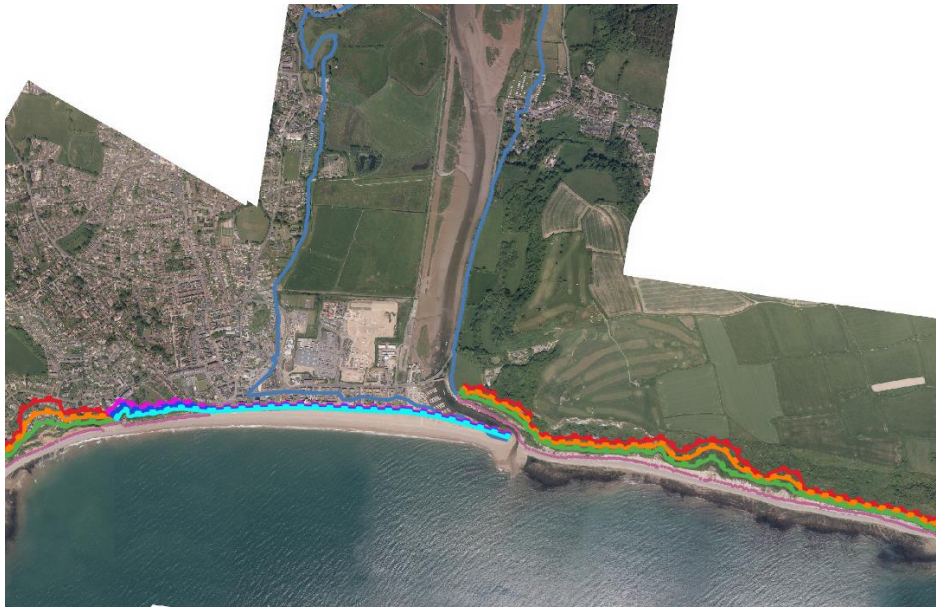


Coastal Change Management Areas in East Devon

DELIVERABLE 2: Complete CCMA Lines



Report provided by: Coastal Marine Applied Research,
University of Plymouth Enterprise Ltd.

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Executive Summary

This report provides a summary of the methodology and data used for the completion of future shoreline and future inundation mapping as part of the development of coastal change management areas (CCMAs) for East Devon District Council (EDDC). The report follows on from an initial draft submission which focused on previously un-mapped extents of the East Devon coastline not covered by historical work undertaken as part of the South West Economic and Environmental Prosperity (SWEEP) project.

The complete coastline is provided within this report and submitted as a digital dataset for application in the determination of CCMAs for the EDDC area. A plain language summary explaining the principle components of the methodology is provided for each of the different coastal environments with reference to the SWEEP Work Package 2 reports previously adopted.

Examples of the impact of historic retreat rates on future shoreline prediction is given to help understand the importance of applying the most up to date and relevant data to the methods. This will further allow reviews of sensitive areas to be undertaken should new coastal defence work be undertaken or changes in coastal behaviour impacts on current rates of retreat.

A breakdown of the digital files generated in support of this report is summarised including details on external data sources adopted as necessary. It is expected the work will form part of ongoing Local Plan submissions and the authors are available to provide further guidance on this topic as necessary.

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1. Introduction

1.1. Final Lines

This report provides a summary of future shoreline positions and future inundation areas predicted for the East Devon District Council region. The report provides a summary of the methodology used to generate the principal outputs and an explanation of the digital files provided in support of this project. It is expected that the output from the project will form the central data source for the designation of coastal change management areas (CCMAs) required as part of the adoption of the current Local Plan being developed by East Devon District Council (EDDC). This report brings together draft lines developed and presented in **CMAR, 2021. East Devon Coastal Change Management Areas, Report 2110_EDDC_TR1_v1** and lines developed as part of the South West Economic and Environmental Prosperity (SWEEP) project completed in 2020.

This report first introduces the overarching methodology with a plain language summary of the approaches for different coastal typologies. It then introduces the digital files and provides examples of how the work may be revisited in the future as our understanding of localised coastal retreat improves.

2. CCMA Method

The method adopted in this project is provided in detail in the SWEEP Work Package 2 Report available via https://sweep.ac.uk/coastal_change_management_areas_ccmas_methodology_and_adoption/. This section will provide a plain language version of the method, should further clarification be required please contact cmar@plymouth.ac.uk.

2.1. Overall Approach

The coastline is made up of different morphological environments, e.g. cliffs, sandy beaches, gravel beaches and estuaries. We need to manage each of these coastal areas differently to consider future shoreline response and inundation extents. The first stage therefore is to classify the coastline into ‘sections’ which reflect a combination of exposure (waves/tides), coastal type e.g. beach/cliff/estuary and geomorphological composition e.g. differing cliff types. For each ‘section’ the appropriate method, summarised below, is adopted to provide future shoreline positions. Figure 2-1 below provides a schematic overview of the steps to be taken for each coastal type. A more detailed summary is provided in the following sections to help explain the steps more clearly.

