Slapton Line Vulnerability Assessment 2023

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Slapton Vulnerability Assessment 2023

Executive Summary

This report builds upon previous assessments of the vulnerability of the A379 'Slapton Line' road, providing an up-to-date assessment of the vulnerability of the road to beach erosion during storms. This study included a detailed photogrammetry survey of the Slapton Line in May 2023, which enabled the quantity and location of existing loose rock armour along the line to be quantified.

To complete this assessment, a combination of digital elevation data were used, including Light Detection and Ranging (LiDAR) data collected between 2008 and 2020, Unmanned Aerial Vehicle (UAV) photogrammetry surveys collected between 2017 and 2023, and topographic beach profiles collected monthly between 2010 and 2023. The buffer distance between the present A379 road alignment and the upper beach was quantified along the Slapton Line, providing conservative estimates of the minimum buffer distance, taking into consideration the dynamic nature of the beach. Furthermore, an Extreme Value Analysis (EVA) was undertaken to estimate beach retreat distances during extreme storms at a range of return periods of up to 1-in-100 years.

The majority of Slapton Line north of the engineered defences has a healthy buffer between the road and the upper beach of between 6 and 60 m, where the road would only become vulnerable during a 100-year erosion event or greater. The frontage at greatest risk from storm erosion is the area immediately fronting the Tank car park to approximately 450 m north of the car park, where the road would become vulnerable to storm erosion from a 10-year to 50-year return period erosion event. Around two-thirds of this frontage would become vulnerable during a 1-in-10-year erosion event, with buffer distances of only 3-6 m between the beach and the front of the road/coast path. This vulnerable section of frontage has some form of defence all the way along it, in the form of either a retaining wall, retaining wall capped with rock armour, or loose rock armour on the beach, but the quantity and quality of the loose rock armour varies along this frontage.

The loose rock armour volume varies between <0.2-0.6 m^3/m at its northern extent where the road is less vulnerable to storm erosion (100-year return period buffer or greater), to 1.2-2.1 m^3/m of rock armour towards the south where the road is highly vulnerable to storm erosion (10-20-year return period buffer). Around the centre of the loose rock armour frontage there are some vulnerable profiles (10-50-year return period buffer) with only 0.8-1 m^3/m of rock armour present.

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1. Introduction

CMAR previously undertook vulnerability assessments for Slapton Line in 2018 and 2021. These studies investigated the vulnerability of the A379 road to beach erosion from a future storm of a similar magnitude to Storm Emma (March 2018), which, given its easterly direction, had a return period of approximately 1-in-50 years and caused significant damage to a section of the Slapton Line. The present project builds upon this previous work, providing an up-to-date assessment of the vulnerability of the A379 road to beach erosion during storms, and includes interrogation of the quantity and location of existing rock armour that currently provides protection to the ~ 800 m frontage north of Torcross village.

1.1. Site Description

Slapton Sands is a gravel barrier beach located in the South Hams district of south Devon, and is approximately 4.5 km long, and aligned in a SSW to NNE orientation. The A379 road runs along the length of the barrier from Torcross to Strete Gate (the 'Slapton Line'), providing access from the coastal community of Torcross to the village of Slapton and Strete, also providing a second emergency route into Dartmouth.

1.2. Aims and Objectives

The aim of the present project is to provide a robust and up-to-date assessment of the present vulnerability of the Slapton Line to storm wave erosion. To achieve this aim, the following objectives have been identified:

1) Compute storm erosion distances and return periods along the Slapton Line using 13 years of available beach topography measurements.
2) Evaluate the present 'buffer distance' between the A379 road and the upper beach using up-to-date survey data.
3) Compare the buffer distances along the Slapton Line to the computed erosion return periods to identify the most vulnerable areas of the Slapton Line.
4) Quantify the volume of rock armour present at the southern portion of the Slapton Line and compare this to the computed level of vulnerability.

1.3. Site morphology and wave climate

The 2018 Slapton Line Vulnerability Assessment report details the morphology and wave climate at the site (CMAR, 2018. Slapton Line Vulnerability Assessment, Report 1801_1_v1, University of Plymouth Enterprise Limited, 33 pp.).

