Royal HaskoningDHV
Enhancing Society Together

Note / Memo

HaskoningDHV UK Ltd.
Water & Maritime

To:	Barratt David Wilson
From:	Thomas Green, Keming Hu
Date:	12 September 2024
Copy:	Click to enter "CopyTo"
Our reference:	PC6658-RHD-XX-XX-ME-X-0001-P03
Classification:	Project related
Checked by	Final

Subject: **East Wittering - Independent Review**

1 Introduction

Royal HaskoningDHV (RHDHV) has been appointed by Barratt David Wilson Homes (referred to as the "Appellant" hereafter), to provide a high level independent assessment of the hydraulic modelling undertaken in respect of the Stubcroft Farm development and associated challenges with regards to the planning application submitted to Chichester District Council (referred to as the "Council"). We understand the planning Inquiry was adjourned by the Inspector to allow this important independent review to be undertaken.

We have briefly summarised below our understanding of the background and scope of works.

- Planning permission was submitted to the Council in 2023 and we understand that they refused the planning application for several reasons. One of the reasons for refusal, pertinent to our scope, was the assessment of future flood risk to the site.

- We understand that the updated modelling in the latest SFRA is a catchment wide assessment covering Arun to East Head, whereas, the Appellant has provided a site-specific FRA with supporting technical input as recommended in the Council's SFRA. This included independent modelling from HR Wallingford (HRW) which the Inspector has instructed to be reviewed by an additional independent body (for which RHDHV was appointed).

- HRW were appointed by the Appellant to carry out a site-specific analysis of flood risk to the site, particularly in respect of potential inundation caused by wave overtopping, the main source of future flood risk identified in the SFRA. HRW produced alternative wave overtopping rates to those calculated in the Council's SFRA, specifically for defences 74 and 75 in East Wittering.

- RHDHV is well placed to undertake this review as we are currently working actively with the Coastal Partners with 5 local councils which includes Chichester District Council. HRW and the Environment Agency also work with the Partnership. RHDHV understands that the adopted modelling of the shingle beaches at Hayling Island, located between Portsmouth and Chichester, was undertaken by HRW using the same methodology as used by HRW in this modelling for East Wittering.

- The aim of our assessment is to better inform the Inspector of the independent modelling and report produced by HRW.

2 Scope of work

A summary of RHDHV's Scope of Work is listed below.

i. RHDHV to review the HR Wallingford (HRW) report titled '*East Wittering Shingle Beach Defences – Calculation of Mean Wave Overtopping Rates'* doc ref: DKR7108-RT001 R01-00 dated 15 July 2024 (referred to as "HRW Report" hereafter).

ii. RHDHV to comment on the appropriateness of the approach/methodology used by HRW in modelling the profiles from CCO at sea defences 74 and 75 in East Wittering in relation to the latest EurOtop neural network manual (second edition 2018).

iii. RHDHV to comment on compliance of the approach used by HRW with the latest '*Coastal Modelling Standards Update'* (doc. ref: LIT 56561), dated 21 April 2022, which was produced by Jacobs for the Environment Agency (this reference is referred to as "*Coastal Modelling Standards Update*" hereafter).

iv. Using the latest CCO profiles for sea defences 74 and 75, and photographic evidence from the beaches (taken in July/Aug 2024), what crest widths would RHDHV deem appropriate to use for these two defences?

v. What is RHDHV's opinion on the use of zero metre crest width in the HRW approach?

vi. In accordance with Coastal Modelling Standards Update, what form of sensitivity testing would be recommended by RHDHV and on what basis?

vii. Is the approach taken by HRW appropriate for this coastal location?

viii. RHDHV to review and comment on the maximum wave overtopping rates presented in HRW Report, Appendices A and B.

ix. RHDHV to present their review in a brief report (this report).

This technical note provides an independent professional review guided by the above scope. It is important to note that the review compares a relatively complex and detailed analysis by HRW specifically for shingle defences 74 and 75 in East Wittering with a relatively simplistic application of the EurOtop neural network model for a relatively small part of a wider wave overtopping model covering Arun to East Head.

3 Beach profiles

HRW used the most up-to-date beach profile data as recommended in the EA's Coastal Modelling Standards Update. Analysis included beach profiles surveyed by the Channel Coastal Observatory (CCO) along the 1,100m length of coastline making up shingle defences 74 and 75 as shown in **Figure 3-1** below obtained during the period of 2021-2023. There are 25nr CCO profiles covering these two shorelines. CCO profile 5a00121 is located at Bracklesham Road to the east of defence 74. Profile 5a00145 is located at Shore Road to the west of defence 75. A selection of the CCO profiles taken from the Southeast Regional Monitoring Programme is shown in **Figure 3-2** which includes profile 5a00146 for comparison which is located on shingle beach 76.

The profiles show crest levels varying between 5.4m ODN and 6.09m ODN. However, where the profile shows a crest level of 5.4m it does not account for the higher natural ground levels behind the beach which East Wittering is built on as shown in **Figure 7-2**. It should be noted that the use of 5:1 scale along the x and y axes exaggerates the crest level variation along the CCO profiles.

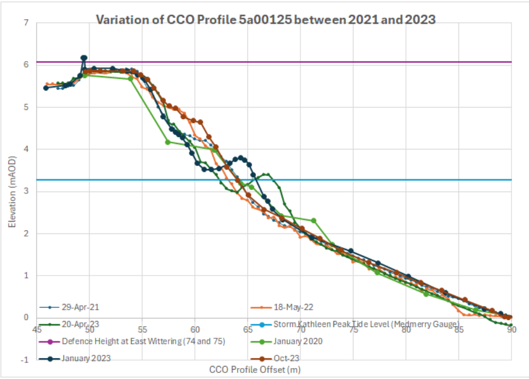
It should be noted that JBA used 6.07m ODN as their crest level for shingle defences 74 and 75 in their updated modelling for the 2023 SFRA.

HRW opted to use a variety of crest levels as a health check including 5.4m ODN, 5.7m ODN and 6.07m ODN in their overtopping assessment. From the surveyed beach profiles, HRW obtained an average slope of cot = 7 between 0m ODN and the beach crest, which was used in the wave runup and overtopping calculation.

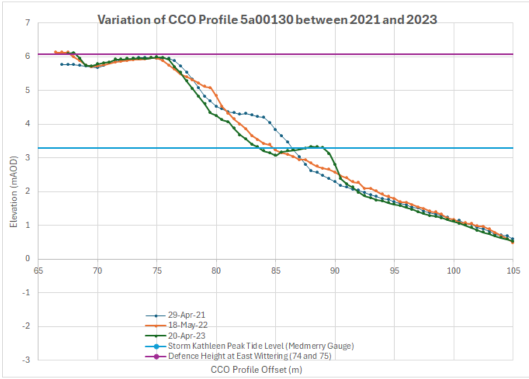
From the surveyed beach profiles in the period of 2021-2023, RHDHV agrees that the use of 3 crest levels (namely 5.4m ODN, 5.7m ODN and 6.07m ODN) and beach slope of cot = 7 is reasonable.

