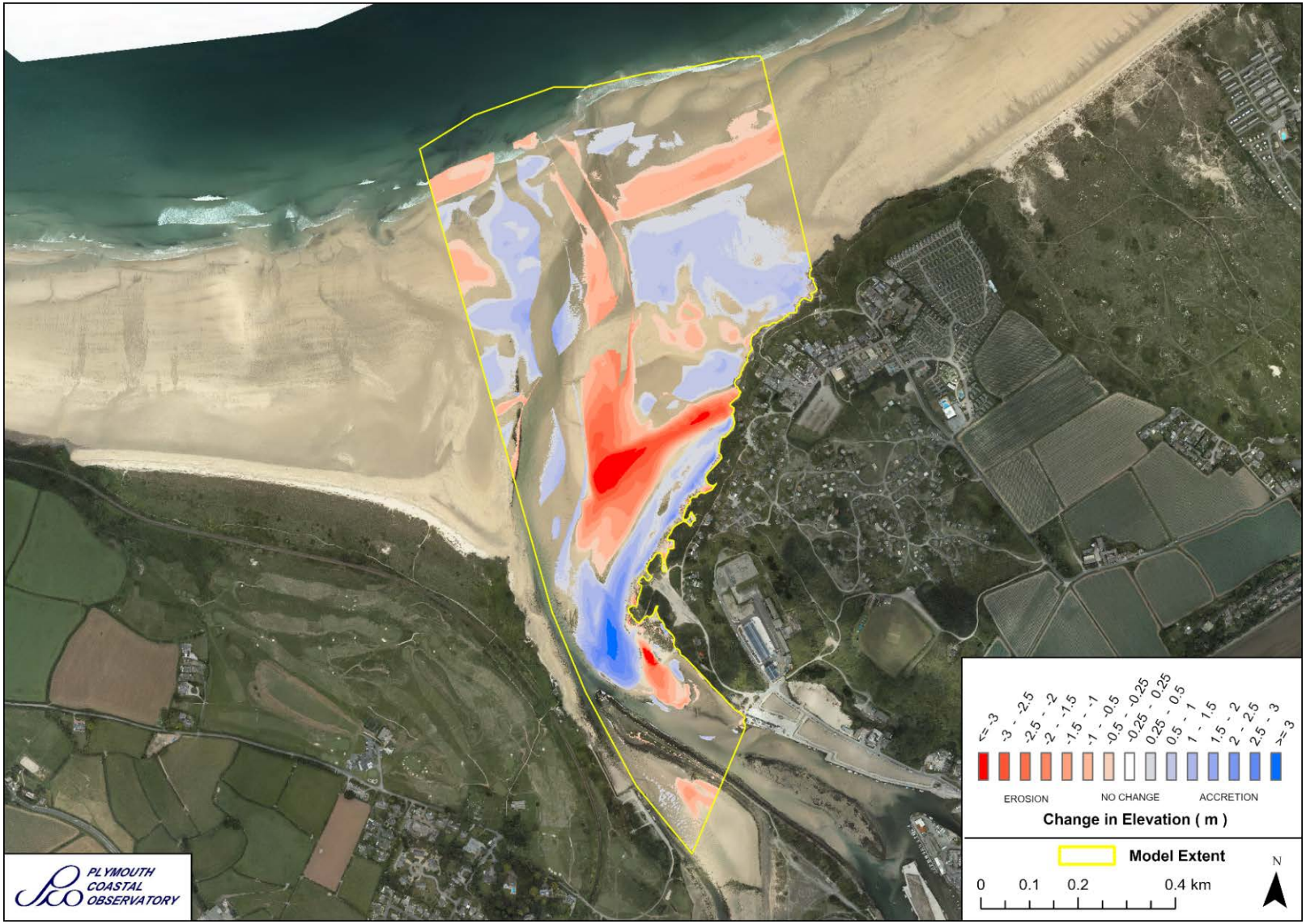


Figure 18 - Difference model indicating the changes in elevation observed between the April 2020 and January 2023 filtered LiDAR datasets within the yellow model extent.

3.2.2 Beach and Dune Volume Extraction

Surface volume extracted from each available LiDAR dataset from the Mobile Zone above the MHWS contour (3.20 m OD) are shown in Table 1 and Figure 19. The overall trend is for erosion, experiencing a noticeable impact in the 2011 and 2017 surveys, losing 6% and 12% in Mobile Zone volume respectively (Fig.19). Despite nearby beaches suffering heavily, the Mobile Zone saw limited impact following the 2013/14 winter period, instead seeing the largest impact following the 2016/2017 winter (Fig.19).

Surface volume extracted from each LiDAR dataset from the Beach Zone above the MLWS contour (-2.60 m OD) are shown in Table 1 and Figure 20. The Beach Zone is closely linked to that of the Mobile Zone, showing a similar trend of erosion, losing 5% in volume between 2008 and 2023. The lowest recorded Beach Zone volume was during the April 2017 survey at 1,371,607 m^3 (Table 1).

Table 1 – Surface volume values (m^3) extracted from all available filtered LiDAR datasets for the Mobile Zone above MHWS (3.20 m OD) and for the Beach Zone above MLWS (-2.60 m OD).

Date	Mobile Zone Volume (m^3)	Beach Zone Volume (m^3)
03/2008	606,813	1,525,203
03/2009	589,303	1,453,854
09/2009	582,307	1,383,317
03/2011	548,985	1,429,945
04/2012	575,995	1,504,867
04/2014	594,668	1,488,467
02/2016	584,307	1,398,918
04/2017	512,542	1,371,607
04/2019	512,125	1,399,227
09/2020	581,139	1,479,606
01/2023	578,031	1,435,116