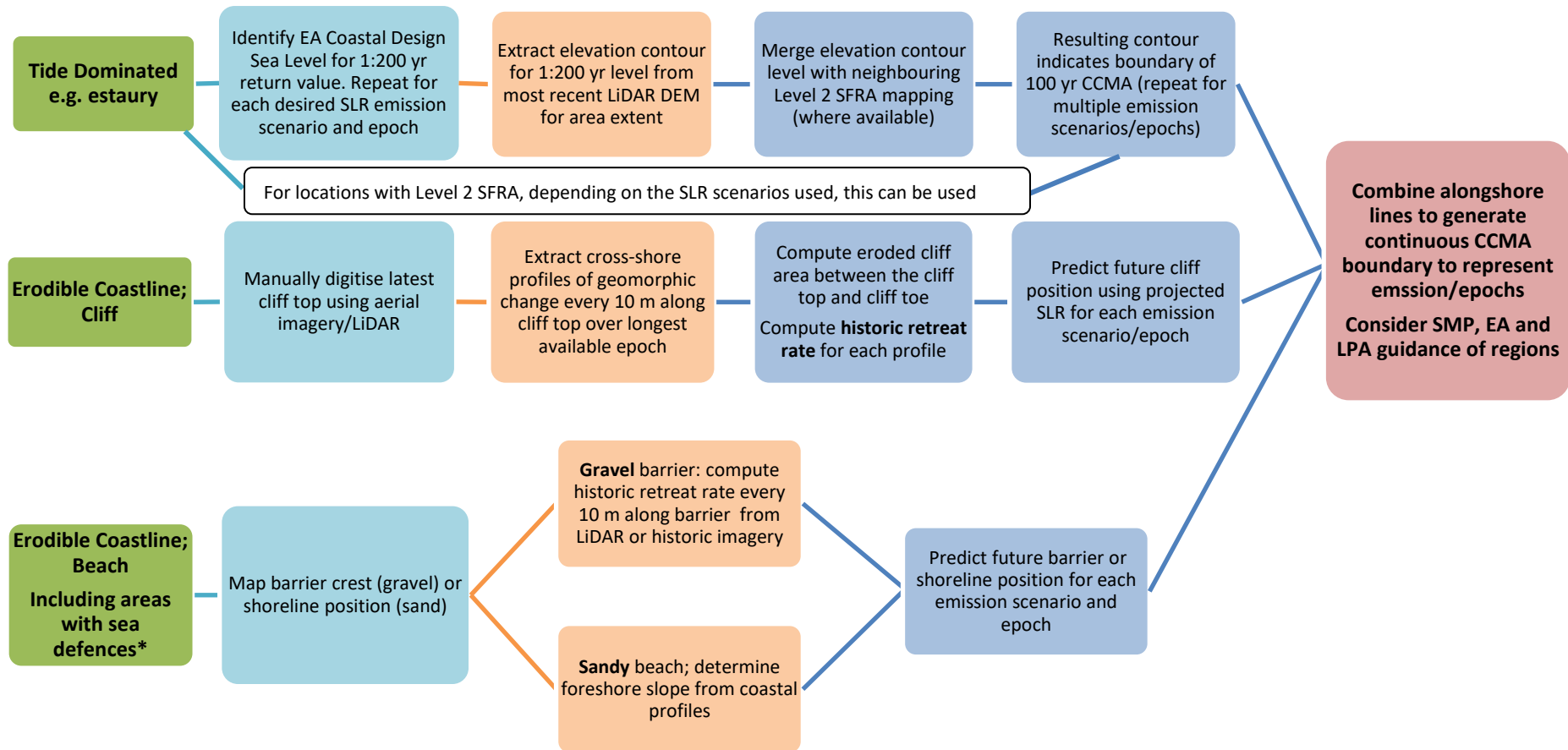


Figure 2-1. Schematic workflow of the main steps required for CCMA generation for different coast types. The final stage would involve detailed assessment of existing SMP and discussion with the LPA, EA and other relevant experts. Further detail on the method is provided in the text.* beaches backed by defences are treated as natural beaches as no method exists to incorporate defence structures so, beaches retreat as if coastal defence is not present.

2.2. Summary Steps for Cliff Backed Coastline

Cliffs are the most straightforward environment to work with because they will only move landward in response to erosion and will not move seaward. Because of this we can examine how the cliff has behaved in the past and from this we can calculate a ‘**historic** retreat rate’ which is usually expressed as meters per year (m/yr). For example, if the cliff position moves 5 m landward over ten years then we say the retreat rate is 0.5 m/yr.

The next step is to calculate the ‘**future** retreat rate’ which we can use to predict where the cliff position will be for a given number of years from now. Due to climate change, it is predicted that current sea-level rise (SLR) rates will accelerate. This means that the **historic** retreat rate is likely to change due to greater wave action on the cliff base. Therefore, we cannot use the historic retreat rate for the **future** retreat rate. Instead, we apply a calculation that looks at the rate of sea-level rise during the historic retreat period and the rate of sea-level rise predicted for the future period we are interested in. With this information we can generate a **future** retreat rate.

The final step is to do this for every coastal cliff section and re-draw the likely position of the cliff top for different epochs (dates in the future).

The principal steps that are taken, including the data required, to generate a future shoreline position are provided below and in Figure 2-2:

1. **Use Plymouth Coastal Observatory cliff-top mapping or aerial imagery to digitise the cliff-top line.** This provides a current position from which future retreat will be calculated.
2. **Create perpendicular profiles to the cliff line** at (e.g.) 10 m along-coast spacing. The cross-shore extent should be sufficient to reach at least the toe of the cliff and at least 10 m inland of the cliff line.
3. **Calculate historic retreat rate at each profile location** by calculating area of negative cliff change (lost cliff area) using LiDAR data between the top of the beach (part of profile coinciding with an elevation = MHWS + 2 m) and the top of the cliff (part of the profile that is 10 m inland of the digitised cliff line). Calculate the maximum cliff height between these two locations, then calculate cliff retreat rate using appropriate retreat equation.
4. **Predict future cliff retreat rate at each profile location**, informed by the historic retreat rate, the best available measurements of past sea-level rise (e.g. long-term tide gauge records), and the best available projections of future sea-level rise (e.g. UKCP18 or similar). We adopted the ‘high-emissions, 50th percentile’ future SLR scenario from UKCP18.

5. **Generate future cliff lines for the years 2040, 2070, and 2100.** At each location along the cliff, use the angle of the perpendicular profile and the predicted retreat distance to calculate a retreated cliff coordinate for that location.
6. **Smooth and clean the retreated cliff line.** No automated approach is perfect and some smoothing and manual editing is undertaken to connect the sections into one complete coastal layer.

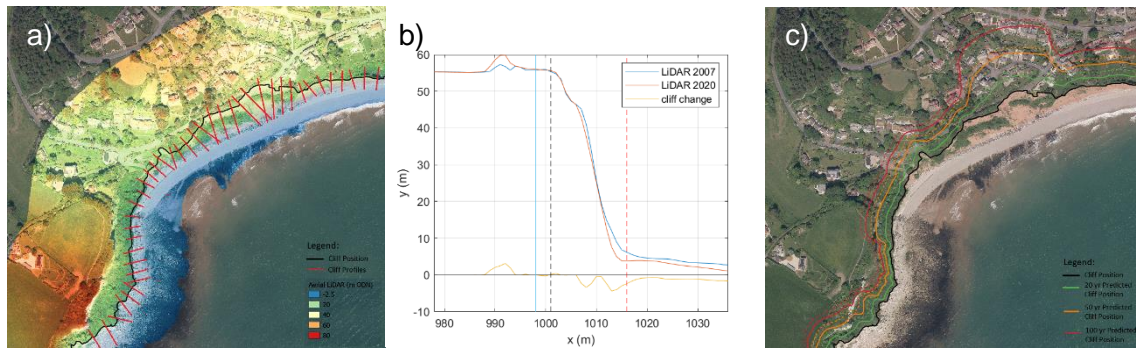


Figure 2-2. Example of the process to compute the future cliff position; a) current cliff top mapped and cross-shore profiles extracted from two LiDAR datasets; b) volumetric profile change computed; c) future retreat rates computed with sea-level rise considered. New lines mapped to show likely retreat distances.

2.3. Summary Steps for Beaches and Sea Defences

For beaches we also need to identify a current shoreline position which is done by extracting the mean high water level (MHW) or for gravel barriers we use the barrier crest. Like cliffs we also extract cross-shore profiles at regular intervals for which we then compute the future shoreline position. Previous research shows us that sandy beaches behave differently to gravel beaches and therefore they require a different approach.

