ARDERSIER PORT
ENERGY TRANSITION FACILITY
PORT EXTENSION

Haventus

November 2025

Appendix 10.1: Legislation, Policy and Guidance

Appendix 10.1: Legislation, Policy and Guidance

The purpose of this appendix is to support Chapter 10 (Coastal Processes and Geomorphology) of the Environmental Impact Assessment Report (EIAR).

The proposed development description is provided in Chapter 3 (Project Description). The Indicative Masterplan is provided in Figure 3.3 of Chapter 3. An Environmental Constraints Plan is provided in Figure 1.4 of Chapter 1 (Introduction).

The assessment for coastal processes and geomorphology has been undertaken with reference to the following relevant legislation, planning policy and guidance presented below.

Legislation

Relevant legislation and guidance documents have been reviewed and taken into account as part of this assessment. Of particular relevance are:

- Water Framework Directive (WFD) 2000/60/EC of the European Parliament;
- Water Environment and Water Services (Scotland) Act 2003;
- Marine (Scotland) Act 2010;
- Coast Protection Act 1949;
- Water Environment (Controlled Activities) (Scotland) Regulations 2011, as amended (CAR);
- Water Environment (Miscellaneous) (Scotland) Regulations 2017;
- Environmental Impact Assessment (EIA) Directive (2014/52/EU);
- The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017; and
- The Marine Works (Environmental Impact Assessment) Regulations (Scotland) 2017.

Planning Policy

- National Planning Policy 4 (NPF4) (The Scottish Government, 2023);
- UK Marine Policy Statement (DEFRA, 2011); and
- Scotland's National Marine Plan (The Scottish Government, 2015).

Guidance

Consideration has been taken of the following best practice guidelines/guidance:

- NetRegs Guidance for Pollution Prevention (GPP) Documents. Available at: https://www.netregs.org.uk/environmental-topics/guidance-for-pollution-prevention-gpp-documents/
    - GPP 1: Understanding your environmental responsibilities – good environmental practices;
    - GPP 5: Works and maintenance in or near water;
- SEPA, 2009. WAT-SG-29: Good Practice Guide - Construction Methods;
- SEPA, 2010. WAT-SG-26: Good Practice Guide - Sediment Management.
- SEPA, 2025. Climate change allowances for flood risk assessment in land use planning (V6). Available at: https://www.sepa.org.uk/media/jjwpxuso/climate-change-allowances-guidance_v6.pdf.

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Appendix 10.2: Assessment Methodology

Appendix 10.2: Assessment Methodology

1.1 Introduction

The purpose of this appendix is to support Chapter 10 (Coastal Processes and Geomorphology) of the Environmental Impact Assessment Report (EIAR). This appendix presents the assessment methodology applied within Chapter 10.

The methodology follows standard Environmental Impact Assessment (EIA) procedures, in accordance with the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017, and involves the following:

- Consultation with key stakeholders;
- Desk based study establishing the existing baseline conditions;
- Coastal processes assessment (Appendix 10.3) including coastal modelling study;
- Identification of sensitive receptors and environmental constraints;
- Identification of potential environmental impacts including cumulative impacts;
- Assessment of impact magnitude;
- Identification and assessment of mitigation, enhancement, and monitoring measures; and
- Statement of significance of residual effects.

1.2 Study Area

The study areas for the different components were as follows:

- In order to investigate the wider impacts of the development on designated sites, a 2 km buffer has been applied to the application site;
- The baseline review and coastal processes assessment, which includes modelling of tides, waves and sediment transport processes, have been considered across the wider Moray Firth with focus on the local coastal system at Whiteness Head;
- Cumulative impacts: The assessment focused on developments within a 15 km of the application site. For coastal processes and geomorphology, the zone of influence (ZOI) for assessment focuses on the receiving coastal waterbody (Hilton of Cadboll to Whiteness Head coastal water body) as shown within Figure 1 and Figure 2. The ZOI covers an area of 15,140 ha.

Figure 1: Zone of Influence

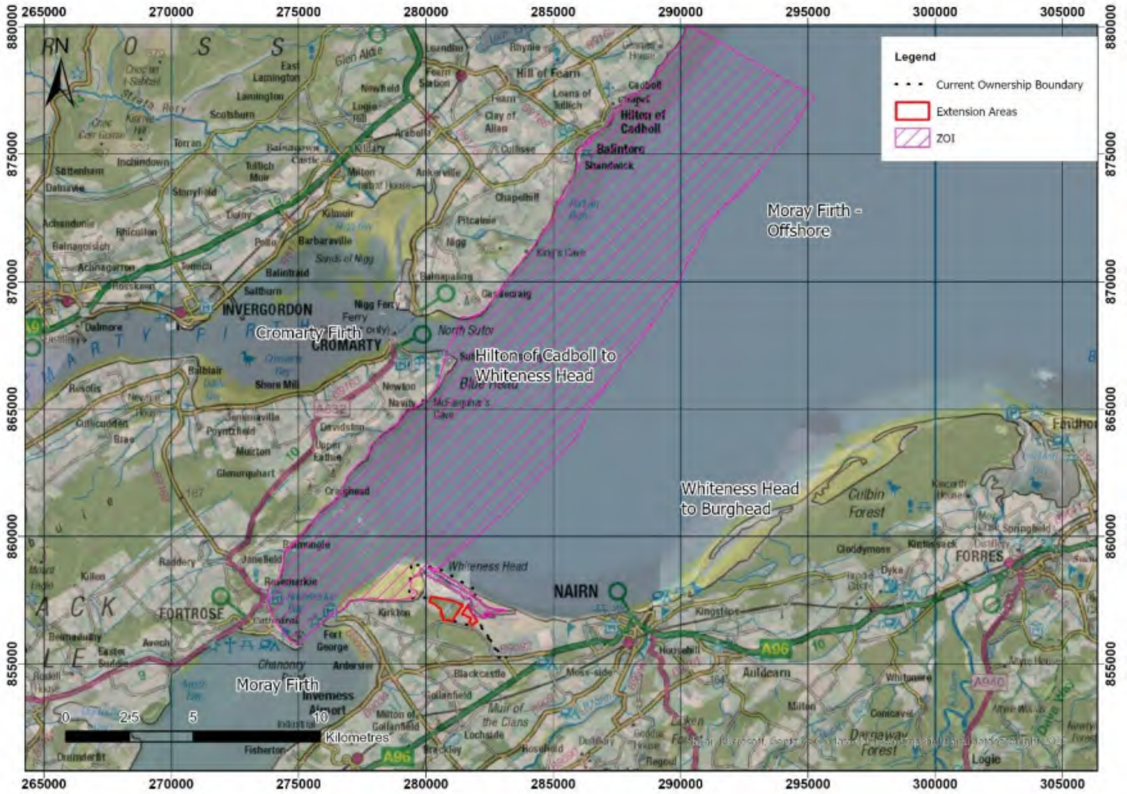
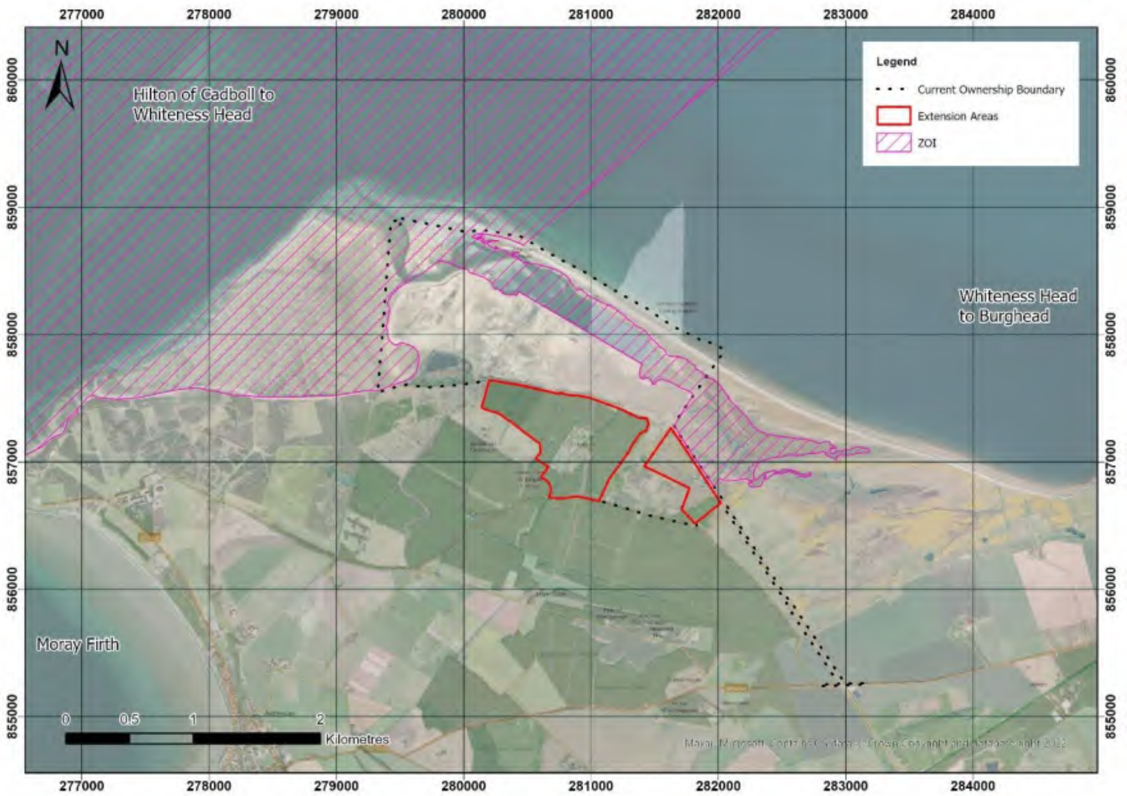


Figure 2: Zone of Influence at the Site



1.3 Data Sources

The following published data sources have been used:

- Admiralty Tide Tables (2025) have been used to establish the tidal conditions;
- Met Office UK Climate Averages have been used to establish the baseline wind speed conditions (Met Office, 2020);
- DHI Metocean Data Portal has been used to establish baseline atmospheric and wave conditions;
- Climates change allowances have been established from SEPA (2025) online web map for the northeast Scotland region;
- The River Basin Management Plan (RBMP) Interactive Map has been used to establish the baseline status for surface water and coastal water bodies (SEPA, 2015); and
- Data sources used within the coastal modelling study are described in Appendix 10.3.

A site walkover was undertaken by EnviroCentre on 30th April 2025 to review coastal conditions and processes at the site.

1.4 Methodology

The assessment follows standard EIA procedures which include:

- Desk based review of the design of the proposed development in relation to the coastal water environment, which include tides, waves and sediment transport processes;
- Consultation with key stakeholders to obtain relevant information and to ensure their concerns are addressed within the study;
- Establishing the existing baseline conditions:
  - Review of coastal processes including bathymetry, tidal levels, tidal flow currents, wave action, bed sediment type and distribution, sediment transport and deposition, and geology;
  - Undertake detailed Coastal Processes Assessment, including coastal modelling study, as provided within Appendix 10.3; and
  - Reporting of baseline conditions to provide a basis for assessment of the potential impact.
- Impact assessment:
  - Identification of sensitive receptors and environmental constraints;
  - Identification of potential impacts;
  - Assessment of impact magnitude;
  - Identification and assessment of mitigation measures to reduce or avoid any potential impacts of the proposed development; and
  - Statement of residual effects.

Potential impacts arising from the proposed development have been predicted and evaluated. The observed baseline data and model outputs have been used along with professional opinion to assess the potential impacts and the significance to receptors.

1.5 Assessment Criteria

The assessment criteria set out in Table 1 and Table have been used to develop a matrix to assess the significance of effects from the proposed development on the local water environment (Table)

The assessment considers whether the impact is positive or negative. The assessment of residual effects takes into consideration the probability of the effect occurring within the following probabilities:

- Certain;
- Likely;
- Possible; or
- Unlikely

The duration of the effect is assessed within the following durations:

- Short (less than 2 years);
- Medium (2 – 5 years);
- Long term (more than 5 years); or
- Permanent

All direct and indirect impacts causing moderate or major effects are considered to be significant.

Table 1: Criteria for Assessing Receptor Sensitivity

Receptor Sensitivity	Description
Low	Receptors with a high capacity to accommodate change, low value or poor condition and no significant uses, for example: • Receptor is not an internationally, nationally or locally designated site. • Not classified as a coastal water body for the River Basin Management Plan (RBMP). • Coastal water body not significant in terms of fish spawning and no other sensitive aquatic ecological receptors. • Coastal water body not used for abstraction. • Coastal water body not used for recreation directly related to water quality e.g. angling, swimming, watersports. • Coastal water body not used by commercial or recreational vessels. Low or very low productivity aquifer with no identified abstractions.

Receptor Sensitivity	Description
Medium	Receptors with a moderate capacity to accommodate change, medium value or condition and limited use, for example: • Receptor is not an internationally or nationally designated site. May be a locally designated site. • Salmonid species may be present and surface water body may be locally important for spawning. No other sensitive aquatic ecological receptors e.g. freshwater pearl mussels. • Coastal water body used for private water supply or medium scale industrial/ agricultural abstractions. • Coastal water body used for occasional or local recreation e.g. local angling clubs. • Navigable coastal water body used by commercial or recreational vessels. • Moderate productivity aquifer. • Groundwater body supports identified private water supplies or medium scale industrial/ agricultural abstractions.
High	Receptors with a low capacity to accommodate change, high value or condition and significant use, for example: • Receptor is an internationally or nationally designated site. • Coastal water body supports sensitive aquatic ecological receptors e.g. freshwater pearl mussels. • Coastal water body used for public water supply or large scale industrial/ agricultural abstractions. • Coastal water body important for recreation directly related to water quality e.g. swimming, watersports, angling. • High or very high productivity aquifer. • Groundwater body supports public water supply or large scale industrial/ agricultural abstractions.

Table 2: Criteria for Assessing Impact Magnitude

Receptor Sensitivity	Description
Negligible	Very light change from baseline conditions. Change barely distinguishable, approximating to the ’no change’ situation.
Low	Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible but underlying character/composition/attributes of the baseline condition will be similar to pre-development circumstances/patterns.
Medium	Loss or alteration to one or more key elements/features of the baseline conditions such that post-development character/ composition/ attributes of baseline will be partially changed.
High	Total loss or major alteration to key elements/features of the baseline (pre-development) conditions such that post-development character/composition/attributes will be fundamentally changed.

Table 3: Criteria for Assessing Effects

		Magnitude of Impact			
		Negligible Impact	Low Impact	Medium Impact	High Impact
Receptor Sensitivity	High Sensitivity	Negligible Effect	Moderate Effect	Major Effect	Major Effect
	Medium Sensitivity	Negligible Effect	Minor Effect	Moderate Effect	Major Effect
	Low Sensitivity	Negligible Effect	Minor Effect	Minor Effect	Moderate Effect

1.6 Assumptions and Limitations

The coastal modelling, as presented as Appendix 10.3, assumes existing baseline conditions as per the topographic and bathymetric survey undertaken in August 2025, following completion of the Phase 1 capital dredge. The model setup assumes static shoreline alignment, which is a limitation when considering longer term shoreline evolution in response to coastal erosion.

1.7 Assessor Information

Martin Nichols BSc (Hons) MSc MCIWEM C.WEM

Martin is an Associate Director is an Associate Director with EnviroCentre. He has over 14 years consultancy experience in coastal processes, hydrology, flood risk, geomorphology, and EIA. He is an experienced hydraulic modeller, having undertaken modelling in support of a range of projects including, port and harbour developments, coastal, catchment and river restoration, and flood risk assessments. Martin has geomorphology field survey experience in coastal, river and upland systems, and has undertaken EIA for a range of developments including coastal protection schemes, harbours, marinas, residential developments, quarries, energy infrastructure and wind farms. He has extensive GIS experience including spatial and 3D data analysis. Martin is a Chartered Water & Environmental Manager (C.WEM), and an experienced project manager.

Jennifer Smith BSc (Hons) MSc MCIWEM

Jennifer Smith is a Senior Environmental Consultant with EnviroCentre. She has gained over 5 years' experience of consultancy whilst working on a range of projects including peat surveys and assessments, hydrological assessments, coastal assessments, EIA, development projects, surface water management and environmental monitoring. Jennifer has gained valuable skills in GIS, including spatial and 3D analysis techniques. Jennifer has undertaken various assessment and written several EIA chapters for a range of development including harbours, wind farms, energy infrastructure and peat extraction sites. Jennifer is a non-chartered member of CIWEM.

Charlotte Hewson BSc (Hons) MSc

Charlotte is an Environmental Consultant with EnviroCentre. She has gained over 3 years' experience in consultancy and regulatory roles, following a BSc in Oceanography & Coastal Processes and an MSc in Hydrology and Water Management. Charlotte has project experience in coastal and terrestrial EIAR's, coastal assessments, private water supply assessments, and peat assessments. Charlotte has developed skills in GIS including spatial and 3D analysis techniques, and has field survey experience including environmental monitoring, hydrology walkovers and peat surveys.

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November 2025

Appendix 10.3 Coastal Processes Assessment

Ardersier Port Extension
Coastal Processes Assessment

October 2025

CONTROL SHEET

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Project Title: Ardersier Port Extension
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1 INTRODUCTION

1.1 Terms of Reference

EnviroCentre Ltd has been appointed by Ardersier Port (Scotland) Limited to undertake a Coastal Processes Assessment to assess the impact of a proposed port extension at Ardersier Port. This assessment forms Appendix 10.3 to Chapter 10 (Coastal Processes and Geomorphology) of the Environmental Impact Assessment Report (EIAR) for the proposed development.

1.2 Scope of Report

This assessment will describe the development of coastal Hydrodynamic (HD), Spectral Wave (SW) and Sand Transport (ST) models of conditions at Ardersier Port, to reflect existing (pre-port extension baseline) conditions, and proposed post-extension conditions with the inner harbour dredge and quay complete. The HD model will enable simulation and characterisation of tidal flow under pre-extension (baseline) and post-extension conditions. The updated SW model will enable simulation and characterisation of wave climate under pre-extension (baseline) and post-extension conditions. The updated ST model will enable simulation and characterisation of sand transport under pre-extension (baseline) and post-extension conditions. Additional model scenarios will simulate predator free island extension options under post-extension conditions.

This report will present details of the baseline coastal conditions at the development site, outline the HD, SW and ST model development, and describe the model simulations and results. The baseline and post-extension model results will be compared in order to assess the relative impact of proposed port extension. This assessment builds on previous assessments of coastal processes at Ardersier Port including the July 2024 Ardersier Port Coastal Model and Assessment Update (EnviroCentre Report No. 13845), the July 2023 Ardersier Port Coastal Processes Assessment (EnviroCentre Report No. 13546) and the 2018 Ardersier Port Coastal Processes Assessment (EnviroCentre Report No. 8364).

1.3 Report Usage

The information and recommendations contained within this report have been prepared in the specific context stated above and should not be utilised in any other context without prior written permission from EnviroCentre Limited. If this report is to be submitted for regulatory approval more than 12 months following the report date, it is recommended that it is referred to EnviroCentre Limited for review to ensure that any relevant changes in data, best practice, guidance or legislation in the intervening period are integrated into an updated version of the report.

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2 CONTEXT

2.1 Site Overview

Ardersier Port is located on the site of the former McDermott Fabrication Yard, which lies some 7.5 km to the west of Nairn, 18 km northeast of Inverness and 3 km northeast of the village of Ardersier, centred on grid reference NH 812 576.

The site is bounded by Whiteness Spit and the Moray Firth to the north; extensive undeveloped sand and mudflats, known as the Carse of Delnies to the east; Carse Wood to the south; and Whiteness Head tidal sands to the west. To the southwest of the site lies the boundary of Fort George owned by the Ministry of Defence (MoD).

The majority of the site was historically reclaimed using dredged sand that was levelled behind a steel pile retaining wall at approximately 4.5 m above ordnance datum (OD). Following reclamation, the site was developed for industrial use as the McDermott Fabrication Yard (as shown in **Error! Reference source not found.**), which specialised in the fabrication and construction of offshore platforms used in the development of the North Sea oil and gas industry. Fabrication activities ceased at the site in 2001.

Figure 2.1: Historic Aerial Photograph of Operational McDermott Yard

The site has more recently been redeveloped to form Ardersier Port, with works undertaken to date including the capital dredge of the navigation channel and harbour entrance, as well as development of 659 m of quay wall and strengthening the associated quayside, providing access to a 182-hectare site.

2.2 Dredging Activity to Date

The original fabrication yard at Ardersier was developed in 1972. Initial construction of the yard area saw the formation of the navigation channel and harbour, with the dredged material being pumped ashore for land reclamation purposes to create the main yard area. Subsequent maintenance dredging operations were carried out at typically 18-24 month intervals up until 2001. No further dredging took place until 2022, when the present harbour and navigation dredging operations commenced.

The original navigation channel width was nominally 100 m with the dredge depth taking account of the particular vessels using the channel. Admiralty Chart 1077 indicates a dredge depth to -4.7 m Chart Datum (CD).

A dredging licence was consented as part of plans to re-open Ardersier Port in 2014, which included a navigation channel width of 120 m and a dredge to -8.5 mCD. The planned dredging did not take place at that time, and a subsequent dredging licence was consented in 2018 which included a navigation channel width of 120 m and a dredge to -6.5 mCD. Dredging of the harbour and navigation channel commenced under this consent in 2022, but the full dredge was not completed.

In summer 2025 dredging was undertaken under a new marine licence to form a navigation channel with a width of 160 m and advertised depth of -12.4 mCD and berths within the outer harbour. This is the existing (baseline) condition present on site.

2.3 Proposed Future Development

The proposed future development considered within this assessment is for extension of the current port by dredging of the inner harbour to -12.4 mCD and -6 mCD, along with replacement of the existing quay wall, including creation of a launch pocket and installation of a rock mattress. Additionally, a short extent of rock armour is proposed towards the harbour mouth. The development description from the EIAR is presented below, whilst further detail including the proposed layout is included in Chapter 3 (Project Description) of the EIAR.

> *‘Continued port development and extension of port related services for energy related uses, including marine dredging within the inner harbour, sea disposal of dredged sands, possible temporary stockpiling of dredged material, quay construction, erection of offices, industrial, and storage buildings, and associated infrastructure including manufacturing, assembly, delivery and export of port related cargo, parking, infrastructure, services, upfilling and re-grading/surfacing of new landward areas and landscaping’.*

2.4 Previous Coastal Studies

Previous investigations undertaken into the coastal processes around Whiteness Head that are relevant to the proposed dredge activities include:

- Geological Conservation Review: Whiteness Head, J.D. Hansom © JNCC 1980–2007. Volume 28: Coastal Geomorphology of Great Britain, Chapter 6: Gravel and ‘shingle' beaches – GCR site reports (GCR ID: 1442) (http://www.jncc.gov.uk/page-2731).
- Port of Ardersier: Whiteness Head Coastal Assessment, May 2013. EnviroCentre Report No 5474 to Port of Ardersier.
- Coastal Processes Assessment, September 2018. EnviroCentre Report No 8364 to Ardersier Port Ltd.

- The coastline at Whiteness Head is also included in the National Coastal Change Assessment (NCCA) led by the Scottish Government (Hansom, Rennie & Fitton, 2017; The Scottish Government, 2017).
- Ardersier Port Coastal Processes Assessment, July 2023. EnviroCentre Report No. 13546 to Ardersier Port Ltd.
- Ardersier Port Coastal Model and Assessment Update, July 2024. EnviroCentre Report No. 13845 to Ardersier Port Ltd.

3 BASELINE CONDITIONS

3.1 Topography and Bathymetry

The adjacent wider bathymetry of the Inner Moray Firth includes the presence of a number of important features to the local hydrodynamic regime, including the channels (north and south) around the Riff Bank sand bank opposite Ardersier Port, and to the west, the narrows between Fort George and Chanonry Point.

The local bathymetry within the harbour and navigation channel has been subject to active change over recent years, particularly in response to dredging operations. Successive bathymetric and topographic surveys have been undertaken for Ardersier Port and immediate surroundings over recent years in order to monitor these changes, the surveys undertaken include:

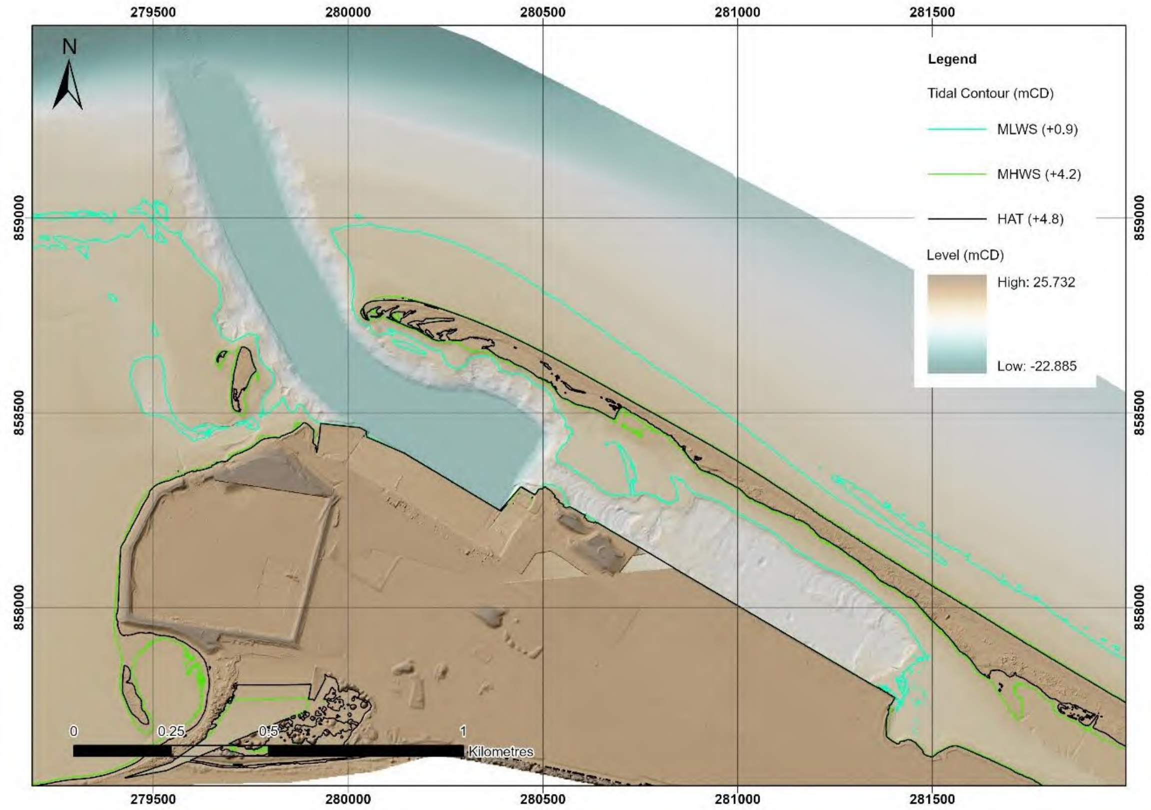
- Aspect Surveys in May 2018, covering the harbour, navigation channel and immediate surrounds;
- FC Geomatics in September 2021, partial coverage of harbour, channel and spit head;
- FC Geomatics in May 2022, covering Whiteness Sands, harbour and spit;
- CainTech Ltd in November 2022, covering the harbour and access channel;
- CainTech Ltd in June 2023, covering the harbour, navigation channel and immediate surrounds;
- SEP Hydrographic during mid-December 2023, and early January 2024, with weather conditions influencing the survey schedule, covering the harbour and approach;
- Aspect Surveys Ltd in June 2024, covering the harbour, navigation channel, Whiteness Sands and immediate surrounds;
- February and March 2025 (pre capital dredge), covering the harbour, navigation channel, Whiteness Sands and immediate surrounds by Zenith Surveys; and
- August 2025 (post capital dredge), covering harbour and navigation channel by Zenith Surveys.

The most recent available bathymetric and topographic survey was completed in August 2025 following completion of the Phase 1 capital dredge campaign. A Digital Surface Model (DSM) has been generated using this survey data for the site and immediate surrounds, as shown in **Error! Reference source not found.**.

The present-day bathymetry of the harbour and navigation channel is reflective of the recently completed capital dredge works, with advertised depths of -12.4 mCD through the channel and outer harbour. The inner harbour is the subject of the proposed development and currently has varying bed levels, with shallower areas of recent deposition and localised areas which have been subject to smaller scale dredge activities over recent years.

Terrestrial elements of the spit to the north and east of the harbour sit above highest astronomical tide (HAT) level of +4.8 mCD, with localised topographic highs of 6.4 mCD. The former spit head to the immediate west of the navigation channel now forms an island feature elevated above HAT level, with peak level of 5.7 mCD. Across the terrestrial extent of Ardersier Port ground levels are generally around 6.8 mCD.

Figure 3.1: Digital Surface Model (DSM) Ardersier Port – Post Dredge August 2025



3.2 Tidal Regime – Levels and Currents

Tidal levels at Ardersier Port (formerly McDermott Base) as presented within the Admiralty Tide Tables show a maximum astronomical tidal range of 4.6 m, a mean tidal range of 3.3 m during spring tides and 1.6 m during neap tides (Table 3.1). More extreme event offshore water levels nearby from SEPA predictions include a 1 in 200 year return period event of 3.51 mAOD (Table 3.2).