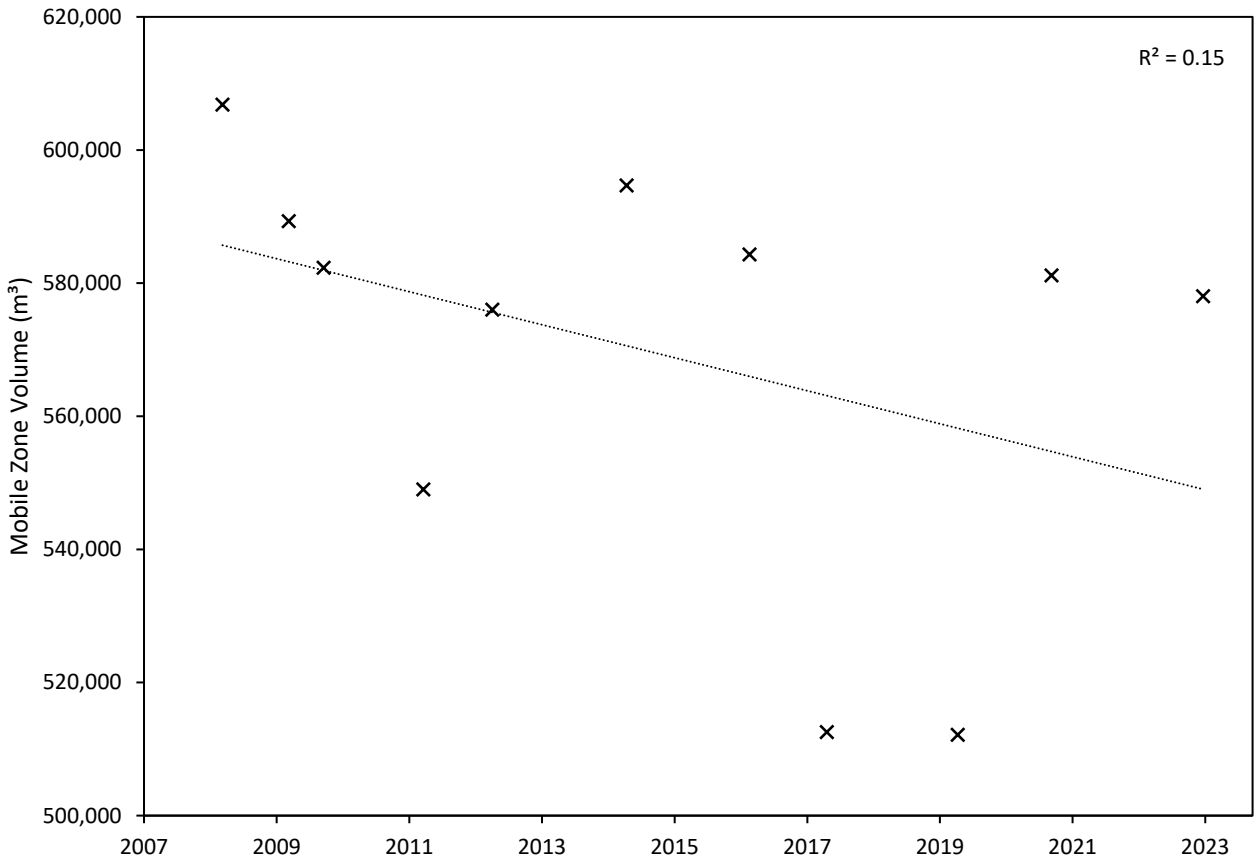


Figure 19 – Plot indicating beach volume (m^3) recorded in the Mobile Zone above MHWS (3.20 m OD) for each filtered LiDAR datasets between 2008 and 2023.

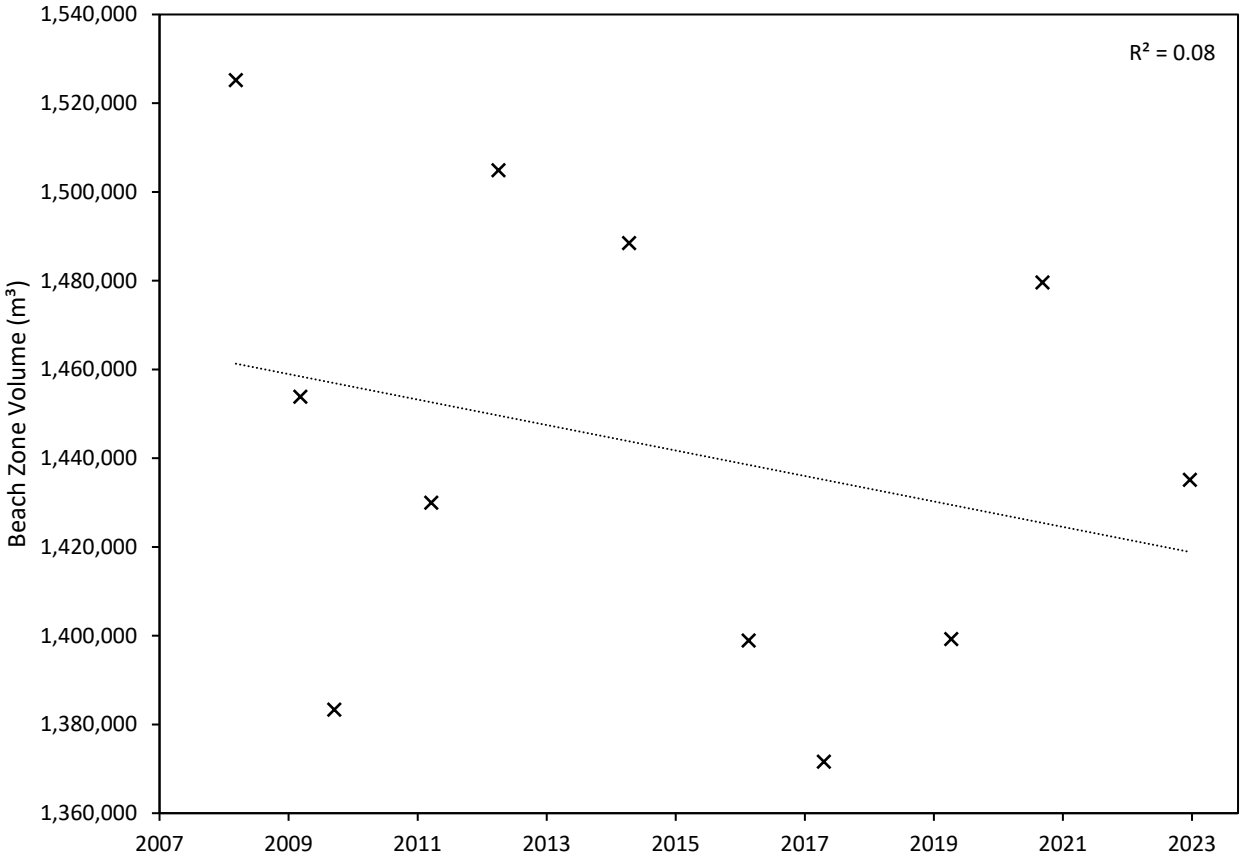


Figure 20 - Plot indicating beach volume (m^3) recorded in the Beach Zone above MLWS (-2.60 m OD) for each filtered LiDAR datasets between 2008 and 2023.

3.2.3 Contour Comparison

Figure 21 indicates the Mean Sea Level (MSL) and Dune Toe contours from the 2008, 2014, 2019 and 2023 LiDAR datasets. MSL contours largely vary from 2008 to 2023, by approximately 44-150 m due to the river changing course. Generally, the north-western area of the beach has widened between 2008 and 2023 but narrowed by to the south of the unit. The Dune Toe contours have retreated by up to 9 m, however to the south the contour has advanced by up to 12 m.

3.3 Historic Aerial Maps

Historic aerial photography captured in 1947 by the RAF, in 2001 by the Environment Agency (Figs. 22 and 23) and from 2006 onwards by the SWCM (Figs. 24-27) are presented here.