Figure 3-1: Location of sea defences and CCO profiles

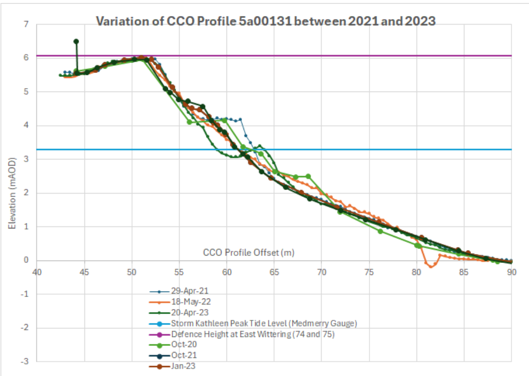
CCO Profile 5a00125



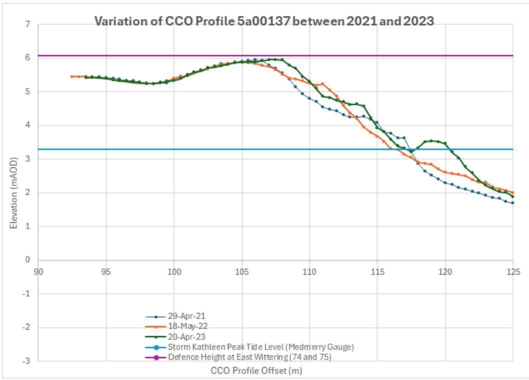
CCO Profile 5a00130



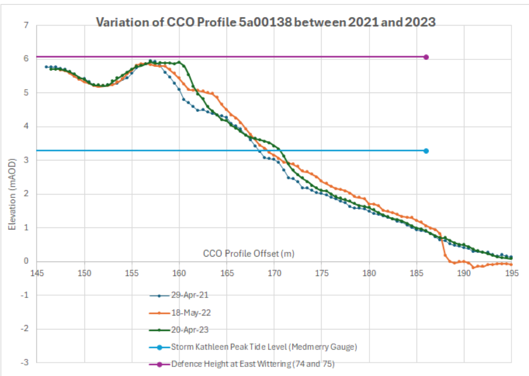
CCO Profile 5a00131



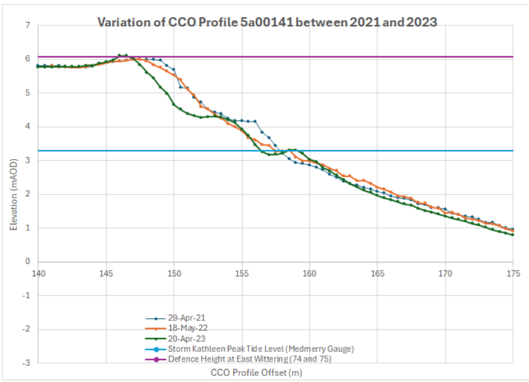
CCO Profile 5a00137



CCO Profile 5a00138

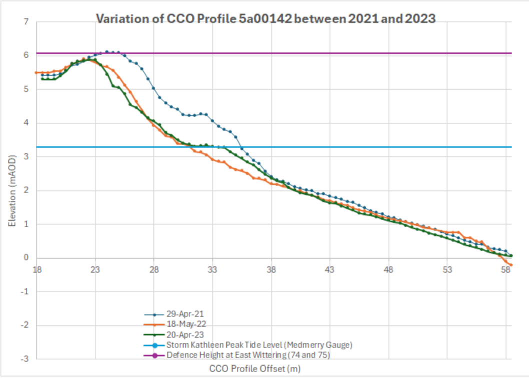


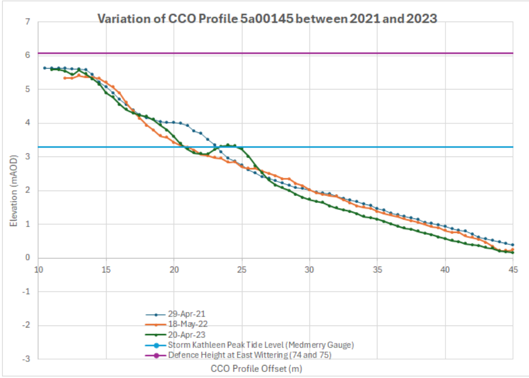
CCO Profile 5a00141



CCO Profile 5a00142

CCO Profile 5a00145





CCO Profile 5a00146

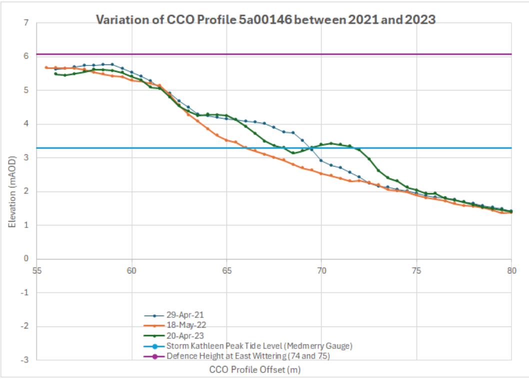


Figure 3-2: CCO beach profiles at sea defences 74 and 75

4 Input water level and wave data

RHDHV understands that HRW used the recorded wave data at the Bracklesham Bay wave buoy for multivariate probability analysis. The wave record is of 16 year duration covering the period between August 2008 and June 2024. This data was also used in the 2023 SFRA modelling but for a shorter duration.

The EA's Coastal Modelling Standards Update recommends at least 30 year measured or hindcast wave data for deriving extreme wave data for the "design" category. As a rule of thumb, the ISO standard ISO 19901-1 (ISO 2005) recommends to not use return periods more than a factor of four beyond the length of the data set when deriving return values for design of offshore structures. Therefore, this raises a question on whether the wave buoy data is of sufficient duration for deriving extreme values of return periods exceeding 100 years.

While RHDHV recognises that the HRW analysis was undertaken in a short time period, dictated by the timescales of the Inquiry, RHDHV would recommend for the future a comparison analysis between the wave buoy data and Met Office hindcast data in the same period and an extreme value analysis of Met Office hindcast data, so a correction factor may be derived. This simplification could lead to either overestimated or underestimated overtopping.

RHDHV understands that the coincident measured water level data from the Portsmouth tide gauge was used, and the extreme distribution of water levels was rescaled to match the relevant marginal extreme levels from the 2019 EA Coastal Flood Boundaries Dataset. RHDHV agrees with this approach.

5 Wave data processing

RHDHV agrees with the method HRW adopted for identifying bimodal waves and deriving wave parameters for the two bimodal wave partitions.

RHDHV understands that the recorded wave data was used without being transformed by a wave model to a suitable inshore location for wave runup and overtopping calculation. The wave buoy is located at a distance of approximately 2.3km to the nearest coastal point at a water depth of -10.4mCD. The direct use without wave transformation is not discussed in the HRW Report.

The EA's Coastal Modelling Standards Update recommends wave transformation modelling from offshore to inshore locations and inclusion of wave setup in wave overtopping calculation. RHDHV understands that the wave buoy is located at a short distance to the coast but ideally, future analysis considering water depth, 1D wave transformation modelling would be recommended to improve the modelling. Without wave transformation, overtopping rates may be slightly overestimated.

6 Joint probability analysis

In common with the Council's SFRA modelling work, HRW used a multivariate probability analysis method for joint probability analysis, which follows the guidance in the EA's Coastal Modelling Standards Update.

HRW used a "composite response index" (CRI) as the primary response variable (for combining all variables) in their multivariate probability analysis. As a result, the derived return periods are related to beach response, rather than wave overtopping. The HRW report suggests that beach response is broadly equivalent to overtopping.

RHDHV is of the view that, for future analysis, evidence would ideally be needed to directly link beach response to overtopping. RHDHV noticed a case in the overtopping results presented in Appendix B of the HRW Report that a 1:200 year event produced higher overtopping than a 1:1,000 year event.

Strictly speaking, the flood risk extent based on HRW's overtopping rates is not directly comparable with those in the Council's SFRA because return periods were defined differently. However, for comparative purposes, RHDHV is of the view that they are close enough.

7 Overtopping calculation

7.1 EurOtop and bespoke methods

In the HRW Report, it is stated that the EurOtop methods and other methods based on the same database (known as the CLASH database) have a high degree of uncertainty because the database under-represents shingle beaches and bimodal waves. RHDHV agrees with this view.

It is understood that HRW developed a bespoke method to calculate wave overtopping rates for this specific site in East Wittering, at defences 74 and 75, for both unimodal and bimodal waves. This method may be summarised as below:

- Use of the EurOtop wave runup equation (Equation 5.1 of EurOtop manual) to calculate wave runup;
- Calculate R* = wave runup – crest level;
- Calculate mean overtopping rate using q = 0.06 * exp (1.15 * R*);
- The same equations are appliable to both unimodal and bimodal waves, but the difference is, for bimodal waves, $T_{m-1,0}$ is calculated from the bimodal wave spectrum using the HRW Shingle-B software

While the HRW approach is more appropriate to that used in the Council SFRA modelling, as it at least make use of shingle beach data, RHDHV would make the following comments for future analysis if this approach is to be adopted more widely to wave overtopping of shingle beaches;

- The EurOtop wave runup equation was developed for a smooth impermeable slope. However, RHDHV understands that the coefficients of the bespoke overtopping equation were adjusted to consider the permeability of a shingle beach;
- Using the same equations for both unimodal and bimodal waves, the bespoke method only considers the longer wave period of the swell component of a bimodal wave. The combined effect and interaction of wind-wave and swell components are not considered explicitly. The report does not provide data to support the use of the bespoke method for bimodal waves although it may exist;
- The HRW Report does not produce direct comparison of estimated overtopping rates using their method and the method used in the Council's SFRA. This data is however available and has been used by Floodline Consulting in their sensitivity modelling of inundation extents as requested by RHDHV as presented in **Appendix A** of this report.
- The HRW Report presents calculated overtopping rates for both unimodal and bimodal waves. RHDHV understands that the maximum overtopping rate for each return period was selected for

inundation modelling, including both unimodal and bimodal waves. This is a reasonable (appropriately conservative) approach.