2. Methodology

Topographic data is essential in assessing the vulnerability of the A379 road and was obtained from a number of sources, including:

- LiDAR (Light Detection and Ranging) data from the Channel Coastal Observatory (CCO) and Environment Agency taken between 2008 and 2020.
- Unmanned aerial vehicle surveys (UAV) from October 2017, March 2018, May 2018, May 2021 and May 2023 conducted by the University of Plymouth.
- Topographic beach profiles collected monthly by the University of Plymouth between 2010 and 2023. Profiles are spaced roughly 200 m apart.

Aspects of the previous 2018 and 2021 assessments have been used in this analysis, including:

- The same cross shore profiles along the length of the Slapton line were used in this assessment. Profile locations were selected from South West Coastal Monitoring Programme (SWCMP) at intervals of no more than 50 m, from the end of the Torcross sea wall northward to Strete Gate car park.
- The digitized line of the back (landward side) of the road. This was checked against the 2023 UAV aerial imagery, which confirmed that the road was in the same location.
- The seaward buffer calculated at 4 m ODN from the October 2017, May 2018 and May 2021 UAV digital elevation models (DEMs).

Two analyses were conducted for this 2023 vulnerability assessment: (1) updating the Slapton A379 vulnerability within the context of extreme erosive events; and (2) quantifying the volume of rock armour on the beach. The methodologies used for these analyses are detailed below.

2.1. Quantifying the Slapton Line vulnerability

An Extreme Value Analysis (EVA) was undertaken to estimate upper beach retreat at a range of return periods. This is a common coastal engineering analysis approach, typically used to determine return periods of storms waves or overtopping discharge. However, given a large enough set of observations of past beach response during storms, we can determine the probability and return period of different retreat distances, allowing us to quantify how dynamic different parts of the beach are along the Slapton Line.

Profiles collected between 2010 and 2023 by the University of Plymouth (UoP) were used to create a timeseries describing the horizontal position of the upper beach along the Slapton Line. The average horizontal position of the beach between 3.5-4.5 mODN was determined from each monthly profile, and the change in horizontal position was quantified over time. Positive values represent landward retreat of the upper beach and typically occur during storms. A peaks-over-threshold (POT) approach was used whereby all positive changes (beach retreat distances) were used to quantify the distribution of retreat at each profile location along Slapton Sands. For each profile, a Generalised Pareto Distribution (GPD) was then fitted to the retreat values, resulting in a statistical characterisation of the profile changes from which profile change of various return periods can be predicted. The GPD is now a well-established marginal distribution model for assessing extreme values of environmental variables (Hamm *et al.*, 2010; Jonathan and Ewans, 2013). A demonstration of the data and a fitted GPD is shown in Figure 2-1. The fitted GPDs at each alongshore profile location were used to quantify the estimated retreat distance at 1-, 10-, 20-, 50- and 100-year return periods.

The UoP profiles are spaced roughly 200 m apart and are therefore more sparce than the selected SWCMP profiles used for the illustrative maps shown in Section 3, which are at 50 m intervals. For this reason, the retreat distance at each return period was interpolated alongshore to provide values at the location of each SWCMP profile.

The retreat distances at a range of return periods were compared to the buffer distance between the A379 road and the upper beach. This compares how dynamic the beach is at each location from the retreat distances, to how vulnerable the road is from the buffer distances. Locations where the buffer distance is small, and the beach is highly dynamic are logically the most vulnerable locations to breaching of the road during storms. To provide conservative estimates of the buffer distance along Slapton Line, all available LiDAR and UAV DEM's between 2008 to 2023 were considered[1], and the closest distance between the present road alignment and the upper beach over this period (i.e. smallest measured buffer) was used (Figure 2-2). More precisely, the buffer distances are the distance between the landward side of the A379 road to the seaward 4 m ODN elevation contour on the beach. To account for the width of the road, 8 m was subtracted from the distance, which includes the approximate 6 m width of road, plus 2 m buffer to account for the Southwest Coast Path. The buffer distances therefore represent a highly conservative measure of the natural buffer between the beach and the road, representing the beach at its most eroded state in recent years.

[1] A LiDAR survey from March 2016 shows that the upper beach had retreated substantially in the area adjacent to the Tank car park (Figure 2-2**Error! Reference source not found.**), and subsequently a retaining wall was built in 2016. For this reason, the 2016 4 mODN contour was excluded from the analysis to better represent the risk with the current defences in place.