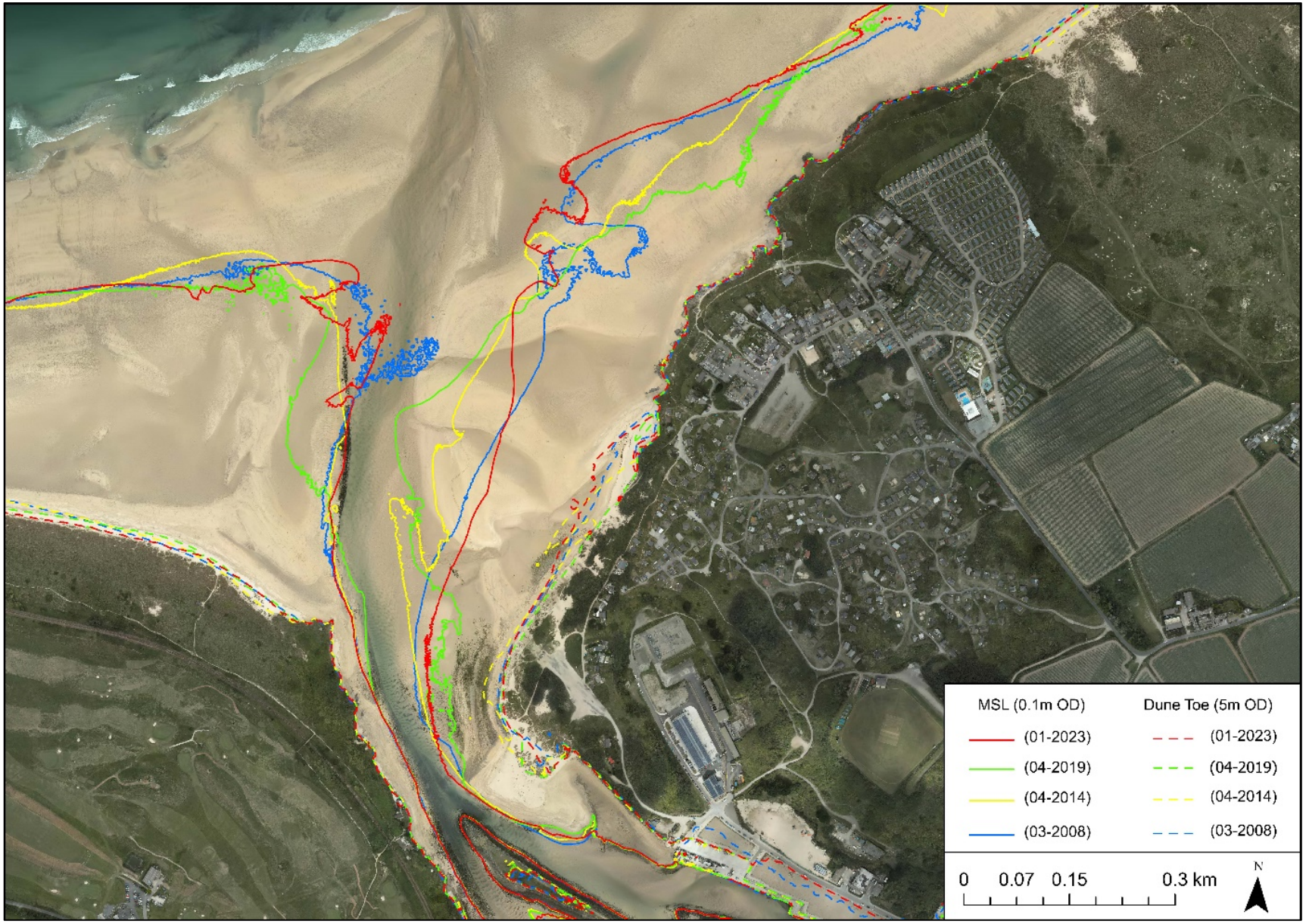


Figure 21 – Contour map indicating Mean Sea Level (solid line) and Dune Toe (dashed line) extracted from 2008, 2014, 2019 and 2032 LiDAR datasets.

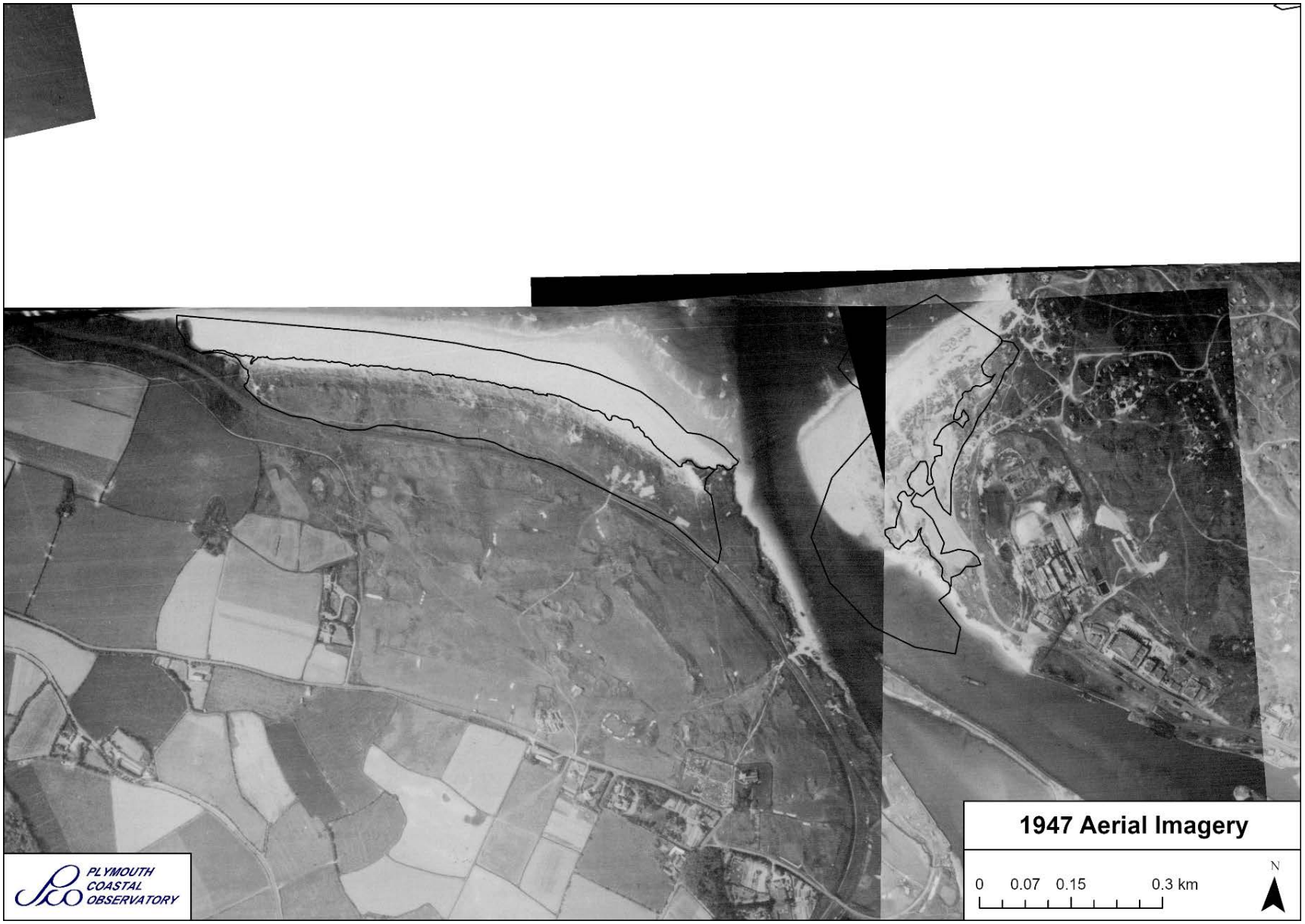


Figure 22 – Aerial imagery from 1947.

