Ardersier Port - Deeper Dredge
Coastal Model and Assessment Update

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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 Model and Assessment Update Study to assess the impact of a proposed revised dredge design and harbour arrangement at Ardersier Port.

1.2 Scope of Report

This study aims to update existing coastal Hydrodynamic (HD), Spectral Wave (SW) and Sand Transport (ST) models of conditions at Ardersier Port, to reflect existing pre-development (baseline) conditions, and proposed post-development conditions with the revised dredge channel and harbour complete. The updated HD model will enable simulation and characterisation of tidal flow under pre-development (baseline) and post-development conditions. The updated SW model will enable simulation and characterisation of wave climate under pre-development (baseline) and post-development conditions. The updated ST model will enable simulation and characterisation of sand transport under pre-development (baseline) and post-development 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-development model results will be compared to model results for the previously consented dredge channel arrangement, in order to assess the relative impact of proposed design changes. This assessment builds on the 2018 Ardersier Port Coastal Processes Assessment (EnviroCentre Report No. 8364) and represents an update to the recent July 2023 Ardersier Port Coastal Processes Assessment (EnviroCentre Report No. 13546) and should be read with reference to those reports.

1.3 Report Usage

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2 CONTEXT

2.1 Site Location, Historic Development and Operations

The development site is located on 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 NH812 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 and mudflats to the west. To the southwest of the site lies the boundary of Fort George owned by the Ministry of Defence (MoD).

The site extends to some 307 hectares, and includes a 1,000 metre long quay and associated berth which is protected by the naturally occurring sand and shingle spit, salt marsh and dunes.

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, 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 and the site has subsequently been cleared. It is proposed to dredge the port entrance and reinstate the site for this industrial use.

Figure 2-1: Historic Aerial Photograph of Operational McDermott Yard

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 has not been completed.

2.3 Proposed Dredge Activity

The variation to the existing consented dredge activity is provided in Drawing 676693-GIS006 (Appendix A), with the details of the outer channel design provided in ARUP Drawing 294067-ARUP-XX-XX-DR-CG-002001 (Appendix A), where the proposed increase to the dredge is as follows:

1. Depth from the approved -6.5 mCD to -12.9 mCD in the navigation channel and harbour approach; and
2. Increased dredge amount from the approved 5,000,000 wet tonnes (wt) by 3,600,000 wt to 8,600,000 wt, with all of the increase being brought to land for beneficial reuse.

The proposal increases the presently consented dredge depth in 2018 by 6.4 m and the previously consented dredge depth in 2014 by 4.4 m. The navigation channel width now varies (130 – 160 m at the outer approach, 160 – 278 m in the mid-channel and 102 – 168 m in the harbour approach), compared to the previously consented 120m width (dimensions from ARUP Drawing 294067-ARUP-XX-XX-DR-CG-002001). Within the inner harbour to the eastern end of the quay, two dredge pockets at -6.5 and -3 mCD are to be retained from the previously consented 2018 dredge design.

2.4 Overview of Previous Coastal Studies

Assessment and modelling were undertaken in support of reinstating the navigation channel and harbour as part of an Environmental Impact Assessment for a capital dredge licence issued by Marine Scotland in 2014, however no dredging was undertaken through this licence. Subsequent to this, the coastal processes were assessed and modelled again in 2018 in support of reinstating the navigation channel and harbour as part of an Environmental Impact Assessment Report in support of the dredge licence that was consented. 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).

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 Figure 2-2 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, 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.

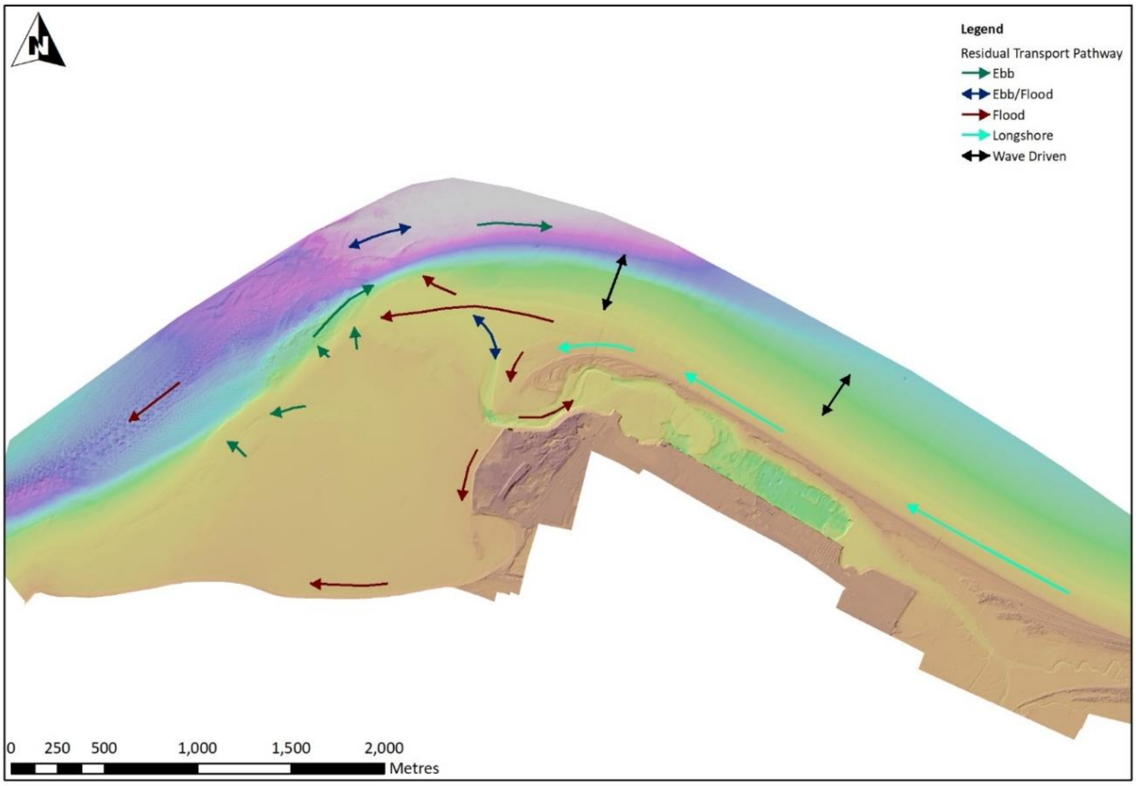


Figure 2-2: Conceptual Model of Sediment Transport Pathways (EnviroCentre, 2018)

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 wider bathymetry of the Inner Moray Firth is discussed further in section 4.3.1.

The local bathymetry within the harbour and navigation channel has been subject to active change over recent years, particularly in response to recent localised dredging operations. An updated bathymetric and topographic survey was completed by CainTech in June 2023. A Digital Surface Model (DSM) has been generated using the 2023 survey data for the site and immediate surrounds, as shown in Figure 3-1 below.

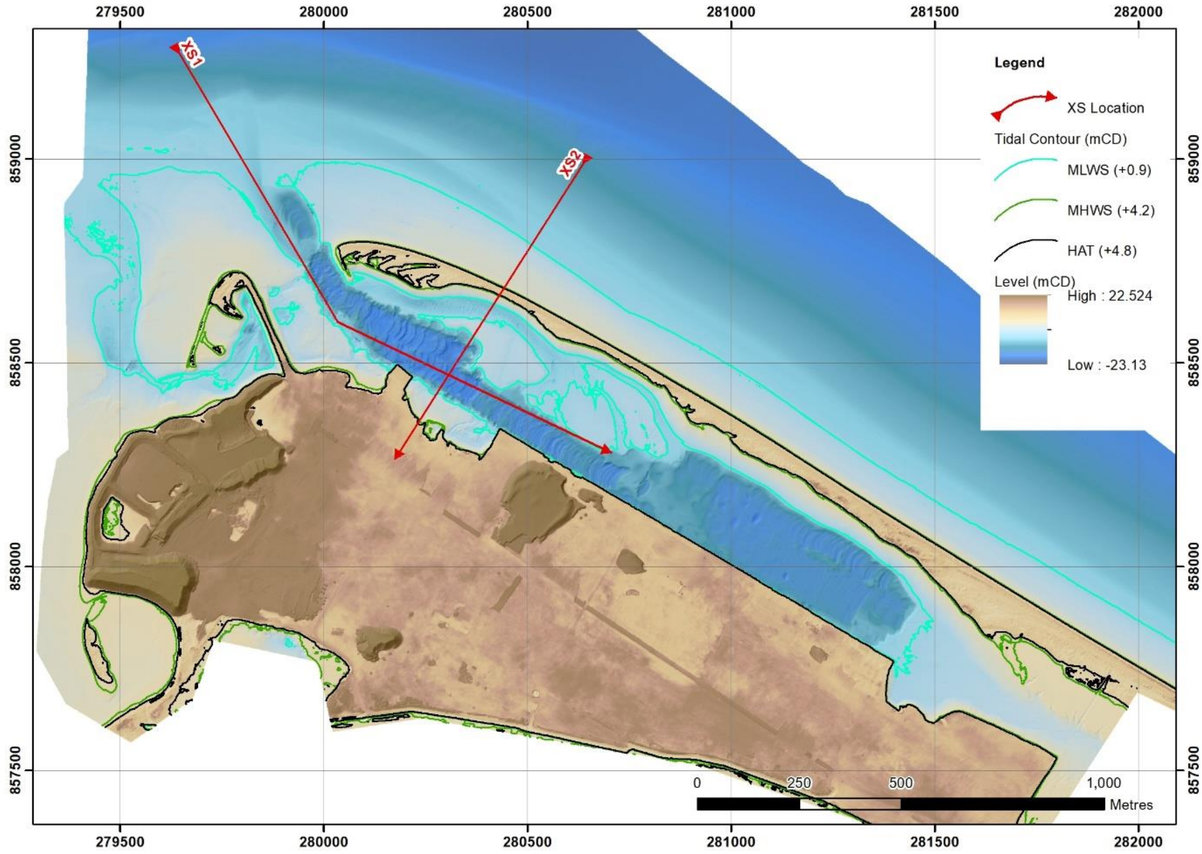


Figure 3-1: Digital Surface Model (DSM) Ardersier Port - CainTech 2023 Survey

3.1.1 Comparison of 2023 Bathymetry Versus 2018 Bathymetry

A comparison has been undertaken between the recent 2023 bathymetry data, and the corresponding 2018 data. Where available 2021 bathymetry data, surveyed by FC Geomatics, has also been considered. Figure 3-2 presents a plot of bathymetry differential between the 2023 and 2018 datasets, red colours indicating areas of increased bed level, and blue colours indicating decreased bed level. Areas shown in white are considered to have no significant change in level (<0.1 m change). Review of this figure highlights the areas (darker blues) dredged since 2018 within the outer harbour, and through the spit recurve, and also the areas (darker reds) of deposition within the harbour and previous navigation channel. Also noticeable are the areas of intertidal spit extension, highlighting the ongoing north-westward extension of the sand spit, and the recurve of the spit head towards the west. Further offshore the bathymetric differentials highlight other sand transport features, including sand waves.

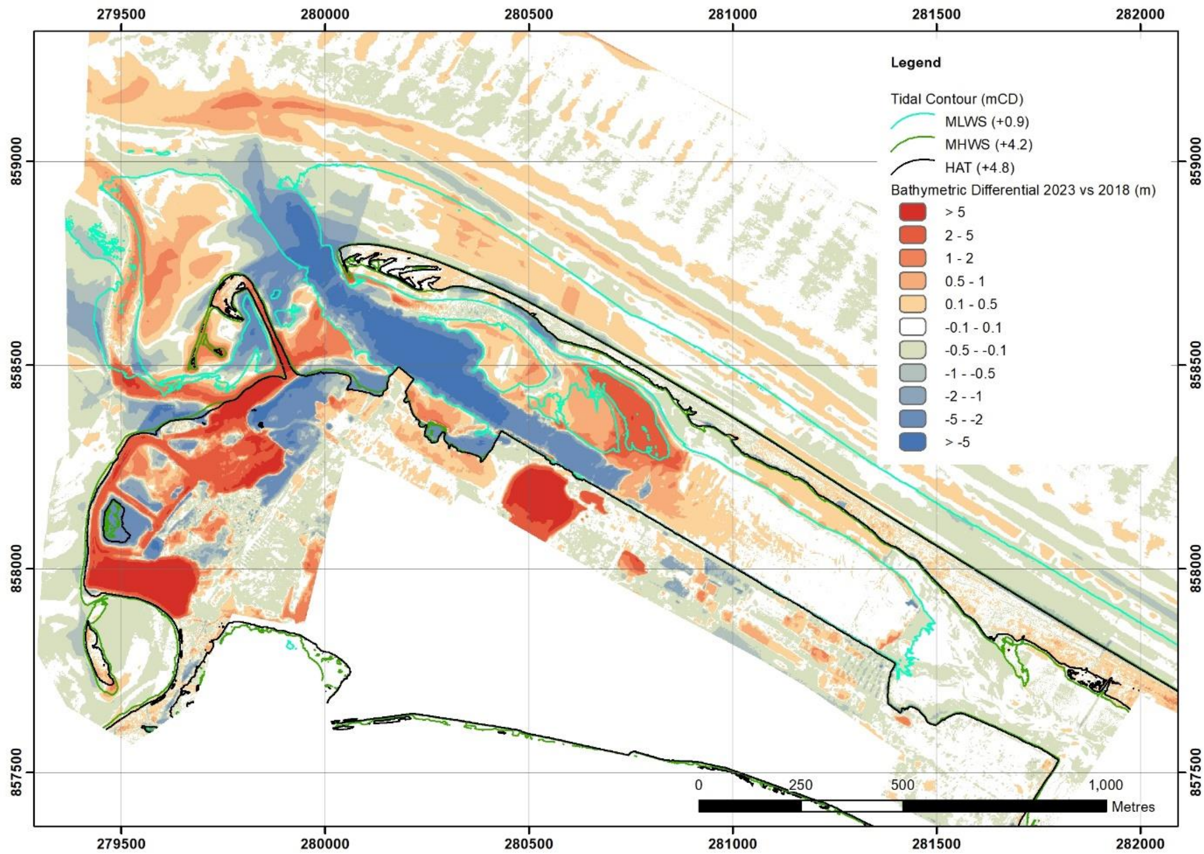


Figure 3-2: Bathymetric Survey Differential (2023 Levels minus 2018 Levels)

As shown in Figure 3-3 and Figure 3-4, cross-sectional comparison has also been undertaken for XS1 and XS2, the locations of which are presented in Figure 3-1. The XS1 comparisons includes 2021 data captured for limited areas within the harbour and approach. Review of the figures highlights similar changes to those captured in the differential plot above. The observed changes are broadly consistent with the conceptual model developed in 2018 (see Figure 2-2), noting that some dredging has taken place.

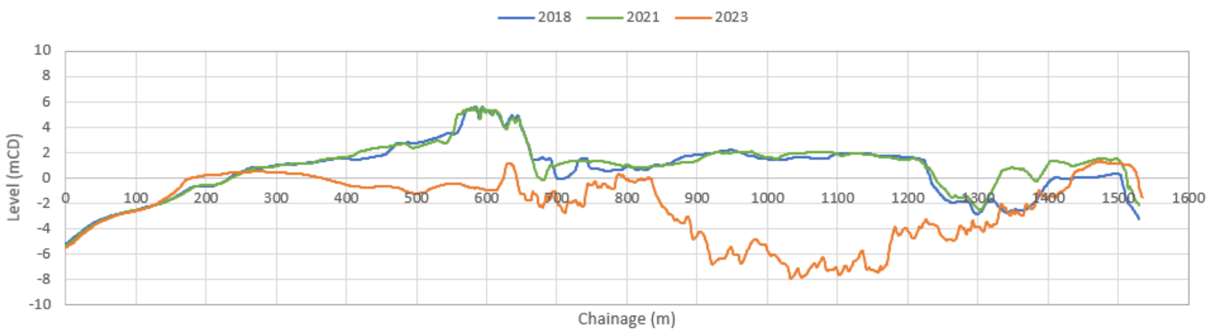


Figure 3-3: XS1 Comparison of 2018, 2021 and 2023 Levels

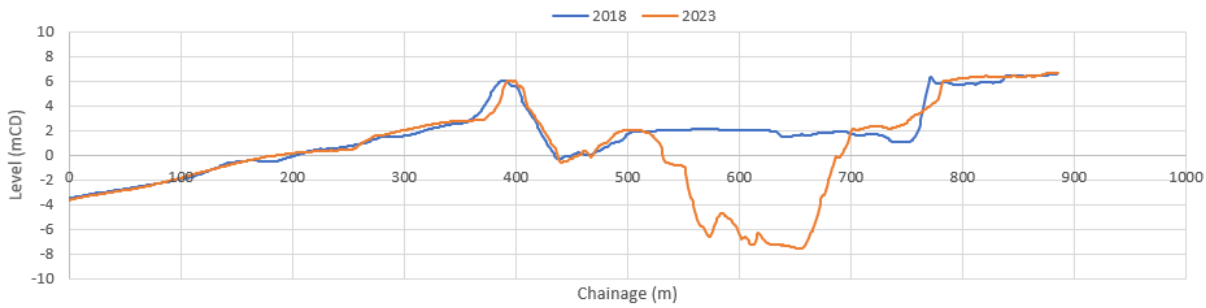


Figure 3-4: XS2 Comparison of 2018, 2021 and 2023 Levels

3.2 Sediment

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 Figure 3-5:

- **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.

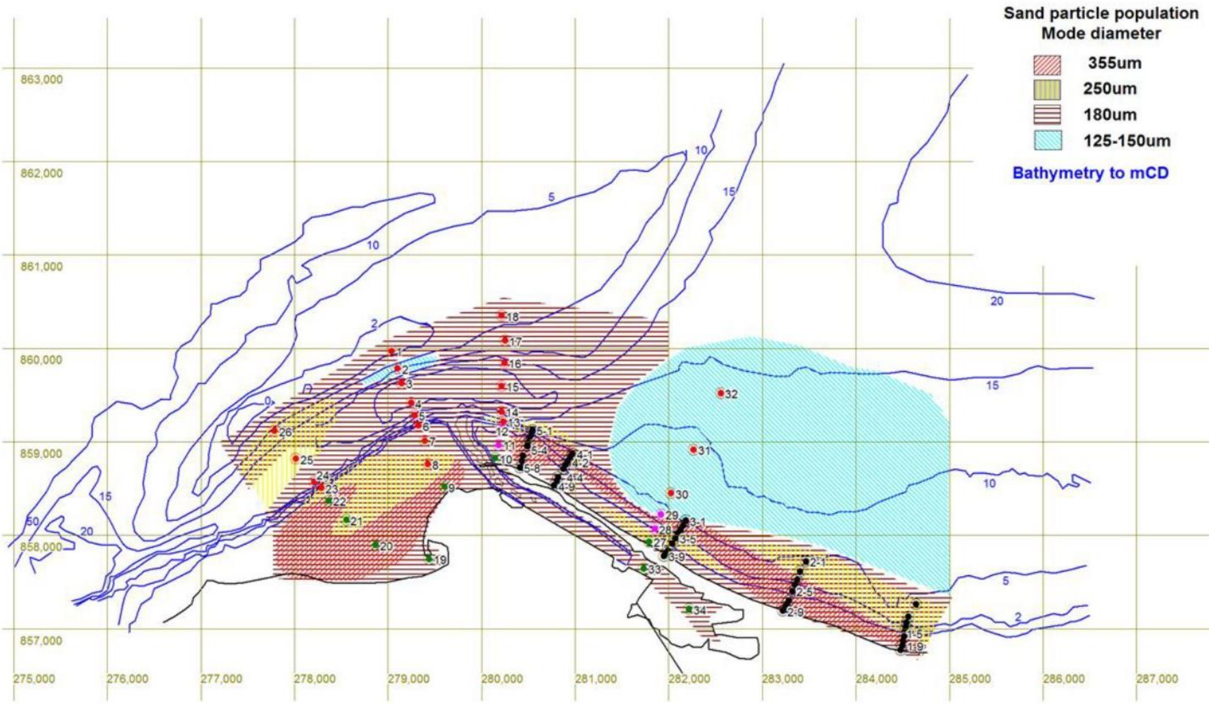


Figure 3-5: Distribution of Sand Particle Populations and Grab Sample Locations (2013)

3.3 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	+2.66
Mean High Water Spring (MHWS)	4.2	+2.06
Mean High Water Neap (MHWN)	3.3	+1.16
Mean Sea Level (MSL)	2.5	+0.36
Mean Low Water Neap (MLWN)	1.7	-0.44
Mean Low Water Spring (MLWS)	0.9	-1.24
Lowest Astronomical Tide (LAT)	0.2	-1.94

*Chart Datum correction for Ordnance Datum is -2.14m (relative to OD at Newlyn)

Table 3-2: Ardersier Port Extreme Sea Levels (SEPA Dataset)

Return Period (Years)	Water Level (mCD)	Water Level (mAOD)
2	5.05	2.91
5	5.14	3.00
10	5.21	3.07
50	5.36	3.22
100	5.43	3.29
200	5.49	3.35
1000	5.65	3.51

4 HYDRODYNAMIC MODEL

4.1 MIKE 21 Flow Model FM – Hydrodynamic (HD) Module

MIKE 21 Flow Model FM is a modelling package based on a flexible mesh (FM) structure, developed by the Danish Hydraulic Institute (DHI). The modelling system has been developed for applications within oceanographic, coastal and estuarine environments. 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 2023, has been used within this assessment.

4.2 Model Extent

The coastal model extent covers a large portion of the Inner Moray Firth, extending from the Beauly Firth in the west, to Balintore and Findhorn in the east, including the Cromarty Firth as shown in Figure 4-1. This model extent is similar to that adopted in previous phases of modelling undertaken in relation to Ardersier Port, however the coastline detail, bathymetry and model mesh have all been updated and refined for this latest phase of modelling.

