

# Aberaeron Coastal Defence Scheme

Conceptual Understanding of Baseline  
Geomorphology

Ceredigion County Council

28 October 2022

5182114-ATK-MAR-GEN-RP-C-1048



# Notice

This document and its contents have been prepared and are intended solely as information for Ceredigion County Council and use in relation to the Aberaeron Coastal Defence Scheme.

Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

## Document history

Document title: Conceptual Understanding of Baseline Geomorphology

Document reference: 5182114-ATK-MAR-GEN-RP-C-1048

| Revision | Purpose description                     | Originated   | Checked | Reviewed | Authorised | Date       |
|----------|-----------------------------------------|--------------|---------|----------|------------|------------|
| 1.0      | For NRW review                          | RB / MT / RM | KW      | HW       | RM         | 27/05/2022 |
| 2.0      | For NRW review following clarifications | RM/CP        | KW      | MT       | RM         | 28/10/2022 |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |
|          |                                         |              |         |          |            |            |

## Client signoff

|                       |                                  |
|-----------------------|----------------------------------|
| Client                | Ceredigion County Council        |
| Project               | Aberaeron Coastal Defence Scheme |
| Job number            | 5182114                          |
| Client signature/date |                                  |

# Contents

| Chapter                                                                                                                                   | Page      |
|-------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| <b>1. Introduction</b>                                                                                                                    | <b>6</b>  |
| 1.1. Purpose                                                                                                                              | 6         |
| 1.2. Client objectives                                                                                                                    | 6         |
| <b>2. Conceptual Understanding</b>                                                                                                        | <b>7</b>  |
| 2.1. Hydrodynamics                                                                                                                        | 7         |
| 2.2. Sediments and geology                                                                                                                | 11        |
| 2.3. Topography / Morphology                                                                                                              | 17        |
| 2.4. Problem definition and study objectives                                                                                              | 17        |
| <b>3. Conclusions</b>                                                                                                                     | <b>34</b> |
| <b>4. References</b>                                                                                                                      | <b>35</b> |
| <b>Appendices</b>                                                                                                                         | <b>36</b> |
| <b>Appendix A. Historic LiDAR Data Comparisons South Beach</b>                                                                            | <b>37</b> |
| <b>Appendix B. Notes on model modifications</b>                                                                                           | <b>44</b> |
| B.1. Introduction                                                                                                                         | 44        |
| B.2. Model modifications                                                                                                                  | 44        |
| B.3. Model setup                                                                                                                          | 45        |
| B.4. Calibration                                                                                                                          | 49        |
| B.5. Model assumptions                                                                                                                    | 50        |
| B.6. Interpretating model outputs                                                                                                         | 51        |
| B.7. Conclusion                                                                                                                           | 61        |
| <b>Appendix C. Model Outputs</b>                                                                                                          | <b>62</b> |
| C.1. Tide only model plots                                                                                                                | 62        |
| C.2. Tide and typical fluvial flow model plots                                                                                            | 66        |
| C.3. 1 in 1 year wave condition with typical fluvial flow plots                                                                           | 70        |
| C.4. 1 in 75 year wave condition and high fluvial flow plots                                                                              | 74        |
| <b>Tables</b>                                                                                                                             |           |
| Table 2-1 - Tidal and extreme water levels for Aberaeron in 2017.                                                                         | 7         |
| Table 2-2 - Extreme offshore wave heights                                                                                                 | 11        |
| Table 2-3 - Peak flow estimates for the River Aeron                                                                                       | 11        |
| Table 2-4 – Trial pit data                                                                                                                | 14        |
| Table 2-5 - Sediment samples [11] used for estimates of threshold bed shear-stress                                                        | 15        |
| Table 2-6 - Identification of potential sources, pathways and receptors                                                                   | 21        |
| Table 2-7 - Potential sources, pathways and receptors to be considered                                                                    | 24        |
| Table 2-8 - Approximate areas affected by change in current speed >1%.                                                                    | 27        |
| Table 2-9 - Approximate areas affected by change in current speed >1% for tide with typical Afon Aeron flow                               | 28        |
| Table 2-10 – Absolute change in the range of current speeds between baseline and breakwater models for Tide with typical Afon Aeron flows | 29        |
| Table 2-11 - Approximate areas affected by change in bed shear-stress.                                                                    | 30        |

|                                                                                                                                             |    |
|---------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 2-12 - Approximate areas affected by change in bed shear stress >1% for tide with typical Afon Aeron flow                             | 31 |
| Table 2-13 – Absolute change in the range of bed shear stress between baseline and breakwater models for Tide with typical Afon Aeron flows | 32 |
| Table 4-1 - Peak flow estimates for the Afon Aeron                                                                                          | 47 |
| Table 4-2 - Extreme Offshore Boundary Conditions                                                                                            | 48 |
| Table 4-3 - Summary of numerical model set-up for individual model run scenarios.                                                           | 48 |
| Table 4-4 - Sediment samples [11] used for estimates of threshold bed shear-stress.                                                         | 51 |
| Table 4-5 - Mean current speed statistics observed over the whole model domain, for the entire simulation period.                           | 59 |
| Table 4-6 - Mean current speed statistics observed over the <i>Sabellaria alveolata</i> reef, for the entire simulation period.             | 59 |
| Table 4-7 - Mean bed shear-stress statistics observed over the whole model domain, for the entire simulation period.                        | 60 |
| Table 4-8 - Mean bed shear-stress statistics observed over the whole model domain for the entire simulation period.                         | 60 |

## Figures

|                                                                                                                                                                                                                                |    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 2-1 - Recorded water levels at Aberaeron.                                                                                                                                                                               | 8  |
| Figure 2-2 - Recorded peak current speed at Aberaeron                                                                                                                                                                          | 9  |
| Figure 2-3 - Offshore wave direction by percentage occurrence.                                                                                                                                                                 | 9  |
| Figure 2-4 - Location of Met Office Wave Data Point                                                                                                                                                                            | 10 |
| Figure 2-5 – Interpreted seabed features (side scan sonar)                                                                                                                                                                     | 12 |
| Figure 2-6 - Trial pit locations                                                                                                                                                                                               | 13 |
| Figure 2-7 – Threshold bed shear-stress for a representative range of Aberaeron Harbour sediment                                                                                                                               | 16 |
| Figure 2-8 – Threshold of motion 1 in 1 year wave condition and typical fluvial flow during flood tide                                                                                                                         | 16 |
| Figure 2-8 - Beach Change 2006 to 2012/2013                                                                                                                                                                                    | 18 |
| Figure 2-9 - Subtidal Survey 2019 Biotope Distribution                                                                                                                                                                         | 20 |
| Figure 2-10 - Existing timber groynes on South Beach                                                                                                                                                                           | 22 |
| Figure 2-11 - Conceptual model of baseline coastal geomorphology at Aberaeron                                                                                                                                                  | 25 |
| Figure 2-12 - Zone of influence along coastal frontage                                                                                                                                                                         | 26 |
| Figure 2-13 - Run scenario: Tide with typical Afon Aeron flows - Area affected by relative changes in current speed.                                                                                                           | 28 |
| Figure 2-15 - Tide with typical Afon Aeron flows, current speed – baseline and proposed                                                                                                                                        | 29 |
| Figure 2-14 - Run scenario: Tide with typical Afon Aeron flows – Area affected by relative changes in bed shear-stress.                                                                                                        | 30 |
| Figure 2-16 - Tide with typical Afon Aeron flows, bed shear-stress – baseline and proposed                                                                                                                                     | 32 |
| Figure 4-1 - Revised model mesh (left), with harbour entrance defined by 4 computational elements (right).                                                                                                                     | 44 |
| Figure 4-2 – Revised model bathymetry in Aberaeron harbour.                                                                                                                                                                    | 45 |
| Figure 4-3 - Plot showing vectors of the typical Fluvial flow rate $Q = 1 \text{ m}^3/\text{s}$ in the baseline model run (Top) and breakwater model run (Bottom). Screenshots taken at the peak of the lowest simulated tide. | 46 |

|                                                                                                                                                                                       |    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 4-4 - 1 in 2 year hydrograph of extreme flows in the Afon Aeron                                                                                                                | 47 |
| Figure 4-5 - Calibration check of the hydrodynamic model, comparing model outputs against measured water level data.                                                                  | 49 |
| Figure 4-6 - Interpreted seabed features (sidescan sonar).                                                                                                                            | 50 |
| Figure 4-7 - Exploratory hole location plan [11].                                                                                                                                     | 51 |
| Figure 4-8 - Estimates* of threshold bed shear-stress for a representative range of sediment found in Aberaeron Harbour.                                                              | 52 |
| Figure 4-9 - Colour palette used in threshold of motion plots                                                                                                                         | 52 |
| Figure 4-10 – Run scenario: Tide only - Statistical mean difference in current speed over the simulated period.                                                                       | 53 |
| Figure 4-11 – Run scenario: Tide and typical Afon Aeron flows - Statistical mean difference in current speed over the simulated period.                                               | 54 |
| Figure 4-12 – Run scenario: 1 in 1 year wave condition and typical Afon Aeron flows - Statistical mean difference in current speed over the simulated period.                         | 54 |
| Figure 4-13 – Run scenario: 1 in 75 year wave condition and Afon Aeron storm flows - Statistical mean difference in current speed over the simulated period.                          | 55 |
| Figure 4-14 - 1 in 75 year wave condition and 1 in 2 year fluvial flow model during ebb tide - Current speed plot showing influence of breakwater (top) and baseline output (bottom). | 56 |
| Figure 4-15 - Run scenario: Tide only - Statistical mean difference in bed shear-stress over the simulated period.                                                                    | 57 |
| Figure 4-16 - Run scenario: Tide and typical Afon Aeron flows - Statistical mean difference in bed shear-stress over the simulated period.                                            | 58 |
| Figure 4-17 - Run scenario: 1 in 1 year wave condition and typical Afon Aeron flows - Statistical mean difference in bed shear-stress over the simulated period.                      | 58 |
| Figure 4-18 - Run scenario: 1 in 75 year wave condition and Afon Aeron storm flows - Statistical mean difference in bed shear-stress over the simulated period.                       | 59 |

# 1. Introduction

## 1.1. Purpose

The purpose of this report is to provide a conceptual understanding of baseline geomorphology at Aberaeron, Wales. The content of this baseline understanding has been gathered from existing published data / information, surveys and reports (listed in Section 4 of this report) and has been supplemented with recent additional survey information. This version of the report is also updated with the findings of additional numerical modelling work which is contained in a separate appendix. These have been provided so that the maximum zone of influence of a proposed breakwater structure, and potential impacts on sediment transport and coastal processes can be understood, as a next step in determining the likely significance of impacts from the proposed breakwater. In preparing this report consideration has been given to best practice guidance as detailed in NRW Guidance Note GN041 [1], NRW Evidence Report No 208 [2] and NRW Evidence Report No 243 [3].

## 1.2. Client objectives

Ceredigion County Council (CCC) has commissioned Atkins to develop proposals and complete the detailed design of a coastal defence scheme at Aberaeron. The aims of the scheme are to:

- Reduce risks of flooding to commercial and residential properties in the town, many of which are listed.
- Provide protection against predicted sea level rise/climate change.
- Reduce effects of fluvial flooding of the River Aeron on the town downstream of the A487 road bridge.
- Maintain the South Beach defences and reduce the effects of coastal erosion.
- Extend the life of the existing dilapidated Grade II listed South Pier.
- Promote opportunities to bring economic, cultural and social benefits to the town and harbour

As detailed in Section 2, particular attention needs to be paid to the likely impact of the structure on receptors and in particular at the adjacent biogenic (*Sabellaria alveolata*, *Mytilus edulis*) and geogenic (bedrock/cobble) reefs in the area; and on the potential for sedimentation/siltation in the navigation channel.

## 2. Conceptual Understanding

A conceptual understanding of the physical processes has been drawn together to inform the requirements for baseline data requirements and to support decisions on the type of numerical modelling that might be used for the study.

### 2.1. Hydrodynamics

#### 2.1.1. Water levels

The Aberaeron coastline is classified as macrotidal with a tidal range greater than 4m. Tide levels for Aberaeron have been calculated based on published (Admiralty tide tables 2017 and Atkins 2019) levels at Aberystwyth and Aberporth as shown in Table 2-1. Extreme water levels can be up to an additional 1.5m higher than Mean High Water Spring (MHWS) (at present day) in the 1 in 1000 scenario.

**Table 2-1 - Tidal and extreme water levels for Aberaeron in 2017.**

| Return Period | Level (mAOD) |
|---------------|--------------|
| 1 in 1000     | 4.00         |
| 1 in 500      | 3.91         |
| 1 in 200      | 3.82         |
| 1 in 100      | 3.75         |
| 1 in 50       | 3.68         |
| 1 in 10       | 3.52         |
| 1 in 1        | 3.26         |
| HAT           | 3.16         |
| MHWS          | 2.51         |
| MHWN          | 1.01         |
| MSL           | 0.17         |
| MLWN          | -0.59        |
| MLWS          | -1.79        |
| LAT           | -2.44        |

Source: Admiralty tide tables 2017 and Atkins 2019.

For this project, a tide gauge was installed in Aberaeron Harbour and water levels were recorded for a period of 30 days in July/August 2020 covering two spring-neap cycles. The recorded water levels are shown in Figure 2-1. It is noted that the tide gauge dries out below approximately mid-tide. There are no water level control structures within the harbour and the harbour bed is exposed at low tide.

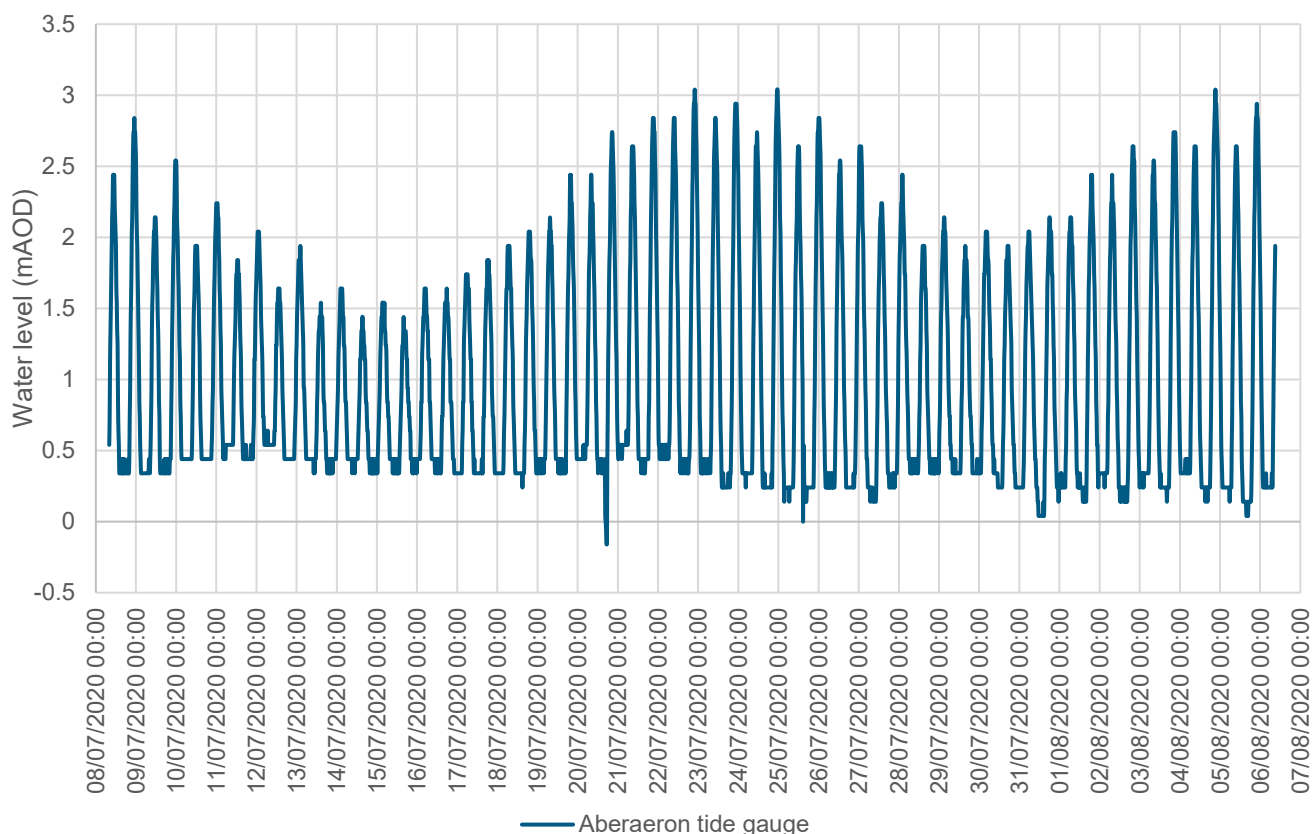


**Figure 2-1 - Recorded water levels at Aberaeron.**

### 2.1.2. Tidal currents

The variation in water level results in a typically north-east/south-west tidal flow with peak spring tidal velocities in the offshore zone of 0.3m/s to 0.5m/s, with the tidal residual for the area being a north-easterly flow (Admiralty Chart Tidal Diamond, 1972).

For this project, an ADCP was deployed approximately 300m seaward of the entrance to Aberaeron Harbour for a period of 30 days in July/August 2020 covering two spring-neap cycles. The recorded peak current speed and direction is shown in Figure 2-2. It is noted that the maximum recorded current speed during the deployment was approximately 0.7m/s.

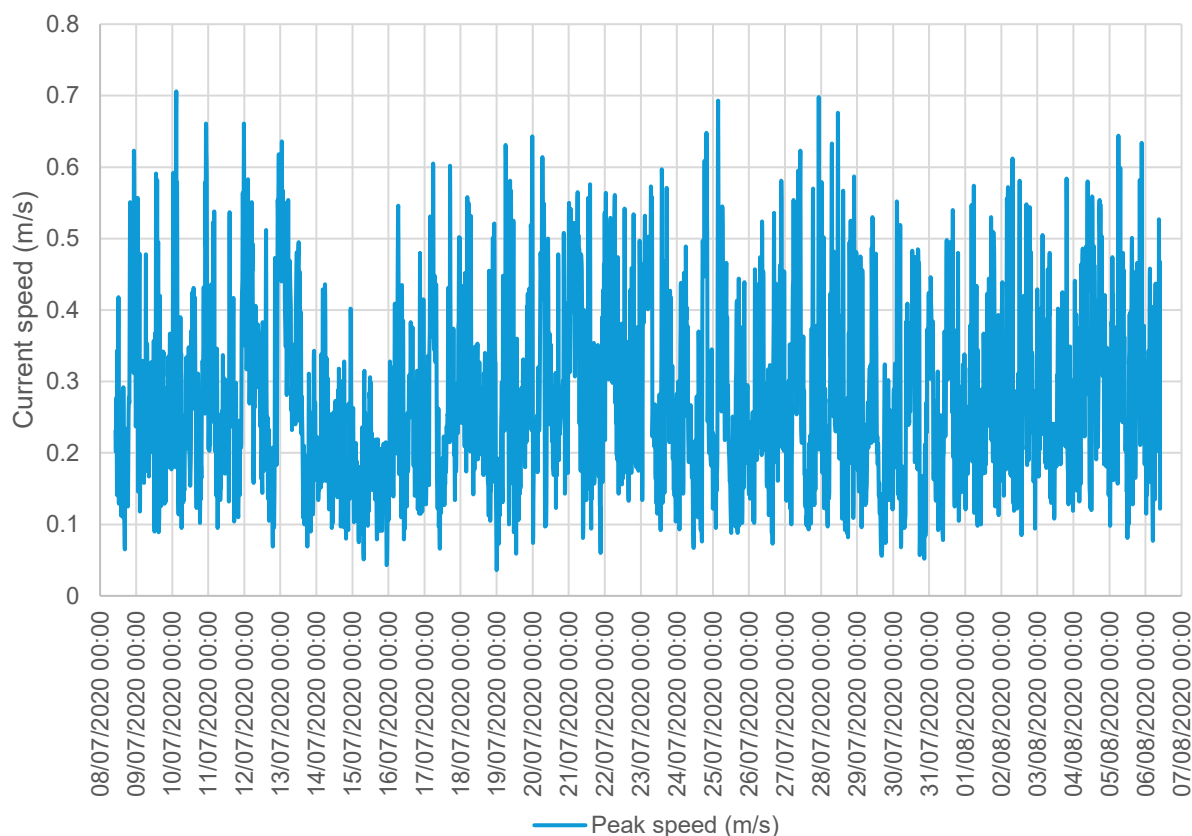


**Figure 2-2 - Recorded peak current speed at Aberaeron**

### 2.1.3. Waves

Hindcast data [4] over a period of 40 years is available to determine representative wave conditions. This shows that waves within Cardigan Bay approach from a broad sector covering the southwest through to the northwest. The dominant wave direction is from the southwest to west, however waves from the northwest can also be significant during storm conditions.

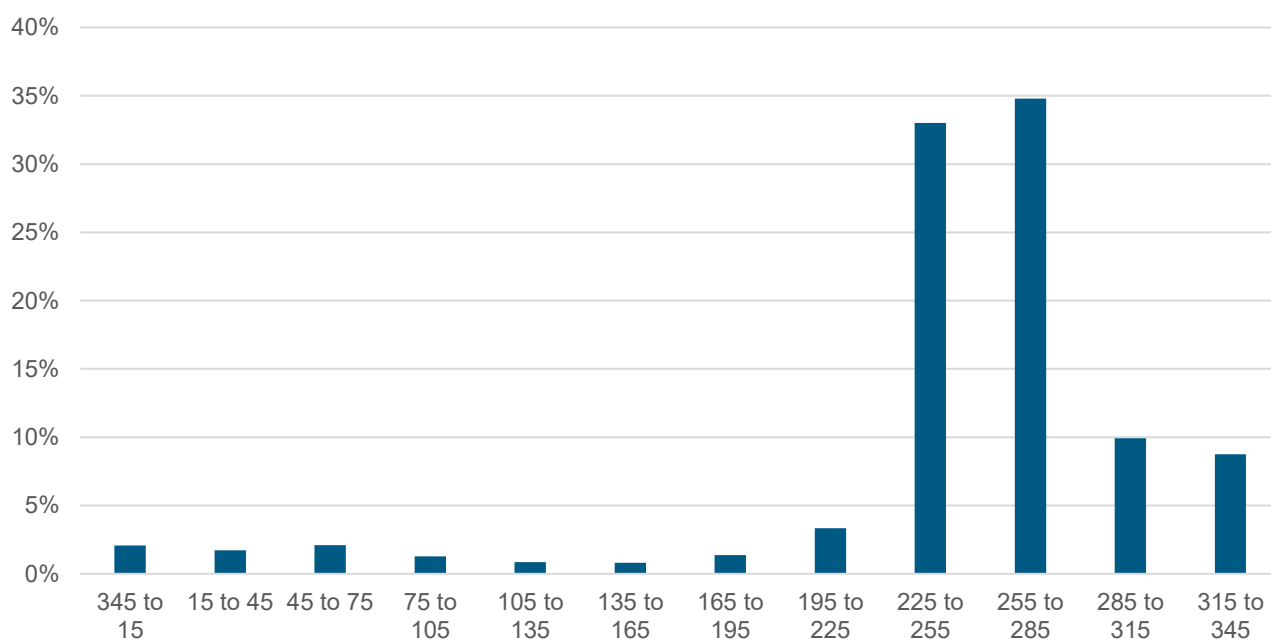


**Figure 2-3 - Offshore wave direction by percentage occurrence.**

The SMP2 [5] also demonstrated that there can be variation in net wave direction on a decadal scale such that in any period of time there may be a slight shift around the normal southwest to west dominance at the shoreline [5].

During north-westerly storms, waves are generated, which despite the presence of the two piers at Aberaeron, are able to enter the harbour. The shape of the harbour entrance means that wave heights increase as they are funnelled through the entrance and move through the entrance channel of the harbour. [6]

Waves from a north-westerly direction enter the harbour and run along the harbour wall on the north side of the harbour, which results in waves overtopping the harbour wall and the secondary wall too. [6]

For this project, a total of 39 years (1980 to 2019) of hindcast wave data at three hours intervals (including wave height, period and direction) was purchased from the UK Met Office at an offshore location (52.334°N, 4.415°W) as illustrated in Figure 2-4. The offshore wave data point is approximately 14km north-west of Aberaeron in approximately 16m of water (from mean sea level).

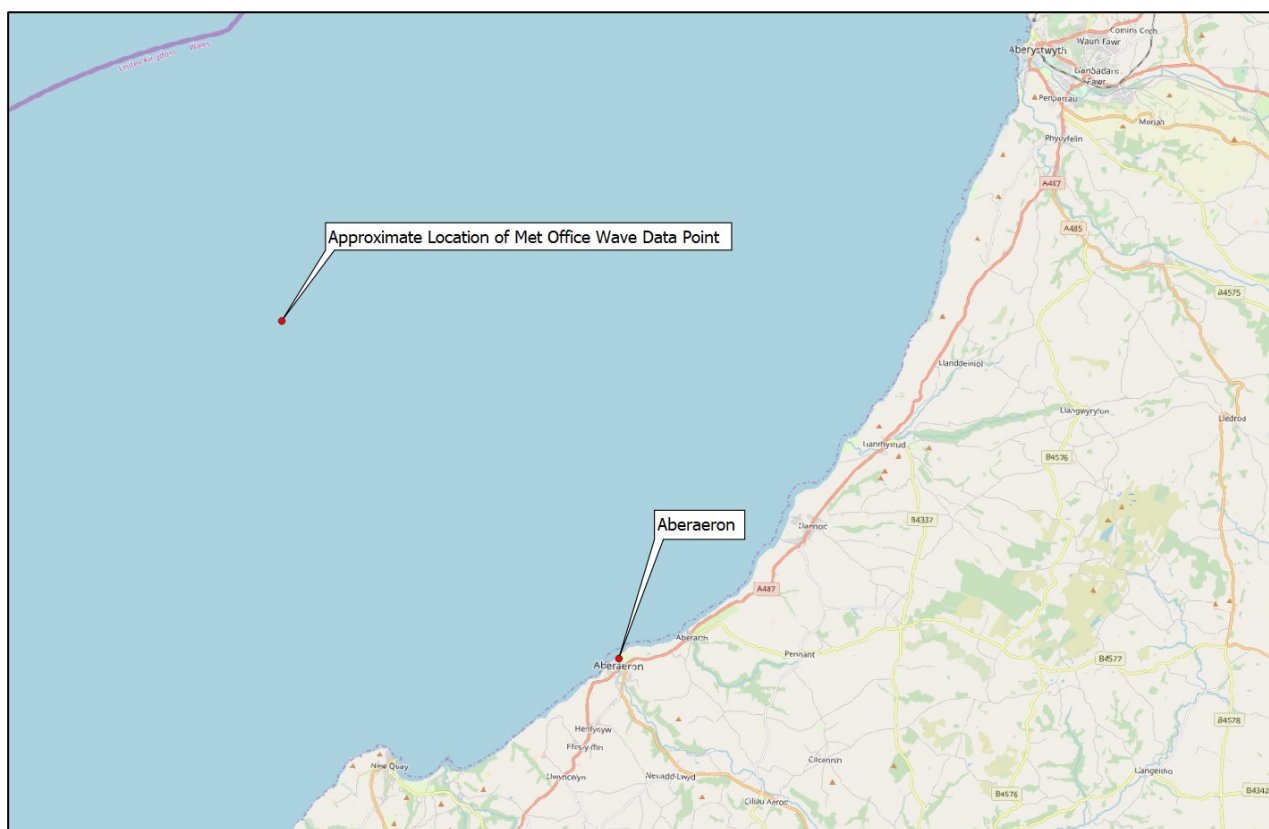


**Figure 2-4 - Location of Met Office Wave Data Point**

An Extreme Value Analysis (EVA) of the offshore wave data determined the following extreme wave heights as shown in Table 2-2. This is for use as offshore boundary conditions for the numerical modelling studies.

**Table 2-2 - Extreme offshore wave heights**

| Return Period | Significant wave height, Hs (m) |
|---------------|---------------------------------|
| 1 in 1        | 4.56                            |
| 1 in 2        | 5.18                            |
| 1 in 5        | 5.65                            |
| 1 in 10       | 6.01                            |
| 1 in 20       | 6.38                            |
| 1 in 25       | 6.50                            |
| 1 in 50       | 6.90                            |
| 1 in 75       | 7.15                            |
| 1 in 100      | 7.33                            |
| 1 in 200      | 7.79                            |
| 1 in 500      | 8.44                            |
| 1 in 1000     | 8.97                            |

#### 2.1.4. Fluvial flows

The River Aeron is one of several rivers flowing into Cardigan Bay. The River Aeron and River Arth are Main Rivers close to Aberaeron. The River Aeron outflows through the harbour at Aberaeron, whereas the River Arth is a further 2.5km to the north.

A Flood Consequence Assessment (FCA) [7] has been produced for Aberaeron in accordance with Technical Advice Note 15 (TAN15, 2004). As part of that assessment, peak flow estimates for the River Aeron were derived using industry standard approaches in the form of the Flood Estimation Handbook (FEH); see Table 2-3 below.

**Table 2-3 - Peak flow estimates for the River Aeron**

| Event AEP <sup>1</sup> | Peak flow (m <sup>3</sup> /s) |
|------------------------|-------------------------------|
| 50% (1 in 2)           | 65                            |
| 25% (1 in 4)           | 80                            |
| 20% (1 in 5)           | 84                            |
| 10% (1 in 10)          | 99                            |
| 5% (1 in 20)           | 114                           |
| 2% (1 in 50)           | 138                           |
| 1% (1 in 100)          | 158                           |
| 0.1% (1 in 1,000)      | 231                           |

Note 1: Annual Exceedance Probability

## 2.2. Sediments and geology

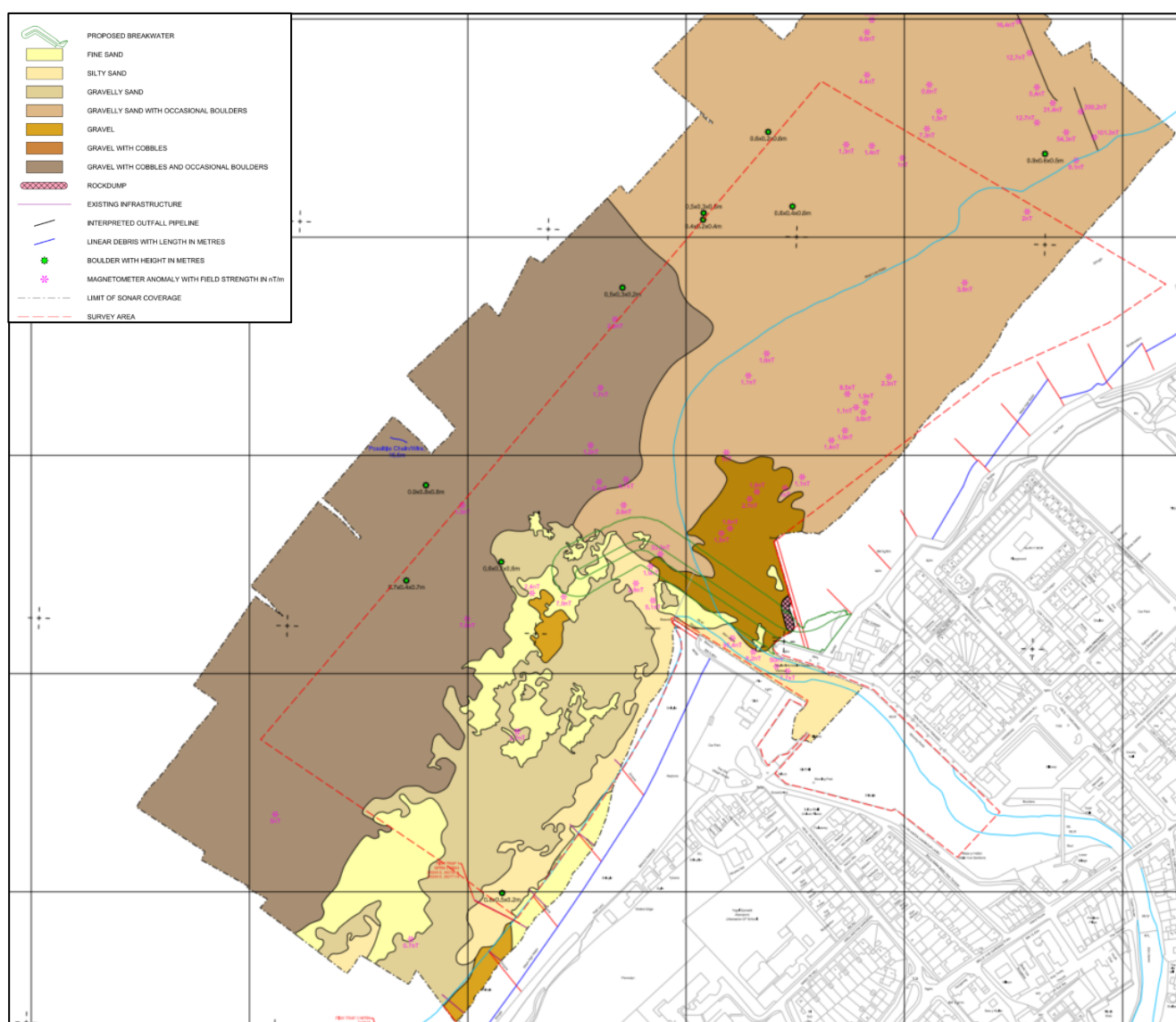
The bedrock geology of the Cardigan Bay area is dominated by a sedimentary succession of sandstones, siltstones and mudstones of Silurian to early Devonian age. Glacial and glaciofluvial sequences were deposited on local bedrock during several major phases of ice-sheet glaciation that culminated approximately 18,000 years ago.

The coastline is dominated by soft boulder clay cliffs, and mudstone outcrops and headlands. The hard points along the coast of New Quay head, Llanina Point, Aberaeron Harbour, Morfa Mawr, the mouth of the Afon

Wyre, Carreg Ti Pw, Allt Wen, Aberystwyth Harbour, Castle Hill, Constitution Hill and Sarn Gynfelyn have created a stepped coastline, where the shore is eroding back in shallow bays [8]

A subtidal video survey of the seabed along the Aberaeron coastline, undertaken for this scheme in 2019 [9] identified a dominant presence of mixed sediments of bedrock, boulders, cobbles and coarse gravel in the subtidal area, with occasional patches of fine sand. The nature of the sediment type is patchy across the site though sand was largely restricted to the south-western portion and a gradient from sand to coarser sediment was evident from shore to sea.

The ground investigation work included side scan sonar surveys [10], which detailed the seabed features shown in Figure 2-5. This figure has been produced by interpreting and integrating side scan sonar data as well as referencing imagery. Seabed sediments are interpreted to comprise gravel and cobbles associated with glacial till across much of the offshore section in the west of the site. Further inshore, accumulations of sand are clearly seen on both bathymetry and side scan sonar datasets as areas forming a surficial veneer. This is predominantly confined to the south of the site. In the north of the site, side scan sonar data shows predominantly gravels. Within the vicinity of the harbour and proposed breakwater, seabed sediments are interpreted to predominantly comprise gravels and silty sand.