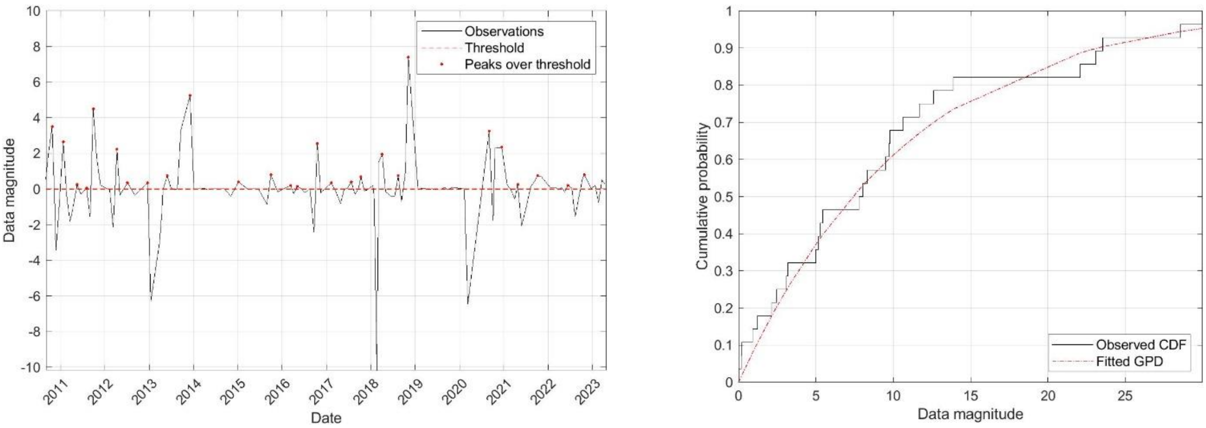

Figure 2-1. Demonstration of the Peaks Over Threshold approach used to determine landward beach retreat distances (left panel, positive values) for a single profile location along Slapton Sands, and the Generalised Pareto Distribution fitted to the cumulative distribution of the retreat distances (right panel) used to estimate retreat at a range of return periods.

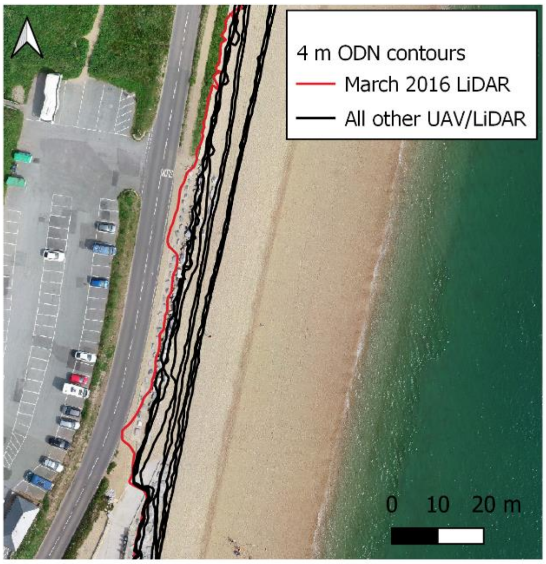

Figure 2-2. Example of all available LiDAR/UAV based 4 m ODN beach contours measured between 2008-2023. The March 2016 contour, which was excluded from the buffer distance analysis because it lies landward of the new retaining wall, is shown in red.

2.2. Rock armour volumes

The May 2023 UAV data collected for this project was used to provide detailed aerial imagery of the rock armour at the southern end of Slapton Line. The aerial imagery was used to digitise the area of rock armour, while the DEM from the May 2023 UAV survey provides the elevation and volume of the rock armour. To extract the rock volume from the surrounding beach area, the DEM was used to create an interpolated surface across the digitised rock armour area, which estimates a base elevation beneath the exposed rock armour. The interpolated surface was then subtracted from the rock armour DEM to obtain the elevation of the rock above the interpolated surface.