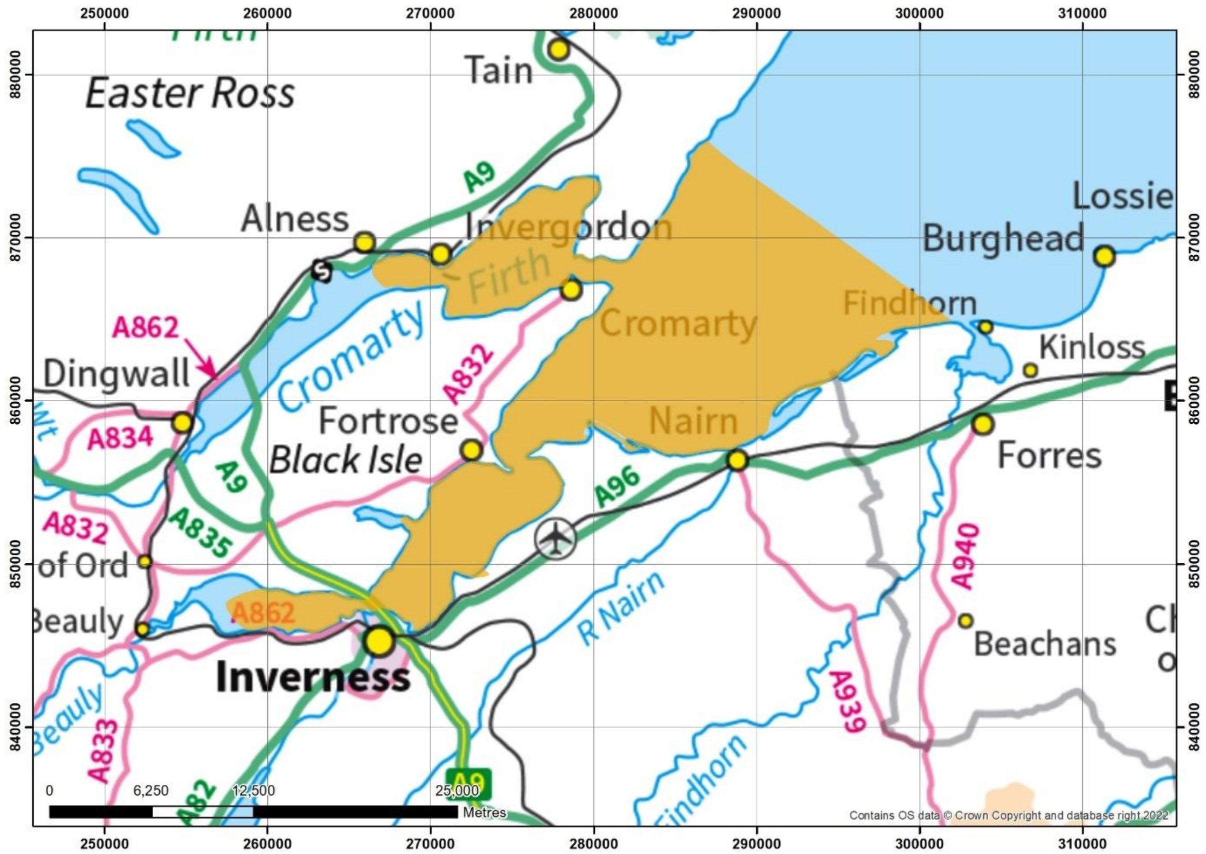


Figure 4-1: Model Extent (Orange)

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[1]
    - Moray Firth 0-40m 2m resolution (2020);
    - Moray Firth 38-40m 4m resolution (2020);
    - Moray Firth Riff Bank 2m resolution (2022).
- DHI C-Map bathymetry data in wider Moray Firth;
- Aspect Surveys – Topographic and Bathymetric Survey Whiteness Head (2018);
- CainTech Surveys - Topographic and Bathymetric Survey Whiteness Head (2023).

The datasets have been used to create a combined Digital Terrain Model (DTM) for use within the hydrodynamic model. Snapshots of the DTM with bathymetry displayed relative to Chart Datum are presented in Figure 4-2 and Figure 4-3 below.

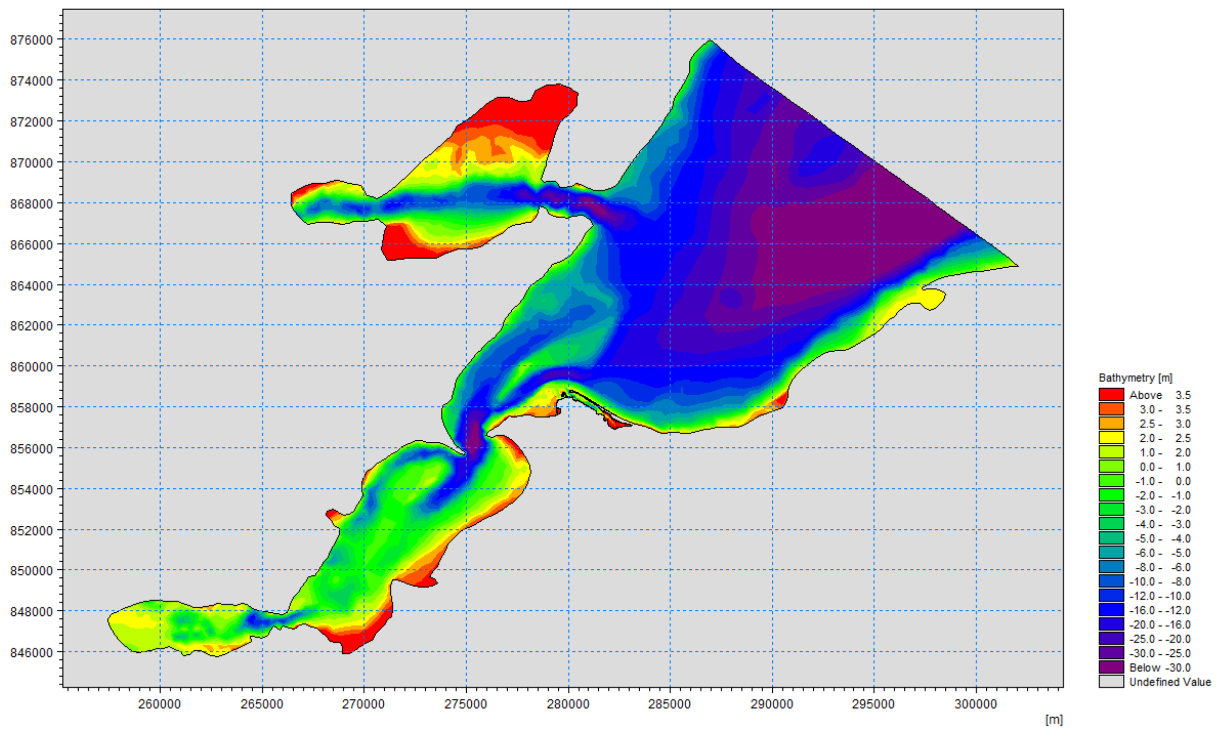


Figure 4-2: Model Bathymetry – Full Extent

[1] Admiralty Maritime Data Solutions: Seabed Mapping Service (https://seabed.admiralty.co.uk/?x=-19567.88&y=6780270.16&z=5.00)

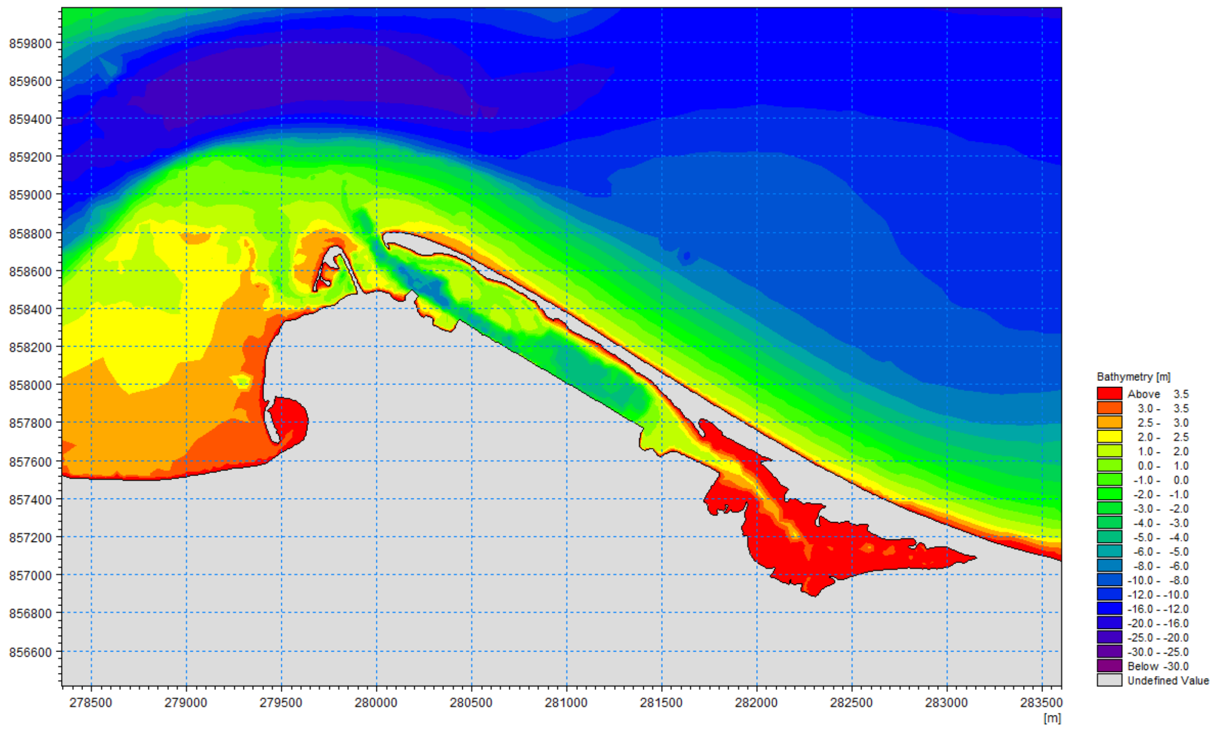


Figure 4-3: Model Bathymetry - Ardersier Port and Immediate Surrounds

4.3.2 Tidal Boundary Conditions

There is a single open tidal boundary within the model extent, located on the eastern perimeter stretching between Balintore in the north and Findhorn in the south. Tidal boundary conditions for the HD model have been extracted from the DHI Global Tide Model.

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.

The 2023 baseline model mesh extent and bathymetry are shown in Figure 4-4 below. The mesh has been generated using the bathymetric data described in section 4.3.1. The mesh has progressive refinement in resolution towards Whiteness Head, becoming finer in the area of interest, as shown in Figure 4-5 and Figure 4-6. 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 HD Mesh Characteristics

Mesh Characteristic	Value
Number of elements	15,929
Number of nodes	9,102
Min. Z level (mCD)	-60.3
Max. Z level (mCD)	+5.9
Max triangular area - Ardersier Port Outer Harbour/Approach	600m^2 (approx. 25m resolution)

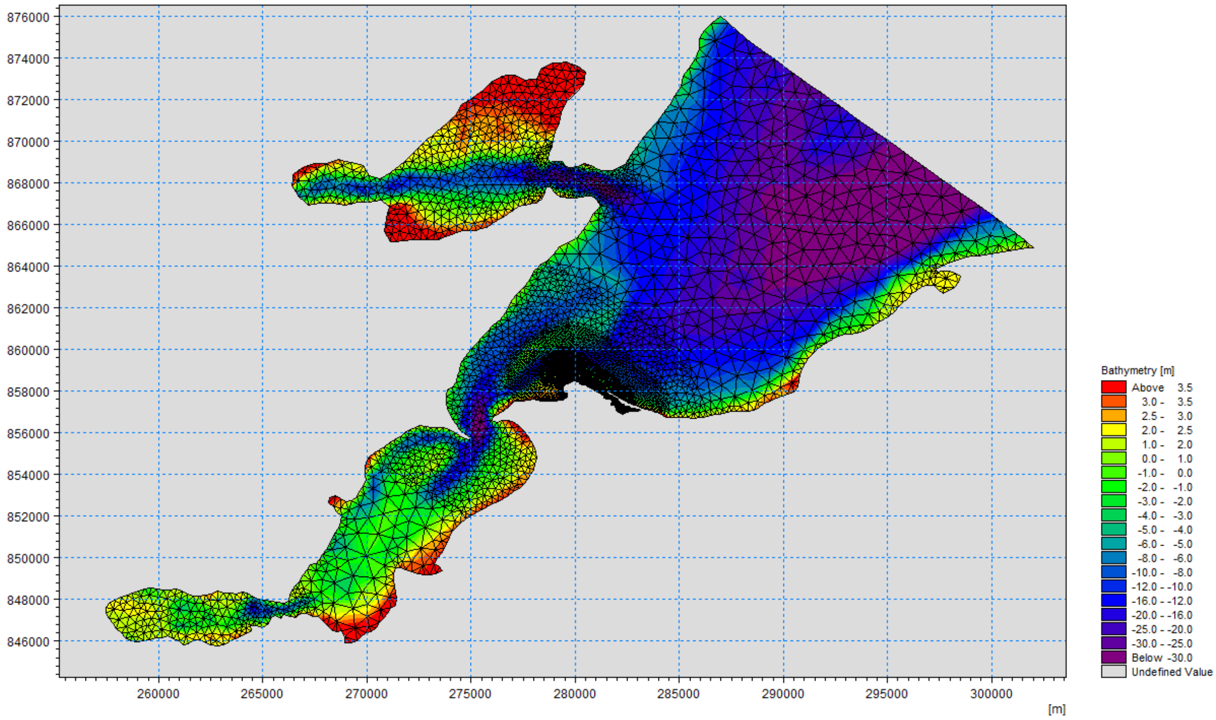


Figure 4-4: Baseline HD Model Mesh – Full Extent

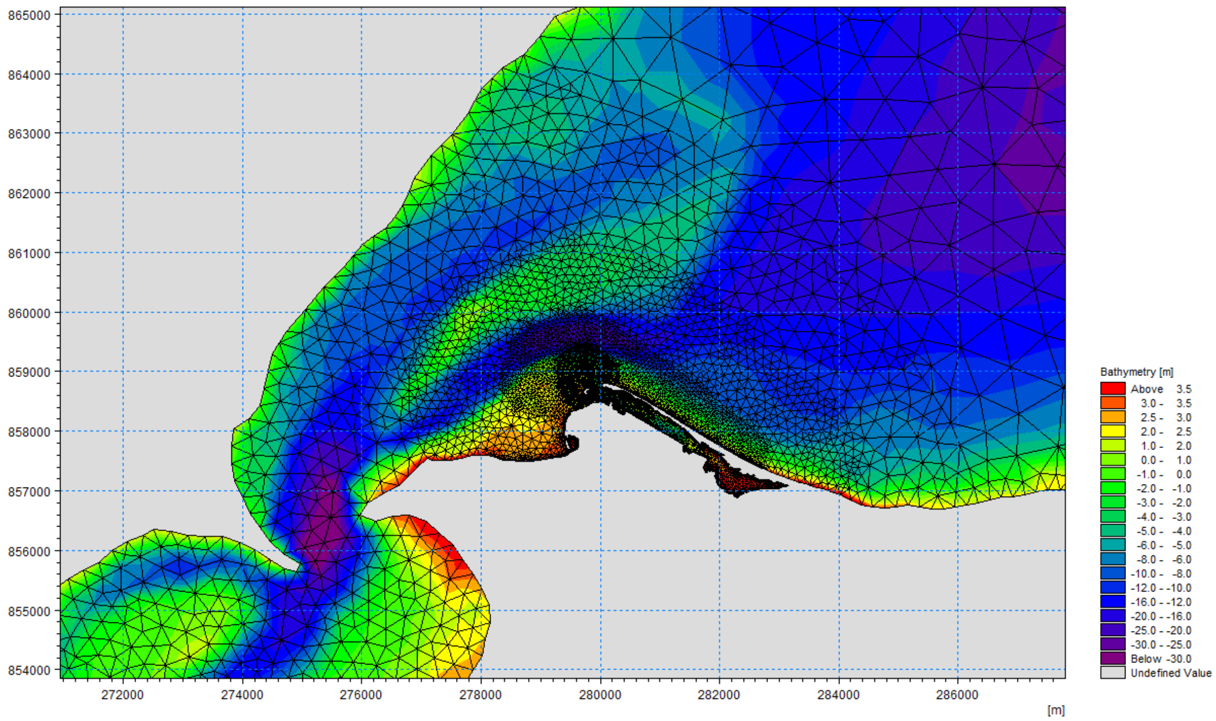


Figure 4-5: Baseline HD Model Mesh – Ardersier Port and Surrounds

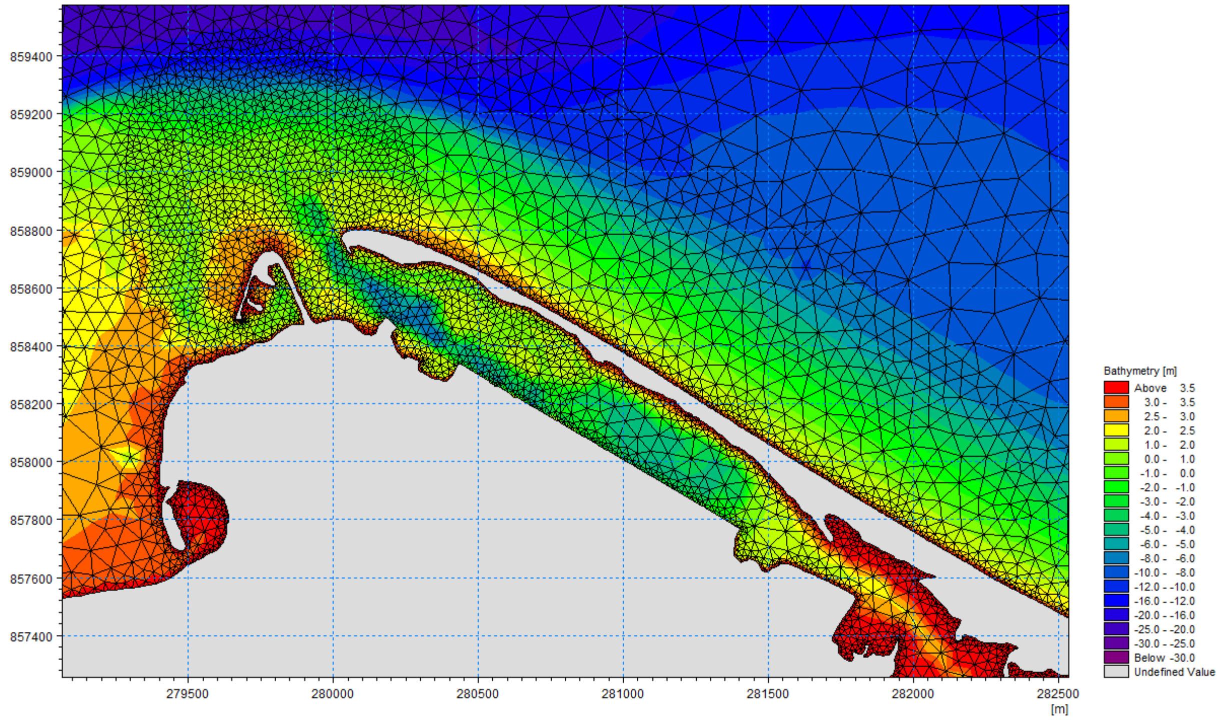


Figure 4-6: 2023 Baseline HD Model Mesh - Ardersier Port

A 2023 post-development version of the HD model mesh has been generated to include the proposed development footprint, as shown in Figure 4-7. The bathymetry for the post-development mesh was also updated to include the proposed dredge pockets. The proposed development layout and proposed dredge details are shown in Appendix A.

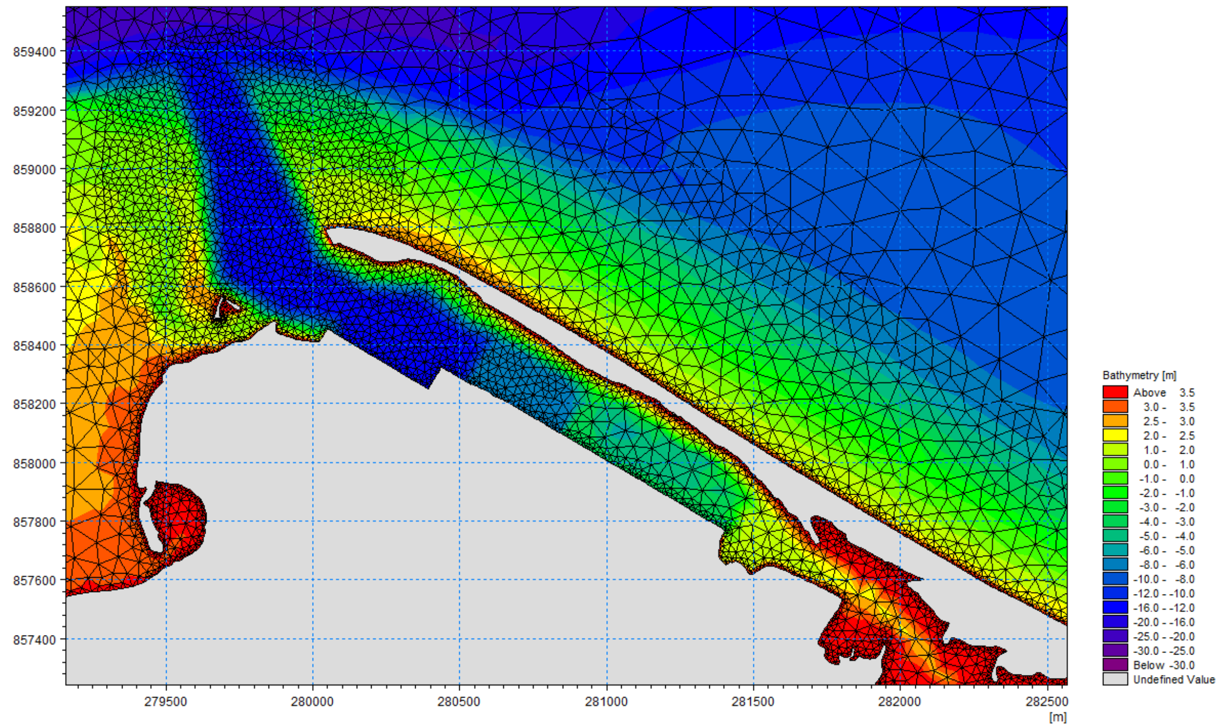


Figure 4-7: 2023 Post-Development HD Model Mesh – Ardersier Port

In addition to the 2023 model meshes described above, updated versions of the 2018 baseline and proposed-development model meshes have been developed. These include both the recently available more detailed wider Moray Firth bathymetry and the same mesh structure used in the 2023 meshes, in order to allow for better comparison with the 2023 model versions. Figure 4-8 and Figure 4-9 show the 2018 baseline and 2018 post-development model meshes respectively.