7.2 Crest width

Crest width was not discussed in the HRW Report but it is understood that a value of Zero metres was used for the full 1,100m extent of defences 74 and 75 according to the SFRA model metadata provided by JBA.

HRW provided a separate note which discussed the effect of flood defence crest width on wave overtopping using Equation 6.8 of EurOtop. The equation was developed from limited cases of highly permeable rock structures with large interstitial voids and high porosity. It gives an exponential reduction of overtopping as a function of crest width, shown in the decay curve shown in **Figure 7-1** provided by HRW.

Floodline Consulting Limited provided photographic evidence that the shingle beach at defences 74 and 75 is backed by higher ground with a slightly upwards slope (see **Figure 7-2**). RHDHV does not believe this can be described realistically by any form of "crest width" and the effect quantified accurately by Equation 6.8 of EurOtop. However, it indicates that it is conservative to use the boundary between shingle slope and high ground as the output location, as suggested by the Zero width crest. The overtopping rates are certain to be lower further landward on the higher ground.

RHDHV would recommend, for future analysis of wave overtopping of shingle beaches, a more sophisticated approach using AMAZON or XBEACH that were designed to model irregular beach profiles, including a higher ground behind a defence "crest".

However it is understood that a EurOtop schematisation of defences 74 and 75 has been adopted by the Council SFRA and HRW for comparative purposes. RHDHV does not agree that the EurOtop method is appropriate for sea defences 74 and 75, however, we note that the EurOtop schematisation has been included in the EA's adopted model.

A EurOtop defence crest with a value of Zero metres in the Council's SFRA is not realistic given that there are no wave walls in this location and a value of Zero metres is not realistic or sustainable just from the considerations of ground slope stability. It is also likely that during a significant wave overtopping event, shingle would be carried over any low defences in this location, further rendering a Zero crest width as unrealistic.

The HRW Report has made use of the Council SFRA EurOtop schematisation for comparative purposes and Equation 6.8 does apply to EurOtop defence schematisations. Consequently, whilst not realistic for shingle beaches, it is reasonable in this case, to make use of this equation for comparative purposes.

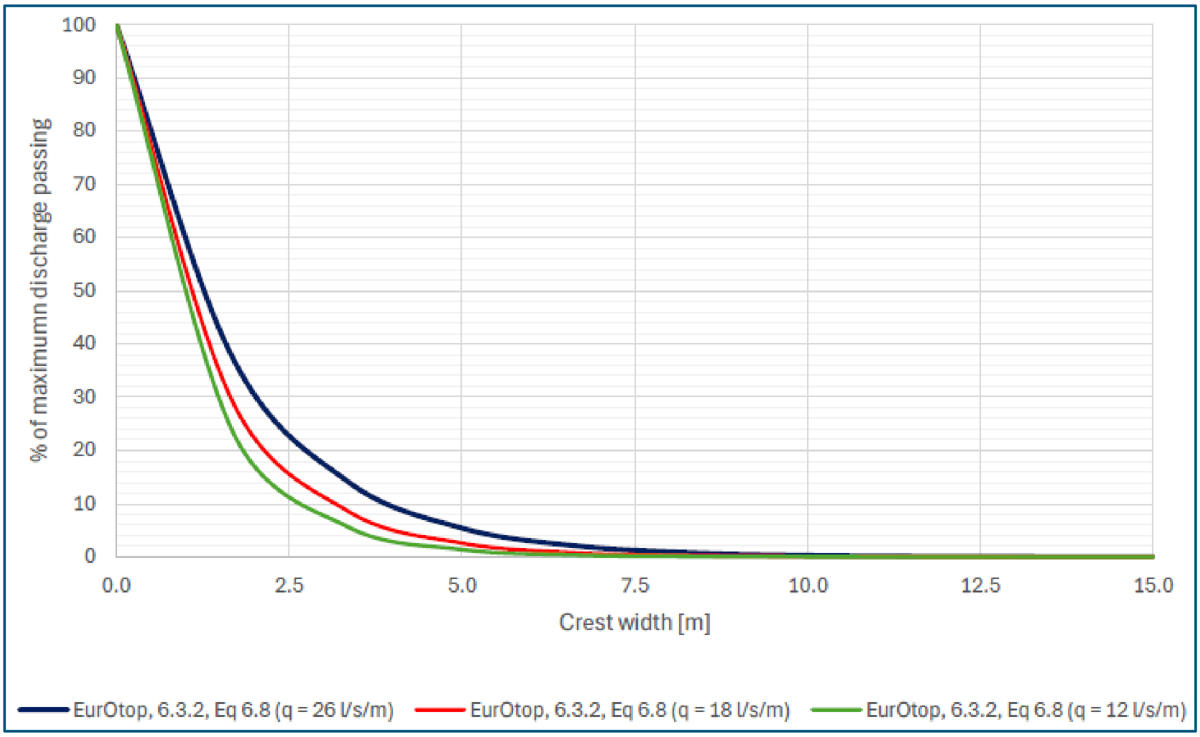


Figure 7-1: maximum overtopping vs crest width

Figure 7-2: shingle beach at sea defence 75 with 74 in the background

8 Compliance with EA Guidance

Regarding compliance with the EA's Coastal Modelling Standards Update, RHDHV would make the following recommendations for future analysis:

- Use of a longer duration of wave buoy data;
- Wave transformation modelling should be undertaken from the selected wave buoy to a suitable inshore location for wave runup and overtopping calculation;
- Explicit consideration of wave set up.
- The HRW approach was consistent with the evidence of the lack of observed wave overtopping in the last 80 years according to historic EA flood extent information. As such, the HRW methodology is consistent with the EA's Coastal Modelling Standards Update which requires calibration and verification. We have been advised that this differs from the Council's SFRA. If this is true, the Council's SFRA modelling is not considered compliant.

9 Recommendations for future work

RHDHV would like to make the following recommendations:

- Use of a longer duration of wave buoy data. A comparative analysis would be recommended between the wave buoy data and Met Office hindcast data for the same period and an extreme value analysis of Met Office hindcast data, so a correction factor may be derived.
- Use of wave transformation modelling from the selected wave buoy to a suitable inshore location for wave runup and overtopping calculation. A 1D wave transformation modelling would be recommended, by which wave setup can be considered.
- Rationalisation of return period calculations between that calculated by EurOtop neural network and the HRW approach.
- RHDHV recommends sensitivity analysis to be undertaken for different crest widths in the EurOtop defence schematisations for defences 74 and 75 even though RHDHV do not agree that any form of EurOtop schematisation for this location is appropriate.
- RHDHV would recommend the use of the most up to date beach profile data to calculate the EurOtop defence schematisations if this approach is to be used. We would also recommend the use of all available beach profile data for this purpose.
- RHDHV understands that a crest width of 9m and 10m has been used in the adopted 2023 SFRA model for defences 73 and 76 respectively and these shingle defences are not materially different to defences 74 and 75. Therefore, for a site-specific analysis, an average crest width needs to be calculated for defences 74 and 75 using site evidence and the latest CCO beach profiles to represent the 1,100m long shoreline. An average crest width of 5m is considered appropriate as a conservative figure if the EurOtop schematisation is to be used.
- For the nature of a shingle beach backed up by a higher ground with a slightly upwards slope, the bespoke method combined with a decay function of Equation 6.8 of EurOtop for crest width is not ideal but reasonable for comparative purposes in this case. For future analysis, RHDHV would recommend the use of AMAZON (or XBEACH). The EA's Coastal Modelling Standards Update does recommend the use of AMAZON as an alternative to EurOtop if a beach profile is

not suitable for EurOtop. This would appear to be the case for defences 74 and 75 in East Wittering where there is no formal raised flood defence or wave wall.