Source: Quantum Geotechnical Ltd. & Titan Environmental Surveys Ltd

**Figure 2-5 – Interpreted seabed features (side scan sonar)**

## 2.2.1. Ground Investigation

A ground investigation was undertaken by Quantum Geotechnical Limited in November 2020 [10] and a plan of the exploratory holes taken is shown in Figure 2-6

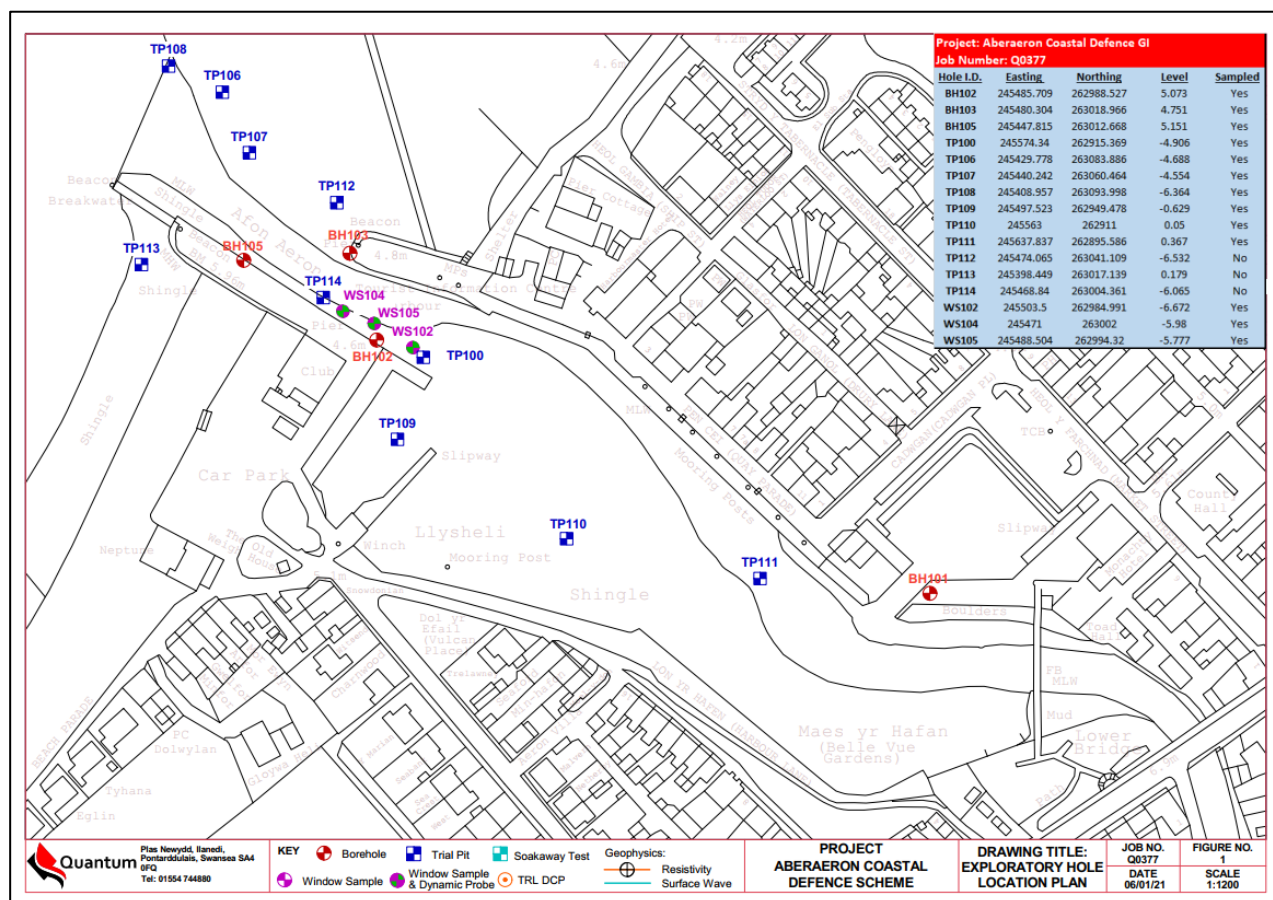


**Figure 2-6 - Trial pit locations**

This information can be used to identify the properties of the alluvial material at the harbour entrance and to also identify sediments that could potentially be mobilised by currents.

The trial pits showed the following strata in Table 2-4 along with Particle Size Distribution (PSD) tests undertaken to determine the percentage sample proportions.

**Table 2-4 – Trial pit data**

| Strata                                                                                                                                                                                                                                                     | Sample depth | Thickness | Location | Sample Proportions <sup>1</sup> |                      |                     |                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------|----------|---------------------------------|----------------------|---------------------|------------------------------|
|                                                                                                                                                                                                                                                            |              |           |          | Percentage of Cobbles           | Percentage of Gravel | Percentage of Sands | Percentage of Silt and clays |
| (i) Very soft dark grey slightly silty slightly Sandy CLAY. Sand is fine to medium. [ALLUVIUM]                                                                                                                                                             | 0-0.2m       | 200mm     | TP109    | No sample                       |                      |                     |                              |
| (ii) Brown gravelly fine to medium SAND. Gravel is fine to coarse angular to sub-rounded siltstone sandstone limestone. [MARINE BEACH DEPOSITS]                                                                                                            | 0-0.05m      | 50mm      | TP107    | No sample                       |                      |                     |                              |
| (iii) Soft to locally stiff dark grey silty slightly sandy gravelly CLAY with high sub-rounded siltstone sandstone cobble/ boulder content. Sand is fine to medium. Gravel is fine to coarse sub-angular to well-rounded siltstone sandstone. [ALLUVIUM]   | 0.05-0.3m    | 250mm     | TP107    | 0                               | 37                   | 25                  | 38                           |
| (iv) Grey slightly silty slightly sandy fine to coarse sub-angular to well-rounded siltstone sandstone limestone GRAVEL with high sub-angular to sub-rounded sandstone cobble content. Sand is fine to medium. [ALLUVIUM]                                  | 0-0.4m       | 400mm     | TP110    | 0                               | 67                   | 27                  | 6                            |
|                                                                                                                                                                                                                                                            | 0.4-0.6m     | 200mm     | TP111    | 32                              | 67                   | 1                   | 0                            |
| (v) Brown locally grey slightly clayey slightly silty sandy fine to coarse angular to well-rounded mudstone siltstone sandstone GRAVEL with high sub-angular to sub-rounded siltstone sandstone cobble/boulder content. Sand is fine to coarse. [ALLUVIUM] | 0-3m         | >3000mm   | TP100    | 10                              | 79                   | 9                   | 2                            |
|                                                                                                                                                                                                                                                            | 0-1m         | 1000mm    | TP106    | 22                              | 73                   | 4                   | 1                            |
|                                                                                                                                                                                                                                                            | 1-3.30m      | 2300mm    | TP107    | 0                               | 84                   | 12                  | 4                            |
|                                                                                                                                                                                                                                                            | 0-1.2m       | 1200mm    | TP108    | 6                               | 82                   | 10                  | 2                            |
|                                                                                                                                                                                                                                                            | 0.2-2m       | 1800mm    | TP109    | 10                              | 79                   | 6                   | 5                            |
|                                                                                                                                                                                                                                                            | 0.6-1.7m     | 1700mm    | TP111    | 7                               | 84                   | 2                   | 7                            |

Note 1: Particle Size Distribution BS 1377: Part 2

### 2.2.1.1. Summary of trial pit results

Referring to the strata in Table 2-4, the trial pit information can be summarised as follows:

- (i) Very soft dark grey slightly silty slightly Sandy CLAY - This stratum was only found in one location (TP109) and found to be 200mm thick.
- (ii) Brown gravelly fine to medium SAND - This stratum was found in only one location (TP107) and found to be 50mm thick.
- (iii) Soft to locally stiff dark grey silty slightly sandy gravelly CLAY with high sub-rounded siltstone sandstone cobble/ boulder content - This stratum was found in only one location (TP107) and found to be 250mm thick
- (iv) Grey slightly silty slightly sandy fine to coarse sub-angular to well-rounded siltstone sandstone limestone GRAVEL with high sub-angular to sub-rounded sandstone cobble content - This stratum was found two locations (TP110 and TP111) and found to be 200mm and 400mm thick, with the gravel percentage above 67%. All the trial pits and samples have a percentage of silts and clays is 6% or less.
- (v) Brown locally grey slightly clayey slightly silty sandy fine to coarse angular to well-rounded mudstone siltstone sandstone GRAVEL with high sub-angular to sub-rounded siltstone sandstone cobble/boulder content - This stratum is a generally thick layer of gravel alluvium with the gravel percentage above 73%. All the trial pits and samples have a percentage of silts and clays is 7% or less.

### 2.2.1.2. Susceptibility to currents

From the results above it is anticipated that the clay and sand materials would be those most easily mobilised by currents and the depth affected is typically 200-250mm and up to 400mm maximum. The side scan sonar data shown in Figure 2-5 also shows that the thickness of silts and sands is very limited at the surface, consistent with the results in Table 2-4 above. The predominantly gravel layers would have low susceptibility to currents as they are well bedded deep layers of materials.

Given the widespread presence of gravels over the area of the study, this would indicate that the potential magnitude of changes to local bed levels is low.

Further modelling work has looked at bed shear stress, as detailed in Appendix B. Table 2-5 below shows selected sediment samples, providing a range of particle size for calculations of threshold bed shear-stress, giving a reasonably well-rounded representation of the spatial variation in sediment size at the site.

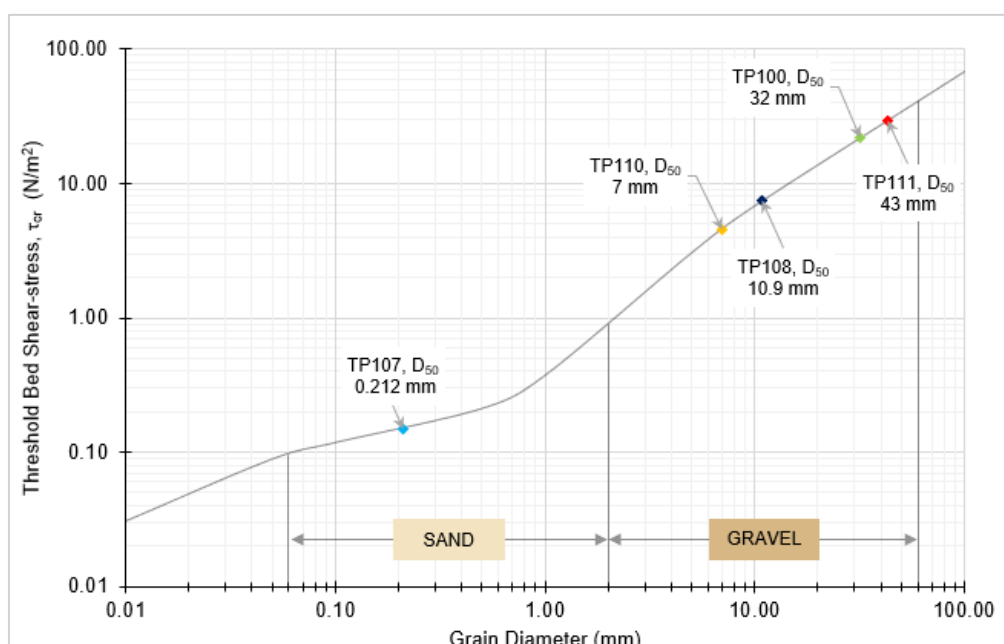
**Table 2-5 - Sediment samples [11] used for estimates of threshold bed shear-stress**

| Trial Pit | Level (mAOD) | Sample Depth (mBGL) | Approximated D <sub>50</sub> (mm) |
|-----------|--------------|---------------------|-----------------------------------|
| TP111     | 0.367        | 0 - 0.2             | 43                                |
| TP110     | 0.050        | 0.2 - 0.4           | 7                                 |
| TP100     | -4.906       | 1.0 - 1.1           | 32                                |
| TP107     | -4.554       | 0.1 - 0.2           | 0.212                             |
| TP108     | -6.364       | 0.4 - 0.5           | 10.9                              |

Figure 2-9 displays the calculated threshold bed shear-stress in relation to sediment grain size. This plot gives an indication of the magnitude of bed shear-stress required mobilise various sediments. As seen in the plot, the threshold bed shear-stress to mobilise particles is:

- Gravel ranges from approximately 0.9 – 40 N/m<sup>2</sup>,
- With threshold bed shear-stresses below 0.9 N/m<sup>2</sup> likely to only mobilise sand and silt.

It should be noted that this is a conservative approximation, valid for well-sorted sediment samples. Therefore, large variations in sediment size distribution will affect the mobilisation of sediments.



Estimated using methods suggested by Soulsby [12], for quartz sediments. Values of D<sub>50</sub> and sediment densities were approximated from Quantum Geotech Report No. Q0377/FR.01 [11]. Water temperature and salinity were assumed at 10°C and 35ppt, respectively.

**Figure 2-7 – Threshold bed shear-stress for a representative range of Aberaeron Harbour sediment**

Threshold of Motion plots are shown in Appendix C, and an example plot is given below in Figure 2-8. These plots illustrate the ‘1 in 1 year wave condition during the flood tide coinciding with typical fluvial flows’ for baseline and proposed scenarios. The location of the Sabellaria reef from the NRW 2021 survey is shown. In the baseline situation much of the beach sediment (gravel, sand and silt) is susceptible to movement (0.9-41N/m²), whereas at the top of the beach it is sand and silts only that are susceptible to movement (0.01-0.9N/m²). Within the harbour the bed shear stress is very low (>0.01N/m²) and the effect on sediment movement would be neutral. In the proposed scenario the only significant change is within the navigation channel south the proposed breakwater. The plots in Appendix C provide other variations in wave and fluvial conditions.

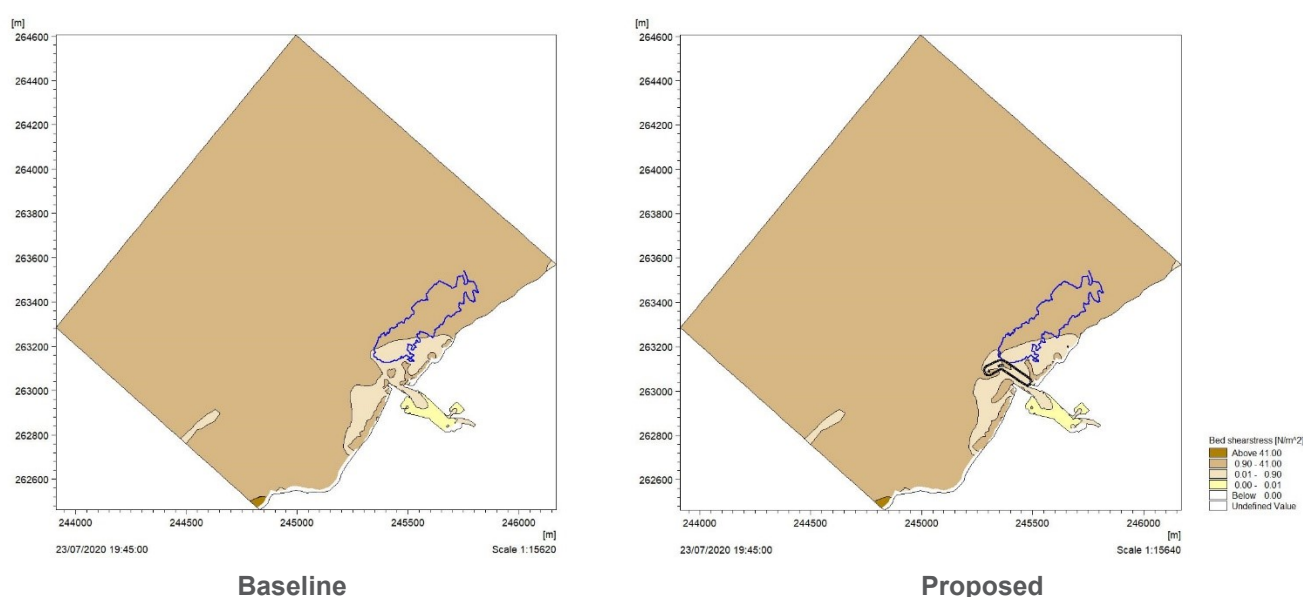


**Figure 2-8 – Threshold of motion 1 in 1 year wave condition and typical fluvial flow during flood tide**

## 2.3. Topography / Morphology

This part of the coast along the frontage of Aberaeron coast is characterised by gently sloping bathymetry and there are no notable bedforms or notable seabed features.

The coastal topography to the south of Aberaeron consists of cliffs and moving north from here the land falls to the valley of the River Aeron. The beach frontage is formed of shingle seaward of a wide plateau. Further inland is the harbour around the mouth of the River Aeron with the town located around the harbour. North of the harbour is the North Beach which has a wide foreshore between 150-250m wide consisting of well bedded and compacted glacial deposits forming the lower beach.

## 2.4. Problem definition and study objectives

### 2.4.1. Baseline conditions

The stepped nature of this coast, with headlands and bays, demonstrates that the processes shaping the coastline are the dominant wave direction and the geology, i.e. erosion and landward retreat of the coastline has occurred in the areas of softer geology, with the harder rocks remaining prominent as headlands. As summarised in the SMP2 [5], the coastline is subject to more slope driven processes rather than alongshore sediment drift. Without current coastal management measures, continued landward retreat would be expected. Increased sea level rise will tend to narrow the intertidal area, and allow larger waves to attack the cliffs, accelerating the recession. Some erosion of the clay cliffs at Aberaeron South Beach is occurring and this could over time allow a breach into a lower-lying area behind, adjacent to the southern flank of the harbour.

Sources of beach sediment are limited along this stretch of coastline, predominantly due to the presence of headlands reducing the longshore sediment transport from and to adjacent bays, as well as the more-resistant hard rock cliff outcrops which are less susceptible to erosion. Erosion of the clay cliffs at Aberaeron South Beach contain little beach supply material and do not have a significant impact on sediment supply [5].

Longshore sediment transport processes are in a north-easterly direction. However, the amount of sediment transported is considered to be limited due to the limited supplies of sediment [5]. There is very little movement of material offshore. The SMP2 [5] highlights for this stretch of coast (i.e. PDZ7, PDZ8 and PDZ9) bays act independently of each other and that engineering work carried out at Aberaeron has had little effect on nearby areas due to local areas of drift reversal and natural sediment accumulation. The dominant feature is therefore local sediment supply from various sections of cliff at the more local scale.

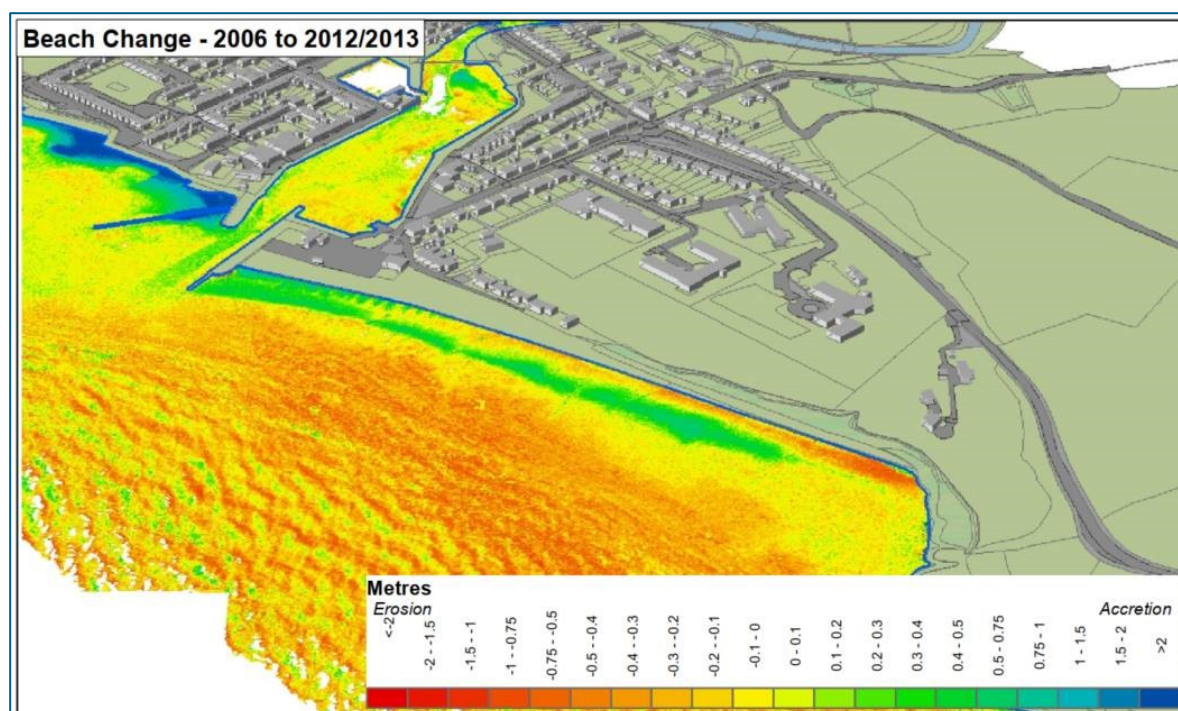
To the north of Aberaeron harbour, extensive coast protection works have been carried out consisting of groynes and a breakwater. The hard underlying intertidal platform means the beach is forward of the rest of the coastline. The groynes along North Beach have helped control the northward drift of sediment on the upper beach, which is recognised to be relatively high, however beyond the groynes the beach has tended to experience accretion as the drift rates reduce along the cliff to the north [5].

South Pier has a significant influence on the coastal processes of the North and South beaches at Aberaeron. The presence of the South Pier retains a significant amount of material that is being transported in a north-easterly direction by the prevailing longshore drift processes, enabling a channel to be maintained into Aberaeron Harbour. Although it acts as a barrier to drift along the frontage to the north, some nearshore movement beyond the influence of the pier is indicated, although this is limited to finer sediment. This has led to a reduction in material being deposited on North Beach. As stated above, the construction of new groynes and beach nourishment at North Beach as part of a coastal defence scheme in 2009 along with regular beach maintenance, has improved beach volumes here.

The presence of South Pier artificially maintains a wide beach crest at the northern end of South Beach, reducing the occurrence of tidal flooding and erosion of the land behind the beach. However, despite the sediment retention role provided by South Pier, as South Beach does not receive a large natural supply of sediment, timber groynes have been installed on the beach to help retain the limited sediment supplies. Additionally, a rock revetment at the southern end of the beach provides protection to the rear of the beach from landward erosion.

Beach monitoring was undertaken on an annual basis at Aberaeron between 2009 and 2012 and a Beach Profile Monitoring report was produced in 2013 [13]. This report indicated that the southern end of Aberaeron South Beach has eroded, with accretion at the northern end of the beach, towards the South Pier. Further, a

LiDAR comparison between 2006 and 2010 indicated that there is evidence that the southern end of South Beach is retreating, while to the northern end it is accreting (see Figure 2-7). This reflects the dominant wave direction from the south-west. It is recognised, however, that when this beach is subject to waves from the northwest, then there is likely to be a tendency for the material to return southwards again. As well as general accretion at the northern end of South Beach, the report indicated that there is evidence of some steepening of the beach; with a narrow strip of erosion in line with and perpendicular to the end of the South Pier. In contrast, erosion to the south is tending to flatten the beach. The general pattern of change highlights the importance of the South Pier as the main control feature, holding the northern section of South Beach.



Source: Royal HaskoningDHV, 2012 [13]

**Figure 2-9 - Beach Change 2006 to 2012/2013**

A further comparison of beach sections using LiDAR data from 2009 with latest dataset dated 2015 (Lle.gov.uk) has also been undertaken and contained in Appendix A. Over this period there was very little difference in measurements showing a discernible pattern of retreat or steepening. Drawing 5182114-ATK-MAR-GEN-DR-C-8001 (which is also contained in Appendix A) shows a comparison between 2015 LiDAR and a 2019 topographic survey. Sections E and F on the above referenced drawing show that some local increase of the shingle has occurred. These sections are to the northern extent of the South Beach, supporting the previous observations that shingle accretes in this area.

Within the harbour, sediment is brought in from both the sea and from upstream river flows. Accretion in the harbour is, however, limited, particularly due to the limited offshore sediment supplies along the Aberaeron coastline and the presence of the two piers, preventing ingress of sediment. Bed levels vary between the north and south sides of the harbour. The River Aeron channel runs along the northern side of the harbour. Here, the bed level is lower as the river flows prevent accumulation of sediment, whereas on the southern side of the harbour bed levels are higher where sediment has accumulated. As a result, up to 2,000 tonnes of material is dredged from the harbour by Ceredigion County Council (CCC) annually in March (usually on the last Spring tide before the end of March). The dredging is timed to coincide with the start of annual summer use of the harbour moorings. Boats are removed from the harbour at the end of October for storage over winter (due to the risk of storm damage) and returned to the harbour at the end of March. The arisings are deposited on the northern end of the South Beach. Pwll Cam (smaller inner harbour) is not dredged.

## 2.4.2. Predicted natural changes

The Shoreline Management Plan 2 [5] indicates that Aberaeron South is an erosional coastline, dominated by wave direction and geology. At the time the SMP was written the long term effect on erosion of the 2009

Aberaeron North Beach defences was not able to be assessed but is likely to have reduced erosion if the design intent was realised.

The effect of sea level rise described in the SMP2 is affected by geology with some areas eroding more rapidly, while in other areas there could be greater accumulation of sediment, but that the area of greatest erosion will vary over time.

### 2.4.3. Predicted anthropogenic changes

The only predicted man-made changes are likely to be related to the creation of sea defences, to reduce the effect of flooding from waves, rising sea levels and erosion. With limited drift for this stretch of coast, the predominant effect of these changes is likely to reduce rates of erosion. The removal of the South Pier either deliberately or through lack of maintenance and collapse would have a significant effect on the width of the beach, lead to increased erosion and initially spilling of sediment material into the navigable channel.

### 2.4.4. Short term impacts due to storms and ability to recover

The impact of storms on the South Beach is likely to result in movement of shingle onto the hinterland behind, along with potential erosion of sandy hinterland to the more central part of the South Beach. The loss of the hinterland to the central part of the beach will be an irreversible loss, whereas the movement of shingle will require increasingly frequent intervention to move shingle off the car park and roadside areas as sea levels increase.

The ability of the beach to naturally recover to its existing situation is considered very low because the level of sediment supply from the adjacent cliffs is insufficient.

### 2.4.5. Protected Sites and Habitats

The Scheme lies within the Aberarth-Carreg Wylan SSSI, designated for its geological, geomorphological and biological interest. The geology and geomorphological processes have enabled a wide range of marine and coastal wildlife to exist along this stretch of coastline, including a large extent of *Sabellaria alveolata* reef. The SSSI extends from the Afon Arth at Aberarth in Ceredigion, south to Carreg Wylan near Ceibwr Bay in North Pembrokeshire. At Aberaeron, the reef is visible at low tide on the lower foreshore along North Beach. A walkover survey carried out by a marine ecologist in summer 2020 did not identify any visible reef area at low tide along South Beach. This is also detailed in NRW mapping of the reef undertaken in 2021.

Specific locations of geological interest listed in the SSSI citation sheet on NRW's website<sup>1</sup> are: Cwmtudu (cliffs and foreshore), Traeth Penbryn (cliffs), Mwnt (cliffs) and Poppit (shore platform). These are all south of Aberaeron beyond the extent of the works to be undertaken (Cwmtudu is the closest at 11km south of Aberaeron).

There are no Regionally Important Geological and Geomorphological Sites (RIGS) in the vicinity of the works. The closest site is south of the scheme at New Quay; the New Quay Coastal Section and Frondolau Old Quarry.

#### Intertidal habitats

The intertidal zone of Aberaeron South Beach is gently sloping, composed of shingle on the upper beach, and sand on the lower beach, which makes it popular with tourists, locals and visitors alike.

The Countryside Council for Wales (CCW, now Natural Resources Wales (NRW)) undertook habitat surveys around the whole of the Welsh coast between 2007 and 2010 known as the HABMAP Scheme. Data from this survey has been downloaded and the intertidal biotopes in the area of the Scheme assessed.

Intertidal habitat types of conservation importance identified within the area of the Scheme include *Sabellaria alveolata* (Honeycomb worm) reefs on sand-abraded eulittoral rock in the area next to South Pier and along South Beach and extending into the subtidal zone.

The Honeycomb worm (*Sabellaria alveolata*) form littoral biogenic reefs (reefs made of living creatures, in the lower intertidal area and shallow subtidal), which help to stabilise the boulders and cobbles.

<sup>1</sup> [www.naturalresources.wales/media/641262/SSSI\\_0355\\_Citation\\_EN0018c6a.pdf](http://www.naturalresources.wales/media/641262/SSSI_0355_Citation_EN0018c6a.pdf) [Accessed March 2021]

Despite *S.alveolata* being identified as present in the HABMAP survey, an ecological walkover survey carried out in 2020 by a marine ecologist found no *S.alveolata* reefs or encrustations in the intertidal area along South Beach or around the piers. Mussel beds on North Beach were visible at low tide. Species observed on the wooden groynes and piers included limpets, barnacles and seaweed species. Images taken during the site visit of the head of the South Pier, groyne at the base of the South Pier and a weathered groyne along South Beach show no evidence of *S.alveolata* reefs. Further discussion of *S.alveolata* in the subtidal zone is discussed in the next section below.

### Subtidal habitats

A subtidal habitat survey was carried out in September 2019 by Eco Marine Consultants as part of the Scheme design (see Figure 2-10). The survey used a Remotely Operated Vehicle (ROV) or drop-down video to survey the seabed offshore of the harbour entrance. The survey was undertaken to establish the benthic habitats present as well as any species of conservation importance, which would be impacted by the footprint of the proposed breakwater. All ROV footage and image analysis was undertaken with JNCC guidance given in the Marine Monitoring Handbook (JNCC, 2001), the JNCC guidance on assigning benthic biotopes (Parry, 2015) and the NMBAQC and JNCC epibiota interpretation guidelines (Turner *et al.*, 2016). Biotopes recorded were assigned in accordance with the EUNIS classification scheme as shown in Figure 2-10 below.

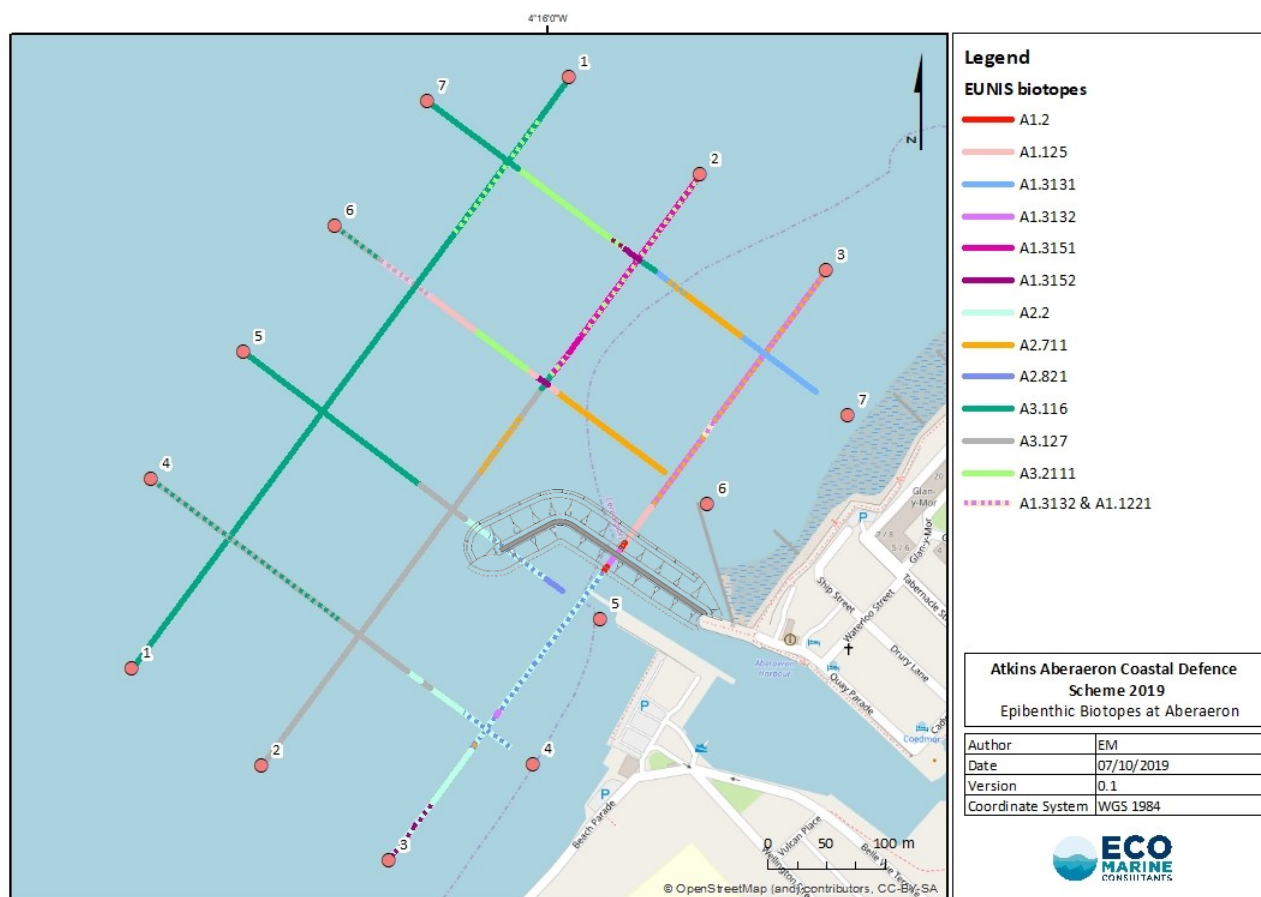


**Figure 2-10 - Subtidal Survey 2019 Biotope Distribution**

A total of 12 intertidal and shallow subtidal biotope complexes were identified suggesting a diverse and ecologically varied site. There were numerous stretches along each of the transects where two habitats were intermittently present. Where this was the case, two biotopes have been recorded in 'mosaic' form.

All of the fauna identified were typical for the intertidal and shallow subtidal habitats and are generally widespread along the coast of west Wales.

## 2.4.6. Potential sources, pathways and receptors

Using the example of Figure 2 in NRW Report 243, and based on the understanding of the available data, Table 2-6 below summarises the links between potential sources and their effects on the marine physical environment.

**Table 2-6 - Identification of potential sources, pathways and receptors**

| Potential source                                                                                                                                                                | Potential pathways from changes to marine physical environment processes                                                                                                                                                                                                                                                                   | Receptor groups                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>New Sea Defences</b> <ul style="list-style-type: none"> <li>Harbour walls</li> <li>Breakwater</li> <li>Groynes</li> <li>Rock revetment</li> <li>Beach Nourishment</li> </ul> | <ul style="list-style-type: none"> <li>Waves-&gt;Sediment transport-&gt;changes in seabed level/changes to inter-tidal coastal morphology/changes to the bed level of the navigable channel.</li> <li>Currents-&gt;Scour/erosion</li> <li>Water temperature</li> <li>Suspended sediment plumes</li> <li>Localised seabed change</li> </ul> | Marine & Coastal Physical Processes<br><br>Marine Water & Sediment Quality<br><br>Marine & Coastal Ecology<br><br>Flood Risk<br><br>Socioeconomics |
| <b>Retained Sea Defences</b> <ul style="list-style-type: none"> <li>South Pier</li> <li>Groynes</li> </ul>                                                                      |                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                    |
| <b>River Aeron</b>                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                    |

### 2.4.6.1. Potential sources

#### New Sea Defences

- Harbour walls**

Raised sea defences are proposed within the harbour itself, this is to reduce the effect of wave overtopping and prevent inundation due to sea level rise. The effect of raising existing sea defences on coastal processes would be negligible. Conversely, if the existing wall was removed or allowed to fail, erosion of the coastline would take place.