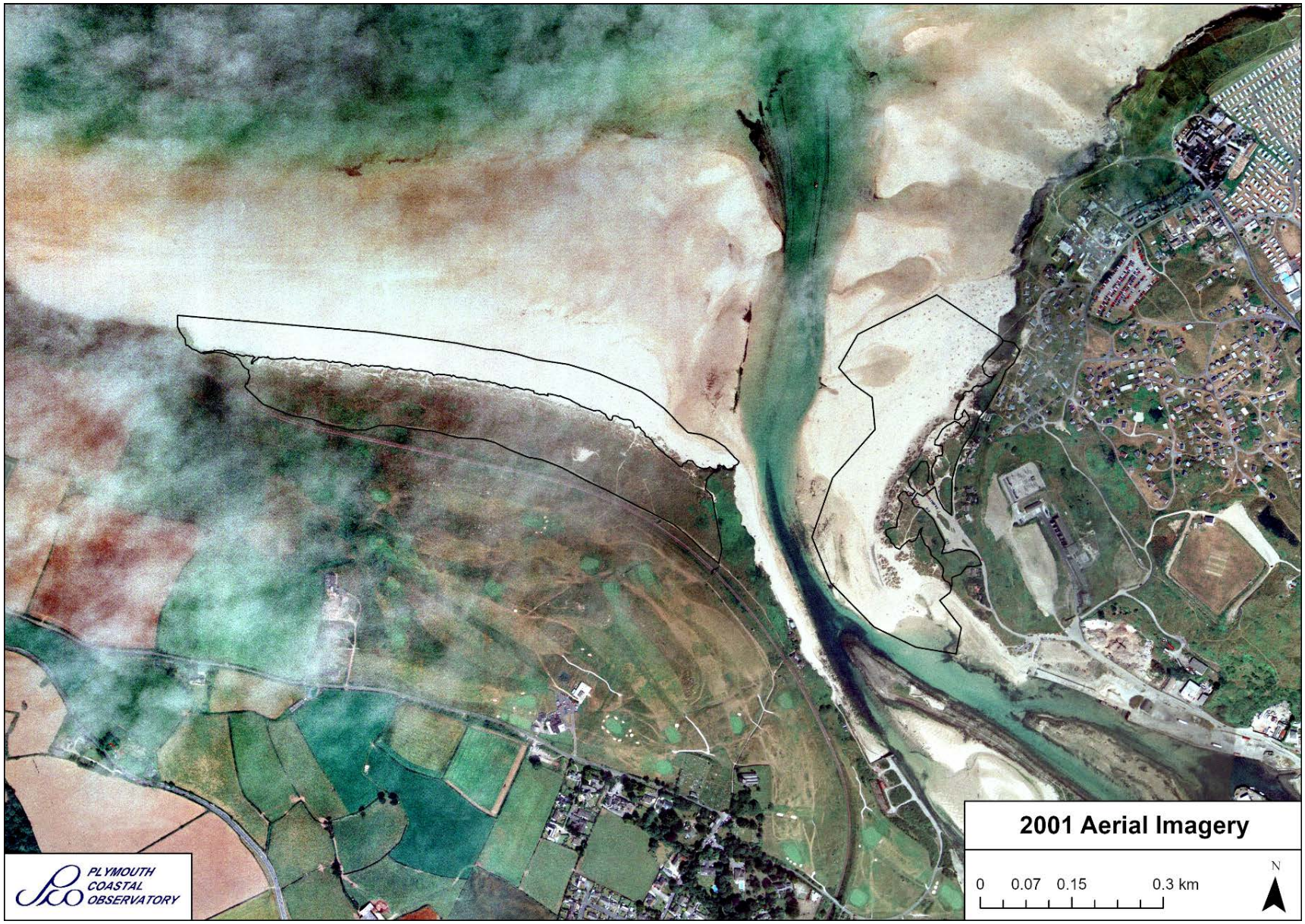


Figure 23 – Aerial imagery from 2001.



Figure 24 – Aerial imagery from 2008.



Figure 25 – Aerial imagery from 2009.



Figure 26 – Aerial imagery from 2014.



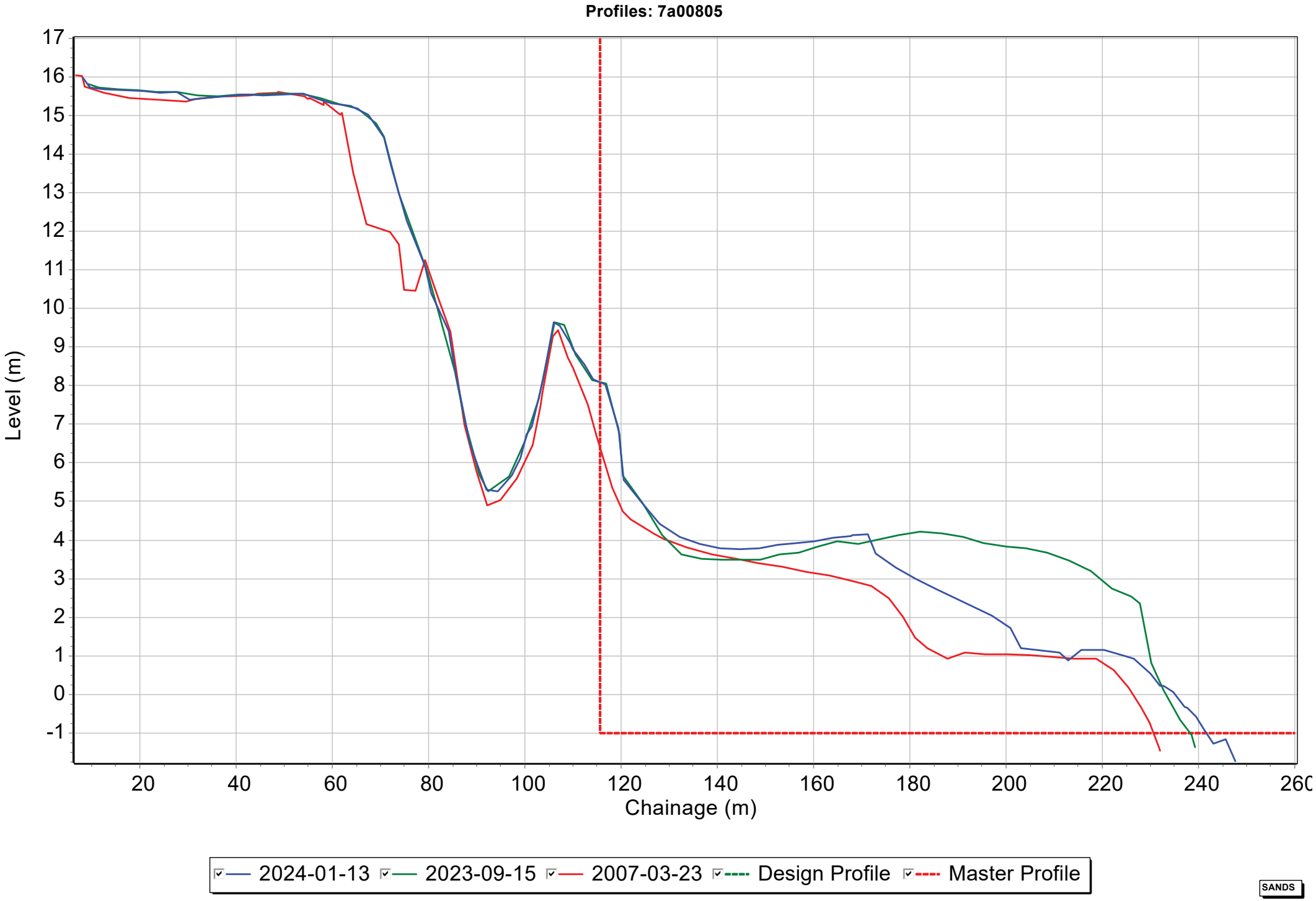
Figure 27 – Aerial imagery from 2018.