For sandy beaches their historic behaviour cannot be used for future predictions because they can both erode and accrete. Instead, we apply a ‘Profile Model’ which predicts how the beach will change under future sea-level rise. This model assumes the profile will retain its current shape but move landward keeping pace with SLR.

For gravel beaches, where they have space to retreat, their historic response is used together with the overall profile shape of the gravel barrier. This allows us to predict how the gravel may retreat under future sea-level rise. The key steps are listed below:

1. **Extract coastline position from LiDAR.** We used the MHW contour line for sandy beaches, and the barrier crest for gravel barriers
2. **Generate perpendicular coastal profiles along the shoreline.**

For sandy beaches:

3. **Determine nearshore slope of sandy beaches.**
4. **Predict future shoreline position** using the measured shoreface slope and future SLR.

For gravel barriers:

5. **Estimate rate of past barrier retreat at gravel barriers** using the earliest and most recently available LiDAR or historic imagery.
6. **Estimate the height and cross-sectional area** of the gravel barrier from the perpendicular profiles extracted from the LiDAR or bathymetry data.
7. **Predict future barrier retreat rate** informed by the past retreat rate, and past and future SLR rates.

For sandy beaches and gravel barriers:

8. **Generate future shorelines for the years 2040, 2070, and 2100.** At each location along the shore, use the angle of the perpendicular profile and the predicted retreat distance to calculate a retreated shoreline coordinate for that location.

7. **Smooth and clean the retreated shoreline.** No automated approach is perfect and some smoothing and manual editing is undertaken to connect the sections into one complete coastal layer.

2.4. Sea Defences

Sea defences such as seawalls, rock armour or gabions are not natural features. As such they do not behave in a natural way that can be used to predict future shoreline change. Where defences are located either the defence will remain in place (pending suitable funding) or in time the defence will no longer be maintained. The only way to predict future shoreline response is to **remove the defence from the analysis** and compute the shoreline change based on the profile that is present e.g. sandy beach or gravel beach. The difficulty is that the current profile at that location is also not a fully natural feature and so it is likely that any prediction for the location will be less reliable.

3. Floodable Areas

Estuaries are vulnerable to the impacts of future climate change in particular SLR. In such environments, shoreline change, and erosion are expected to play a far smaller role in determining the CCMA than enhanced coastal flooding, as storm surge is considered the main coastal hazard. The focus here is on the enhanced/modified flood risk and not necessarily a modified coastline position. The Environment Agency provides Flood Maps for Planners (<https://flood-map-for-planning.service.gov.uk/>) which are publicly accessible and provide information on flood risk. For areas with high population density the flood mapping is likely to be quite comprehensive and consist of a Strategic Flood Risk Assessment (SFRA). This is a detailed study that explores the impacts of climate change on flood hazards. For less populated areas the flood hazard assessment will be less detailed and may not consider future SLR impacts.

Unlike erosive coastlines where we expect to see a shoreline position move, for floodable areas the concern centres on the frequency of inundation. **This is often expressed as areas where there is a 1:200 (0.5% or greater) chance of flooding each year (for Flood Zone 2).**

The approach we adopt for mapping future flood areas depends on whether an SFRA is available. If this is not the case we establish the 1:200 level and then add the expected SLR for 2100. We can then map this new elevation as a continuous line around the estuary. The approach to achieve this is given below.

3.1. Summary Steps for a Floodable Estuary

While the workflow describe below has been undertaken using QGis, which is an open source free software, the tools mentioned are generic between GIS platforms, although exact names may vary.

1. **Load the most recent LiDAR datasets available for the area of interest**
2. Compute the required 1:200 elevation from the **Environment Agency Design Sea Level** dataset and add the SLR level for 2100.
3. ‘Extract’ the corresponding contour (for 1:200 + SLR) from the most recent LiDAR surface.
4. If the area is a straightforward small region it is likely **this layer can be used as the CCMA boundary**, however, it is possible that there will be a lot of ‘noise’ around the edge, particularly in urban areas.
5. Edit the new layer to remove spatial errors and create a smooth boundary region
6. The final step is to **add a buffer to the mapped region** (see next section). A vertical 0.25 m buffer can be applied using the same method outlined in step 3. A horizontal buffer, to accommodate the South West Coast Path is added by creating a 2 m single sided buffer. In QGis the ‘Single Sided Buffer’ found under the Vector Geometry tool can be used.
7. Save layer as a shape file (.shp) file for export into the relevant planning portal.

4. Retreat Line Buffers

As outlined within the National Planning and Policy Framework guidance, a buffer of between 10 and 30 m is advocated along CCMA extents, in addition to the expected future position of coastal change. There is not very clear guidance on how the buffer is applied and so for our areas we have tried to adopt a clear and consistent approach that includes:

Tidal Coastlines

1. A 2 m horizontal allowance for the South West Coast Path
2. A vertical buffer of 0.25 m where we have computed the inundation area

Erosive Coastlines

The greater of:

1. A 10 m horizontal buffer that includes the 2 m allowance for the South West Coast Path

OR

2. A variable horizontal buffer computed as 10% of the projected retreat distance for each section of coastline assessed at each epoch.

5. External Data

For the East Devon coast (not previously mapped in SWEEP) there are two sections which are estuaries and therefore treated as ‘Floodable Estuaries’ following the SWEEP methodology. The two areas cover the Exe estuary and the Otter estuary which have both benefited from detailed modelling and flood mapping as part of wider flood and coastal erosion risk management activities. The data for the Exe estuary comes from a modelling study undertaken in 2012 by Mott McDonald on behalf of the Environment Agency:

In November 2011, the Environment Agency commissioned Mott MacDonald to undertake a flood risk modelling and mapping study for the Exe Estuary. A fully hydrodynamic 1D/2D ISIS/TUFLOW model was developed to assess flood risk and hazard. The calibrated design model was used to:

- *Simulate flood paths, depths, velocities and hazard across the floodplain and in-estuary for the 1 in 10, 30, 50, 75, 200 and 1000 year tidal events as well as the 1 in 200 and 1000 year under 2060 and 2115 climate change*
- *Simulate flood paths, depths, velocities and hazard across the floodplain and in-channel for Shutterton Brook, Withycombe Brook and Wotton Brook for the 1 in 2, 10, 20, 50, 75, 100, and 1000 year fluvial events as well as the 1 in 100 and 1000 year climate change.*
- *Derive improved flood zones and flood hazard information.*
- *Create 2D visualisation of overtopping.*

A separate 1D/2D hydraulic model was developed for the 1 in 1000 year tidal extreme event, and the 1 in 200 and 1 in 1000 year climate change events to assess the flood risk along the Estuary. The model was developed to overcome instabilities arising from limitations in the 1D ISIS/2D TUFLOW link when calculating large exchange of lateral flows.