- A further study is recommended for consideration of bimodal waves and again AMAZON could be used. AMAZON uses wave spectral data as input so could be used to model both unimodal and bimodal waves naturally. In addition, the software includes a porous layer facility for the shingle layer. RHDHV would like to discuss with HRW the potential of using AMAZON to validate their bespoke method for bimodal waves.
- The HRW Report presents calculated overtopping rates for both unimodal and bimodal waves but does not discuss which one should be selected for flood inundation modelling. The flood risk inundation maps presented in **Appendix A** covering the 200yr+70%CC and the 200yr+95%CC future flood risk scenarios for 1.667m, 5m and 10m crest widths, made use of the highest overtopping rates for each return period considering both unimodal and bimodal waves. This approach is reasonable.

10 Appendices

Appendix A – Inundation Outlines for the T200yr+70%CC and T200yr+95%CC future events

- T200+70%CC, Crest Width 1.667m, Crest Height 5.4mAOD
- T200+70%CC, Crest Width 5.00m, Crest Height 5.4mAOD
- T200+70%CC, Crest Width 10.00m, Crest Height 5.4mAOD

- T200+70%CC, Crest Width 1.667m, Crest Height 6.07mAOD
- T200+70%CC, Crest Width 5.00m, Crest Height 6.07mAOD
- T200+70%CC, Crest Width 10.00m, Crest Height 6.07mAOD

- T200+95%CC, Crest Width 1.667m, Crest Height 5.4mAOD
- T200+95%CC, Crest Width 5.00m, Crest Height 5.4mAOD
- T200+95%CC, Crest Width 10.00m, Crest Height 5.4mAOD
-
- T200+95%CC, Crest Width 1.667m, Crest Height 6.07mAOD
- T200+95%CC, Crest Width 5.00m, Crest Height 6.07mAOD
- T200+95%CC, Crest Width 10.00m, Crest Height 6.07mAOD

11 References

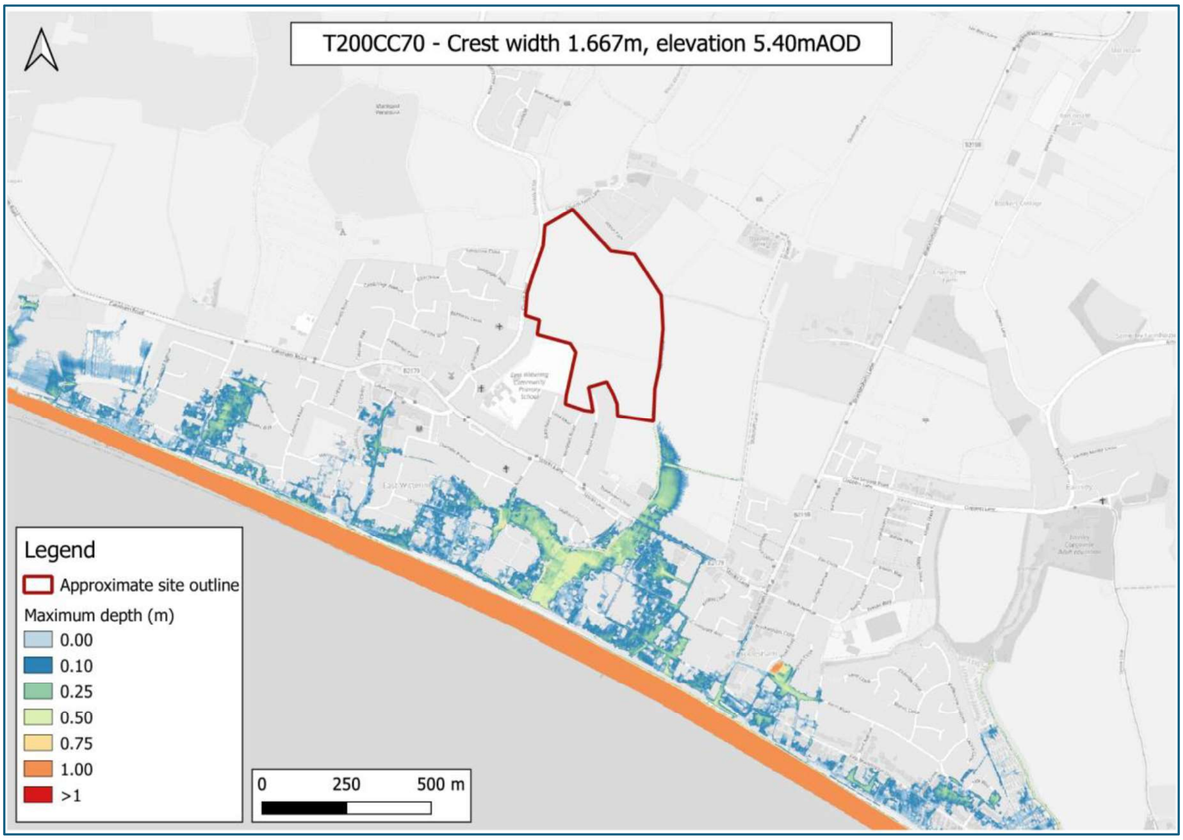
[1] HR Wallingford (2024). East Wittering Shingle Beach Defences - Calculation of Mean Wave Overtopping Rates. Report Number: RT001. 15 July 2024.

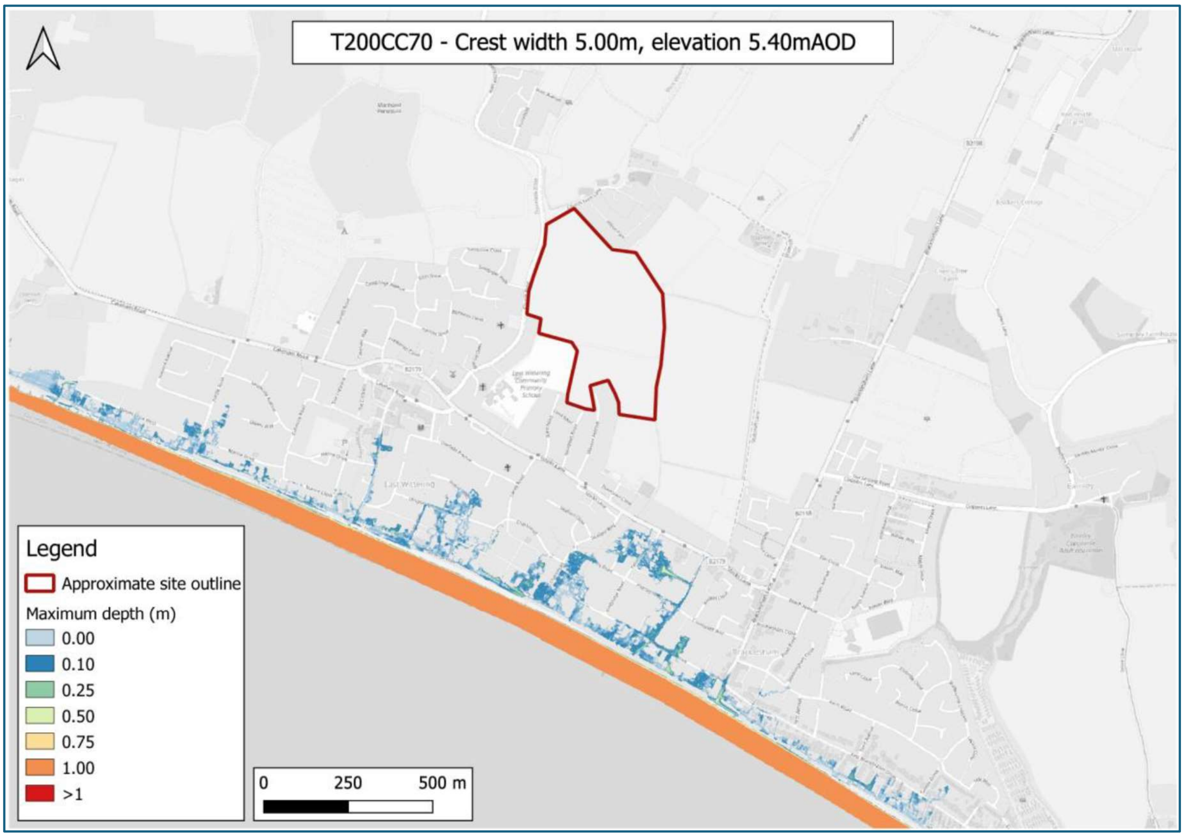
[2] Jacobs Coastal Modelling Standards Update for the Environment Agency. Revision 1.1 dated 21 April 2022.