- Breakwater**

The breakwater structure extends from high water to below low water i.e. the full intertidal range. It has potential to affect currents and patterns of sediment deposition and accretion. The breakwater structure will reduce wave heights entering the harbour which in turn will reduce the height of the walls required within the harbour.

- Rock revetment**

The proposed rock revetment is along the high-water line of the South Beach. The rock revetment will reduce wave overtopping and prevent erosion. The rock revetment will reduce reflection of waves and limit any effect on its immediate foreshore. The effect on coastal processes is likely to be limited to reducing erosion. There is limited benefit in carrying out computational modelling of the effect of the rock revetment and understanding of the coastal processes can be drawn from information in the SMP2.

- **Beach Nourishment**

The proposed beach nourishment is along the high-water line of the South Beach. The beach nourishment will reduce wave overtopping and prevent erosion. The location of the nourishment is in a location where annual dredging disposal already occurs and the pattern of dispersal of the shingle is well understood from observations which show there is very little movement of material taking place currently. The effect on coastal processes is likely to be limited to reducing erosion. There is limited benefit in carrying out computational modelling of the effect of the beach nourishment and understanding of the coastal processes can be drawn from information in the SMP2.

## **Retained Sea Defences**

- **South Pier**

As discussed in Section 2.4.1 above and within the SMP2, the South Pier is a critical structure in retaining the beach and maintaining the navigable channel.

- **Groynes**

Timber groynes are already in place on the beach and have a role in containing shingle in bays along the South Beach but have reached the end of their design life. The groynes show that there has not been much recession of the beach over the lifetime of the groynes (likely to be in excess of 50 years). Replacement will be on a like for like basis. Given the observations in Section 2.4.1 above, the groynes together with the South Pier contribute to slowing migration of shingle to the north and slowing the effects of sediment migration. The effect on the coastal processes is likely to be limited to reducing erosion and with like for like replacement there is no change to the status quo. There is limited benefit in carrying out computational modelling of the effect of the groynes and understanding of the coastal processes can be drawn from information in the SMP2.



**Figure 2-11 - Existing timber groynes on South Beach**

- **River Aeron**

Fluvial currents cause river-bed material to travel downstream. Gravel sediment is deposited in the harbour, at a rate of 2,000 tonnes per annum and is subsequently mechanically removed and deposited on the South Beach (Marine Licence DML1758). No sediment plumes have been observed that would indicate high levels of suspended materials.

#### 2.4.6.2. Potential pathways

The following potential pathways from changes to marine physical environment processes are outlined below:

- **Waves**

The hydrodynamic effect of waves is considered to be the main factor in driving sediment transport. Sediment movements are anticipated to result in changes in seabed level, changes to inter-tidal coastal morphology and changes to the bed level of the navigable channel.

- **Currents**

Currents are anticipated to be less of an influence on coastal processes than the wave effects above. However, flows from the River Aeron keep the navigable channel clear in the harbour through the natural mechanism of scour. Fluvial currents would have an influence on materials carried offshore. No observable erosion effects have been seen from the river current, despite a record river level recorded during Storm Callum in 2018.

- **Water temperature**

Water temperature is not considered a significant factor in this area, since there is no change anticipated. There are no physical or man-made processes which increase or decrease water temperature.

- **Suspended sediment plumes**

The presence or creation of sediment plume is not considered a significant factor in this area, to the extent that no observable sediment plumes have been noted as being characteristic of the Aeron. No change is expected to the incoming sediment sources. However, direct measurement of sediment suspension could be obtained by taking water samples to further verify its significance. Routine water quality monitoring data that includes suspended sediment measurements would remove this need, if this data exists elsewhere.

- **Localised seabed change**

The geology is formed from well bedded glacial deposits that are not prone of scour as evidenced in the stability of the North Beach in conjunction with the presence of the engineering works (groynes and breakwater already present). Superficial deposits consist of patches of sand to the upper shore of the North Beach and sandy lower foreshore to the South Beach but is predominantly gravel material within the intertidal area of the North Beach. The harbour is also entirely gravel alluvium. The changes are likely to be local in proximity to proposed structures, however, these effects are primarily as a result of the effects of waves and not intrinsically from localised seabed change. As detailed in section 2.2.1.2 the maximum likely depth affected in the close vicinity of the proposed breakwater is 250mm where there are current superficial deposits of sand or clay.

Summarising the above, the effects of **waves** needs to be considered in identifying likely significant impacts, as this is the main factor identified above.

#### 2.4.6.3. Potential receptor groups

The following receptor groups have been identified as potentially being affected by the proposed engineering works:

- **Marine & Coastal Physical Processes**

There is potential to affect these processes in the future and this should be considered a key factor in sediment transport.

- **Marine Water & Sediment Quality**

There is potential to effect water and sediment quality. Modelling is unlikely to add a significant additional degree of understanding to the assessment of the potential impacts and they can be assessed through desk study. A Water Framework Directive Assessment will be carried out as part of the impact assessment.

- **Marine & Coastal Ecology**

This is closely linked to any changes to the coastal processes which may affect habitats and species. The outputs of the assessment of impacts to coastal processes will be used to update and inform the impacts to marine and coastal ecology and protected features.

- **Flood Risk**

Extensive modelling of flood risk has taken place to assess the impacts of wave overtopping and sea level rise in combination with fluvial flooding. For further detail refer to the Flood Consequence Assessment. [7]

- **Socioeconomics**

The impact of flooding on socioeconomics has been considered in a separate FCERM Business Case and will be more widely considered within the EIA. For further detail refer to document ref 5182114-ATK-MAR-GEN-CP-C-7000.

In summary, studies will be focussed on receptor groups of the **marine and coastal processes** and the **marine and coastal ecology**.

## 2.4.7. Summary of key sources, pathways and receptors

From the sections above, the items highlighted in green in Table 2-7 below will form the areas of future study to be considered.

**Table 2-7 - Potential sources, pathways and receptors to be considered**

| Potential source                                                                                                                                                                   | Potential pathways from changes to marine physical environment processes                                                                                                                                                                                                                                                                           | Receptor groups                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| New Sea Defences <ul style="list-style-type: none"> <li>• Harbour walls</li> <li>• Breakwater</li> <li>• Groynes</li> <li>• Rock revetment</li> <li>• Beach Nourishment</li> </ul> | <ul style="list-style-type: none"> <li>• Waves-&gt;Sediment transport-&gt;changes in seabed level/changes to inter-tidal coastal morphology/changes to the bed level of the navigable channel</li> <li>• Currents-&gt;Scour/erosion</li> <li>• Water temperature</li> <li>• Suspended sediment plume</li> <li>• Localised seabed change</li> </ul> | Marine & Coastal Physical Processes<br><br>Marine Water & Sediment Quality<br><br>Marine & Coastal Ecology<br><br>Flood Risk<br><br>Socioeconomics |
| Retained Sea Defences <ul style="list-style-type: none"> <li>• South Pier</li> <li>• Groynes</li> </ul>                                                                            |                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                    |

## 2.4.8. Summary of assessment objectives

Given the above consideration of sources/pathways/receptors, the assessment can be summarised as determining the effect of the breakwater as a source of change. The pathways created by waves will need to be considered to understand its effect on coastal processes and changes to the bed level or patterns of sediment deposition or scour. The effect of the breakwater on currents will need to be reviewed. The assessment will be primarily concerned with the effect on marine and coastal processes, and inform the effect on intertidal and subtidal ecology.

The objectives of the assessment will be to:

- Understand the effect of the construction and operation of the breakwater as a source of change.
- Understand the potential pathway of change to the marine physical environment and specifically:
  - The changes to sea-bed level in the inter-tidal area.

- The changes to inter-tidal coastal morphology.
- The periods of time over which areas of reef and protected areas might be submerged by sediment (to inform an ecological assessment of the reef habitat).
- The changes to sea-bed level in the location of the navigable channel or offshore of the breakwater.

#### 2.4.9. Conceptual model

Aberaeron is within Policy Development Zone 8, Coastal Area C of the West of Wales Shoreline Management Plan 2 (Haskoning, 2011). Sediment transport in the wider Cardigan Bay is characterised by a predominantly, wave-driven northerly drift of material (Halcrow, 2002). Nearer to shore, to the south of Aberaeron, Pen-y-Gloyn cliffs provide some control and sediment supply to the shoreline. Sediment transport has been considered in two fractions; the sand on the lower foreshore and the shingle on the upper.

A baseline conceptual model of the coastal geomorphology has been developed by Atkins (see Figure 2-12), which splits the processes into those affecting the sand (yellow arrows) and the shingle fractions (orange arrows). The key coastal geomorphological features are shown in oval boxes. The associated yellow and orange arrows indicate the direction/s of sediment transport. Anthropogenic influences are shown in black boxes with white text, with their associated dashed arrows indicating the features that they influence. The relative significance of each process is illustrated by the size of the connecting lines/arrows. The dashed red lines indicate the extent of each policy unit.

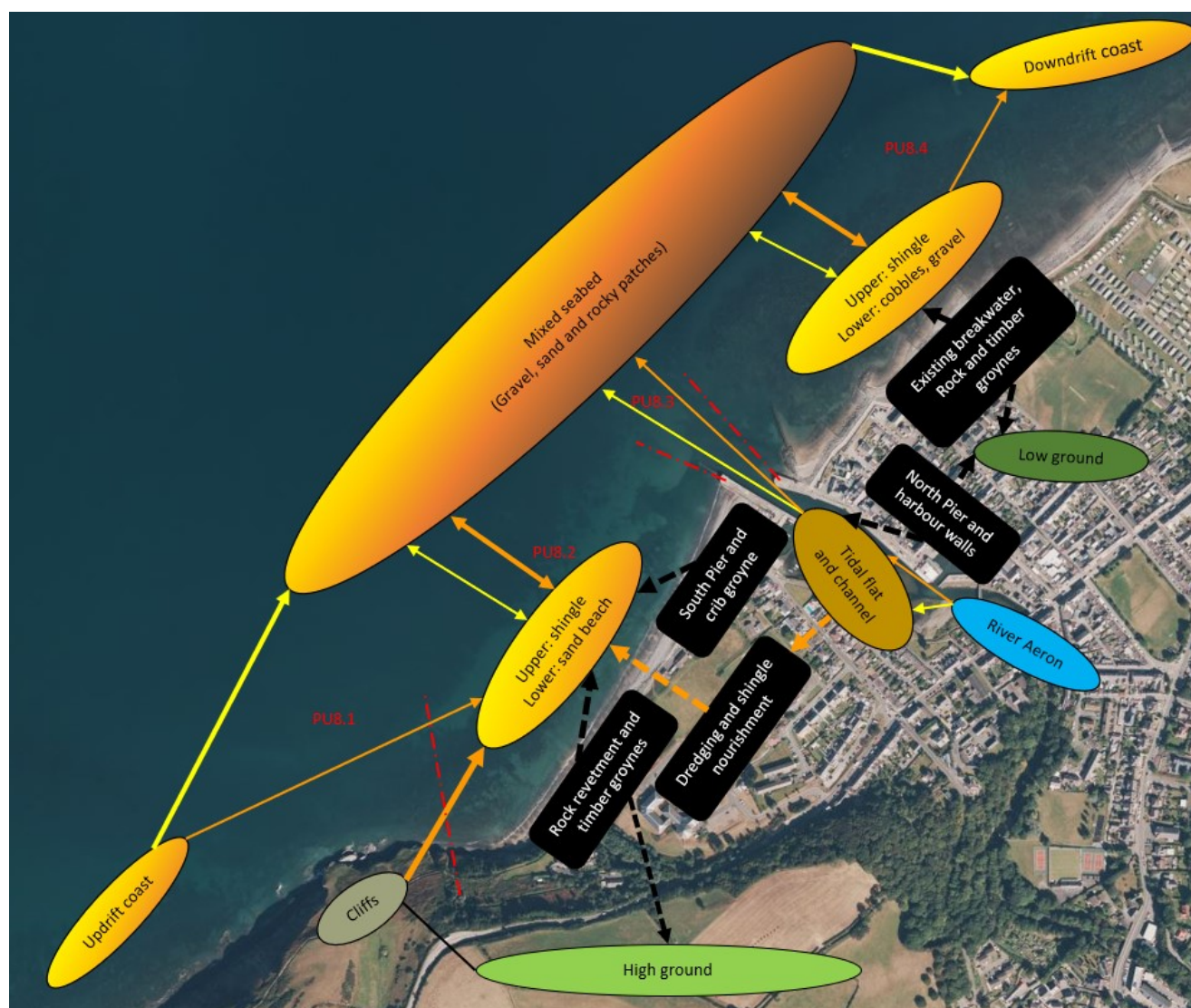


**Figure 2-12 - Conceptual model of baseline coastal geomorphology at Aberaeron**

## 2.4.10. Zone of Influence

Based on the conceptual understanding outlined above, consideration was given to the zone of influence likely to be affected by the proposed breakwater structure.

Reference was made to SMP2 for understanding of the coastal processes in relation to sediment transport and is covered within the detail in section 2.4.1. A brief summary from the SMP2 is listed below in relation to each section of the coast described in respect of Coastal Processes.

- Aberaeron South Beach (PU 8.2) - Limited drift from the South, fed by long term erosion of the cliffs and the sediment is retained at Aberaeron South Beach, or through to the area to the north.
- Aberaeron Harbour (PU 8.3) – Consists of the harbour entrance downstream of the River Aeron, existing South Pier, North Pier and existing breakwater and harbour walls.
- Aberaeron North Beach (PU 8.4) – The existing sea defence works help control the northward drift which is recognised to be relatively high in comparison to the weak drift along other parts of this coast. Beyond the groynes to the north-east accretion occurs due to cliffs further north.
- Aberarth frontage (PU8.5 and 8.6) – The frontage gains sediment principally from the cliffs directly to the south and beach material is retained in position partly by cliffs to the north.



**Figure 2-13 - Zone of influence along coastal frontage**

In considering the extent of the Zone of Influence, consideration was also taken of likely interaction of the proposed breakwater with waves. This exercise has been carried out for the numerical wave modelling [14] completed by Atkins. A key factor is that wave energy is dissipated on the structure through wave breaking, run-up and overtopping, resulting in partial reflection. Reflected wave energy causes local increases to wave heights on the seaward side of the structure (within 3-4 wavelengths). The presence of the breakwater also affects the pattern of tidal flows local to the structure, with some locally increased current speeds around the toe of the structure. Considering these factors, a zone of influence of <1km from the structure can be inferred.

Further work has been undertaken, as detailed in Appendix B that indicated that the zone of influence is within this area and extends to around 500 to 600m of the breakwater.

### 2.4.11. Changes to sediment and coastal processes

This section updates the previous report, following discussions held with NRW and Atkins undertaking further modelling work. Discussions with NRW Advisory indicate that they have concerns regarding the possible changes that the new breakwater could have on coastal processes. These focus on the possible decrease in sediment supply to the *Sabellaria* reef on North Beach. They do not have concerns regarding any *Sabellaria* on South Beach as this is considered to be more ephemeral and not creating 'reef' structures (as are defined in NRW, 2019). They also do not have concerns regarding an increase in sedimentation or smothering of North Beach.

As shown in Appendix B, models have been created for bed shear stress, flows and current speed for baseline conditions (now) and to model the potential changes the new breakwater could have on these parameters.

Four different scenarios were modelled to produce outputs showing the influence of both tidal currents and wave-induced currents. The model scenarios were carried out for a baseline condition and for the inclusion of the breakwater:

- Tide only
- Tide and typical Afon Aeron flows
- 1 in 1 year wave condition and typical Afon Aeron flow
- 1 in 75 year wave condition and Afon Aeron storm flow

The following sections show the run outputs for tide and typical Afon Aeron flows, as these represent 'day to day' conditions that would be experienced following the construction of the breakwater. They therefore represent the conditions that would exert the most influence over the environment in which the *Sabellaria* / reef feature exists.

#### Changes in current speed

The following Figure 2-14 and Table 2-8 shows the total areas with at least a 1% relative difference in current speeds from the baseline runs with the presence of the breakwater. It also shows in outline the area of *Sabellaria* reef monitored by NRW annually.

The plots show areas with mean increases in current speed due to the presence of the breakwater in red, and areas with mean decreases in blue. The reason the plots are not expressed in magnitudes of relative difference (%) is because in some areas, small deviations from the baseline output show large relative differences in the breakwater runs. For example, a current speed output from the baseline run: 0.0002 m/s, and breakwater run: 0.0006 m/s results in a 200% relative increase but would only be a very small actual change in current speed.

**Table 2-8 - Approximate areas affected by change in current speed >1%.**

| Model run scenario                                              | Area of increased current speed (m <sup>2</sup> ) | Area of decreased current speed (m <sup>2</sup> ) | Total area affected (m <sup>2</sup> ) |
|-----------------------------------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------|
| <b>Tide Only</b>                                                | 149,900                                           | 329,870                                           | 479,770                               |
| <b>Tide with typical Afon Aeron flow</b>                        | 150,310                                           | 332,290                                           | 482,600                               |
| <b>1 in 1 year wave condition &amp; typical Afon Aeron flow</b> | 340,180                                           | 249,600                                           | 589,780                               |
| <b>1 in 75 year wave condition &amp; Afon Aeron storm flow</b>  | 357,180                                           | 156,810                                           | 513,990                               |

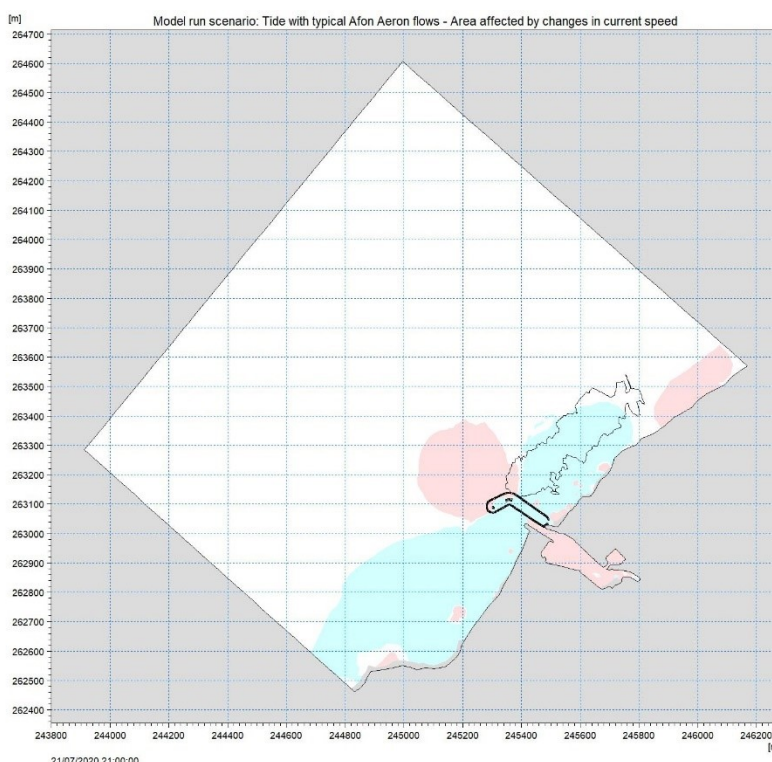


**Figure 2-14 - Run scenario: Tide with typical Afon Aeron flows - Area affected by relative changes in current speed.**

Decreases in current speed to the south of the breakwater are to be expected. This may slightly slow the rate of erosion of sand from South Beach, however, it is not expected to affect the overall pattern of sediment movement shown in the conceptual model (Figure 2-12). Sediment will continue to be lost to the offshore area and move inshore along South Beach towards South Pier.

The decrease in currents on North Beach will similarly not reduce the sediment supply to the *Sabellaria* – reduced flows may retain sediment in the area slightly longer.

Some increases in flow are shown in a localised area off the end of the new breakwater. The breakwater is 220m long and this area of influence is approximately the same length again, extending approximately 250m offshore.

The total area that might be affected by any change in current speed >1% are therefore those areas on South and North Beach affected by a decrease in current speed plus the area at the end of the new breakwater affected by an increase in current speed. While it can be seen that much of the *Sabellaria* on North Beach within 500m of the new breakwater is affected by a change in flow, this needs to be considered in the context of what those changes mean to the biology of the *Sabellaria* in this area, as well as in the context of the feature of the SAC.

**Table 2-9 - Approximate areas affected by change in current speed >1% for tide with typical Afon Aeron flow**

| Location of change            | Area (m2) |
|-------------------------------|-----------|
| South Beach area of decrease  | 228,789   |
| South Beach area of increase  | 2,274     |
| Aberaeron Harbour / mouth     | 27,690    |
| Seaward of the new breakwater | 85,611    |
| North Beach area of decrease  | 101,075   |
| North Beach area of increase  | 34,326    |

The plots show all **relative** changes in current speed >1% between the baseline and breakwater models. The range of **actual** current speed in the baseline and breakwater models is shown in Table 2-10 and Figure 2-15. This shows that the absolute change in the range of current speed of the baseline compared to the breakwater models are very small. This means that even large relative changes (much greater than 1%) are very small in absolute terms.

The changes are too small to significantly alter the overall coastal processes or change the conceptual model of and transport process for sediment in the area. They are too small to affect the exposure climate of the area – it will remain an exposed coast with the same coastal processes as shown in Table 2-11. As such, these very small changes are not expected to impact the *Sabellaria* reef, or the wider intertidal reef feature. They are also too small to significantly impact the subtidal reef feature of the SAC.

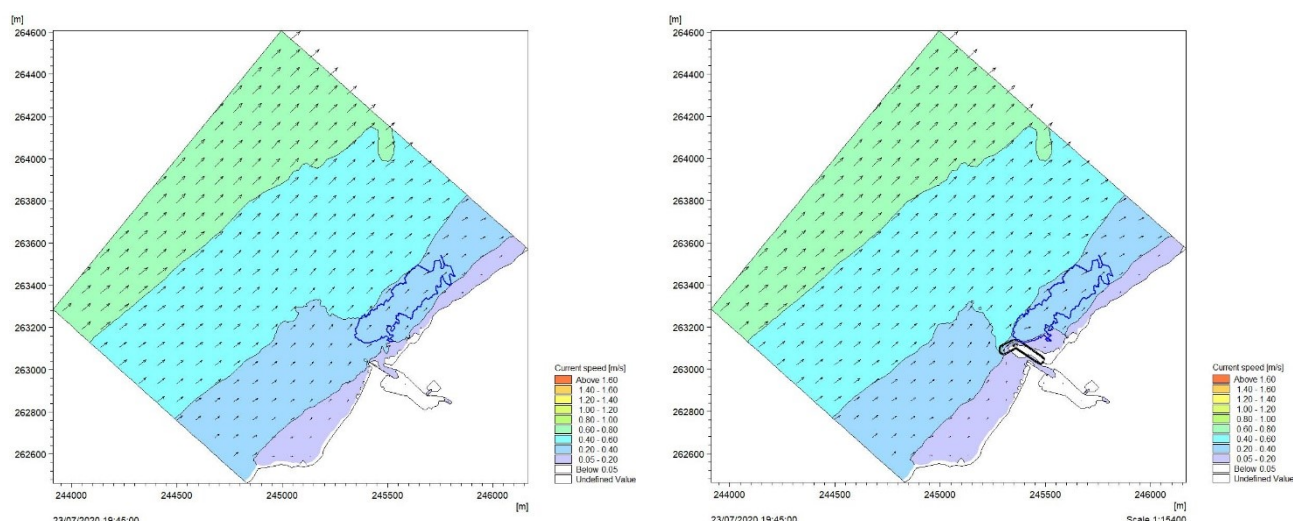


**Figure 2-15 - Tide with typical Afon Aeron flows, current speed – baseline and proposed**

**Table 2-10 – Absolute change in the range of current speeds between baseline and breakwater models for Tide with typical Afon Aeron flows**

|              | Over whole model             |                                     | Over Sabellaria Reef on North Beach |                                     |
|--------------|------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
|              | Baseline current speed (m/s) | With breakwater current speed (m/s) | Baseline current speed (m/s)        | With breakwater current speed (m/s) |
| <b>Max</b>   | 0.65                         | 0.65                                | 0.25                                | 0.25                                |
| <b>Min</b>   | 0.00                         | 0.00                                | 0.08                                | 0.08                                |
| <b>Range</b> | 0.65                         | 0.65                                | 0.17                                | 0.17                                |
| <b>Mean</b>  | 0.21                         | 0.20                                | 0.19                                | 0.19                                |

The maximum area over which any change in current speeds occur are spatially limited around the new breakwater and that this area of influence is within 500m to 1km of the structure. The spatial extent of these changes are insufficient to materially alter the wider coastal processes impacting the supply of sediment to the area.

Furthermore, the absolute changes in current are very small such that they will not change the volume or grain size of sediment mobilised in the area sufficiently to alter the among or type of sediment available for *Sabellaria*.

The changes are very small and very localised such that changes to the geology, sedimentology, geomorphology, hydrography and meteorology, water and sediment chemistry and biological interactions that take place along the coast, as these are driven by much larger processes which will not be interrupted or affected by the presence of the breakwater. The physical biological and chemical structure and functions necessary for the long-term maintenance and quality of the structure and function of habitat will not be affected.

### Changes in bed shear stress

The following figures express the total areas with at least a 1% relative difference in current speeds from the baseline runs with the presence of the breakwater. The plots show areas with mean increases in bed shear-stress due to the presence of the breakwater in red, and areas with mean decreases in blue. The reason the plots are not expressed in magnitudes of relative difference (%) is because in some areas, small deviations from the baseline output show large relative differences in the breakwater runs. For example, a bed shear-stress output from the baseline run: 0.001 N/m<sup>2</sup>, and breakwater run: 0.002 N/m<sup>2</sup> results in a 100% relative increase but would only be a very small actual change in bed shear stress.

**Table 2-11 - Approximate areas affected by change in bed shear-stress.**

| Model run scenario                                   | Area of increased bed shear-stress (m <sup>2</sup> ) | Area of decreased bed shear-stress (m <sup>2</sup> ) | Total area affected (m <sup>2</sup> ) |
|------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|---------------------------------------|
| Tide Only                                            | 278090                                               | 437590                                               | 715680                                |
| Tide with typical Afon Aeron flow                    | 285040                                               | 445160                                               | 730200                                |
| 1 in 1 year wave condition & typical Afon Aeron flow | 558410                                               | 291800                                               | 850210                                |
| 1 in 75 year wave condition & Afon Aeron storm flow  | 645560                                               | 163490                                               | 809050                                |

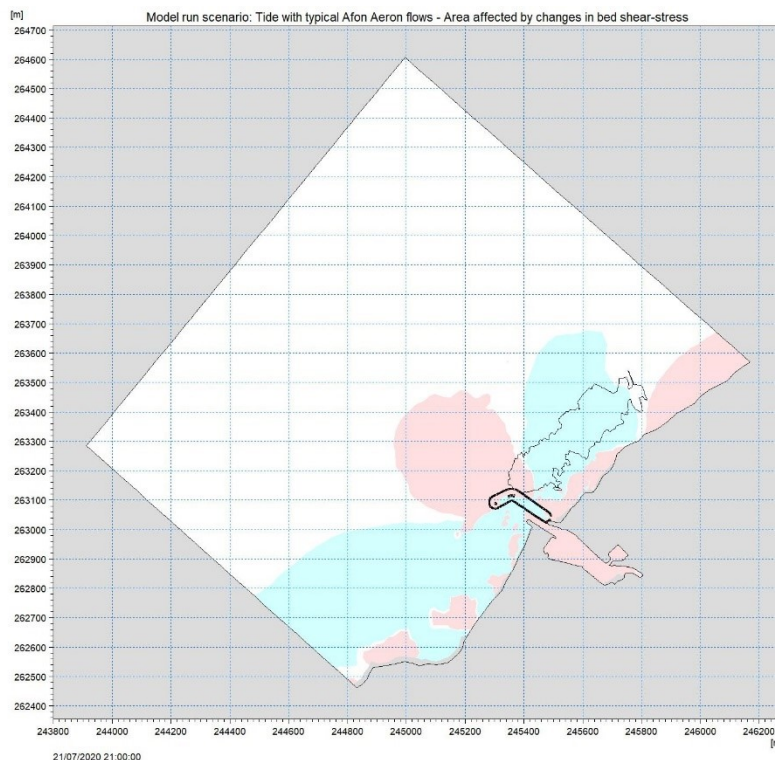


**Figure 2-16 - Run scenario: Tide with typical Afon Aeron flows – Area affected by relative changes in bed shear-stress.**

Similar patterns in the changes to bed shear stress can be seen as to those in the current speed model outputs – the same general areas experience a relative increase or decrease in bed shear stress. The size of area affected by relative changes in bed shear stress are greater than those for changes in current speed, but still restricted to approximately 600m from the breakwater. This may mobilise slightly larger particles of sediment in this area. The general on / offshore and northerly sediment processes are not expected to change as a result of this change.

A reduction in bed shear stress on South Beach corresponds to a decrease in current speed in this area and may also help retain sediment in the area, slightly reducing the rate of beach lowering / erosion in this area.

The change in bed shear stress in the harbour may mobilise more / larger sediment particles in the harbour area, which may slightly increase sediment transport. The reduction immediately in the 'shadow' to the south of the new breakwater could then cause this to reduce with sediment not being transported as far from the harbour mouth. This may increase the rate of sedimentation in the approach to the harbour, which may result in a need for dredging. As the intent would be to continue the practice of adding any dredged sediment to South Beach, the overall transportation of sediment from the river to the coastal area is unlikely to be affected significantly.

The decrease in bed shear stress on North Beach will similarly not reduce the sediment supply to the *Sabellaria* and may retain sediment in the area slightly longer.

Some increases in bed shear are shown in a localised area off the end of the new breakwater. The breakwater is 220m long and this area of influence is approximately twice the length again, extending no more than approximately 600m offshore.

The total area that might be affected by any change in bed shear stress >1% is therefore that area on North Beach affected by a decrease in current speed plus the area at the end of the new breakwater affected by an increase in current speed. While it can be seen that much of the *Sabellaria* on North Beach within 500m of the new breakwater is affected by a change in flow, this needs to be considered in the context of what those changes mean to the biology of the *Sabellaria* in this area, as well as in the context of the feature of the SAC.

**Table 2-12 - Approximate areas affected by change in bed shear stress >1% for tide with typical Afon Aeron flow**

| Location of change            | Area (m2) |
|-------------------------------|-----------|
| South Beach area of decrease  | 288,749   |
| South Beach area of increase  | 2,274     |
| Aberaeron Harbour / mouth     | 27,690    |
| Seaward of the new breakwater | 85,611    |
| North Beach area of decrease  | 101,075   |
| North Beach area of increase  | 34,326    |

The plots show all **relative** changes in bed shear stress >1% between the baseline and breakwater models. The range of **actual** bed shear stresses in the baseline and breakwater models is shown in Table 2-13 and in Figure 2-17. This shows that the absolute change in the range of bed shear stresses of the baseline compared to the breakwater models are very small. This means that even large relative changes (much greater than 1%) are very small in absolute terms.

The changes are too small to significantly alter the overall coastal processes or change the conceptual model of and transport process for sediment in the area. They are too small to affect the exposure climate of the area – it will remain an exposed coast with the same coastal processes as shown in Figure 2-12. As such, these very small changes are not expected to impact the *Sabellaria* reef, or the wider intertidal reef feature. They are

also too small to significantly impact the subtidal reef feature of the SAC. This is discussed in more detail in the HRA.

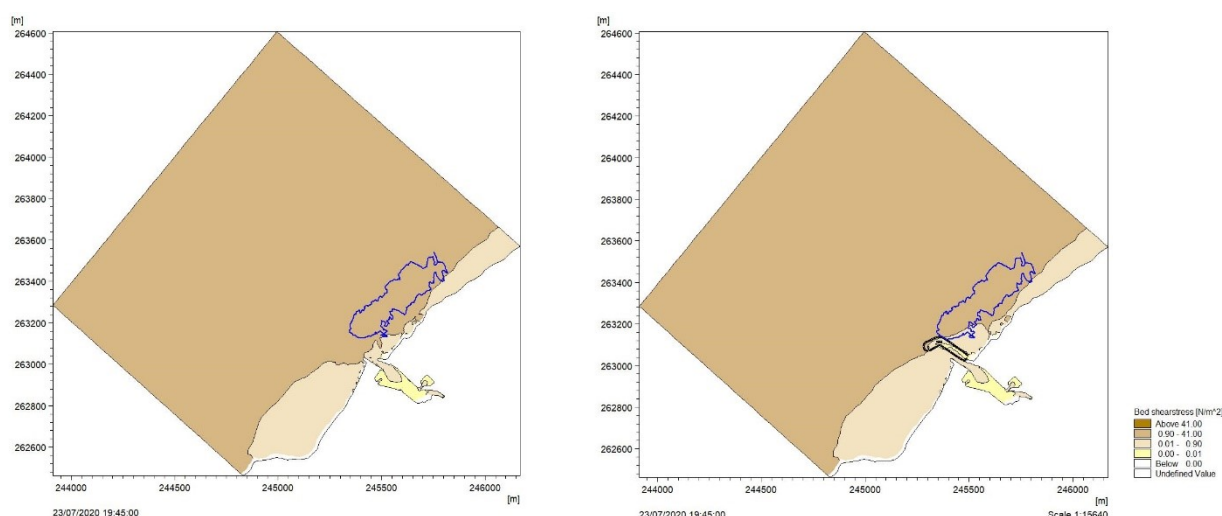


**Figure 2-17 - Tide with typical Afon Aeron flows, bed shear-stress – baseline and proposed**

**Table 2-13 – Absolute change in the range of bed shear stress between baseline and breakwater models for Tide with typical Afon Aeron flows**

|              | Over whole model                              |                                                      | Over Sabellaria Reef on North Beach           |                                                      |
|--------------|-----------------------------------------------|------------------------------------------------------|-----------------------------------------------|------------------------------------------------------|
|              | Baseline bed shear stress (N/m <sup>2</sup> ) | With breakwater bed shear stress (N/m <sup>2</sup> ) | Baseline bed shear stress (N/m <sup>2</sup> ) | With breakwater bed shear stress (N/m <sup>2</sup> ) |
| <b>Max</b>   | 16.95                                         | 16.93                                                | 1.29                                          | 1.27                                                 |
| <b>Min</b>   | 0.00                                          | 0.00                                                 | 0.22                                          | 0.11                                                 |
| <b>Range</b> | 16.95                                         | 16.93                                                | 1.07                                          | 1.16                                                 |
| <b>Mean</b>  | 1.00                                          | 0.96                                                 | 0.86                                          | 0.71                                                 |

The maximum area over which any change in bed shear stress occurs are spatially limited around the new breakwater and that this area of influence is within 500m to 1km of the structure. The spatial extent of these changes are insufficient to materially alter the wider coastal processes impacting the supply of sediment to the area.

Furthermore, the absolute changes in bed shear stress are very small such that they will not change the volume or grain size of sediment mobilised in the area sufficiently to alter the among or type of sediment available for *Sabellaria*.

Given the very high likelihood that the main source of sediment for *Sabellaria* is marine, the lack of impact to coastal processes, the geographically limited area over which any changes will take place and the very small magnitude of those changes, along with the very large area of *Sabellaria* and intertidal reef in the SAC, any changes to bed shear stress will be too small and too localised to significantly impact the subtidal reef feature of the SAC.