Table 3.1: Tidal Water Levels – Ardersier Port

Tide Condition	Chart Datum (mCD)*	Ordnance Datum (mOD)
Highest Astronomical Tide (HAT)	4.8	+2.7
Mean High Water Spring (MHWS)	4.2	+2.1
Mean High Water Neap (MHWN)	3.3	+1.2
Mean Sea Level (MSL)	2.5	+0.4
Mean Low Water Neap (MLWN)	1.7	-0.4
Mean Low Water Spring (MLWS)	0.9	-1.2
Lowest Astronomical Tide (LAT)	0.2	-1.9

*Chart Datum correction for Ordnance Datum is -2.1m (relative to OD at Newlyn)

Table 3.2: Ardersier Port Extreme Sea Levels (SEPA Dataset)

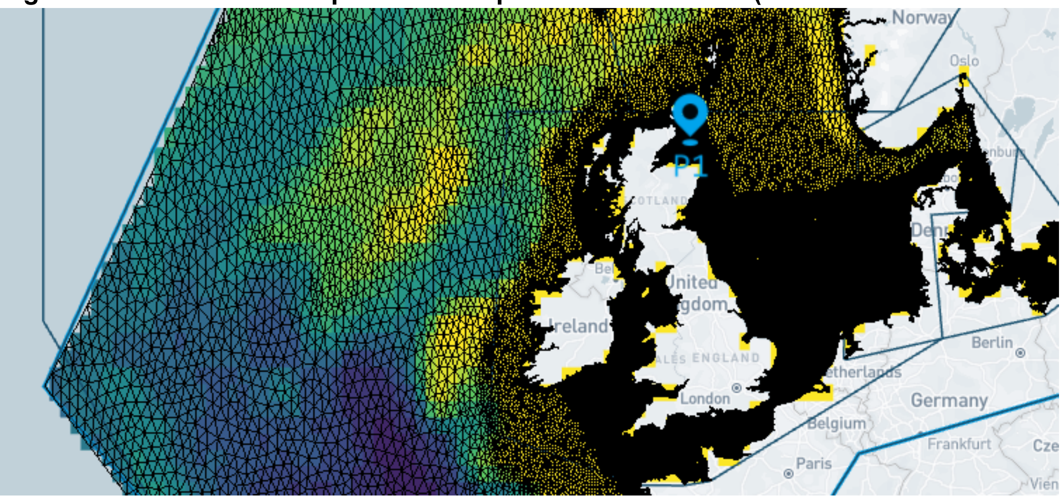
Return Period (Years)	Water Level (mCD)	Water Level (mOD)
2	5.02	2.92
5	5.11	3.01
10	5.18	3.08
50	5.32	3.22
100	5.39	3.29
200	5.45	3.35
1000	5.60	3.50

The key tidal flows near the development site have been identified through site observation, monitoring and coastal modelling studies. During flood tides, tidal flow is east to west around the spit and into the harbour. During ebb tides, the flow reversed. Peak current speeds reach approximately 1 m/s in the main channel (South Channel) located to the north of Whiteness Sands, with lower velocities across the sands and within the harbour. Current speeds generally decrease at high and low tide, influenced by local seabed features. Residual current analysis has shown a dominant flood flow around the spit and into the harbour, while ebb flows dominate in deeper offshore waters. Within the inner harbour and further east into intertidal extents there is a marginal ebb current dominance, although peak current speeds are generally low. Further consideration of tidal currents is presented in Sections 4.9.1 and 5.1.1

3.3 Waves

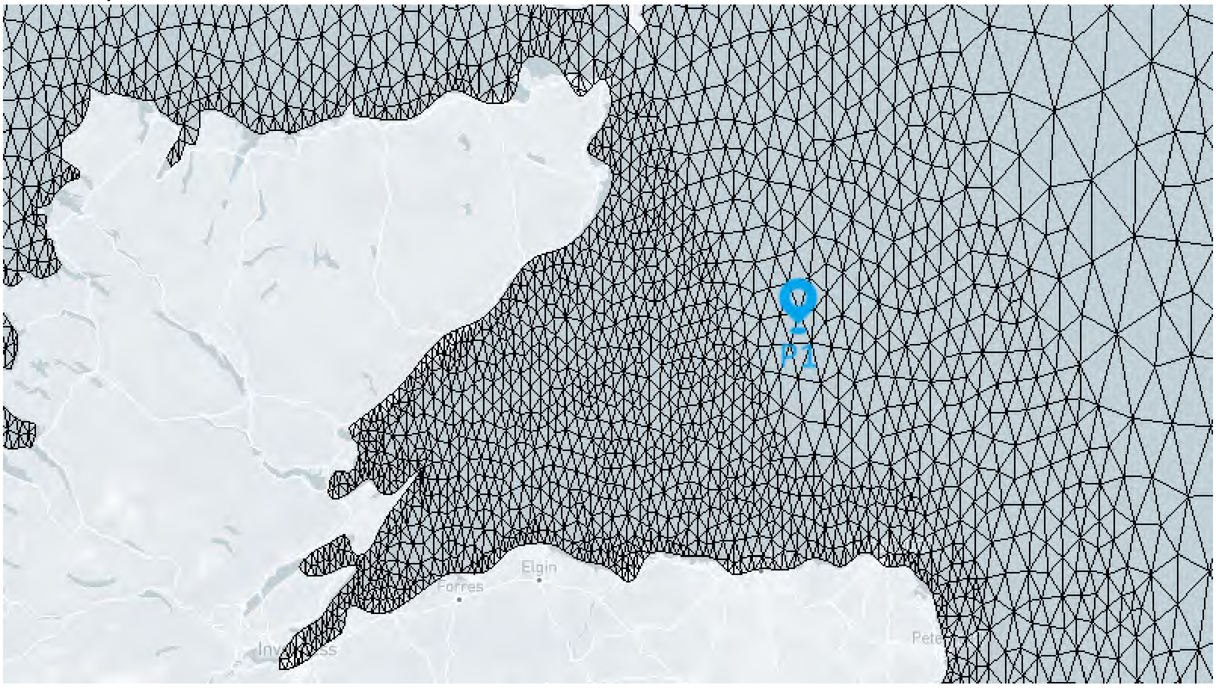
Hindcast offshore wave data has previously been obtained from the DHI Metocean Data Portal[1] for location 58.139360°N, -2.338164°E, covering the period 01/01/1979 to 01/10/2023. The data is derived from the DHI North Europe MIKE 21 Spectral Wave Model, the wider structure of which is shown in **Error! Reference source not found.**, with the data extraction location shown in more detail in **Error! Reference source not found.**.

Figure 3.2: DHI North Europe MIKE 21 Spectral Wave Model (Hindcast Data Location – Blue Pin)



[1] https://www.metocean-on-demand.com/

Figure 3.3: DHI North Europe MIKE 21 Spectral Wave Model Mesh (Hindcast Data Location – Blue Pin)



The hindcast wave data includes the following key components:

- Significant wave height (m)
- Peak wave height (m)
- Mean wave period (s)
- Zero-crossing wave period (s)
- Peak wave direction (Deg. From North)
- Mean wave direction (Deg. From North)
- Directional standard deviation (Deg.)

The significant wave height and directional data is summarised in wave rose form within **Error! Reference source not found.**, highlighting the prominence of waves from the north and north-easterly sectors (0 – 45 degrees). These sectors align with the orientation of the Moray Firth, and the longest fetch from Ardersier Port, and therefore are considered the key wave sectors for the site and surrounds. **Error! Reference source not found.** presents a time-series plot of significant wave height for the full hindcast record (1979 – 2023), highlighting the frequency of storm events and associated large significant wave heights.

Figure 3.4: Wave Rose – Significant Wave Height by Directional Sector (1979 – 2023) for Hindcast Data Location

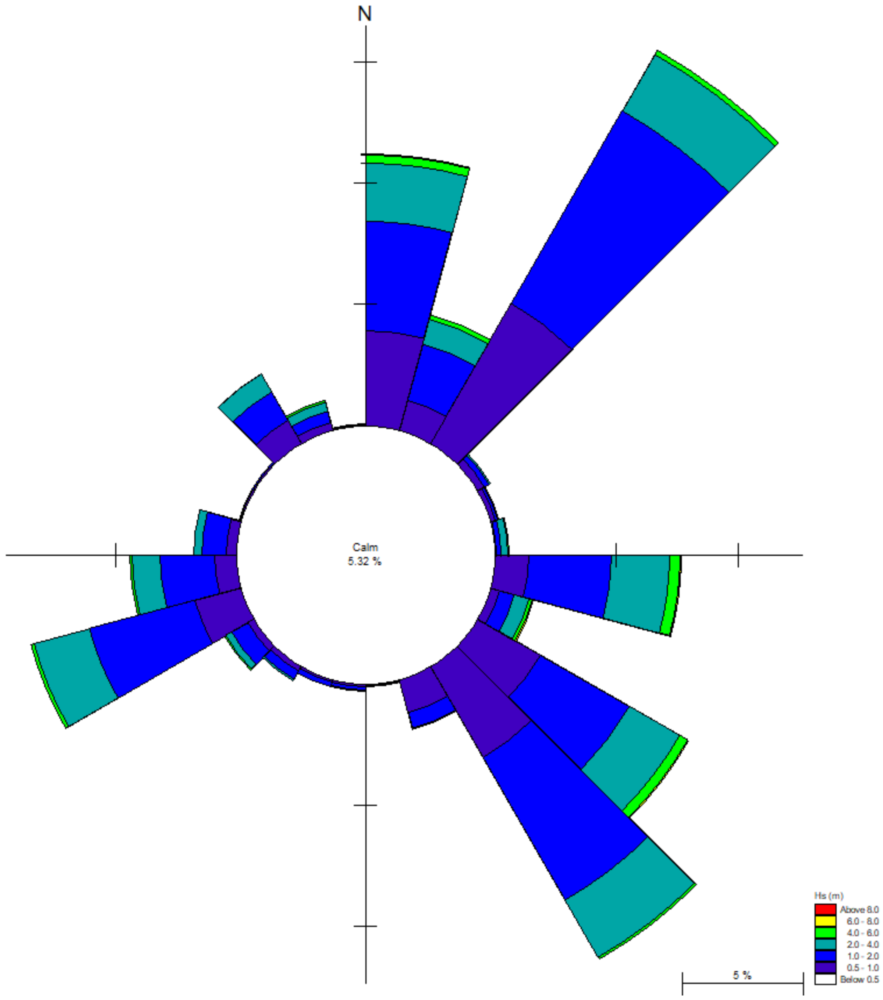
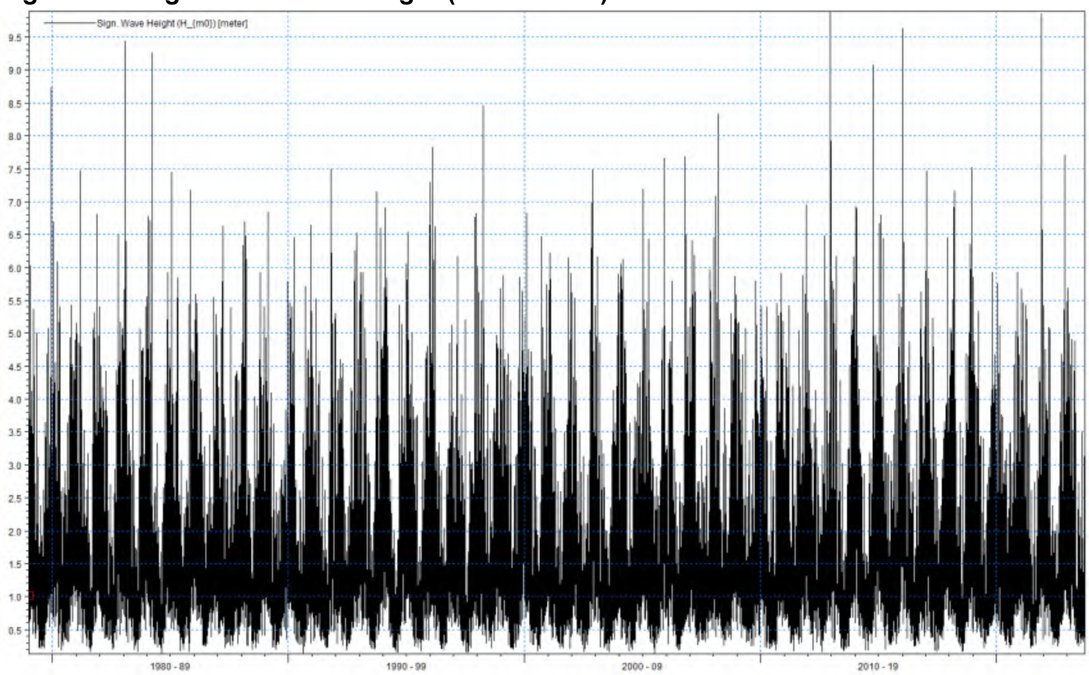


Figure 3.5: Significant Wave Height (1979 - 2023) for Hindcast Data Location



3.4 Wind

Hindcast wind data has also been obtained from the DHI Metocean Data Portal the offshore location 57.736780 °N, -3.69260°E. The data is derived from the Global, Atmosphere, Fifth ECMWF ReAnalysis (ERA5) Model. This is a global high accuracy wind dataset for the period from 1979 until present with hourly values at a spatial resolution of 0.25° during the full period. The dataset includes the following components:

- Wind Speed at 10 m (m/s)
- Wind Direction at 10 m (Deg. From North)
- Air Pressure at Mean Sea Level (hPa)
- Wind Speed at 100 m (m/s)
- Wind Direction at 100 m (Deg. From North)

Error! Reference source not found. shows the location of the hindcast data within the Inner Moray Firth. **Error! Reference source not found.** presents a rose plot of wind speed by directional sector for the whole hindcast dataset (1979 – 2023), highlighting the prevalence of wind from the south-western sectors.

Figure 3.6: ERA5 Model Cells (Hindcast Data Location – Blue Pin)

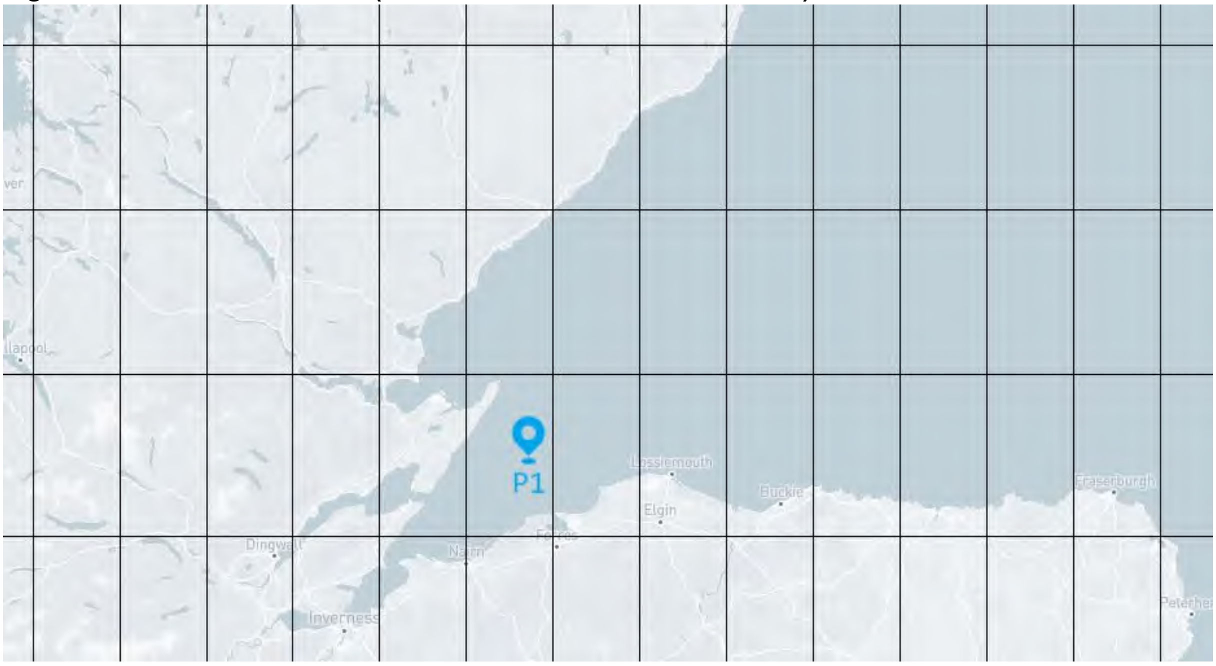
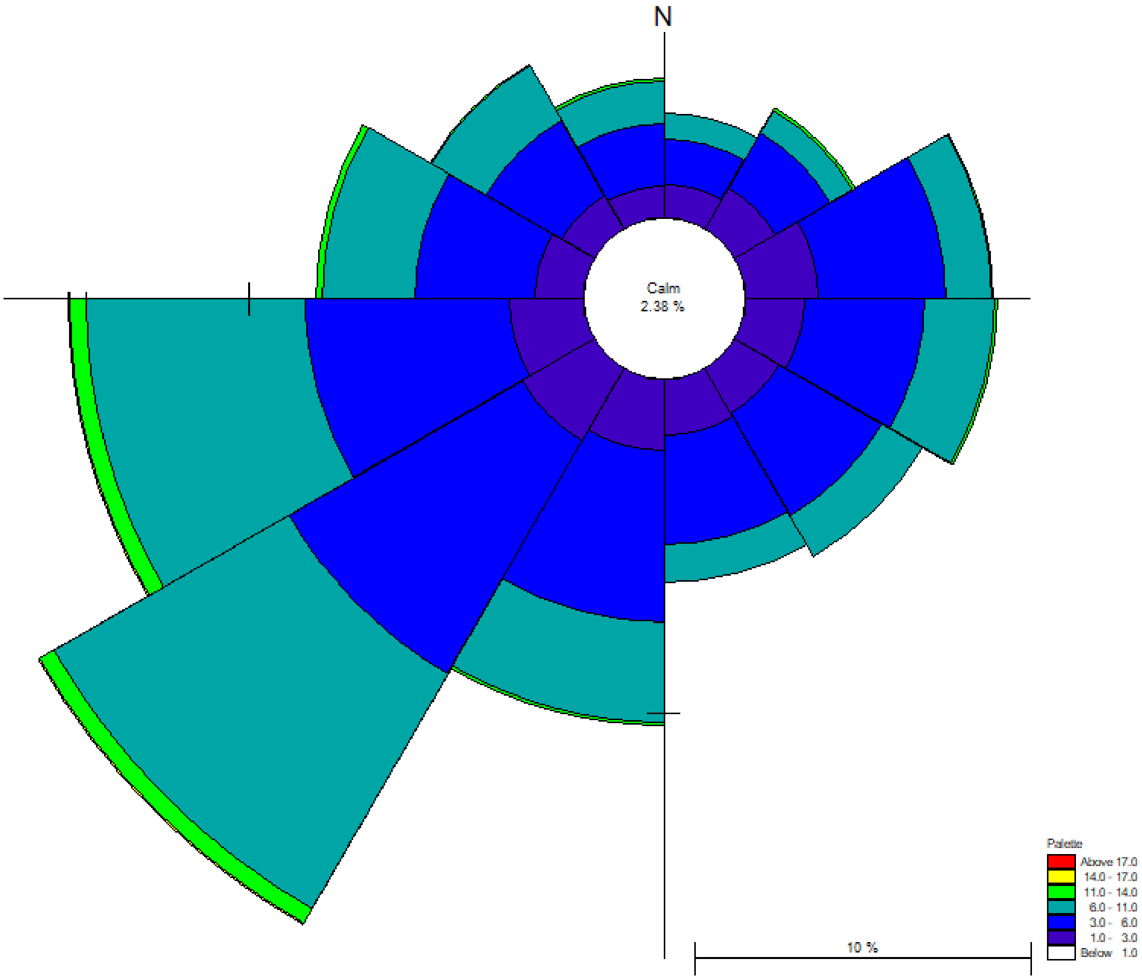


Figure 3.7: Wind Rose – Wind Speed by Directional Sector (1979 – 2023) for Hindcast Data Location



3.5 Sediment

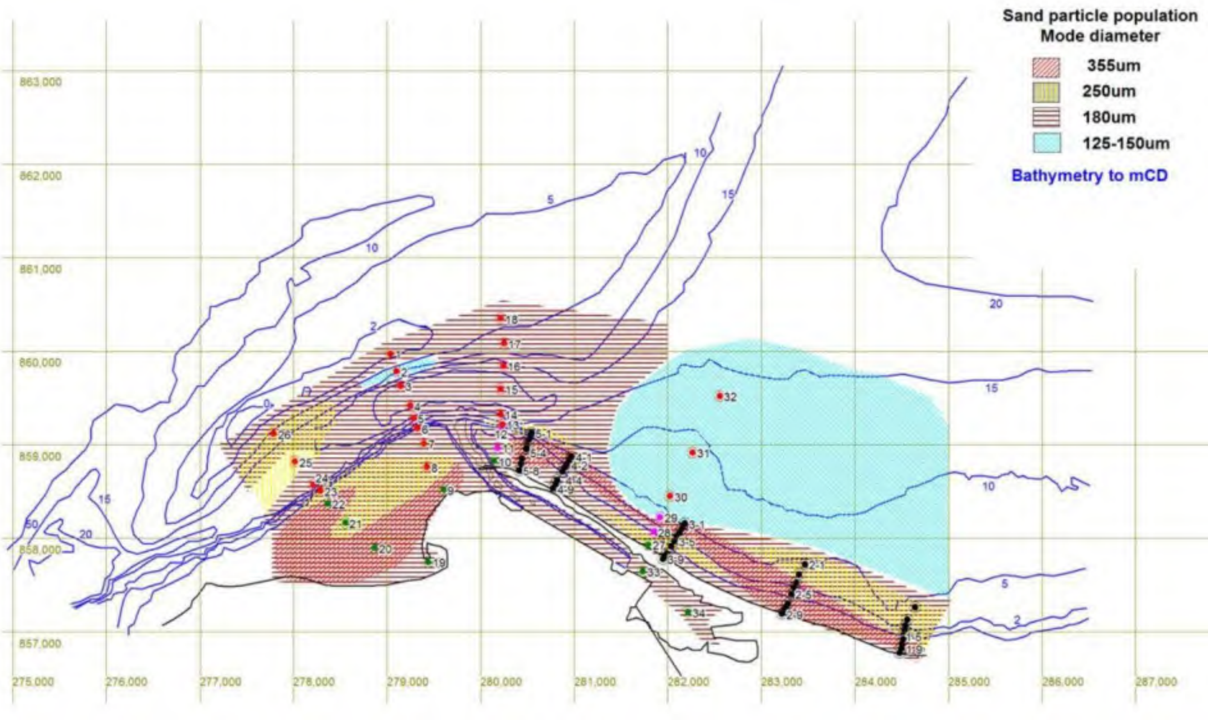
3.5.1 Sediment Character

Several phases of sediment sampling have been undertaken over recent years in the vicinity of Ardersier Port. The site investigations to date have found that Whiteness Sands, spit and associated channel are essentially formed in mobile sand deposits. Four sand types can be identified based on lognormal particle size populations. The spatial distributions of the following sand fractions at the time of survey (2013) are shown in **Error! Reference source not found.**:

- **Medium-coarse sand** – Mode 0.355 mm. Normally present forming a secondary bimodal grain population with a dominant medium-fine sand. Indicative of bedload transport.
- **Medium sand** – Mode 0.250 mm. Normally present forming a bimodal grain population with a dominant medium-fine sand. Indicative of bedload transport.
- **Medium-fine well-sorted sand** - Mode 0.180 mm. Almost ubiquitous outside the zone immediately offshore from the spit. The sand population most easily set in motion by flowing water, typically moving as near-bed suspension.
- **Fine sand** – Mode 0.150 – 0.125 mm. Dominates the seabed offshore from the spit, typically unimodal. Indicative of suspended load transport processes.

Gravel deposits are present to the surface of the spit, predominantly along and above the high water mark, and are present in lower quantities within the immediate vicinity of the spit. Sediment within the immediate vicinity of the dredging activity is generally associated with present day processes, however, chart annotations of seabed conditions highlight adjacent areas of drift deposit exposure. These annotations indicate there are two eroding Holocene or Pleistocene deposits in the area, the foreshore and offshore area to the east of the spit, and the Fort George narrows area. In these two zones recent deposits are probably thin or absent, with erosion providing an important source of gravel to be reworked by present day processes.

Figure 3.8: Distribution of Sand Particle Populations and Grab Sample Locations (2013)



3.5.2 Morphology and Sediment Transport

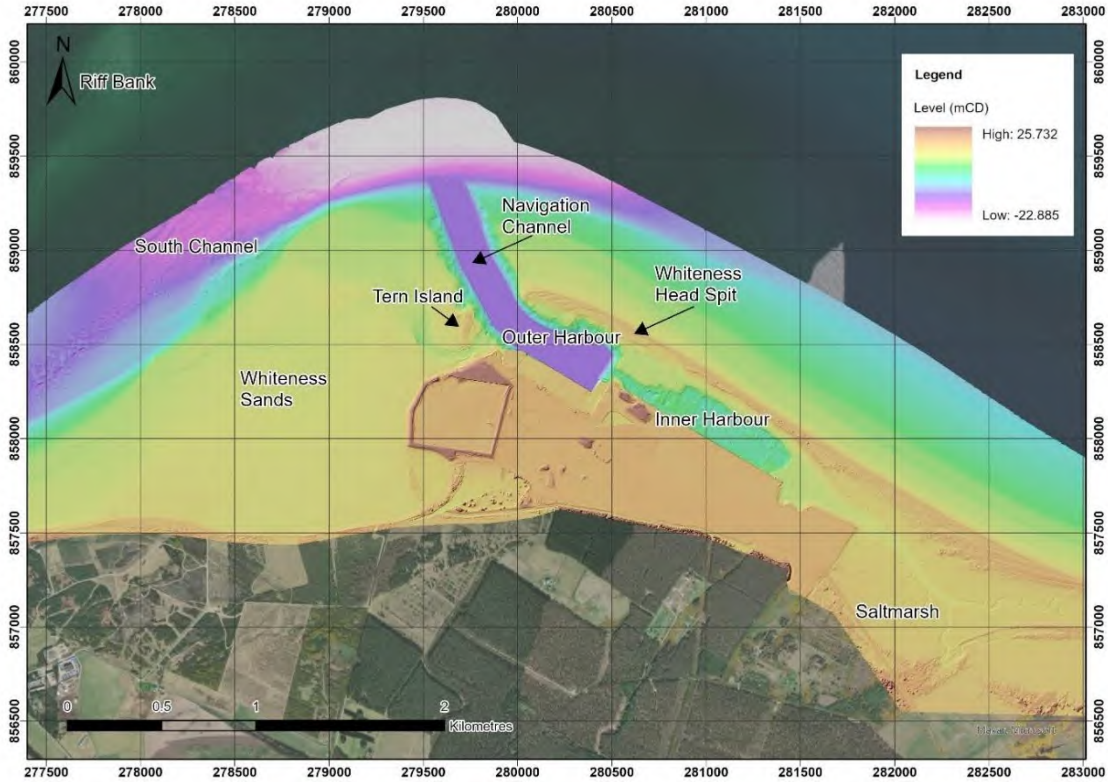
A number of key morphological features are present within the site and surrounding area, as shown in **Error! Reference source not found.**. An intertidal spit with a prominent intertidal recurve, truncated by the recently dredged navigation channel, extends immediately north of the present-day terrestrial spit head. Historically this has been orientated in a northwestern direction in line with the longshore sediment feed. Below MLWS, areas of subtidal deposition are present to the northwest of the spit and navigation channel, extending along the northern fringe of Whiteness Sands. The historic spit head remains as an island feature (Tern Island) to the immediate west of the navigation channel, with the historic meandering harbour inlet channel still present further west, separating the island from Whiteness Sands.

Within the harbour recent spit restoration works have restored the inner face of Whiteness Head spit where erosion had occurred. To the south-east of the inner harbour the modified waters of the harbour transition to a network of creek features associated with saltmarsh habitat.

The main Moray Firth channel, known as the South Channel is located to the north of Whiteness sands, with various large scale bedforms including dunes, megaripples, ribbons, and possible landslips, present on the bed and surrounding slopes. These features indicate both westward and eastward sediment transport, shaped by flood and ebb currents. The Riff Bank sandbank forms the northern edge of the South Channel, with the intertidal Whiteness Sands to the south. The intertidal

Whiteness Sands is relatively flat, with small scale ripples dominant, a few channel features are associated with tidal flow and a general absence of larger scale bedforms. A small sand spit feature is present on the southern shoreline of Whiteness Sands, indicative of westerly longshore transport of sand in this area. To the south of this a former lagoon is present, historically disconnected from the marine environment by historic site operations.

Figure 3.9: Key Morphological Features – Ardersier Port

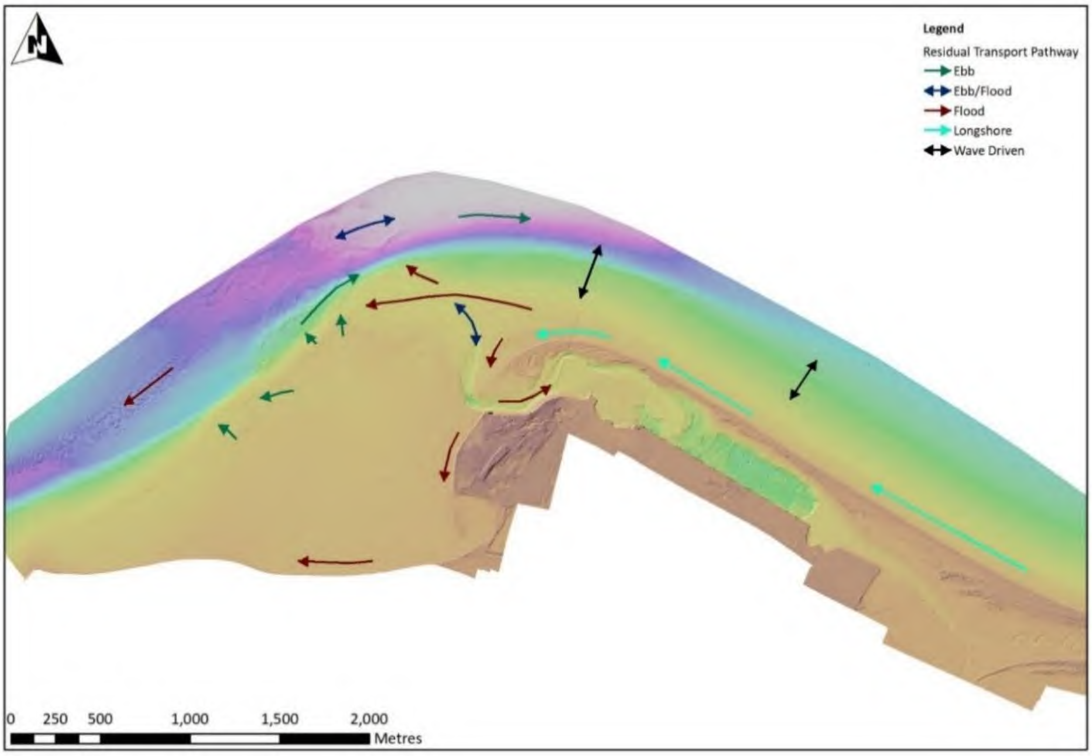


Previous assessments into the coastal processes around Whiteness Head are highlighted in Section 2.4. The 2018 coastal assessment built upon the 2013 assessment through continued assessment of bathymetry change in the period between assessments and adoption of more detailed sediment modelling techniques. A conceptual understanding of sediment transport and coastal morphology within the local coastal system was developed through review of observed and historic changes, supplemented by hydraulic modelling, as presented in **Error! Reference source not found.** below.

The conceptual model includes the longshore transport of sand and gravel along the eastern shore of Whiteness Head spit resulting in continued spit extension to the north-west, with recurves to the south-west. A continuity of this north-western transport pathway is highlighted, both offshore to the deeper waters of the main channel, and further west to the north-eastern intertidal and subtidal margin of Whiteness Sands.

The conceptual model includes the offshore movement of sand from the northern margin of Whiteness Sands, and a returning eastern transport pathway further offshore. This eastern pathway is considered to also contribute sediment to the tidal inlet, and the southern coastline of Whiteness Sands. Central areas of Whiteness Sands are considered to be generally stable within the local context of Whiteness Head. This local coastal system has been subject to modification in the form of dredging for the McDermott Construction Yard from the early 1970’s until around 2001. This site history was noted to remain an influence on present day processes in 2018, particularly on the extent and direction of spit head recurve, and on the volume of water exchanged within the tidal inlet. These have resultant localised impacts on currents and associated sediment transport processes, while the wider scale processes continue uninterrupted.

Figure 3.10: Conceptual Model of Sediment Transport Pathways (EnviroCentre, 2018)



Review and analysis of successive survey data enables further assessment of sediment transport processes. **Error! Reference source not found.** presents a comparison between the June 2023 and January 2024 surveys of key tidal contours from Mean High Water Springs (MHWS) to Mean Low Water Springs (MLWS). Review of this figure highlights the intertidal north-westward extension of the spit, and the westward extension of the gravel spit head at higher elevations. **Error! Reference source not found.** presents a comparison between the January 2024 and June 2024 surveys of key tidal contours from Mean High Water Springs (MHWS) to Mean Low Water Springs (MLWS). Review of this figure again, as for the previous comparisons, highlights the intertidal north-westward extension of the spit, and the westward extension of the gravel spit head at higher elevations.