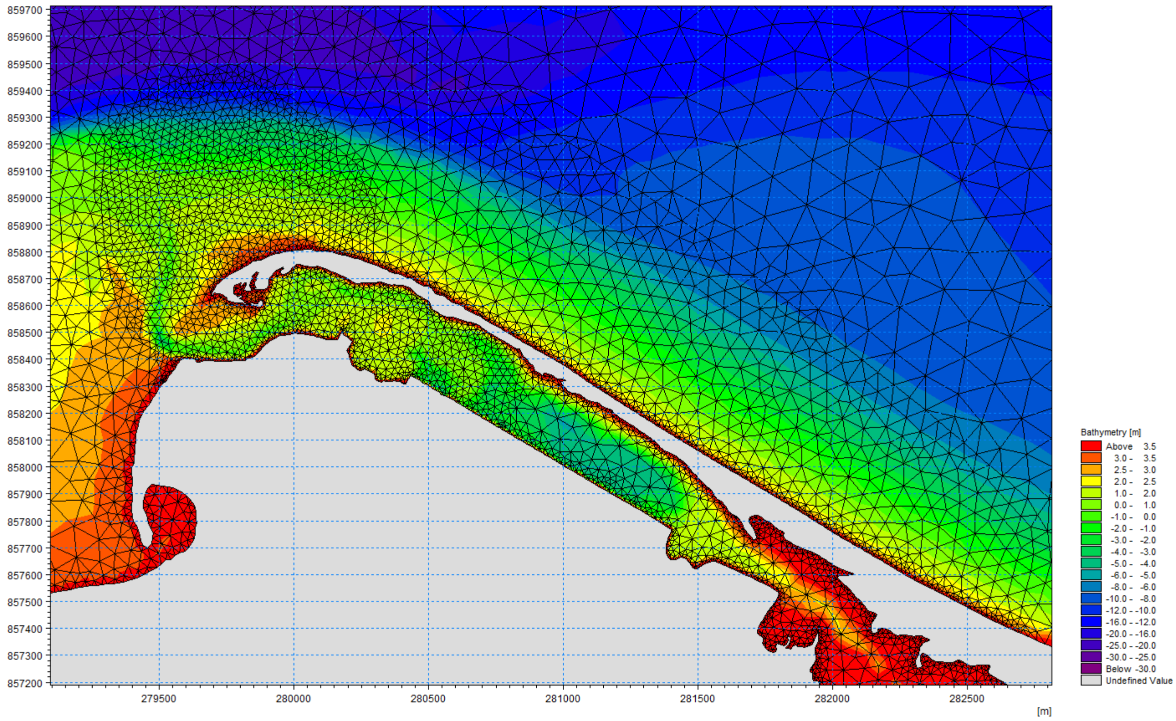


Figure 4-8: 2018 Baseline HD Model Mesh - Ardersier Port

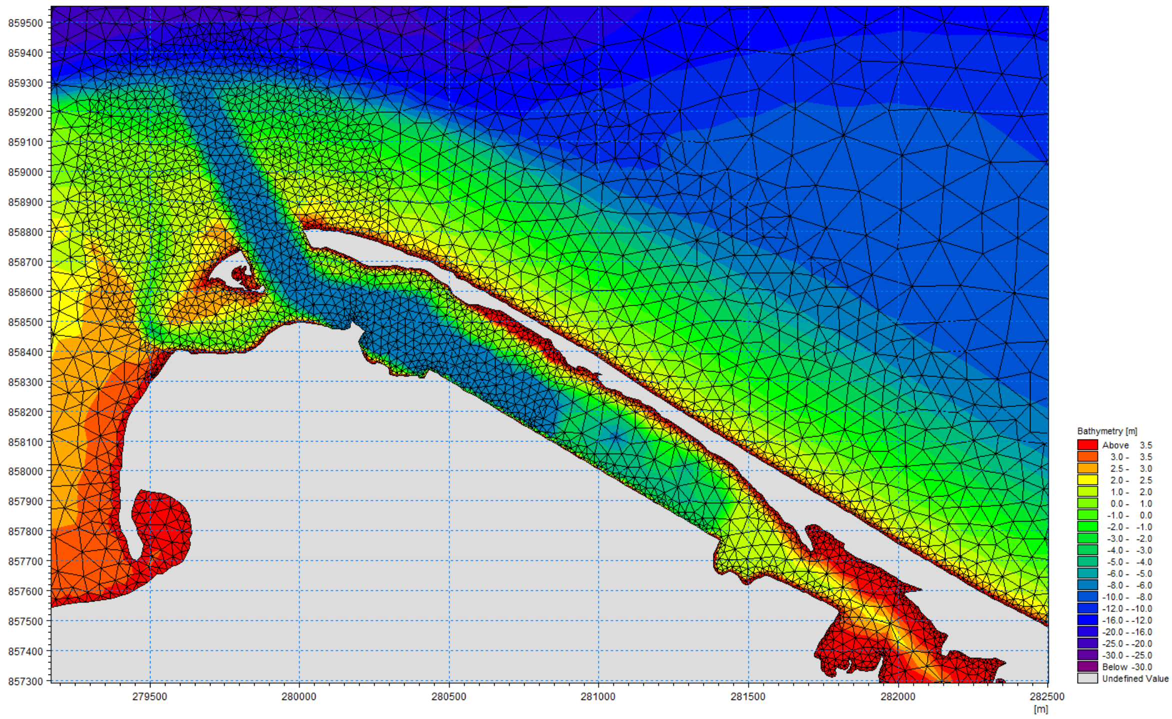


Figure 4-9: 2018 Post-Development HD Model Mesh – Ardersier Port

4.5 Model Setup

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: 300s
    - Model solution technique: Higher order shallow water equations
    - Model solution time-step: Minimum (0.01s) Maximum (30s)
    - Drying depth: 0.005m
    - Wetting depth: 0.1m
    - Bed resistance: $32m^{(1/3)}/s$

The modelling has been undertaken with the following computing specification:

- Dell Precision 5820 Tower:
    - 64GB RAM;
    - Utilising 14 Cores – Intel Xeon CPU (2.5GHz);
    - Windows 10 Pro 64-bit operating system.

4.6 Model Outputs

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 Table 4-2. The locations of the selected key point outputs are situated within the immediate vicinity of Whiteness Head and the proposed development including the capital dredge pockets. Point output locations are shown in Figure 4-10.

Table 4-2: HD Model Point Output Locations

Point Output Location	Easting	Northing
Point 2	279900	858850
Point 4	280200	858550
Point 6	281000	858150
Point 16	279500	859600

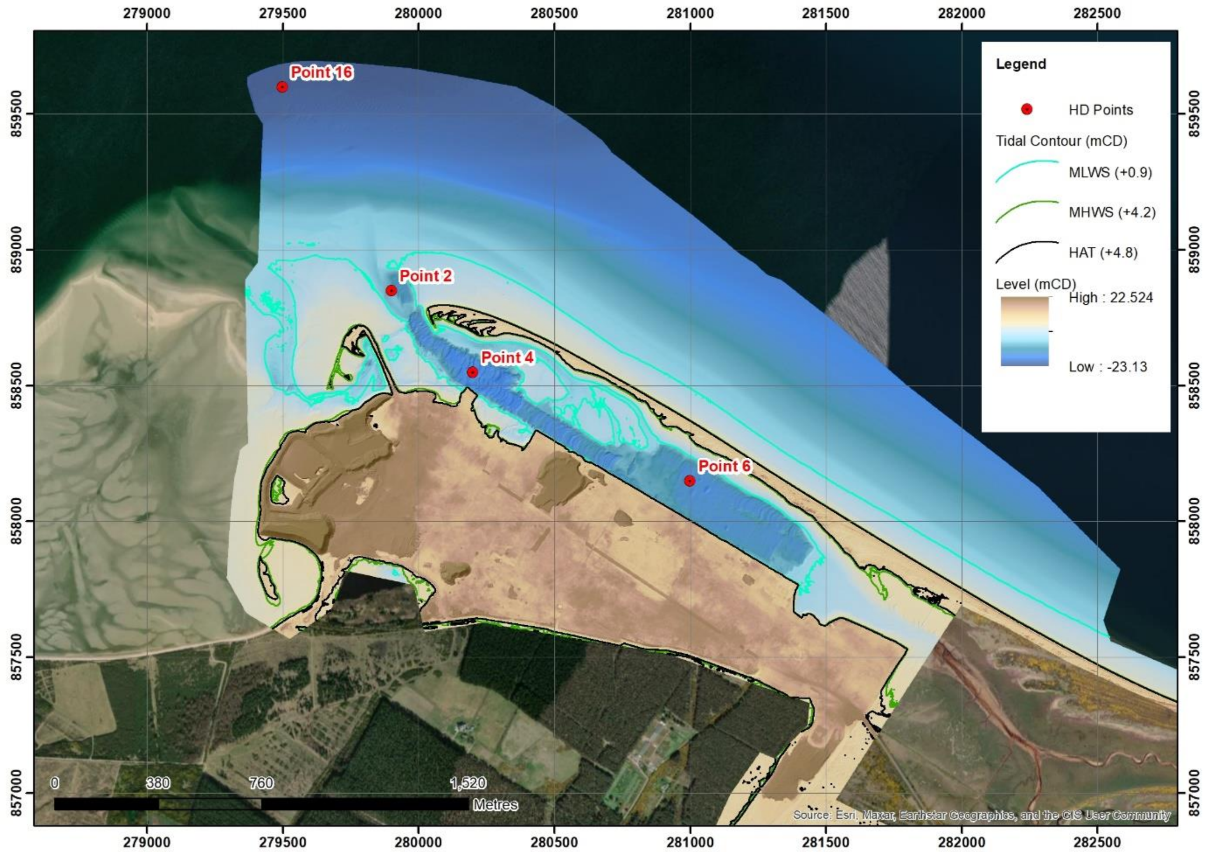


Figure 4-10: Selected Key HD Point Output Locations

4.7 Model Simulations

The key model simulations undertaken using the MIKE 21 FM HD model are presented in Table 4-3.

Table 4-3: HD Model Simulations

HD Model Simulation	Description
FMHD_A Baseline 2023	Baseline HD model simulating existing conditions, with present day (CainTech 2023) bathymetry. Run for January 2003 tidal cycle, including spring and neap tides.
FMHD_B PostDev 2023	Post-development HD model simulating conditions following proposed 2023 (-12.9 mCD) capital dredge, with present day (CainTech 2023) bathymetry. Run for January 2003 tidal cycle, including spring and neap tides.
FMHD_C Baseline 2018	Baseline HD model simulating pre-development conditions in 2018, with 2018 (Aspect 2018) bathymetry. Updated version of model scenario from previous 2018 assessment, run for January 2003 tidal cycle, including spring and neap tides.
FMHD_D PostDev 2018	Post-development HD model simulating conditions following proposed 2018 (-6.5 mCD) capital dredge, with 2018 (Aspect 2018) bathymetry. Updated version of model scenario from previous 2018 assessment, run for January 2003 tidal cycle, including spring and neap tides.

4.8 Model Validation

Validation of the model has been undertaken through comparison of baseline modelled tidal levels with measured tidal levels for the same tide, at McDermott Base (the site), as shown for the first 10 days of the model run in Figure 4-11. 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.

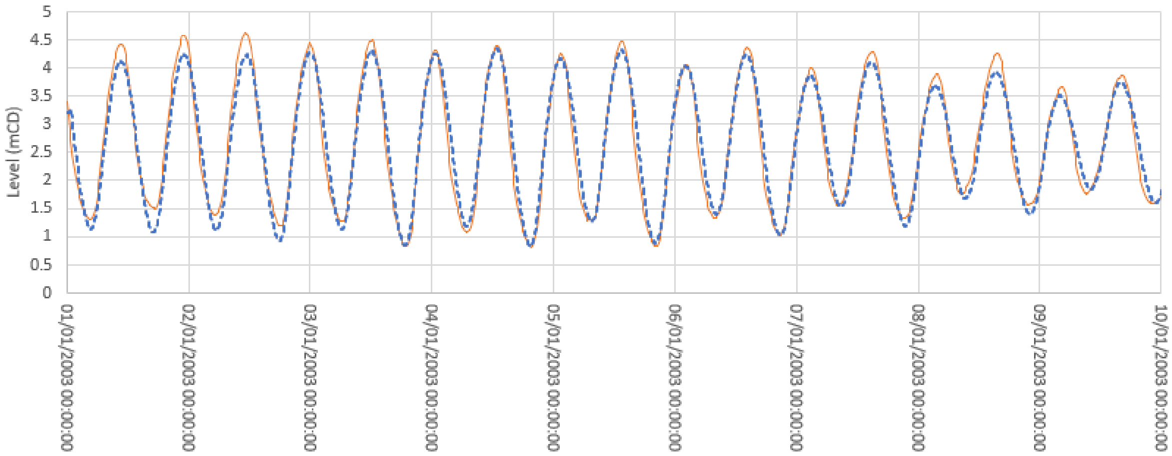


Figure 4-11: Comparison of Measured (Orange) and Modelled 2023 Baseline (Blue) Water Levels

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.

4.9 Model Results

4.9.1 2023 Baseline

The modelled water levels at Point 4 within the harbour are shown in Figure 4-12 for the whole 2023 baseline scenario. Figure 4-13 and Figure 4-14 present area plots of current speed in and around Ardersier Port for mid-flood and mid-ebb spring tides respectively. Figure 4-15 presents modelled current speeds at selected key locations for the whole 2023 baseline scenario.