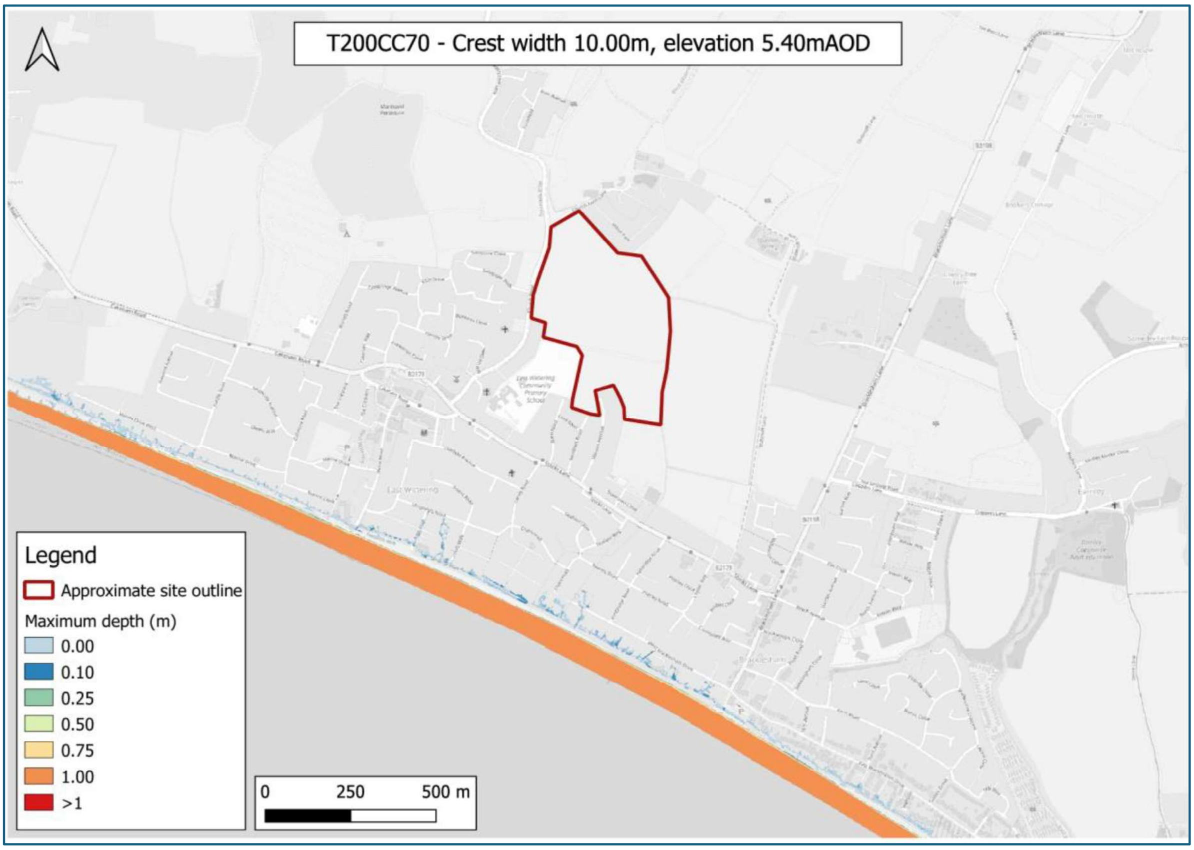
[3] EurOtop. Manual on wave overtopping of sea defences and related structures. Second Edition 2018.

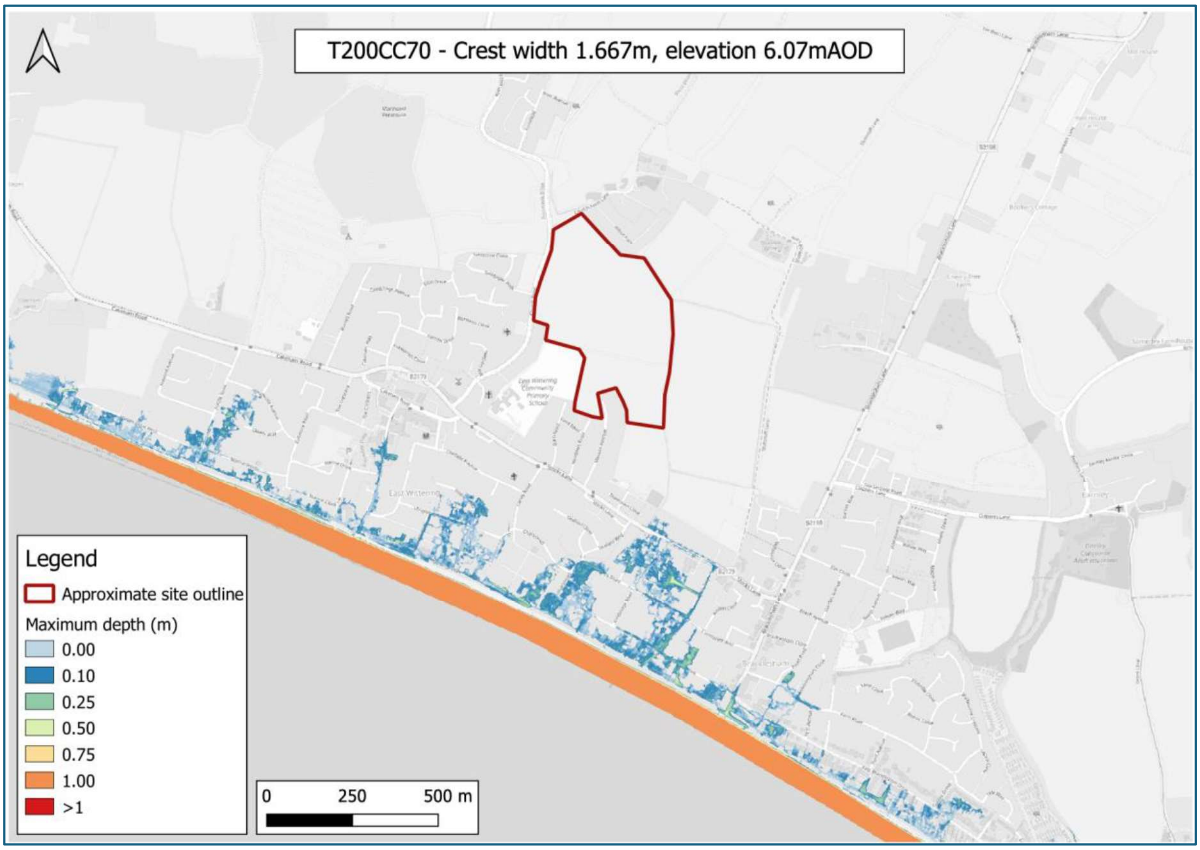
Appendix A

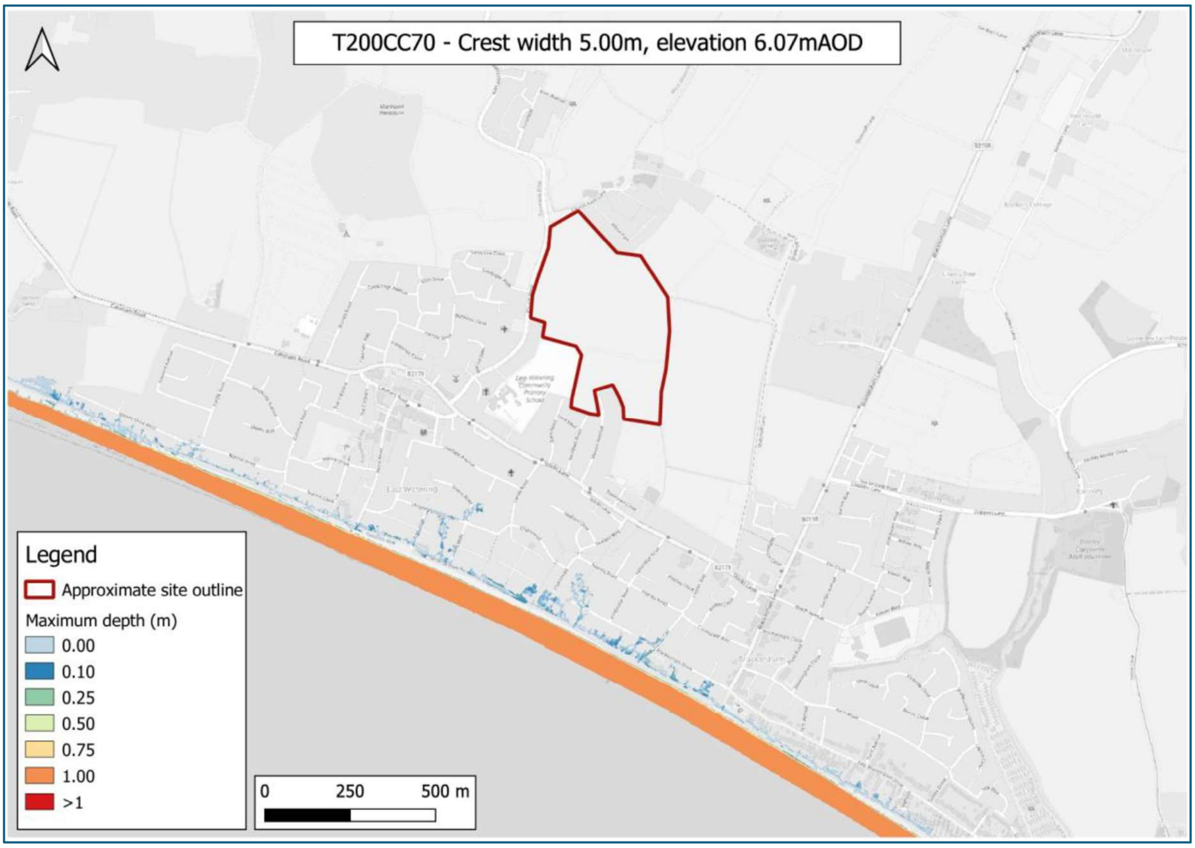
Inundation Outlines for the T200yr+70%CC and T200yr+95%CC future events