Table 3.3 presents a summary of the measured movement in key tidal contours, along with the direction of movement, between the 2023 and 2024 surveys. Review of this table highlights that greatest movement is observed at lower elevations (MLWS), with movement reducing in extent towards MHWS, and direction of movement also switching from north-west to west, consistent with previous findings and conceptual understanding of the processes at work.

Table 3.3: Key Tidal Contour Movement and Direction at the Spit Head

Tidal Contour (mCD)	June 2023 to Jan 2024		Jan 2024 to June 2024	
	Movement (m)	Direction	Movement (m)	Direction
MLWS (+0.9)	115 – 155	North-west	35 - 105	North-west
MLWN (+1.7)	60 – 100	North-west	10 – 55	North-west
MSL (+2.5)	30 – 50	North-west	10 – 35	North-west
MHWN (+3.3)	~20	West	<10	West
MHWS (+4.2)	~20	West	<5	West

Figure 3.11: Comparison of Key Tidal Contours – Jan 2024 Survey (Solid Lines) and June 2023 Survey (Dashed Lines)

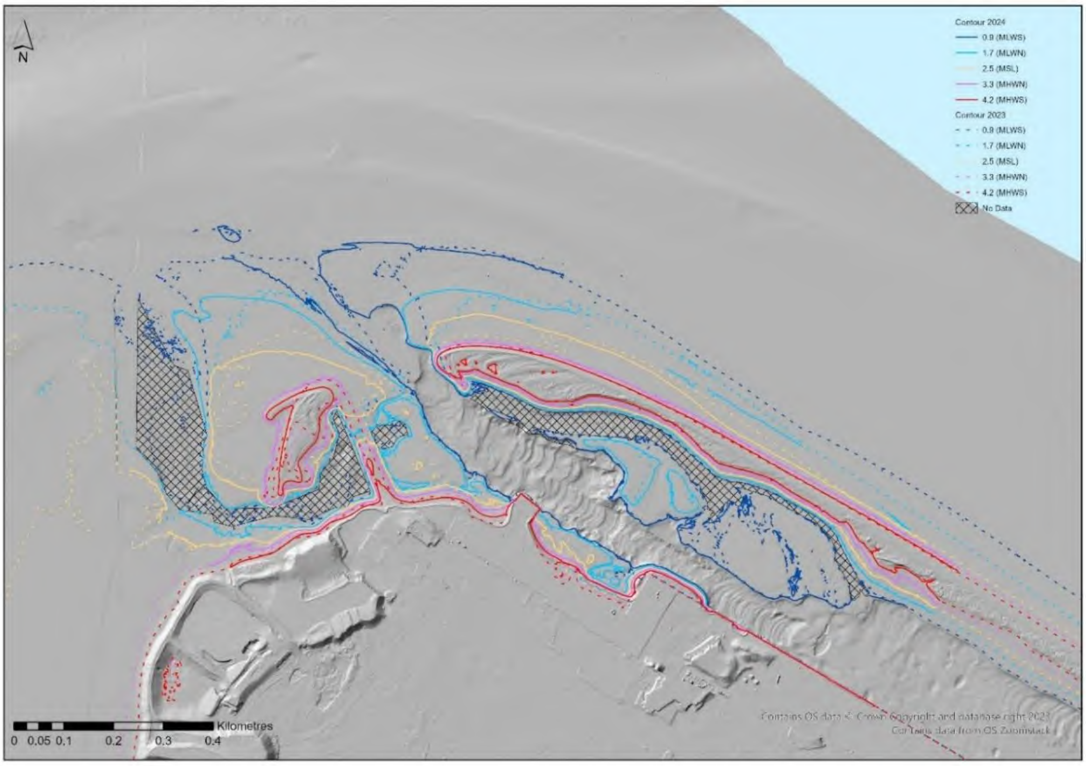
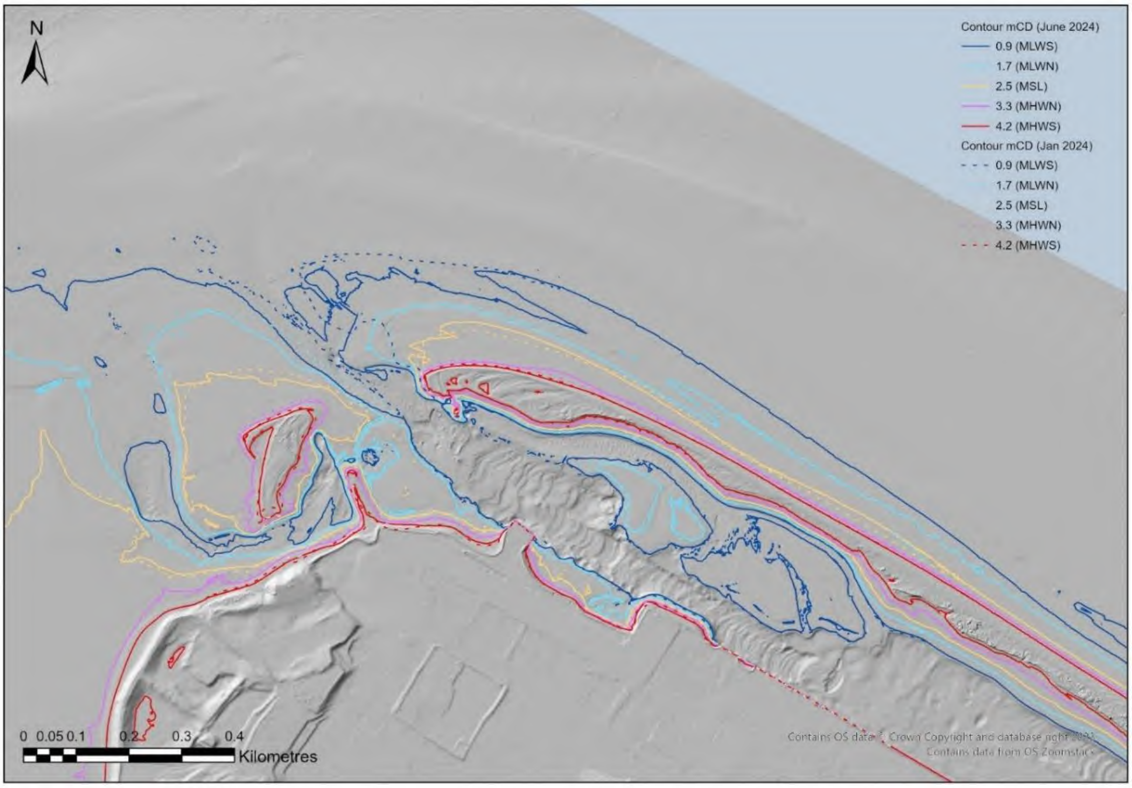
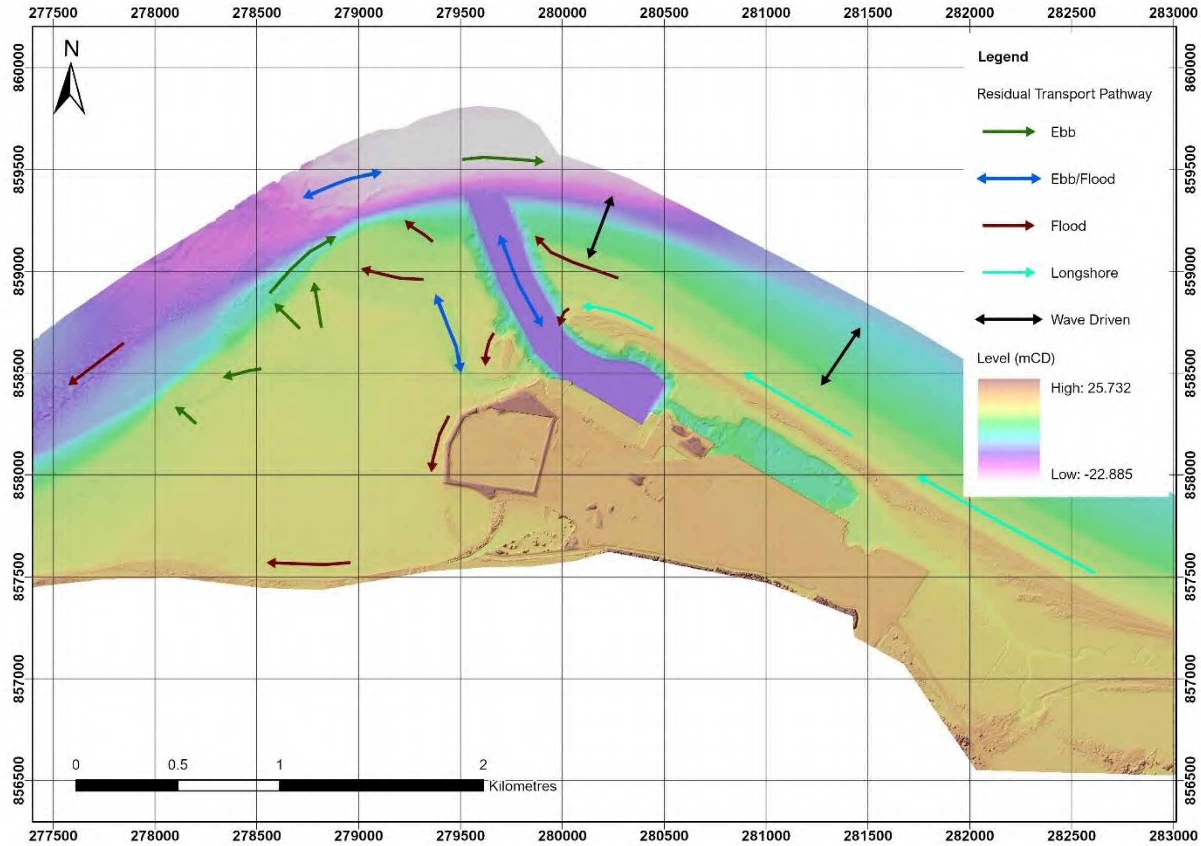


Figure 3.12: Comparison of Key Tidal Contours – June 2024 Survey (Solid Lines) and Jan 2024 Survey (Dashed Lines)



The 2018 conceptual model of coastal processes has been updated to reflect the present-day post 2025 capital dredge conditions, as shown in **Error! Reference source not found.**. Sediment transport, and thus deposition local to Ardersier Port, is heavily influenced by wind and wave forcing from the 0 – 90 degree sector. The occurrence of storm events from this sector will result in significant sediment transport and deposition in the navigation channel. The volume of sediment transported and deposited will depend on the occurrence, timing, frequency, duration and intensity of wind and waves from this key sector The dominant sediment source in this process is from the spit and associated intertidal extents to the east of the navigation channel. Wider scale processes remain consistent with the 2018 conceptual model.

Figure 3.13: Conceptual Model of Sediment Transport Pathways – 2025 Baseline



4 COASTAL MODELLING

4.1 Model Overview

A coastal model has been developed to allow simulation of coastal processes under existing (baseline) and proposed conditions (port extension) at Ardersier Port. The model has been built within the MIKE 21 FM modelling package based on a flexible mesh (FM) structure, developed by the Danish Hydraulic Institute (DHI). The MIKE 21 software has been developed for applications within marine, coastal and estuarine environments. This study utilises the Hydrodynamic (HD), Spectral Wave (SW) and Sand Transport (ST) modules as further described below.

4.1.1 Hydrodynamic (HD) Module

The Hydrodynamic Module (HD) is the central computational component of the package, solving 2D shallow water equations. The module simulates unsteady flow taking account of bathymetry, sources and external forcing, it consists of continuity, momentum, temperature, salinity and density equations. The latest version of the software, MIKE 2025, has been used within this assessment.

4.1.2 Spectral Waves (SW) Module

Offshore to inshore wave transformation modelling has been undertaken using the MIKE 21 Spectral Waves (SW) module. MIKE 21 SW FM is a new generation spectral wind wave model based on unstructured meshes. The latest version of the software, MIKE 2025, has been used in this assessment. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas.

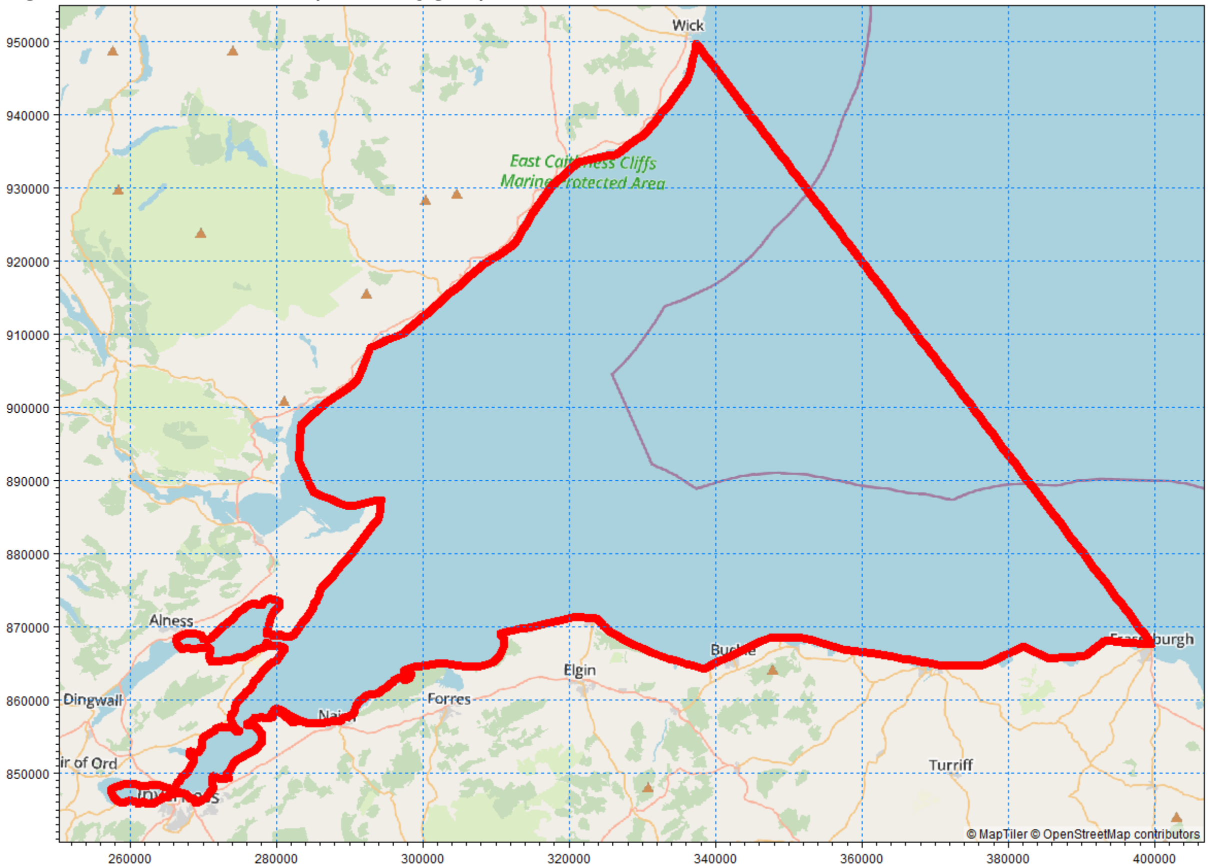
4.1.3 Sand Transport (ST) Module

The MIKE 21 ST module allows calculation of sediment transport capacity and associated bed level changes for non-cohesive sediment (sand) resulting from tidal currents or a combination of tidal currents and waves. The module applies the sediment transport calculations to a flexible mesh, and allows for the functionality to include morphological feedback on the bathymetry and coupled hydrodynamic modelling of tidal currents.

4.2 Model Extents

The coastal model extent covers the Moray Firth, extending from the Beauly Firth in the west, to Wick and Fraserburgh in the east, including the Cromarty Firth and Dornoch Firth as shown in **Error! Reference source not found.**. This model is similar to that utilised in previous phases of modelling undertaken in relation to Ardersier Port, including that described in EnviroCentre Report 13845 (July 2024), however the model has been extended to include the outer Moray Firth, in order to allow the use of suitable offshore hindcast data as boundary conditions within the assessment, whilst the model bathymetry and model mesh have all been updated and refined for this latest phase of modelling, particularly within the harbour and adjacent extents.

Figure 4.1: Model Extent (Red Polygon)



4.3 Input Data

4.3.1 Bathymetry

The following bathymetric data has been used within the modelling study:

- UK Hydrographic Office (UKHO) Bathymetric Survey[2]
  - Moray Firth 0-40 m 2 m resolution (2020);
  - Moray Firth 38-40 m 4 m resolution (2020);
  - Moray Firth Riff Bank 2 m resolution (2022).
- DHI C-Map bathymetry data in wider Moray Firth;
- EMODnet[3] bathymetry data for Outer Moray Firth;
- Aspect Surveys – Topographic and Bathymetric Survey Whiteness Head (2018 and 2024); and
- Pre and Post Capital Dredge Topographic and Bathymetric Surveys Whiteness Head (2025).

The datasets have been used to create a combined Digital Surface Model (DSM) for use within the hydrodynamic model. Snapshots of the DSM with bathymetry displayed relative to Chart Datum are presented in **Error! Reference source not found.** and **Error! Reference source not found.** below.

[2] Admiralty Maritime Data Solutions: Seabed Mapping Service (https://seabed.admiralty.co.uk/?x=-19567.88&y=6780270.16&z=5.00)
[3] EMODnet Bathymetry (https://emodnet.ec.europa.eu/en/bathymetry)

Figure 4.2: Model Bathymetry – Full Extent

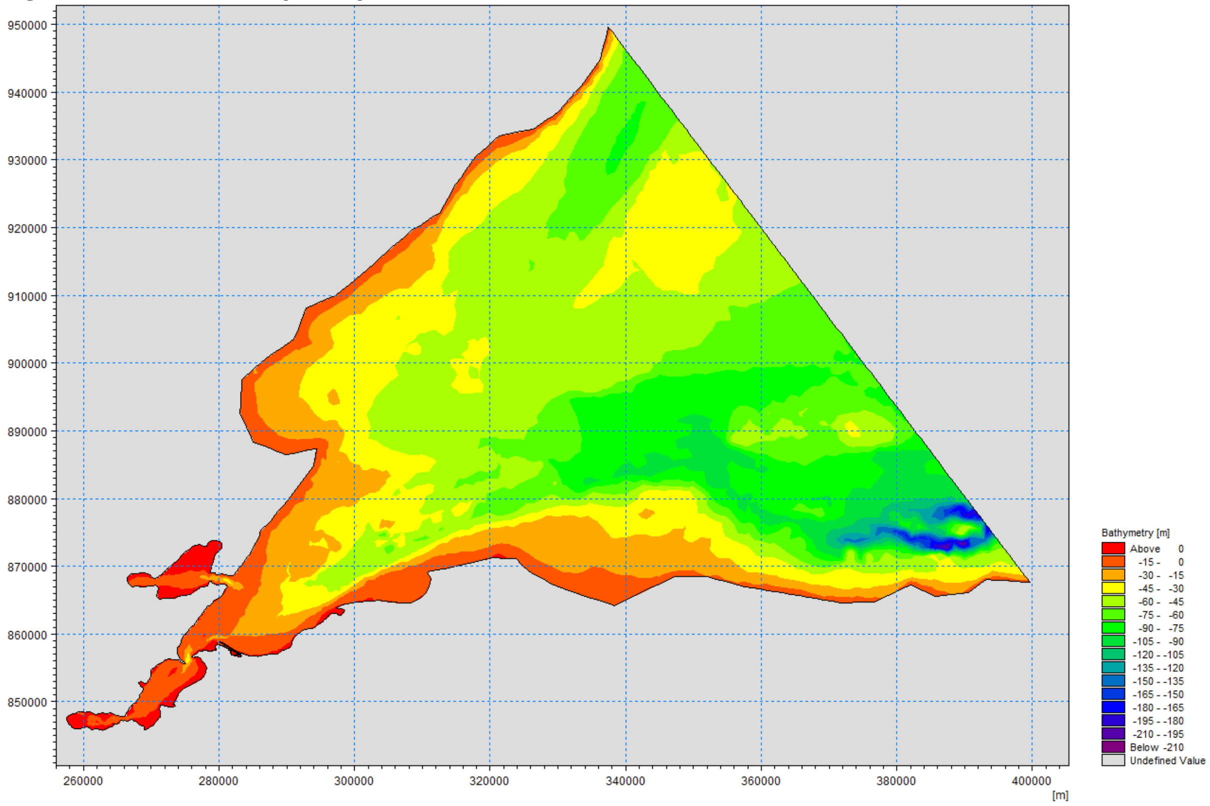
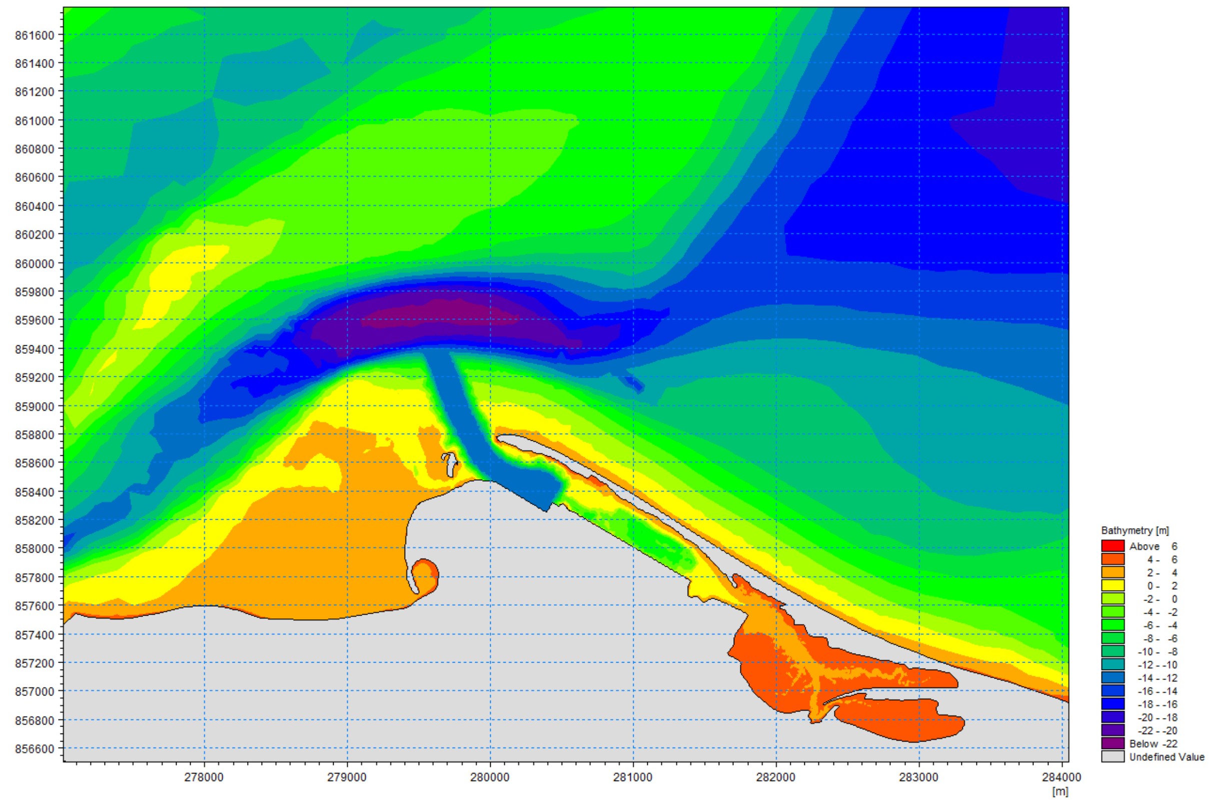


Figure 4.3: Model Bathymetry – Ardersier Port and Immediate Surrounds



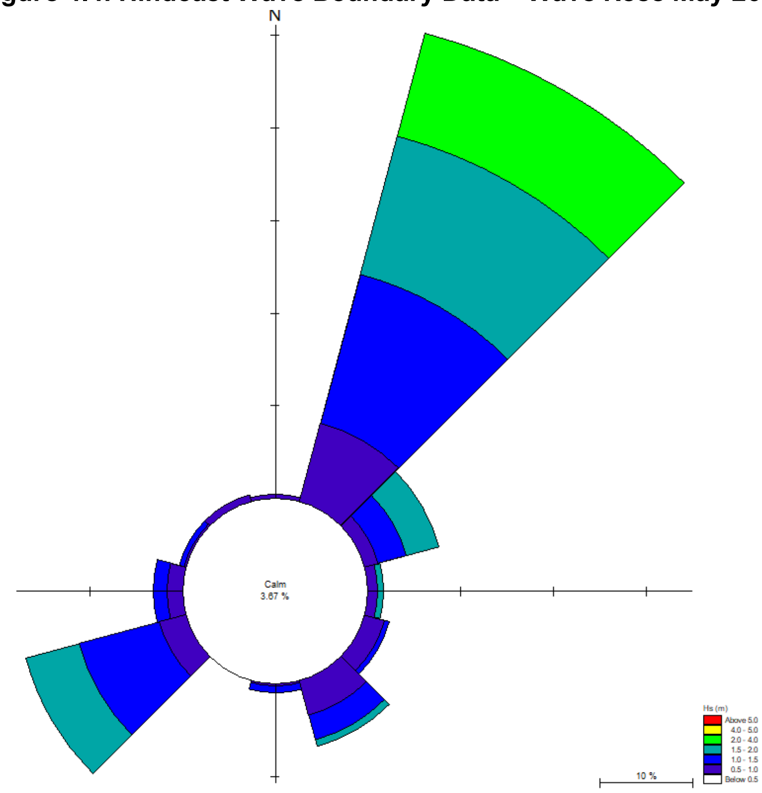
4.3.2 Tidal Boundary Conditions

There is a single open tidal boundary within the model extent, located on the eastern perimeter stretching between Wick in the north and Fraserburgh in the south. Tidal boundary conditions for the HD model have been extracted from the DHI Global Tide Model, this provides 0.125 x 0.125 degree resolution, 15-minute interval, tidal level data.

4.3.3 Wave Boundary Conditions

The wave boundary conditions for the SW and coupled models have been obtained from the DHI Metocean Data Portal[4] for location 58.139360°N, -2.338164°E. The data is hindcast data derived from the DHI North Europe MIKE 21 Spectral Wave Model. For the SW models the hindcast data for May 2025 has been utilised (see **Error! Reference source not found.**), aligning with a period covering both neap and spring tides, as well as a range of typical wind and wave conditions. For the coupled models including sand transport, hindcast data for Storm Ciaran from 2023 has been stitched into the dataset (see **Error! Reference source not found.** and **Error! Reference source not found.**) to enable simulation of storm driven transport processes. Further details on the hindcast dataset are presented in Section 3.3 and the model simulations in Section 4.7.

Figure 4.4: Hindcast Wave Boundary Data – Wave Rose May 2025



[4] https://www.metocean-on-demand.com/

Figure 4.5: Wave Boundary Conditions Coupled Models – Wave Rose (May 2025 incl. Storm)

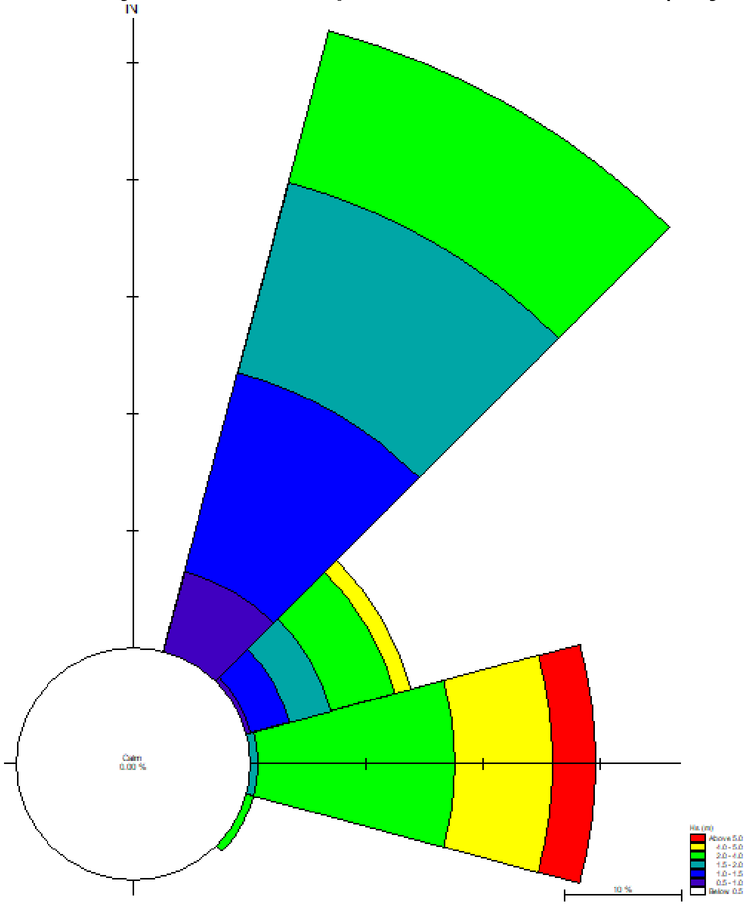
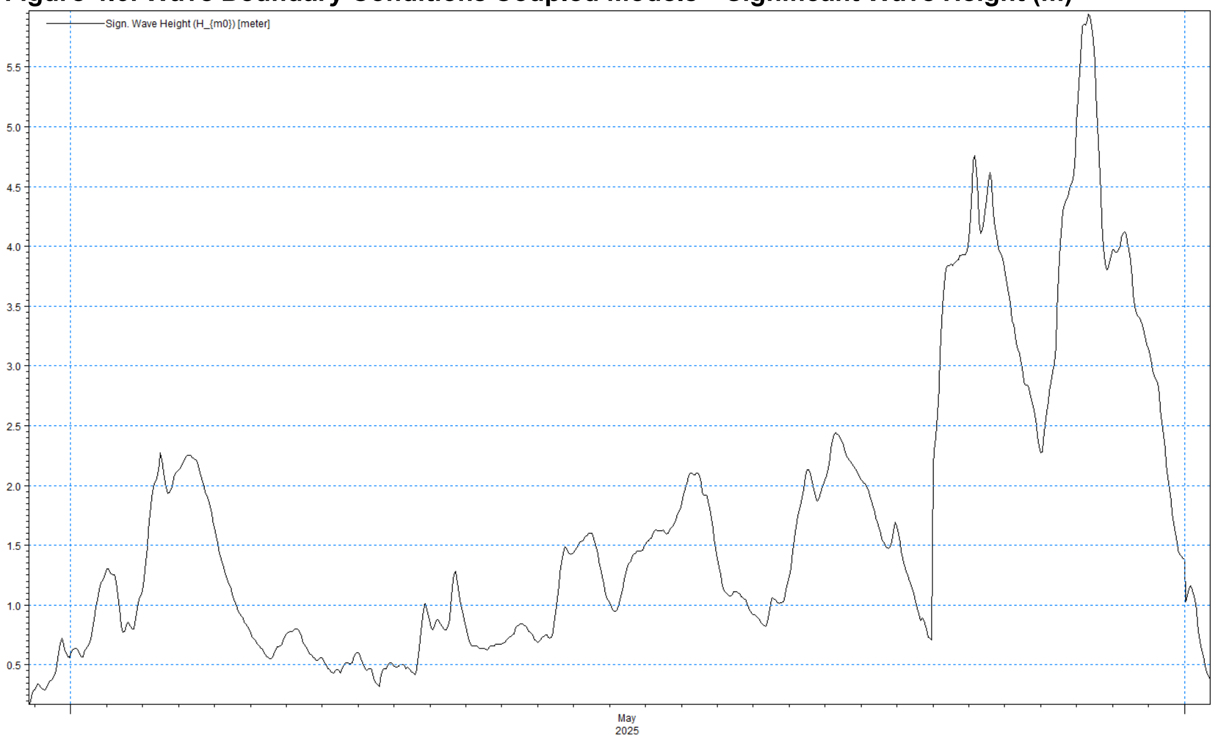


Figure 4.6: Wave Boundary Conditions Coupled Models – Significant Wave Height (m)



4.3.4 Wind Boundary Conditions

The wind boundary conditions for the SW model and coupled models have also been obtained from the DHI Metocean Data Portal. The data is derived from the Global, Atmosphere, Fifth ECMWF ReAnalysis (ERA5) Model. This is a global high accuracy wind dataset. For the SW models the hindcast data for May 2025 has been utilised (see **Error! Reference source not found.**), whilst for the coupled models including sand transport, hindcast data for Storm Ciaran from 2023 has been stitched into the dataset (see **Error! Reference source not found.** and **Error! Reference source not found.**) to enable simulation of storm driven transport processes. Further details on the hindcast dataset are presented in Section 3.4 and the model simulations in Section 4.7.