The rock armour frontage was divided into 16 zones either side of the selected SWCMP profiles, with each zone ~ 50 m long. The exposed rock armour volume within each zone was then calculated. This approach assumes that the rock armour sits above the slope of the surrounding area, which is true in most locations, in which case a reasonable estimate of the exposed rock volume can be made. In some locations, however, the rock armour sits within a slumped (concave) section of the beach profile, and is therefore below the interpolated surface, while in some other areas some non-rock features may sit above the interpolated surface. Figure 2-3 shows cross sections of the data in locations where the rock armour is above (top profile) and below (bottom profile) the interpolated surface. Figure 2-3 also shows the calculated elevation above the interpolated surface, used to calculate total volumes for each zone.

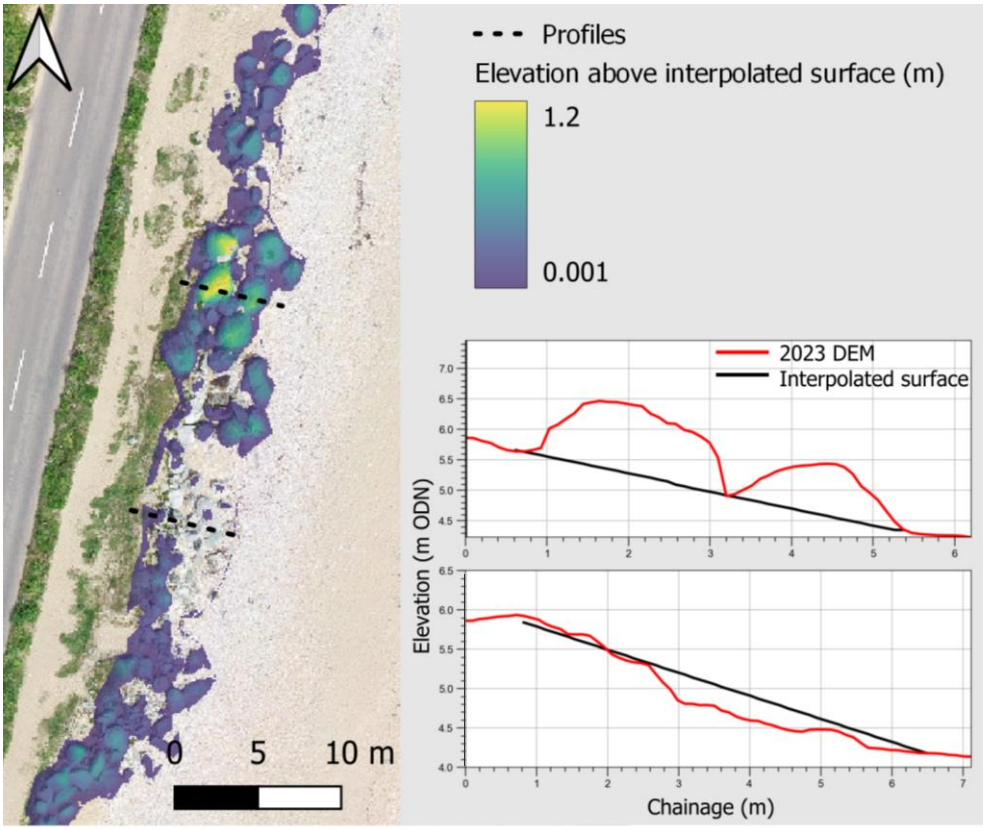

Figure 2-3, Map demonstrating rock armour elevation determined from the May 2023 UAV survey data (left panel). Profiles in the right panels show the 2023 DEM and interpolated surface elevation providing examples of a location where the rock armour elevation is well captured (top) and where the rock armour is not captured (bottom).

3. Results

3.1. Updated Slapton Line vulnerability assessment

Figure 3-1 and Table 3-1 demonstrate the buffer distances along the Slapton Line. The majority of Slapton Line north of the engineered defences has a healthy buffer between the road and the upper beach, where the road would only become vulnerable during a 100-year erosion event or greater (dark green and blue lines). The buffer distances along this 'healthy' portion of the Slapton Line vary between 6-60 m, with the greatest buffers at memorial car park and Strete Gate. Between Sands Road and Strete Gate there is a single profile that has a return period below 100 years which is approximately at the location where the section of road re-aligned following Storm Emma re-joins the pre-storm Emma road alignment.