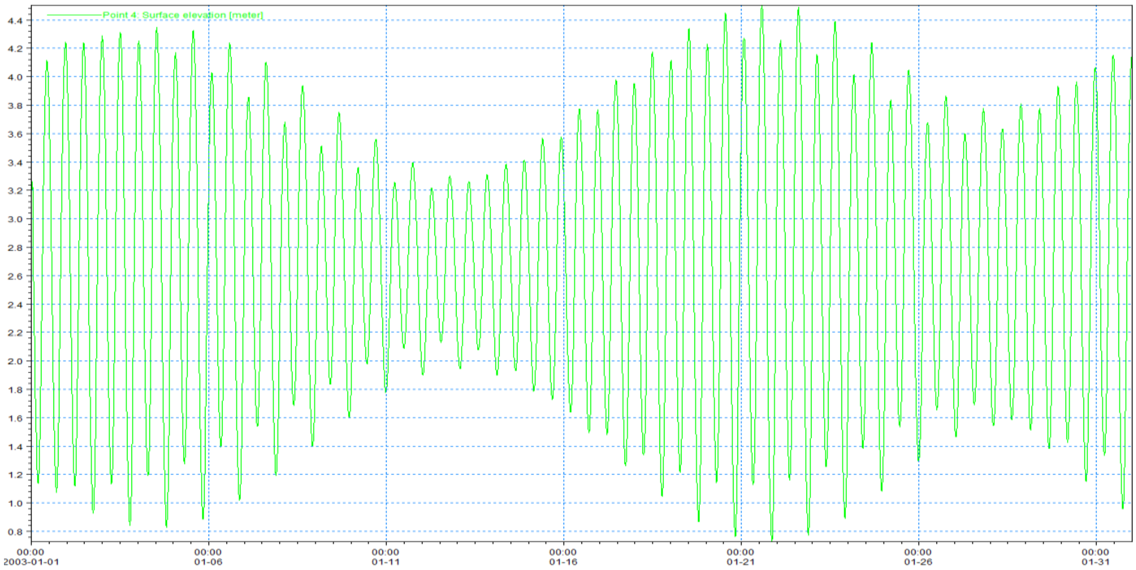


Figure 4-12: FMHD_A Baseline 2023 Full Model Run – Water Level at Point 4

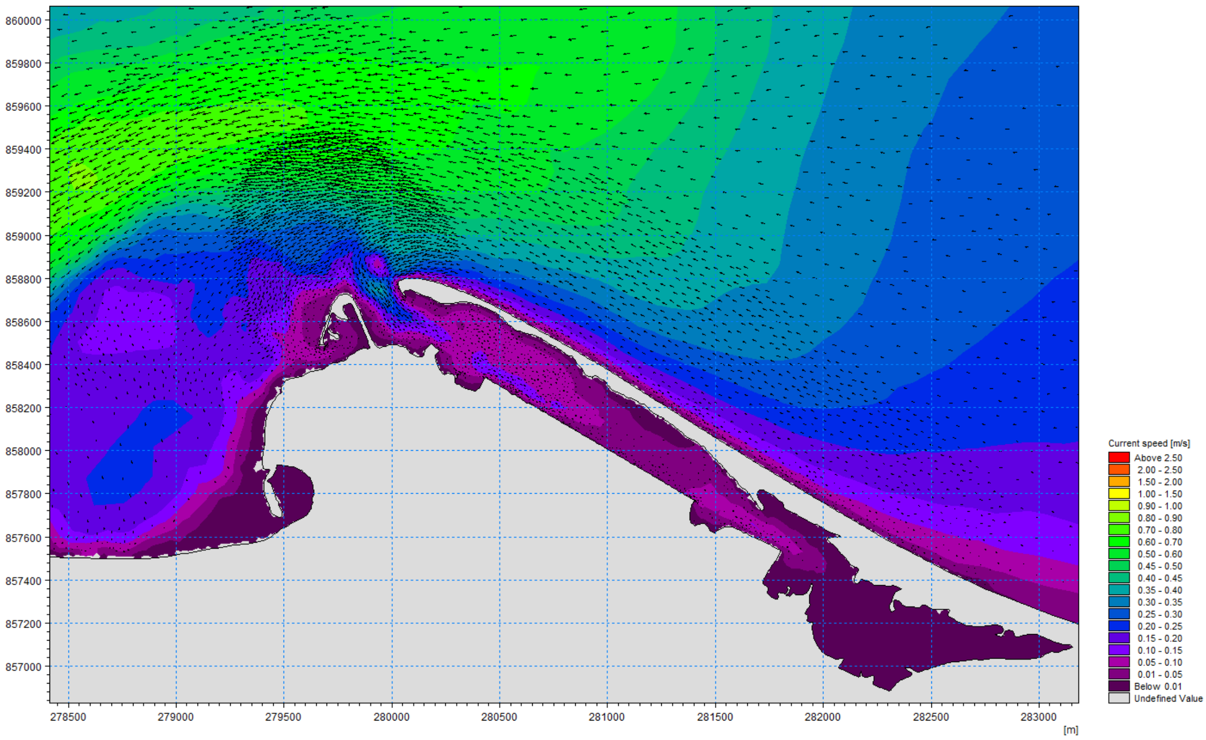


Figure 4-13: FMHD_A Baseline 2023 Mid-Flood Spring Tide – Current Speed

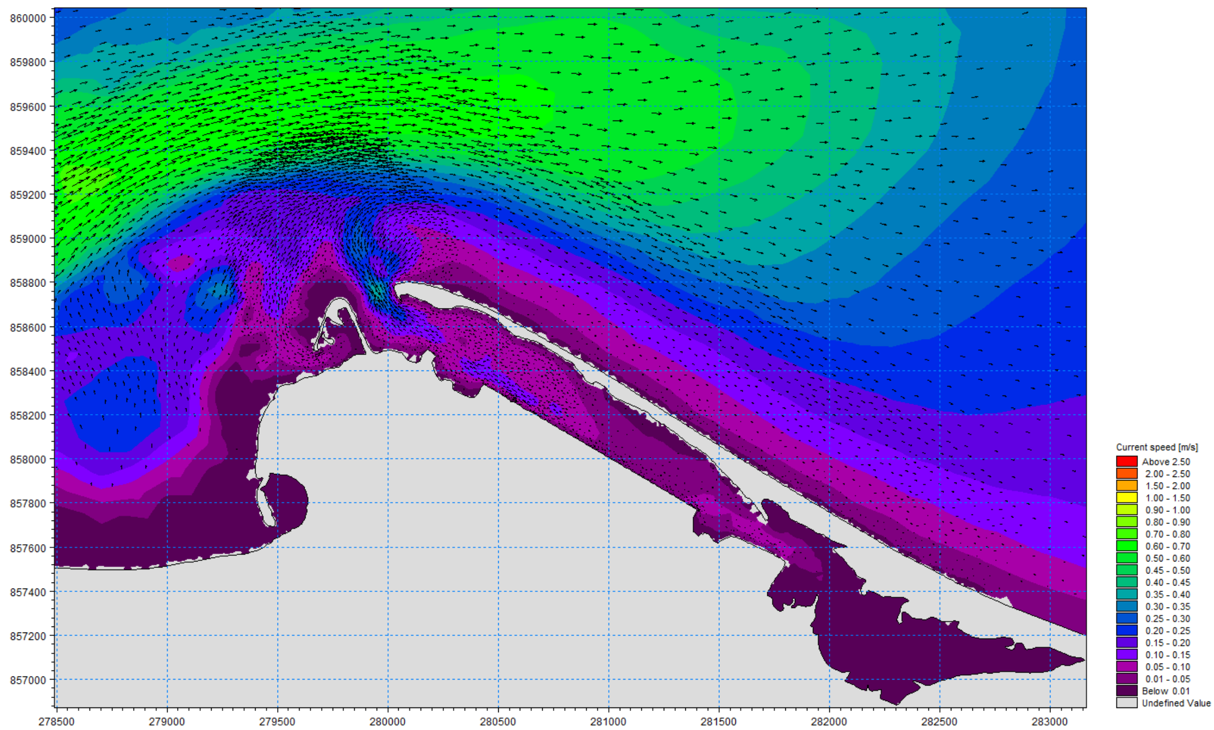


Figure 4-14: FMHD_A Baseline 2023 Mid-Ebb Spring Tide – Current Speed

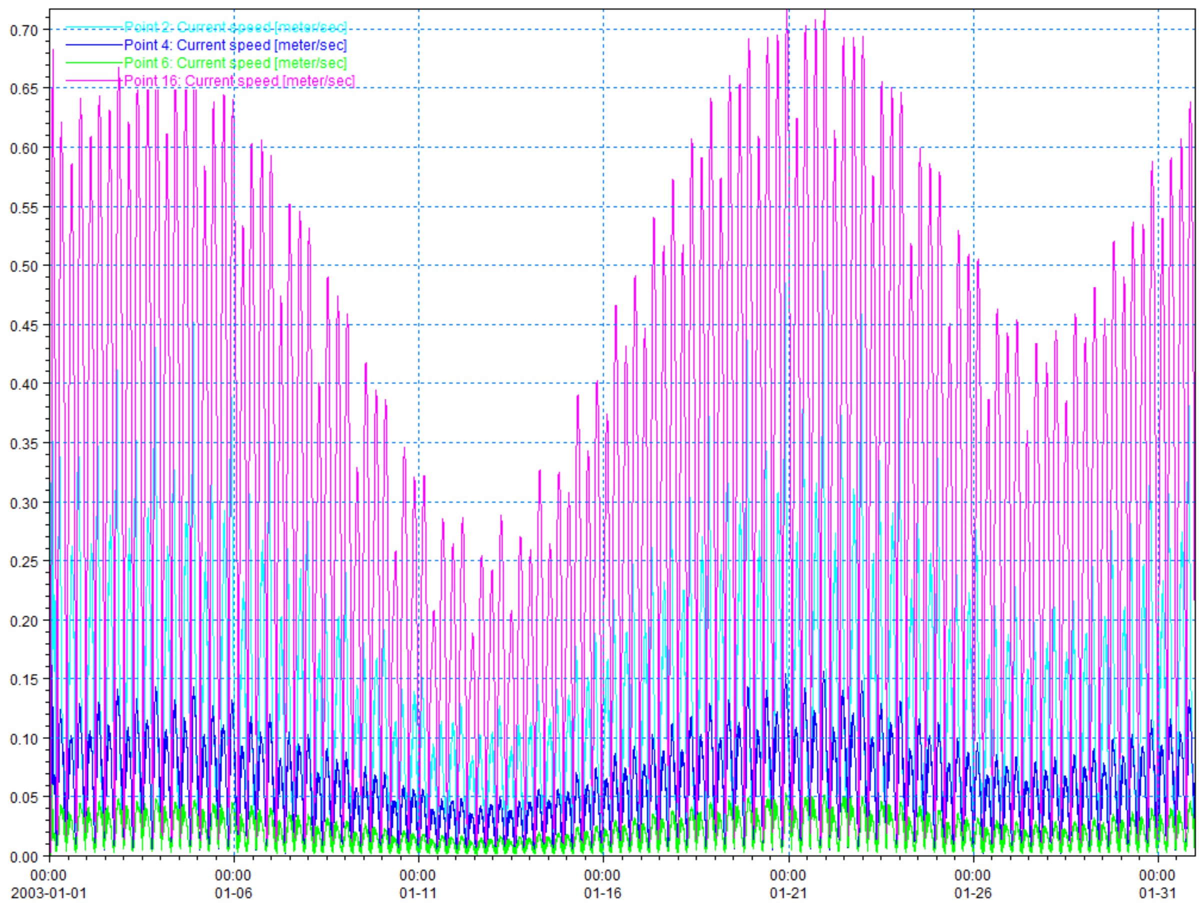


Figure 4-15: FMHD_A Baseline 2023 Point Output – Current Speed

4.9.2 2023 Post-Development

Figure 4-16 and Figure 4-17 present 2023 post-development scenario area plots of current speed in and around Ardersier Port for mid-flood and mid-ebb spring tides respectively. Figure 4-18 presents modelled current speeds at selected key locations for the whole 2023 post-development scenario.

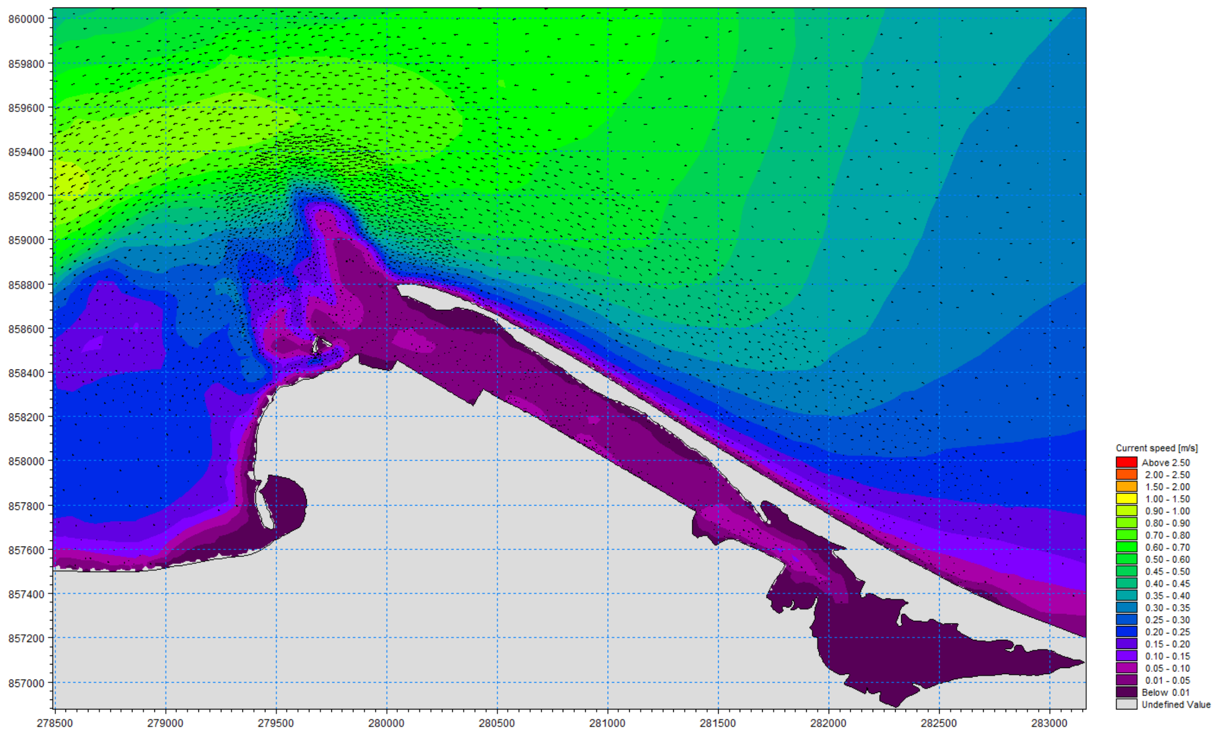


Figure 4-16: FMHD_B Post-Development 2023 Mid-Flood Spring Tide – Current Speed

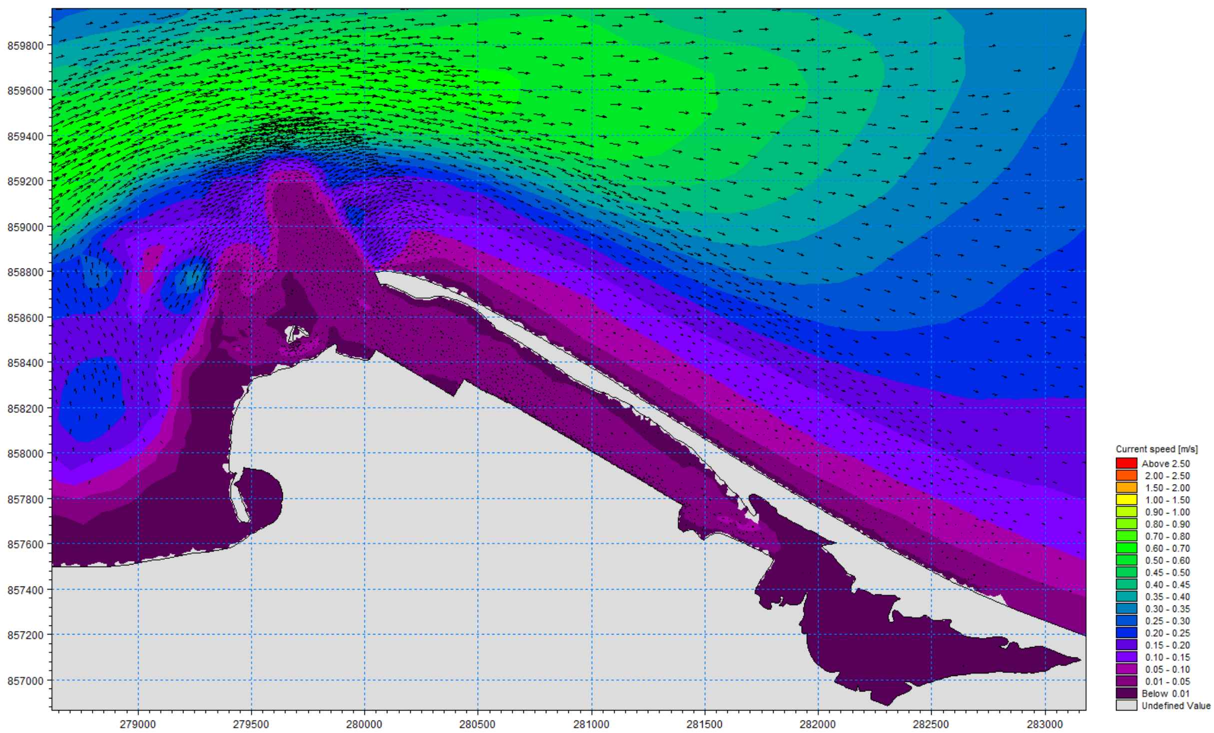


Figure 4-17: FMHD_B Post-Development 2023 Mid-Ebb Spring Tide – Current Speed

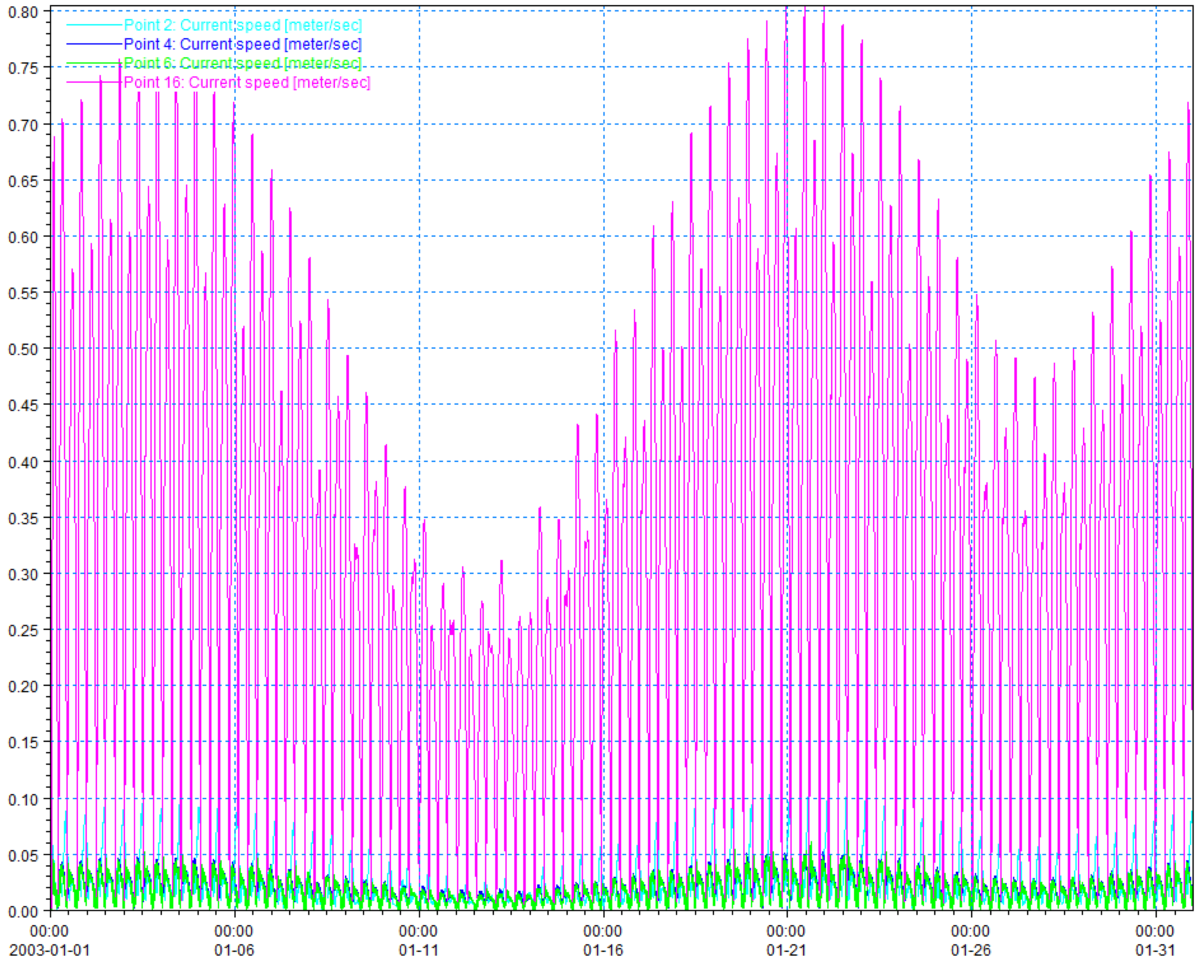


Figure 4-18: FMHD_B Post-Development 2023 Point Output – Current Speed

4.9.3 2018 Baseline

Figure 4-19 and Figure 4-20 present 2018 baseline scenario area plots of current speed in and around Ardersier Port for mid-flood and mid-ebb spring tides respectively.

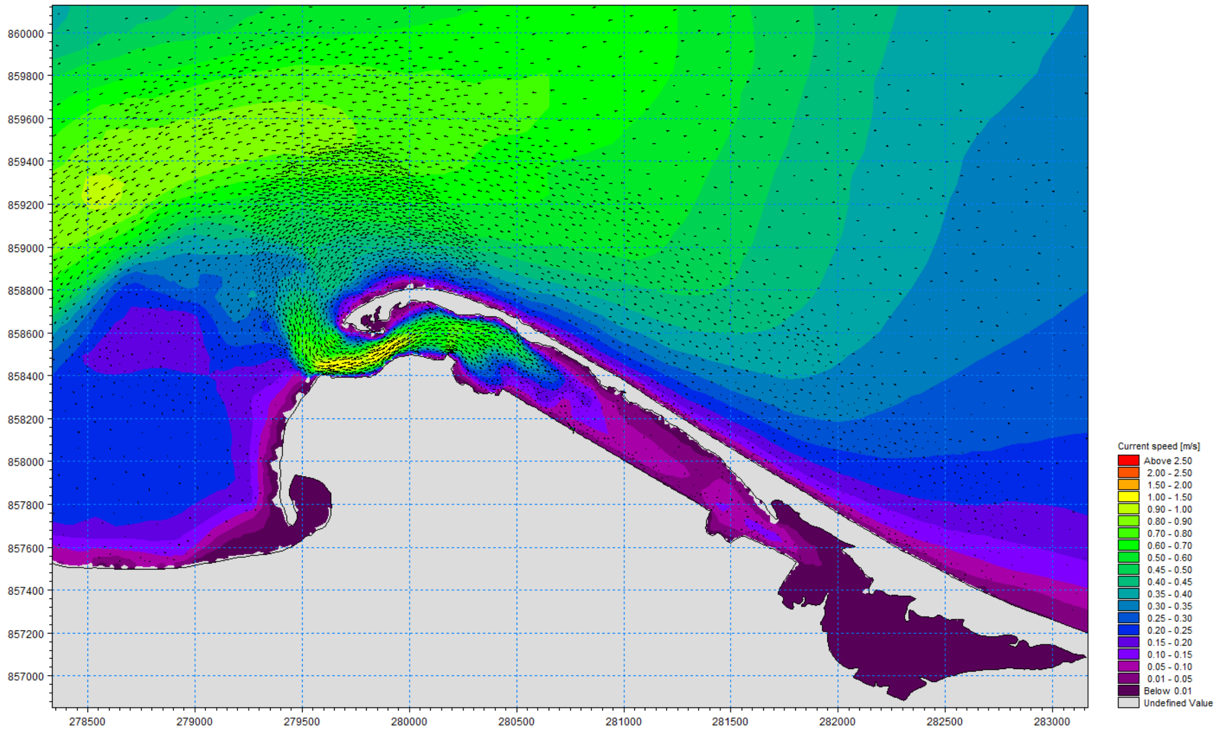


Figure 4-19: FMHD_C Baseline 2018 Mid-Flood Spring Tide – Current Speed

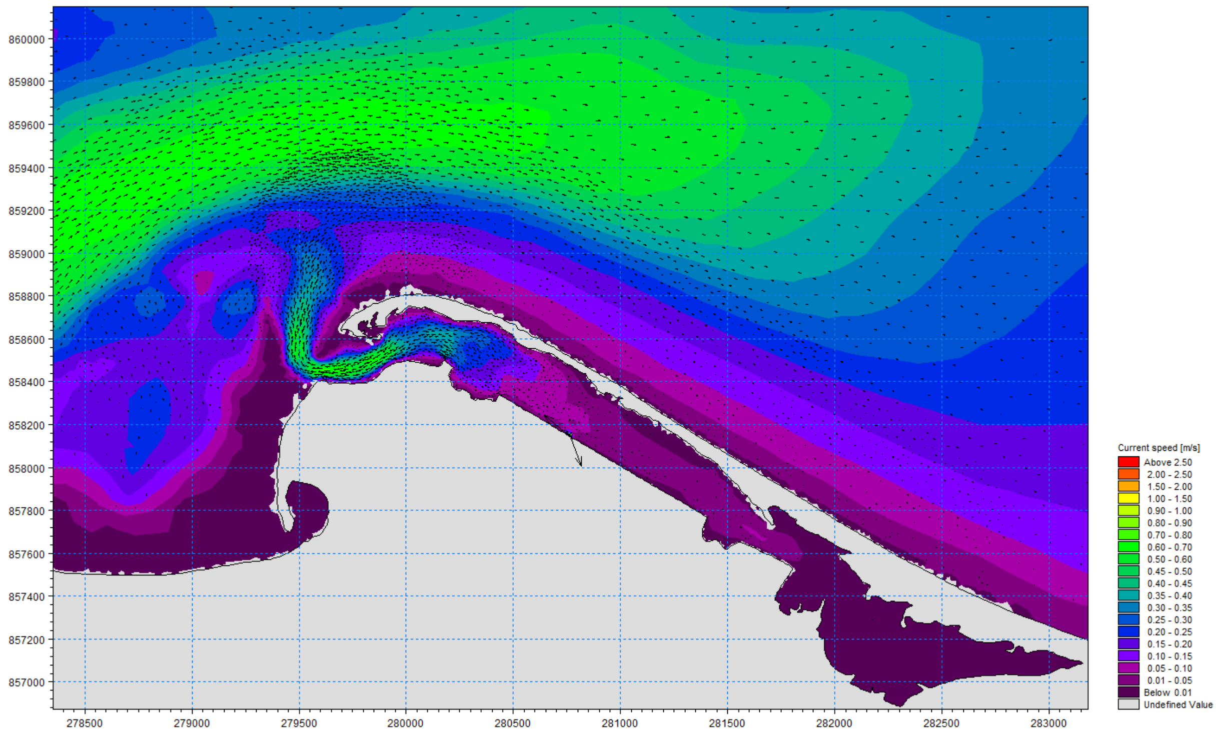


Figure 4-20: FMHD_C Baseline 2018 Mid-Ebb Spring Tide – Current Speed

4.9.4 2018 Post-Development

Figure 4-21 and Figure 4-22 present 2018 post-development scenario area plots of current speed in and around Ardersier Port for mid-flood and mid-ebb spring tides respectively.