Figure 4.7: Hindcast Wind Boundary Data – Wave Rose May 2025

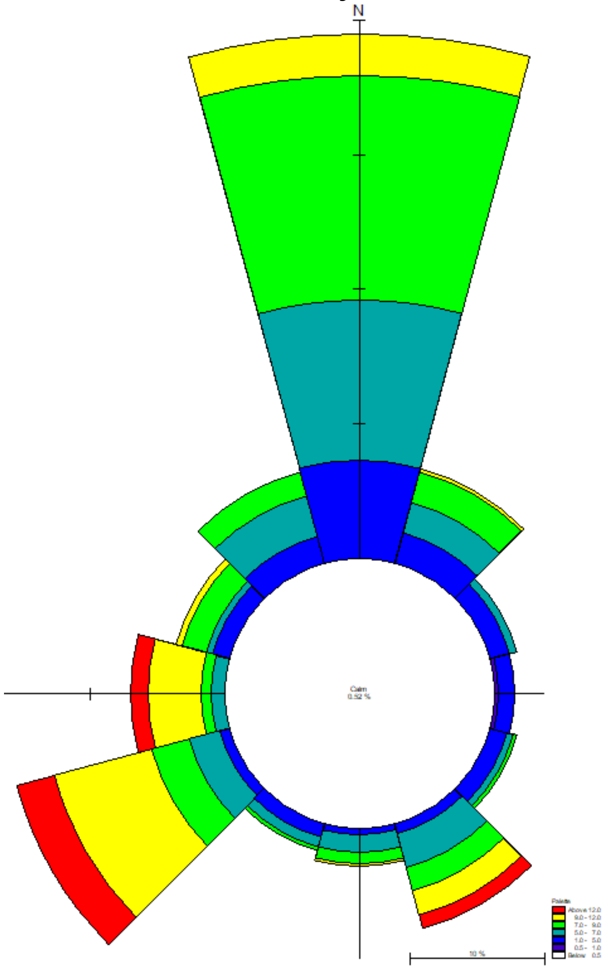


Figure 4.8: Wind Boundary Conditions Coupled Models – Wind Rose (May 2025 incl. Storm)

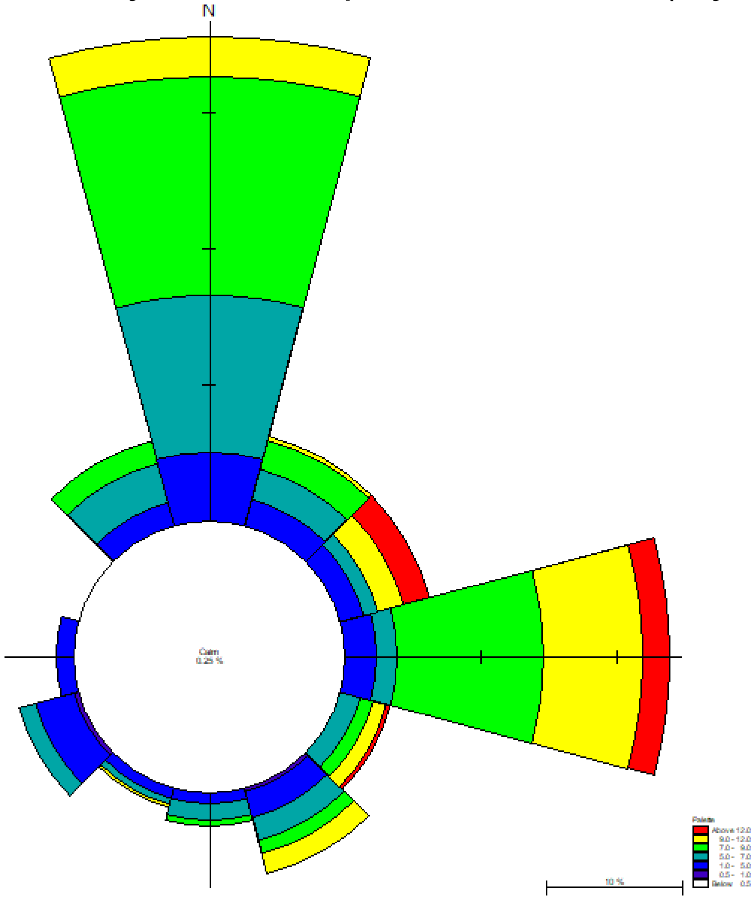
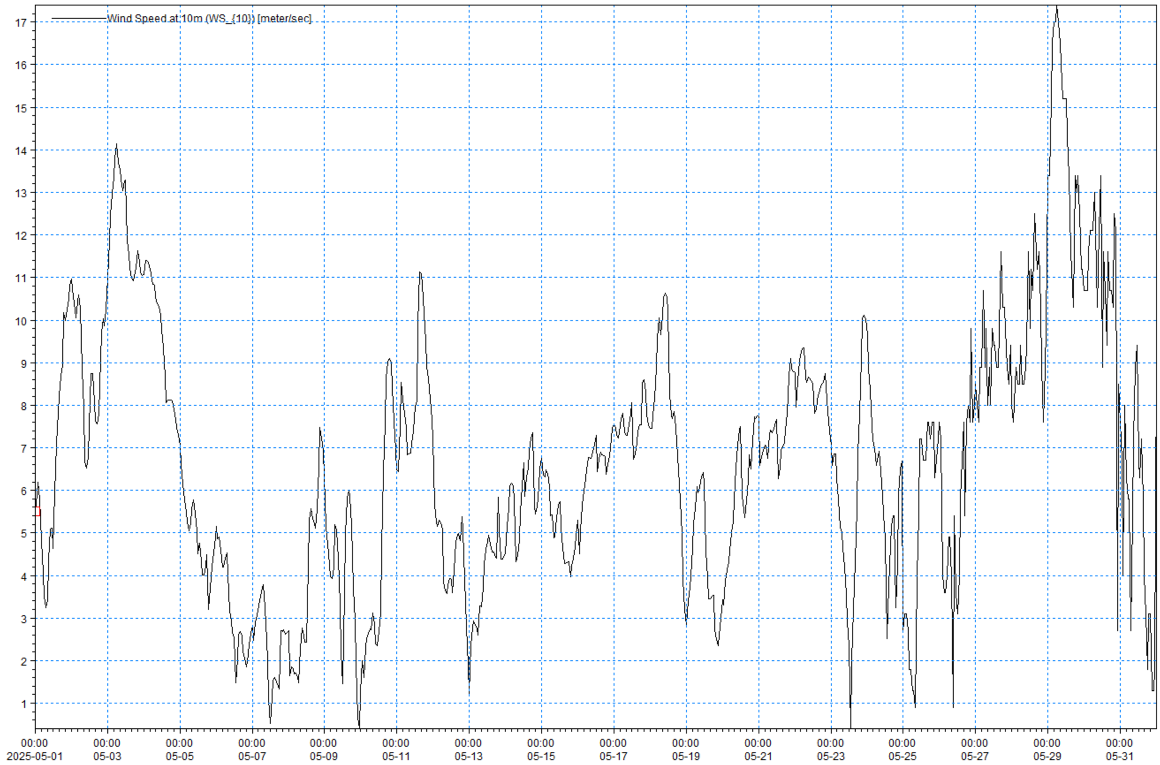


Figure 4.9: Wind Boundary Conditions Coupled Models – Wind Speed (m/s)



4.4 Model Mesh

The model utilises a flexible mesh to represent the offshore and coastal areas. The flexible mesh is composed of triangles of varying size and can therefore represent complex coastal alignments or bathymetry accurately.

4.4.1 Baseline Mesh

The 2025 baseline model mesh extent and bathymetry are shown in **Error! Reference source not found.** below. The mesh has been generated using the bathymetric data described in section 3.1. The mesh has progressive refinement in resolution towards Whiteness Head, becoming finer in the area of interest, as shown in **Error! Reference source not found.** and **Error! Reference source not found.**. Finer mesh regions have also been used to represent areas near the mouth of the Cromarty Firth, between Fort George and Chanonry Point, and at the Kessock Bridge, where narrow channels influence local hydrodynamics. Key characteristics of the baseline mesh are summarised in Table 4.1.

Table 4.1: Baseline Mesh Characteristics

Mesh Characteristic	Value
Number of elements	30,276
Number of nodes	16,425
Min. Z level (mCD)	-213
Max. Z level (mCD)	+7
Max triangular area - Ardersier Port Outer Harbour/Approach	400 m^2 (approx. 20 m resolution)
Max triangular area - Ardersier Port Inner Harbour	300 m^2 (approx. 17 m resolution)
Max triangular area - Ardersier Port S-E Intertidal / Saltmarsh	150 m^2 (approx. 12 m resolution)

Figure 4.10: 2025 Baseline Model Mesh – Full Extent

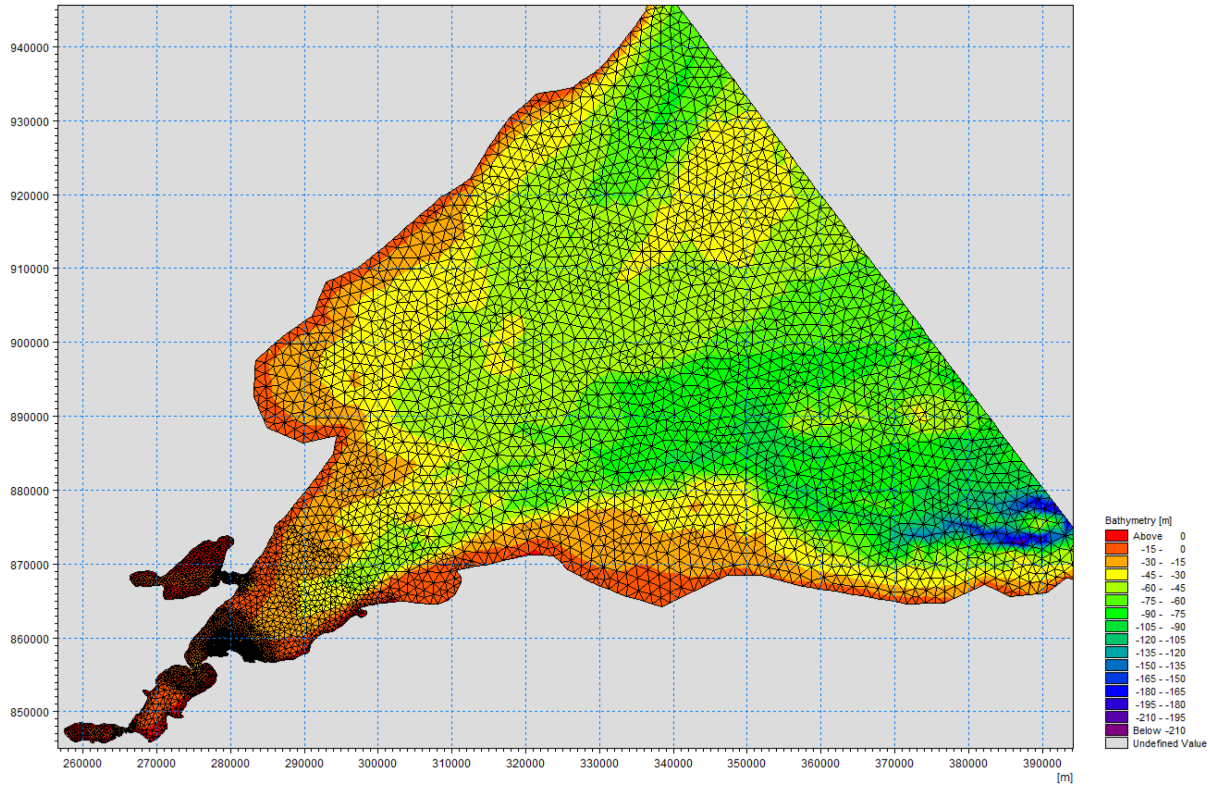


Figure 4.11:2025 Baseline Model Mesh – Ardersier Port and Surrounds

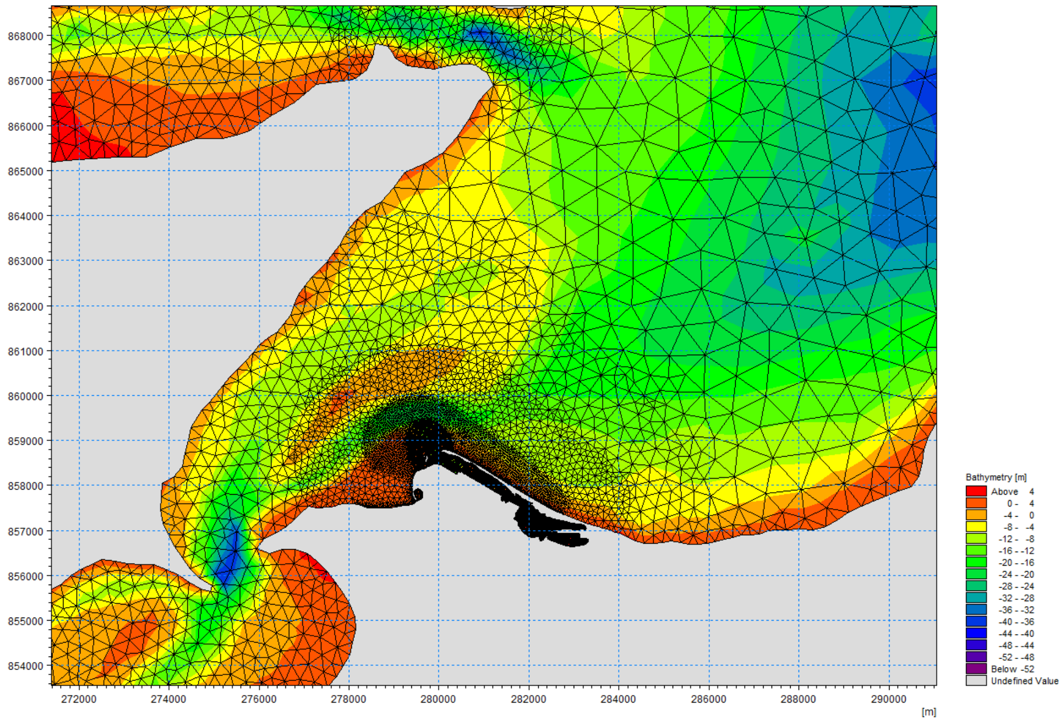
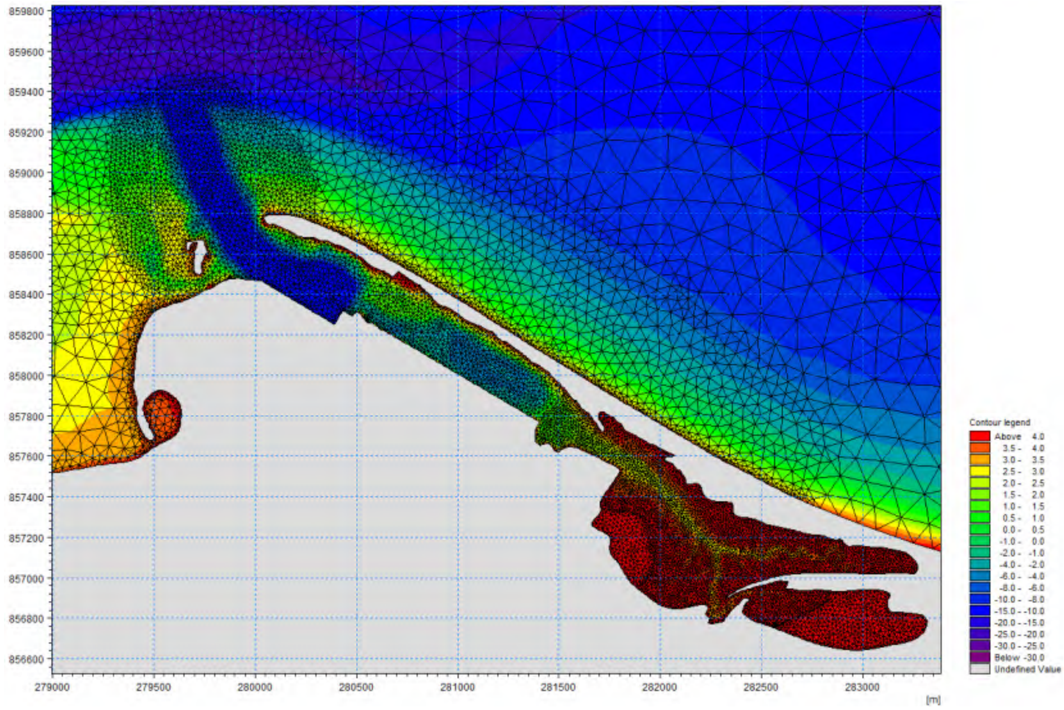


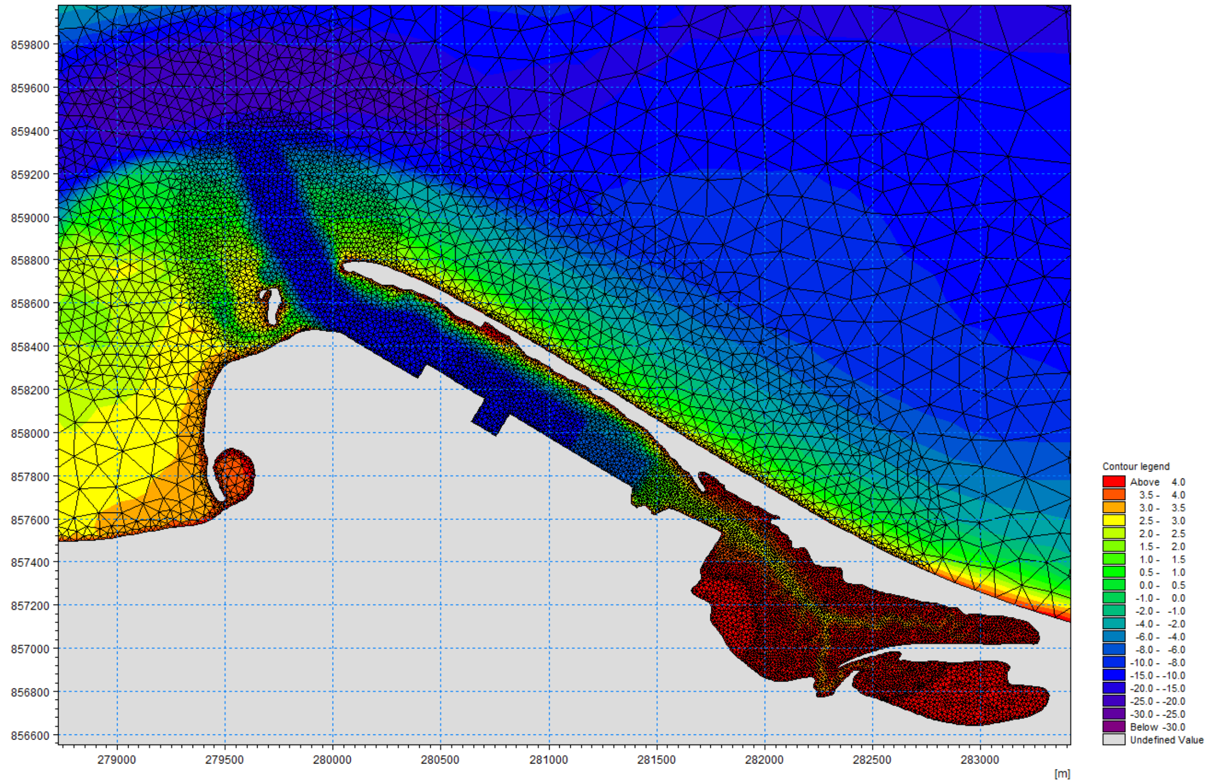
Figure 4.12: 2025 Baseline Model Mesh – Ardersier Port



4.4.2 Post Port Extension Mesh

The post port extension model mesh has the same extent and wider bathymetry as the baseline model mesh, with the only differences being within the harbour extent, reflecting the proposed development as described in Section 2.3. **Error! Reference source not found.** shows the post port extension model mesh and bathymetry at Ardersier Port.

Figure 4.13: Post Port Extension Model Mesh – Ardersier Port



4.4.3 Island Extension Options

The island extension option model meshes replicate the post port extension model mesh, with the only differences being to the terrestrial extent of the island feature. The island extension option 1 model mesh is shown in **Error! Reference source not found.** and the option 2 mesh in **Error! Reference source not found.**.

Figure 4.14: Post Port Extension Island Extension Option 1 Model Mesh – Ardersier Port

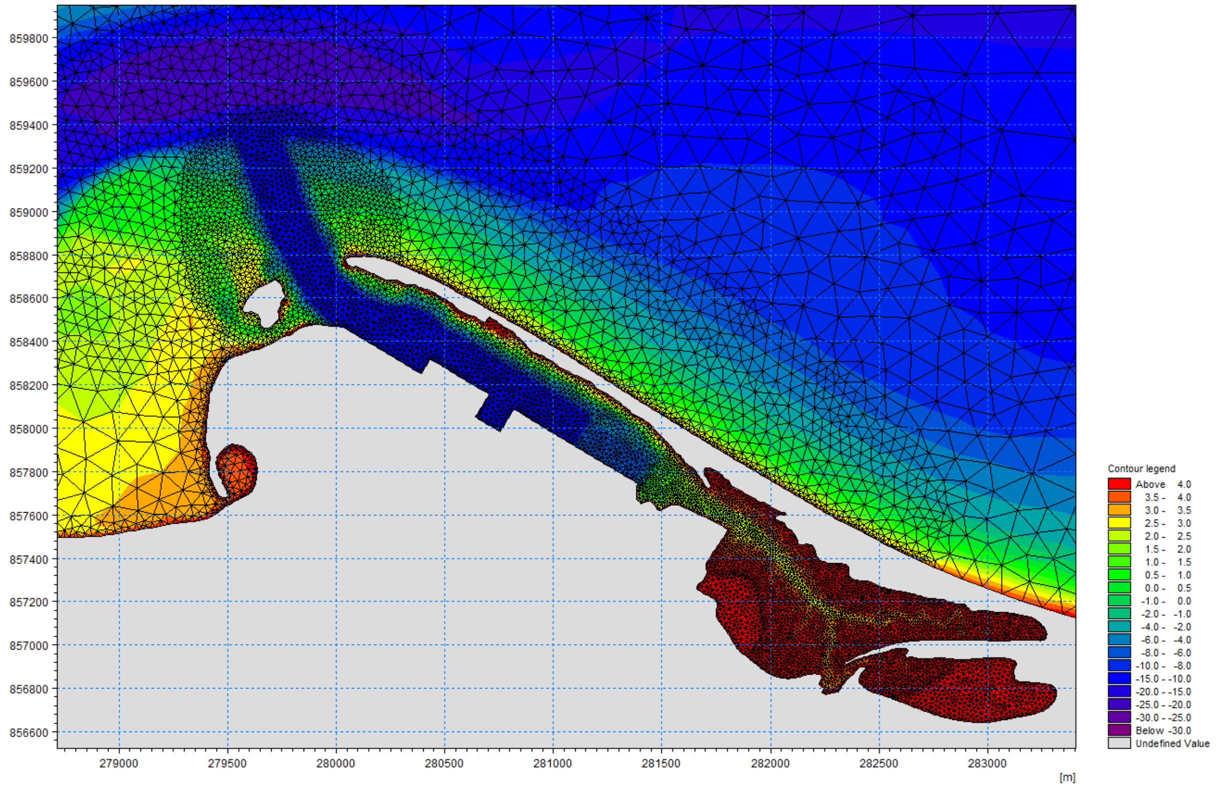
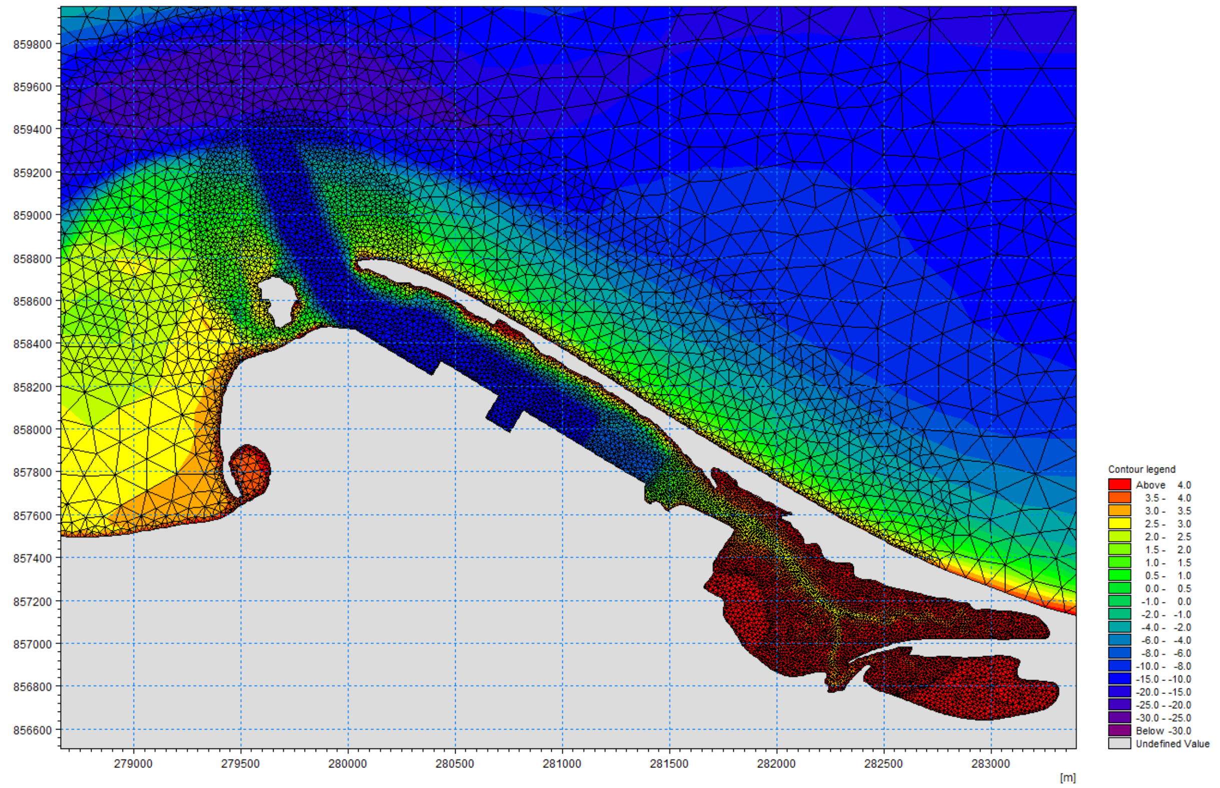


Figure 4.15: Post Port Extension Island Extension Option 2 Model Mesh – Ardersier Port



4.5 Model Setup

4.5.1 Hydrodynamic Module

Further details of the MIKE 21 FM HD model setup are provided below:

- For each model simulation the modelled extent includes the entire mesh as described in section 4.4;
- Open boundary time-varying tidal water level conditions have been derived from the DHI global tide model as described in section 4.3.2;
- Further model parameters are detailed below:
  - Simulation time-step interval: 300 s
  - Model solution technique: Higher order shallow water equations
  - Model solution time-step: Minimum (0.01 s) Maximum (30 s)
  - Drying depth: 0.005 m
  - Wetting depth: 0.1 m
  - Bed resistance: 32 $m^{(1/3)}$/s (22 $m^{(1/3)}$/s for post extension rock mattress / armour)

The modelling has been undertaken with the following computing specification:

- Dell Precision 7960 Tower:
  - 256 GB RAM;
  - Utilising 28 Cores – Intel Xeon CPU (2.5GHz);
  - Windows 11 Pro 64-bit operating system

4.5.2 Spectral Wave Module

Further details of the MIKE 21 SW model setup are presented below:

- For each model simulation the modelled extent includes the entire mesh as described in section 4.4;
- Model input data is described in sections 4.3.3 and 4.3.4;
- The model applies the fully spectral and quasi stationary (time) formulations;
- Diffraction is included using the phase-decoupled refraction-diffraction approximation;
- Wave breaking is accounted for based on the formulation of Battjes and Janssen (1978);
- The model time step interval is 300 seconds; and
- Computing specification is as per HD model setup.

4.5.3 Sand Transport Module

Further details of the MIKE 21 ST model setup are presented below:

- For each model simulation the modelled extent includes the mesh as described in section 4.4;
- Model input data is described in section 4.3;
- The ST model is coupled with HD and SW models, the HD and SW model setups are as described above;
- The ST model includes for sand transport by both waves and currents;
- The sediment data format is 'varying in domain', with sediment characteristics as per those shown in **Error! Reference source not found.**;
- Wave forcing is provided by the coupled SW model run; and
- Dynamic feedback on the hydrodynamic and sand transport calculations are included.