The project looked at a wide range of scenarios for both fluvial and tidal flooding including wave overtopping. In line with the SWEEP method and that of other Strategic Flood Risk Assessments we have adopted the **1 in 200 year under climate change conditions (2115)** run including wave overtopping for an undefended coast referred to as:

- EXE_T0200CC2F0002D_EXTREME_WO_EXTENT

For more detail on the specific nature of the model simulations please see Table 7.1 in the **Exe Estuary Mapping & Modelling Study Final Report (2012)** from Mott McDonald.

The data for the Otter estuary currently comes from two sources; the Environment Agency Flood Zones for planning database (<https://data.gov.uk/dataset/cf494c44-05cd-4060-a029-35937970c9c6/flood-map-for-planning-rivers-and-sea-flood-zone-2>) and modelling output from the Lower Otter Restoration Project (LORP). From the Environment Agency data we have provided the **Flood Zone 2** data as a comparison to the LORP dataset. The Flood Zone 2 data is described as:

*“It is our best estimate of the areas of land at risk of flooding, when the presence of flood defences are ignored and covers land between Zone 3 and the extent of the flooding from rivers or the sea with a **1 in 1000** (0.1%) chance of flooding each year.”*

This is therefore more conservative than the **1 in 200 year** approach we normally adopt for Floodable Estuaries and therefore a reasonable indication of the extent we may expect to see given future SLR.

The data from the LORP that was provided to us contained four scenarios/model runs including:

1. *2-yr RP fluvial + LWN tide (low water neap with fluvial peak at low tide)*
2. *100-yr RP fluvial & LWN tide (low water neap with fluvial peak at low tide)*
3. ***100-yr RP fluvial + CC allowance of 85% & MHWS tide + 100-yr SLR (UKCP18 Upper End)***
4. *mean river discharge + CC allowance of 85% & MHWS tide + 100-yr SLR (UKCP18 Upper End)*

We have adopted Run 3) (in bold) as the most suitable model scenario with the most conservative parameters to align with the other 2100 predictions within this report. The data was provided in the Mike21 (model) format which we processed in Matlab to extract the timestep within the output which reflected the peak tide level. This was then converted into a .shp file for use in GIS and has been provided as such.

6. Retreat Rates

Predicting the future retreat of cliff systems is dependant, in part, on calculation of historic retreat rates. Through future coastal stabilisation/defence works current retreat rates may be reduced and therefore future retreat will also be reduced. The future shoreline predictions presented within this report are based on the best available data at the time of publication. However, we advise that where possible the retreat rates are monitored and future shoreline positions can be updated using the most recent retreat rates particularly where new coastal defence works have occurred.

To provide an indication of how the retreat rate may impact on the future shoreline position we have provided a look-up table which gives examples of how historic rate may impact future retreat rates (Table 6-1).

The cliff retreat equation (Ashton *et al.*, 2011) predicts the **future retreat rate R_2 (m/yr)**, as a function of the **historic cliff retreat rate R_1 (m/yr)** and the **past and future SLR rates S_1 and S_2 , respectively (mm/yr)**:

$$R_2 = R_1 \left[\frac{S_2}{S_1} \right]^m \quad (1)$$

Table 6-1. Indicative retreat rates for coastal cliffs for different historic retreat scenarios. * Historic sea-level rates for the period LiDAR data are available. ^ Future sea-level rates given as an average for the period up to 2100.

Historic Retreat Rate (m/yr)	Historic sea-level rise (mm/yr)*	Future sea-level rise (mm/yr)^	Future Retreat Rate (m/yr)	Landward Retreat by 2100 (m)
0.1	2.54	8.2	0.18	14
0.2	2.54	8.2	0.36	28
0.3	2.54	8.2	0.54	42
0.4	2.54	8.2	0.72	56
0.5	2.54	8.2	0.90	70
0.6	2.54	8.2	1.08	84
0.7	2.54	8.2	1.26	98
0.8	2.54	8.2	1.44	112
0.9	2.54	8.2	1.62	126
1.0	2.54	8.2	1.80	140
1.1	2.54	8.2	1.98	154
1.2	2.54	8.2	2.16	168
1.3	2.54	8.2	2.34	182
1.4	2.54	8.2	2.52	196
1.5	2.54	8.2	2.70	210
1.6	2.54	8.2	2.87	224
1.7	2.54	8.2	3.05	238
1.8	2.54	8.2	3.23	252

1.9	2.54	8.2	3.41	266
2.0	2.54	8.2	3.59	280

Our approach to this work has always been about improving the transparency of how projections are computed. To further add to this we have included, as part of the digital file delivery, the **historic retreat rates** for all coastal cliff sections (Cliff_R1). This means that for every ~10 m of coastal cliff we have provided a GiS layer which provides the rate (m/yr) of cliff retreat for that profile. This will allow any future changes to retreat rates - possibly from coastal defence work/cliff stabilisation - to be used in future calculations of shoreline retreat. Using Table 6-1, above, it is possible to explore how future retreat may be impacted as current retreat rates are managed. For example for the coastal cliffs parallel to Cliff Road in Sidmouth the retreat rate of the profiles for that area vary between 0.7 m/yr to 1.75 m/yr over 165 m of coast. This means the retreat for this area could be between 98 m and 238 m by 2100 without any further management of the site (Figure 6-1).



Figure 6-1. Snapshot of CCMA lines for Sidmouth (see Appendix A for full regional maps and legends). Pink dots indicate the location of profiles used to calculate historic retreat rates.

7. Digital Files

In line with the SWEEP method we have provided three predicted retreat lines to represent the short term, medium term and long term likely position of the coastline/cliff based on the most recently mapped position. The predicted retreats are based on the high emissions 50 % ile scenario. A summary of the layer names as provided in the digital dataset (.zip file ED_CCMA_V2.zip) are provided in Table 7-1.

Table 7-1. Layer names and descriptions that are provided, as digital files (ED_CCMA_V2.zip).

Layer Name	Description
ST_20_yr	The 2040 cliff/coastline position using the High Emissions (HE) 50 %ile output
MT_50_yr	The 2070 cliff/coastline position using the High Emissions (HE) 50 %ile output
LT_100_yr	The 2100 cliff/coastline position using the High Emissions (HE) 50 %ile output
ST_20_yr_Buffer	The cliff/coastline position (for each epoch) using the High Emissions (HE) 50 %ile output plus the horizontal buffer (10 m or 10 % of projected retreat distance)
MT_50_yr_Buffer	
LT_100_yr_Buffer	
ST_20_yr_SD	The cliff/coastline position (for each epoch) using the High Emissions (HE) 50 %ile output, for areas backed by a sea defence (SD)
MT_50_yr_SD	
LT_100_yr_SD	
ST_20_yr_SD_Buffer	The cliff/coastline position (for each epoch) using the High Emissions (HE) 50 %ile output, for areas backed by a sea defence (SD), plus the horizontal buffer (10 m or 10 % of projected retreat distance)
MT_50_yr_SD_Buffer	
LT_100_yr_SD_Buffer	
ExeFlood_Line_V1	Modelled flood extent produced by Mott McDonald in 2012.
ExeFlood_Line_V1_Buffer	Modelled flood extent produced by Mott McDonald in 2012 with an additional 2 m horizontal buffer for future coast path space.
LORP_MM_Model	LORP model output flood extent.
LORP_MM_Model_Buffer	LORP model output flood extent with 2 m horizontal buffer.