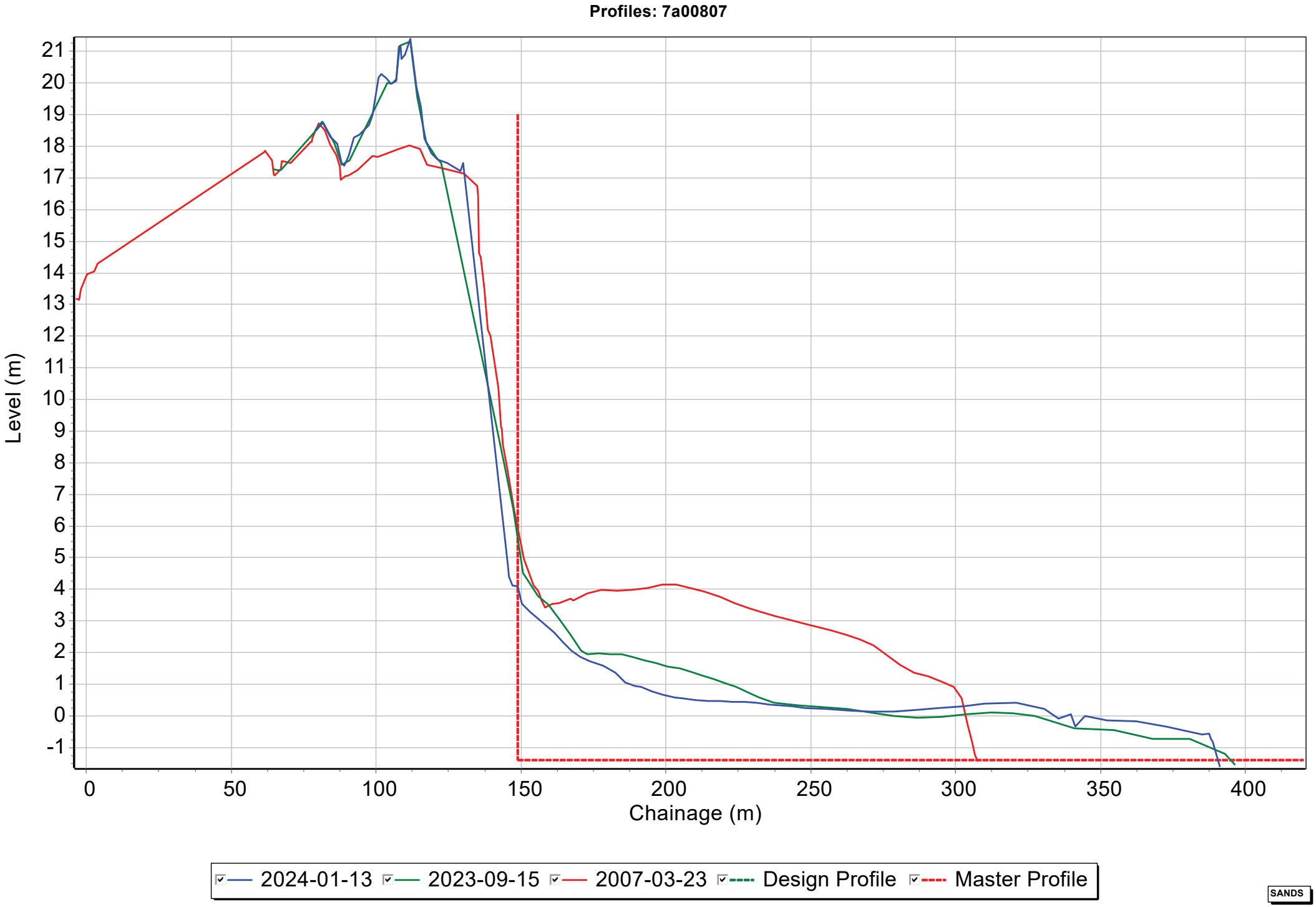
Glossary

1. Accretion: The net accumulation of deposited sediment, deposited by waves, tides or current.
2. Coastal Morphodynamics: The study of changes in coastal landforms and landscapes over time.
3. Contour Analysis: Mapping of contours from LiDAR datasets to represent Mean Sea Level (MSL) and Dune Toe elevations.
4. Cross-Sectional Area (CSA): The area of a two-dimensional cross-section of a cross-shore beach profile, running between Mean Low Water Spring and the back of the beach.
5. Developed Zone: Areas of urban development built atop previously present dune systems.
6. Difference Modelling: Comparison of separate LiDAR surfaces to produce a difference model of change based on gridded spot height elevations.
7. Digital Elevation Model (DEM) and Digital Terrain Model (DTM): DEM represents the Earth's surface with all features, while DTM represents the bare earth surface, excluding vegetation and structures.
8. Embryo Dune: The earliest stage of dune growth, typically found along the seaward extent of a dune system or newly formed dune.
9. Erosion: The process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and sands along the coast.
10. Fixed Zone: Area defined by permanent dune vegetation, including scrub or invasive species, denoting vegetation atop sandy soil.
11. Intertidal Bar: A ridge or mound of sand, gravel, or other sediment deposited in the intertidal zone along a shoreline.
12. LiDAR: Light Detection and Ranging, a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth.
13. Mean High Water Spring (MHWS): The height of mean high-water springs is the average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
14. Mean Low Water Spring (MLWS): The height of the mean low-water springs is the average height obtained by the two successive low waters during the same period.
15. Mobile Zone: The area including the active dune face and embryo dune that is in motion due to wind action or other factors.
16. Root-Mean-Square Error (RMSE): A measure of the differences between values predicted by a model and the observed values.
17. Tidal Range: The vertical difference between high tide and low tide during a tidal cycle.