4.6 Model Outputs

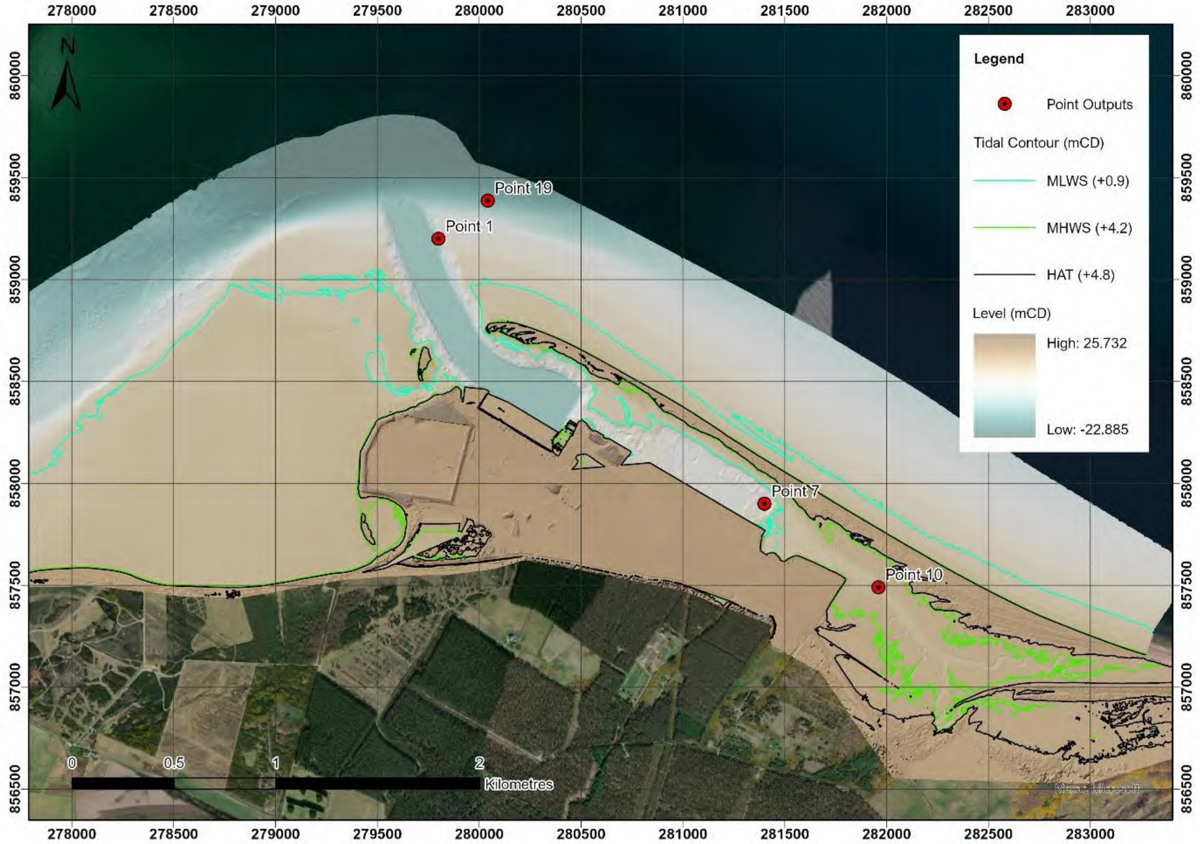
4.6.1 Hydrodynamic Module

The MIKE 21 FM HD model simulations have been setup to produce results as both point and area outputs. The outputs include the following key parameters:

- Water surface elevation;
- Current speed;
- Current direction; and
- Bed shear stress

The area outputs are generated for the whole model extent, whilst point outputs have been generated at a number of identified locations within the model extent, selected key locations are detailed in **Error! Reference source not found.**.

Figure 4.16: Selected Key Model Point Output Locations



4.6.2 Spectral Wave Module

The MIKE 21 SW model simulations have been setup to produce results as both point and area outputs. The outputs include the following key parameters:

- Significant wave height;
- Maximum wave height;
- Peak wave period; and
- Mean wave direction

The area outputs are generated for the whole model extent, whilst point outputs have been generated at a number of locations within the model extent, selected key locations are detailed in **Error! Reference source not found.**.

4.6.3 Sand Transport Module

The MIKE 21 ST model simulations have been setup to produce results as area and point outputs. The outputs include the following key parameters:

- Total load, x-component;
- Total load, y-component;
- Rate of bed level change;
- Bed level change; and
- Bed level

The area outputs are generated for the whole model extent, selected key point output locations are detailed in **Error! Reference source not found.**.

4.7 Model Simulations

The key model simulations undertaken using the MIKE 21 FM HD, FM SW and Coupled models are presented in Table 4.2.

Table 4.2: Model Simulations

Model Simulation	Description
A – Baseline 2025 HD	Baseline HD model simulating tidal action under existing conditions with navigation channel and outer harbour dredge complete. Run for period in May 2025 covering spring and neap tidal cycle.
B – Post-Extension HD	Post port extension HD model simulating tidal action under proposed conditions with inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle.
C – Baseline 2025 SW	Baseline SW model simulating wave action under existing conditions with navigation channel and outer harbour dredge complete. Run for period in May 2025 utilising hindcast data with tidal conditions from Simulation A.
D – Post Extension SW	Post port extension SW model simulating wave action under proposed conditions with inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 utilising hindcast data with tidal conditions from Simulation B.

Model Simulation	Description
E – Baseline 2025 Coupled ST HD SW	Baseline coupled model with HD SW and ST modules simulating tides, waves and sediment transport under existing conditions with navigation channel and outer harbour dredge complete. Run for period in May 2025 covering spring and neap tidal cycle, with hindcast wave and wind forcing, including a storm event taken from Storm Ciaran in 2023.
F – Post Extension Coupled ST HD SW	Post port extension coupled model with HD SW and ST modules simulating tides, waves and sediment transport under proposed conditions with inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle, with hindcast wave and wind forcing, including a storm event taken from Storm Ciaran in 2023.
G – Island Option 1 Post Extension HD	Island extension option 1 (post port extension) HD model simulating tidal action under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle.
H – Island Option 2 Post Extension HD	Island extension option 2 (post port extension) HD model simulating tidal action under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle.
I – Island Option 1 Post Extension SW	Island extension option 1 (post port extension) SW model simulating wave action under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 utilising hindcast data with tidal conditions from Simulation G.
J – Island Option 2 Post Extension SW	Island extension option 2 (post port extension) SW model simulating wave action under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 utilising hindcast data with tidal conditions from Simulation H.

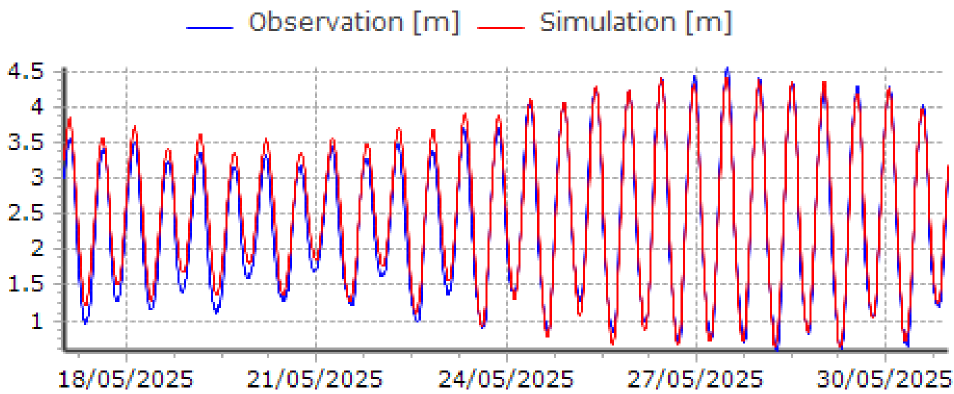
Model Simulation	Description
K – Island Option 1 Post Extension Coupled ST HD SW	Island extension option 1 (post port extension) coupled model with HD SW and ST modules simulating tides, waves and sediment transport under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle, with hindcast wave and wind forcing, including a storm event taken from Storm Ciaran in 2023.
L – Island Option 2 Post Extension Coupled ST HD SW	Island extension option 2 (post port extension) coupled model with HD SW and ST modules simulating tides, waves and sediment transport under proposed conditions with island expanded, inner harbour dredge, quay and ancillary works complete. Run for period in May 2025 covering spring and neap tidal cycle, with hindcast wave and wind forcing, including a storm event taken from Storm Ciaran in 2023.

4.8 Model Validation

4.8.1 Hydrodynamic Module

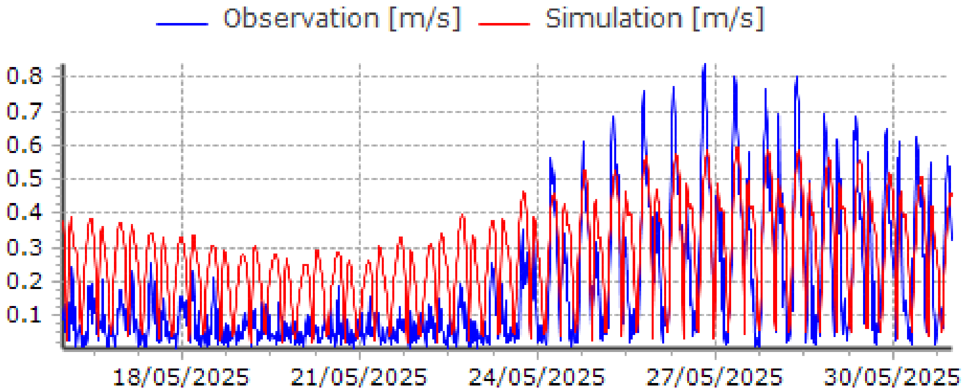
Validation of the model has been undertaken through comparison of baseline modelled tidal levels with measured tidal levels for the same duration and tidal sequence, at Ardersier Port, as shown in **Error! Reference source not found.**. This comparison highlights that the modelled levels and tidal phasing have good agreement with the observed data, generally returning levels within a few centimetres at correct timings.

Figure 4.17: Comparison of Measured (Blue) and Modelled 2025 Baseline (Red) Water Levels



Validation of current speed predictions has been undertaken by comparison of baseline modelled current speeds and measured data from a wave buoy positioned at Point Output Location 19, for the modelled duration and tidal sequence, as shown in **Error! Reference source not found.**. The measured current speed is a mid-depth ADCP measurement, whilst the modelled current speed output is depth-averaged. Noting the difference in the nature of the current speed datasets, and the potential for noise, errors, weather and local influence in the measured dataset, it is considered that the model predictions show good agreement in terms of phasing and relative magnitude between flood and ebb current speeds. Neap tide model predictions are elevated above the measured observations, whilst spring tide model predictions sit slightly below the observed data, particularly for flood tide currents.

Figure 4.18: Comparison of Measured (Blue) and Modelled 2025 Baseline (Red) Current Speed



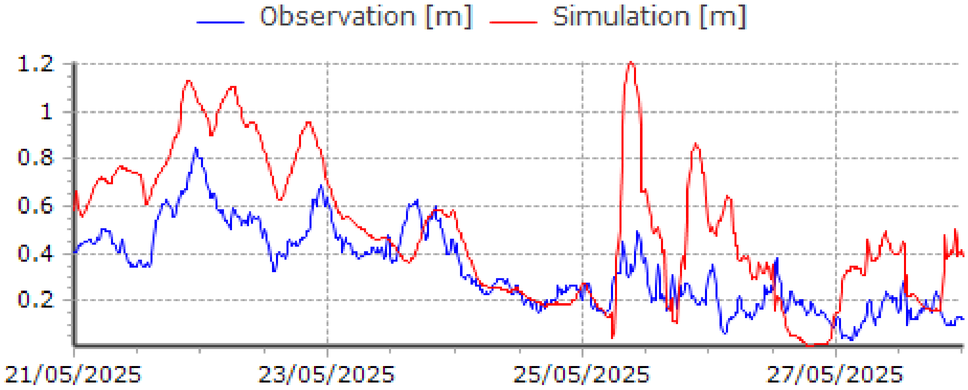
Additionally, tidal current speeds predicted by the baseline model have been compared to annotated tidal stream speeds on UKHO hydrographic charts for the Moray Firth, with model peak current speed predictions lying within the published range of current speed.

Given the results of the above validation exercise the model is therefore considered to perform well.

4.8.2 Spectral Waves Module

Validation of spectral wave model predictions has been undertaken through comparison of baseline modelled significant wave heights with measured significant wave height from a wave buoy positioned at Point Output Location 19, for the modelled duration, as shown in **Error! Reference source not found.**. Noting the difference in the nature of the wind forcing between the datasets, and the potential for noise, weather and local influence in the measured dataset, it is considered that the model predictions show good agreement in terms of phasing and relative magnitude. Model predictions can be seen to generally return higher values, however this is considered a conservative result in the context of the assessment scope and purpose.

Figure 4.19: Comparison of Measured (Blue) and Modelled 2025 Baseline (Red) Significant Wave Height



4.8.3 Sand Transport Module

As per previous phases of assessment at Ardersier Port, the sand transport model has been validated through both comparison to successive bathymetric surveys, conceptual understanding of processes and hindcast modelling utilising earlier bathymetry. The duration of the sand transport model runs are short in comparison to the duration between successive bathymetric surveys, additionally, the model works with fixed shoreline alignments which cannot represent processes associated with terrestrial spit extension or terrestrial erosion. Therefore, the validation approach has been to compare simulated zones of sediment deposition and erosion with observed changes and the conceptual understanding of the coastal processes. It is considered that the model provides a reasonable representation of the patterns of intertidal and subtidal sand erosion, transport and deposition observed and is therefore deemed suitable for use in assessing coastal processes.

4.9 Model Results

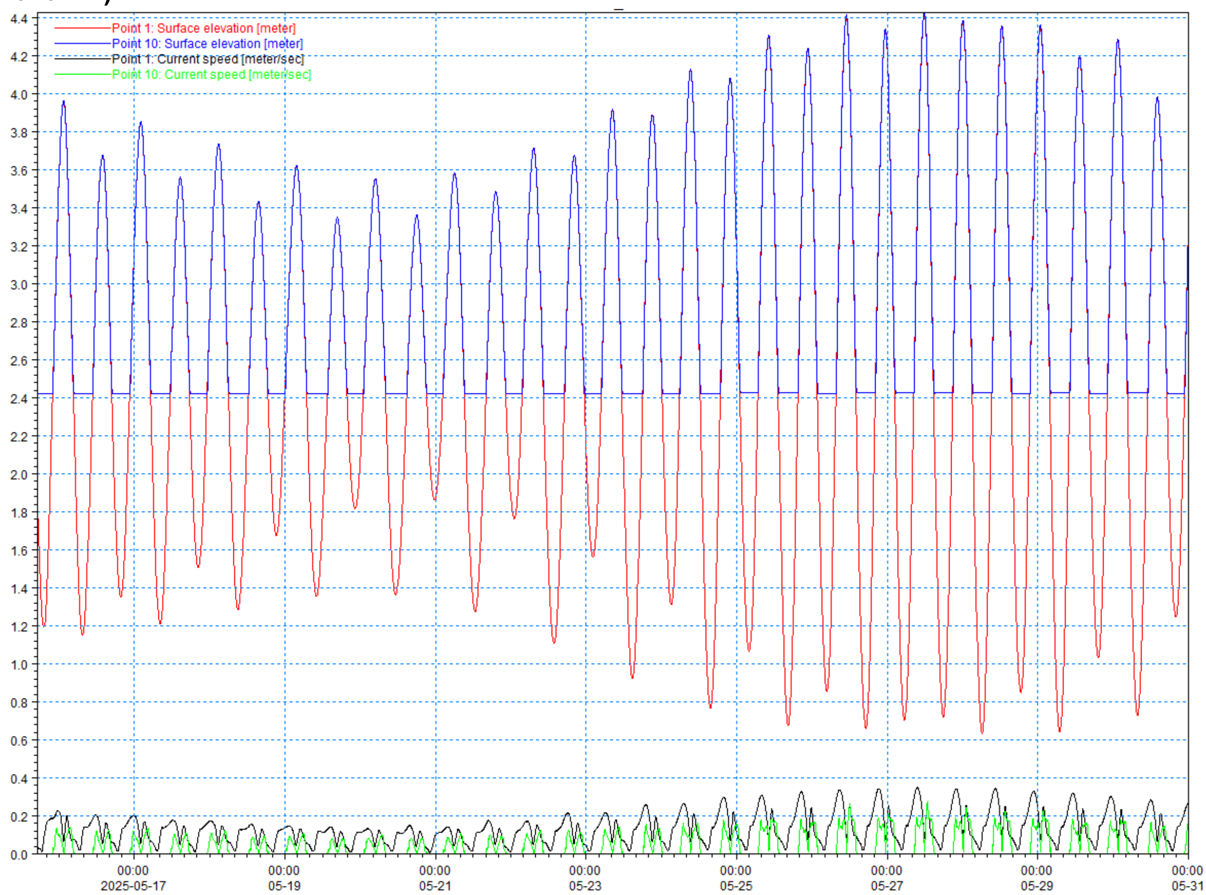
The following sub-sections summarise the key results for the model simulations detailed in Table 4.2, split by model type (HD, SW and Coupled HD SW ST). HD model result summaries focus on predicted water levels and current speeds. SW model result summaries focus on predicted significant wave heights, whilst coupled model results on predicted bed level change.

4.9.1 Hydrodynamic Module

Simulation A – Baseline 2025 HD

The modelled baseline current speed and water level at Point 1 (navigation channel) and Point 10 (saltmarsh main creek) are shown in graphical form in **Error! Reference source not found.** for the simulation duration. Review of this figure highlights the reduced tidal range within the saltmarsh creek versus the navigation channel due to the shallower bed level. At Point 1 peak flood tide current speeds can be seen to be slightly greater than the corresponding ebb tide current, with speeds reducing towards 0 at high and low water. At Point 10 peak flood and ebb current speeds are lower than those at Point 1, but also closer in magnitude with a marginally higher ebb speed, particularly during spring tides. Peak current speeds also occur slightly after those predicted at Point 1.

Figure 4.20: Point 1 and 10 Time-Series Current Speed and Water Level – Simulation A (Baseline 2025 HD)



Error! Reference source not found. presents an area plot of peak spring flood current speed at a selected timestep during the baseline simulation, whilst **Error! Reference source not found.** presents the corresponding ebb current speed plot. **Error! Reference source not found.** presents an area plot of the statistical maximum current speed throughout the simulation duration, whilst **Error! Reference source not found.** and **Error! Reference source not found.** present the equivalent statistical mean and minimum plots respectively. Comparison between the flood and ebb timestep plots and the statistical maximum current speed plot highlights the temporal variation in peak current speeds within the harbour and immediate vicinity.

Figure 4.21: Current Speed Mid Spring Flood – Simulation A (Baseline 2025 HD)

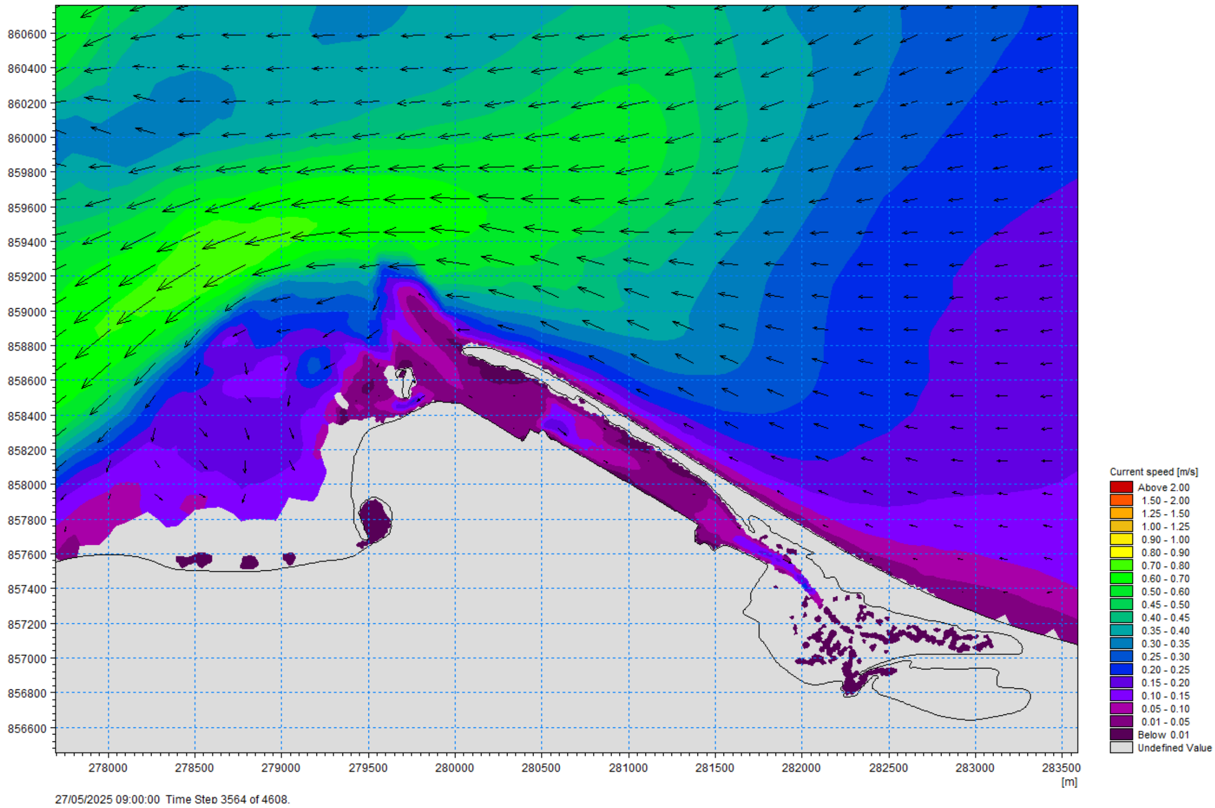


Figure 4.22: Current Speed Mid Spring Ebb – Simulation A (Baseline 2025 HD)

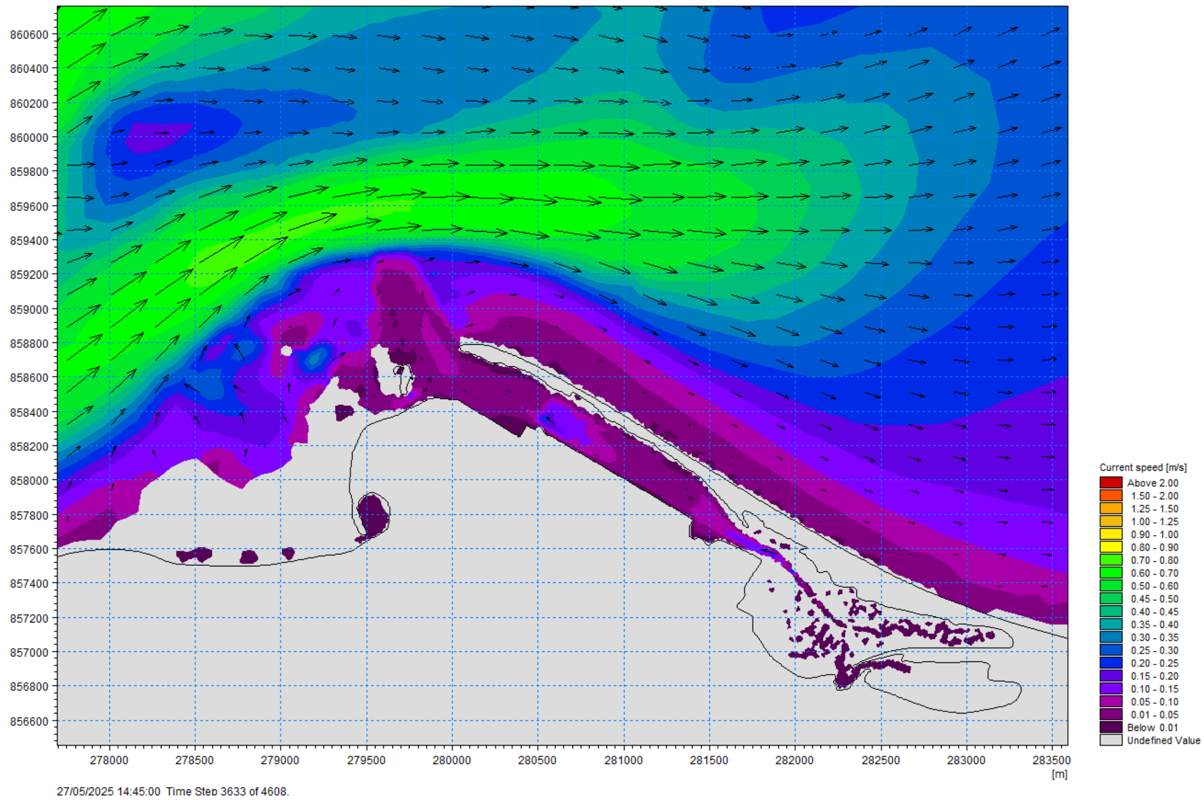


Figure 4.23: Current Speed Statistical Maximum – Simulation A (Baseline 2025 HD)

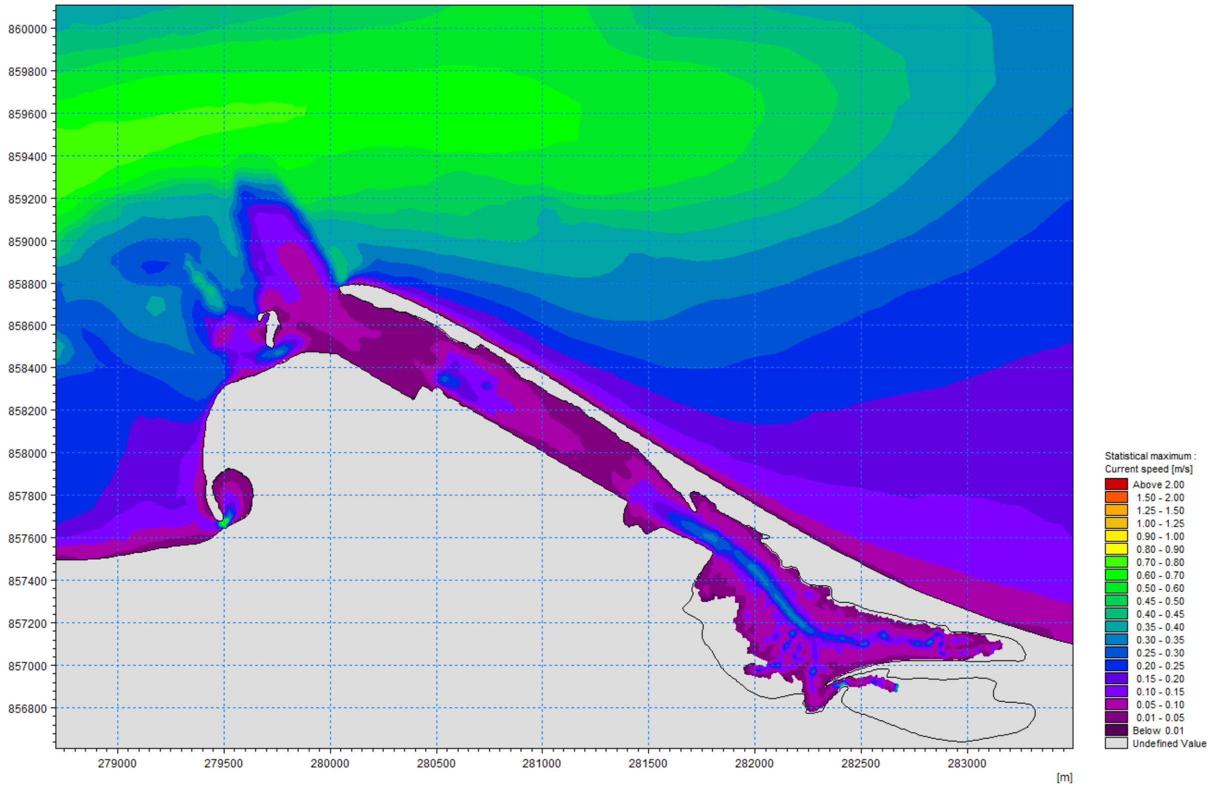


Figure 4.24:Current Speed Statistical Mean – Simulation A (Baseline 2025 HD)

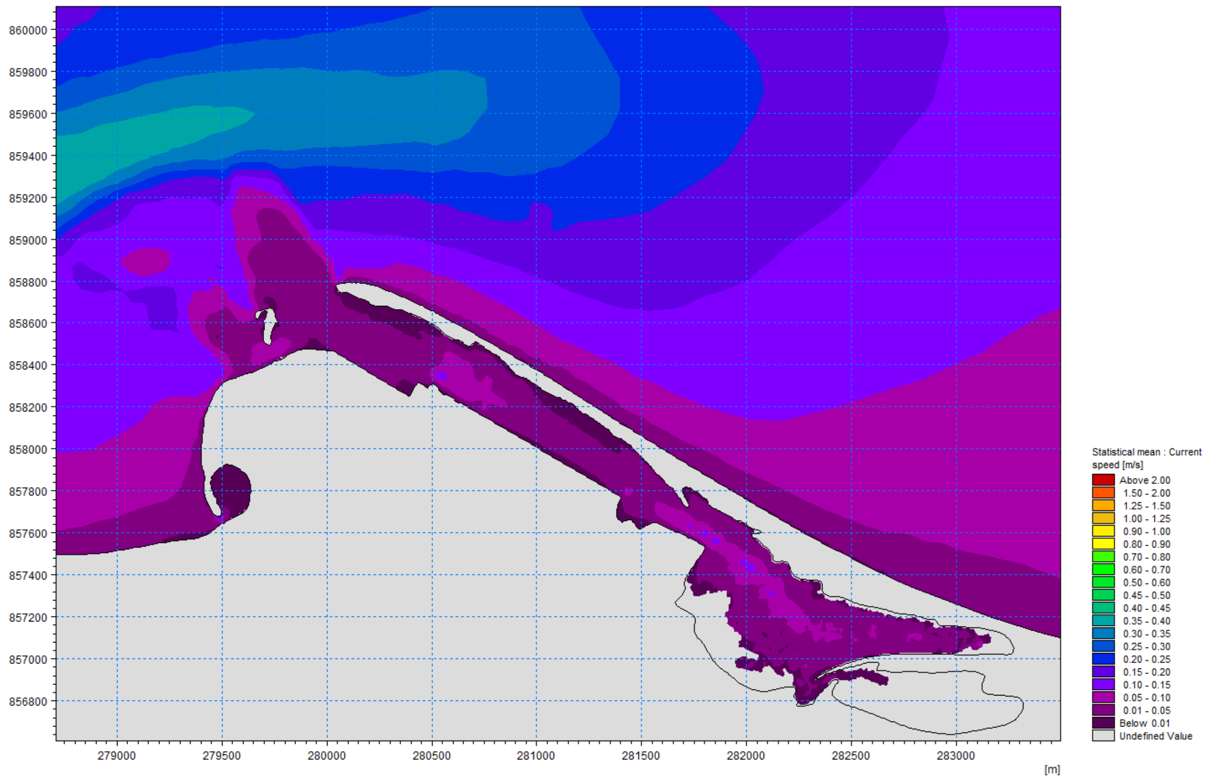
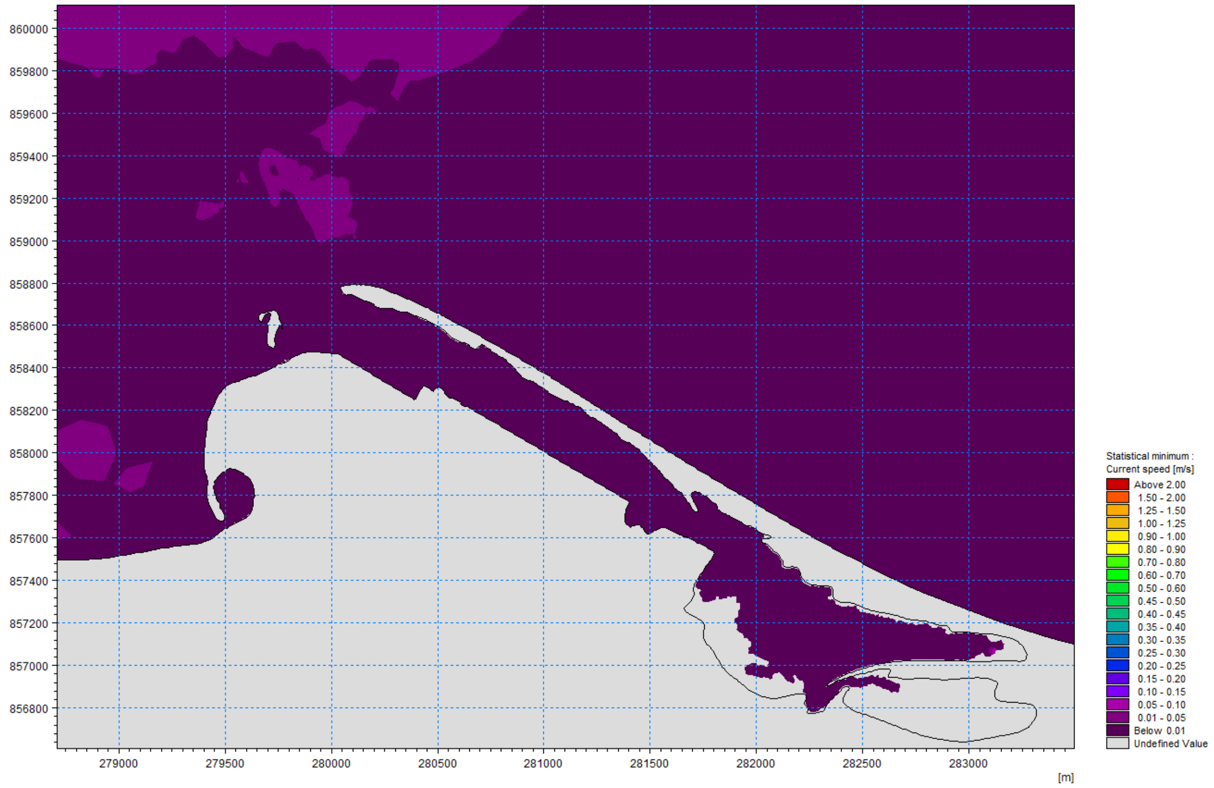


Figure 4.25: Current Speed Statistical Minimum – Simulation A (Baseline 2025 HD)



Simulation B – Post Extension HD

Error! Reference source not found. and **Error! Reference source not found.** present area plots from the post port extension HD simulation of mid spring flood and ebb current speeds respectively. **Error! Reference source not found.** presents an area plot of statistical maximum current speed over the duration of Simulation B, whilst **Error! Reference source not found.** and **Error! Reference source not found.** present the equivalent plots for statistical mean and minimum respectively. Comparison and assessment of the model results for baseline (Simulation A) and post extension (Simulation B) is presented in Section 5.1.