EA_FloodMapForPlanningRivers AndSeaFloodZone2_Clean_Line	EA Flood Mapping for Planners Flood Zone 2 for the Otter. No tidal limit imposed.
EA_FloodMapForPlanningRivers AndSeaFloodZone2_Clean_Line_Buffer	EA Flood Mapping for Planners Flood Zone 2 for the Otter. No tidal limit imposed. With an additional 2 m horizontal buffer for future coast path space.
Axe_HE_Flood_V1	2100 flood extent for the River Axe
Axe_HE_Flood_VertBuffer	2100 flood extent for the River Axe plus a vertical buffer
Axe_HE_Flood_VertBuffer_CP	2100 flood extent for the River Axe plus a vertical and horizontal buffer for the coast path
Cliff_R1	Historic retreat rates (R1) computed for each cliff profile
SMP	
Line20yr_upper_final	South Devon and Dorset Shoreline Management Plan (2) short term shoreline position
Line50yr_upper_final	South Devon and Dorset Shoreline Management Plan (2) medium term shoreline position
Line100yr_upper_final	South Devon and Dorset Shoreline Management Plan (2) long term shoreline position

9. Summary

This project has looked to complete the full extent of future shoreline and future flood inundation areas to be used in support of designating CCMA's. This report brings together work previously done under the SWEEP project with new data analysis for the western section of EDDC's coastal extent. The work has followed the previously adopted SWEEP methodology and replicated this approach over further coastal and estuarine sections as required.

Where possible we have utilised the most recent data or analysis that has been undertaken in the region to ensure the outputs are as relevant and accurate as possible. However, we also recognise that the coastline is highly dynamic and ongoing management practices will undoubtedly impact on the future predictions generated. In addition a clear synopsis of the methods and explanation as to the importance of historical retreat rates has been included to help conversations with communities that may be affected by the CCMA areas.

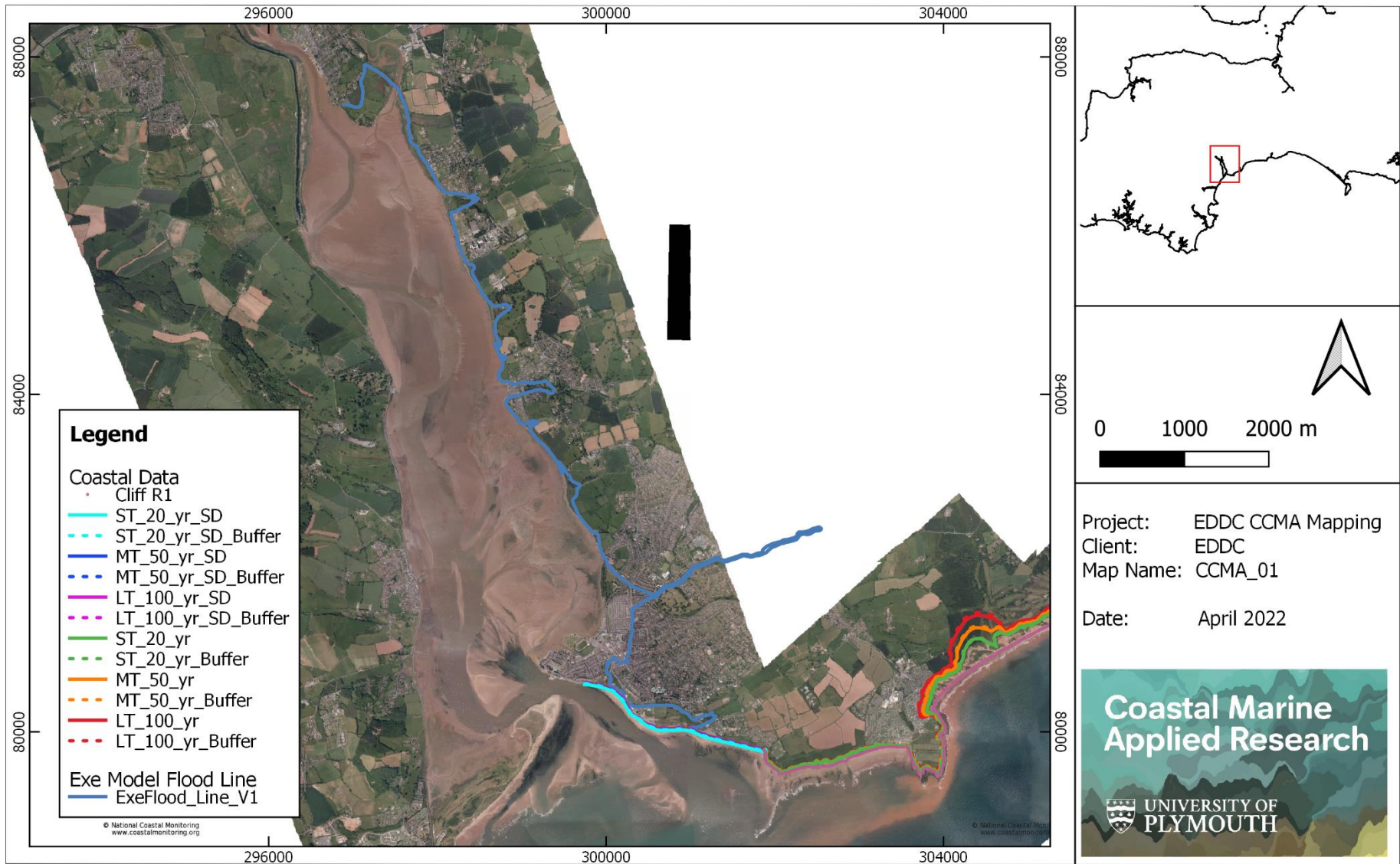
The authors recognise the nature of such work can be alarming to those affected and the work sits within a far wider need for improved understanding on coastal management and impacts of coastal change. As such the authors have agreed to make themselves available for ongoing discussions to better explain the science and steps taken to arrive at the datasets provided. Ongoing mapping of coastal erosion is a central component of the Environment Agency activities and it is likely that this work can be further improved in coming years. To facilitate this we have provided a transparent approach which supports future review as our understanding and data access also improves.