The changes are very small and very localised such that changes to the geology, sedimentology, geomorphology, hydrography and meteorology, water and sediment chemistry and biological interactions that take place along the coast, as these are driven by much larger processes which will not be interrupted or affected by the presence of the breakwater. The physical biological and chemical structure and functions necessary for the long-term maintenance and quality of the structure and function of habitat will not be affected.

### Fluvial Sediment Transport

NRW water quality data shows that the River Aeron is low in suspended sediment. Looking at the coast overall, it can be seen that Sabellaria extend north beyond the extent of the SAC boundary as Sabellaria is mapped in Article 17 habitat data as Aberystwyth and beyond. Along this area of coast there are a few small fluvial outfalls but these could not provide a sufficient supply of sediment needed to support such widespread *Sabellaria* growth.

Sediment from the River Aeron is not likely to naturally be deposited on South Beach given its offshore to northwards direction of travel. However, the placement of sediment from CCC's annual dredging of the harbour on South Beach adds to the South Beach 'source' of sediment, before on / offshore movement and then movement further northwards.

### 3. Conclusions

The report provides an understanding of the coastal processes as follows:

SMP 2 outlines:

- That the coastline is influenced by more slope driven processes rather than alongshore sediment drift.
- Longshore sediment transport processes are in a north-easterly direction. However, the amount of sediment transported is considered to be limited due to the limited supplies of sediment. There is very little movement of material offshore.
- Past engineering work in Aberaeron has had little effect on nearby areas due to local areas of drift reversal and natural sediment accumulation.

The maximum Zone of Influence therefore is within a localised area less than 1km in either direction along shore from the harbour entrance.

Beach monitoring carried out also shows stability of beach levels at the South Beach. There has been little, if any, recession of the beach over the lifetime of the groynes (likely to be in excess of 50 years). A further comparison of beach sections since 2009 has also been undertaken and over this period there was very little difference in measurements showing a discernible pattern of retreat or steepening. This reflects the dominant wave direction from the south-west. It is recognised, however, that if this beach is subject to waves from the northwest, then there is likely to be a tendency for the material to return southwards again.

The magnitude of bed change forecast for the beach in the intertidal area is low, given the modelled changes to current and bed stress result in very little change. The hard underlying intertidal platform means the beach is forward of the rest of the coastline and beach materials on the North Beach are well bedded gravels at the surface. Where sands and silts are present in the intertidal area they are patchy and in relatively thin layers typically 200-250mm and up to 400mm maximum.

The presence of the sands and silts sediments within the local area could be mobilised to alter sea-bed levels compared to the baseline conditions. This process already occurs in baseline conditions but the pattern of deposition could alter with proposed works with the likelihood that the *Sabellaria alveolata* reef and other protected features being affected by both sediment accretion and removal. This needs to be considered in the context of what those changes mean to the biology of the *Sabellaria* in this area, as well as in the context of the feature of the SAC and is discussed in the HRA report.

There is transportation of sediment from the River Aeron to the offshore area. The general northwards direction of the offshore sediment transportation plus the on / offshore flows between North Beach and the offshore area suggest that some of this may feed the *Sabellaria* on North Beach. This is not the only source of sediment for North Beach / the *Sabellaria* reef, as the updrift transportation also feeds the offshore area. NRW water quality data shows that the River Aeron is low in suspended sediment. Looking at the coast overall, it can be seen that *Sabellaria* extend north beyond the extent of the SAC boundary as *Sabellaria* is mapped in Article 17 habitat data as Aberystwyth and beyond. Along this area of coast there are a few small fluvial outfalls but these could not provide a sufficient supply of sediment needed to support such widespread *Sabellaria* growth. It is much more likely that the majority of sediment utilised by *Sabellaria* along the whole coast and on North Beach is marine in nature.

The findings of the additional modelling detailed in Appendix B is also discussed in more detail in respect of the significance of the impacts on *Sabellaria* in the revised HRA Report (ref 5182114-ATK-MAR-GEN-RP-EN-3014), dated October 2022.

## 4. References

- [1] Natural Resources Wales, “GN041. Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA),” 2020.
- [2] Pye, K., Blott, S., Brown, J, “NRW Report No 208. Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments,” Natural Resources Wales, Cardiff, 2017.
- [3] Brooks, AJ., Whitehead, PA., Lambkin, DO., “NRW Report No 243. Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Reporting Requirements to inform EIA of Major Development Projects,” Natural Resources Wales, Cardiff, 2018.
- [4] Met Office, “Met Office WAVEWATCH III Wave Model Hindcast Data,” 2020. [Online]. Available: <https://www.metoffice.gov.uk/research/weather/ocean-forecasting/ocean-waves>.
- [5] Royal Haskoning, “West of Wales Shoreline Management Plan 2,” 2011.
- [6] Hyder Consulting, “Aberaeron PAR,” 2013.
- [7] Atkins, “Flood Consequence Assessment, 5182114-ATK-GEN-RP-HY-3401,” 2022.
- [8] Atkins, “Technical note: Aberaeron Coastal Defence Scheme – Desk Study Technical Note. Reference 20181465-GEO-NOT-001,” 2018.
- [9] Eco Marine Consultants, “Aberaeron Seabed Survey: Technial report for seabed imaging survey,” 2019.
- [10] Quantum Geotechnical Limited, “Ground Investigation Factual Report, ref: Q0377/FR.01,” 2020.
- [11] Quantum Geotech, “Aberaeron Coastal Defence, Ground Investigation - Ground Investigation Factual Report, Report No. Q0377/FR.01,” Quantum Geotech, February 2021.
- [12] R. Soulsby, Dynamics of marine sands, London: Thomas Telford Publications, 1997.
- [13] Royal HaskoningDHV, “Ceredigion Beach Profile Monitoring Volume 1,” 2013.
- [14] Atkins, “5182114-ATK-MAR-GEN-RP-C-1033, Aberaeron Coastal Defence Scheme: Options Assessment- Numerical Modelling Report (Rev1),” 2020.
- [15] EcoSpan, “Aberaeron ADCP and Tide gauge deployment Surveys 2020, Report No. ER20-442,” 2020.
- [16] Atkins, “Report on a Ground Investigation at Aberaeron North Beach - SI FR 1.03.,” 2007.
- [17] Atkins, “Environmental Statement, Appendix K,” 2021.

# Appendices

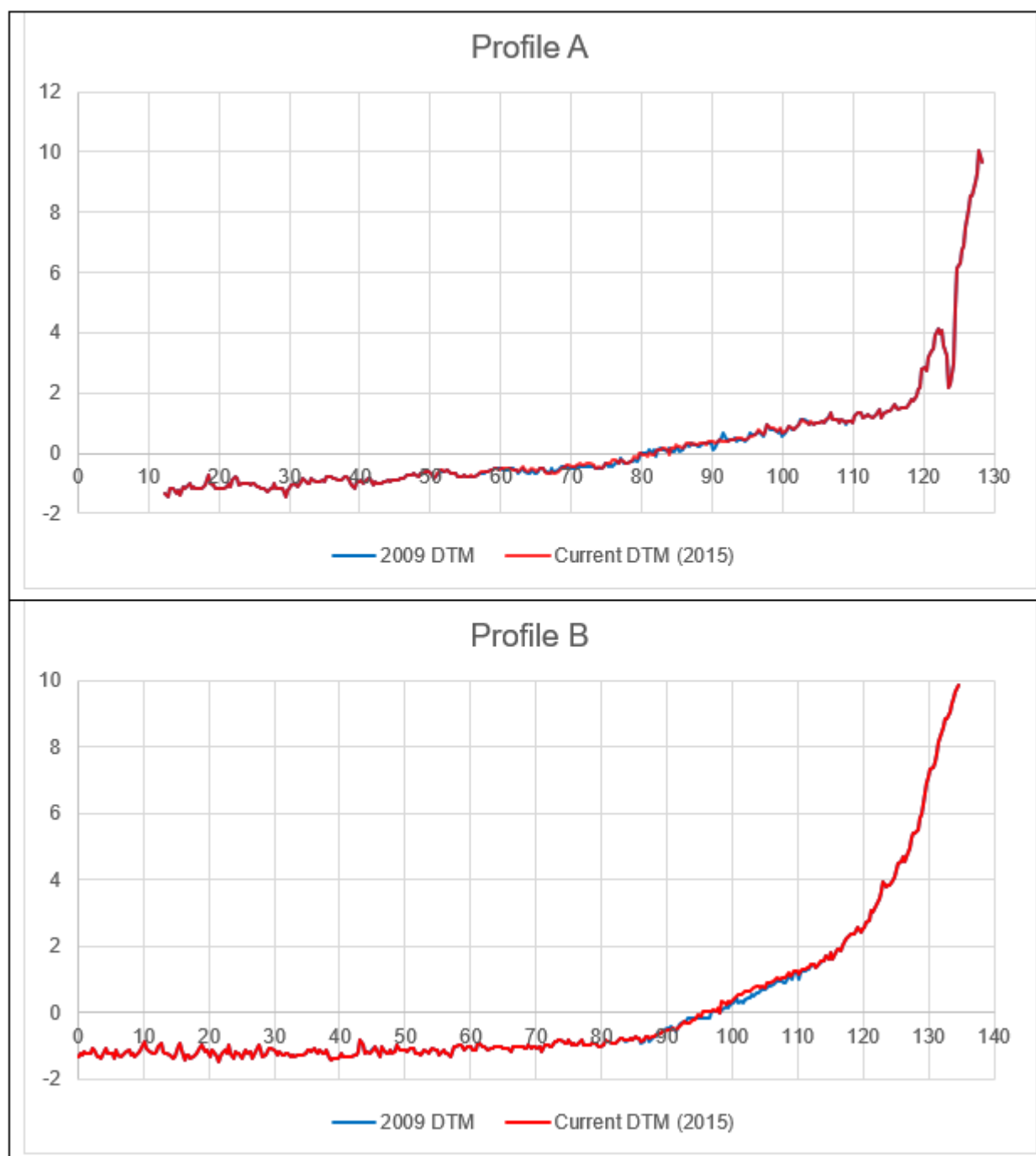


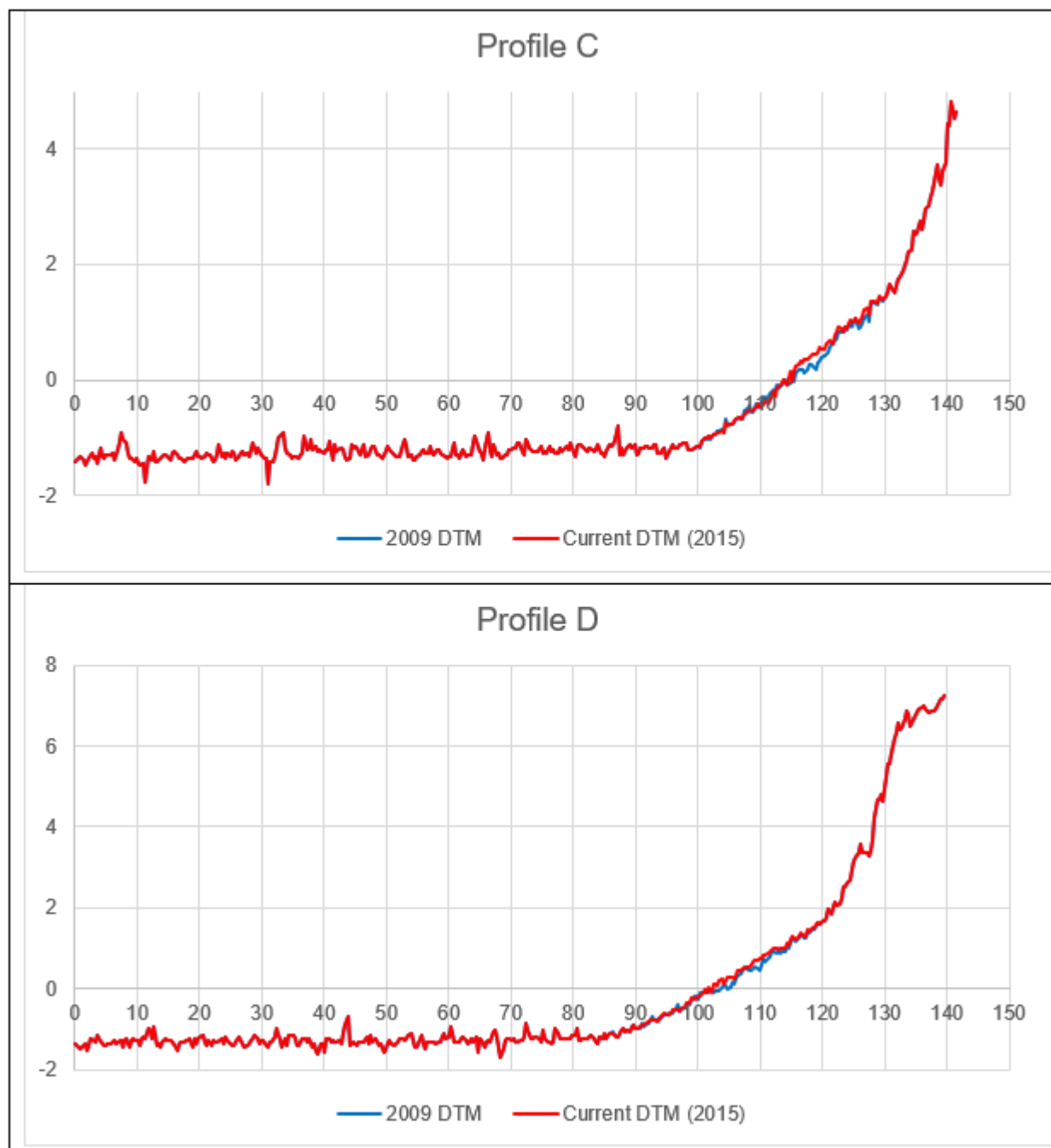
# Appendix A. Historic LiDAR Data Comparisons South Beach

## Key Plan

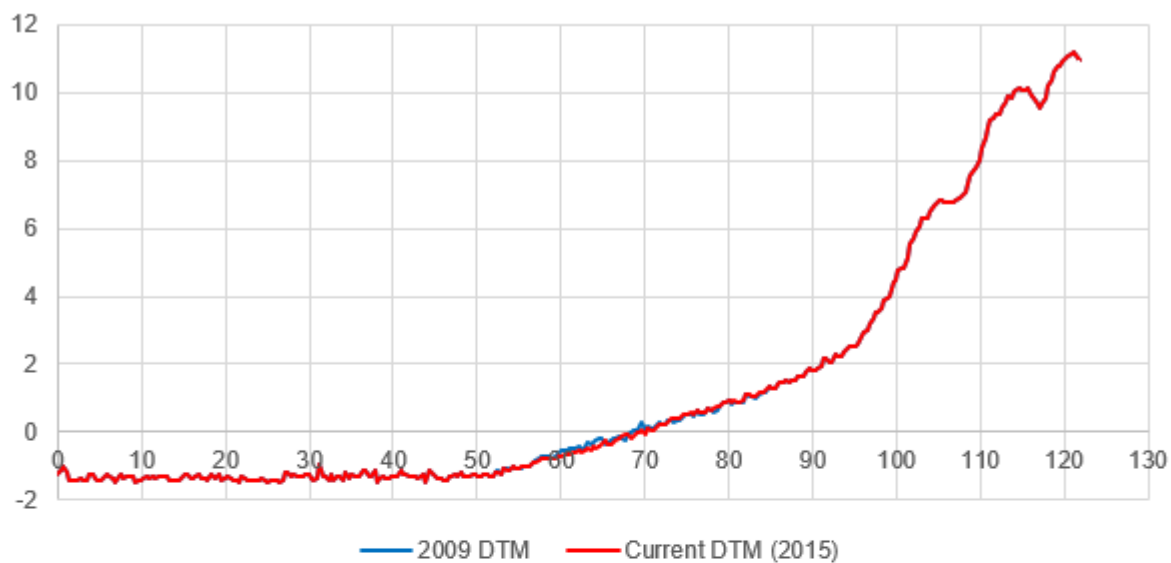


## Profile Comparisons 2009 Digital Terrain Model v 2015 Digital Terrain Model

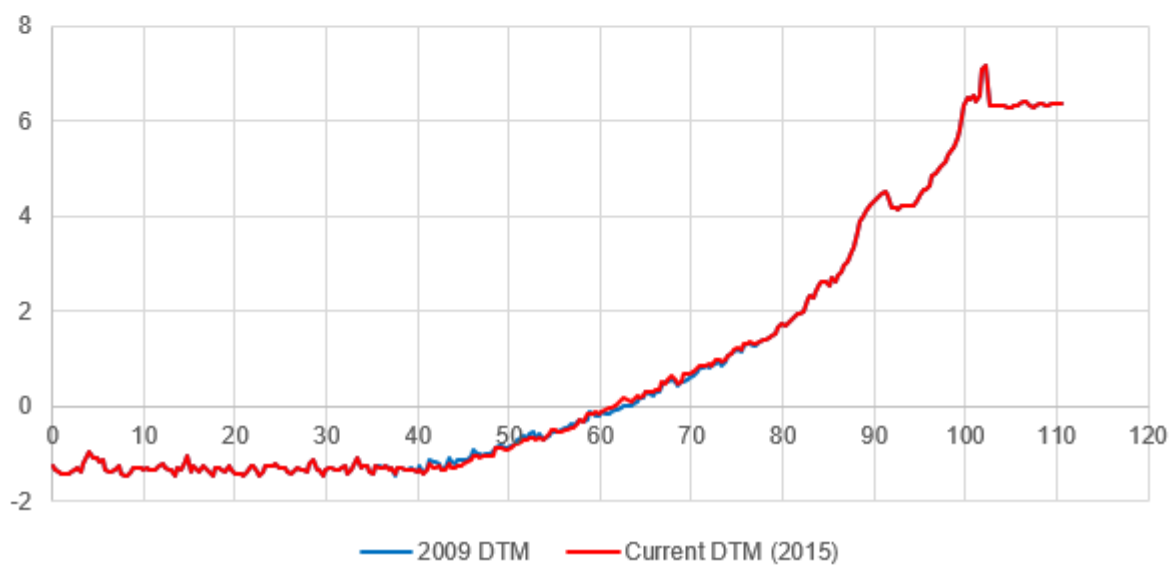


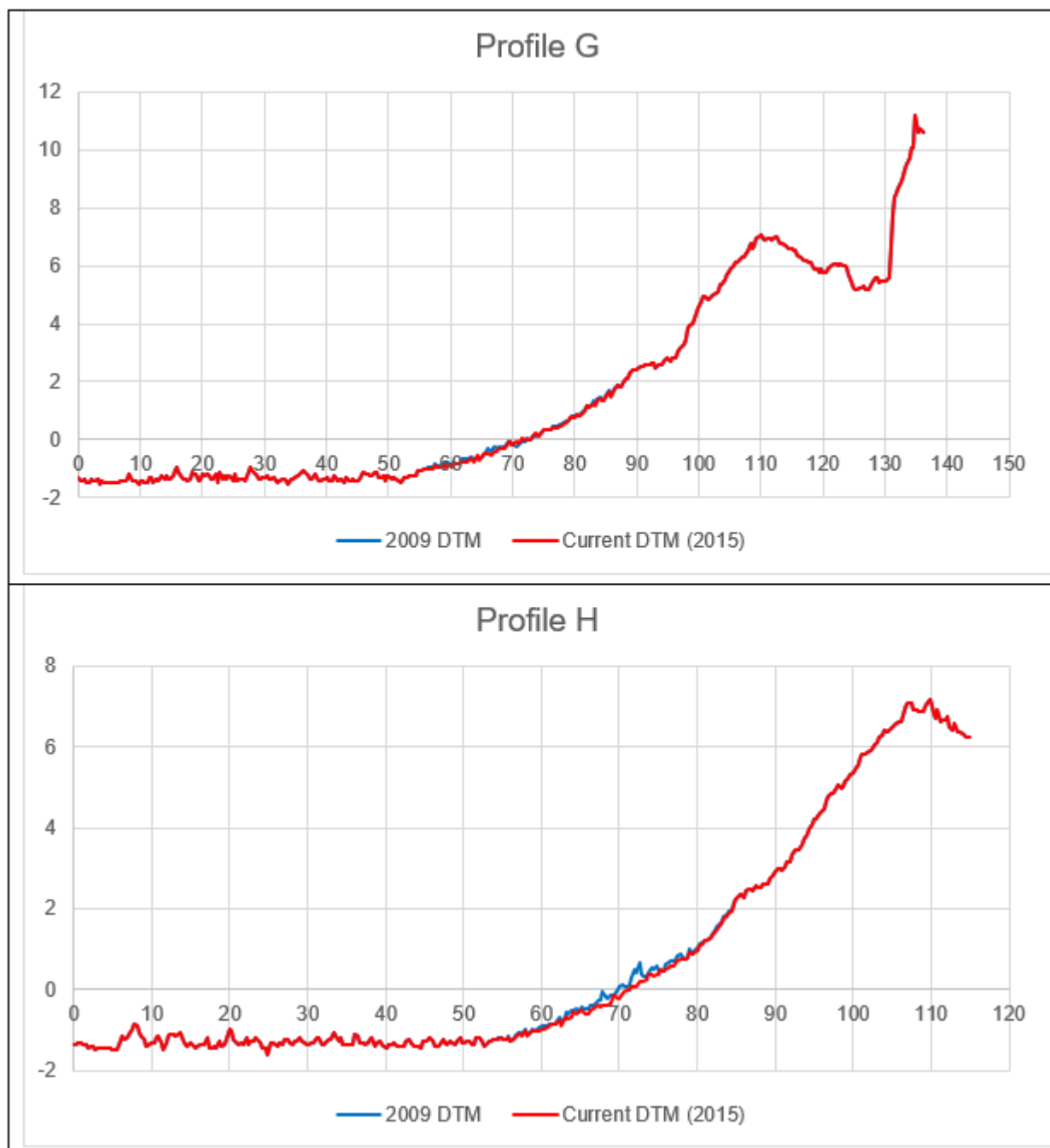


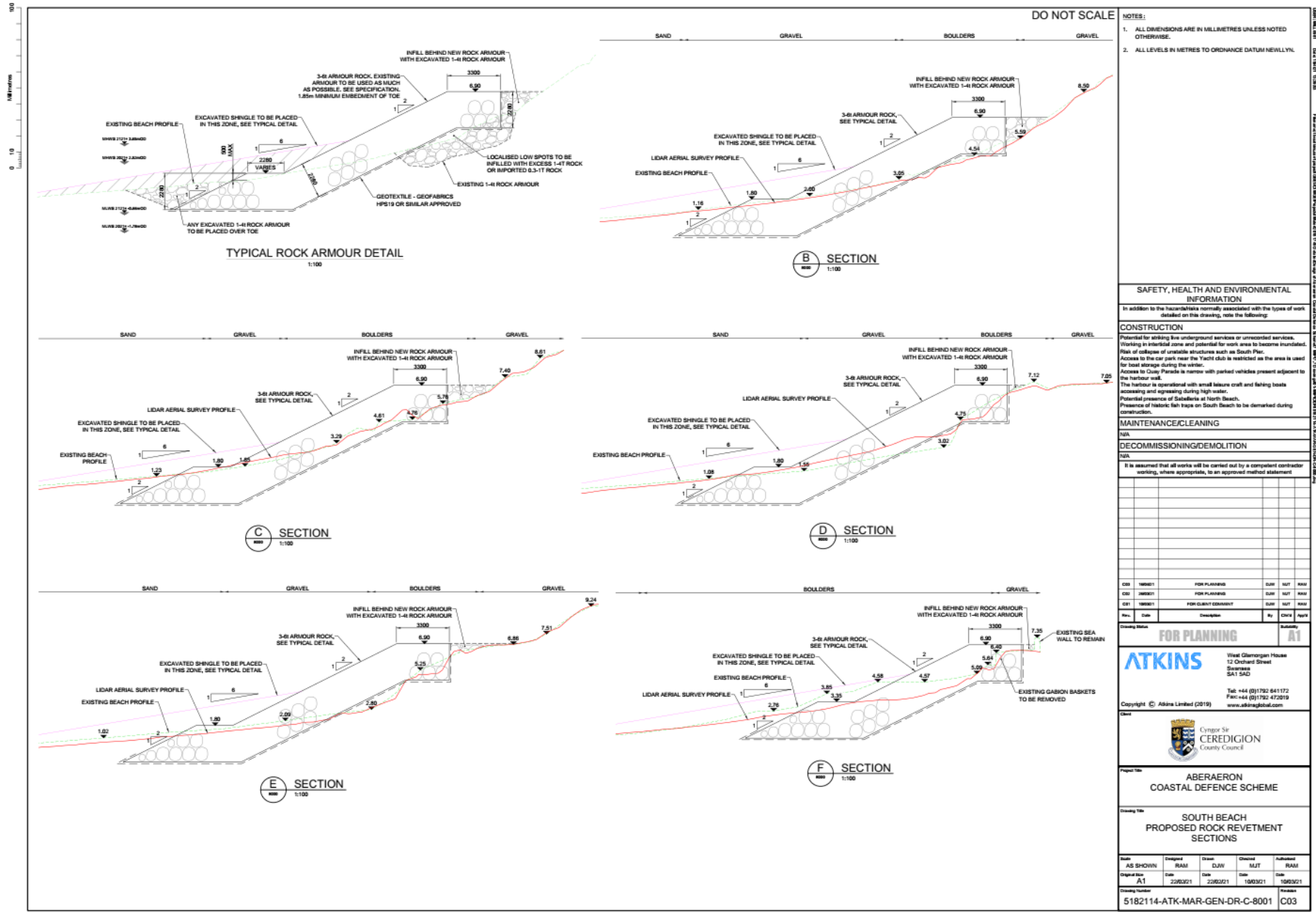
Profile E



Profile F







# Appendix B. Notes on model modifications

## B.1. Introduction

Previous numerical modelling studies of the Aberaeron Coastal Defence Scheme were modified as part of this study to provide a more detailed assessment of the breakwater as a source of change during both construction and operation. Specifically, additional modelling was necessary to estimate the extent of variations in current speeds and bed shear-stresses caused by the breakwater. Earlier modelling work concluded a zone of influence < 1 km from the breakwater, which will be further investigated in this appendix.

Further consideration of river flows has been included in the model in combination with tide and storm wave conditions.

## B.2. Model modifications

### B.2.1. Mesh refinement

In comparison to the previous mesh, which had a resolution with a maximum area of 200 m<sup>2</sup>, the revised mesh now allows for a resolution with a maximum area of 25 m<sup>2</sup> in Aberaeron harbour as seen in Figure 4-1 below. Whilst increasing the mesh resolution is more computationally expensive to model, this modification was necessary to accurately represent the complex hydraulic processes in the system. Improvements to the resolved bathymetry in the harbour can be seen in Figure 4-2

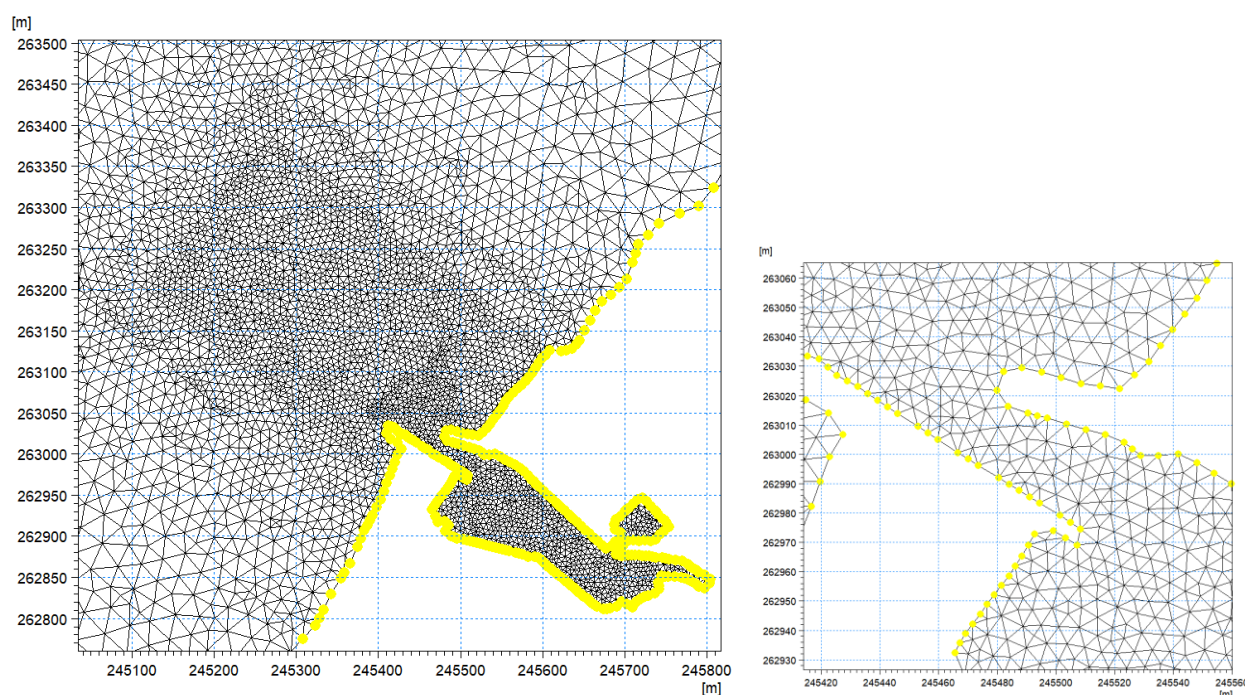


**Figure 4-1 - Revised model mesh (left), with harbour entrance defined by 4 computational elements (right).**

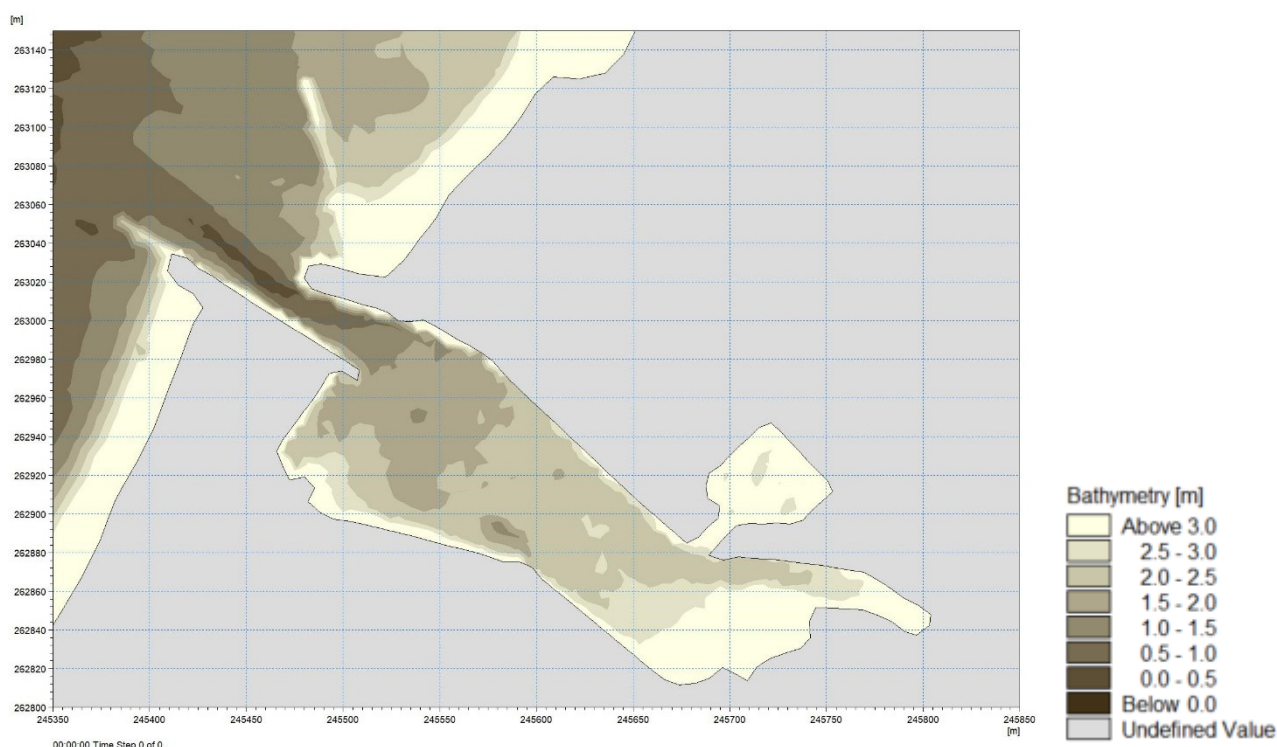


**Figure 4-2 – Revised model bathymetry in Aberaeron harbour.**

## B.3. Model setup

A total of 8 models were set up to assess any spatial variations in current speeds and bed shear-stresses caused by the breakwater. The modelled scenarios each covered a simulation period of 100 hours, over the peak of a spring tide cycle.

The model considers the single (worst-case) wave direction 304°N as defined from the wave modelling report 'Options Assessment – Numerical Modelling Report' (ref 5182114-ATK-MAR-GEN-RP-C-1033).

### B.3.1. Fluvial flows

The whole time series of Afon Aeron stage data provided by NRW was modelled using TUFLOW to predict typical fluvial flows. The recorded stage levels at the river gauge were very low and the lowest flow corresponding to the lowest stage level in the TUFLOW model was predicted to be  $Q = 0.78 \text{ m}^3/\text{s}$ . For simplicity, the flow input for the MIKE model was adjusted to  $Q = 1 \text{ m}^3/\text{s}$  to simulate typical Afon Aeron Flows.

Previous hydraulic modelling using TUFLOW has provided estimates of peak flows in the Afon Aeron for a range of annual exceedance probabilities.