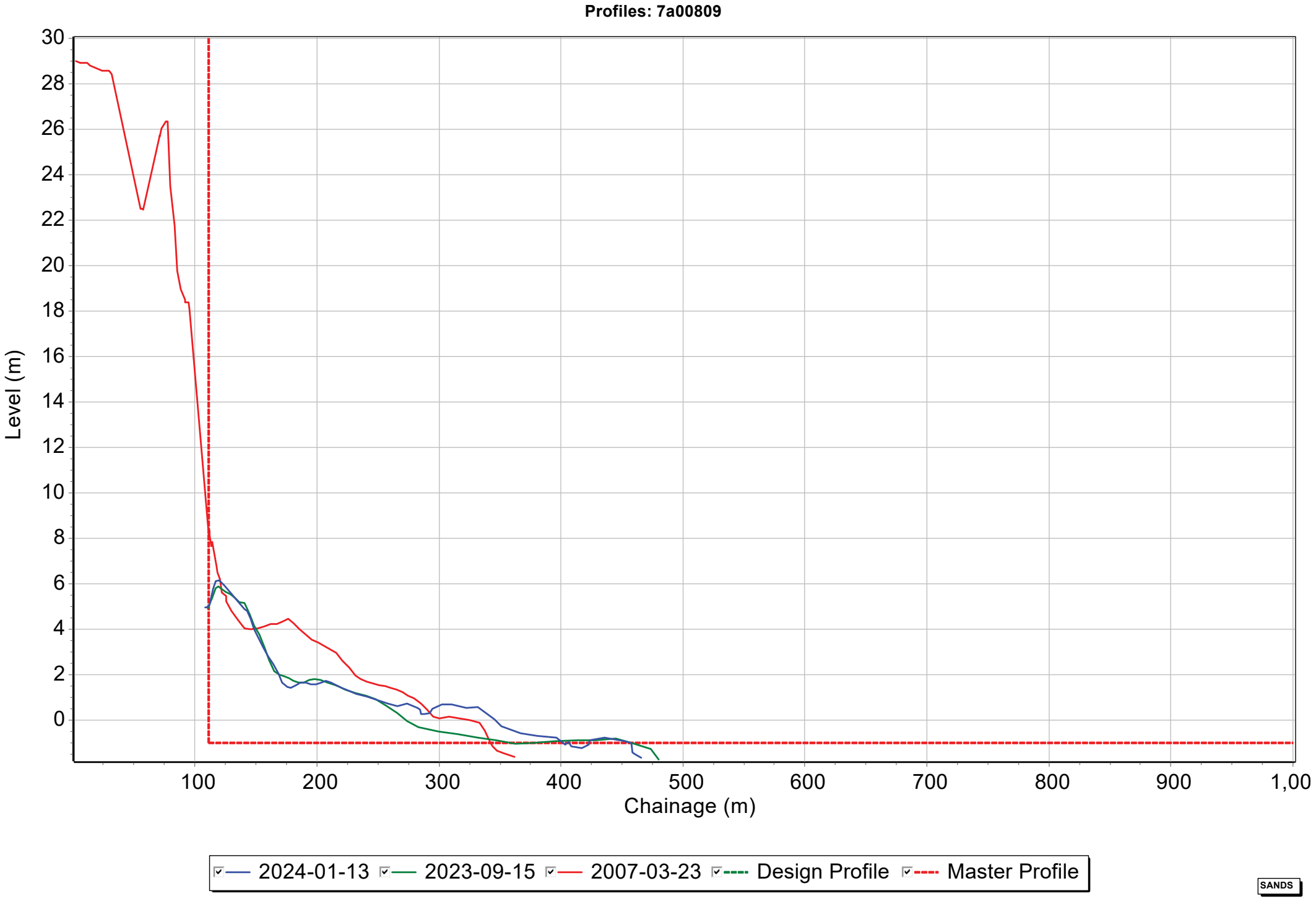
Appendices

Appendix 1 – Profile charts showing the cross-shore area of each interim profile from the most recent survey (blue), second most recent survey (green) and first survey, also known as the baseline (red) at Harvey's Towans are presented below.