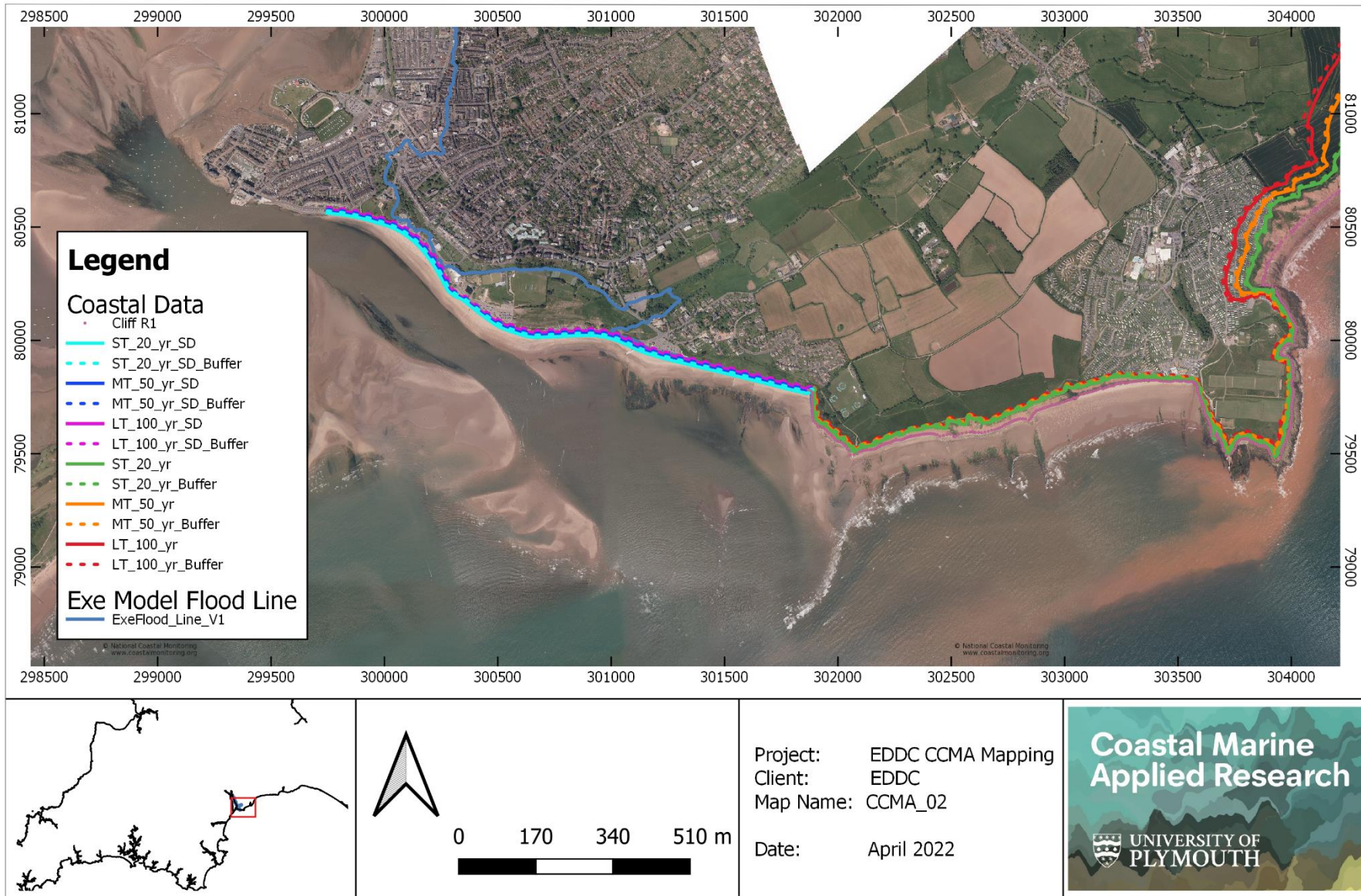
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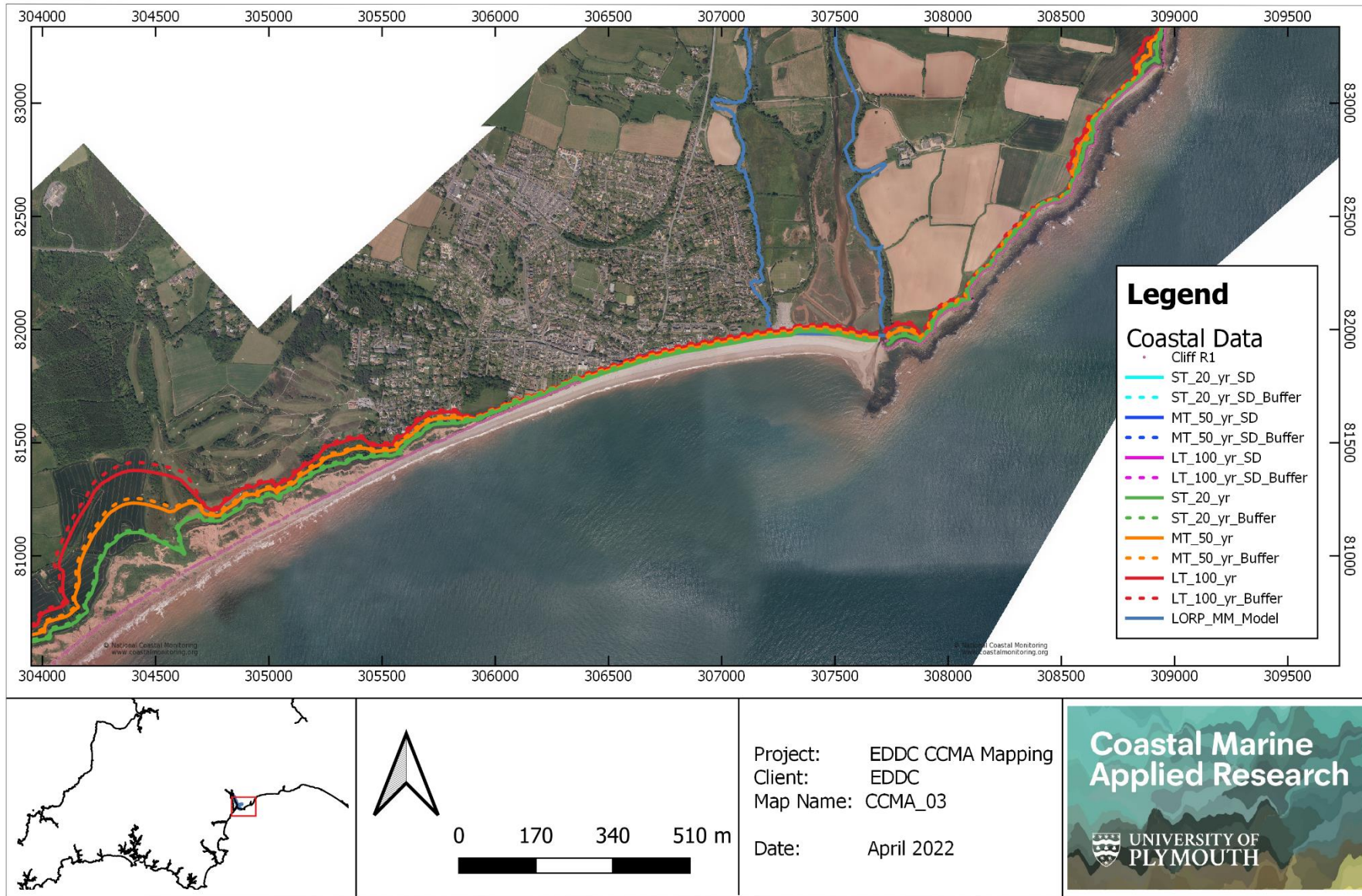
Ashton, A.D., Walkden, M.J.A., Dickson, M.E., 2011. Equilibrium responses of cliffed coasts to changes in the rate of sea level rise. *Marine Geology*. doi:[10.1016/j.margeo.2011.01.007](https://doi.org/10.1016/j.margeo.2011.01.007).