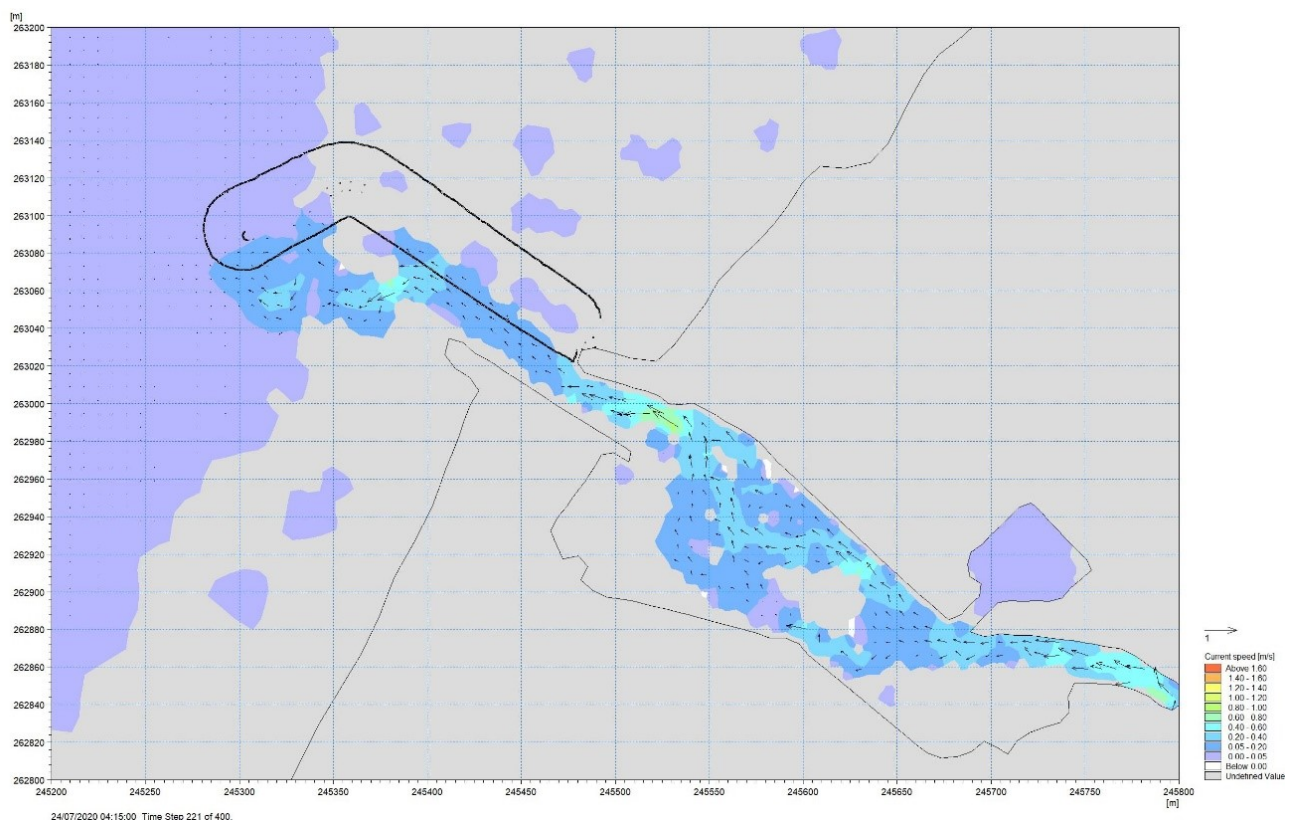
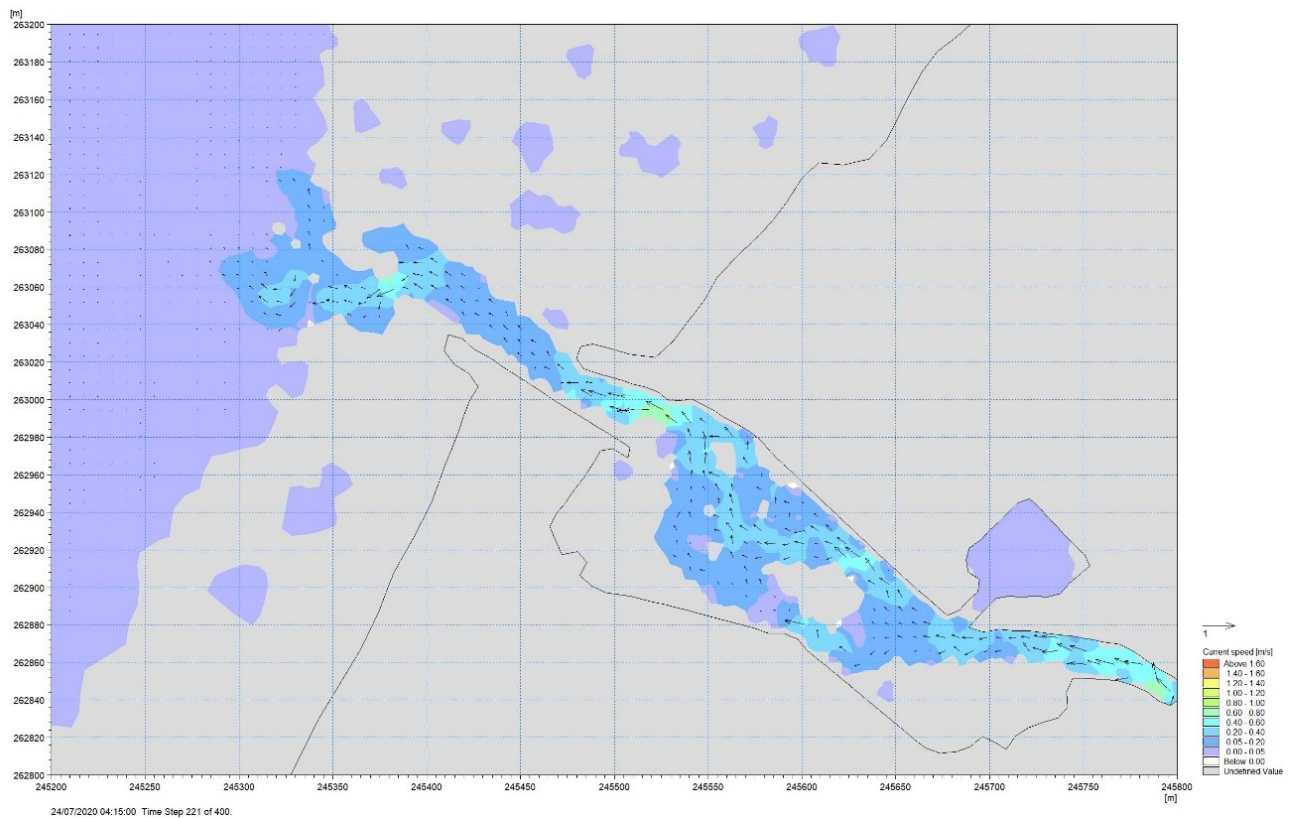


**Figure 4-3 - Plot showing vectors of the typical Fluvial flow rate  $Q = 1 \text{ m}^3/\text{s}$  in the baseline model run (Top) and breakwater model run (Bottom). Screenshots taken at the peak of the lowest simulated tide.**

**Table 4-1 - Peak flow estimates for the Afon Aeron**

| Event AEP <sup>[1]</sup> | Peak flow (m <sup>3</sup> /s) |
|--------------------------|-------------------------------|
| 50% (1 in 2 years)       | 65                            |
| 25% (1 in 4 years)       | 80                            |
| 20% (1 in 5 years)       | 84                            |
| 10% (1 in 10 years)      | 99                            |
| 5% (1 in 20)             | 114                           |
| 2% (1 in 50)             | 138                           |
| 1% (1 in 100)            | 158                           |
| 0.1% (1 in 1000)         | 231                           |

<sup>[1]</sup> Annual Exceedance Probability

For the purpose of the hydrodynamic model, a 1 in 2 year peak flow input of  $Q = 65 \text{ m}^3/\text{s}$  was chosen as an adequate storm fluvial flow. It was decided that a flow input higher than this would overwhelm the resolution of the model mesh, resulting in unrealistic outputs. The corresponding hydrograph for a peak flow of  $Q = 65 \text{ m}^3/\text{s}$  is shown in Figure 4-4 below.

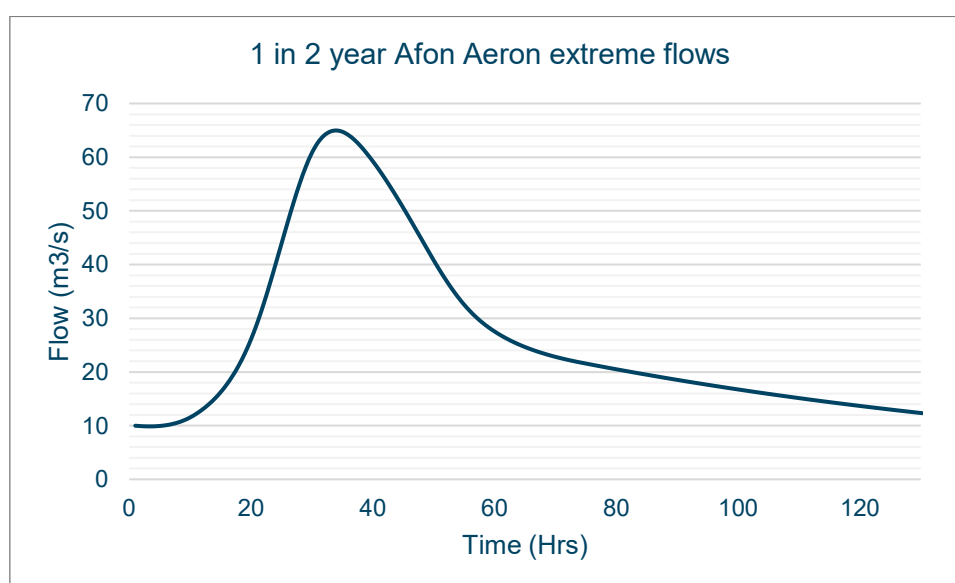


**Figure 4-4 - 1 in 2 year hydrograph of extreme flows in the Afon Aeron**

### B.3.2. Wave conditions

An Extreme Value analysis (EVA) of offshore wave data determined the following extreme wave parameters shown in Table 4-2. Highlighted in the table are the constant wave conditions applied at the numerical model boundaries for the individual modelled scenarios.

**Table 4-2 - Extreme Offshore Boundary Conditions**

| Return Period (Year) | H <sub>s</sub> (m) | T <sub>p</sub> (s) |
|----------------------|--------------------|--------------------|
| 1 in 75 (2021)       | 7.15               | 11.40              |
| 1 in 75 (2021)       | 6.36               | 10.59              |
| 1 in 75 (2021)       | 5.40               | 9.55               |
| 1 in 75 (2021)       | 5.14               | 9.26               |
| 1 in 1 (2021)        | 3.39               | 7.12               |
| 1 in 1 (2121)        | 3.74               | 7.58               |

### B.3.3. Run scenarios

Four different scenarios were modelled to produce outputs showing the influence of both tidal currents and wave-induced currents. The model scenarios were carried out for a baseline condition and for the inclusion of the breakwater. Results of the hydrodynamic processes present at the site were modelled for the following scenarios:

- Tide only
- Tide and typical Afon Aeron flows
- 1 in 1 year wave condition and typical Afon Aeron flow
- 1 in 75 year wave condition and Afon Aeron storm flow

MIKE21 Flow Model FM was used to model the first two scenarios that separate the impact of tidal currents. Using the MIKE21/3 Coupled Model FM, the effect of wave-induced currents was then incorporated for the two remaining situations. In the coupled models, the water level and current variation from the hydrodynamic model is applied to the wave model. As a result, the width and position of the surf zone fluctuates with the tidal cycle and the wave model is also able to account for tidal currents. A summary of the modelled scenarios is given in Table 4-3.

**Table 4-3 - Summary of numerical model set-up for individual model run scenarios.**

| Run Scenarios                                        | MIKE21 Module             | Fluvial Flows |                               | Wave Conditions                             |                                      |
|------------------------------------------------------|---------------------------|---------------|-------------------------------|---------------------------------------------|--------------------------------------|
|                                                      |                           | Source Type   | Peak Flow (m <sup>3</sup> /s) | Significant Wave Height, H <sub>s</sub> (m) | Peak Wave Period, T <sub>p</sub> (s) |
| Tide Only                                            | MIKE21 Flow Model FM      | N/A           |                               | N/A                                         |                                      |
| Tide and typical Afon Aeron flows                    | MIKE21 Flow Model FM      | Constant      | 1                             | N/A                                         |                                      |
| 1 in 1 year wave condition & typical Afon Aeron flow | MIKE21/3 Coupled Model FM | Constant      | 1                             | 3.39                                        | 7.12                                 |
| 1 in 75 year wave condition & Afon Aeron storm flow  | MIKE21/3 Coupled Model FM | Time-varying  | 65                            | 7.15                                        | 11.4                                 |

The models took roughly 8 hours to run overall, each simulating 100 hours of hydrodynamic change. Previous modelling studies took approximately 8 hours to simulate an entire month of wave simulation, indicating that the revised mesh is considerably more computationally heavy.

## B.4. Calibration

The model has been calibrated using the measured water level data recorded during a physical survey of Aberaeron Harbour by EcoSpan in 2020 [15]. The tide was simulated at the boundary of the model using a Global Tide Model. Figure 4-5 shows the model output of surface elevation at the same location of the measured data, with outputs of the previous model mesh shown in yellow. Whilst the graph shows levelling differences between the measured and modelled data, the revised model mesh can reach larger peaks. The rate of increase and decrease of the tide is in good agreement; however, improvements to the tidal boundary condition would result in a better fit by raising the boundary by 200-300 mm and delaying the tide by 45 minutes.

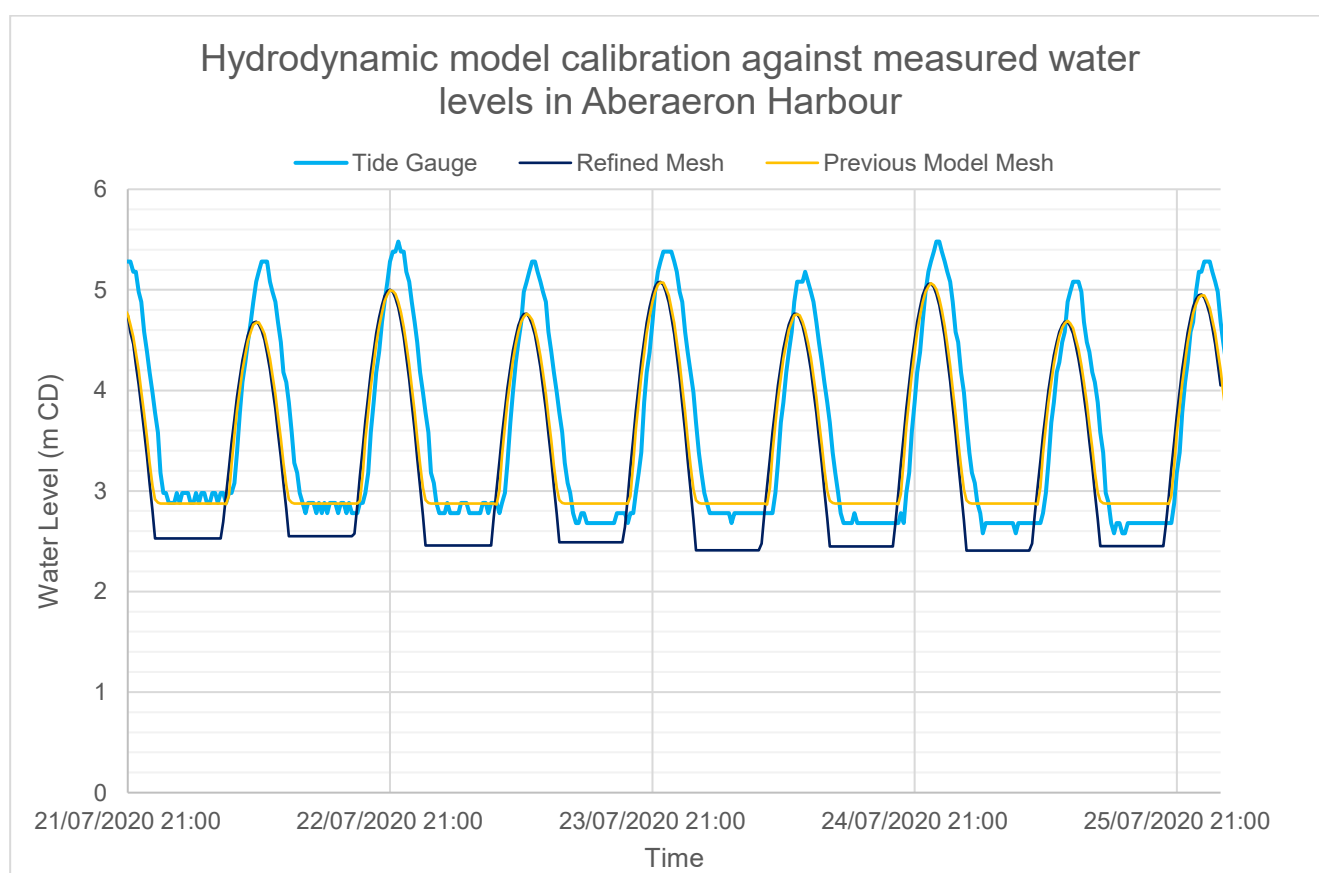


**Figure 4-5 - Calibration check of the hydrodynamic model, comparing model outputs against measured water level data.**

To avoid quantifying results, the model outputs were mostly analysed in terms of relative differences from the baseline run scenarios. However, in some cases, current speeds and bed shear-stresses have been discussed in relation to their numerical output to demonstrate the breakwater's expected magnitudes of change.

## B.5. Model assumptions

### B.5.1. Bed roughness

A ground investigation report undertaken by Quantum Geotech [11] provided information on the seabed characteristics at the site, identifying superficial materials using sidescan sonar. The seabed features identified in the survey are shown in Figure 4-6. As shown in the figure, the seabed exhibits wide spatial variations in sediment features, ranging from fine sands to gravel with cobbles and occasional boulders. It is therefore understood that the bed roughness would also spatially vary. However, given the lack of measured data along this stretch of the coastline, it was determined that deviating from standard methods of describing bed roughness would not be proportional to the scale of this project. The bed resistance was therefore specified for each of the model runs by applying a constant Manning number, which is standard practice for describing bed roughness in hydrodynamic modelling. The MIKE21 manual suggests values within the range of 20 – 40  $\text{m}^{1/3}/\text{s}$  when the relative variation of the water depth in a 2D simulation is substantial. Lower values in this range correspond to high bed resistance, thus a Manning number of 20  $\text{m}^{1/3}/\text{s}$  was applied based on the superficial knowledge of the seabed.

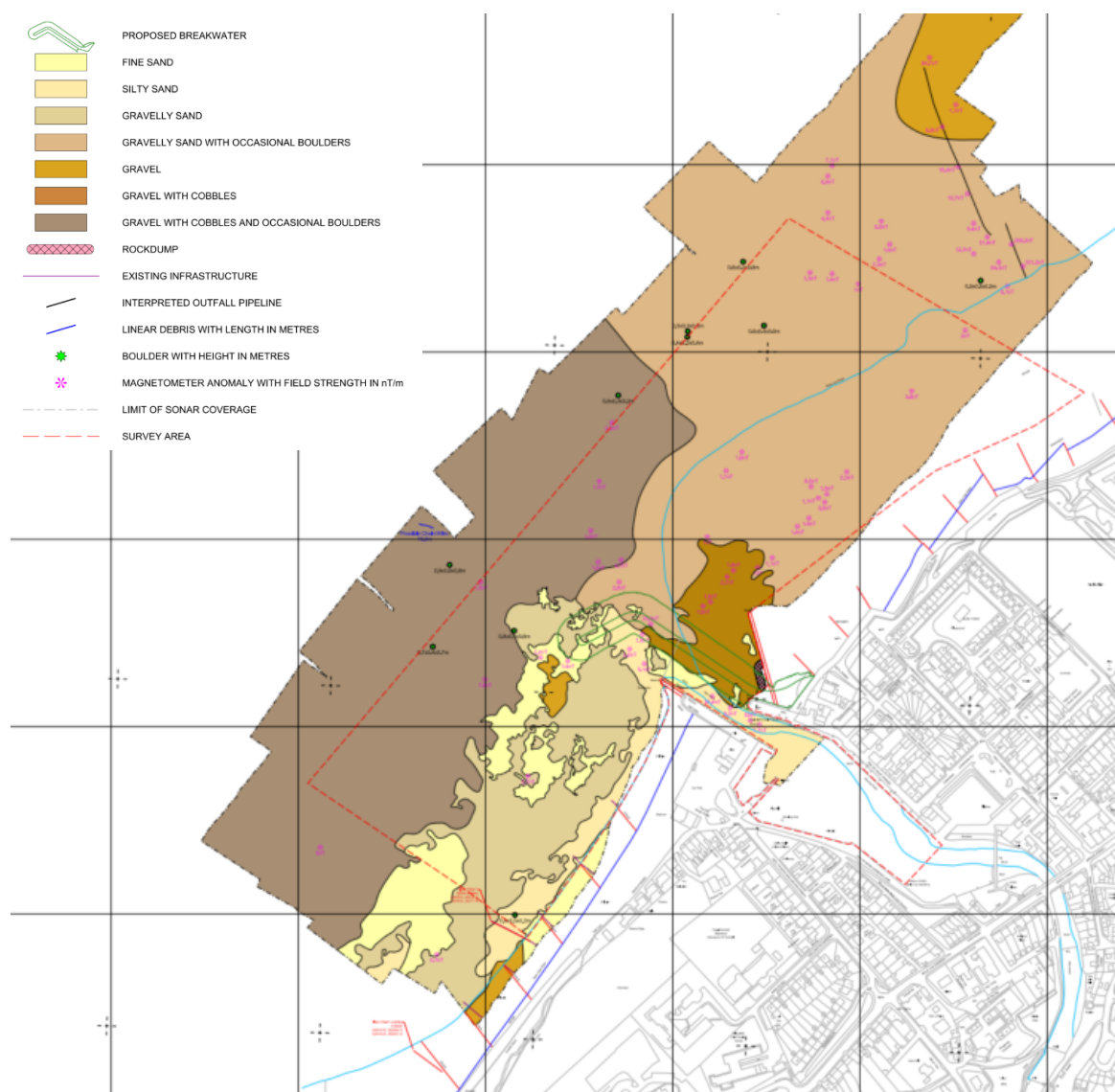


**Figure 4-6 - Interpreted seabed features (sidescan sonar).**

## B.6. Interpretating model outputs

Model output plots were selected during the flood and ebb of the highest spring tide, for a timestep 2 hours before and after high water. These timesteps were selected as tidal current velocities are particularly high at this stage in the simulation.

### B.6.1. Sediments & threshold bed shear-stress

In order to understand the magnitude of bed shear-stress required for sediments to become mobilised, a threshold bed shear-stress was estimated [12] for a representative range of sediment sizes in Aberaeron harbour. A ground investigation undertaken by Quantum Geotech [11] studied sediment samples from several exploratory holes in Aberaeron Harbour, the location of which is shown in Figure 4-7.

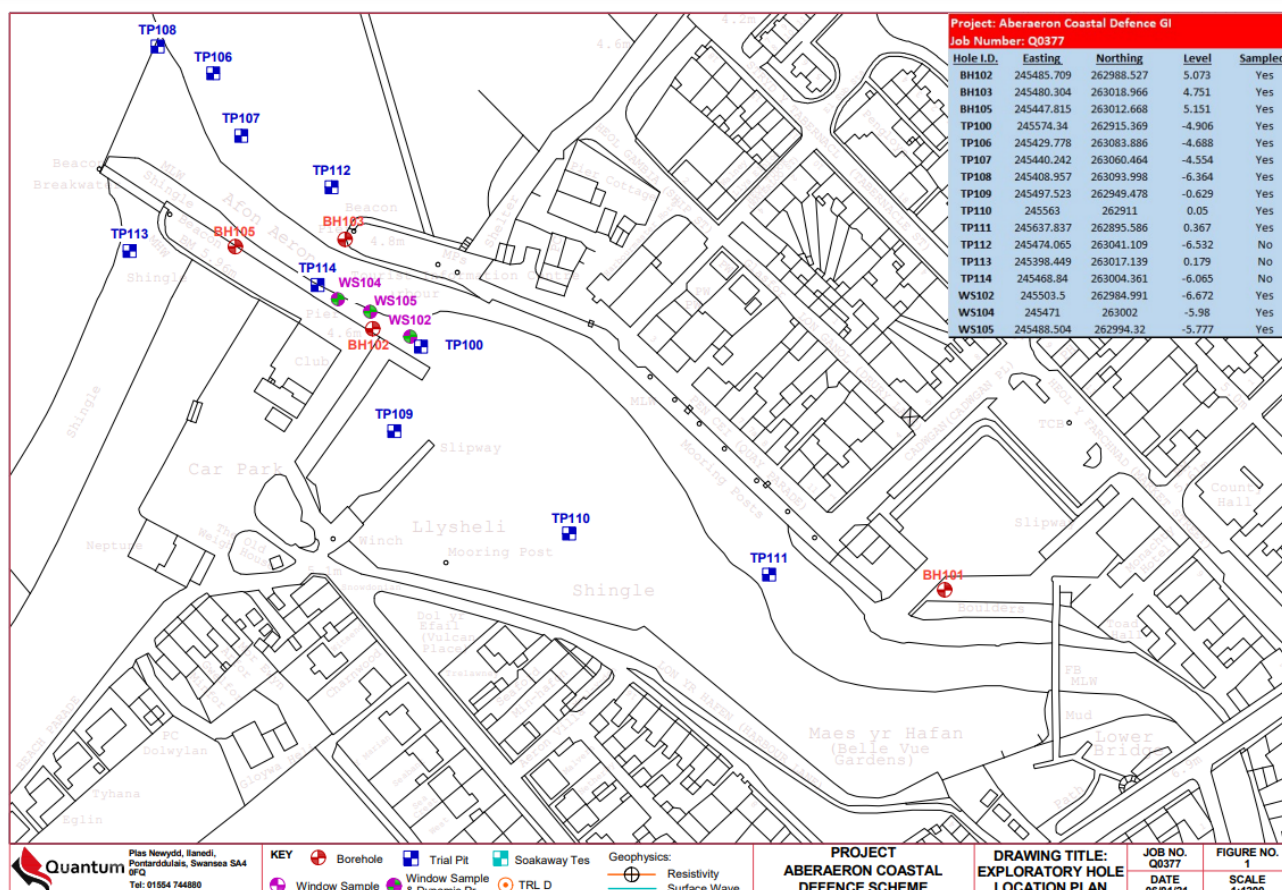


Figure 4-7 - Exploratory hole location plan [11].

Table 4-4 below shows the selected sediment samples for calculations of threshold bed shear-stress, giving a reasonably well-rounded representation of the spatial variation in sediment size at the site.

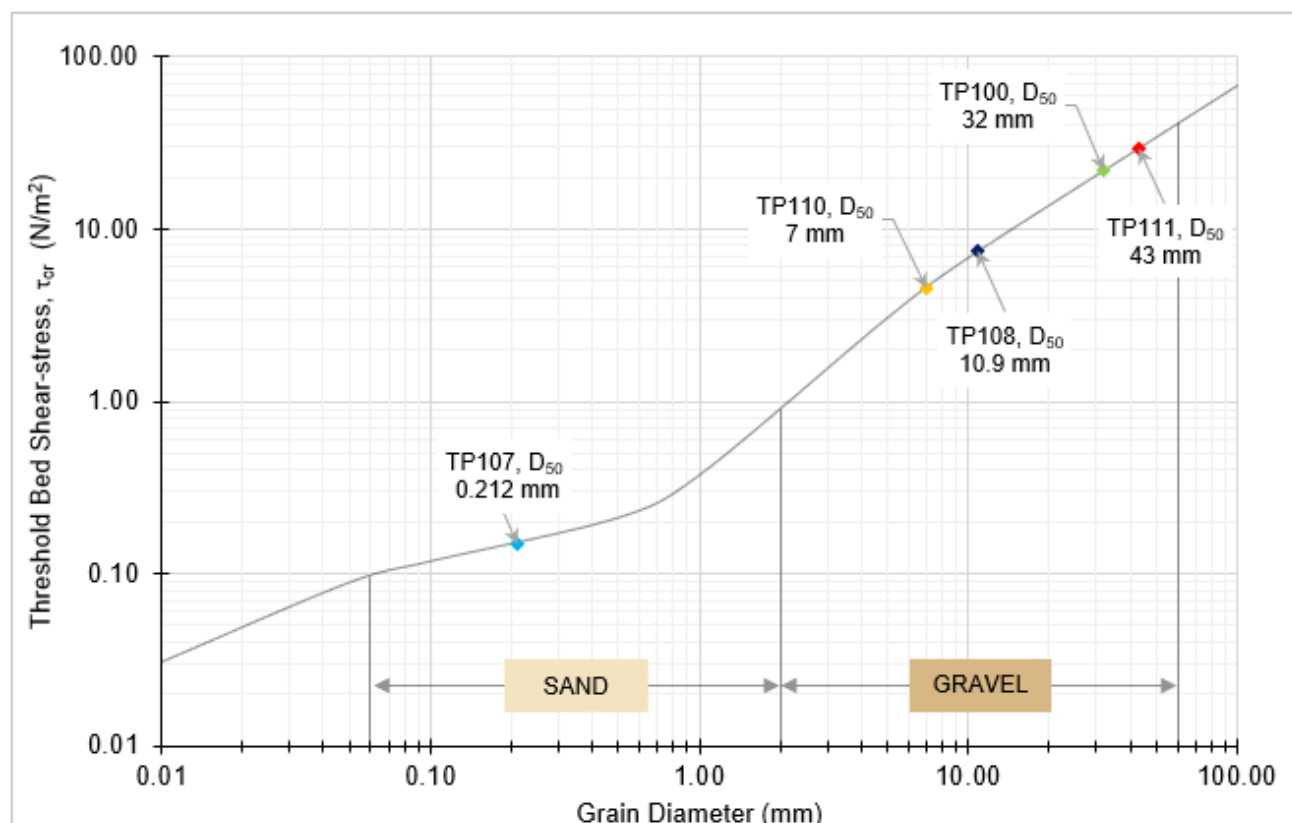
Table 4-4 - Sediment samples [11] used for estimates of threshold bed shear-stress.

| Trial Pit | Level (mAOD) | Sample Depth (mBGL) | Approximated D <sub>50</sub> (mm) |
|-----------|--------------|---------------------|-----------------------------------|
| TP111     | 0.367        | 0 - 0.2             | 43                                |
| TP110     | 0.050        | 0.2 - 0.4           | 7                                 |
| TP100     | -4.906       | 1.0 - 1.1           | 32                                |
| TP107     | -4.554       | 0.1 - 0.2           | 0.212                             |
| TP108     | -6.364       | 0.4 - 0.5           | 10.9                              |

Figure 4-8 displays the calculated threshold bed shear-stress in relation to sediment grain size. This plot gives an indication of the magnitude of bed shear-stress required mobilise various sediments. As seen in the plot, the threshold bed shear-stress required

- To mobilise gravel ranges from approximately 1 – 40 N/m<sup>2</sup>,
- With threshold bed shear-stresses below 1 N/m<sup>2</sup> likely to only mobilise sand and silt.

It should be noted that this is a conservative approximation, valid for well-sorted sediment samples. Therefore, large variations in sediment size distribution will affect the mobilisation of sediments.



\*Estimated using methods suggested by Soulsby [12], for quartz sediments. Values of D<sub>50</sub> and sediment densities were approximated from Quantum Geotech Report No. Q0377/FR.01 [11]. Water temperature and salinity were assumed at 10°C and 35ppt, respectively.

**Figure 4-8 - Estimates of threshold bed shear-stress for a representative range of sediment found in Aberaeron Harbour.**

### B.6.2. Threshold of motion

Threshold of motion plots have been created for each of the model run scenarios (see Appendix C). The plots show areas where various materials may be mobilised, with exceeded thresholds denoted by the following palette:

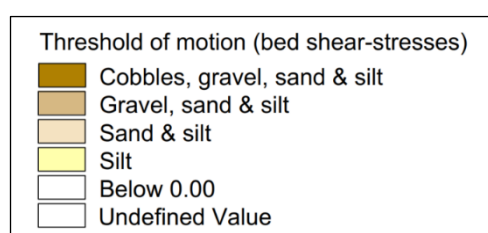


**Figure 4-9 - Colour palette used in threshold of motion plots**

It should be noted that the plots in Appendix C are 'snapshots' taken at various stages of the tide, and thus areas that appear to have high bed shear-stress may also have lower magnitudes of bed shear-stress over a single tidal cycle. As a result, the plots do not fully represent the erosional/accretional patterns that are likely to occur.

### B.6.3. Areas affected by changes in current

The following plots express the total areas experiencing at least a 1% difference in current speeds with the presence of the breakwater when compared to baseline runs. The reason the plots are not expressed in magnitudes of relative difference (%) is because in some areas, small deviations from the baseline output show large relative differences in the breakwater runs. For example, a current speed output from the baseline run: 0.0002 m/s, and breakwater run: 0.0006 m/s results in a 200% relative increase but would only be a very small actual change in current speed.

#### B.6.3.1. Outputs – difference in current speeds

The following Figure 4-10 - Figure 4-13 show the statistical mean difference in current speeds over the entire simulation period. The plots show mean increases in current speeds with the presence of the breakwater represented in red, and mean decreases in current speeds represented in blue.