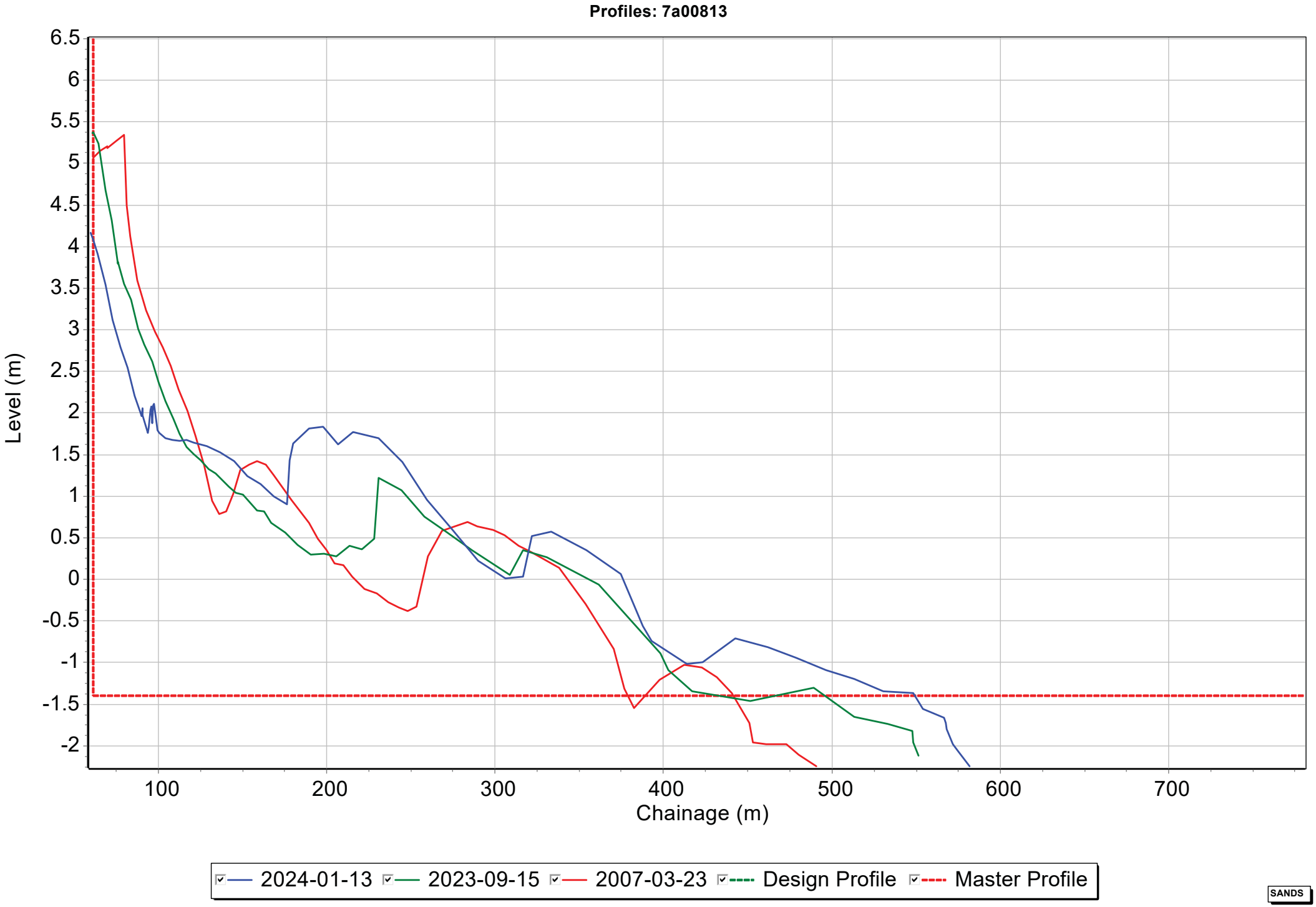

Profiles: 7a00805
Level (m)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
20
40
60
80
100
120
140
160
180
200
220
240
260
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile

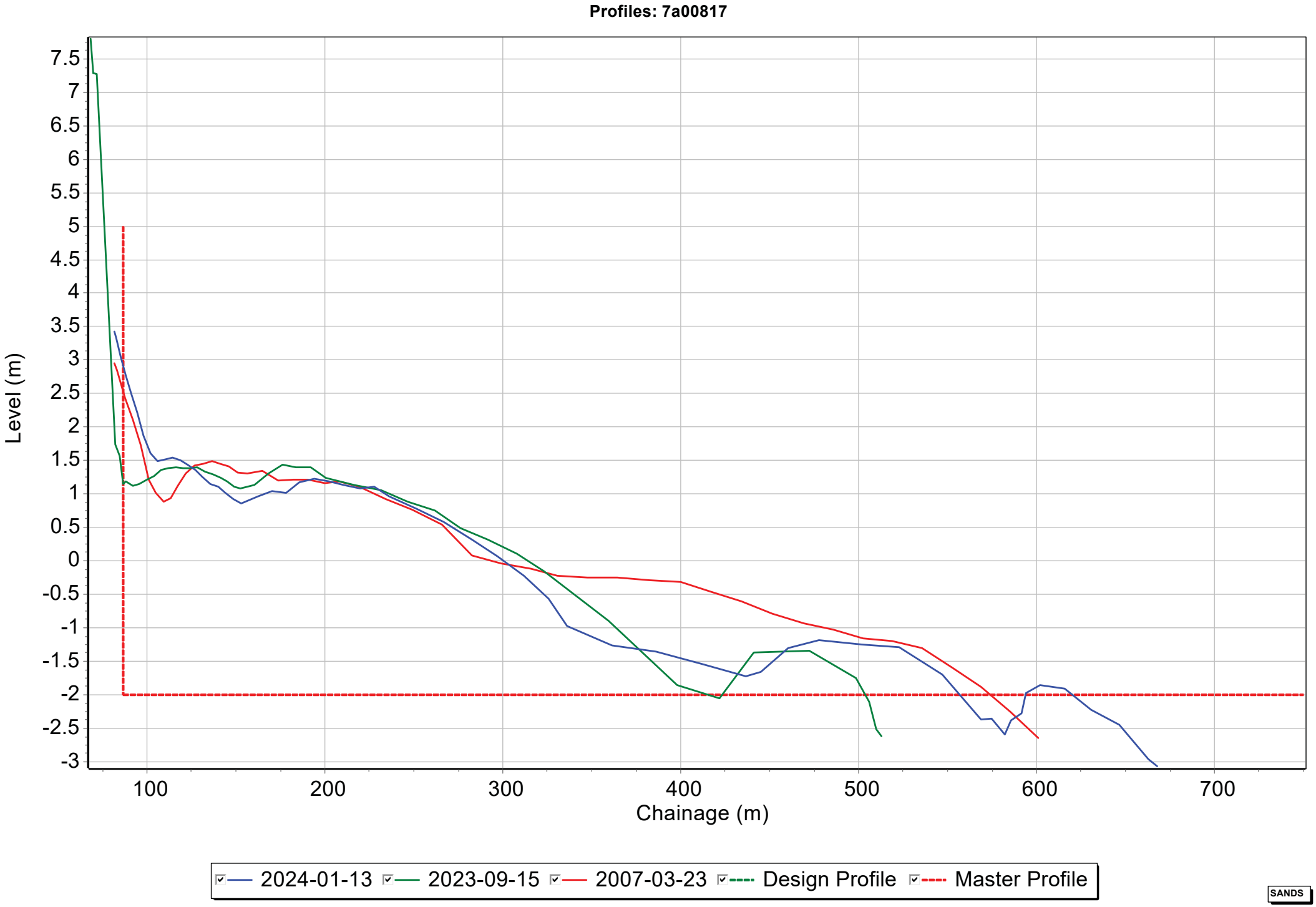

Profiles: 7a00807
Level (m)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350
400
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile