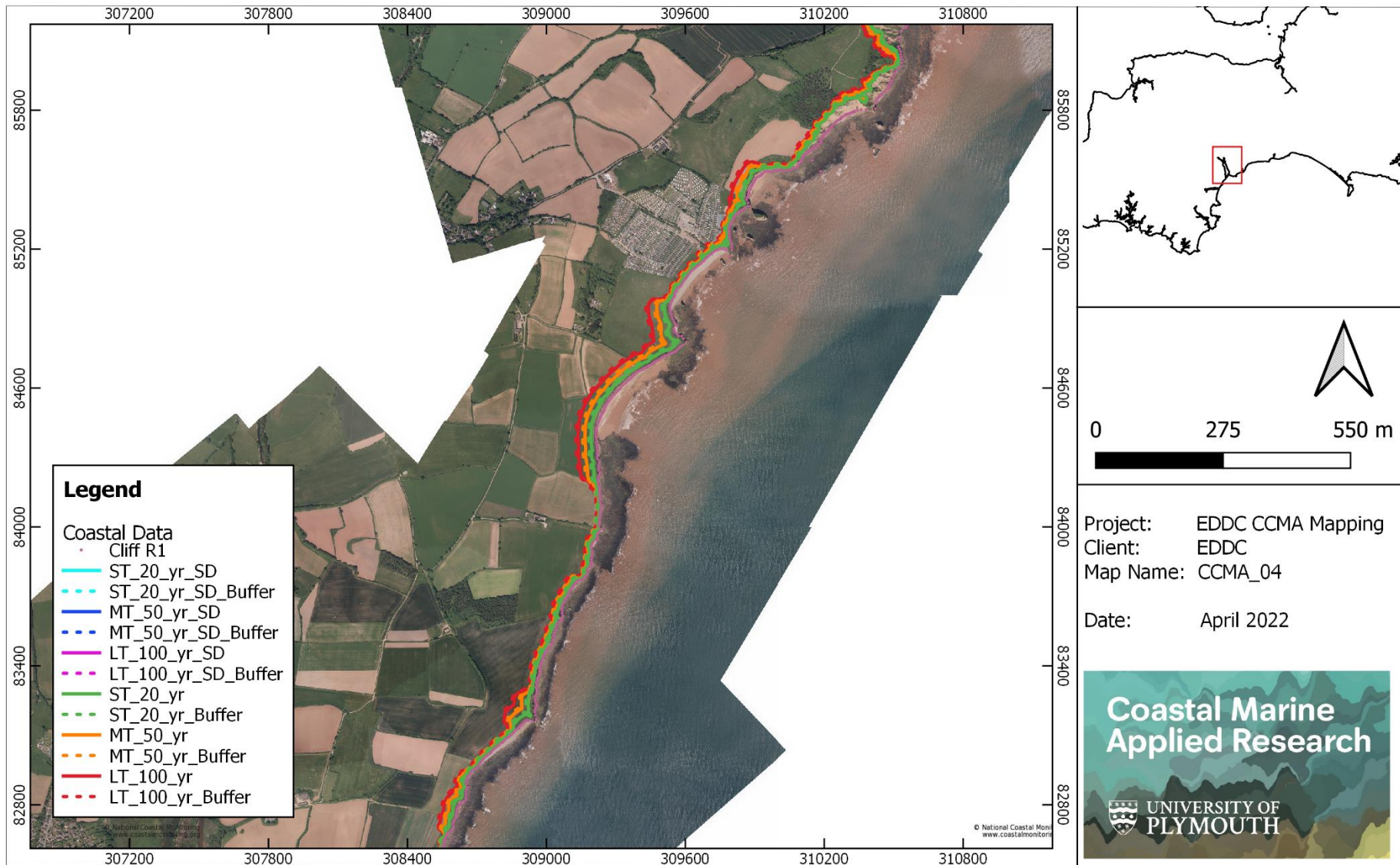
11. Appendix A

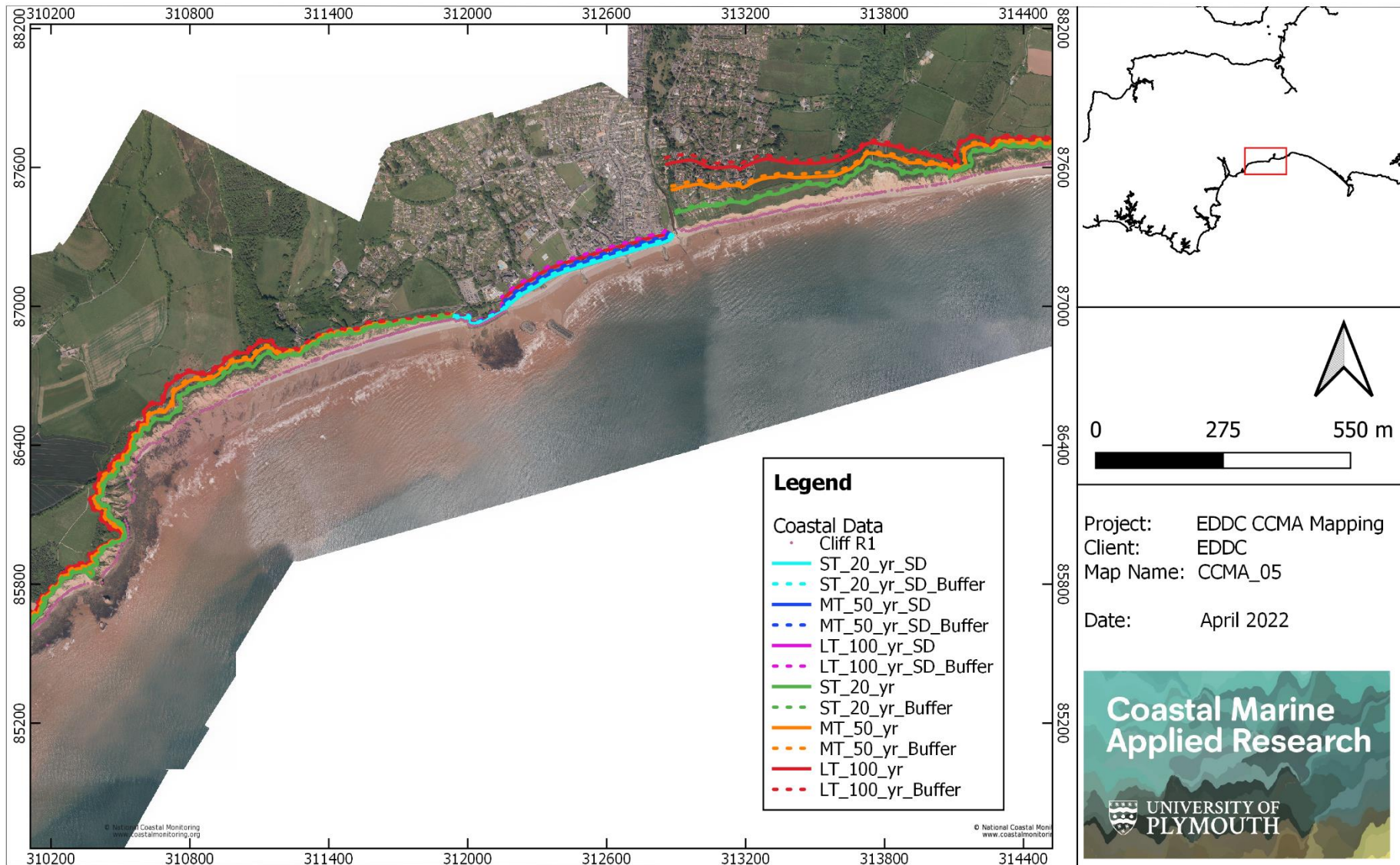
The following pages contain the regional maps for the East Devon District Council coastal extent. They are provided as an overview in support of the digital files accompanying this report.