The frontage at greatest risk from storm erosion is the area immediately fronting the Tank car park to approximately 450 m north of the car park, where the road would become vulnerable to storm erosion from a 10-year to 50-year return period erosion event. Around two-thirds of this frontage would become vulnerable during a 1-in-10-year erosion event, with buffer distances of only 3-6 m between the beach and the front of the road/coast path. This vulnerable section of frontage has some form of defence all the way along it, in the form of either a retaining wall, retaining wall capped with rock armour, or loose rock armour on the beach, which would provide some erosion protection to the road in the event of a storm. However, the type and quality of the engineered defences varies along this section. The next section assesses the volume of rock within the rock armour along this vulnerable section of the Slapton Line.

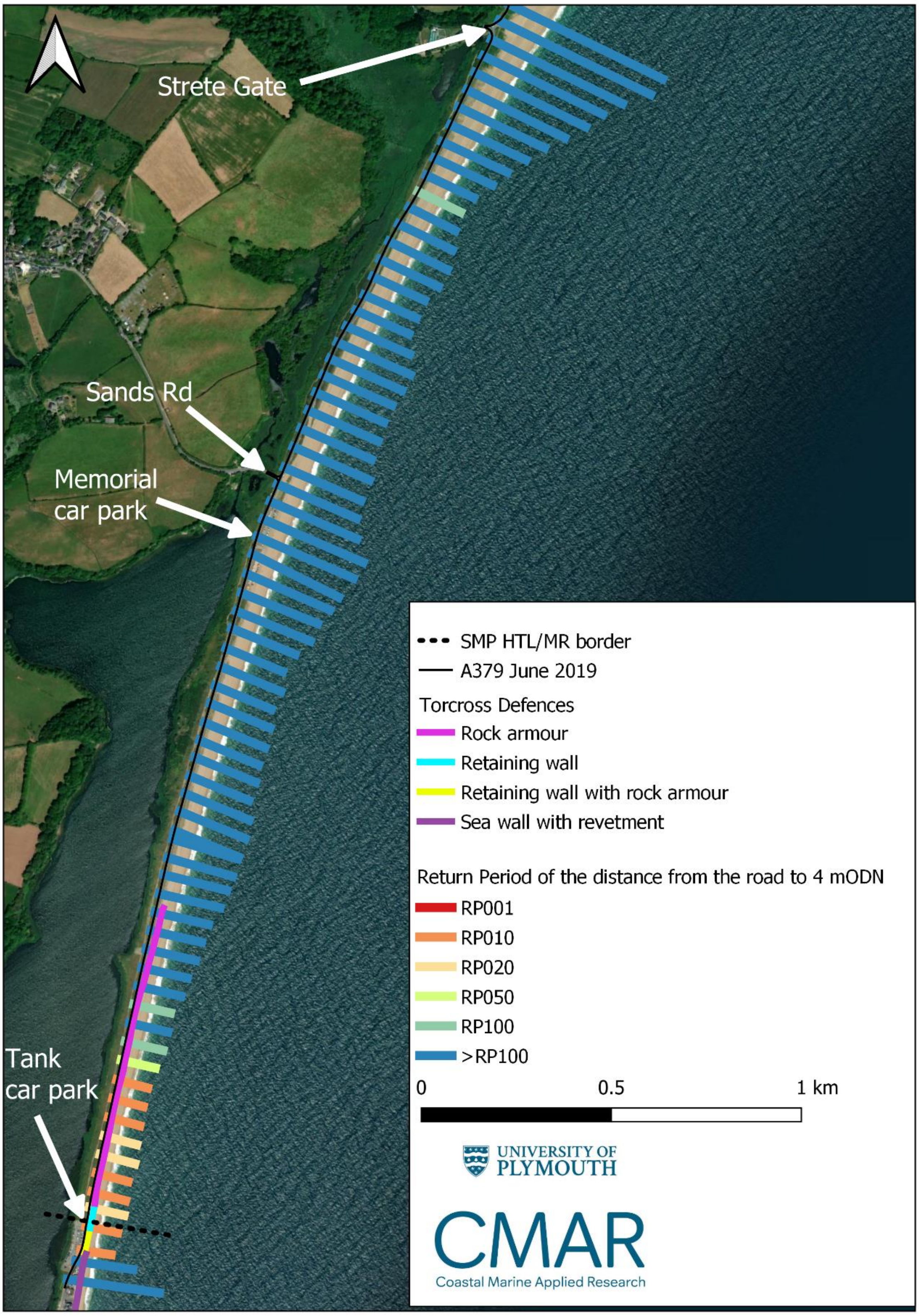

Figure 3-1. Buffer distances between the A379 'Slapton Line' road and the 4 mODN beach contour, shown as lines with colour representing the vulnerability to extreme storm recession (return period) and length representing the relative buffer distance at each location.