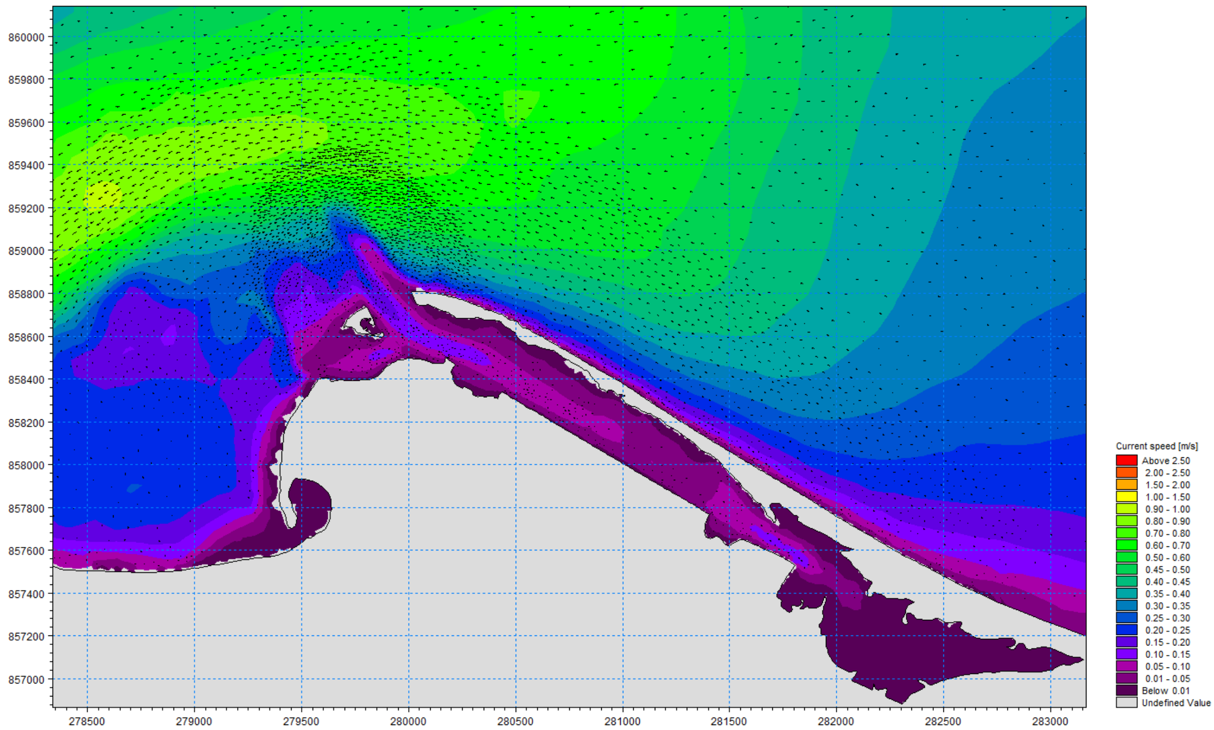


Figure 4-21: FMHD_D Post-Development 2018 Mid-Flood Spring Tide – Current Speed

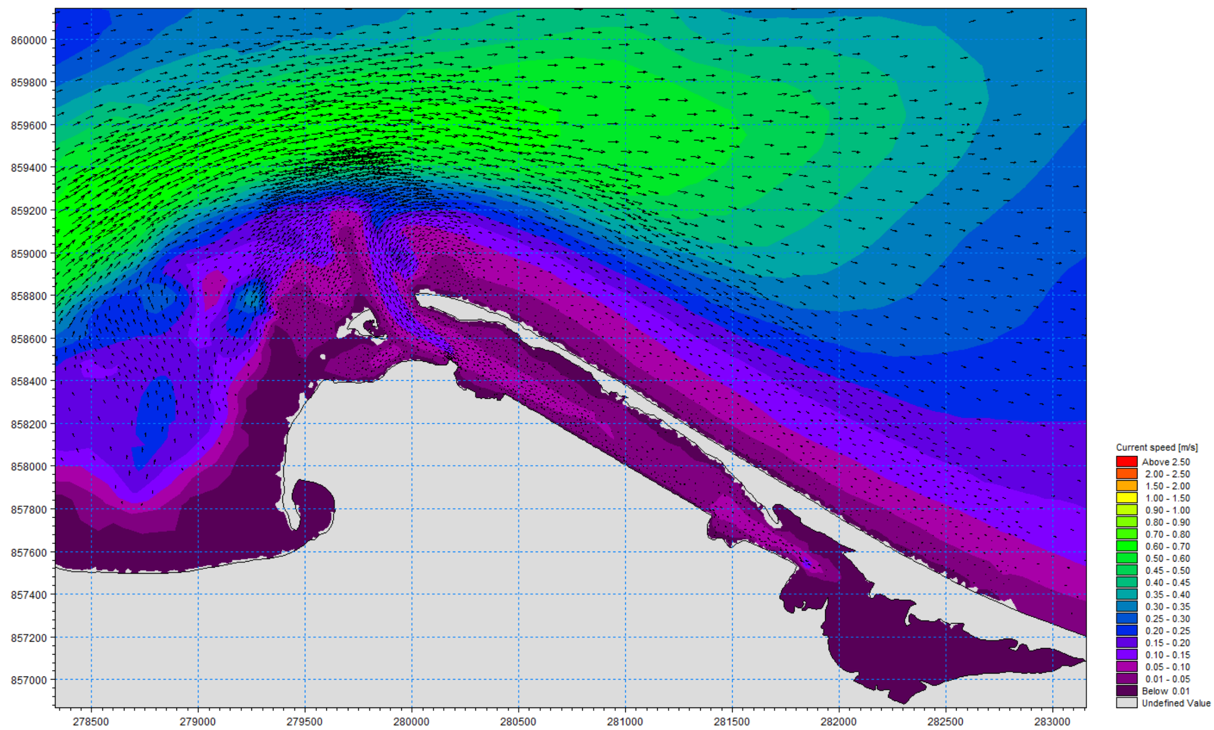


Figure 4-22: FMHD_D Post-Development 2018 Mid-Ebb Spring Tide – Current Speed

5 SPECTRAL WAVES MODEL

5.1 MIKE 21 Flow Model FM – 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 versions of the software, MIKE 2023 and 2024, have been used in this assessment. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas.

5.2 Model Extent

The SW model extent is the same as that of the HD model, as outlined in section 4.2.

5.3 Input Data

All bathymetry input data remains the same as that of the HD model, as outlined in section 4.3.1. Corresponding HD model results form the input water level data to SW model runs for the same scenario, as described in Table 5-2.

5.3.1 Wave and Wind Data

UK Meteorological Office wind and wave data for the Moray Firth at 57.7 N, 3.75 W (12 km grid) from their 2nd Generation UK Water Wave Model for the period March 2000 to March 2007 forms the input wave and wind data to the spectral wave model. The Met Office model data is provided at 3 hour intervals, with the wave data containing the significant wave height, peak wave period and direction. The wave data is input to the model open boundary, whilst the wind data is applied across the whole model extent.

5.4 Model Mesh

The SW model meshes are the same as that of the HD model, as outlined in section 4.4.

5.5 Model Setup

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 section 5.3;
- 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); and
- The model time step interval is 1,800 seconds.

5.6 Model Outputs

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 as detailed for selected key locations in Table 5-2, and shown in Figure 5-1.

Table 5-1: HD Model Point Output Locations

Point Output Location	Easting	Northing
Point 3	281000	859500
Point 4	280000	860000
Point 6	280100	858600

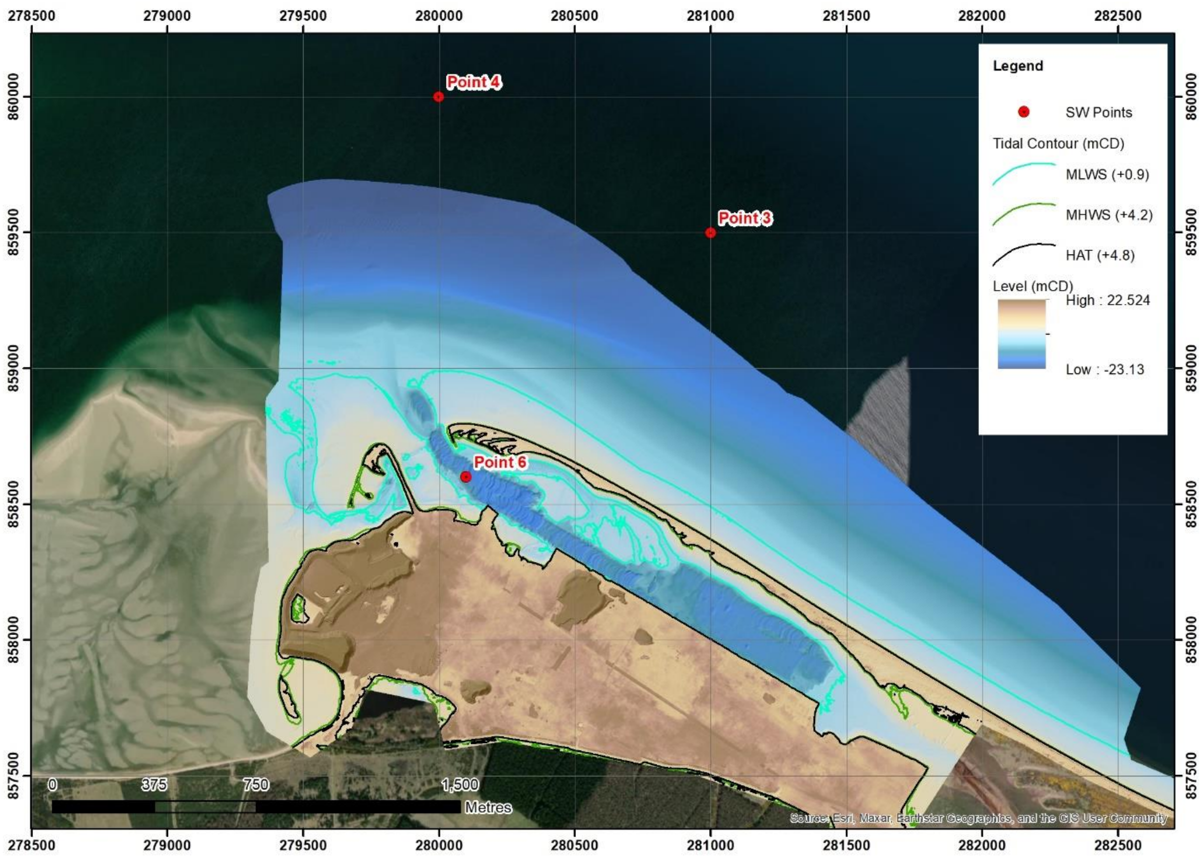


Figure 5-1: Selected Key SW Point Output Locations

5.7 Model Simulations

The key model simulations undertaken using the MIKE 21 FM SW model are presented in Table 5-2.

Table 5-2: SW Model Simulations

SW Model Simulation	Description
FMSW_A Baseline 2023	Baseline SW model simulating wave climate under existing conditions, with present day (CainTech 2023) bathymetry. Run for January 2003 wave and wind conditions, with water levels from FMHD_A_Baseline2023 including spring and neap tides.
FMSW_B PostDev 2023	Post-development SW model simulating wave climate under conditions following proposed 2023 (-12.9 mCD) capital dredge, with present day (CainTech 2023) bathymetry. Run for January 2003 wave and wind conditions, with water levels from FMHD_B_PostDev2023 including spring and neap tides.
FMSW_C Baseline 2018	Baseline SW model simulating wave climate under pre-development conditions in 2018, with 2018 (Aspect 2018) bathymetry. Updated version of model scenario from previous 2018 assessment. Run for January 2003 wave and wind conditions, with water levels from FMHD_C_Baseline2018 including spring and neap tides.
FMSW_D PostDev 2018	Post-development SW model simulating wave climate under conditions following proposed 2018 (-6.5 mCD) capital dredge, with 2018 (Aspect 2018) bathymetry. Updated version of model scenario from previous 2018 assessment. Run for January 2003 wave and wind conditions, with water levels from FMHD_D_PostDev2018 including spring and neap tides.

5.8 Model Validation

Due to lack of observed wave data in the vicinity of Whiteness Head it is not possible to validate the model outputs with respect to waves. However, simulated results for wave heights are closely aligned with those of previous modelling exercises, and it is considered that the simulated values are as expected for the physical setting.

5.9 Model Results

5.9.1 Baseline 2023

Figure 5-2 presents an area plot of modelled significant wave height in the vicinity of Ardersier Port for a selected storm event on 22nd January 2003. Figure 5-3 presents point output results for significant wave height at locations 3, 4 and 6 for the full model run duration.

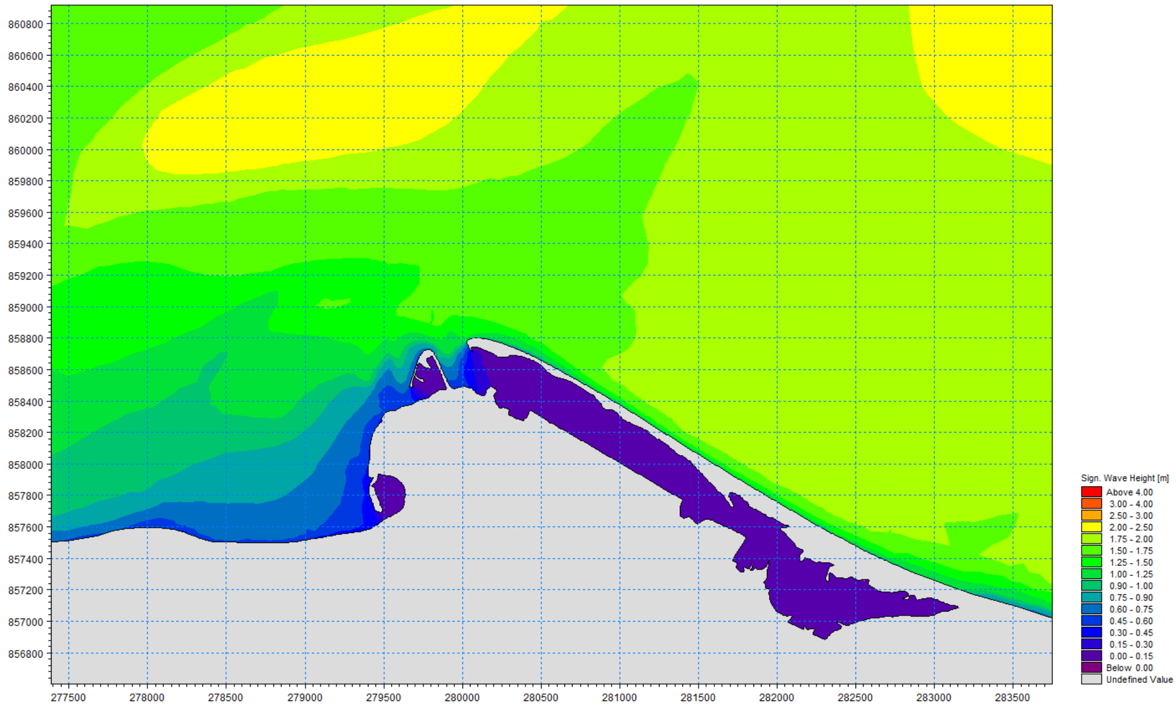


Figure 5-2: FMSW_A Baseline 2023 Storm Event – Significant Wave Height

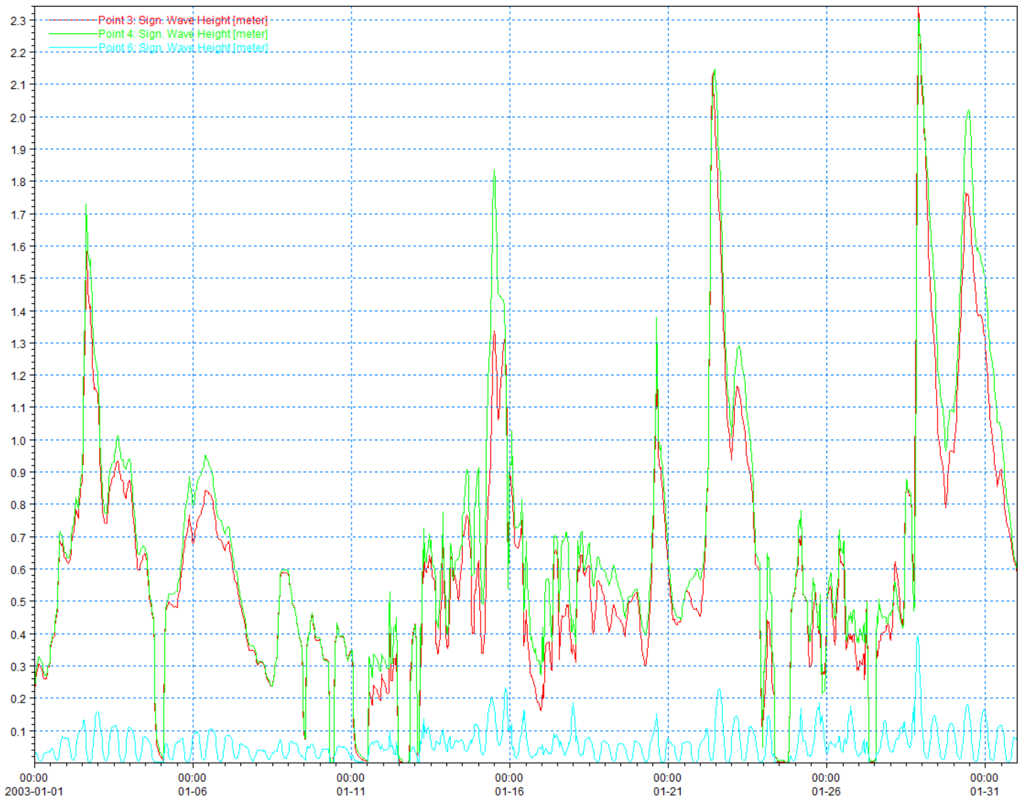


Figure 5-3: FMSW_A Baseline 2023 Full Model Run Point Output – Significant Wave Height

5.9.2 Post-Development 2023

Figure 5-4 presents an area plot of modelled significant wave height in the vicinity of Ardersier Port for a selected storm event on 22nd January 2003. Figure 5-5 presents point output results for significant wave height at locations 3, 4 and 6 for the full model run duration.

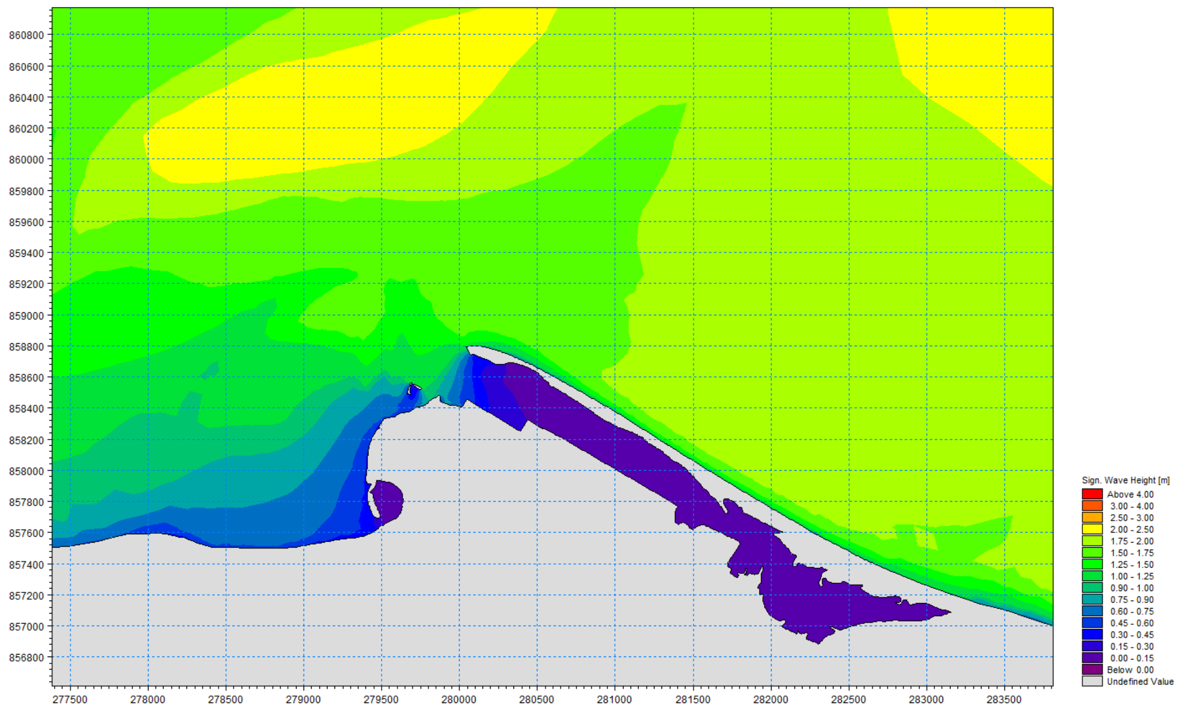


Figure 5-4: FMSW_B PostDev 2023 2023 Storm Event – Significant Wave Height

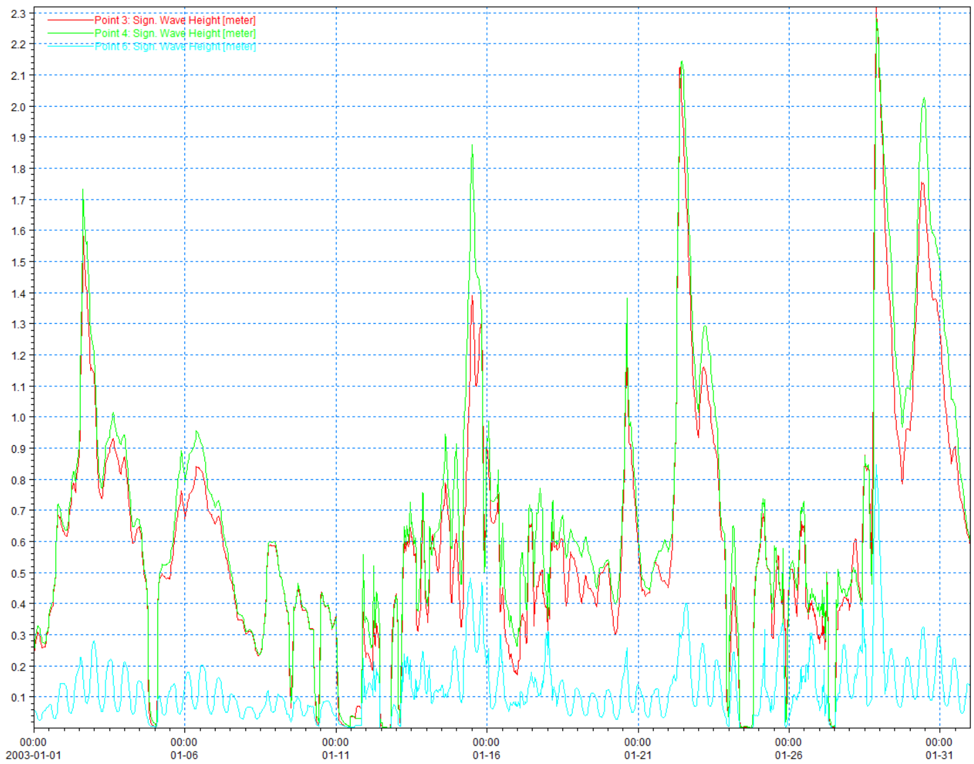


Figure 5-5: FMSW_B PostDev 2023 Full Model Run Point Output – Significant Wave Height

5.9.3 Baseline 2018

Figure 5-6 presents an area plot of modelled significant wave height in the vicinity of Ardersier Port for a selected storm event on 22nd January 2003. Figure 5-7 presents point output results for significant wave height at locations 3, 4 and 6 for the full model run duration.