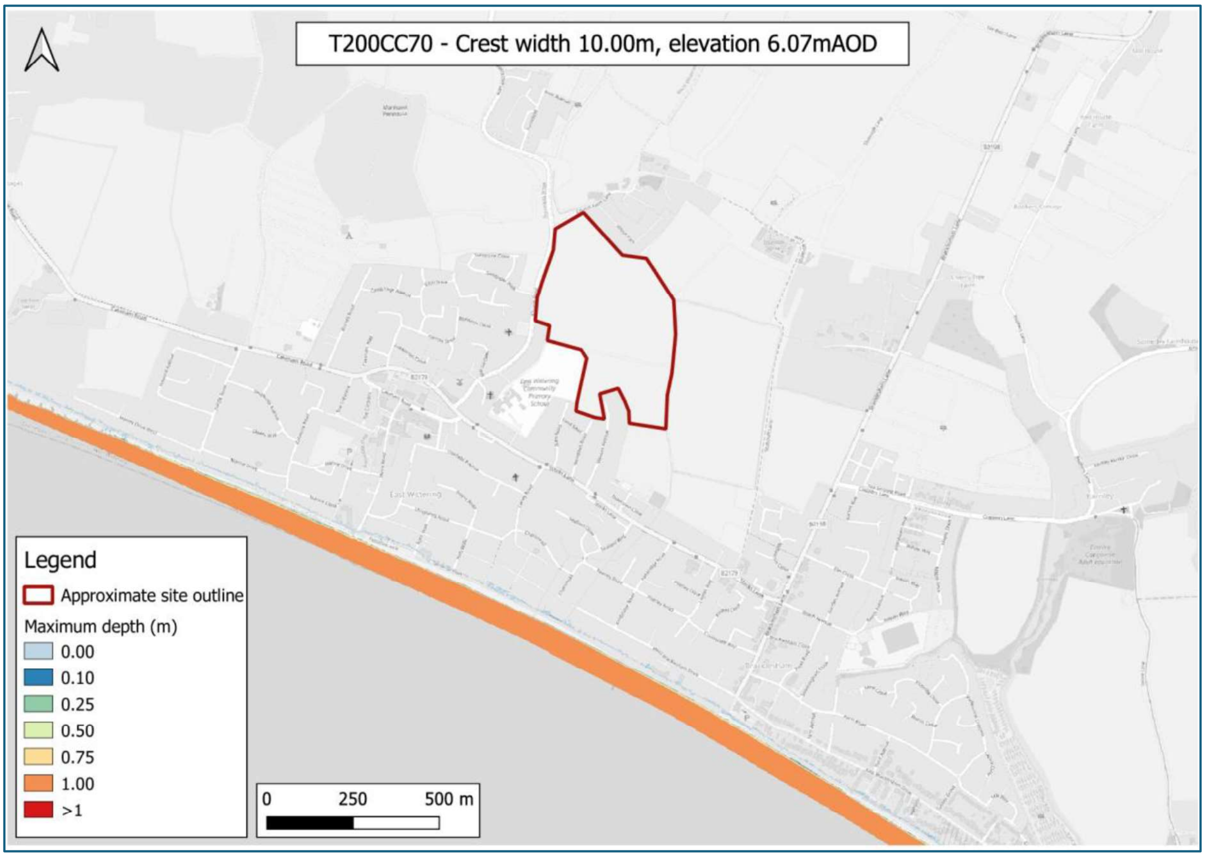

T200CC70 - Crest width 1.667m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

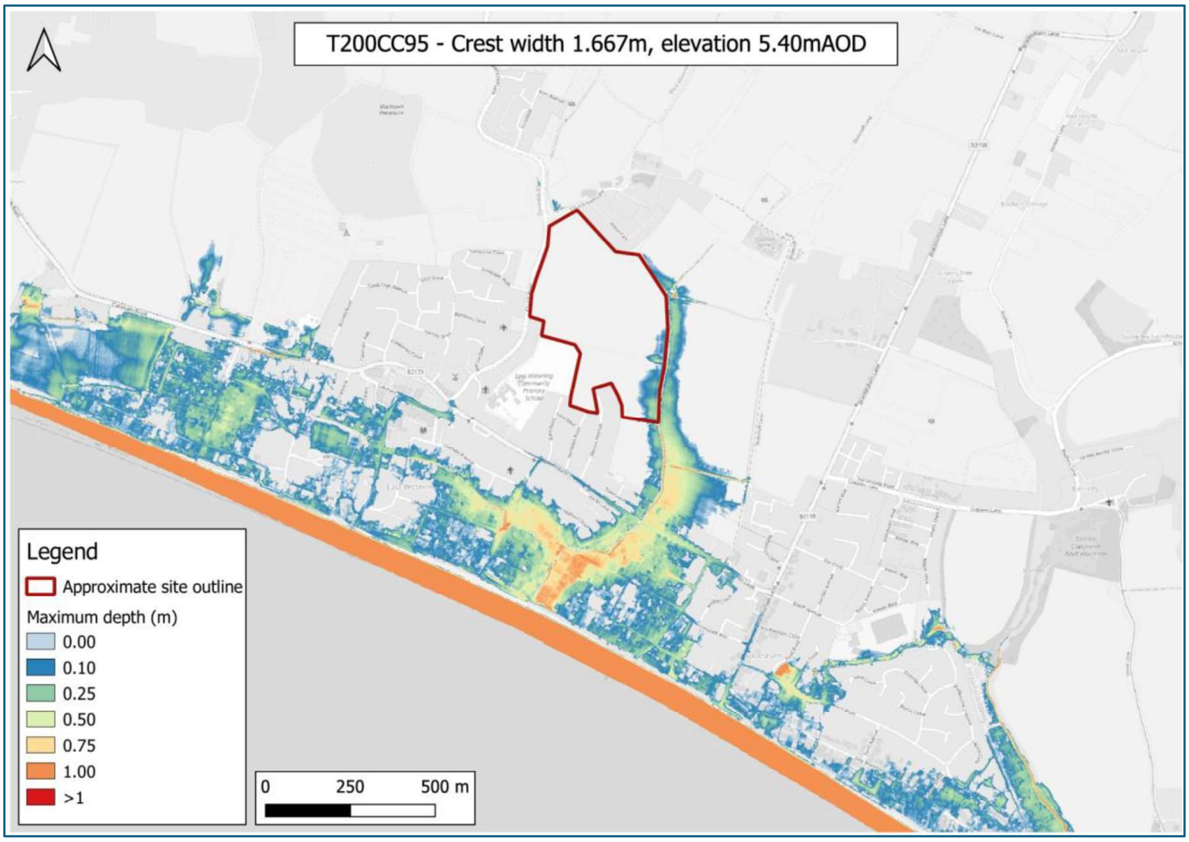

T200CC70 - Crest width 5.00m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