Table 3-1. Buffer distances between the A379 road and the upper beach (4 mODN contour). Two distances are shown - the distance from the landward edge of the A379 and that distance with 8 m removed to represent the width of the road plus the Southwest Coast Path.

Profile	SMP Strategy	Distance from the back of the A379 road to the 4 mODN contour (m)	Distance from the front of the A379 road to the 4 mODN contour (m)	Return period recession event required to reach road (yrs)
6b01243	Do nothing	64.07	56.07	>RP100
6b01244	Do nothing	63.34	55.34	>RP100
6b01245	Do nothing	54.78	46.78	>RP100
6b01246	Do nothing	49.83	41.83	>RP100
6b01247	Do nothing	46.28	38.28	>RP100
6b01248	Do nothing	40.97	32.97	>RP100
6b01249	Do nothing	35.70	27.70	>RP100
6b01250	Do nothing	31.24	23.24	>RP100
6b01251	Do nothing	26.91	18.91	>RP100
6b01252	Do nothing	23.86	15.86	>RP100
6b01253	Do nothing	19.50	11.50	>RP100
6b01254	Do nothing	17.63	9.63	RP100
6b01255	Do nothing	19.39	11.39	>RP100
6b01256	Do nothing	22.40	14.40	>RP100
6b01257	Do nothing	24.31	16.31	>RP100
6b01258	Do nothing	24.04	16.04	>RP100
6b01259	Do nothing	21.27	13.27	>RP100
6b01260	Do nothing	21.29	13.29	>RP100
6b01261	Do nothing	21.79	13.79	>RP100
6b01262	Do nothing	25.88	17.88	>RP100
6b01263	Do nothing	29.94	21.94	>RP100
6b01264	Do nothing	29.45	21.45	>RP100
6b01265	Do nothing	28.17	20.17	>RP100
6b01266	Do nothing	27.86	19.86	>RP100
6b01267	Do nothing	28.53	20.53	>RP100
6b01268	Do nothing	28.93	20.93	>RP100
6b01269	Do nothing	31.27	23.27	>RP100
6b01270	Do nothing	31.25	23.25	>RP100
6b01271	Do nothing	32.39	24.39	>RP100
6b01272	Do nothing	35.43	27.43	>RP100
6b01273	Do nothing	40.95	32.95	>RP100
6b01274	Do nothing	39.42	31.42	>RP100
6b01275	Do nothing	36.32	28.32	>RP100
6b01276	Do nothing	33.95	25.95	>RP100
6b01277	Do nothing	30.82	22.82	>RP100
6b01278	Do nothing	29.87	21.87	>RP100
6b01279	Do nothing	25.73	17.73	>RP100