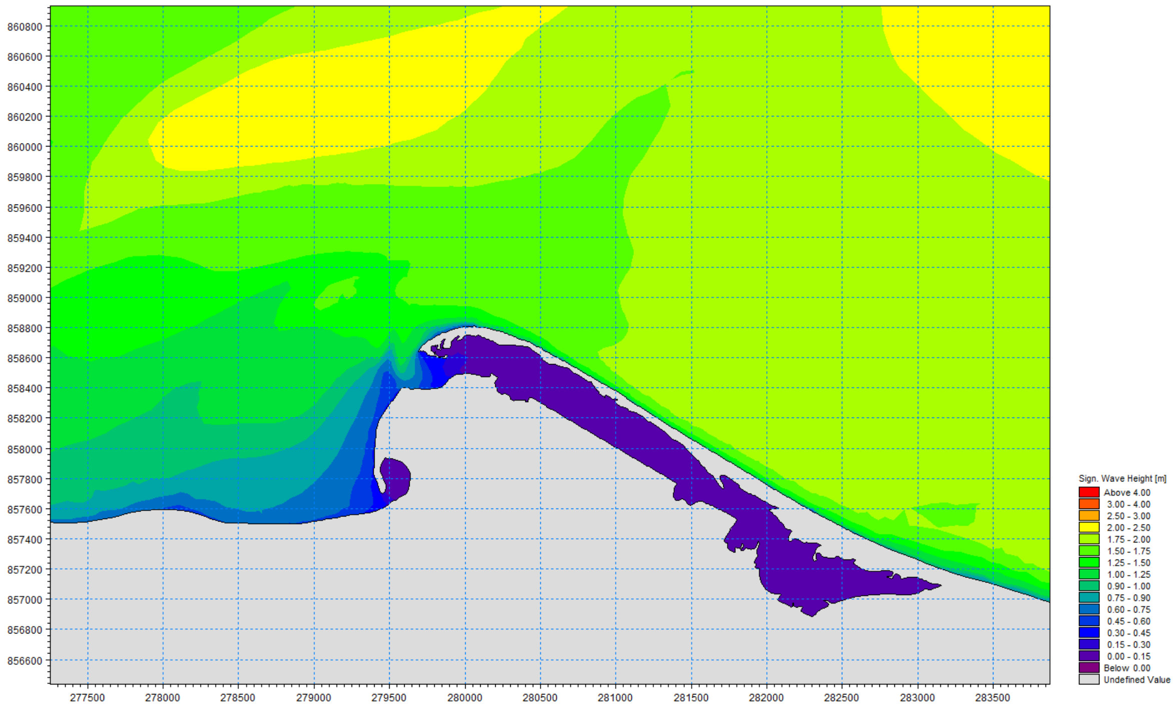


Figure 5-6: FMSW_C Baseline 2018 Storm Event – Significant Wave Height

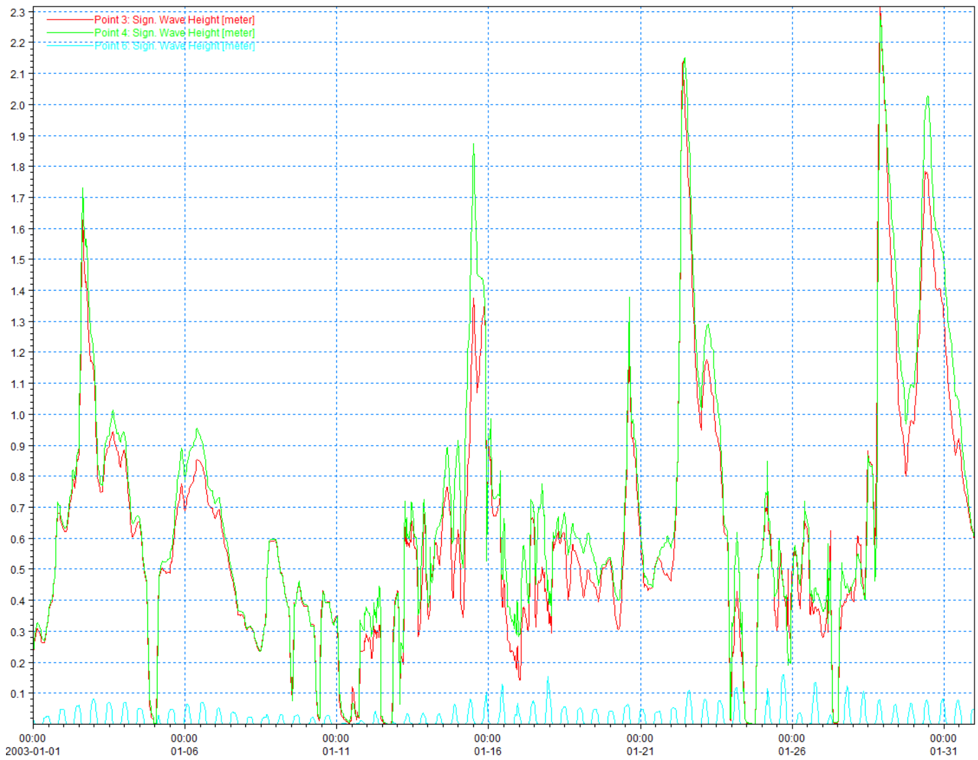


Figure 5-7: FMSW_C Baseline 2018 Full Model Run Point Output – Significant Wave Height

5.9.4 Post-Development 2018

Figure 5-8 presents an area plot of modelled significant wave height in the vicinity of Ardersier Port for a selected storm event on 22nd January 2003. Figure 5-9 presents point output results for significant wave height at locations 3, 4 and 6 for the full model run duration.

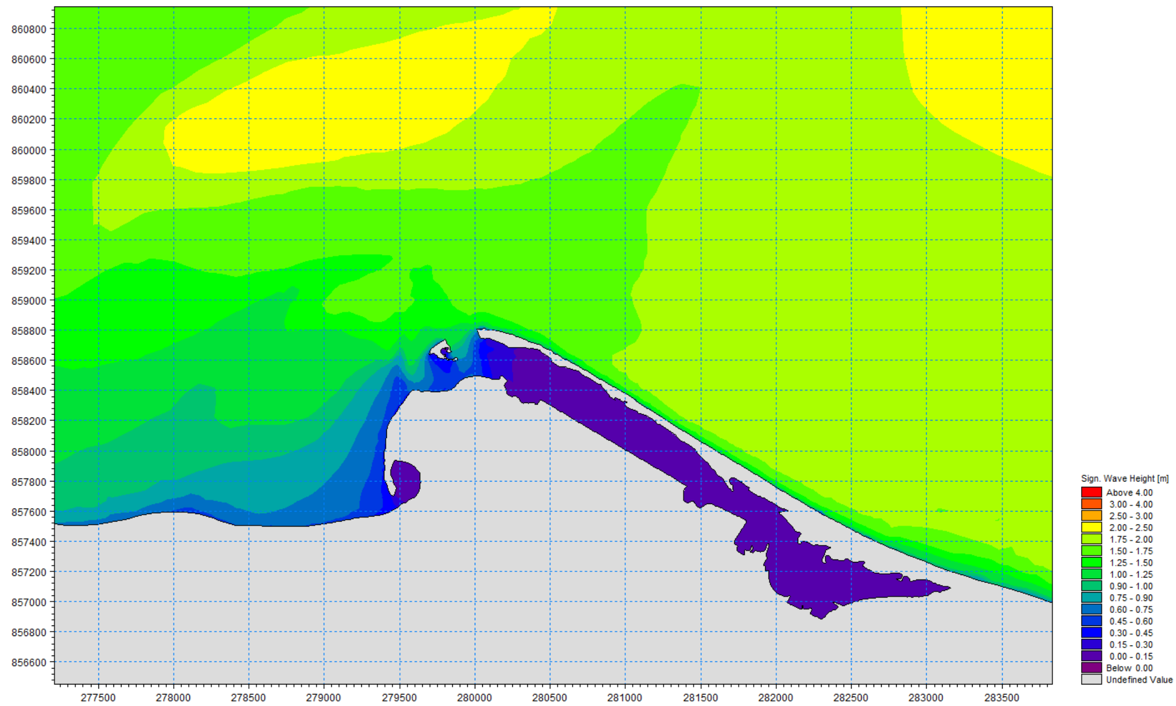


Figure 5-8: FMSW_D PostDev 2018 Storm Event – Significant Wave Height

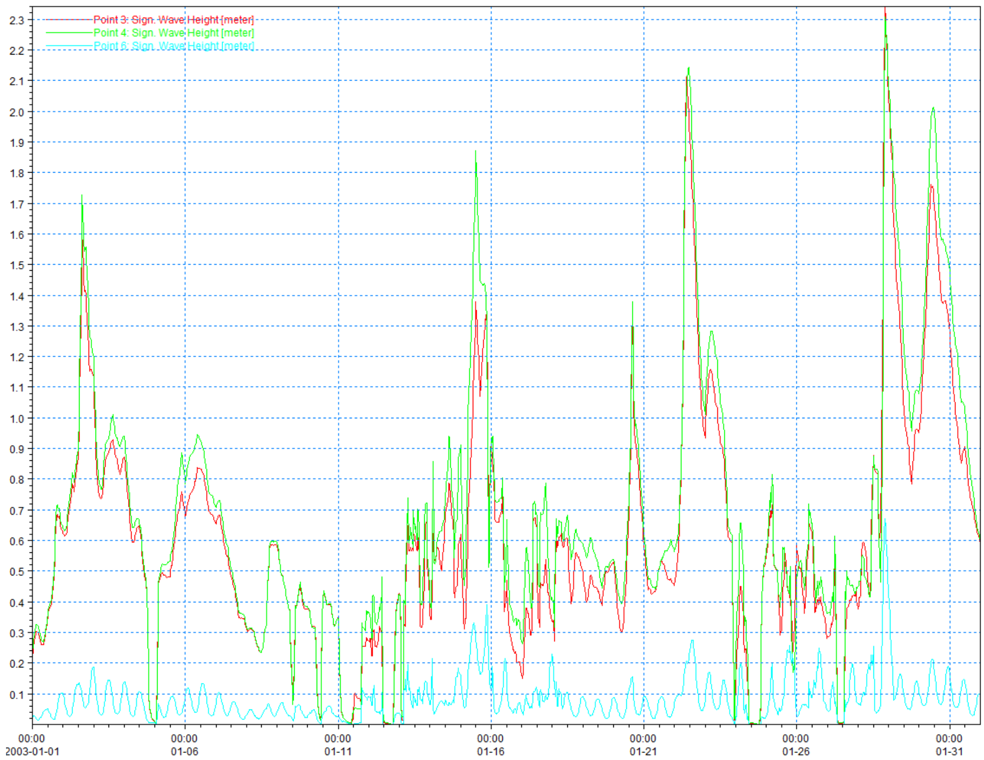


Figure 5-9: FMSW_D PostDev 2018 Full Model Run Point Output – Significant Wave Height

6 SEDIMENT TRANSPORT MODEL

6.1 MIKE 21 Flow Model FM – 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.

6.2 Model Extent

The ST model extent is the same as that of the HD model, as outlined in section 4.2 and Figure 4-1.

6.3 Input Data

All bathymetry input data remains the same as that of the HD model, as outlined in section 4.3.1. Corresponding SW model results form the input wave conditions to ST model runs for the same scenario, as described in Table 6-1. The ST model is run with a coupled HD model providing the water level and current forcing, as described in Table 6-1.

Input sediment characteristics are derived from the sediment data described in section 3.2 and Figure 3-5.

6.4 Model Mesh

The ST model meshes are the same as that of the HD model, as outlined in section 4.4.

6.5 Model Setup

Further details of the MIKE 21 ST 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 section 6.3;
- The ST model is coupled with an HD model, the HD model setup is as described in section 4.5;
- 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 Figure 3-5;
- Wave forcing is provided by the corresponding SW model run, as described in Table 6-1; and
- Dynamic feedback on the hydrodynamic and sand transport calculations are included, with a constant speedup factor of 3 applied to all results, effectively extending 1 month simulations to 3 months; and
- For the spit and sands trace model scenarios the initial sediment layer thickness available for transport is varying in domain, restricted to areas around the spit and sands respectively.

6.6 Model Outputs

The MIKE 21 ST model simulations have been setup to produce results as area 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.

6.7 Model Simulations

The key model simulations undertaken using the MIKE 21 FM ST model are presented in Table 6-1.

Table 6-1: ST Model Simulations

ST Model Simulation	Description
FMHDST_A Baseline 2023	Baseline HD and ST model simulating tidal action and sand transport under existing conditions, with present day (CainTech 2023) bathymetry. Run for January 2003 tidal cycle, including spring and neap tides. Wave forcing from FMSW_A Baseline 2023. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_B PostDev 2023	Post-development HD and ST model simulating tidal action and sand transport under conditions following proposed 2023 (-12.9 mCD) capital dredge, with present day (CainTech 2023) bathymetry. Run for January 2003 tidal cycle, including spring and neap tides. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_C PostDev 2018	Post-development HD and ST model simulating tidal action and sand transport under conditions following proposed 2018 (-6.5 mCD) capital dredge, with 2018 (Aspect 2018) bathymetry. Updated version of model scenario from previous 2018 assessment, run for January 2003 tidal cycle, including spring and neap tides. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_D PostDev 2023 Spit Trace	As per FMHDST_B but with available sand extent for transport limited to the sand spit and adjacent nearshore. To assess westward transport of sand in relation to proposed dredge channel. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_E PostDev 2018 Spit Trace	As per FMHDST_C but with available sand extent for transport limited to the sand spit and adjacent nearshore. To assess westward transport of sand in relation to proposed dredge channel. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_F PostDev 2023 Sands Trace	As per FMHDST_B but with available sand extent for transport limited to the Whiteness Sands and adjacent nearshore. To assess eastward transport of sand in relation to proposed dredge channel. Morphology speed up factor of 3 to extend sand transport results to 3 months.
FMHDST_G PostDev 2018 Sands Trace	As per FMHDST_C but with available sand extent for transport limited to the Whiteness Sands and adjacent nearshore. To assess eastward transport of sand in relation to proposed dredge channel. Morphology speed up factor of 3 to extend sand transport results to 3 months.

6.8 Model Validation

As per the 2018 assessment, the sand transport model has been validated through both comparison to successive bathymetric surveys, and hindcast modelling utilising earlier bathymetry. The duration of the sand transport model runs are shorter than the duration between successive bathymetric surveys, so 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 sand erosion, transport and deposition observed and is therefore deemed suitable for use in assessing coastal processes.

6.9 Model Results

6.9.1 Baseline 2023

Figure 6-1 presents predicted bed level change in the vicinity of Ardersier Port at the end of the 2023 baseline simulation.

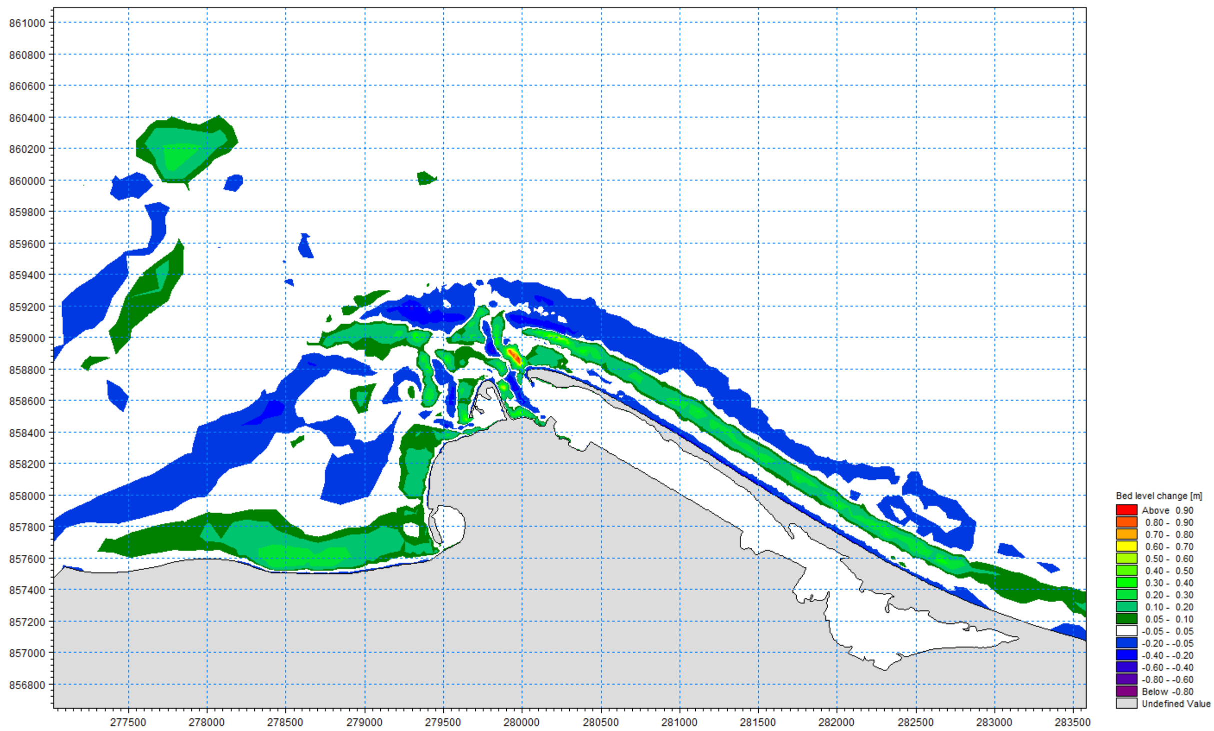


Figure 6-1: FMHDST_A Baseline 2023 Final Timestep – Bed Level Change

6.9.2 Post-Development 2023

Figure 6-2 presents predicted bed level change in the vicinity of Ardersier Port at the end of the 2023 post-development simulation.

Figure 6-3 presents predicted bed level change in the vicinity of Ardersier Port at the end of the 2023 post-development spit trace simulation, whilst Figure 6-4 presents equivalent results for the sands trace simulation.