Figure 4.26: Current Speed Mid Spring Flood – Simulation B (Post Extension HD)

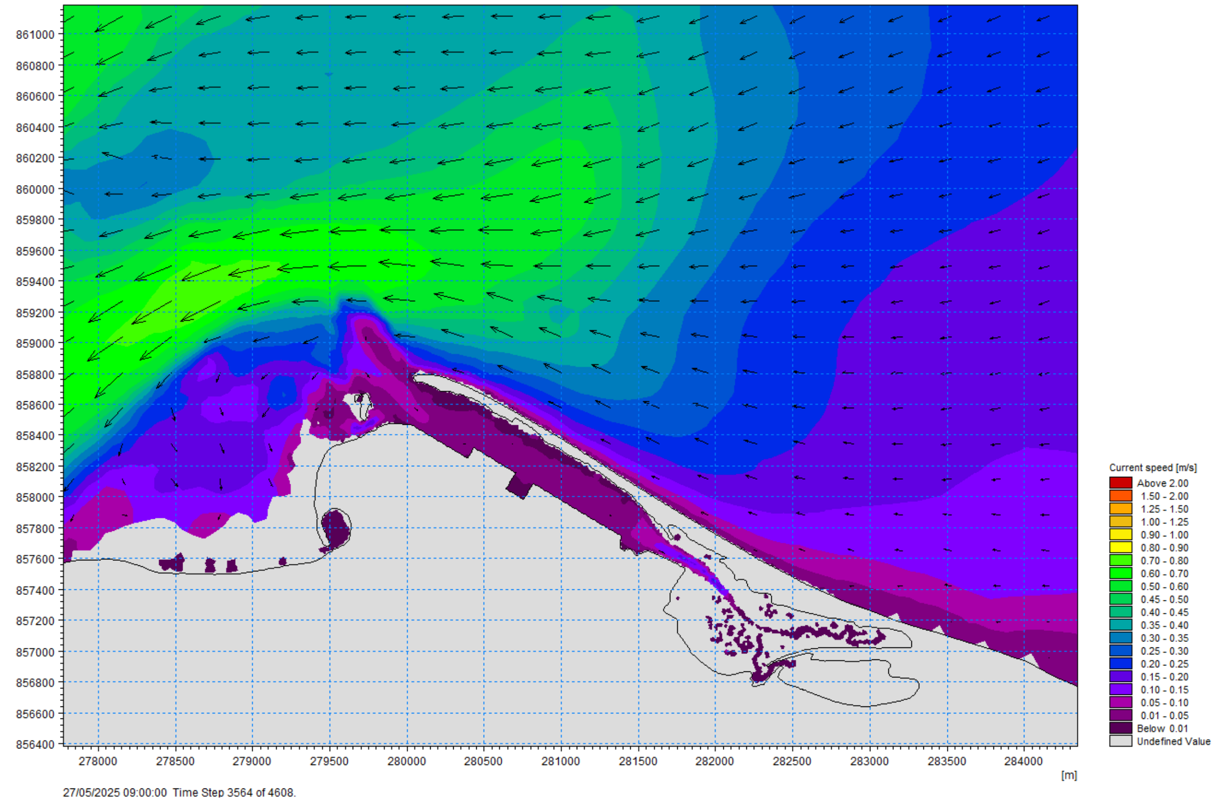


Figure 4.27: Current Speed Mid Spring Ebb – Simulation B (Post Extension HD)

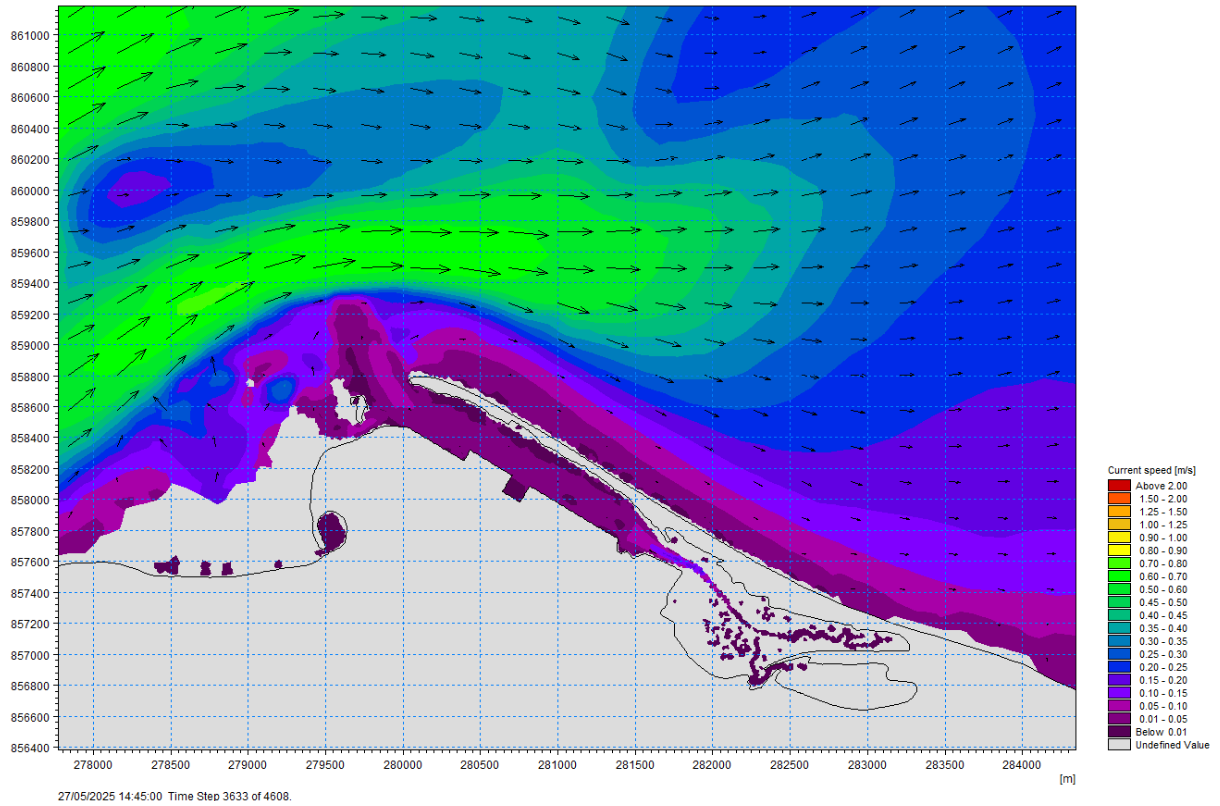


Figure 4.28: Current Speed Statistical Maximum – Simulation B (Post Extension HD)

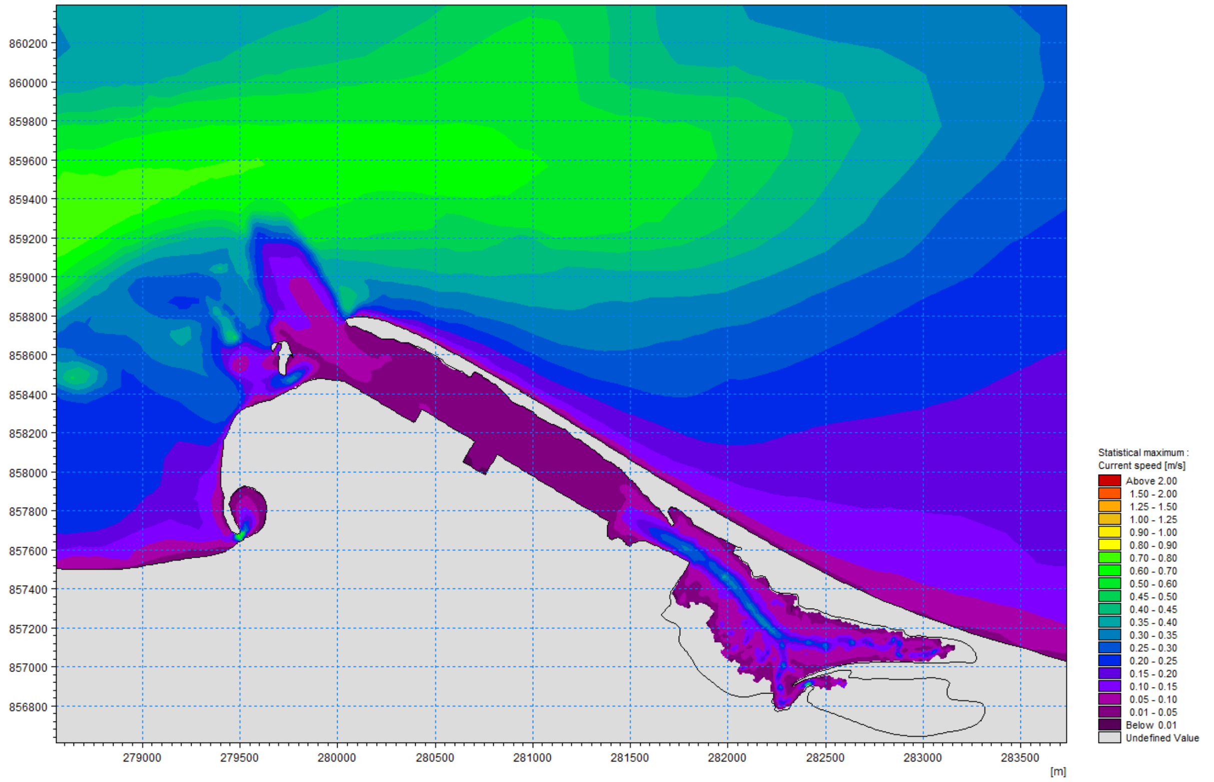


Figure 4.29: Current Speed Statistical Mean – Simulation B (Post Extension HD)

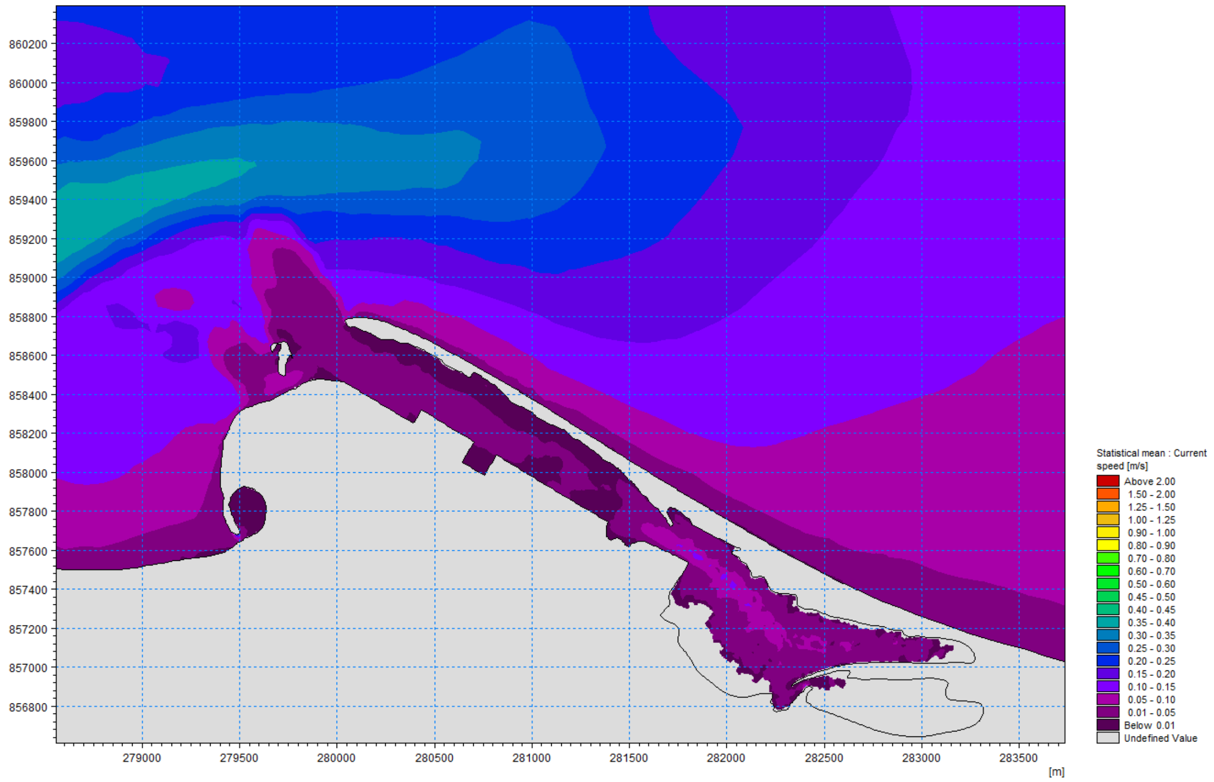
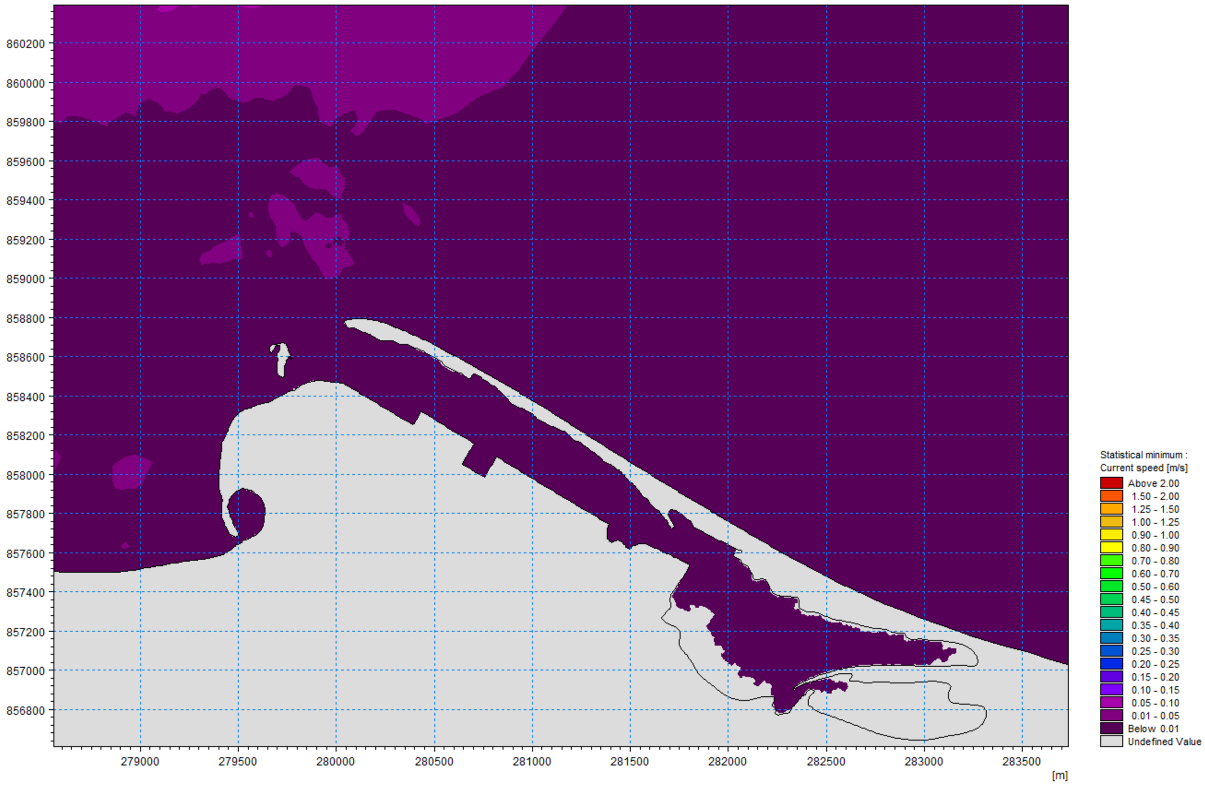


Figure 4.30: Current Speed Statistical Minimum – Simulation B (Post Extension HD)



4.9.2 Spectral Waves Module

Simulation C – Baseline SW

The modelled baseline significant wave height at Point 1 (navigation channel) and Point 10 (saltmarsh main creek) are shown in graphical form in Error! Reference source not found. for the simulation duration. Review of this figure highlights the peaks in wave height at Point 10 are limited to specific durations, these are associated with wind and locally generated wind waves from the west and north-west, aligned with the harbour. Review of the statistical maximum significant wave heights (**Error! Reference source not found.**) highlights the protection the spit affords the harbour from wave action, with statistical maximum height progressively reducing from the harbour entrance further to the east into more sheltered areas, with minimal wave action reaching the intertidal saltmarsh extents. **Error! Reference source not found.** and **Error! Reference source not found.** present area plots of the statistical mean and minimum significant wave height respectively.

Figure 4.31: Point 1 and 10 Time-Series Significant Wave Height – Simulation C (Baseline SW)

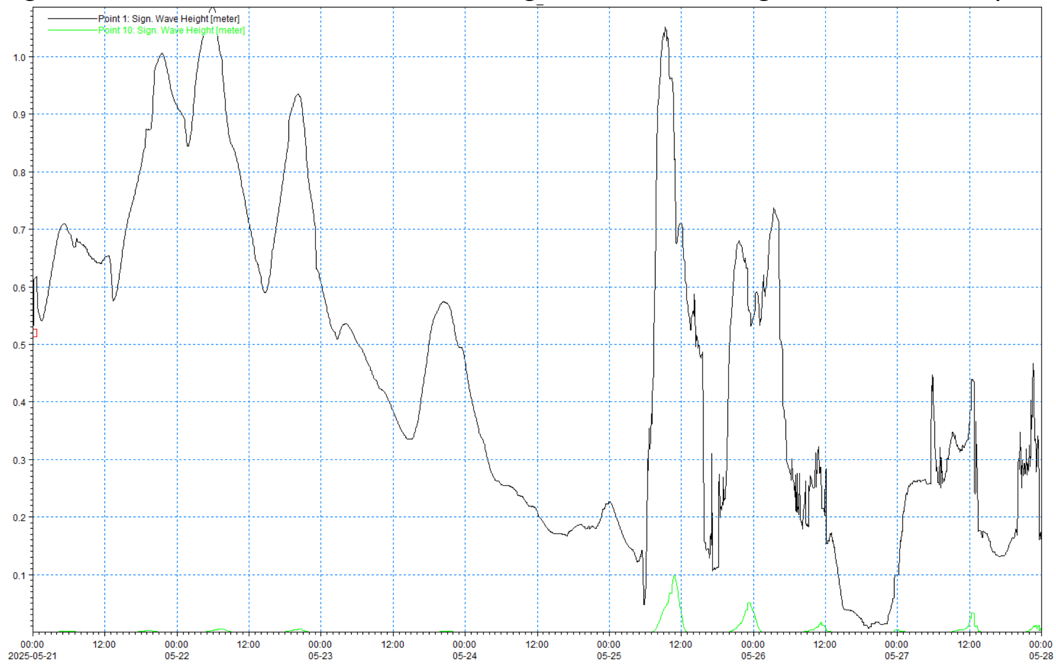


Figure 4.32: Significant Wave Height (Hs) Statistical Maximum – Simulation C (Baseline SW)

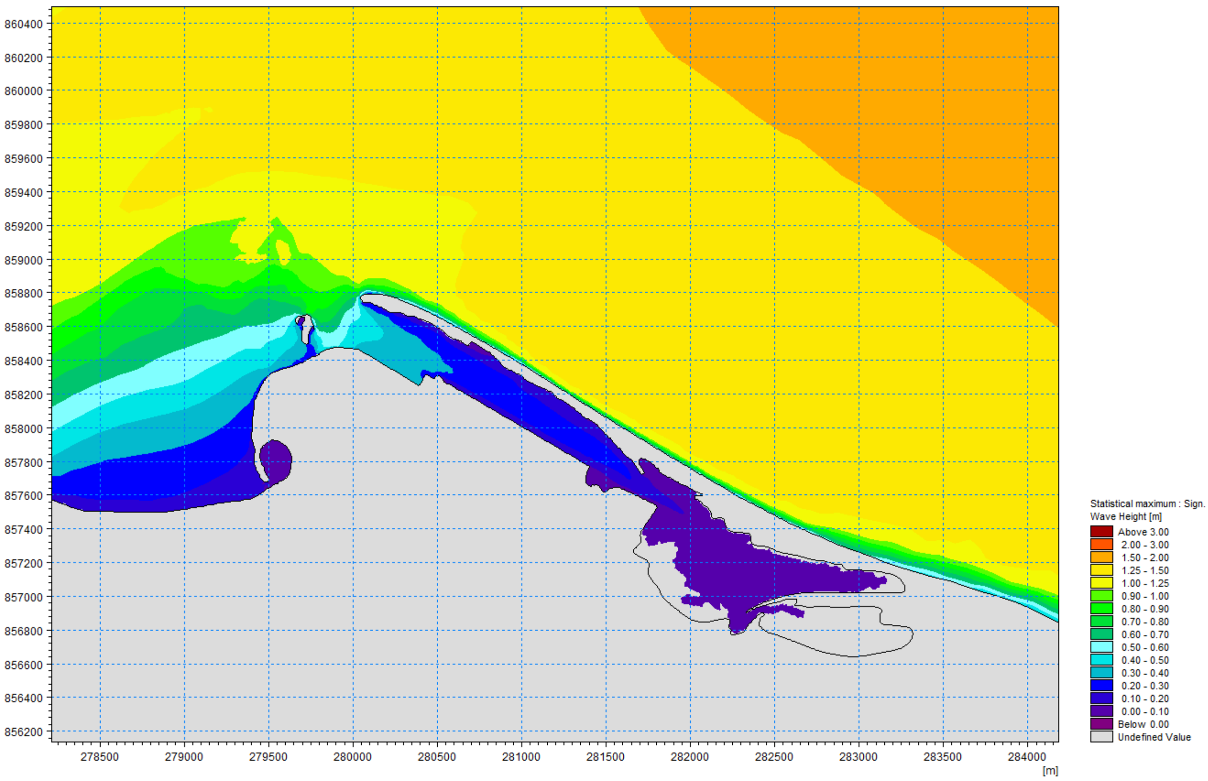


Figure 4.33: Significant Wave Height (Hs) Statistical Mean – Simulation C (Baseline SW)

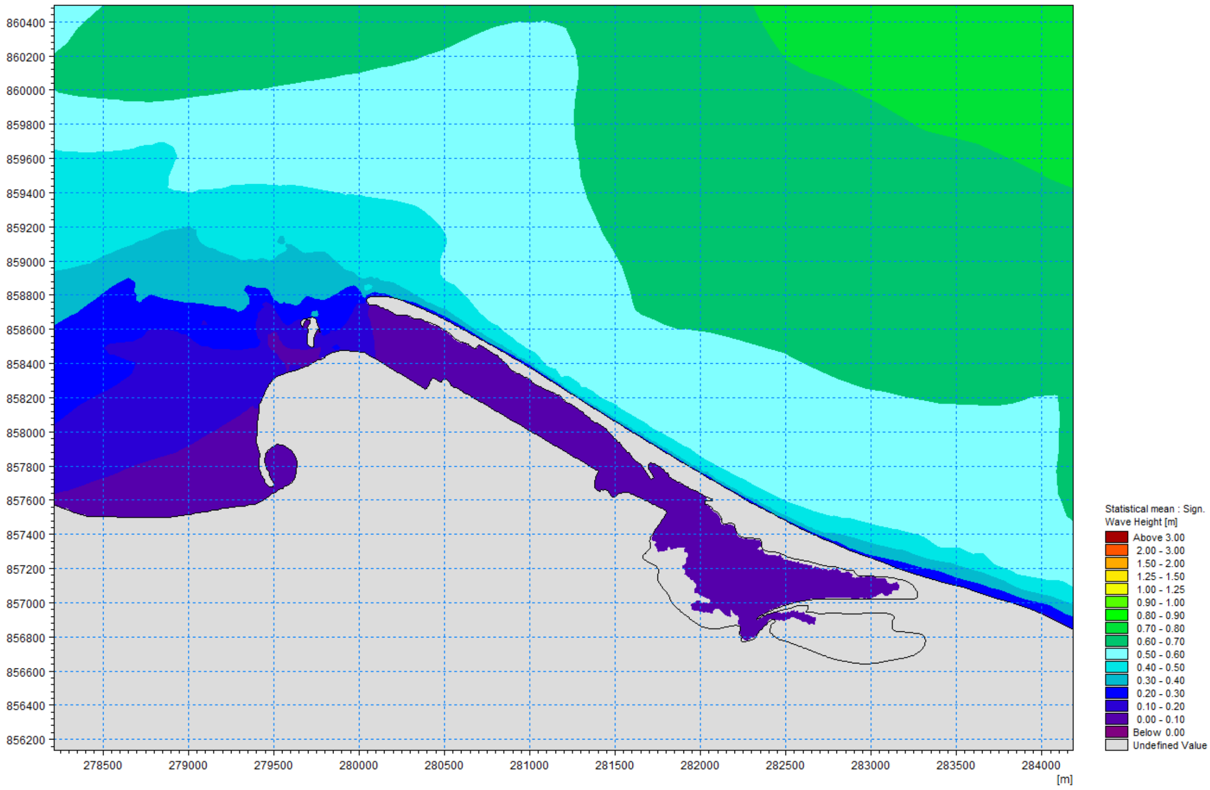
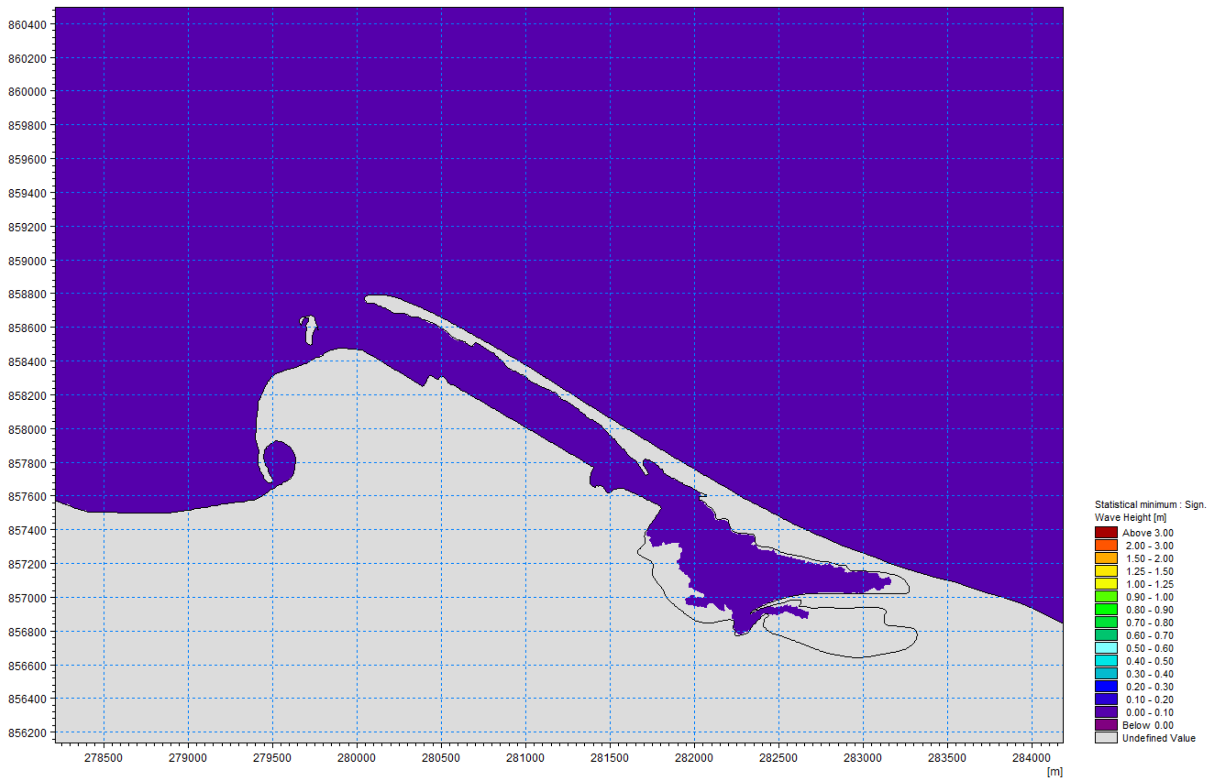


Figure 4.34: Significant Wave Height (Hs) Statistical Minimum – Simulation C (Baseline SW)



<u>Simulation D – Post Extension SW</u>

An area plot of statistical maximum significant wave height for the duration of the post port extension simulation is presented in **Error! Reference source not found.**. **Error! Reference source not found.** and **Error! Reference source not found.** present the equivalent statistical mean and minimum plots respectively. Comparison and assessment of the model results for baseline (Simulation C) and post extension (Simulation D) is presented in Section 5.1.2.