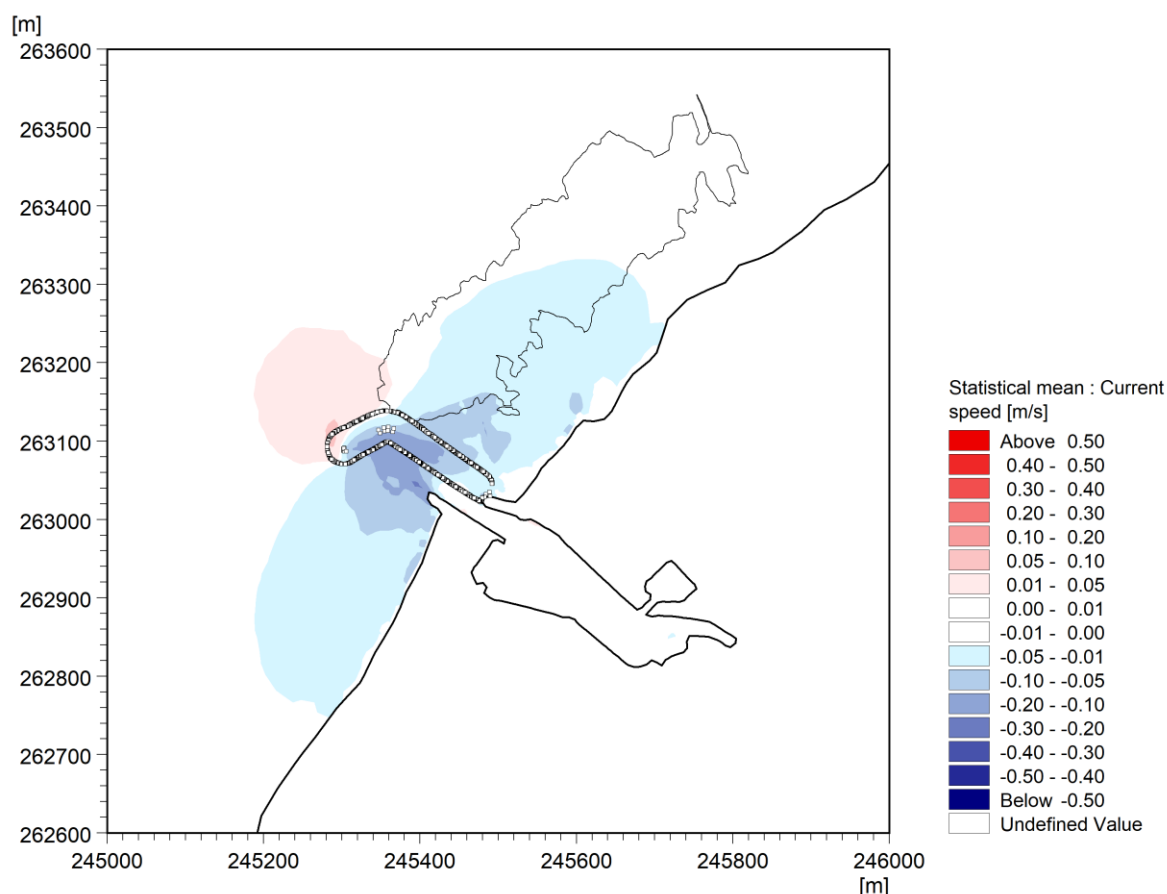


**Figure 4-10 – Run scenario: Tide only - Statistical mean difference in current speed over the simulated period.**

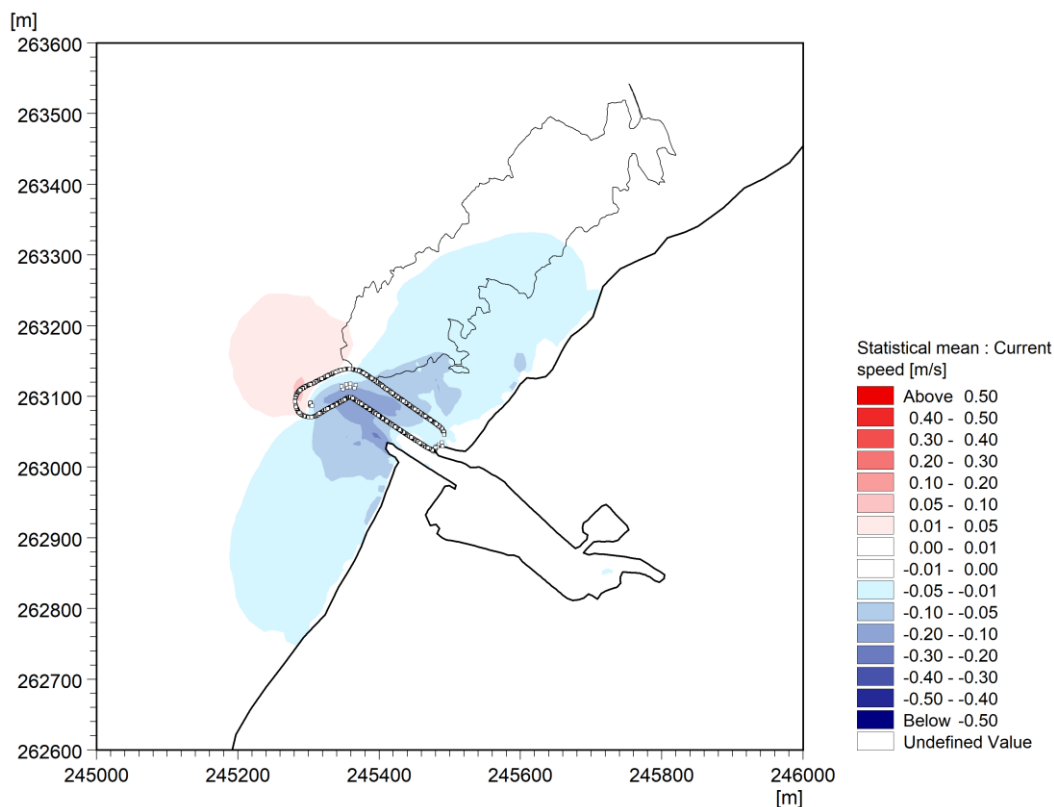


**Figure 4-11 – Run scenario: Tide and typical Afon Aeron flows - Statistical mean difference in current speed over the simulated period.**

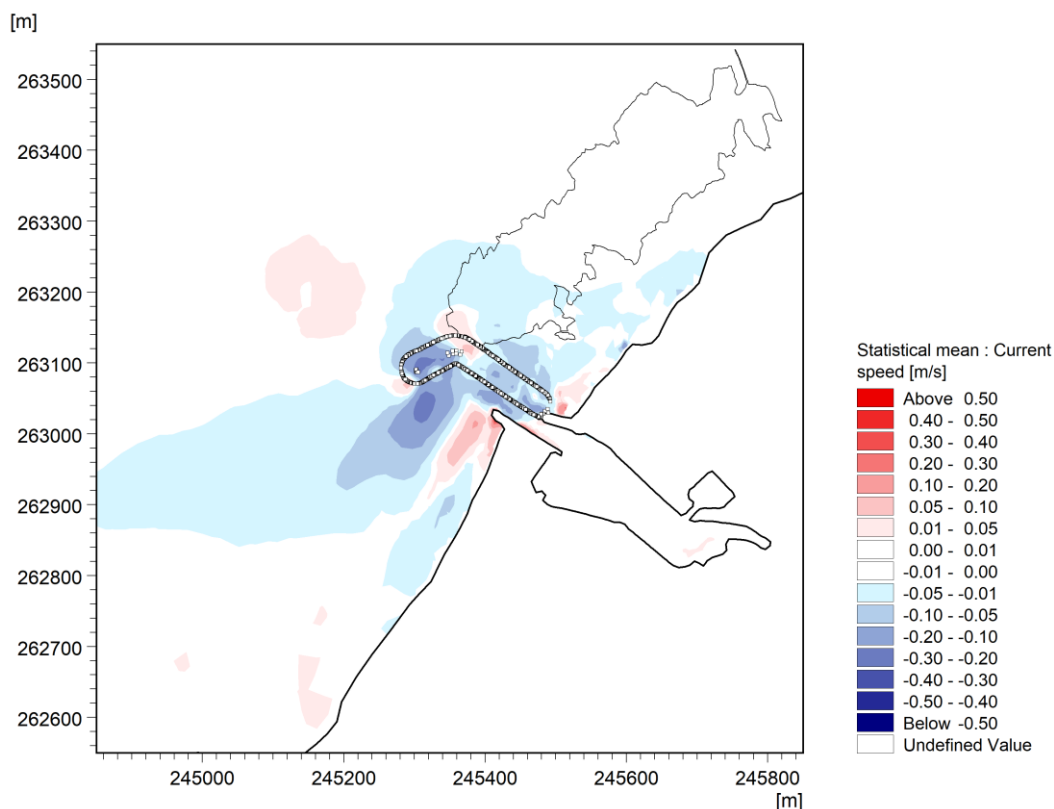


**Figure 4-12 – Run scenario: 1 in 1 year wave condition and typical Afon Aeron flows - Statistical mean difference in current speed over the simulated period.**

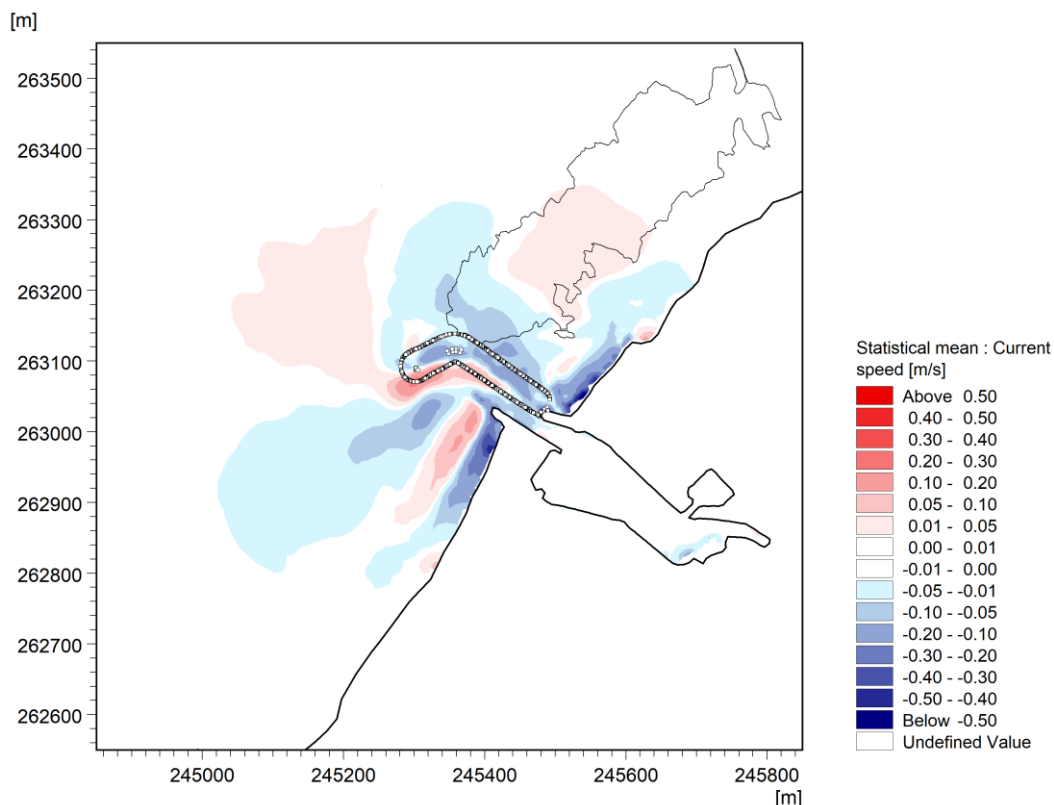


**Figure 4-13 – Run scenario: 1 in 75 year wave condition and Afon Aeron storm flows - Statistical mean difference in current speed over the simulated period.**

As seen in the above plots, model run scenarios excluding wave-induced currents show a similar spatial extent of the zone of influence from the breakwater. For these scenarios, the *Sabellaria alveolata* reef is subject to overall reductions in current speeds between 0.01 – 0.05 m/s (shown in Figure 4-10 - Figure 4-11).

For model run scenarios including wave-induced currents (Figure 4-12 - Figure 4-13), the zone of influence over the entire simulation period becomes more varied. For the 1 in 1 year wave condition (Figure 4-12), both increases and decreases in current speeds over the *Sabellaria alveolata* reef are largely in the range of 0.01 – 0.05 m/s. The 1 in 75 year wave condition shows more localised changes in current speed around the head of the breakwater (Figure 4-13). The largest changes over the *Sabellaria alveolata* reef are reductions in current speeds between 0.05 – 0.1 m/s occurring near the breakwater. Figure 4-13 also shows a larger portion of the reef to experience an overall increase in current speed between 0.01 – 0.05 m/s.

### B.6.3.2. Outputs – baseline and proposed current speed

Figure 4-14 below shows current speed vectors in Aberaeron harbour whilst the Afon Aeron is experiencing 1 in 2 year storm flows. As demonstrated in the plots, the breakwater has little effect on current speeds in the inner harbour. As a result, it is considered unlikely that the structure would lead to changes in sediment mobilisation in the harbour area.

There is a reduction in current speeds through the harbour entrance as a result of the breakwater.

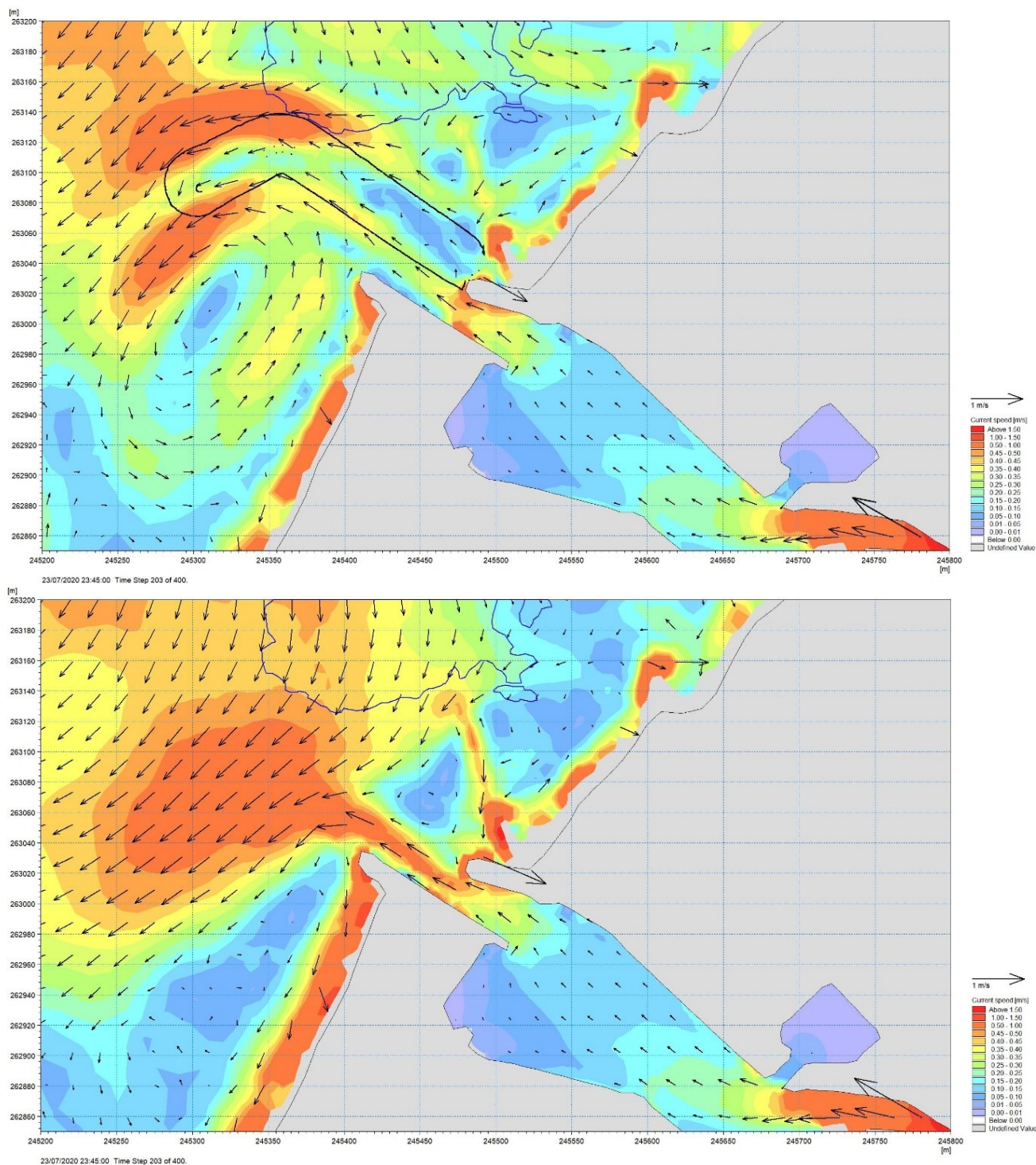


**Figure 4-14 - 1 in 75 year wave condition and 1 in 2 year fluvial flow model during ebb tide - Current speed plot showing influence of breakwater (top) and baseline output (bottom).**

### B.6.3.3. Outputs – difference in current speed

The statistical mean difference in bed shear-stresses over the entire simulation period is given in the following plots (Figure 4-15 - Figure 4-18). Mean increases in bed shear-stresses due to the presence of the breakwater are indicated in red, with mean decreases in bed shear-stresses in blue.

Figure 4-15 and Figure 4-16 show the identical extent of the breakwater's zone of influence. These model run scenarios simulate tidal currents only, with Figure 4-16 including typical fluvial flows. It can be seen in both plots that the *Sabellaria alveolata* reef primarily experiences a mean reduction in bed shear stresses between 0.1 – 1 N/m<sup>2</sup> as a result of the breakwater. Typical Afon Aeron flows appear to have negligible effects on the statistical mean difference in bed shear-stresses in the absence of wave-induced currents.

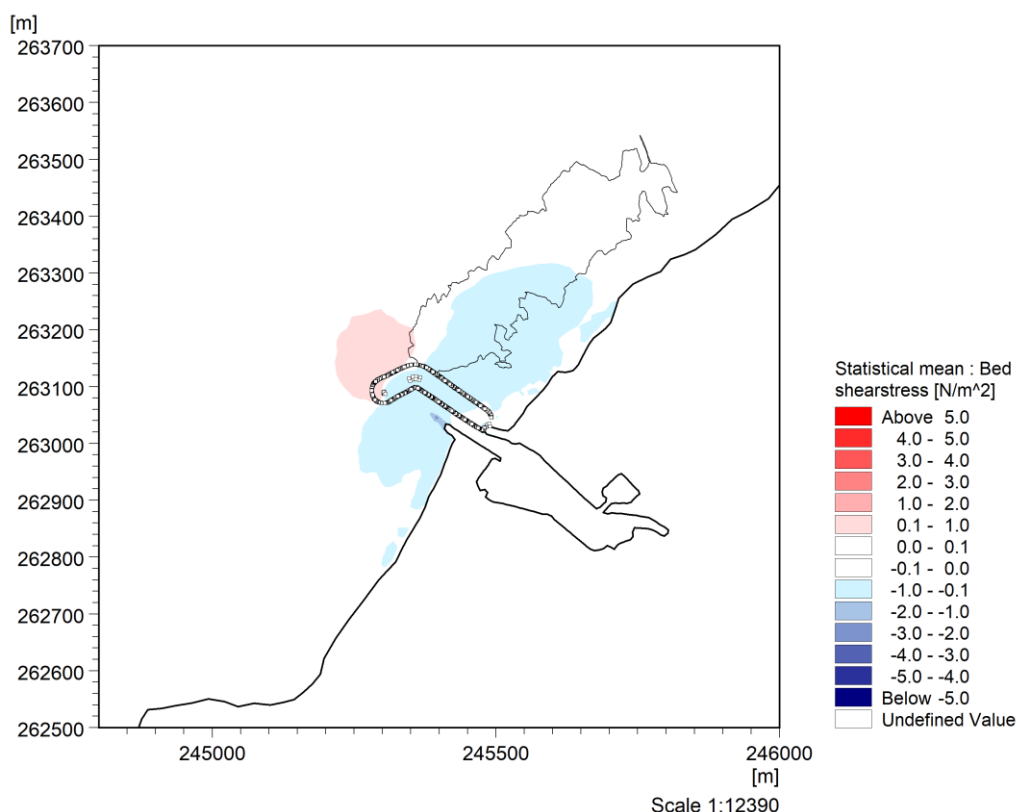


**Figure 4-15 - Run scenario: Tide only - Statistical mean difference in bed shear-stress over the simulated period.**

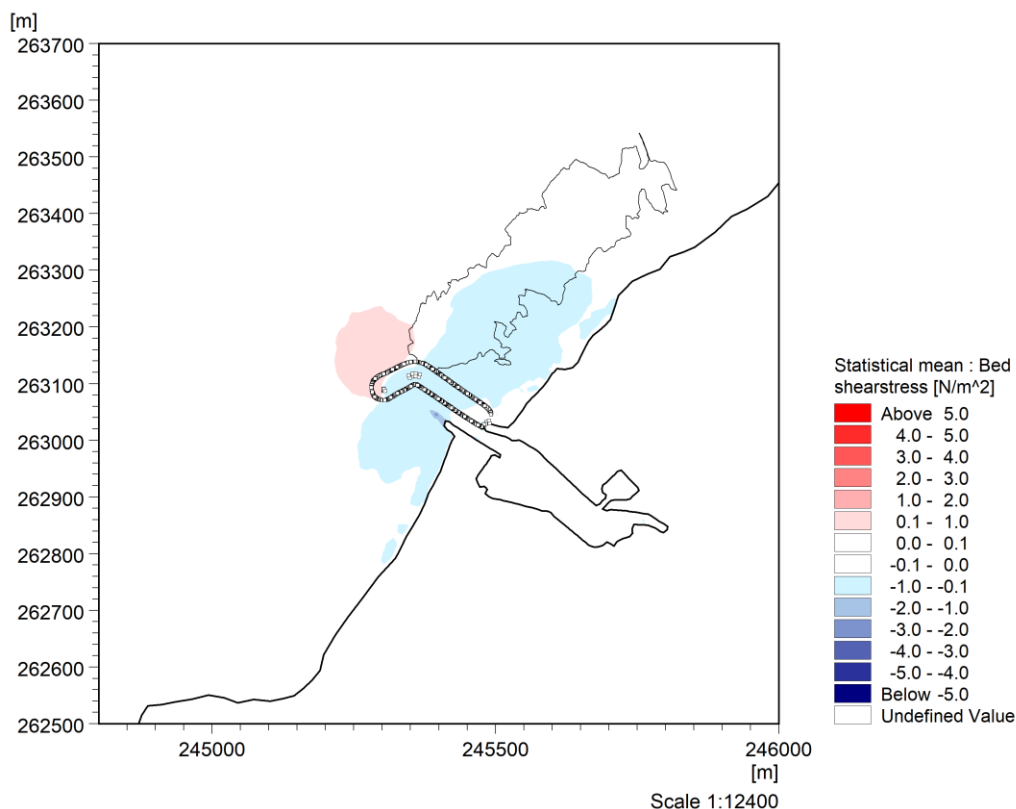


**Figure 4-16 - Run scenario: Tide and typical Afon Aeron flows - Statistical mean difference in bed shear-stress over the simulated period.**

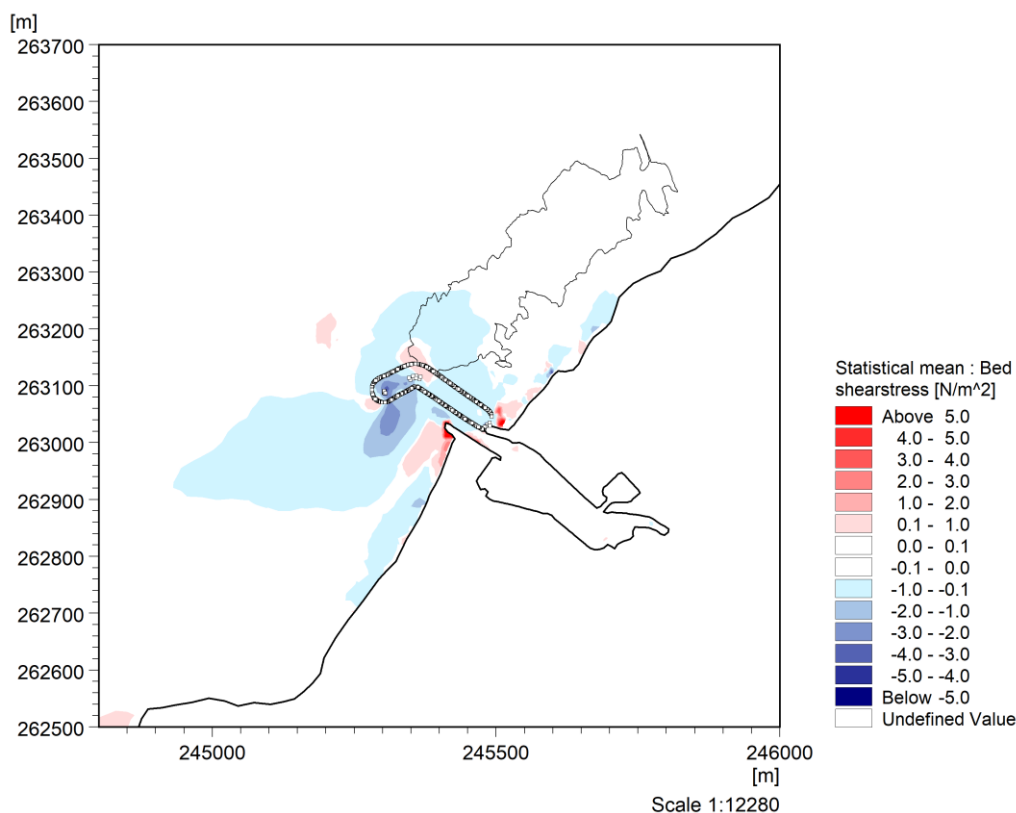


**Figure 4-17 - Run scenario: 1 in 1 year wave condition and typical Afon Aeron flows - Statistical mean difference in bed shear-stress over the simulated period.**

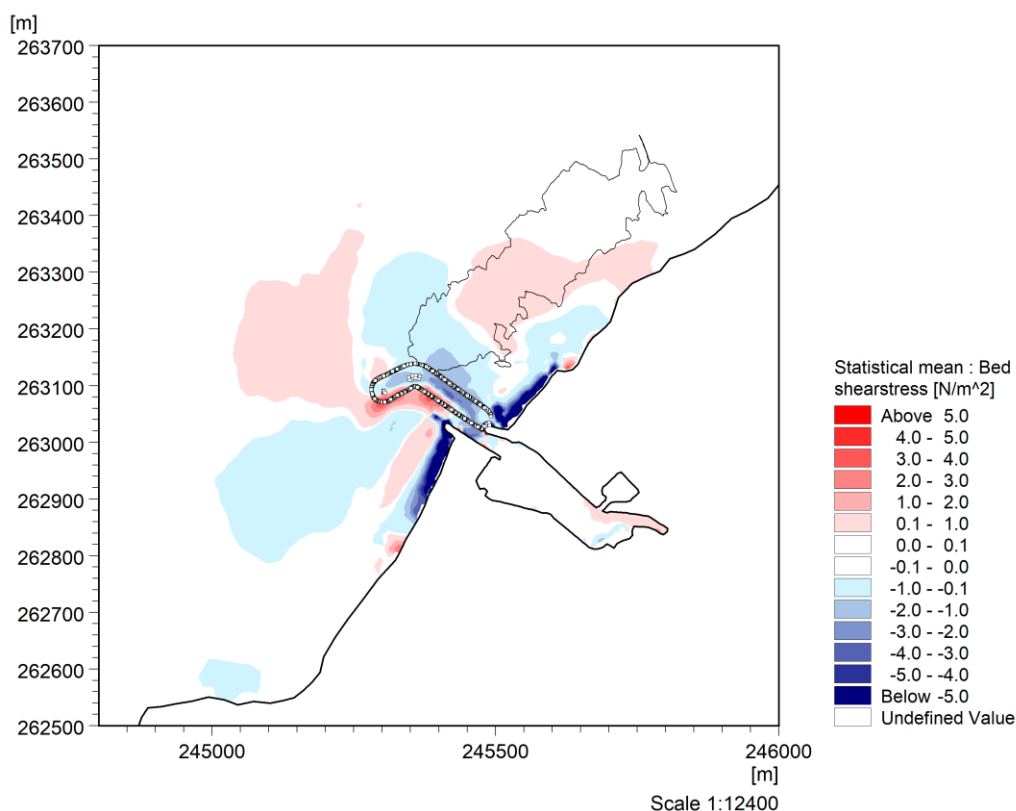


**Figure 4-18 - Run scenario: 1 in 75 year wave condition and Afon Aeron storm flows - Statistical mean difference in bed shear-stress over the simulated period.**

#### B.6.3.4. Changes observed over the Sabellaria Alveolata reef

Averaged current speeds over the simulation period are shown to remain constant over the entire model domain and over the Sabellaria alveolata reef for the 'tide and typical Afon Aeron flows' run scenario. The mean current speed was used to disregard irregularities created in the wetting/ drying of computational elements, which skews the maximum and minimum output of the model. The range of mean current speeds are shown in Table 4-5 and Table 4-6.

**Table 4-5 - Mean current speed statistics observed over the whole model domain, for the entire simulation period.**

| Current speed [m/s] | Baseline | Breakwater |
|---------------------|----------|------------|
| Max                 | 0.65     | 0.65       |
| Min                 | 0.00     | 0.00       |
| Range               | 0.65     | 0.65       |

**Table 4-6 - Mean current speed statistics observed over the *Sabellaria alveolata* reef, for the entire simulation period.**

| Current speed [m/s] | Baseline | Breakwater |
|---------------------|----------|------------|
| Max                 | 0.25     | 0.25       |
| Min                 | 0.08     | 0.08       |
| Range               | 0.17     | 0.17       |

Variations in the mean bed shear-stress statistics remain low for the ‘tide and typical Afon Aeron flows’ model run scenario, shown in Table 4-7 and Table 4-8. A difference of 0.02 N/m<sup>2</sup> in mean bed shear-stress is observed over the whole model domain when comparing the breakwater model run to the baseline scenario. The range of bed shear-stresses over the *Sabellaria alveolate* reef is shown to increase by 0.09 N/m<sup>2</sup>. Considering the nature of the seabed here (gravelly sand with occasional boulders), the mobilisation of sediment over the reef is unlikely to change.

**Table 4-7 - Mean bed shear-stress statistics observed over the whole model domain, for the entire simulation period.**

| Bed shear-stress [N/m <sup>2</sup> ] | Baseline | Breakwater |
|--------------------------------------|----------|------------|
| Max                                  | 16.95    | 16.93      |
| Min                                  | 0.00     | 0.00       |
| Range                                | 16.95    | 16.93      |

**Table 4-8 - Mean bed shear-stress statistics observed over the whole model domain for the entire simulation period.**

| Bed shear-stress [N/m <sup>2</sup> ] | Baseline | Breakwater |
|--------------------------------------|----------|------------|
| Max                                  | 1.29     | 1.27       |
| Min                                  | 0.22     | 0.11       |
| Range                                | 1.07     | 1.16       |

While the calibration status of the hydrodynamic model cannot confirm the absolute figures provided in the tables above, the overall relative change between the baseline and breakwater model outputs indicates that additional calibration and model iterations would likely yield similar results.

## B.7. Conclusion

The statistical **mean** difference in current speeds and bed shear-stresses supports the conclusion of previous modelling work in that the breakwater has a zone of influence of around 500m to 600m which is less than the 1 km anticipated.

The area affected by any change >1% is localised to the breakwater. Comparisons between the absolute range of speeds in the baseline compared to the absolute range of current speeds with the breakwater show that the absolute change in speeds are very small i.e. even large relative changes (much greater than 1%) are very small in absolute terms.

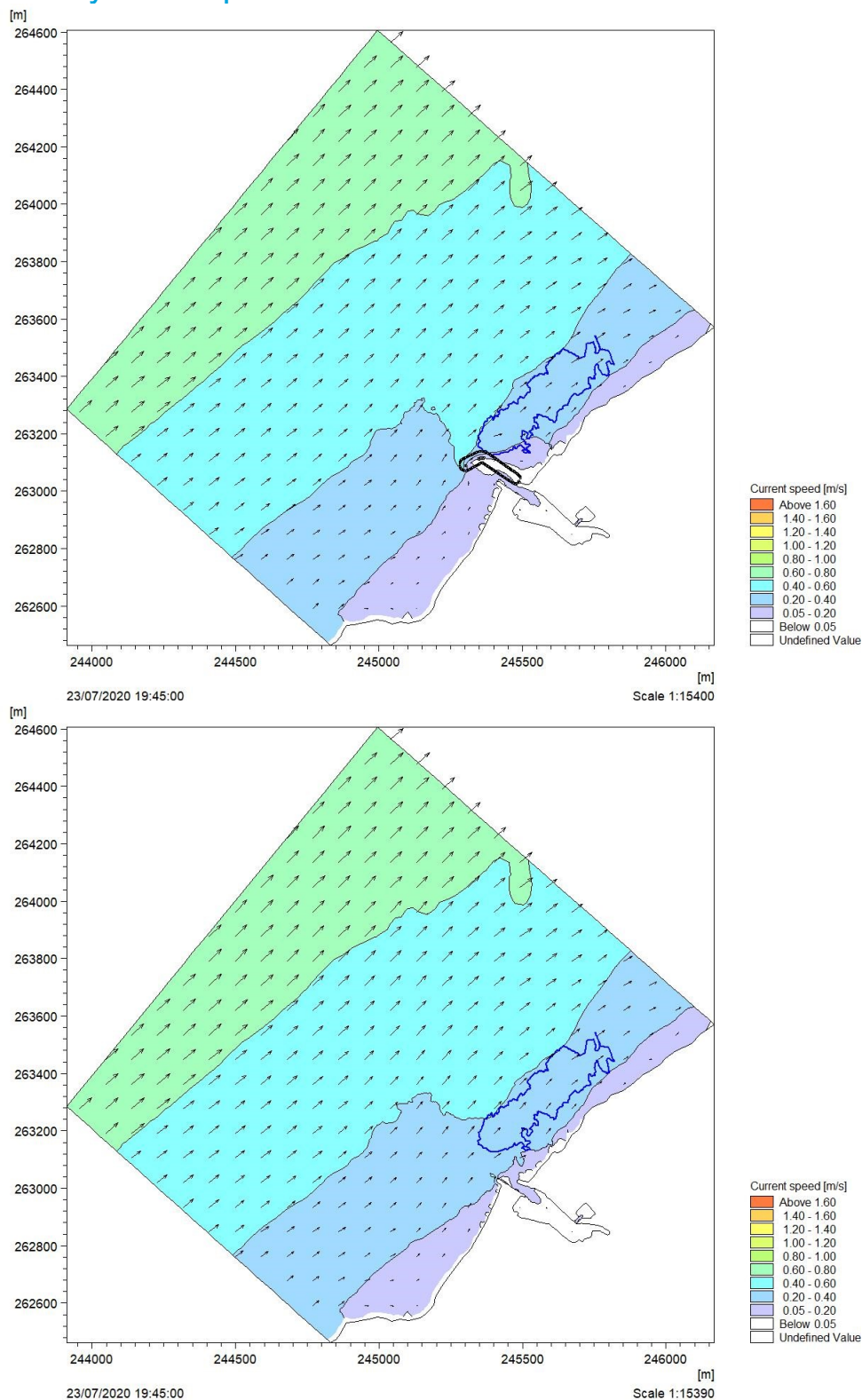
Changes in bed shear stress show a similar pattern to those for current speed. The size of area affected by relative changes in bed shear stress are greater than those for changes in current speed, but still restricted to approximately 600m from the breakwater. Similarly, a comparison between the absolute range of bed shear stress in the baseline compared to the absolute range of bed shear stress with the breakwater show that the absolute changes in bed shear stress are very small i.e. even large relative changes (much greater than 1%) are very small in absolute terms.

The maximum area over which any changes occur are spatially limited around the new breakwater and that this area of influence is within 500m – 600m of the structure. The spatial extent of these changes are insufficient to materially alter the wider coastal processes impacting the supply of sediment to the area or the degree of exposure to which the coast is subject (except in the harbour and harbour entrance, which is the purpose of the new breakwater).

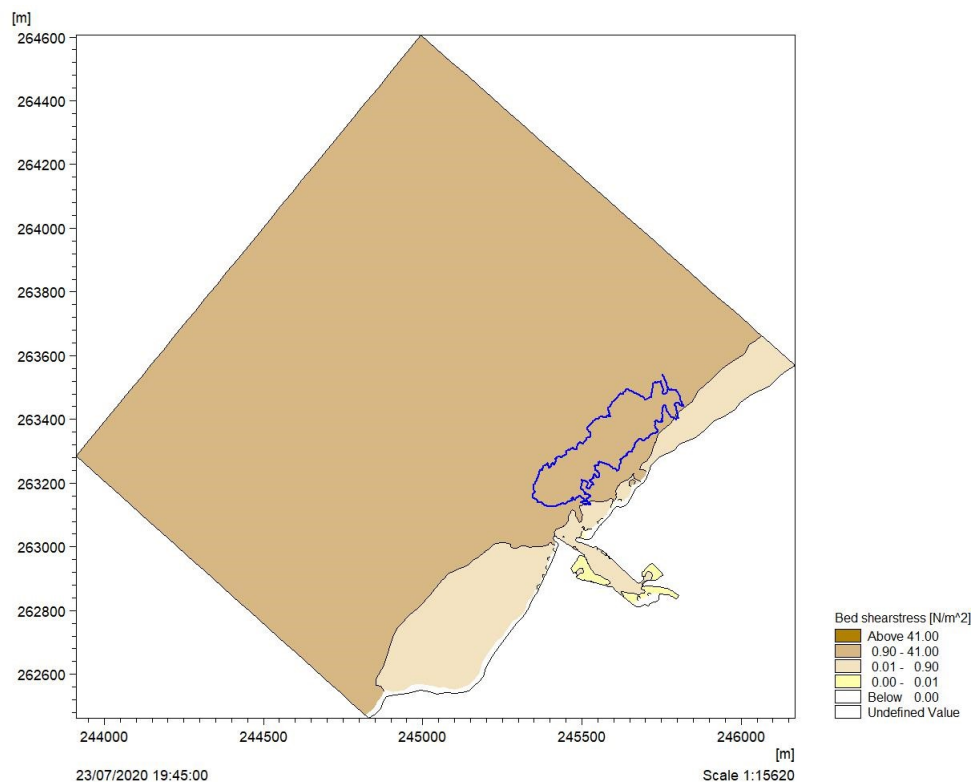
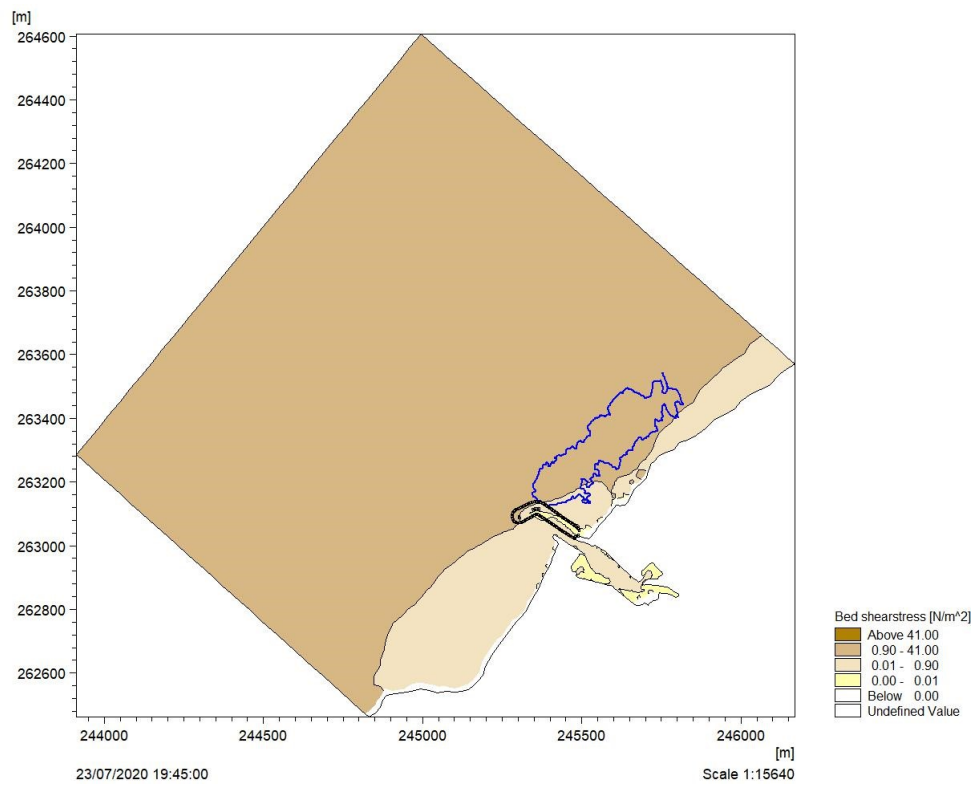
While the calibration status of the hydrodynamic model cannot confirm the absolute figures provided in the tables above, the overall relative change between the baseline and breakwater model outputs indicates that additional calibration and model iterations would likely yield similar results.