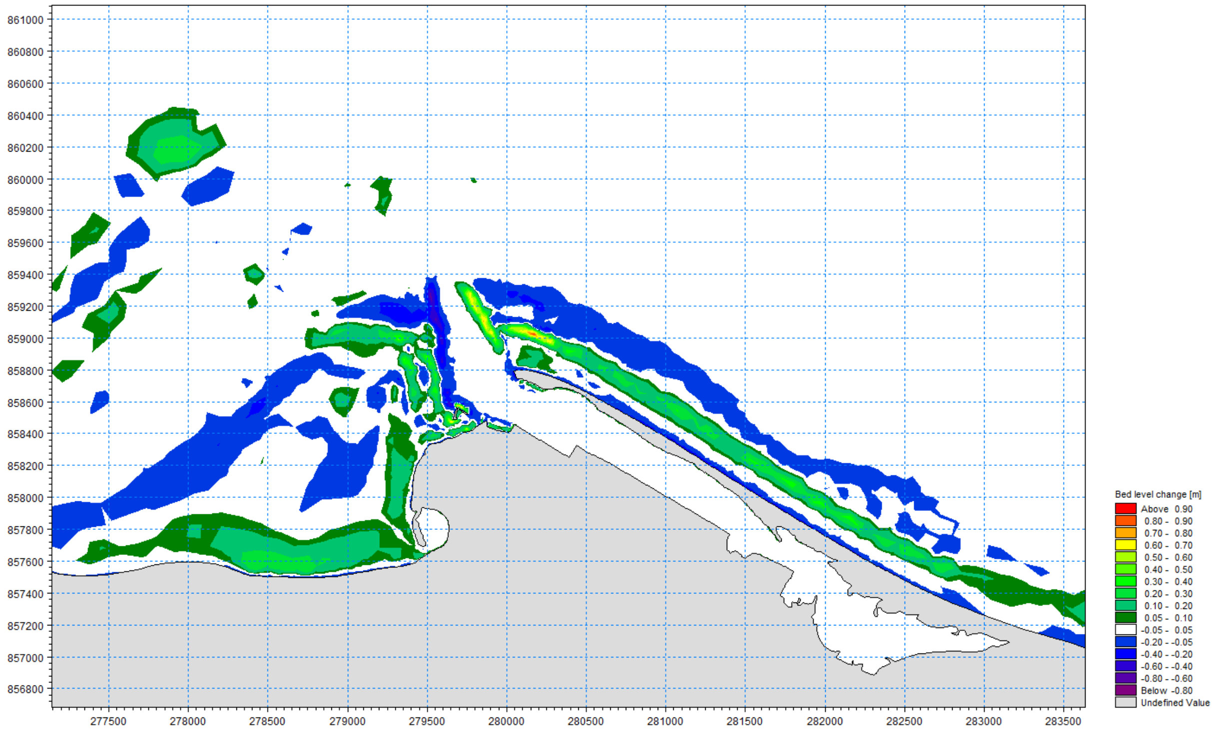


Figure 6-2: FMHDST_B PostDev 2023 Final Timestep – Bed Level Change

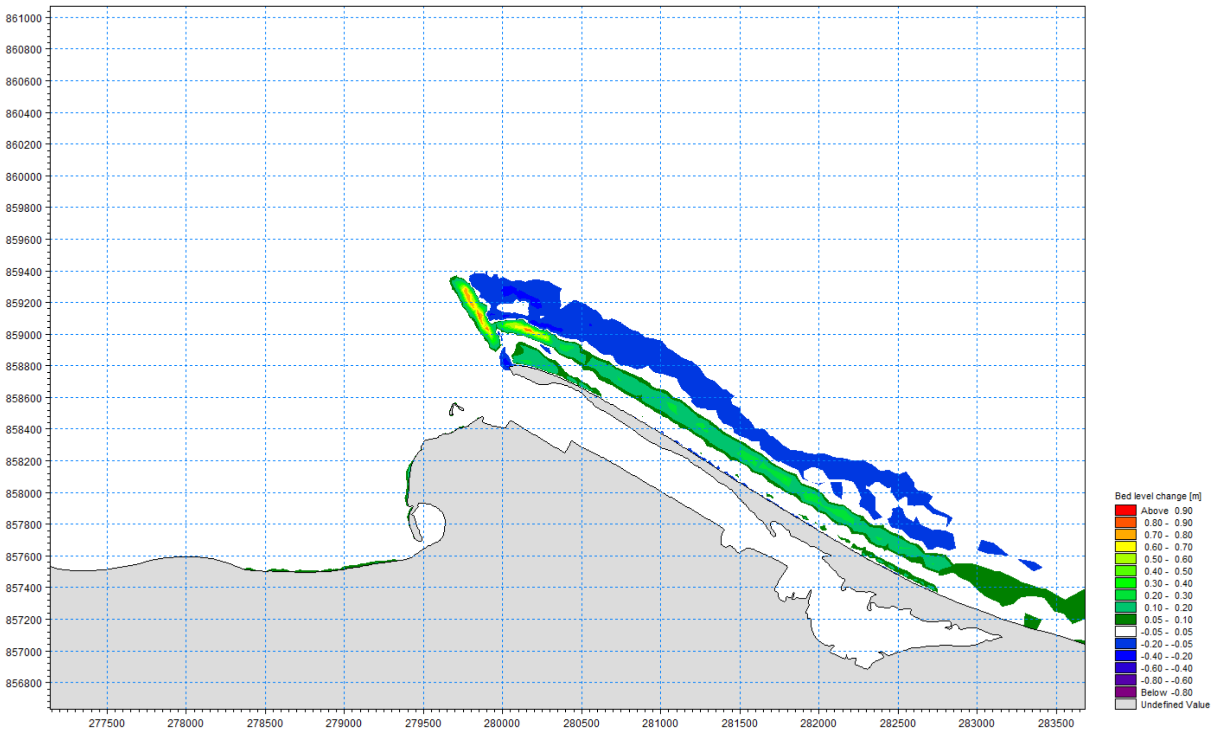


Figure 6-3: FMHDST_D PostDev 2023 Spit Trace Final Timestep – Bed Level Change

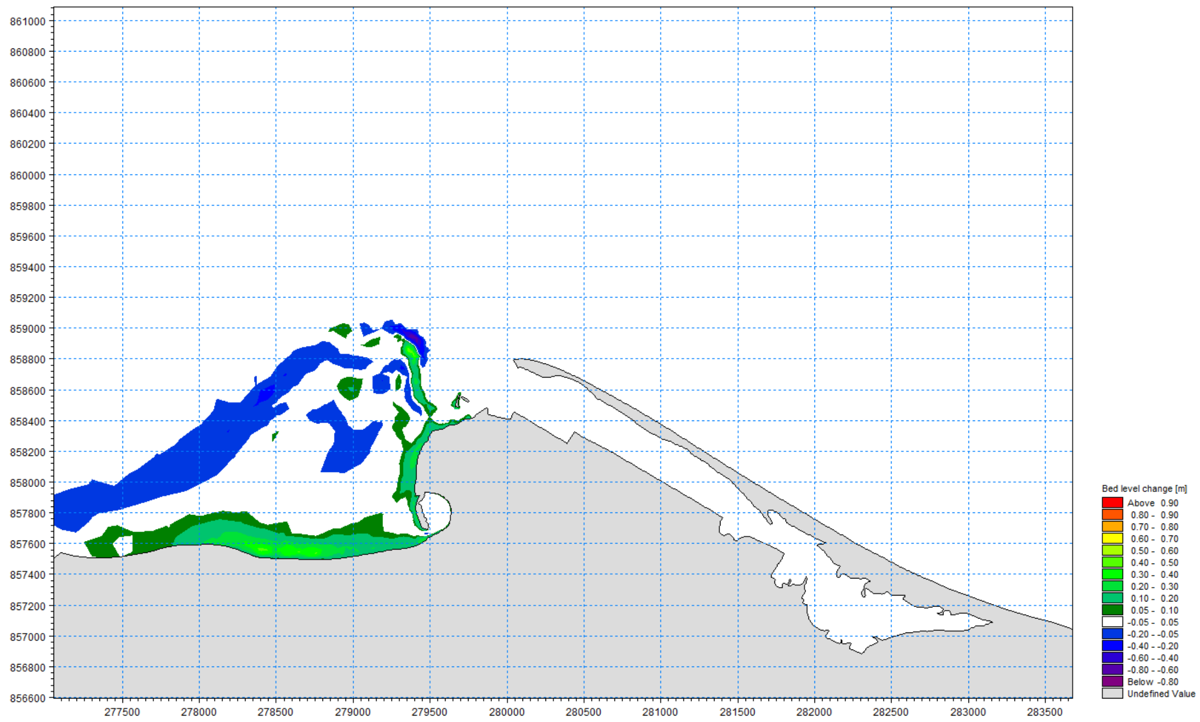


Figure 6-4: FMHDST_F PostDev 2023 Sands Trace Final Timestep – Bed Level Change

6.9.3 Post-Development 2018

Figure 6-5 presents predicted bed level change in the vicinity of Ardersier Port at the end of the 2018 post-development simulation. Figure 6-6 presents predicted bed level change in the vicinity of Ardersier Port at the end of the 2018 post-development spit trace simulation, whilst Figure 6-7 presents equivalent results for the sands trace simulation.

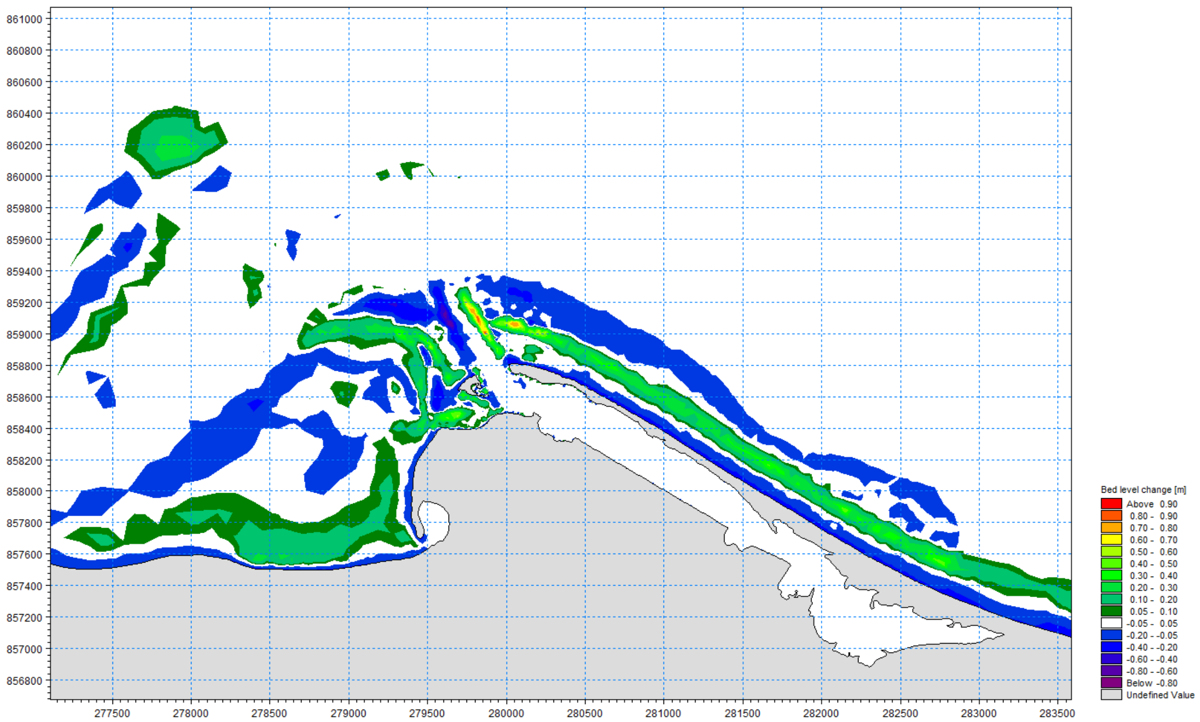


Figure 6-5: FMHDST_C PostDev 2018 Final Timestep – Bed Level Change

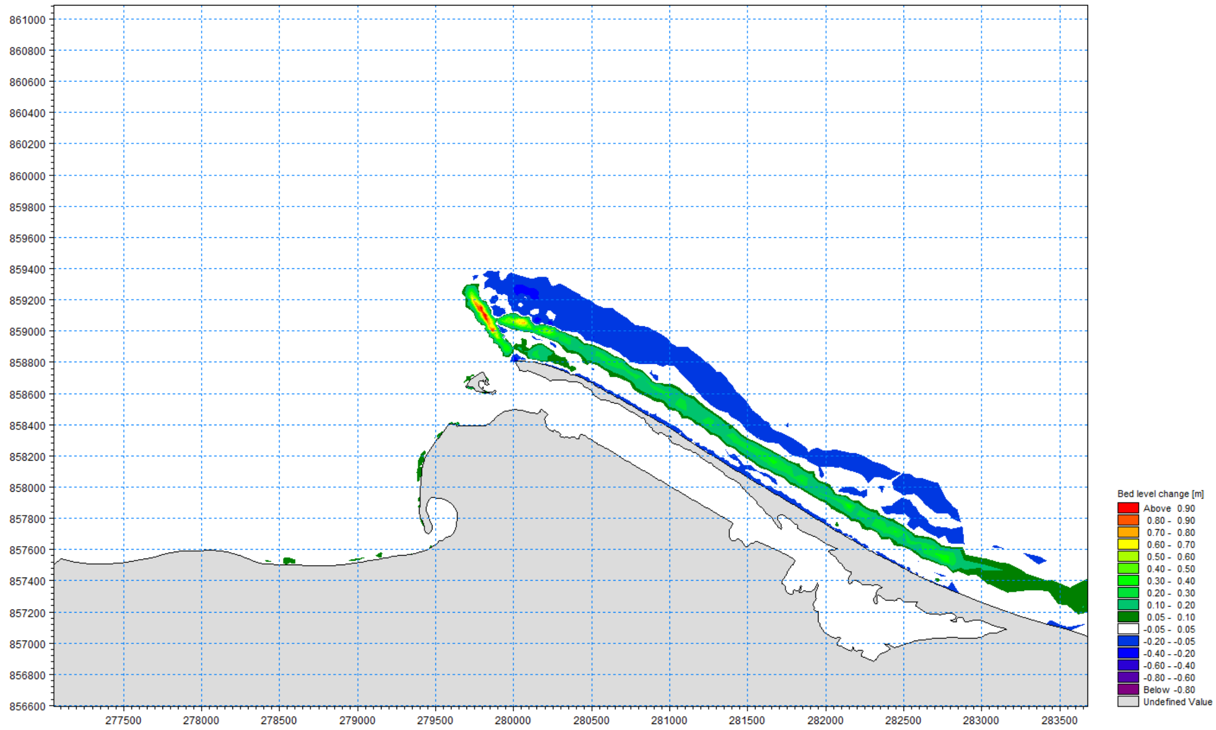


Figure 6-6: FMHDST_E PostDev 2018 Spit Trace Final Timestep – Bed Level Change

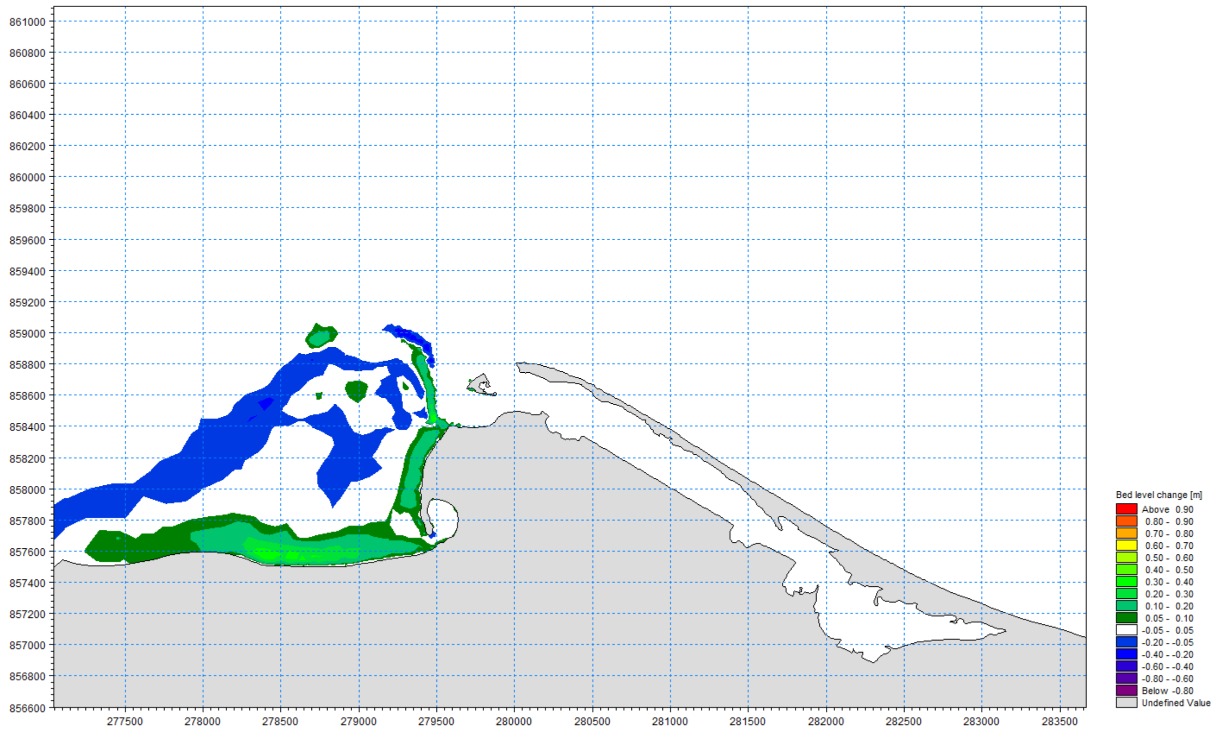


Figure 6-7: FMHDST_G PostDev 2018 Sands Trace Final Timestep – Bed Level Change

7 IMPACT ASSESSMENT

7.1 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 variation to the consented dredge activity. Comparisons between model results for the proposed 2023 post-development (dredge) scenario, results for the existing baseline (2023), and results for the previously consented 2018 post-development (dredge) scenario, are outlined in the following sections.

7.1.1 Tides

2023 Post-Development Versus 2023 Baseline

A comparison of the modelling results with and without the proposed 2023 dredge variation has been undertaken. This comparison highlights that there will be no significant impact on tidal levels, except to increase low water tidal range within the dredge zone. This is particularly evident where deposition has occurred in the harbour.

Hydrodynamic modelling results allow comparison of both flood and ebb tidal currents during a spring tidal cycle, with and without the 2023 dredge extent. A differential plot of mid-flood spring tidal currents (2023 post-development minus 2023 baseline) is presented in Figure 7-1. Figure 7-2 presents the equivalent plot for mid-ebb tide, and Figure 7-3 for the statistical maximum current speeds from each model scenario.

Comparison of the model results for the mid flood spring tidal currents indicates that there would be localised reductions in tidal velocity (up to 0.45 m/s) within the immediate vicinity of the navigation channel. Further outside the immediate vicinity of the proposed dredge zone, comparison of modelling results indicates there would be no significant impact on tidal velocities during the flood tide.

The ebb tide comparison of modelling results indicates a similar pattern to the flood tide, although with a slightly reduced extent, and reductions in current velocity (up to 0.45 m/s) within, and immediately adjacent to, the navigation channel. Again, outside the immediate vicinity of the proposed dredge zone comparison of modelling results indicates there would be no significant impact on tidal velocities during the ebb tide.

A similar pattern is shown on review of the statistical maximum differential plot, with results indicating reductions in current velocity (up to 0.6 m/s) within, and immediately adjacent to, the navigation channel. Again, outside the immediate vicinity of the proposed dredge zone comparison of modelling results indicates there would be no significant impact on tidal velocities.

Whilst the modelling results indicate that the proposed dredging will produce localised changes in current velocities. It is considered that these variations are insignificant in terms of the wider hydrodynamic regime of the Moray Firth, with post development velocities of a similar nature to those observed elsewhere.

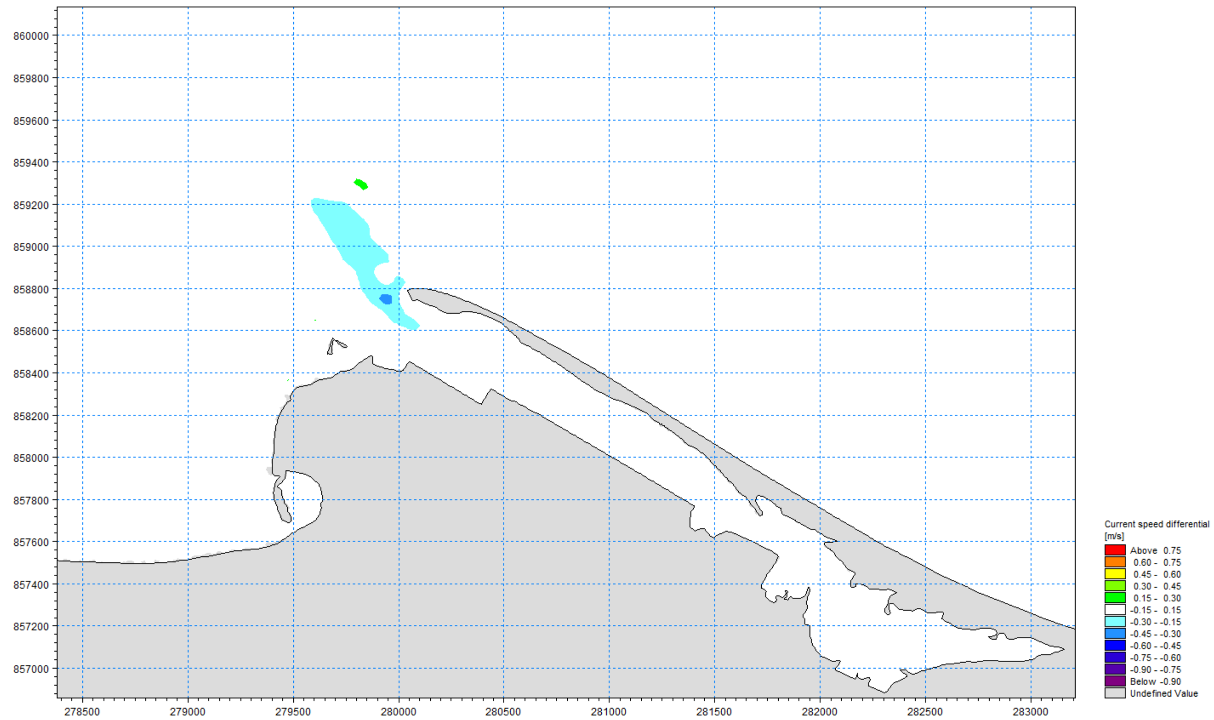


Figure 7-1: 2023 Post-Development Versus 2023 Baseline Mid-Flood Spring Tide – Current Speed Differential

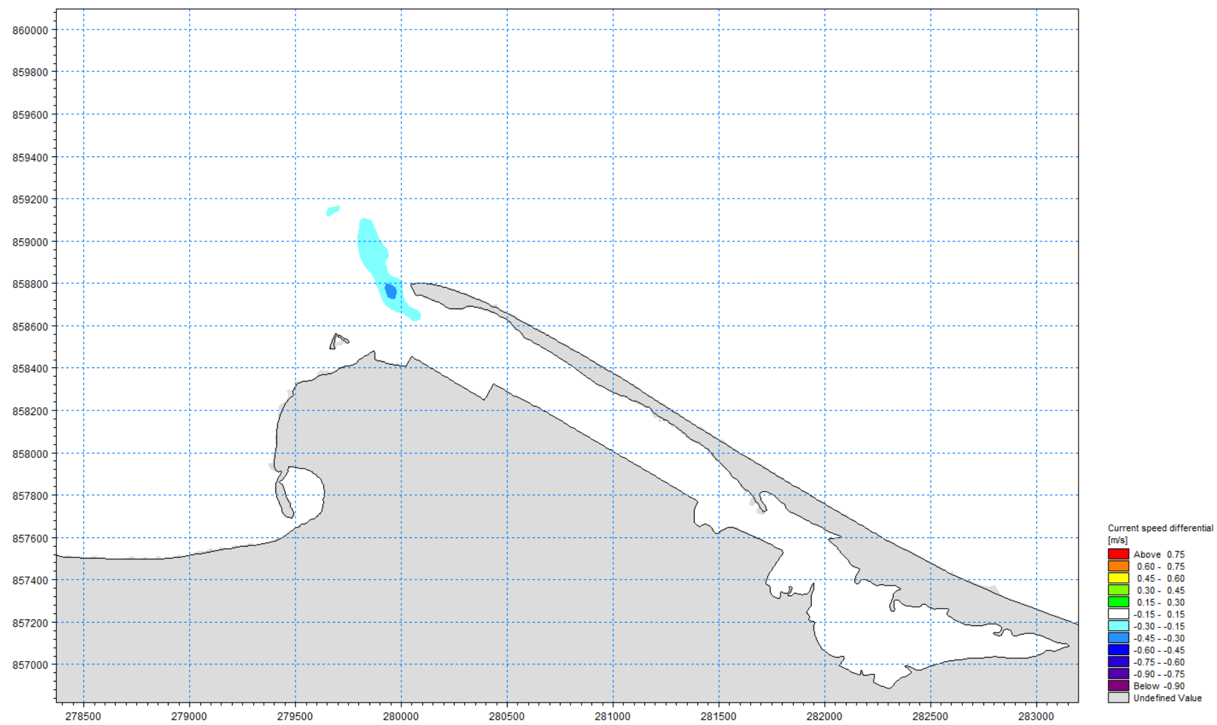


Figure 7-2: 2023 Post-Development Versus 2023 Baseline Mid-Ebb Spring Tide – Current Speed Differential