Figure 4.35: Significant Wave Height (Hs) Statistical Maximum – Simulation D (Post Extension SW)

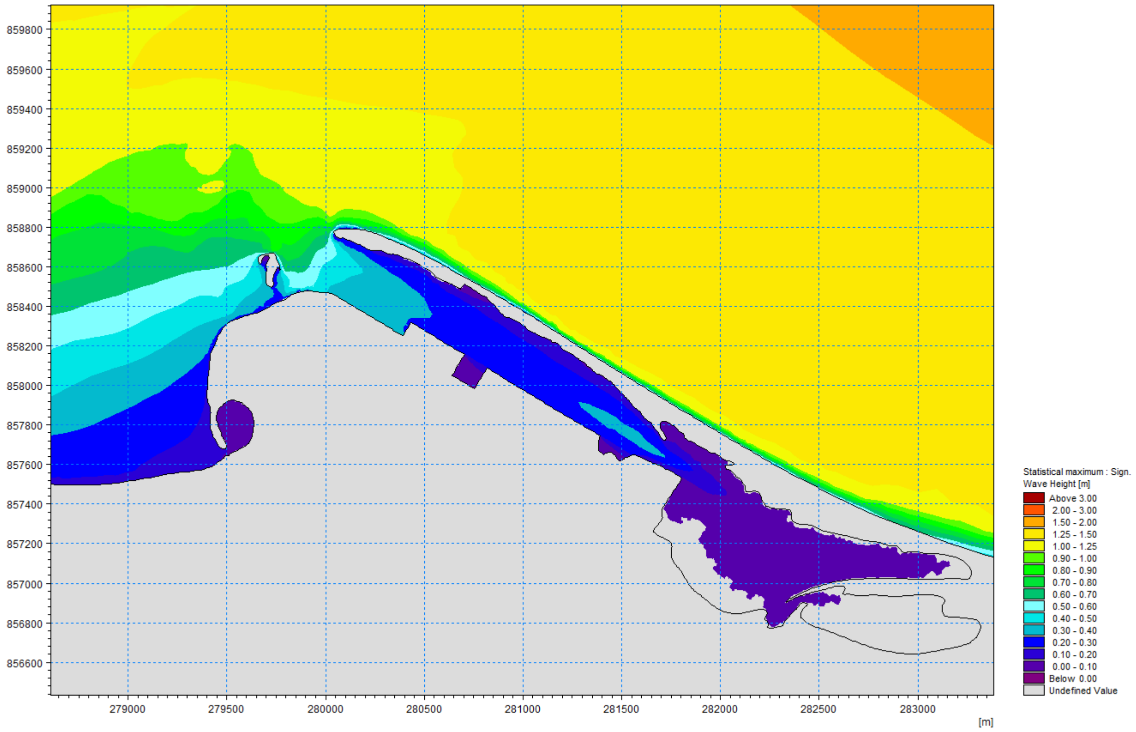


Figure 4.36: Significant Wave Height (Hs) Statistical Mean – Simulation D (Post Extension SW)

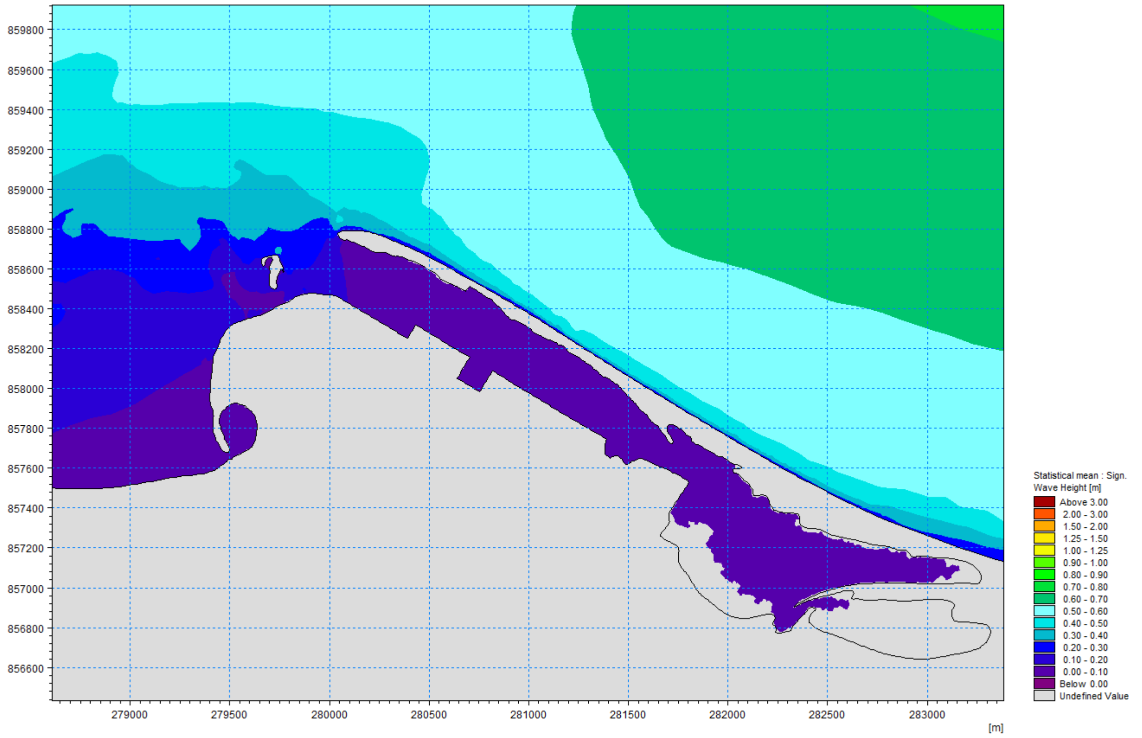
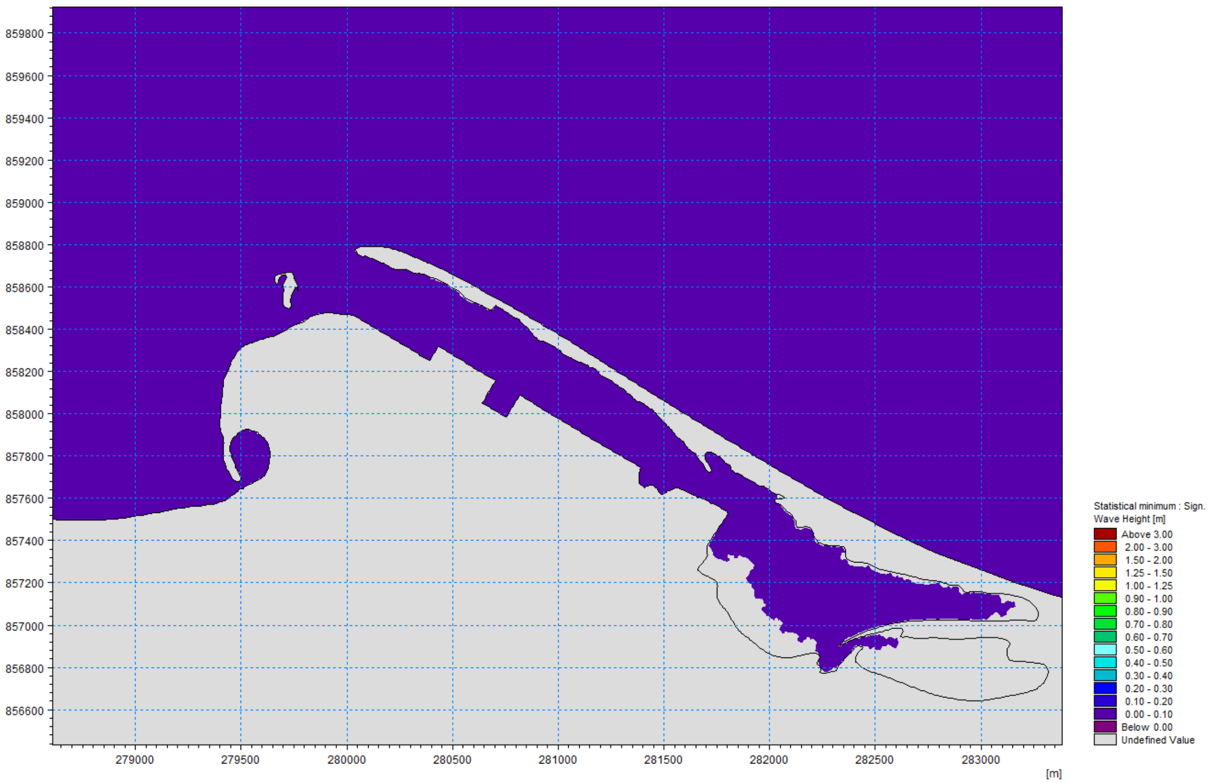


Figure 4.37: Significant Wave Height (Hs) Statistical Minimum – Simulation D (Post Extension SW)



4.9.3 Sand Transport Module

Simulation E – Baseline Coupled ST

Error! Reference source not found. presents an area plot of bed level change at the end of the baseline coupled sand transport simulation (Simulation E). Positive values (Red to Green) are reflective of deposition, whilst negative values (blue to purple) are reflective of erosion. Review of this figure shows a pattern of erosion and deposition consistent with the findings of previous modelling phases, observed change and the conceptual model of processes. The longshore transport of sand on the outer face of the spit is evident, along with the north north-westward intertidal extension of the spit head. Deposition is predicted along the eastern edge of the navigation channel adjacent to the spit head. Immediately west of the navigation channel some localised erosion is predicted, with onwards reworking of sand to the west. A westward pattern of sand transport is observed along the southern shoreline around Whiteness Sands, whilst central areas of the sands show little change.

Error! Reference source not found. shows a time-series plot of bed level change and rate of bed level change at point output location 1 through the simulation duration. Review of this figure highlights the increase in rate of bed level change associated with the modelled storm event in the latter part of the simulation (25/05 onwards), along with the temporal influence of the tidal cycle.

Figure 4.38: Bed Level Change End of Simulation – Simulation E (Baseline 2025)

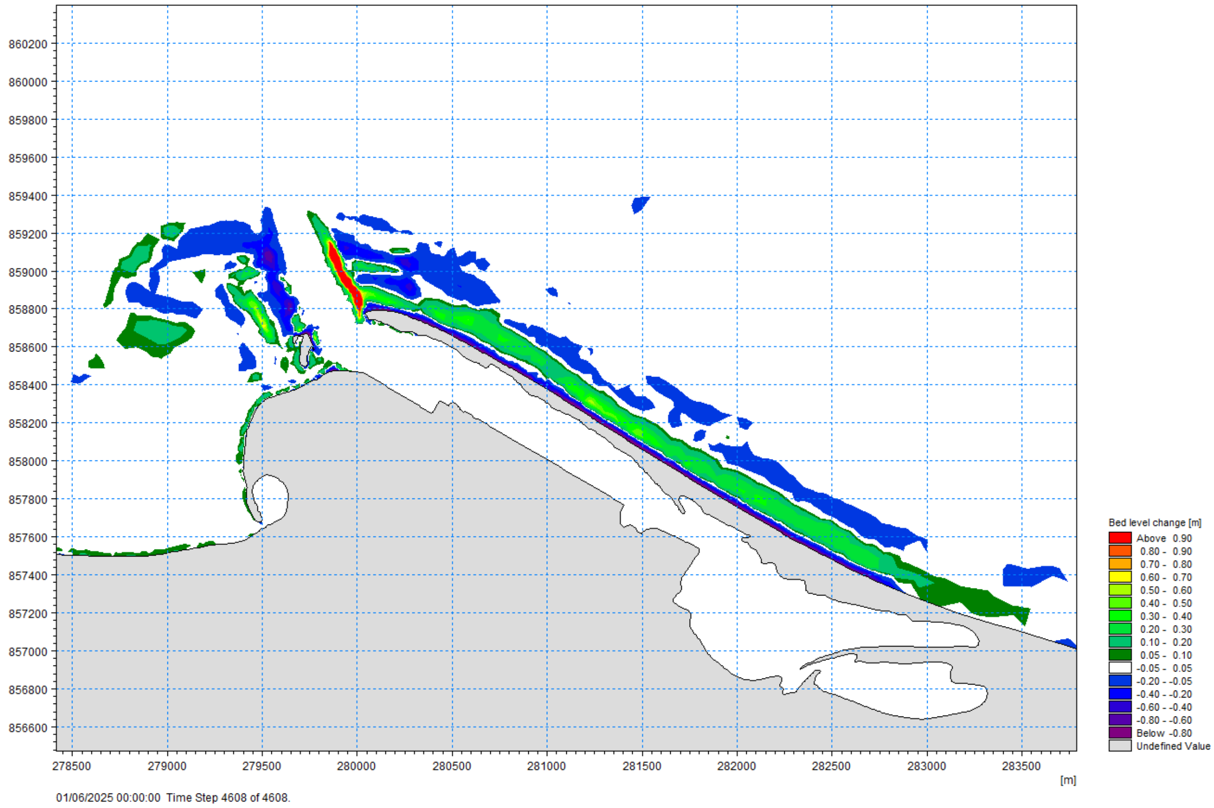
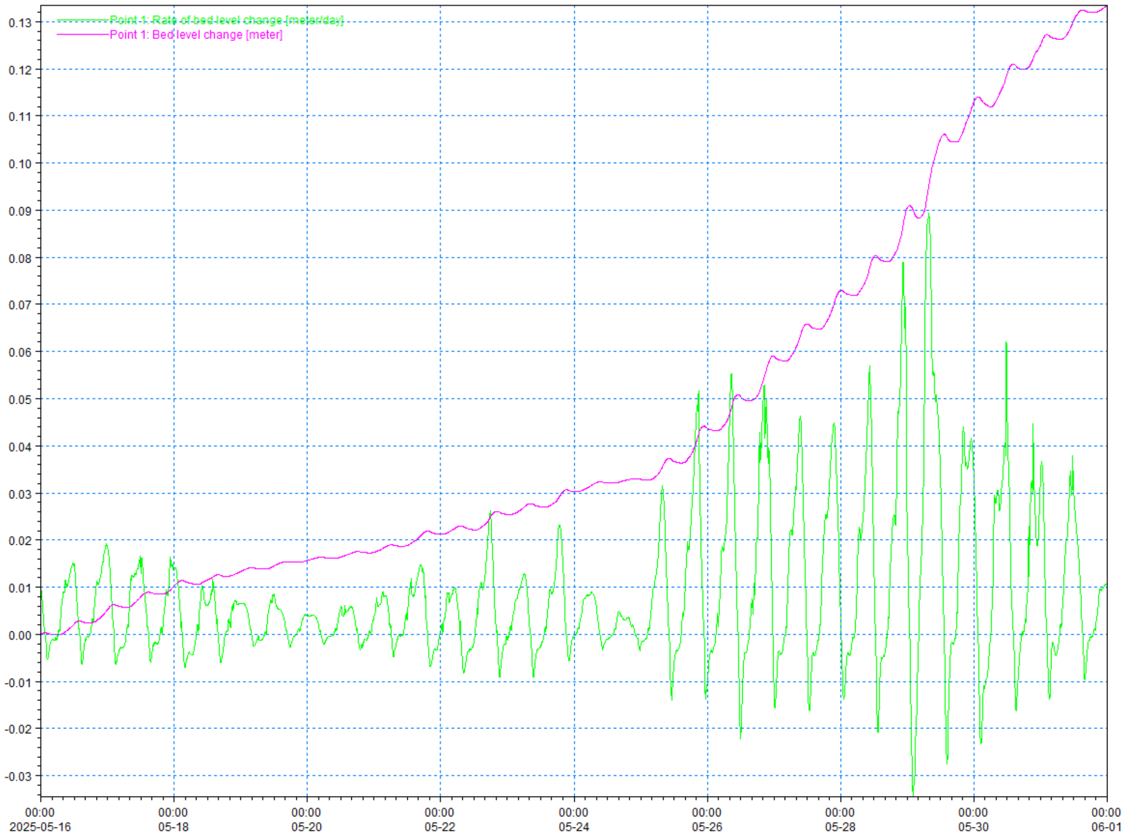


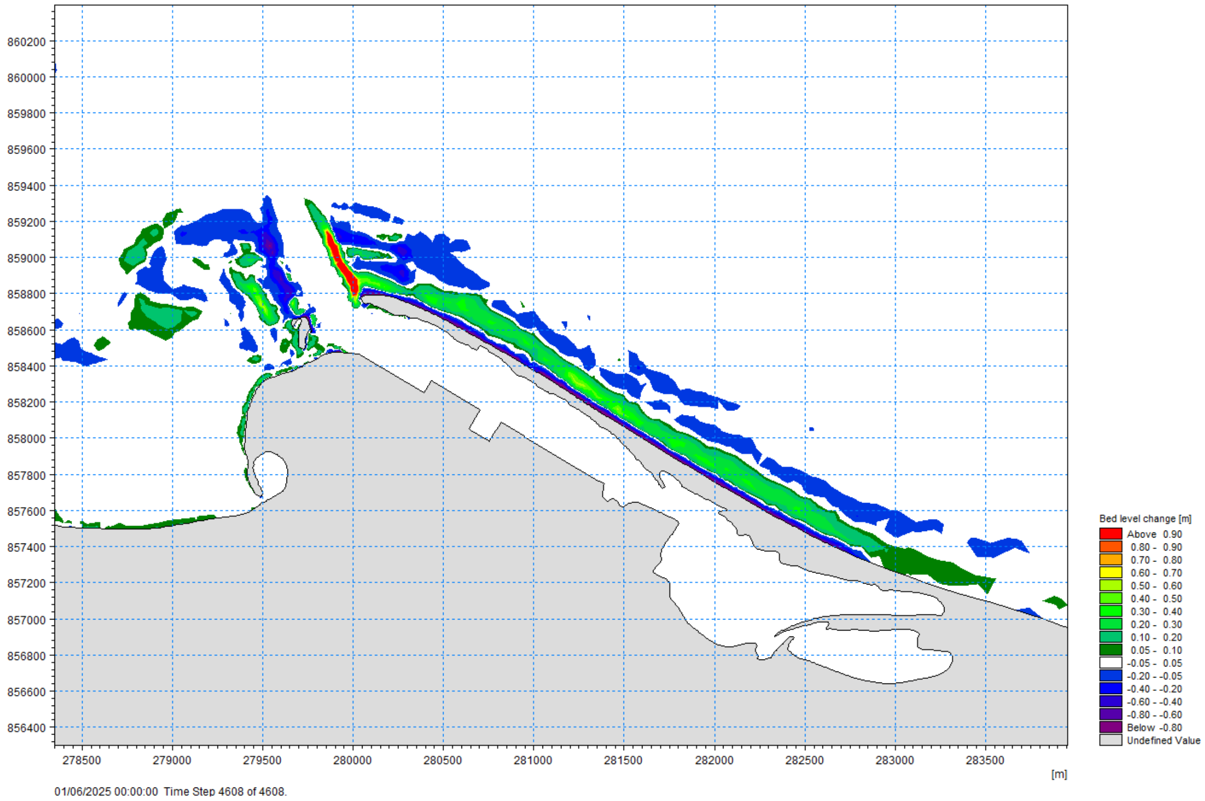
Figure 4.39: Bed Level Change (m) and Rate of Bed Level Change (m/day) at Point 1 – Simulation E (Baseline 2025)



Simulation F – Post Extension Coupled ST

Error! Reference source not found. presents a plot of bed level change at the end of the post port extension coupled sand transport simulation (Simulation F). A similar pattern of deposition and erosion is observed to that shown in the baseline equivalent. Comparison and assessment of the model results for baseline (Simulation E) and post extension (Simulation F) is presented in 5.1.3.

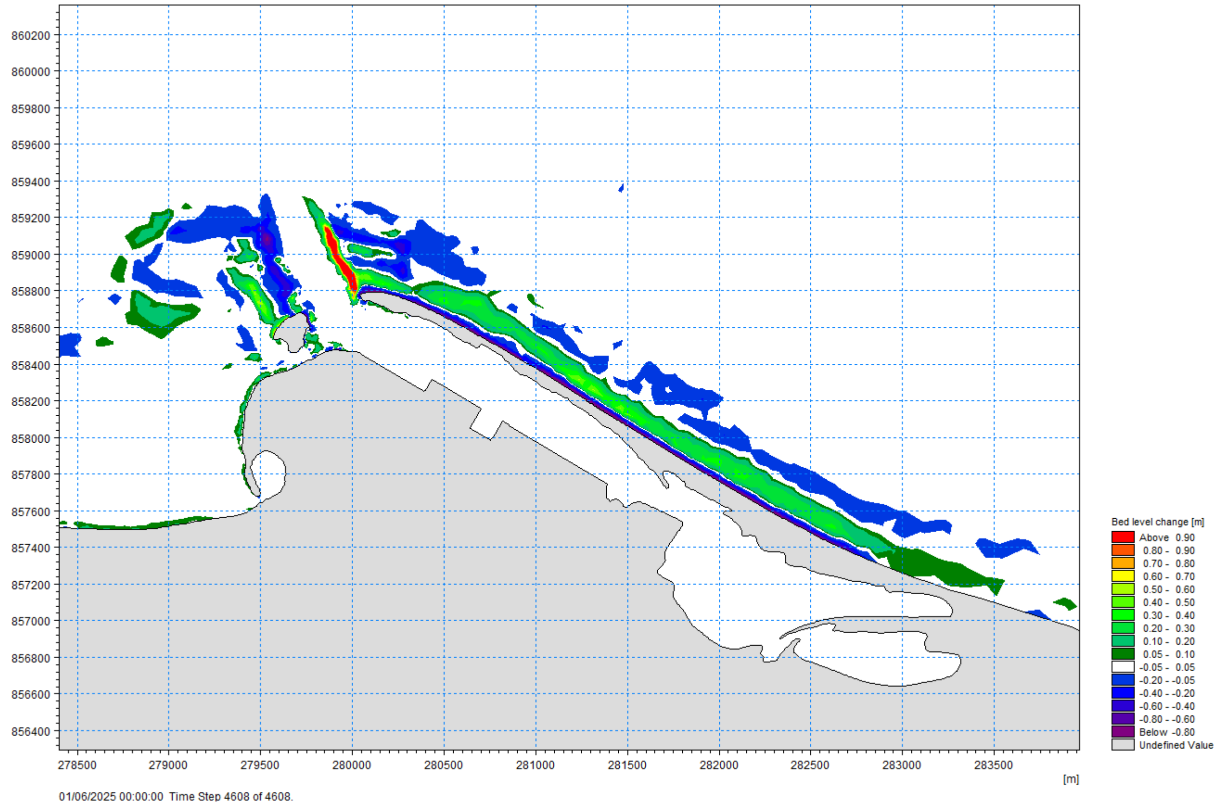
Figure 4.40: Bed Level Change End of Simulation – Simulation F (Post Extension)



Simulation K – Post Port Extension Island Extension Option 1

Error! Reference source not found. presents a plot of bed level change at the end of the island extension option 1 coupled sand transport simulation (Simulation K). A similar pattern of deposition and erosion is observed to that shown in the baseline and post extension equivalents. The impacts of the island extension options on local processes is considered further in Section 5.1.3.

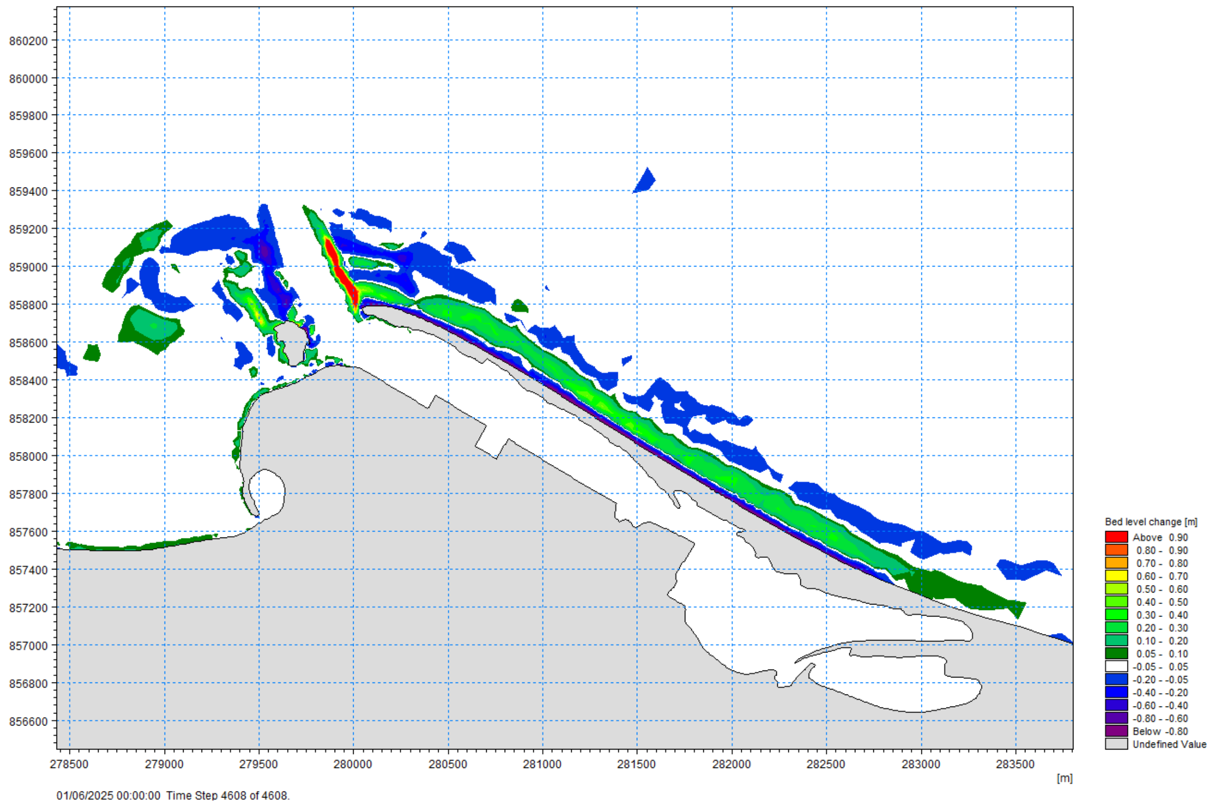
Figure 4.41: Bed Level Change End of Simulation – Simulation K (Island Extension Option 1)



<u>**Simulation L – Post Port Extension Island Extension Option 2**</u>

Error! Reference source not found. presents a plot of bed level change at the end of the island extension option 2 coupled sand transport simulation (Simulation K). A similar pattern of deposition and erosion is observed to that shown in the baseline, post extension and option 1 equivalents. The impacts of the island extension options on local processes is considered further in Section 5.1.3.

Figure 4.42: Bed Level Change End of Simulation – Simulation L (Island Extension Option 2)



5 IMPACT ASSESSMENT

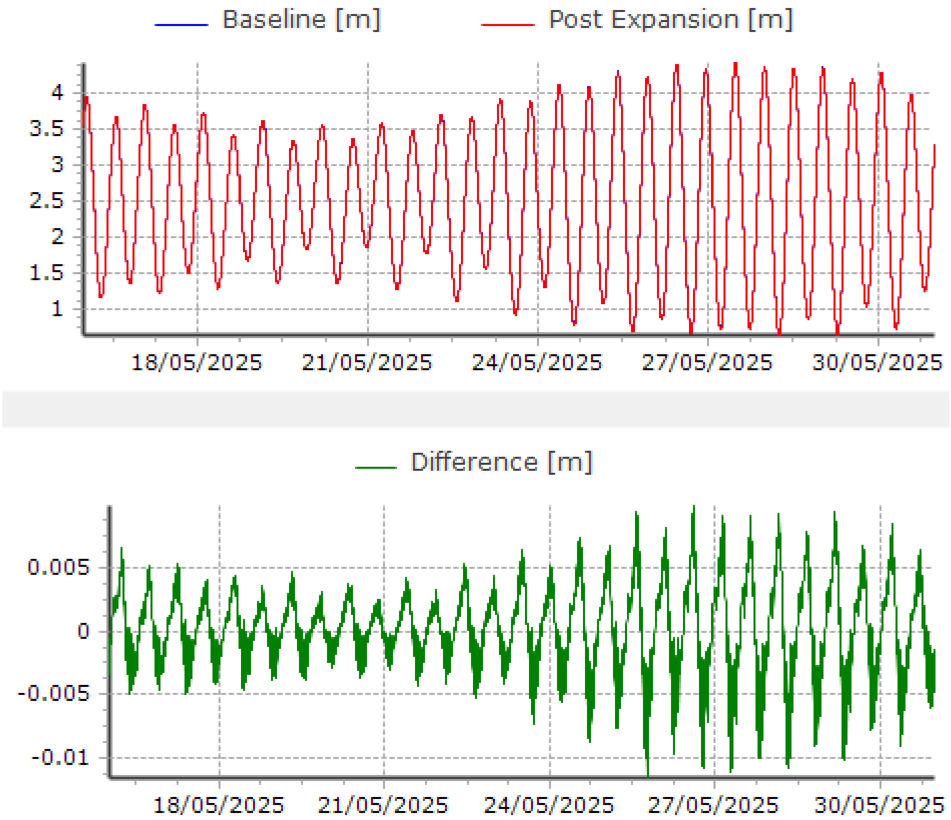
5.1 Coastal Processes

The model results described in the previous sections of this report have been reviewed and compared to assess the likely impacts to coastal processes resulting from the proposed port extension into the inner harbour. Comparisons between model results for the proposed port extension and results for the existing baseline (2025) are outlined in the following sections. Additionally, comparison between the proposed port extension results and the island extension options is also detailed.

5.1.1 Tides

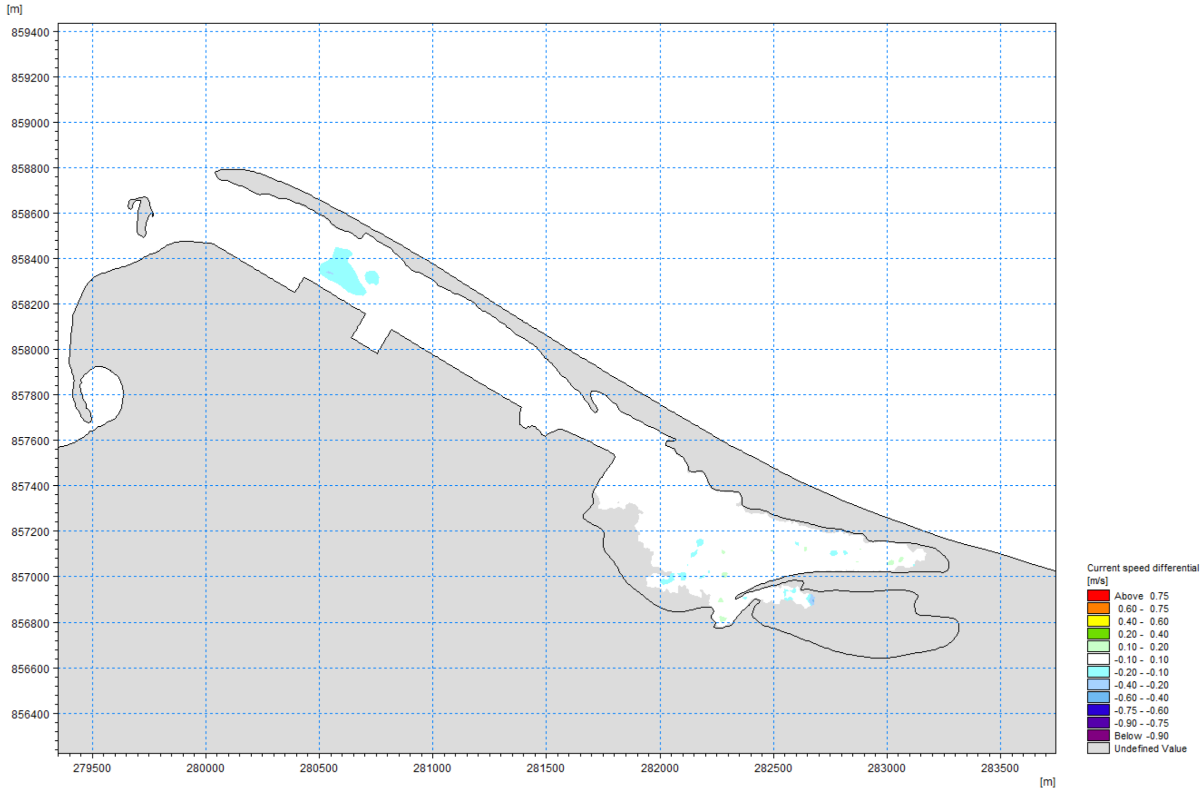
A comparison of the modelling results with and without the proposed port extension has been undertaken. This comparison highlights that there will be no significant impact on tidal levels or phasing, except to increase low water tidal range within the dredge zone where deposition has occurred in the harbour under existing (baseline) conditions. **Error! Reference source not found.** presents a comparison of predicted baseline and post extension water level through the modelled duration at point output location 7, located at the eastern extent of the proposed port extension dredge. Review of this figure highlights the difference in modelled water level is insignificant, generally less than 1 cm throughout.