6b01280	Do nothing	22.92	14.92	>RP100
6b01281	Do nothing	24.31	16.31	>RP100
6b01282	Do nothing	22.75	14.75	>RP100
6b01283	Do nothing	24.19	16.19	>RP100
6b01284	Do nothing	24.46	16.46	>RP100
6b01285	Do nothing	23.86	15.86	>RP100
6b01286	Do nothing	24.60	16.60	>RP100
6b01287	Do nothing	23.98	15.98	>RP100
6b01288	Do nothing	26.06	18.06	>RP100
6b01289	Do nothing	26.57	18.57	>RP100
6b01290	Do nothing	25.98	17.98	>RP100
6b01291	Do nothing	25.40	17.40	>RP100
6b01292	Do nothing	25.23	17.23	>RP100
6b01293	Do nothing	24.33	16.33	>RP100
6b01294	Do nothing	23.32	15.32	>RP100
6b01295	Do nothing	20.51	12.51	>RP100
6b01296	Do nothing	19.56	11.56	>RP100
6b01297	Do nothing	18.92	10.92	>RP100
6b01298	Do nothing	17.48	9.48	>RP100
6b01299	Do nothing	16.50	8.50	>RP100
6b01300	Do nothing	14.12	6.12	RP100
6b01301	Do nothing	14.78	6.78	>RP100
6b01302	Do nothing	14.49	6.49	RP100
6b01303	Do nothing	13.08	5.08	RP050
6b01304	Do nothing	11.91	3.91	RP010
6b01305	Do nothing	11.80	3.80	RP010
6b01306	Do nothing	12.11	4.11	RP010
6b01307	Do nothing	12.56	4.56	RP020
6b01308	Do nothing	13.40	5.40	RP020
6b01309	Do nothing	12.33	4.33	RP010
6b01310	Do nothing	12.95	4.95	RP010
6b01311	Do nothing	13.36	5.36	RP020
6b01312	Do nothing	12.14	4.14	RP010
6b01313	Hold the line	11.36	3.36	RP010
6b01314	Hold the line	21.52	13.52	>RP100
6b01315	Hold the line	34.97	26.97	>RP100

3.2. Rock armour volumes

Figure 3-2 shows the estimated rock armour volume in each zone surrounding the SWCMP profile locations. Table 3-2 details the values and the area of each zone. The rock armour volume is smallest in the north where the profiles are less vulnerable (100-year return period buffer or greater), with only 8-30 m^3 of rock armour per 50 m of frontage estimated, which equates to approximately <0.2-0.6 m^3/m. The rock volume increases towards the south where the profiles are highly vulnerable (10-20-year return period buffer), with 60-106 m^3 of rock armour per 50 m of frontage, or approximately 1.2-2.1 m^3/m. Around the centre of the rock armour frontage there are some vulnerable profiles (10-50-year return period buffer) with only 40-50 m^3 of rock armour per 50 m of frontage, which equates to approximately 0.8-1 m^3/m.