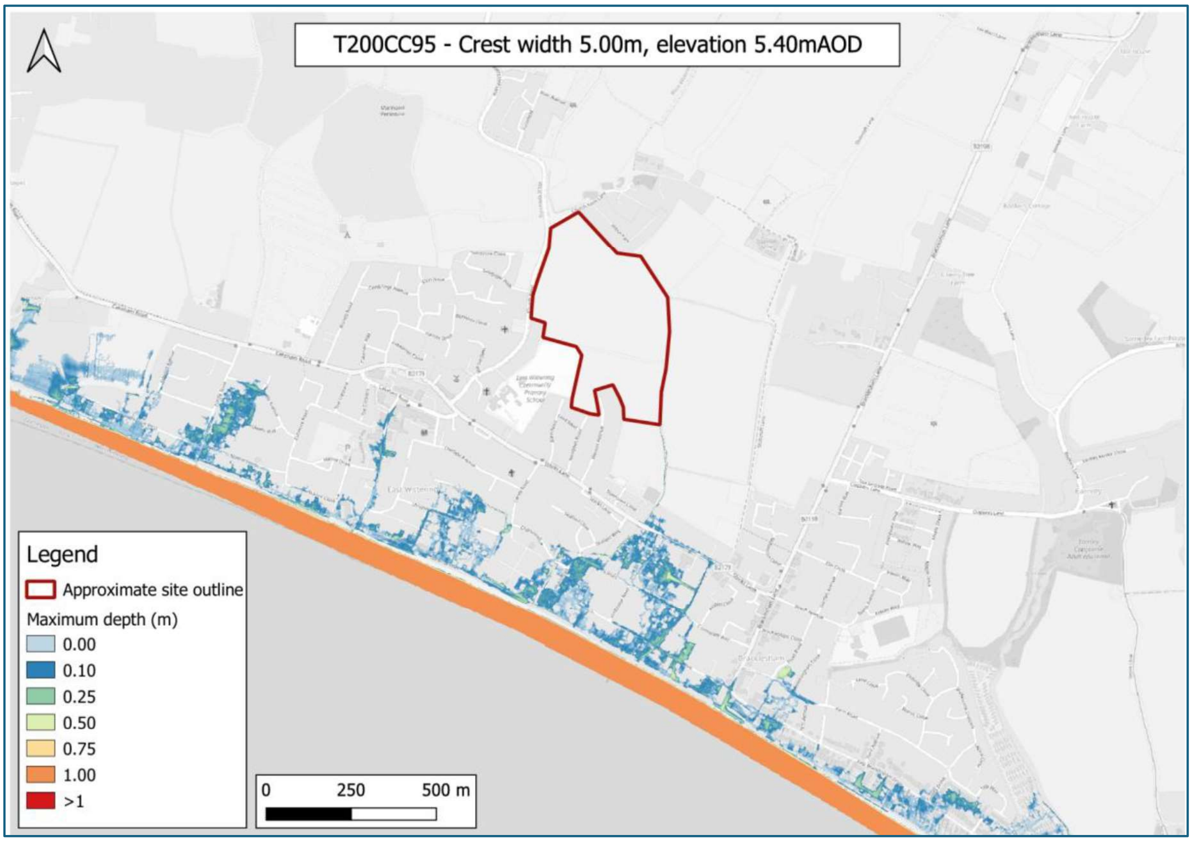

T200CC70 - Crest width 10.00m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

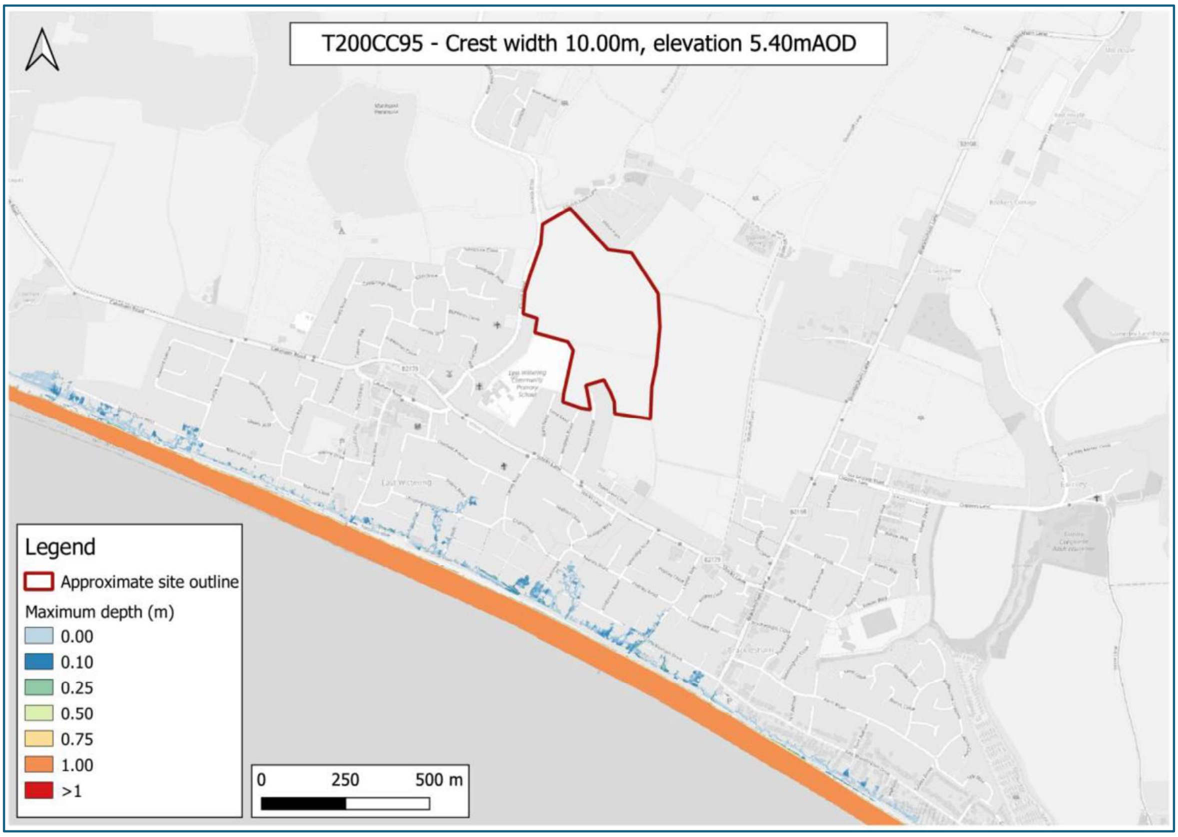

T200CC70 - Crest width 1.667m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