SANDS

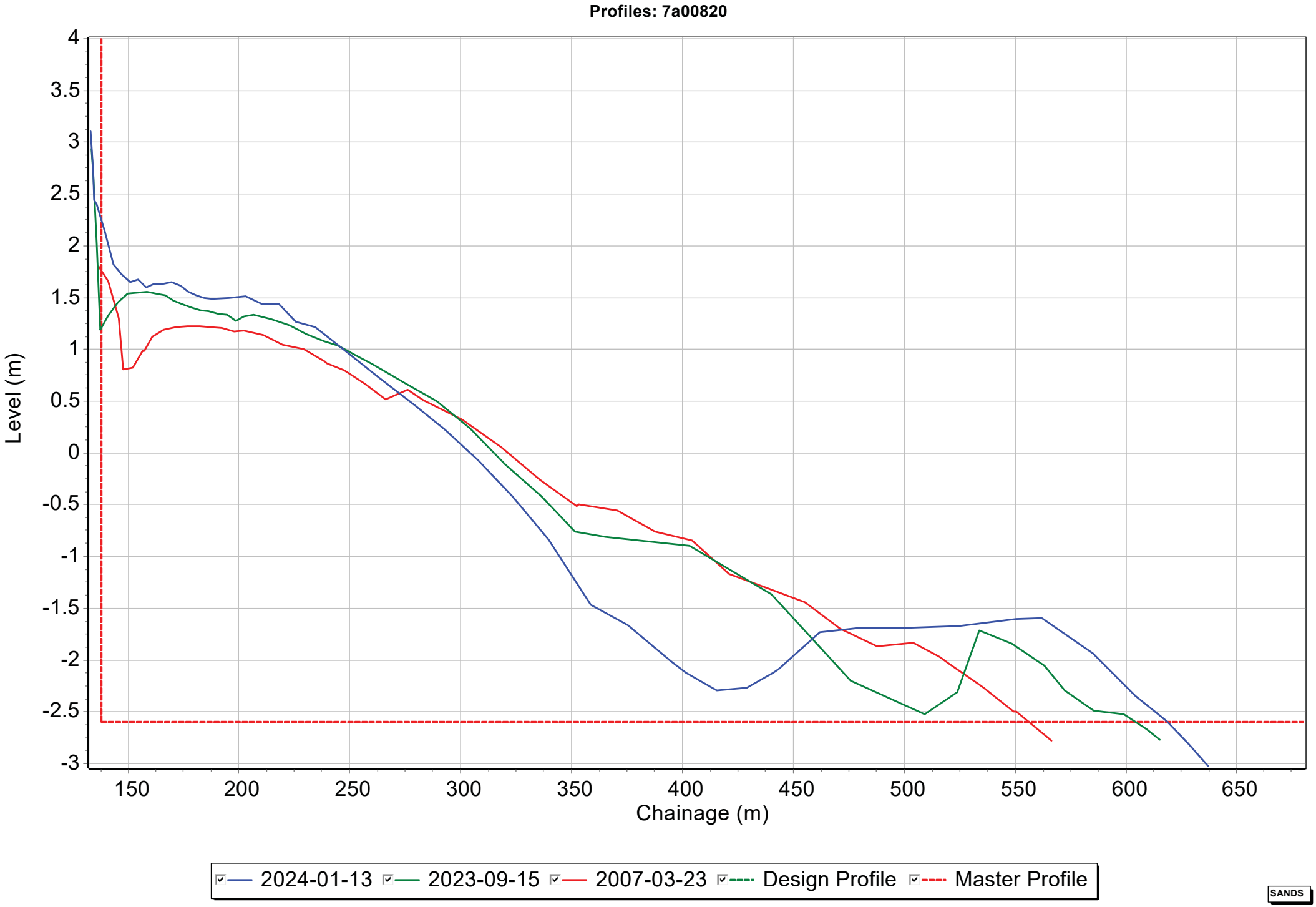

Profiles: 7a00809
Level (m)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
200
300
400
500
600
700
800
900
1,00
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile

SANDS

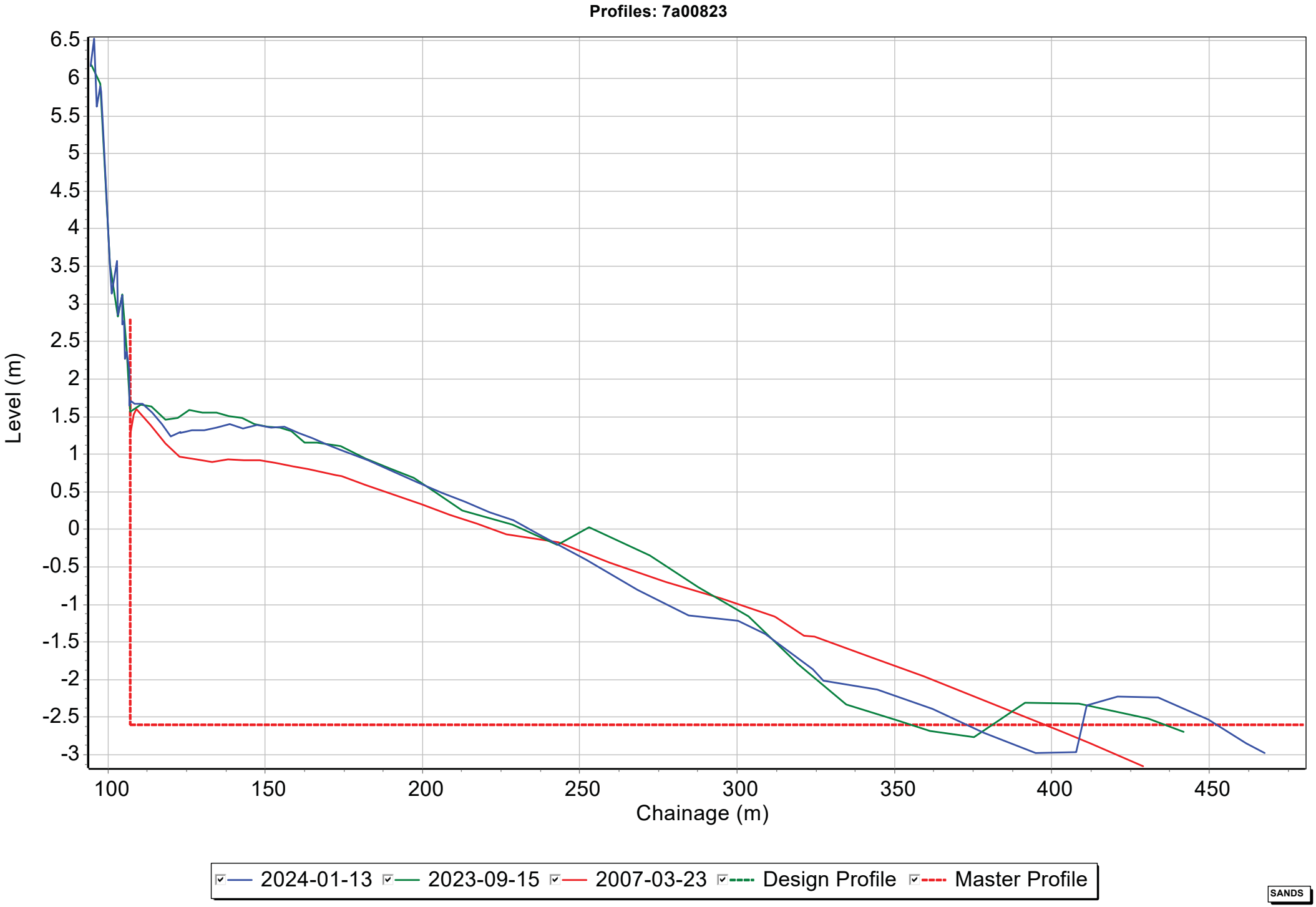

Profiles: 7a00813
Level (m)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
100
200
300
400
500
600
700
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile
SANDS


Profiles: 7a00817
Level (m)
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
100
200
300
400
500
600
700
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile

SANDS


Profiles: 7a00820
Level (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
150
200
250
300
350
400
450
500
550
600
650
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile

SANDS


Profiles: 7a00823
Level (m)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
100
150
200
250
300
350
400
450
Chainage (m)
2024-01-13
2023-09-15
2007-03-23
Design Profile
Master Profile