Figure 5.1: Comparison of Modelled Baseline and Post Extension Water Levels at Location 7



Error! Reference source not found. presents a differential plot of statistical maximum current speed for the post extension and baseline model scenarios (post extension minus baseline). Review of this plot highlights that only minor reductions in maximum current speed are predicted at the transition from the existing baseline dredge pocket into the expanded deeper dredge pocket (-12.4 mCD). Whilst the modelling results indicate that the proposed dredging will produce minor localised changes in current velocities, it is considered that these variations are insignificant in terms of both the local and wider hydrodynamic regime of the Moray Firth, with post development velocities of a similar nature to those observed elsewhere.

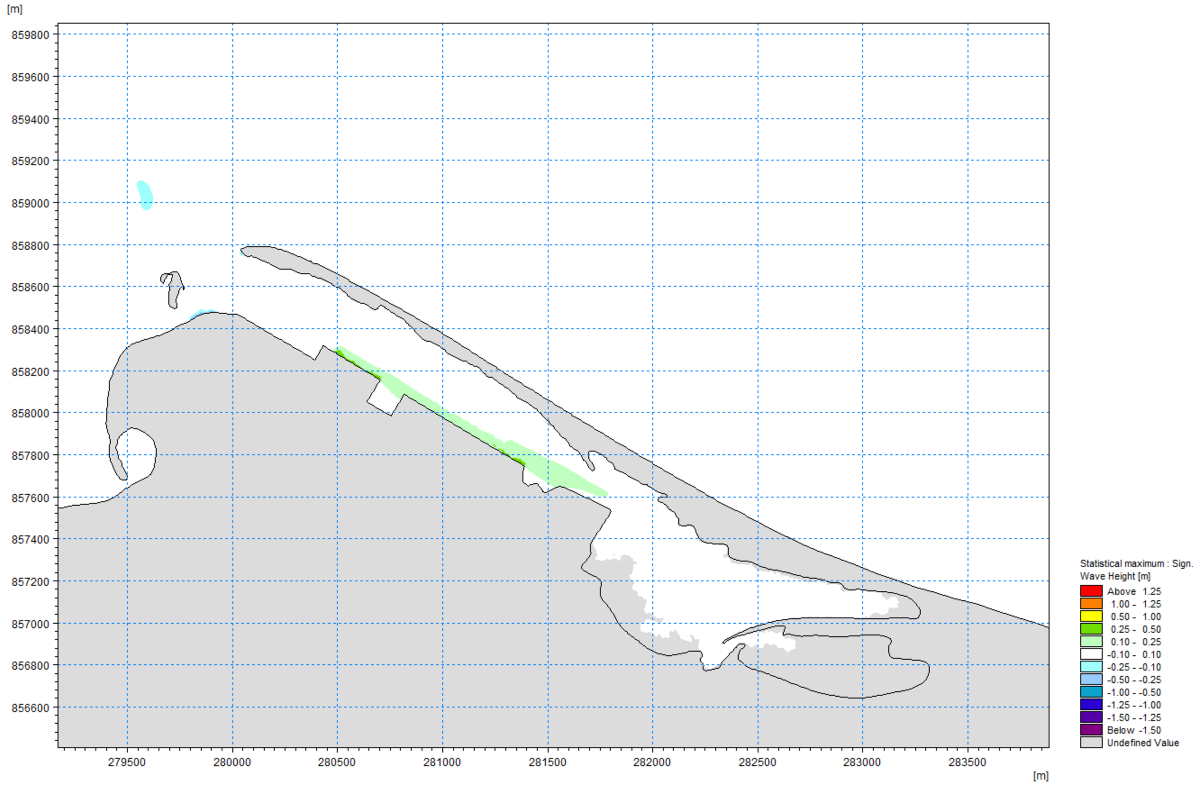
Figure 5.2: Statistical Maximum Current Speed Differential - Post Extension Minus Baseline



5.1.2 Waves

Error! Reference source not found. presents a differential plot (post extension minus baseline) of statistical maximum significant wave height for the modelled duration. Review of this figure shows a minor increase in wave height predicted along the quay within the proposed port extension dredge pocket. Analysis of the model results and input parameters highlights that peak wave heights in this area occur during winds from the west and north-west, aligned with the harbour entrance and quay. Waves would be able to penetrate further into the harbour through the navigation channel and dredge pocket with wind from this direction. Elsewhere, outside the immediate vicinity of the proposed dredge zone the modelling indicates that the proposed development will have no significant impact on wave climate.

Figure 5.3: Statistical Maximum Significant Wave Height Differential – Post Extension Minus Baseline

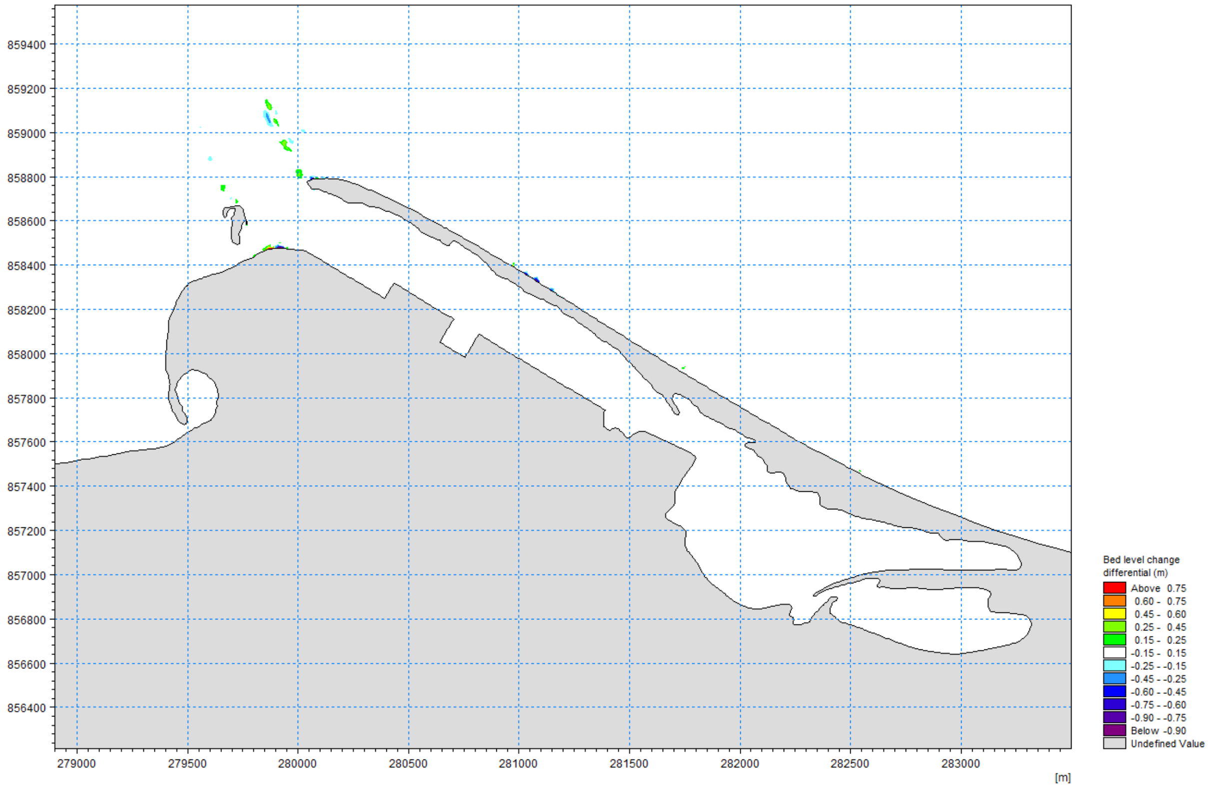


5.1.3 Sediment Transport (Coastal Morphology)

Error! Reference source not found. presents a differential plot of bed level change (post extension minus baseline) at the end of the simulated period, which includes a significant storm event equivalent to Storm Ciaran (2023). Review of this figure highlights that no significant difference is predicted between the baseline and post extension scenarios. The deepening of the inner harbour is not predicted to impact the key sediment transport processes or pathways, particularly those associated with the active spit extension and intertidal Whiteness Sands.

Due to the large volume of sediment currently available within the local coastal system, it is considered that the removal of the proposed extension dredge budget will not be significant in terms of the wider system. Observed trends, model results and the conceptual understanding of local sediment transport processes all indicate that potential impacts to sediment transport and coastal morphology will be insignificant and localised in extent. The key longshore feed of sediment along the spit will continue, with change limited to the footprint and immediate vicinity of the extension works.

Figure 5.4: Bed Level Change Differential – Post Extension Minus Baseline



Error! Reference source not found. and **Error! Reference source not found.** present statistical maximum current speed differential plots versus the post extension scenario for island extension options 1 and 2 respectively (island option minus post extension scenario). Review of both figures highlights that neither of the potential island extension options is predicted to have a significant impact on tidal currents.

Patterns of bed level change in the two scenarios are compared to the post port extension results within the bed level change differential plots for island extension Option 1 (**Error! Reference source not found.**) and option 2 (**Error! Reference source not found.**). Review of these figures highlights that the island extension options are predicted to only result in localised impacts to sand transport. Given the lack of impact to tidal currents, predictions of additional localised deposition are considered to be primarily a result of provision of additional shelter from wave action. It is noted that the model does not account for change to the terrestrial extents of the island as a result of erosion and onward transport, which during storm events would be anticipated to occur, and would likely be a locally significant process.

Figure 5.5: Statistical Maximum Current Speed Differential – Island Option 1 Minus Post Extension

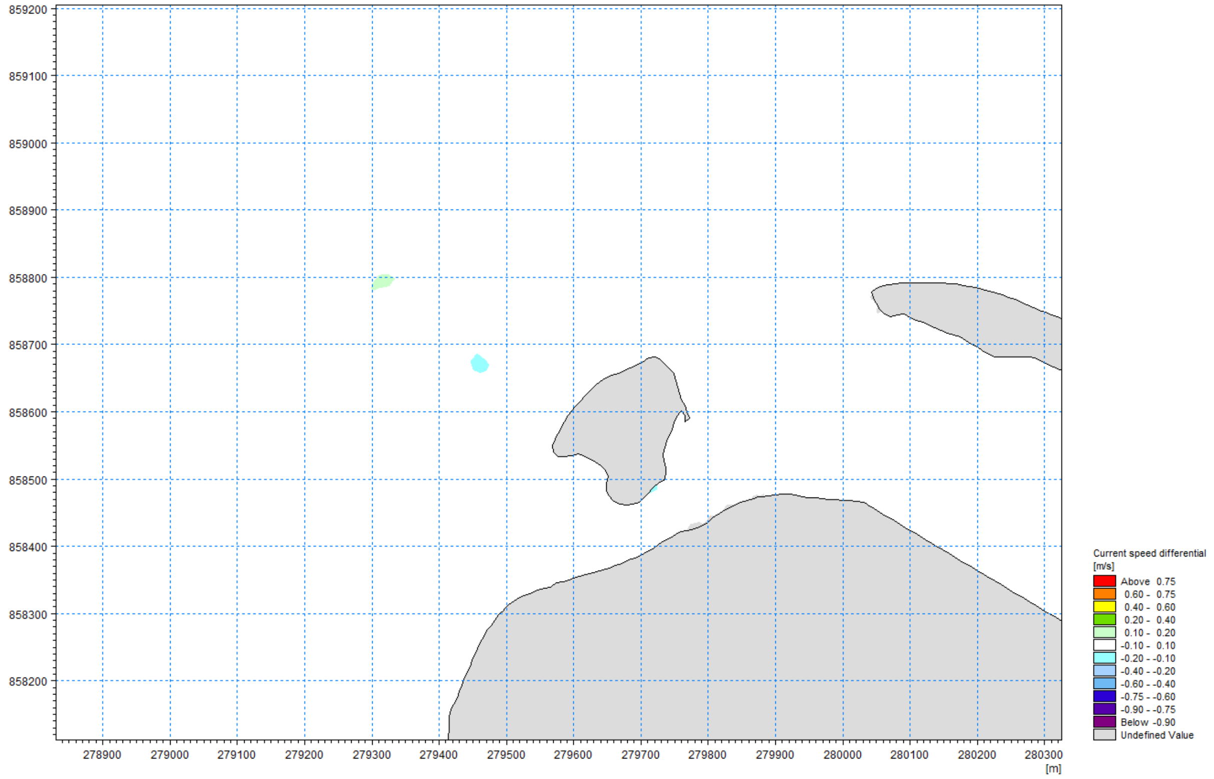


Figure 5.6: Statistical Maximum Current Speed Differential – Island Option 2 Minus Post Extension

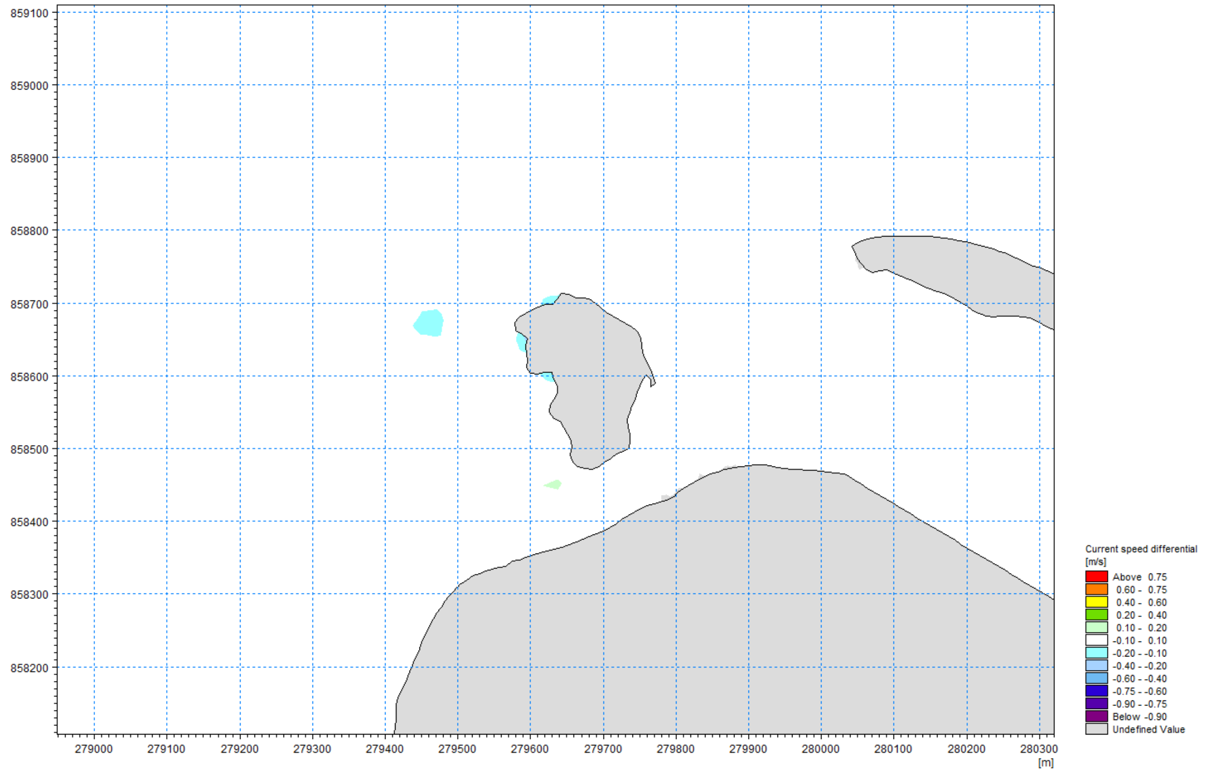


Figure 5.7: Bed Level Change Differential – Island Extension Option 1 Minus Post Extension

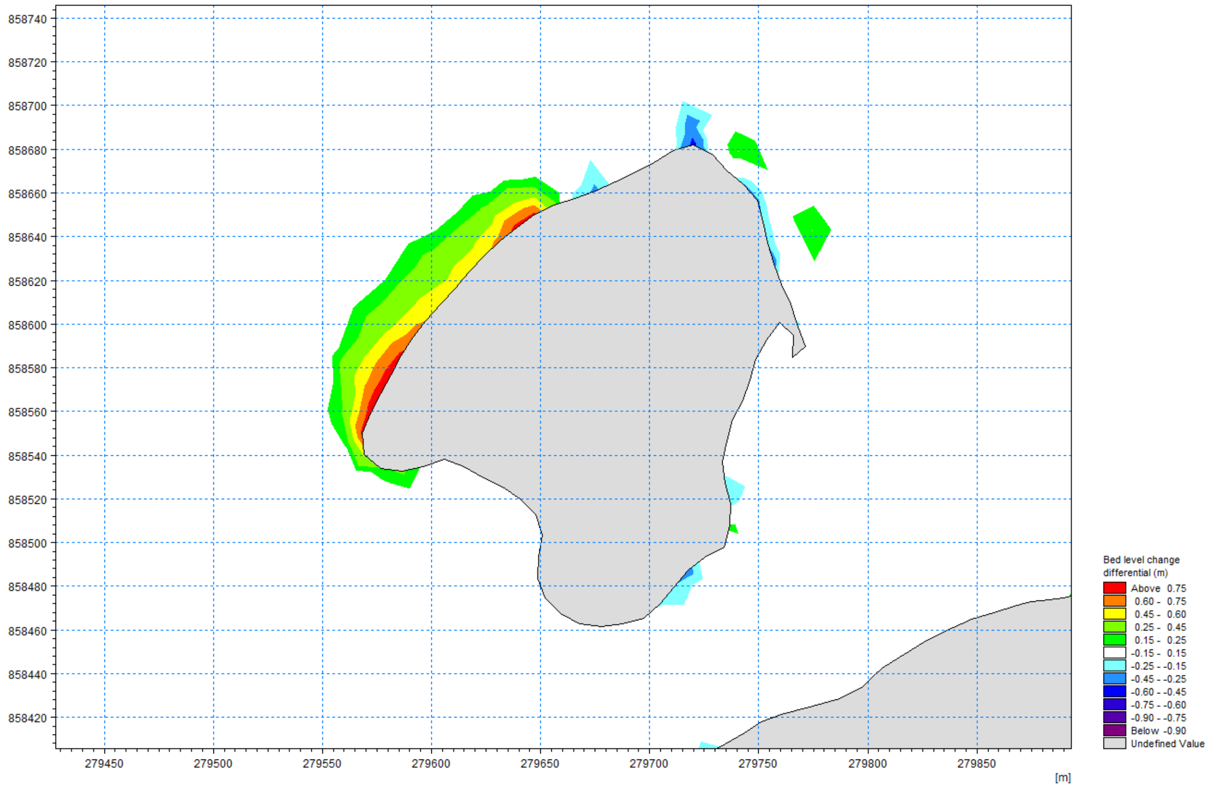
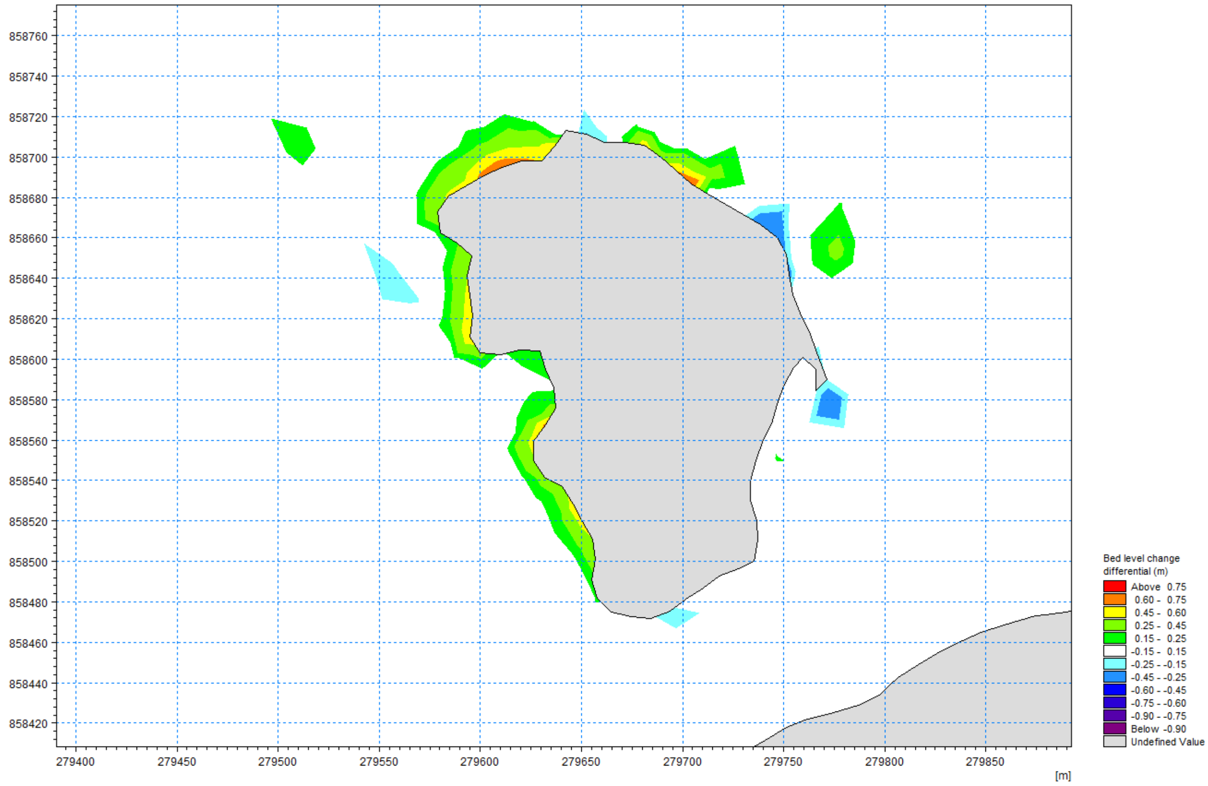


Figure 5.8: Bed Level Change Differential - Island Extension Option 2 Minus Post Extension



5.2 Impact on Designations

The predicted zone of impact to coastal processes from the wider Ardersier Port development extent, in relation to designated sites, as previously assessed in 2024, is identified in **Error! Reference source not found.**. The extents shown are based on the conceptual understanding of coastal processes and supported by hydraulic modelling. It is noted that the design layout assessed in 2024 included creation of the navigation channel through the spit and the deeper outer harbour dredge (-12.9 mCD), and dredging to shallower depths (-6 and -3.5 mCD) within the inner harbour. However, the identified impacts relate primarily to the dredging activities to reinstate the navigation channel and harbour, the most significant aspects of which have been undertaken during the capital dredge of summer 2025 (Phase 1). This zone of impact can therefore be considered to equate to the impact of the existing development, or the baseline condition.

Given the results of the current coastal modelling exercise, as presented in this report, it is considered that this predicted zone of impact remains true for the proposed expanded port development, when considered cumulatively with the existing development extent. The proposed port extension with dredging of the inner harbour is however not predicted to independently result in any significant impact to surrounding designations when considered in isolation.

Comments in relation to the extent of the impact on the designated sites, and relative proportions of designation impacted, are provided in Table 5.1. The areas of the designated sites potentially impacted by the cumulative development are small.

The findings of this assessment remain consistent with those of the NCCA report, Cell 3 – Cairnbulg Point to Duncansby Head, for Whiteness Head (Site 34) as presented below.

'Currently the site has planning permissions for both a new town development (postponed after 2006) and a renewables fabrication yard, which has yet to advance due to the Port of Ardersier going into

administration. The past, recent and anticipated changes do not present a risk or threat to the nature conservation designation interest of the site.' (Hansom et al., 2017)

Figure 5.9: Existing Development Predicted Zone of Impact in Relation to Designated Sites

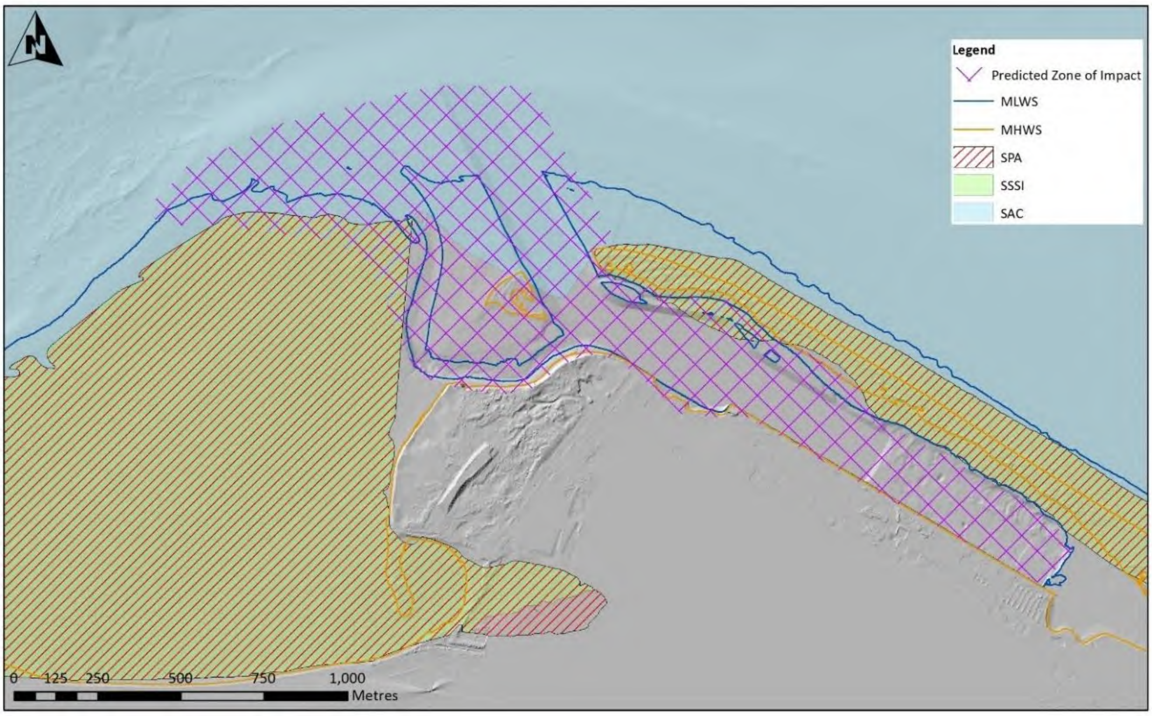


Table 5.1: Existing Development Zone of Impact Extents in Relation to Designated Sites

Designated Site	Comment	Approximate Area of Site Impacted
Whiteness Head SSSI	Spit: Predominantly outside designated boundary, but includes present spit head and future development area.	<3%
	Sands: Small area limited to north-eastern extent of intertidal sands.	
Inner Moray Firth SPA	Impact zone limited to Whiteness Head and Whiteness Sands. Comments as per SSSI above.	0.1%
Moray Firth SAC	Intertidal and subtidal zone around dredge channel and immediately to the west.	<0.1%

6 SUMMARY OF IMPACTS

In general terms, the proposed port extension represents an increase in depth to the inner harbour versus that previously assessed in 2013, 2018 and 2024, while the relative positioning of dredge extents remains similar. The port and dredge design considered within the 2024 assessment has been partially delivered during the summer of 2025 with the dredging of the navigation channel and outer harbour, and formation of associated quay. This is the 2025 baseline condition. The key findings of the 2024 assessment have been reviewed in relation to the proposed port extension design and the updated modelling and assessment presented in this report, as summarised in Table 6.1.

Table 6.1: Review of Coastal Processes Impacts - 2024 Assessment to 2025 Port Extension

Coastal Process	2024 Assessment Findings	2025 Proposed Port Extension
Tides	No significant impact on tidal levels.	No Change.
	Low water tidal range will increase within dredge zone.	No Change.
	Localised reductions in tidal velocities within the immediate vicinity of dredge zone.	Marginal further reduction in tidal velocities at transition into extension deeper dredge zone due to increased depth.
	No significant impact on tidal velocities outside the immediate vicinity of dredge zone.	No change.
	Variations in tidal velocities considered insignificant in terms of the wider hydrodynamic regime of the Moray Firth.	No change.
Waves	Slight increase in significant wave height within the dredge extent with waves able to penetrate into the harbour via the dredge channel.	Sight increases in wave height and penetration into inner harbour adjacent to quay during winds from north-west.
	No significant impact on wave climate outside the immediate vicinity of the dredge zone.	No change.
Sand Transport (Coastal Morphology)	Longshore transport of sand along spit from east will continue unaffected by the dredge.	No change.
	Intertidal and subtidal build-up of the spit will continue to the east of the navigation channel.	No change.
	The navigation channel dredge zone will act as a trap to onward westward sediment transport along spit, with material being deposited.	No change.
	Immediately west of the navigation channel dredge zone, the remaining intertidal and subtidal head of the spit (predator free island) will be subject to ongoing erosion, with material being transported predominantly west into the former dredged channel and the north-eastern fringe of Whiteness Sands, with some material moving south and east into the navigation channel.	No change.
	Further west across the central parts of Whiteness Sands will remain relatively unaffected.	No change.
	The proposed material removal by dredging is not considered significant in terms of the wider system due to the large volume of sediment currently available within the local coastal system.	No change.
	Impacts to sediment transport and coastal morphology will be localised in extent, with areas of change limited to the	No change.

Coastal Process	2024 Assessment Findings	2025 Proposed Port Extension
	footprint and immediate vicinity of the dredge channel and the north-eastern fringe of Whiteness Sands	
Impact on Designated Sites	Areas potentially impacted assessed as being small. Whiteness Head SSSI (<3%); Inner Moray Firth SPA (0.1%); and Moray Firth SAC (<0.1%)	No significant change. Considered in isolation, the proposed extension is not likely to significantly impact the designated sites.

This assessment has described existing coastal conditions, following completion of navigation channel and outer harbour capital dredge, presented results of a coastal modelling study, and reviewed the findings of the previous 2024 coastal processes assessment, in the context of the proposed port extension including a deeper inner harbour dredge. The assessment finds that the proposed port extension is unlikely to result in any significant change to coastal processes. Where changes have been predicted from existing (baseline) conditions, these are predominantly within the immediate vicinity of the extension dredge zone.

Considered cumulatively with the existing port development, the overall impact of the Ardersier Port development on coastal processes is therefore not predicted to significantly change from the overall findings of the 2024 assessment for the previous design proposal.