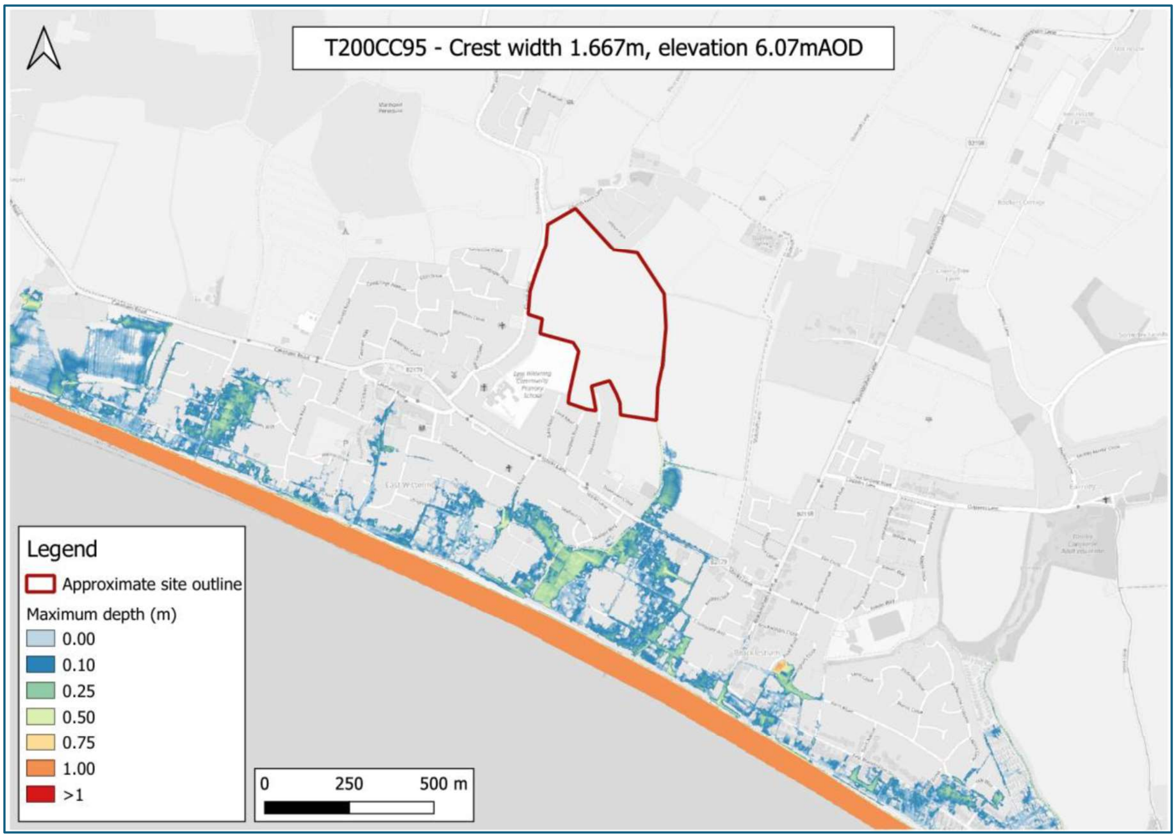

T200CC70 - Crest width 5.00m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

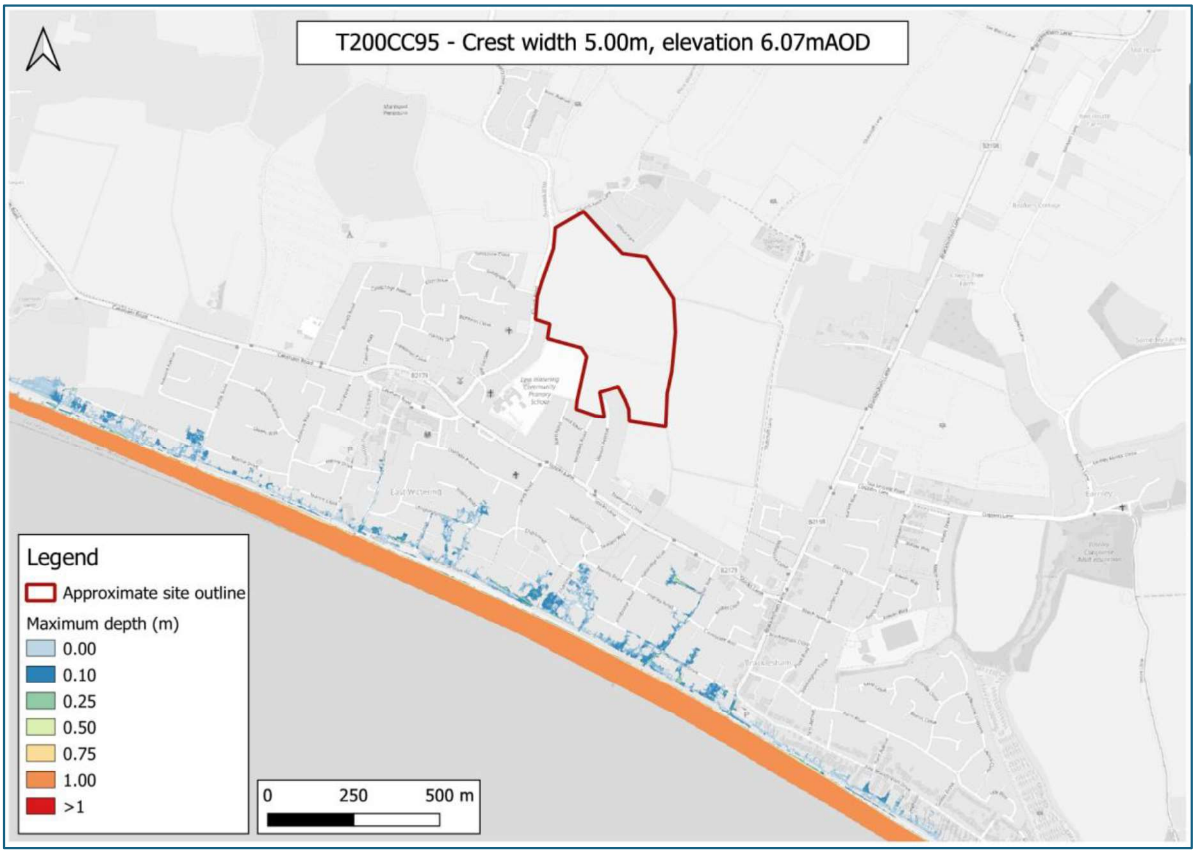

T200CC70 - Crest width 10.00m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m

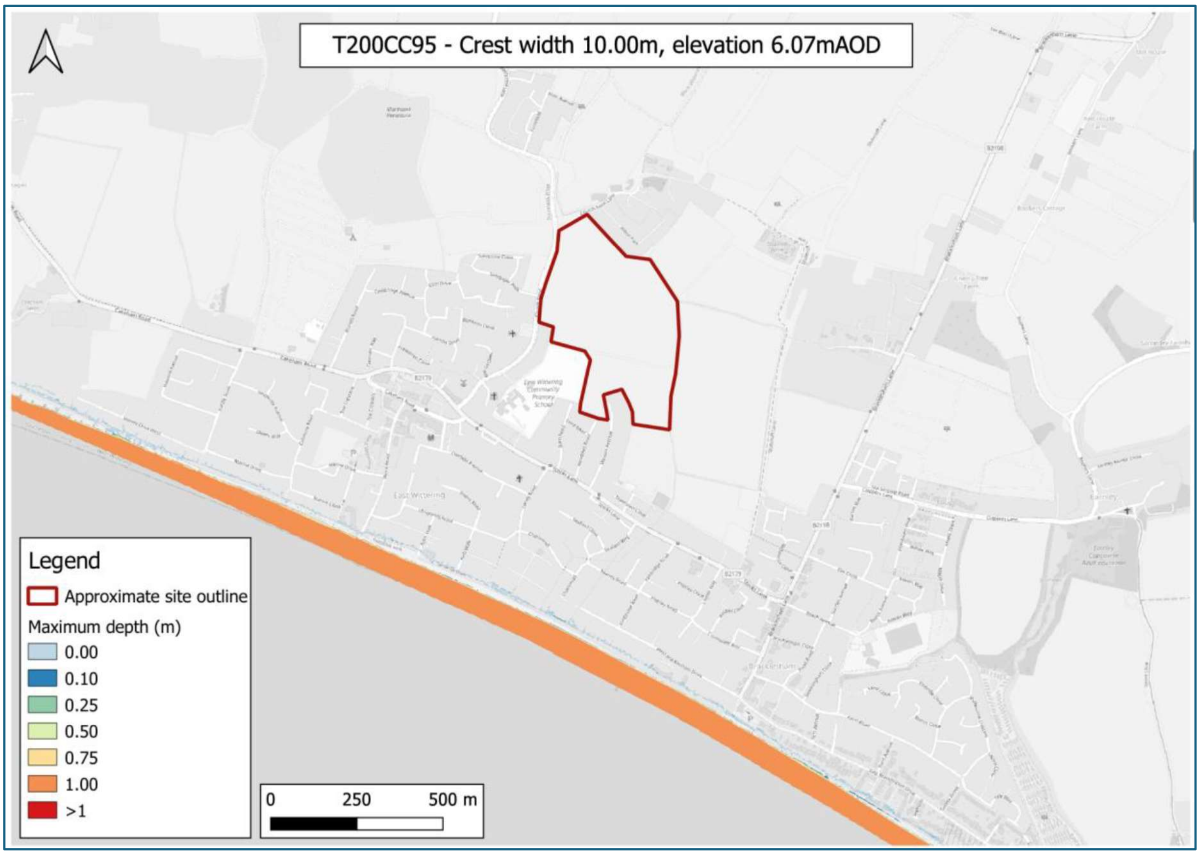

T200CC95 - Crest width 1.667m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m


T200CC95 - Crest width 5.00m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m


T200CC95 - Crest width 10.00m, elevation 5.40mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m


T200CC95 - Crest width 1.667m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m


T200CC95 - Crest width 5.00m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m


T200CC95 - Crest width 10.00m, elevation 6.07mAOD
Legend
Approximate site outline
Maximum depth (m)
0.00
0.10
0.25
0.50
0.75
1.00
>1
0
250
500 m