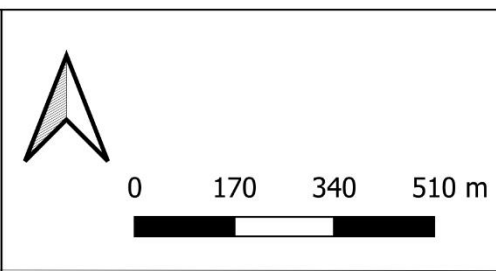
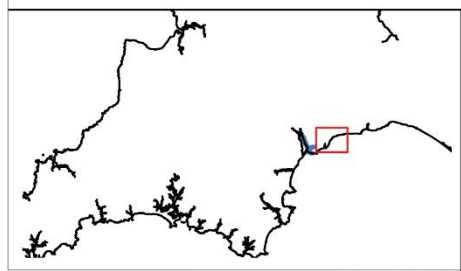
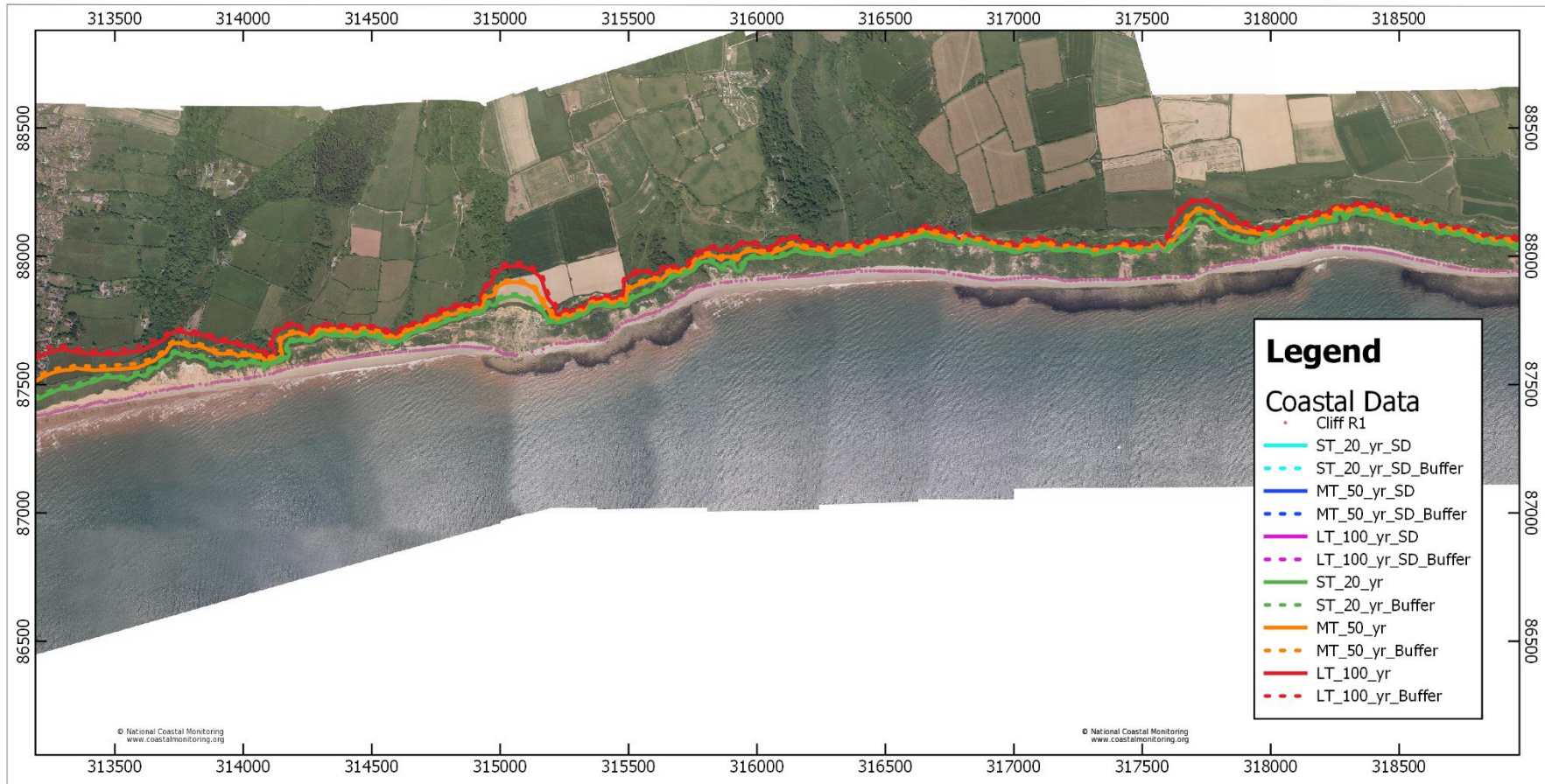












Project: EDDC CCMA Mapping
 Client: EDDC
 Map Name: CCMA_06
 Date: April 2022