# Appendix C. Model outputs

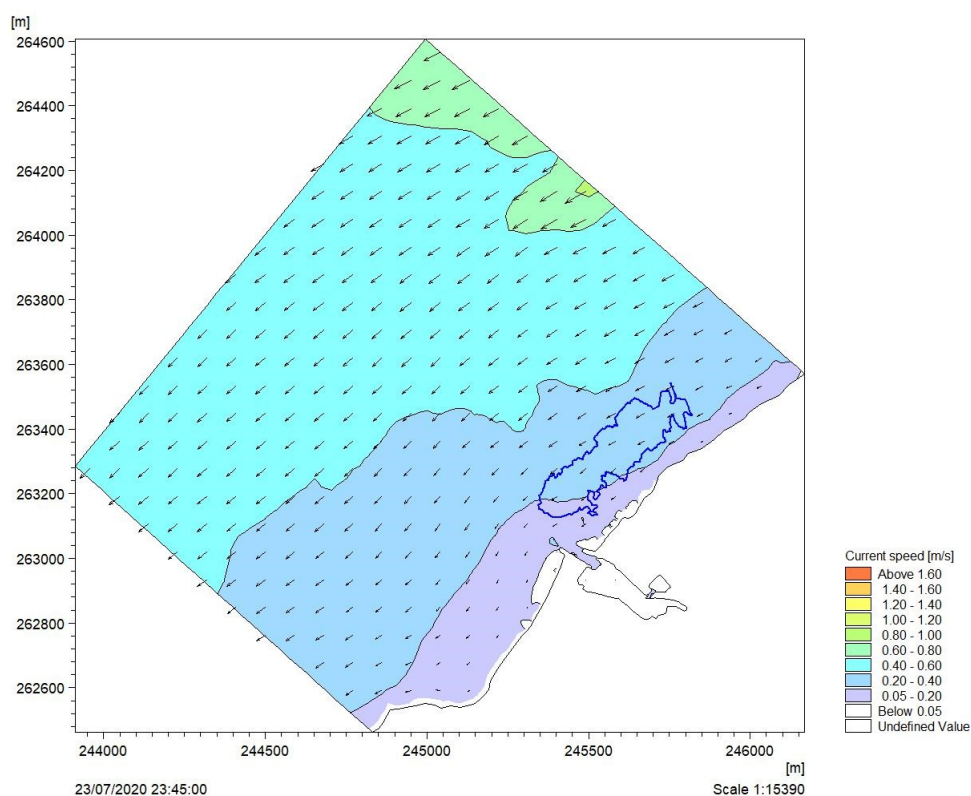
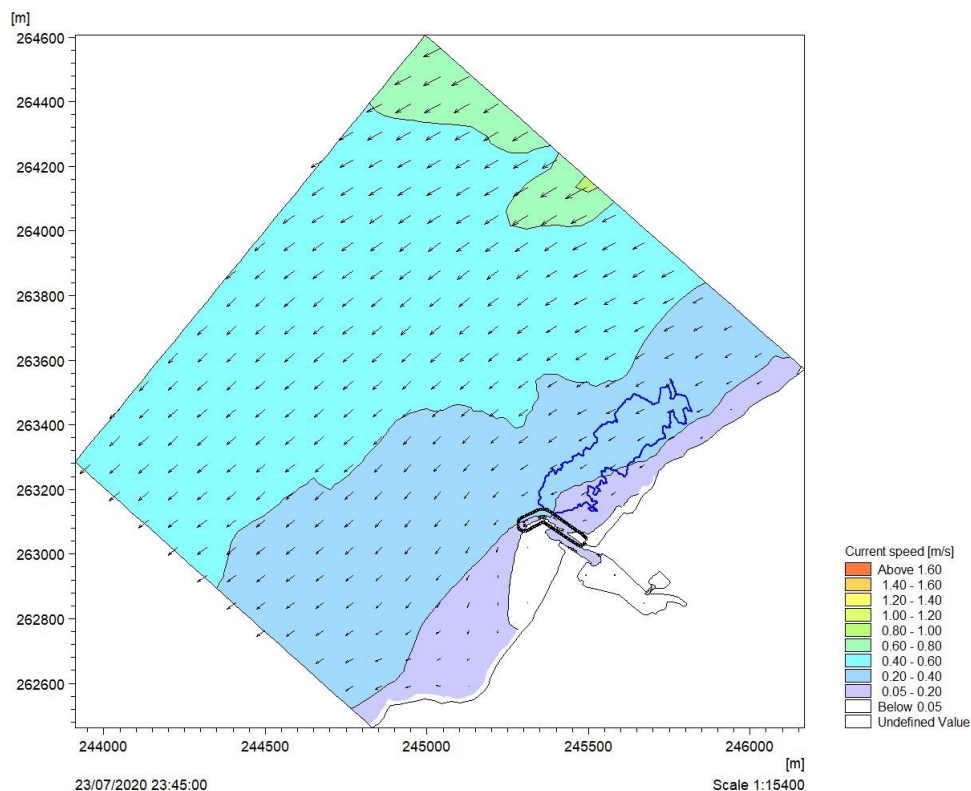
## C.1. Tide only model plots



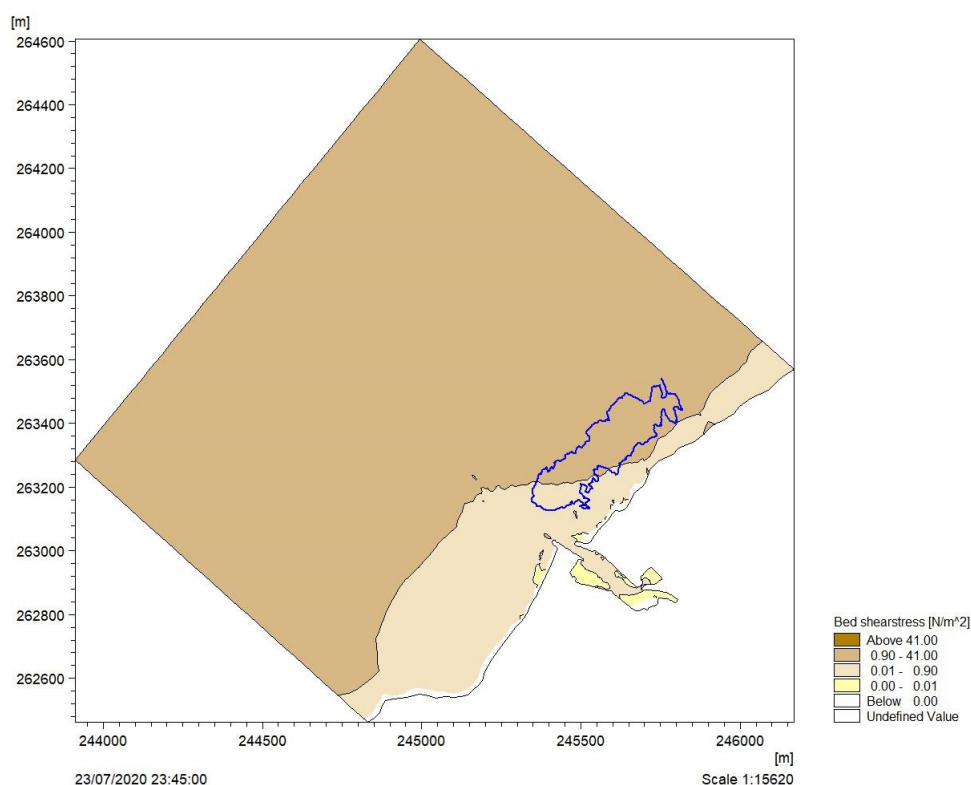
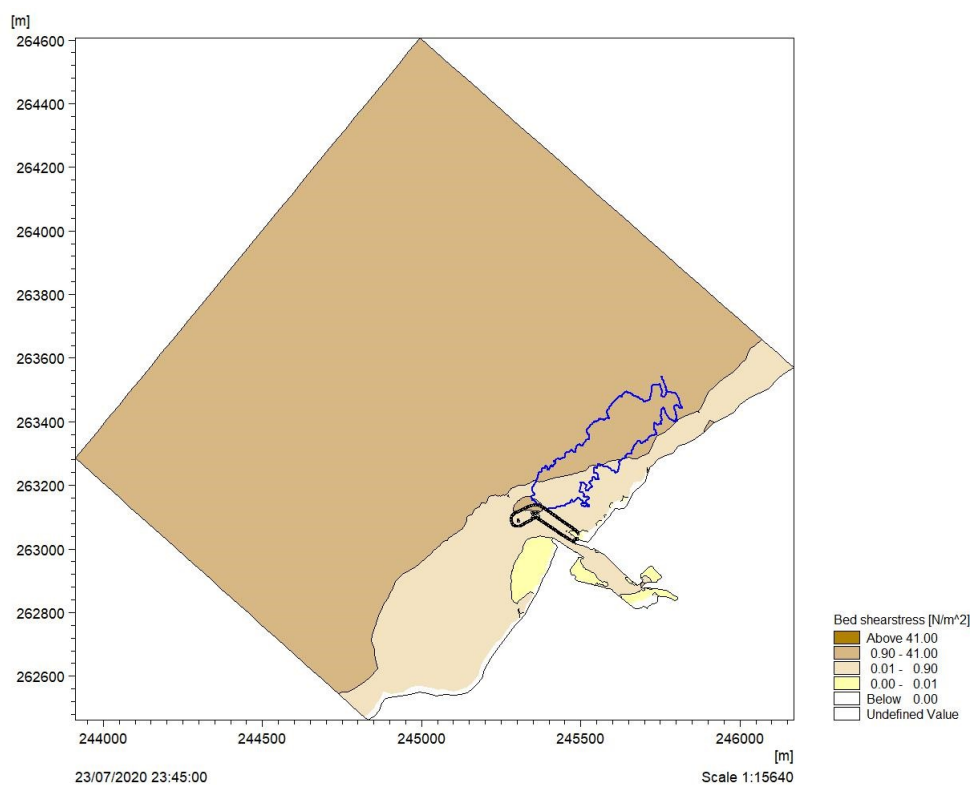
**Tide only model during flood tide – Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**



**Tide only model during flood tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

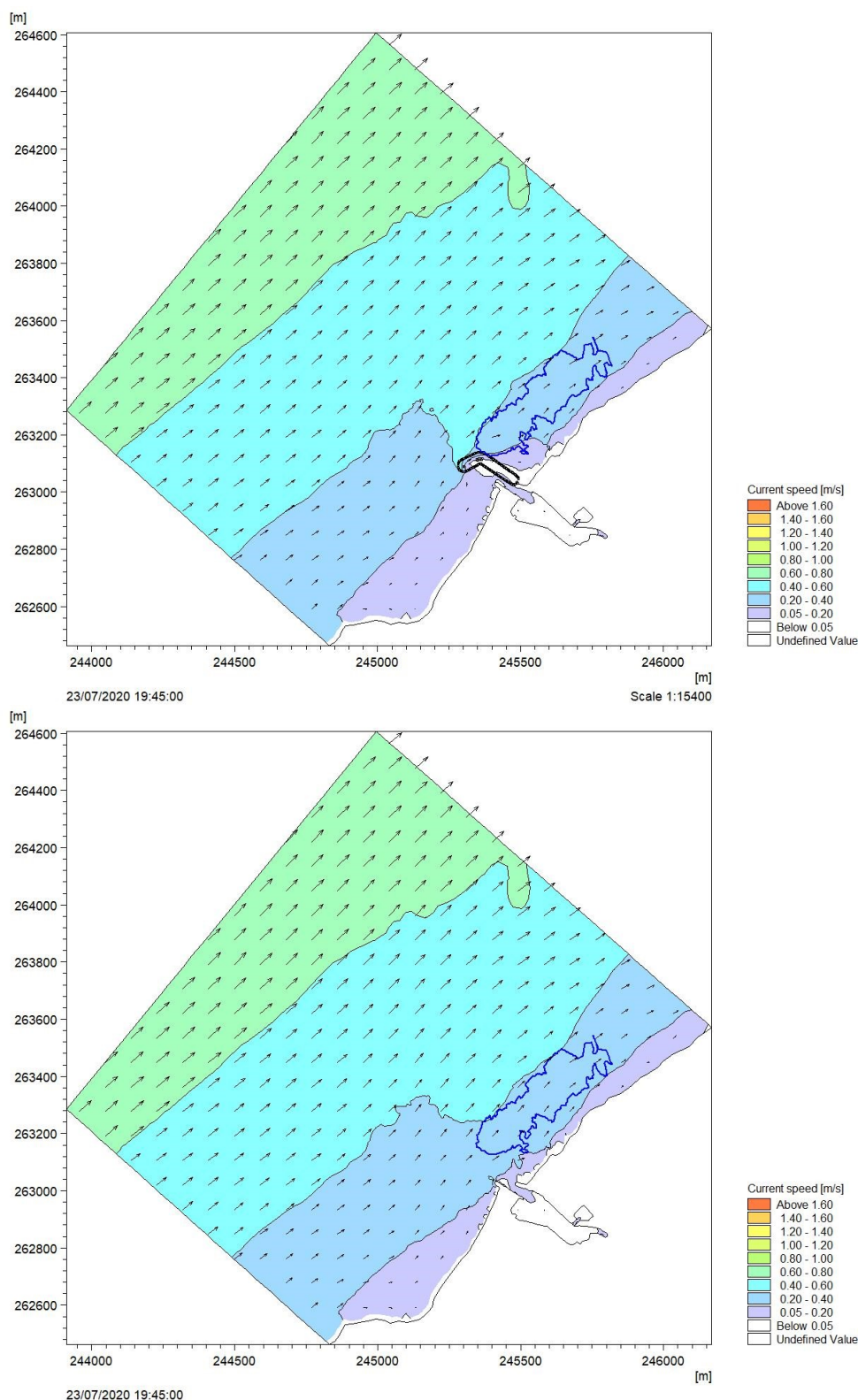


**Tide only model during ebb tide – Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**

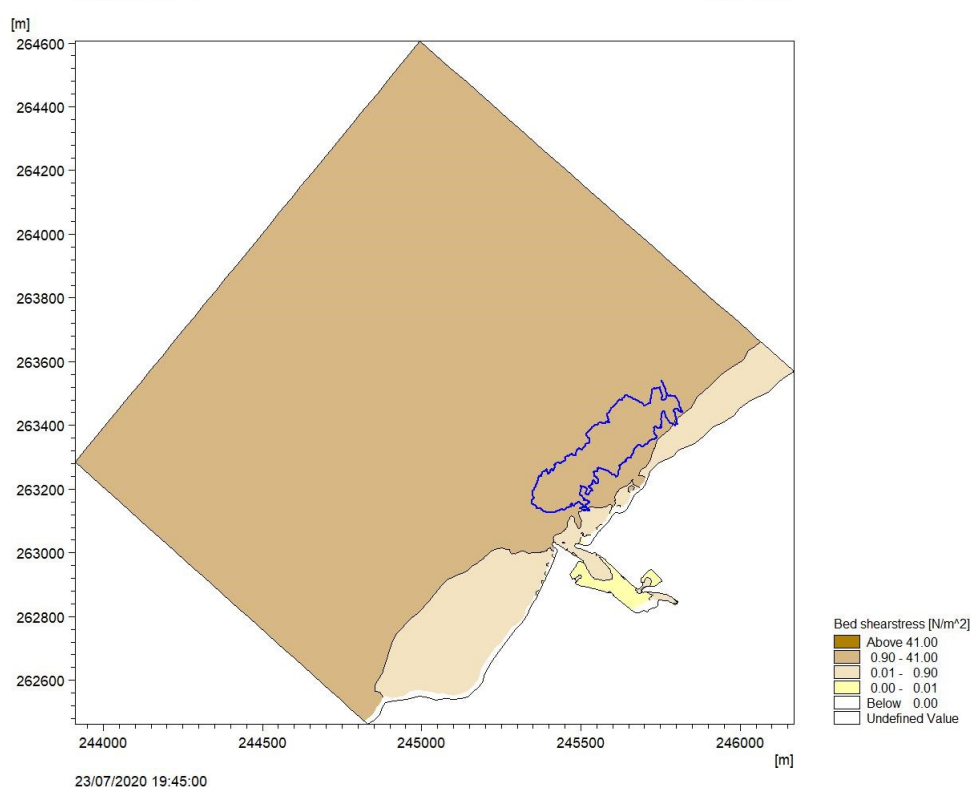
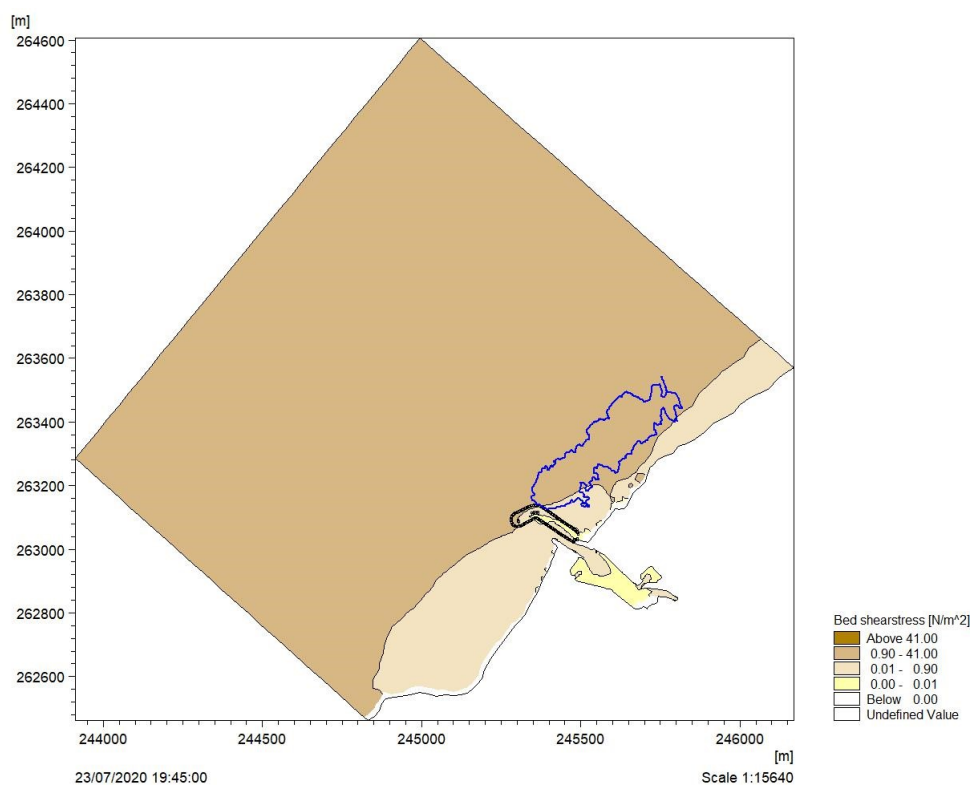


**Tide only model during ebb tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

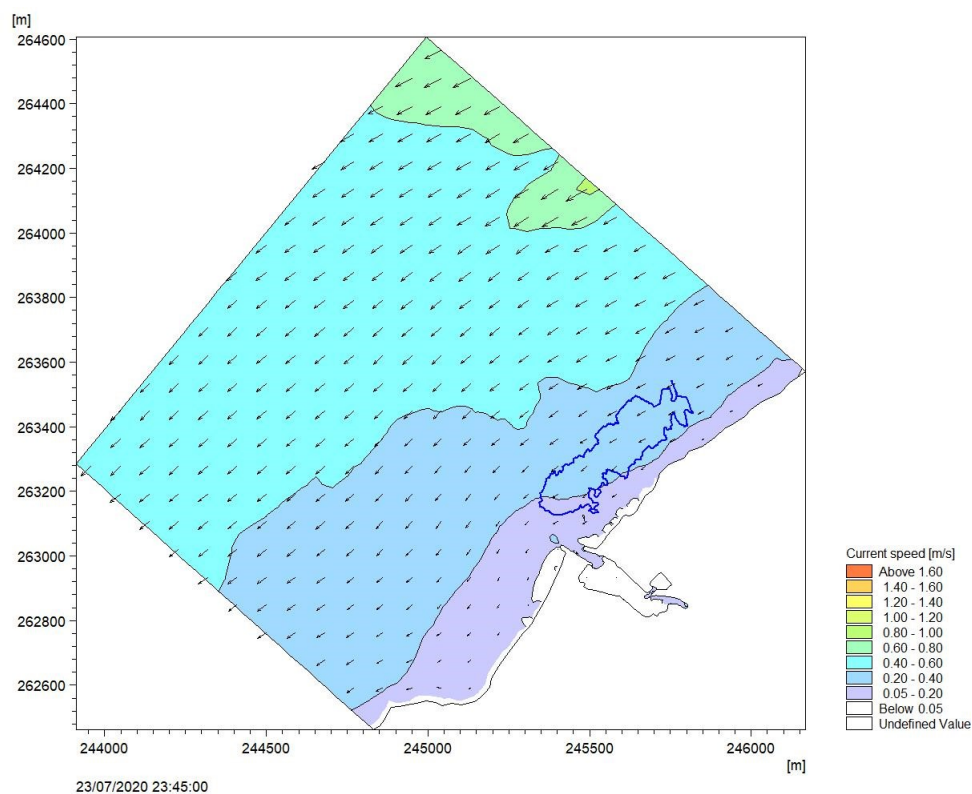
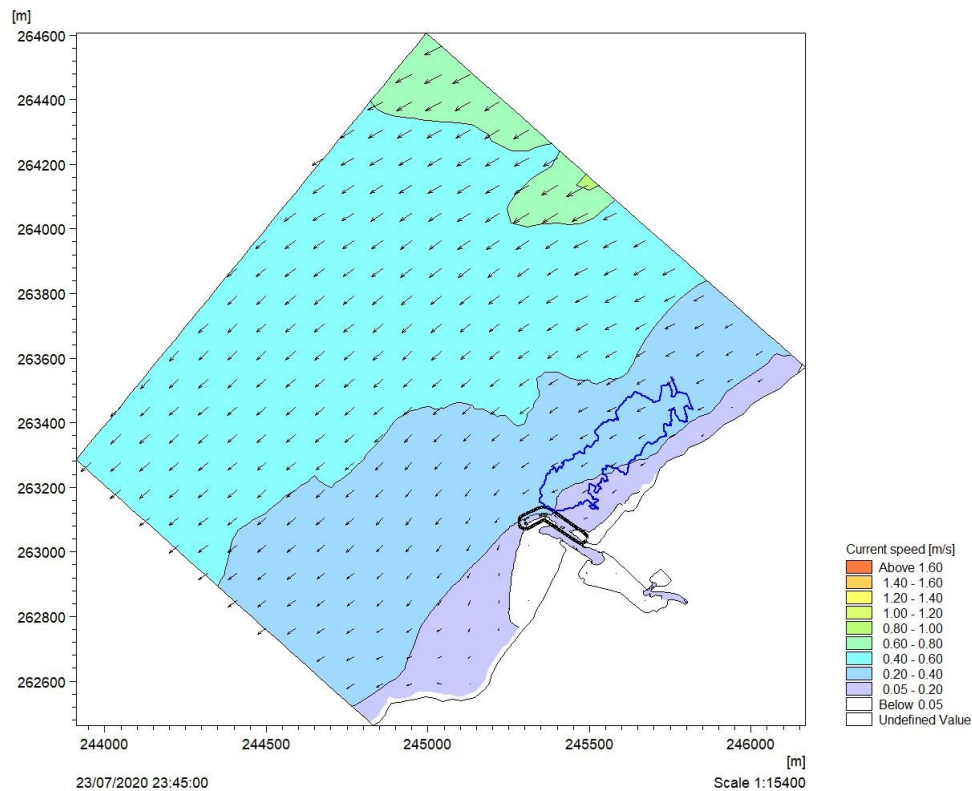
## C.2. Tide and typical fluvial flow model plots



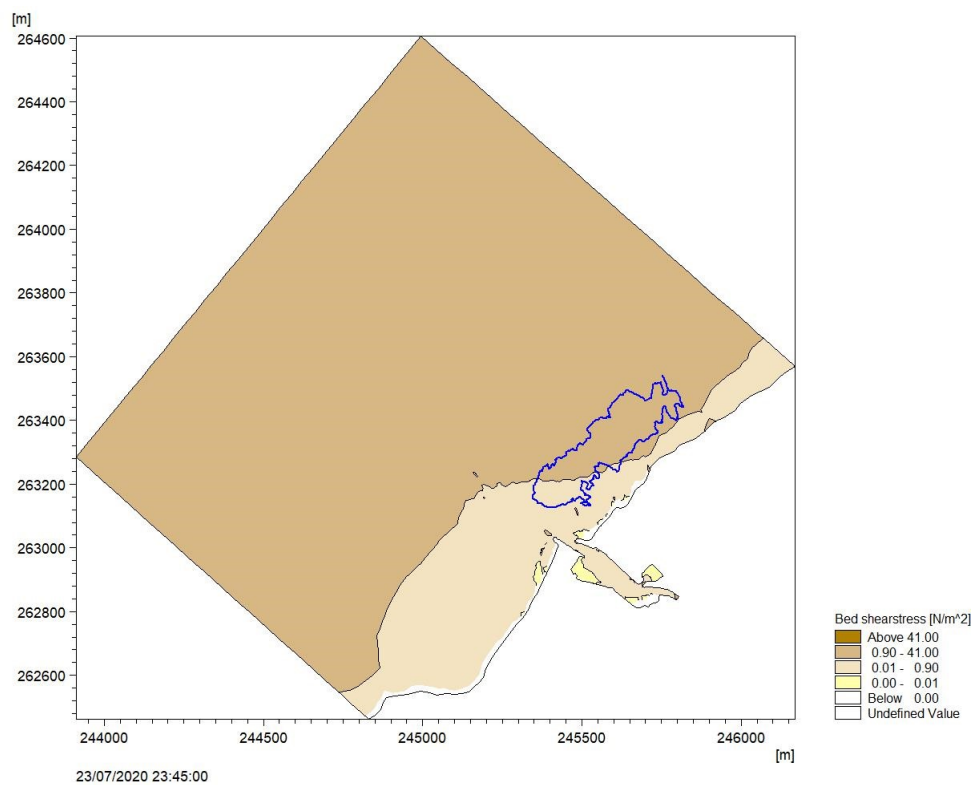
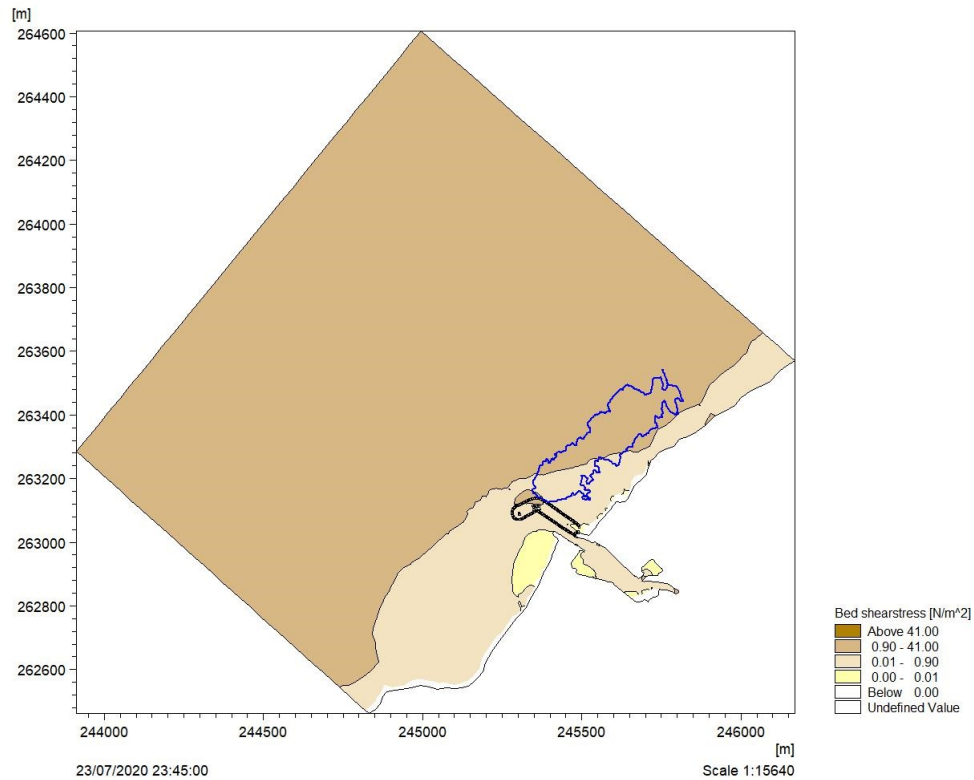
**Tide and typical fluvial flow model during flood tide– Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**



**Tide and typical fluvial flow model during flood tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

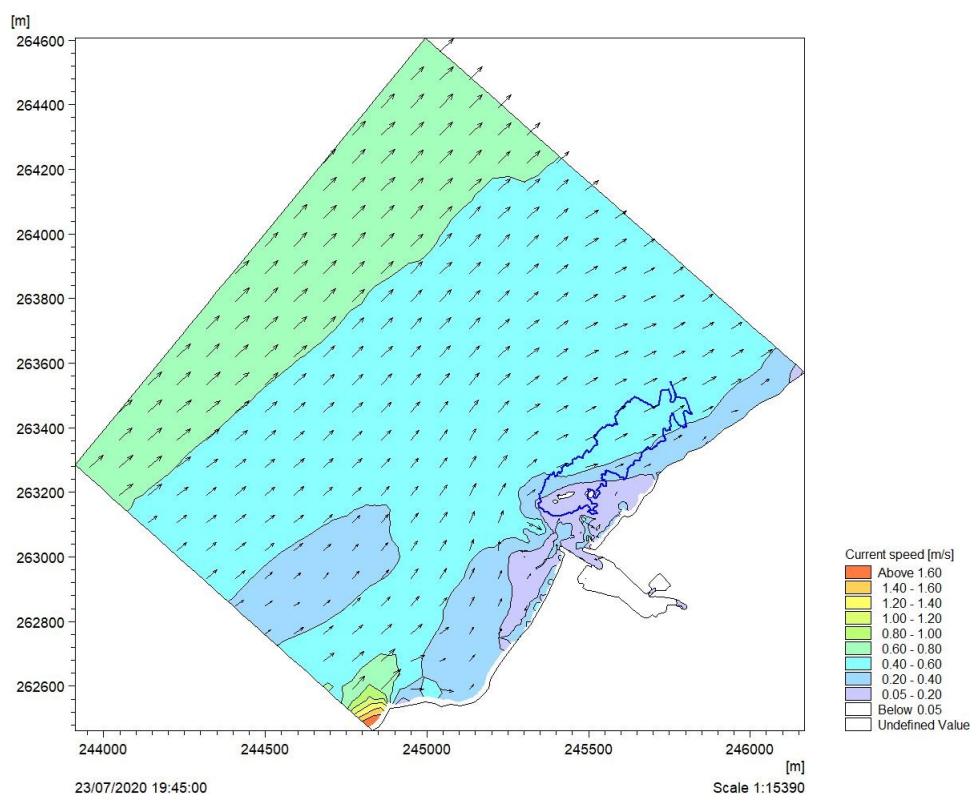
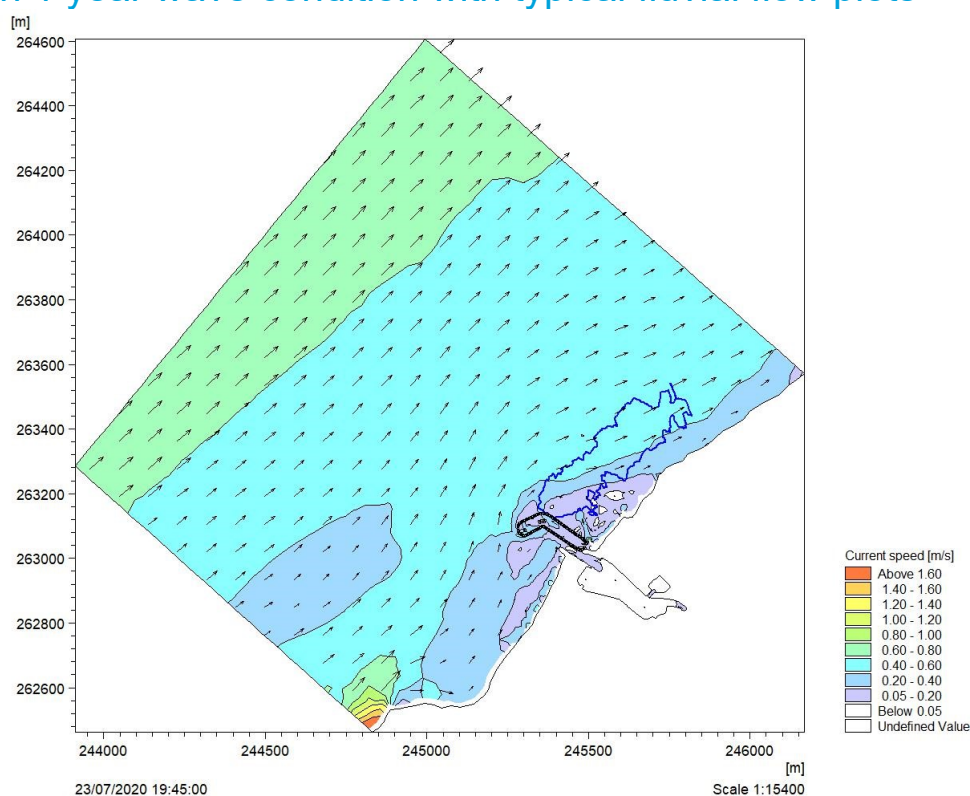