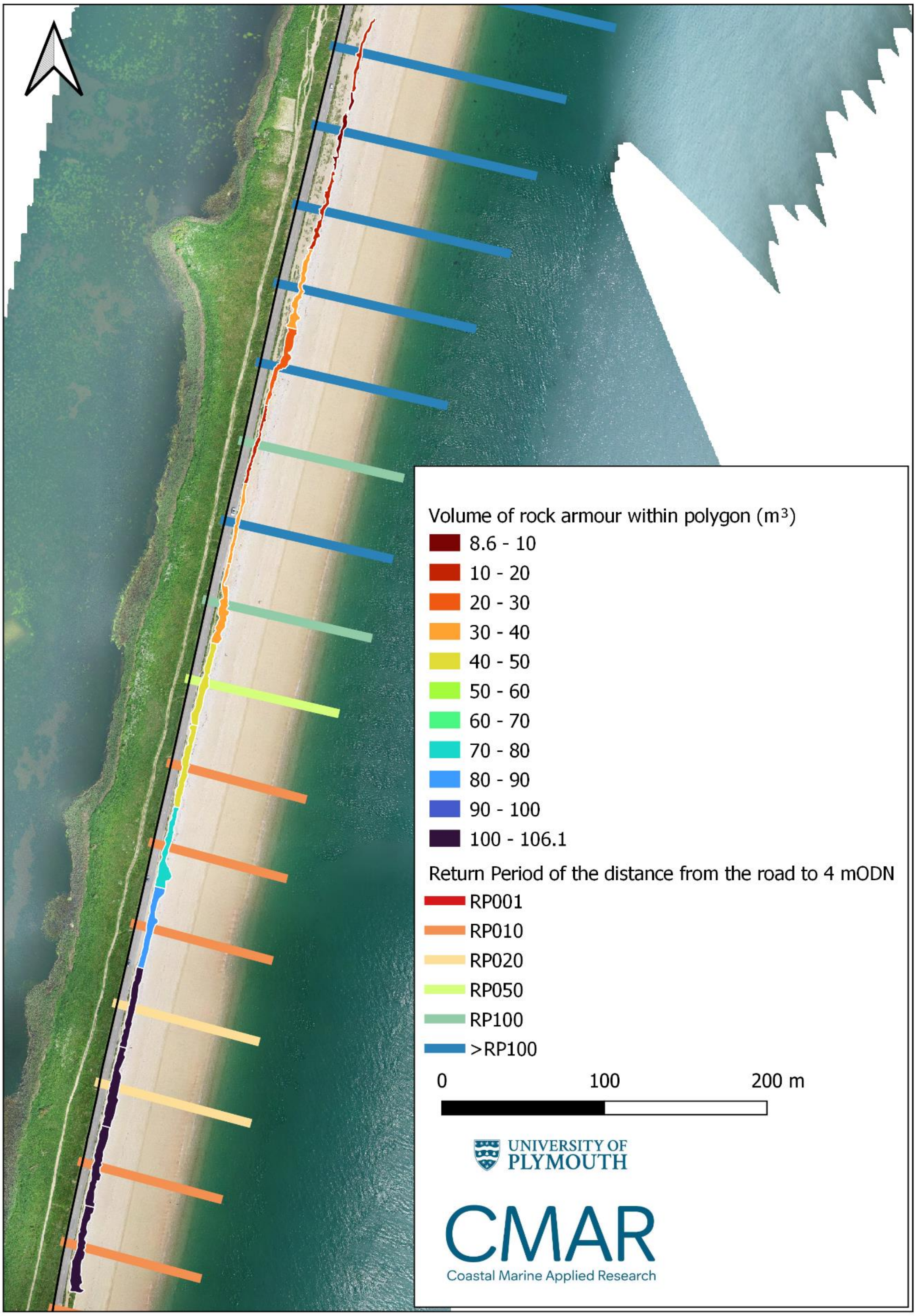

Figure 3-2, Rock armour volumes within each ~50 m zone surrounding the SWCMP profiles.

Table 3-2 Area of the rock armour polygon and volumes for each zone.

Profile Zone	Return period recession event required to reach road (yrs)	Area of polygon (m)	Volume (m^3)	Volume per m of frontage (m^3/m)
6b01295	>RP100	103.3	16.6	0.3
6b01296	>RP100	111.1	8.6	0.2
6b01297	>RP100	138.1	11.4	0.2
6b01298	>RP100	183.3	30.8	0.6
6b01299	>RP100	206.8	21.6	0.4
6b01300	RP100	114.0	19.3	0.4
6b01301	>RP100	119.4	32.9	0.7
6b01302	RP100	208.6	35.2	0.7
6b01303	RP050	220.7	43.9	0.9
6b01304	RP010	209.3	40.9	0.8
6b01305	RP010	231.6	73.1	1.5
6b01306	RP010	233.3	81.9	1.6
6b01307	RP020	221.3	103.4	2.1
6b01308	RP020	281.2	100.3	2.0
6b01309	RP010	267.6	104.9	2.1
6b01310	RP010	307.4	106.1	2.1

4. Conclusions

- The majority of Slapton Line north of the engineered defences has a healthy buffer between the road and the upper beach of between 6 and 60 m, where the road would only become vulnerable during a 100-year erosion event or greater.
- The frontage at greatest risk from storm erosion is the area immediately fronting the Tank car park to approximately 450 m north of the car park, where the road would become vulnerable to storm erosion from a 10-year to 50-year return period erosion event.
- Around two-thirds of this frontage would become vulnerable during a 1-in-10-year erosion event, with buffer distances of only 3-6 m between the beach and the front of the road/coast path.
- This vulnerable section of frontage has some form of defence all the way along it, in the form of either a retaining wall, retaining wall capped with rock armour, or loose rock armour on the beach, but the quantity and quality of the loose rock armour varies along the beach.
- The loose rock armour volume is smallest (8-30 m^3 of rock armour per 50 m of frontage estimated) at its northern extent, where the profiles are less vulnerable (100-year return period buffer or greater).
- The rock volume increases towards the south where the profiles are highly vulnerable (10-20-year return period buffer), with 60-106 m^3 of rock armour per 50 m of frontage estimated.
- Around the centre of the loose rock armour frontage there are some vulnerable profiles (10-50-year return period buffer) with only 40-50 m^3 of rock armour per 50 m of frontage estimated.

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