**Tide and typical fluvial flow model during ebb tide– Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**

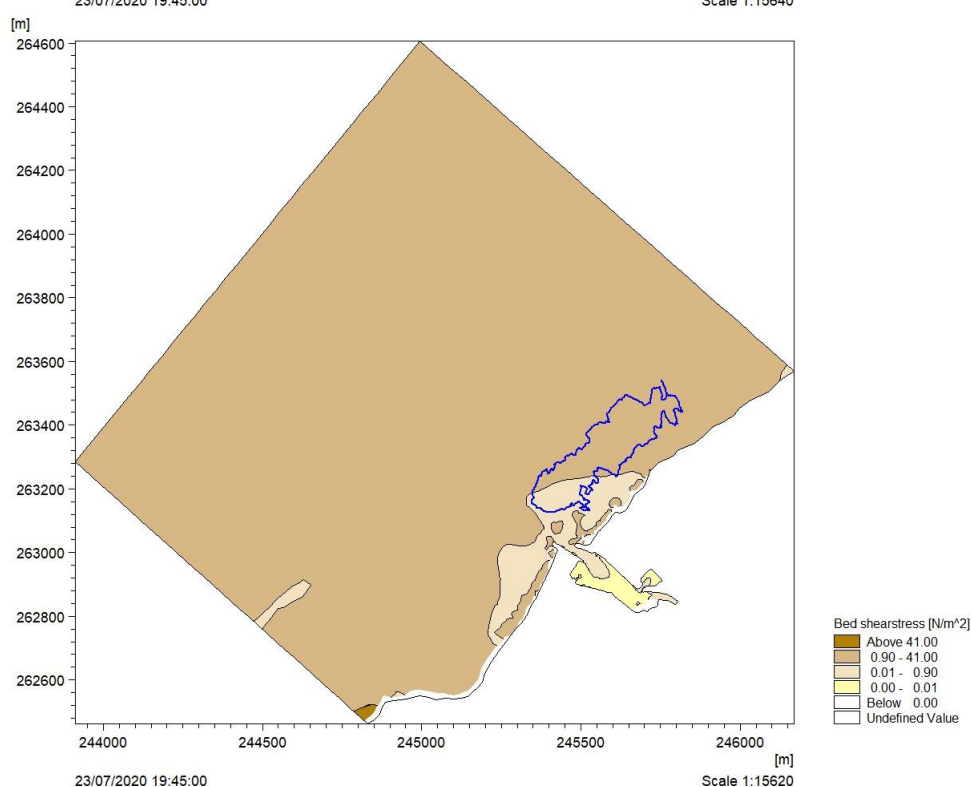
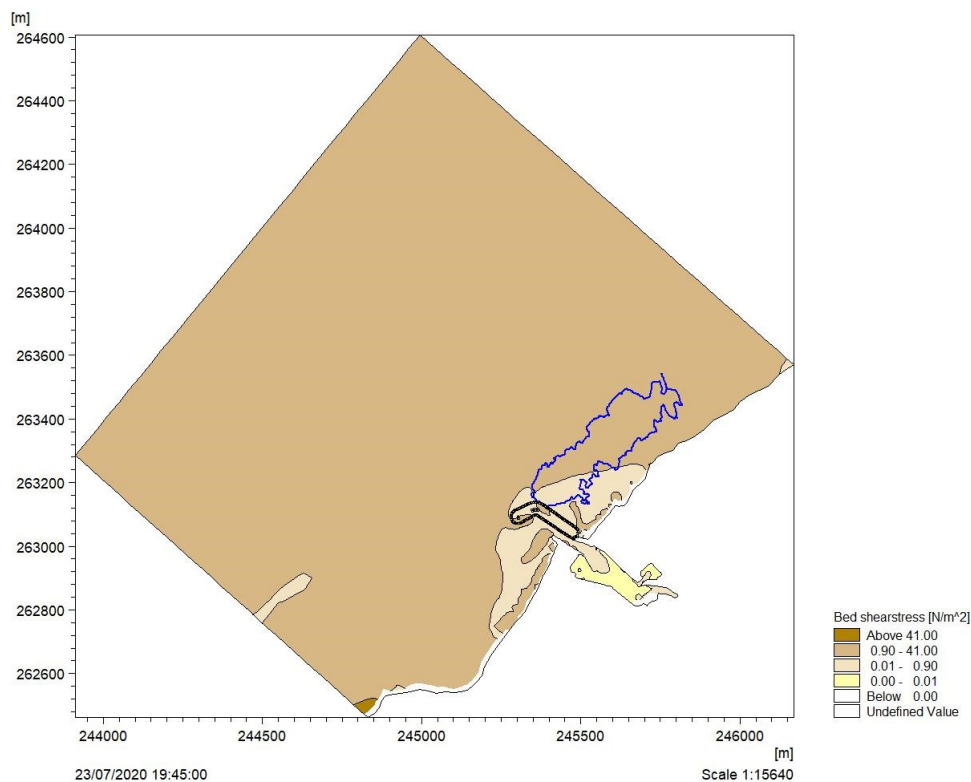


**Tide and typical fluvial flow model during ebb tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

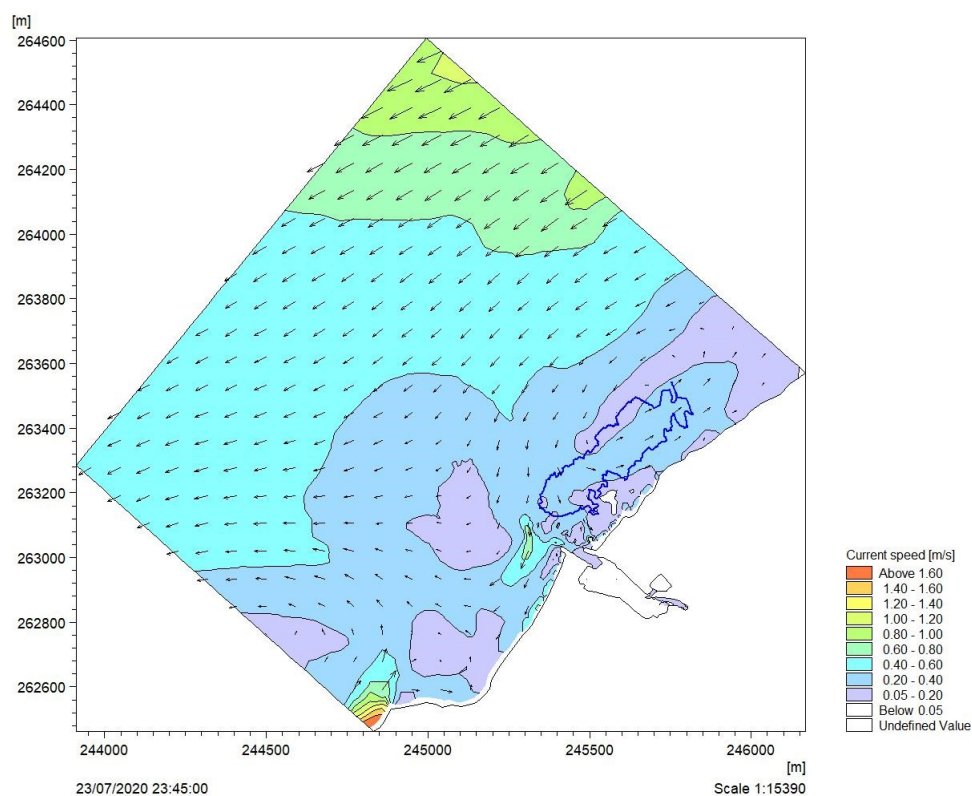
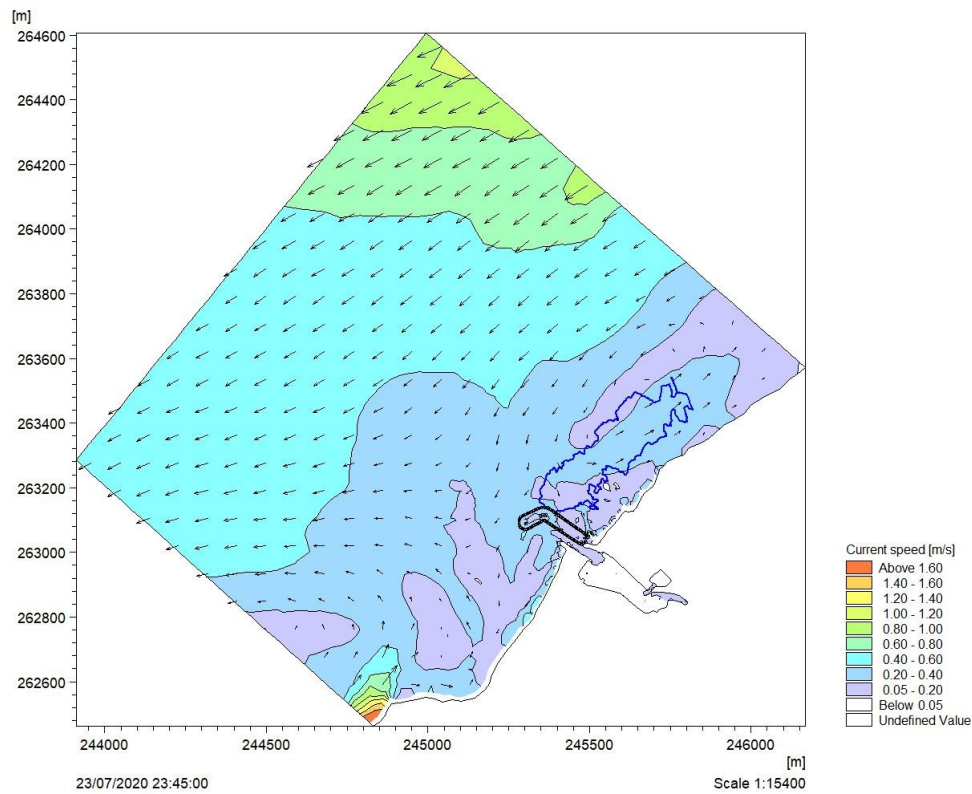
### C.3. 1 in 1 year wave condition with typical fluvial flow plots



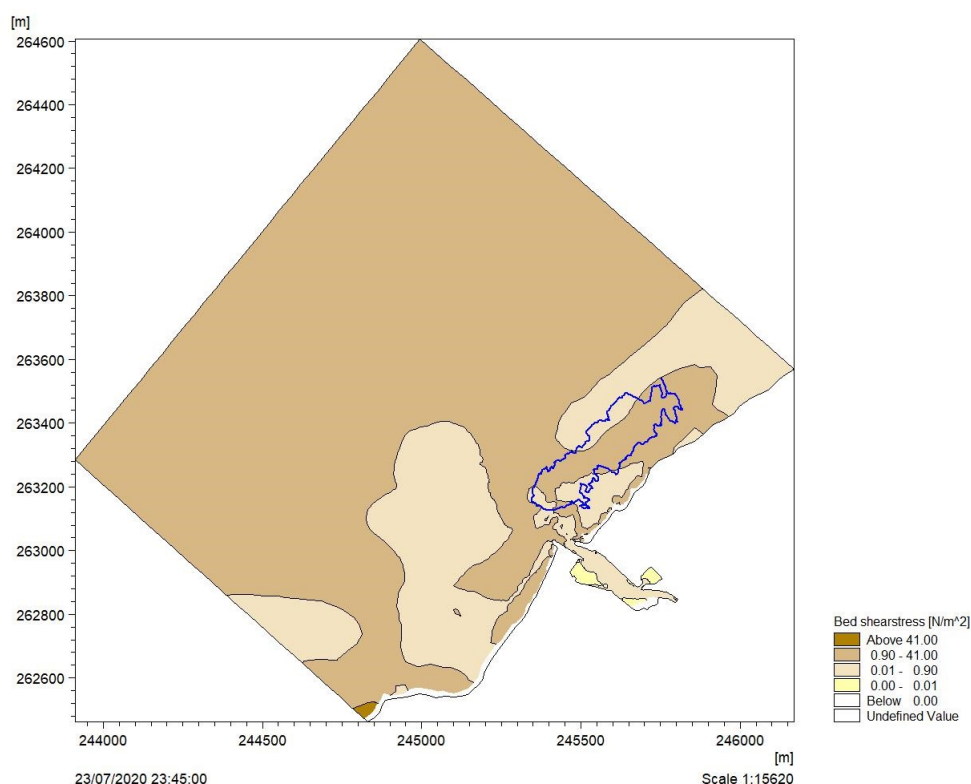
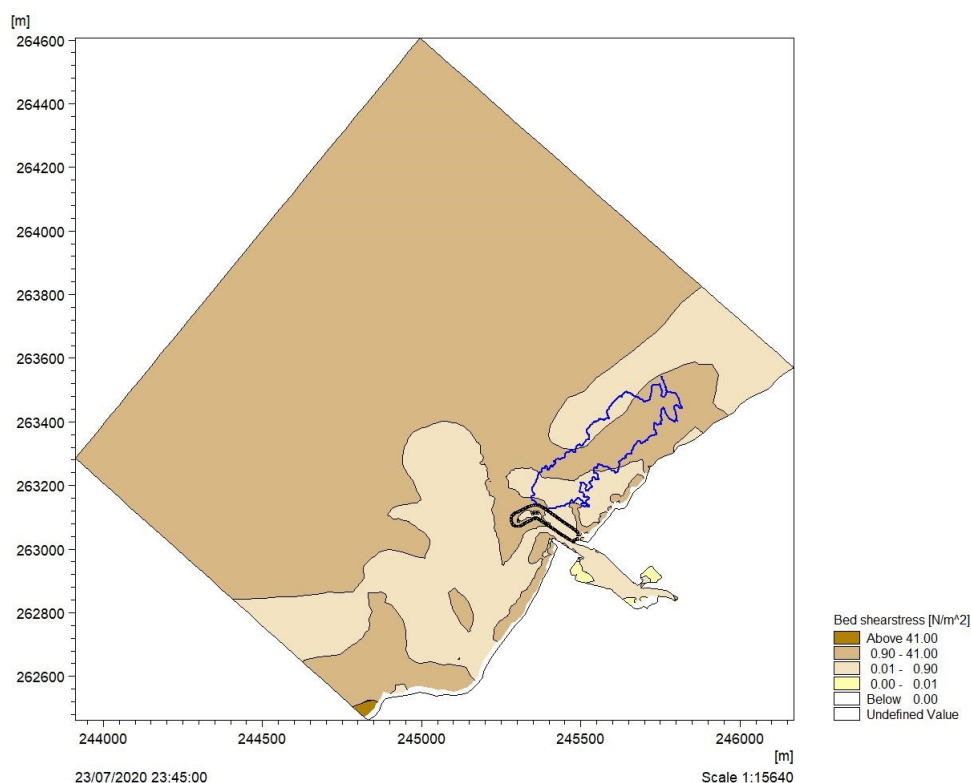
**1 in 1 year wave condition and typical fluvial flow model during flood tide– Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**



**1 in 1 year wave condition and typical fluvial flow model during flood tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

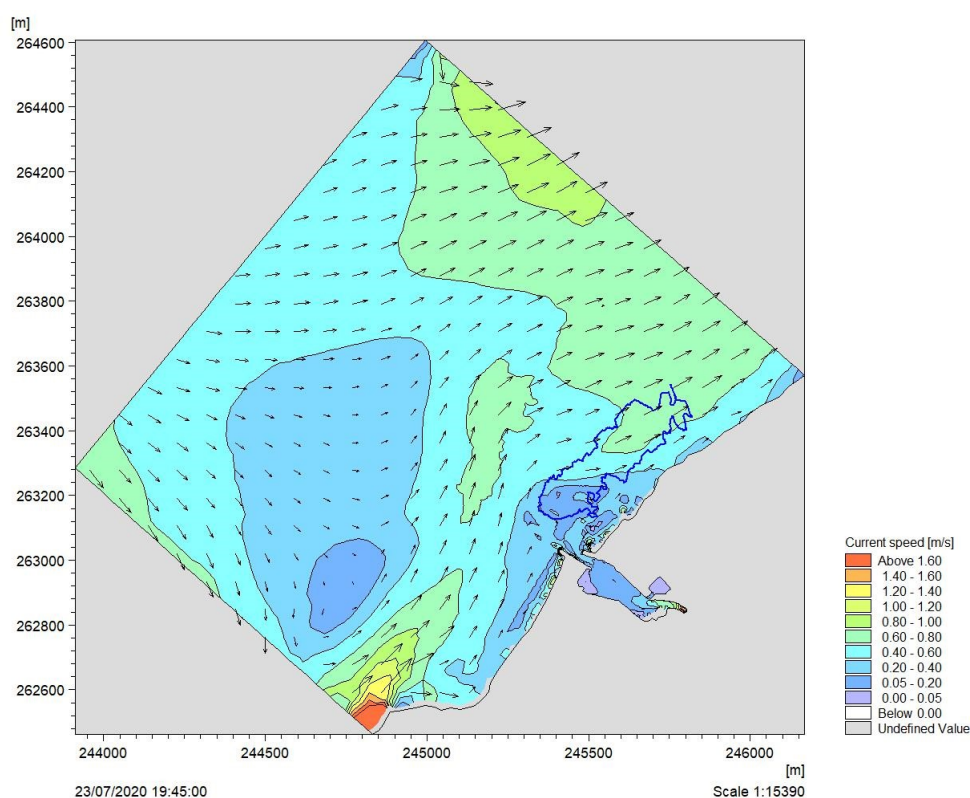
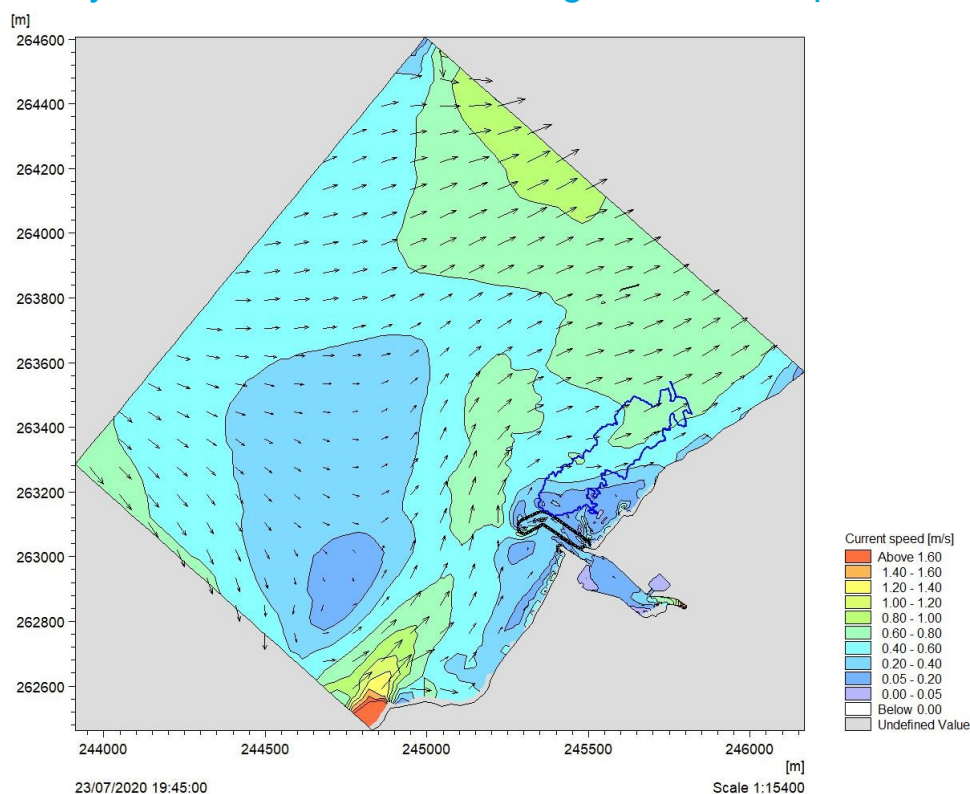


**1 in 1 year wave condition and typical fluvial flow model during ebb tide– Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**

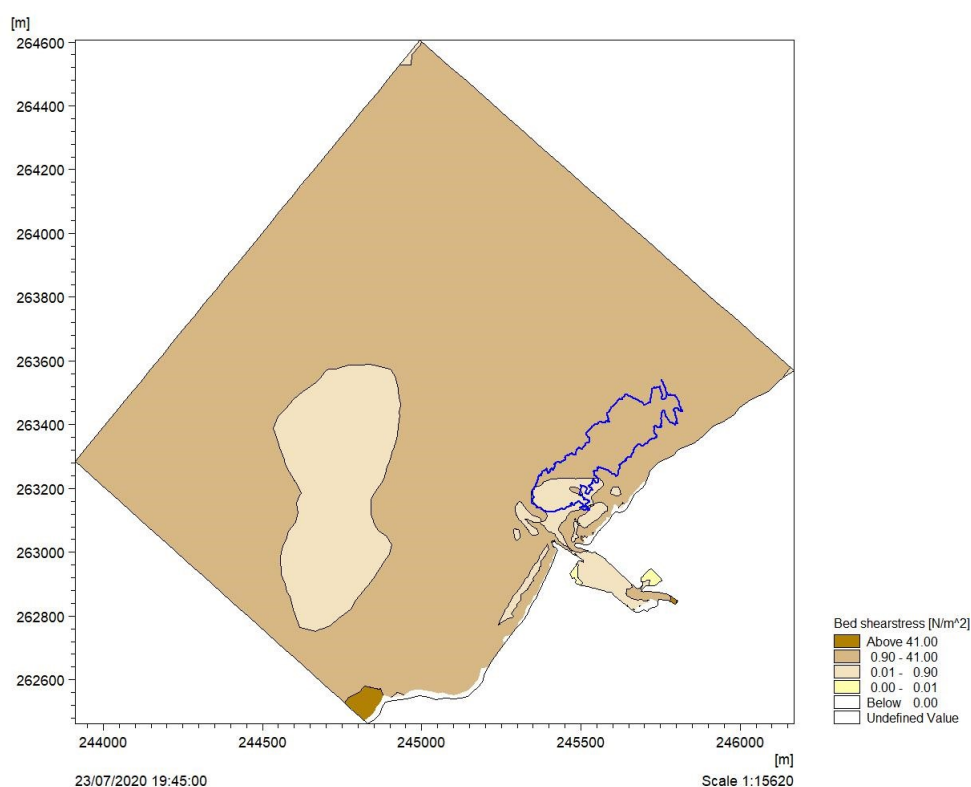
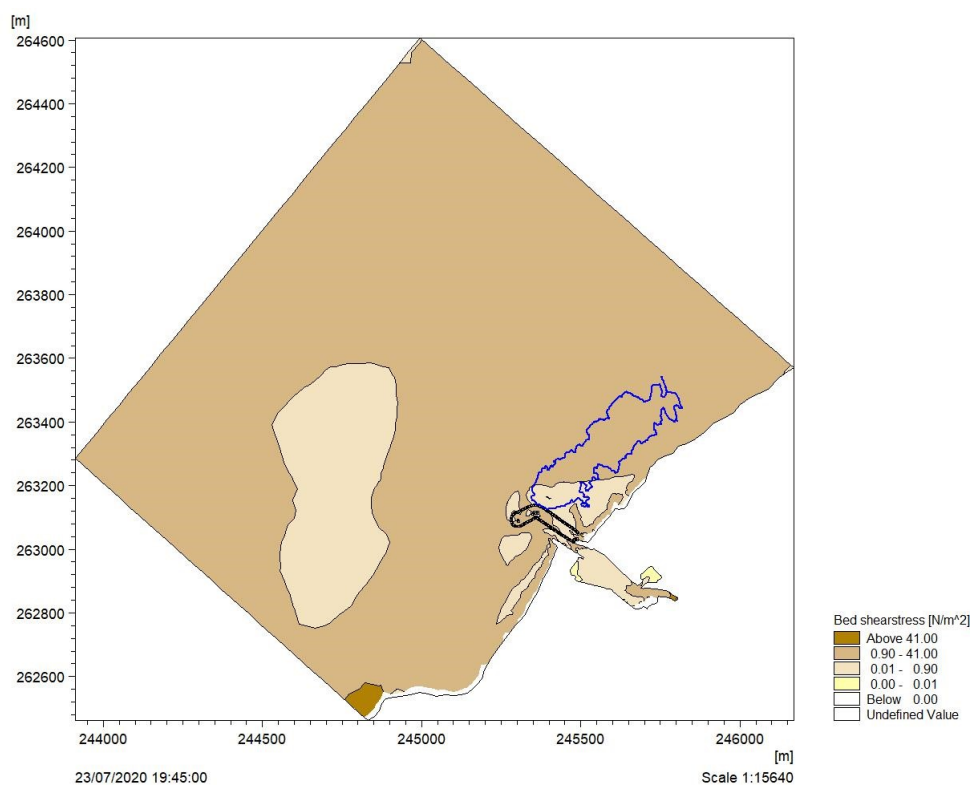


**1 in 1 year wave condition and typical fluvial flow model during ebb tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**

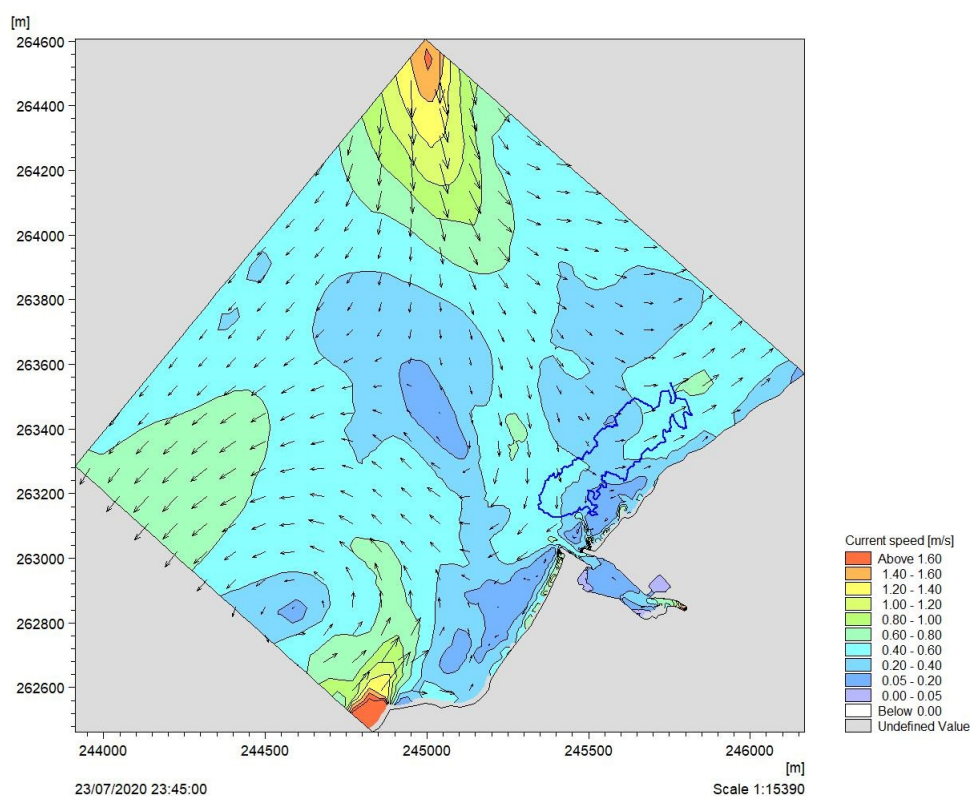
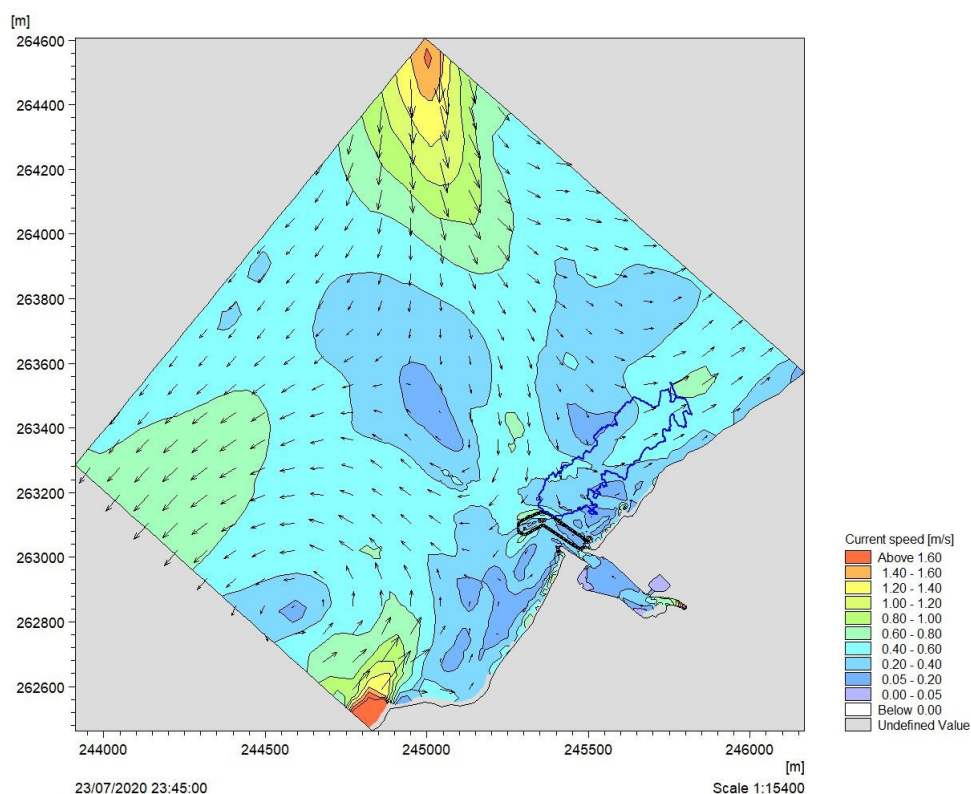
## C.4. 1 in 75 year wave condition and high fluvial flow plots



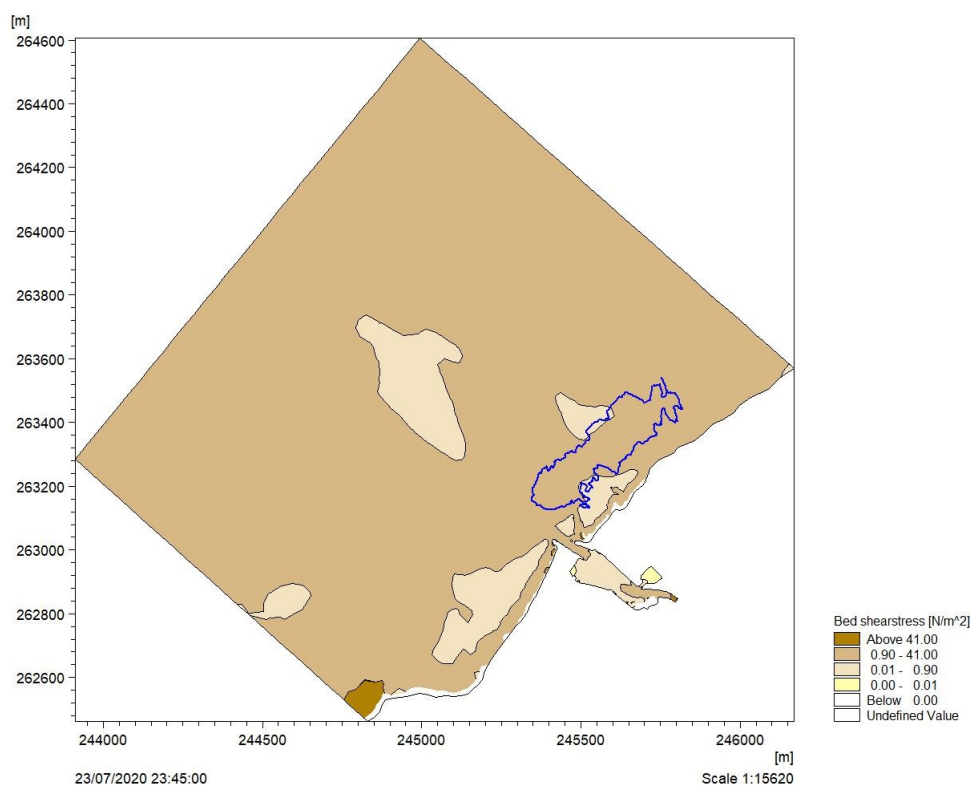
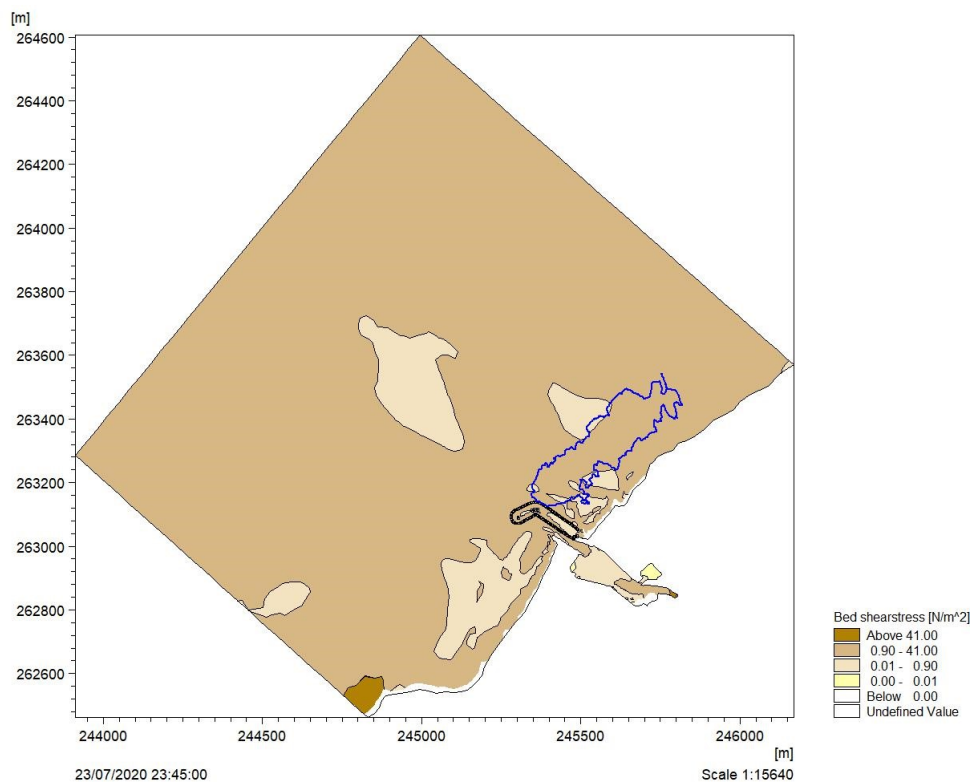
**1 in 75 year wave condition and 1 in 2 year fluvial flow model during flood tide - Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**



**1 in 75 year wave condition and 1 in 2 year fluvial flow model during flood tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).**



**1 in 75 year wave condition and 1 in 2 year fluvial flow model during ebb tide - Current speed and direction plot showing influence of breakwater (top) and baseline output (bottom).**



1 in 75 year wave condition and 1 in 2 year fluvial flow model during ebb tide - Threshold of motion plot showing influence of breakwater (top) and baseline output (bottom).

**Atkins Limited**  
West Glamorgan House  
12 Orchard Street  
Swansea  
SA1 5AD

© Atkins Limited except where stated otherwise