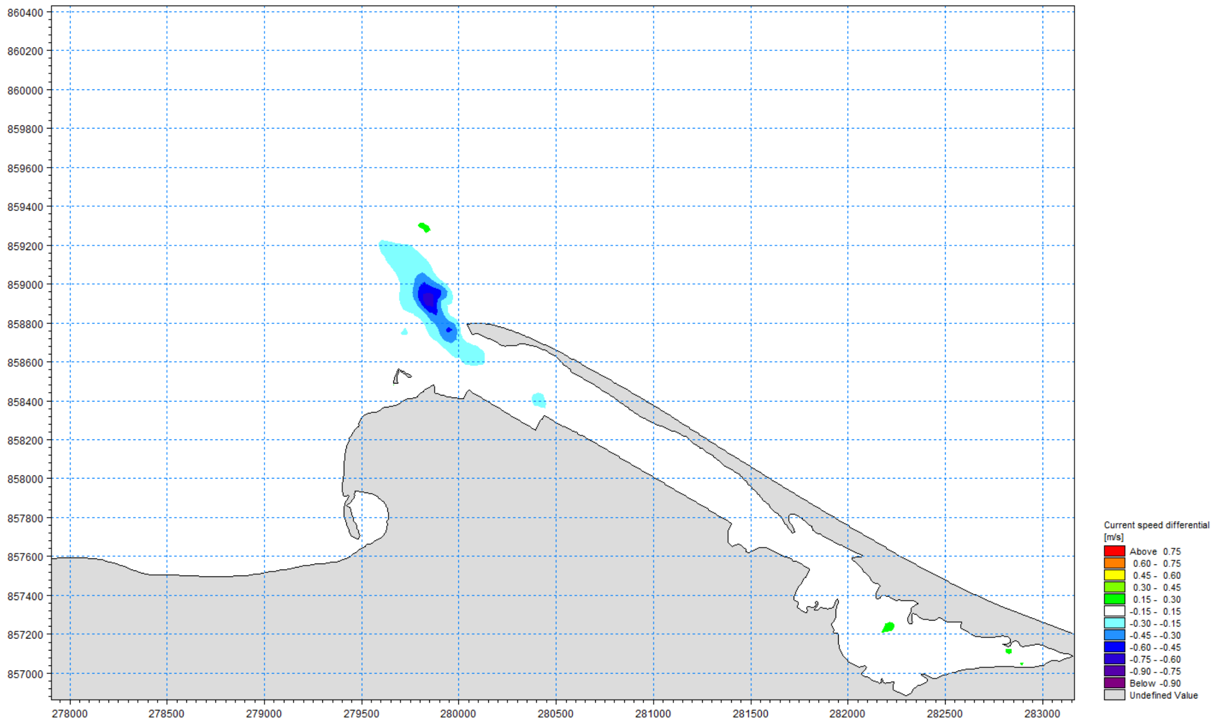


Figure 7-3: 2023 Post-Development Versus 2023 Baseline – Statistical Maximum Current Speed Differential

2023 Post-Development Versus 2018 Post-Development

A comparison of the modelling results with the proposed 2023 dredge variation versus the proposed 2018 consented dredge extent has been undertaken. This comparison highlights that there will be no significant impact on tidal levels.

Hydrodynamic modelling results allow comparison of both flood and ebb tidal currents during a spring tidal cycle, with the 2023 dredge extent versus the 2018 dredge extent. A differential plot of mid-flood spring tidal currents (2023 post-development minus 2018 post-development) is presented in Figure 7-4. Figure 7-5 presents the equivalent plot for mid-ebb tide, and Figure 7-6 for the statistical maximum current speeds from each model scenario.

Comparison of the model results for the mid flood spring tidal currents indicates that there would be limited and localised reductions in tidal velocity (up to 0.3 m/s) within the immediate vicinity of the navigation channel. Further outside the immediate vicinity of the proposed dredge zone, comparison of modelling results indicates there would be no significant impact on tidal velocities during the flood tide.

On the ebb tide comparison of modelling results indicate no significant change in current velocity between the two scenarios.

A similar pattern to the flood tide results is shown on review of the statistical maximum differential plot, with results indicating limited and localised reductions in current velocity (up to 0.3 m/s) within, and immediately adjacent to, the navigation channel. Alongside the quay face limited reductions (up to 0.6 m/s) are also observed. Outside the immediate vicinity of the proposed dredge zone comparison of modelling results indicates there would be no significant impact on tidal velocities.

The modelling results indicate that the proposed 2023 dredge variation will produce very limited and localised changes in current velocities within the dredge extent versus the consented 2018 dredge. It is considered that these variations are insignificant in terms of the wider hydrodynamic regime of the Moray Firth, with post development velocities of a similar nature to those observed elsewhere.

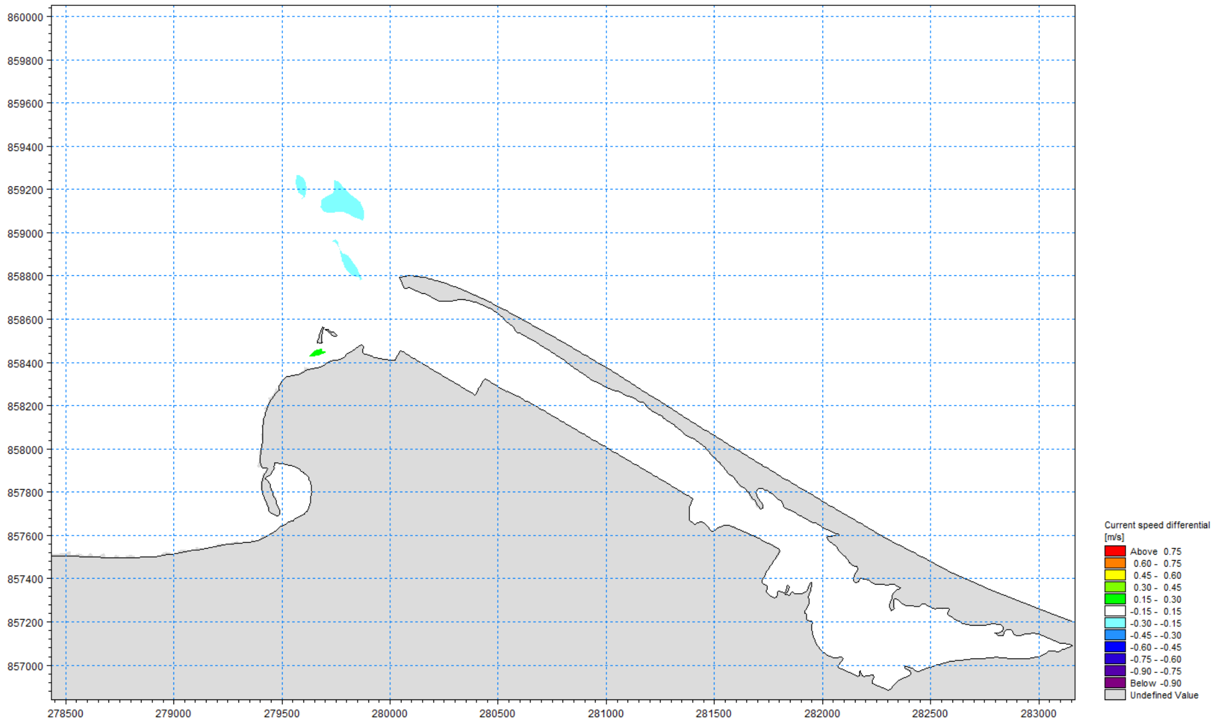


Figure 7-4: 2023 Post-Development Versus 2018 Post-Development Mid-Flood Spring Tide – Current Speed Differential

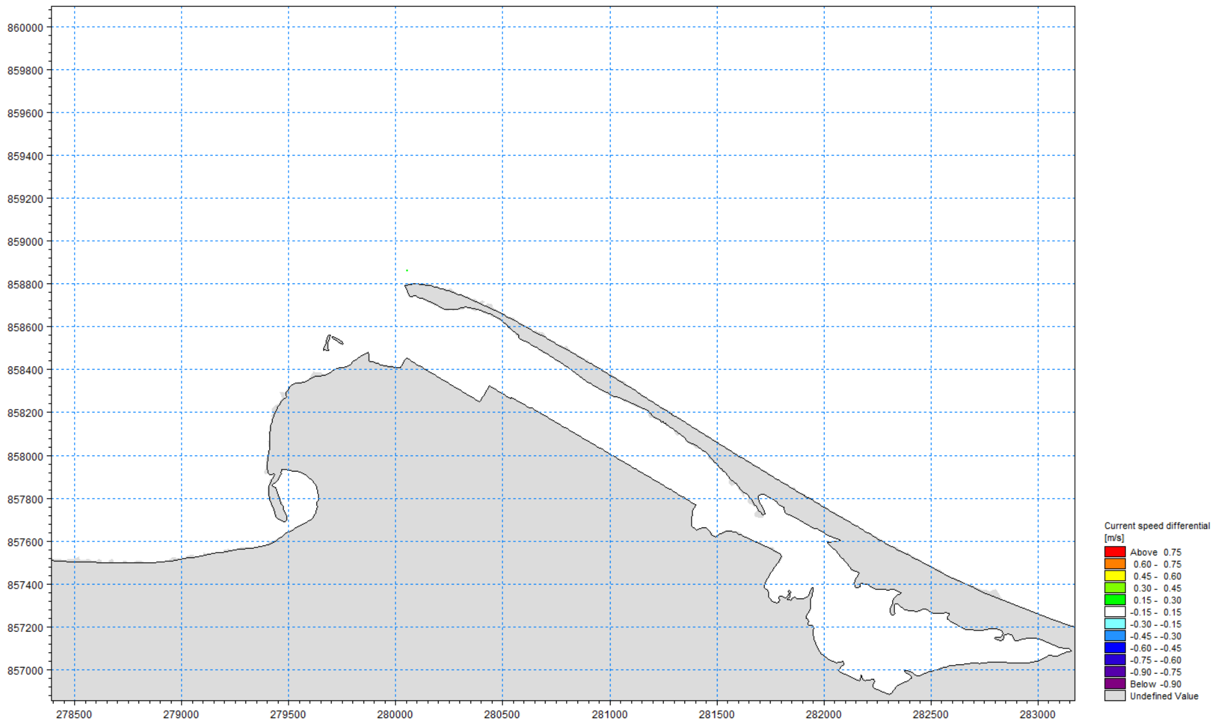


Figure 7-5: 2023 Post-Development Versus 2018 Post-Development Mid-Ebb Spring Tide – Current Speed Differential

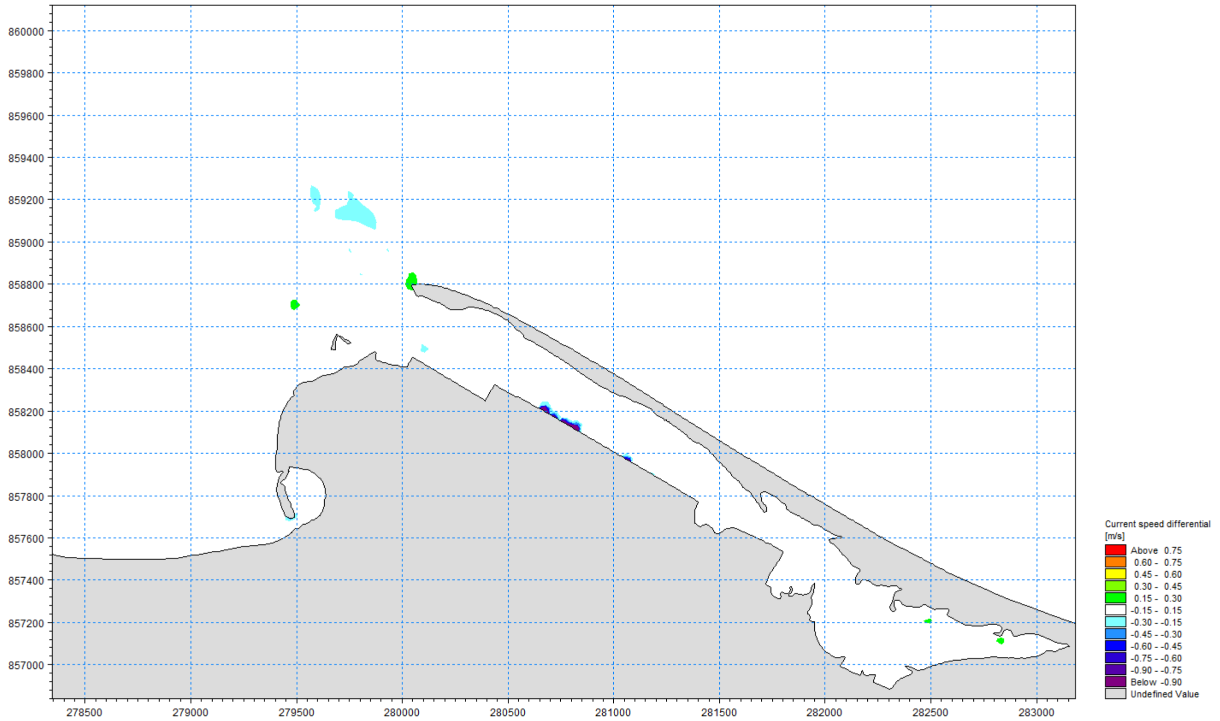


Figure 7-6: 2023 Post-Development Versus 2018 Post-Development – Statistical Maximum Current Speed Differential

7.1.2 Waves

2023 Post-Development Versus 2023 Baseline

Figure 7-7 presents a differential plot (2023 post-development minus 2023 baseline) of significant wave height for a selected storm in January 2003. Modelling results show that during such a typical winter period storm from the north-east the proposed dredging generally results in a slight increase in significant wave height within the dredge zone and immediate vicinity.

Waves would also be able to penetrate further into the harbour through the navigation channel. 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.

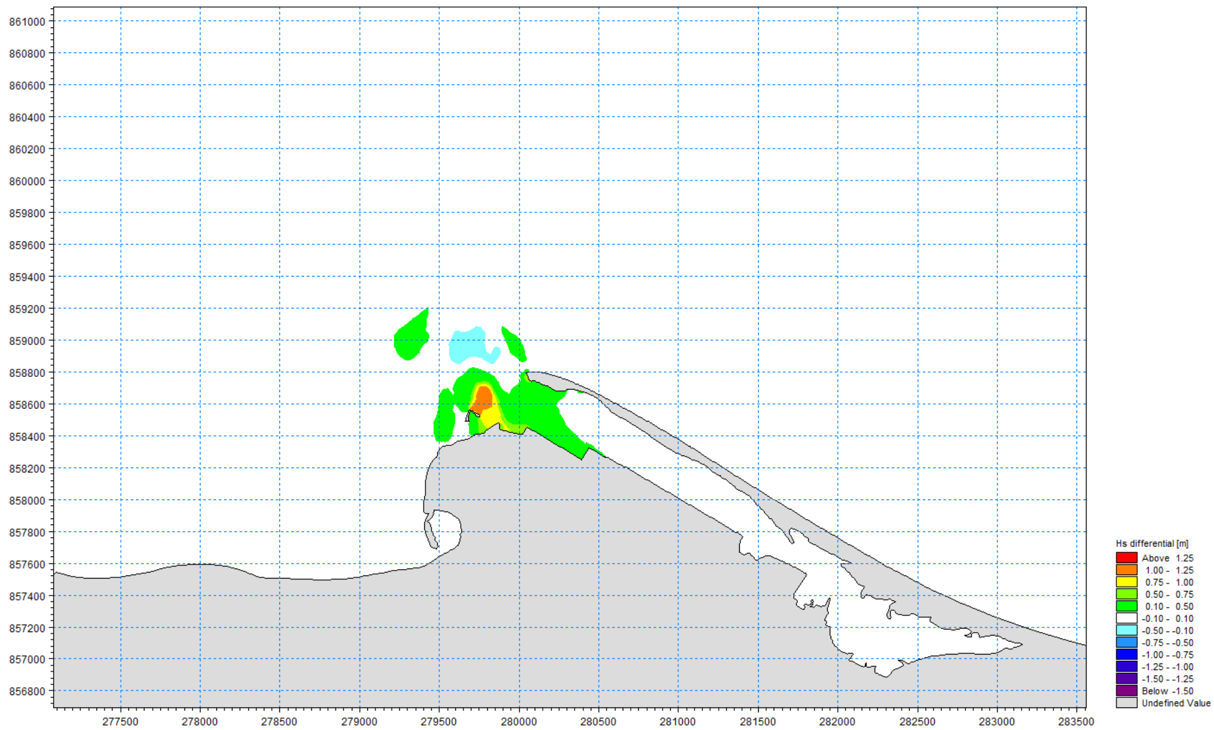


Figure 7-7: 2023 Post-Development Versus 2023 Baseline – Significant Wave Height Differential

2023 Post-Development Versus 2018 Post-Development

Figure 7-8 presents a differential plot (2023 post-development minus 2018 post-development) of significant wave height for the same storm in January 2003. Modelling results show that during such a typical winter period storm from the north-east the proposed dredge variation generally results in a slight increase in significant wave height within the dredge zone and immediate vicinity.

Waves would also be able to penetrate further into the harbour through the deeper and wider navigation channel. 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, with some minor differences observed related to bathymetric changes between 2018 and 2023.

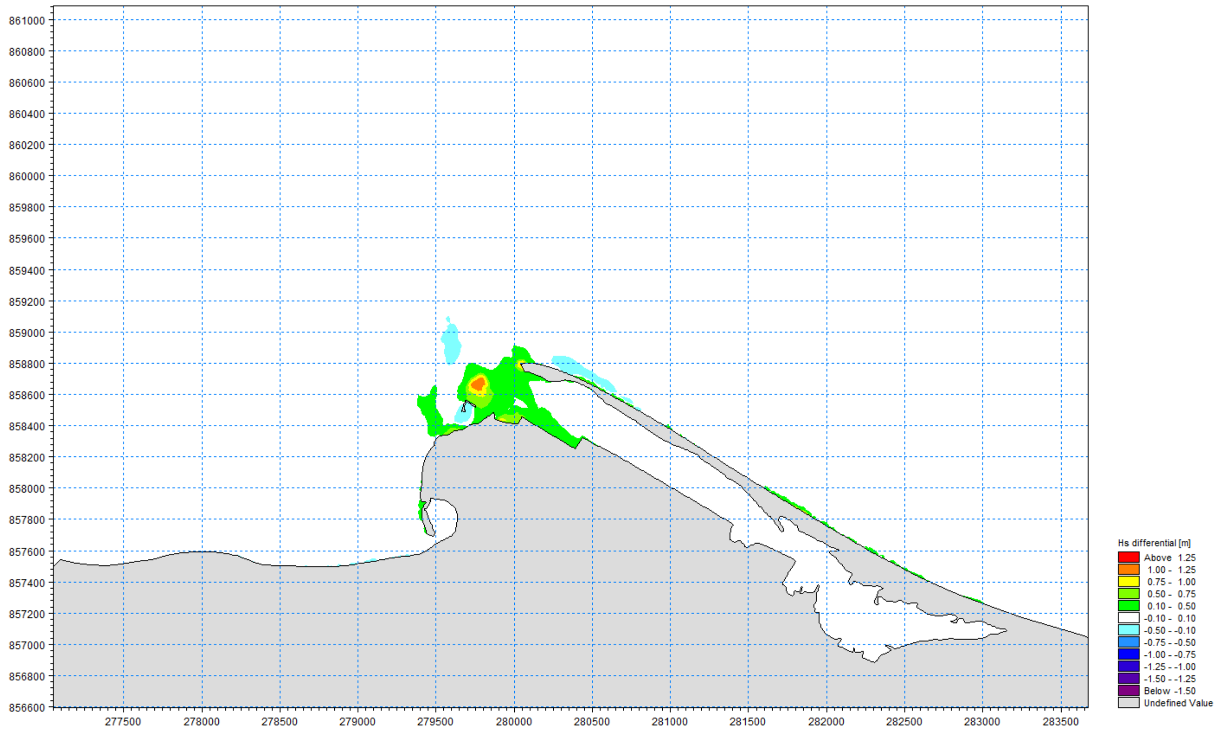


Figure 7-8: 2023 Post-Development Versus 2018 Post-Development – Significant Wave Height Differential

7.1.3 Sediment Transport (Coastal Morphology)

2023 Post-Development Versus 2023 Baseline

Sand transport patterns and pathways have been modelled for conditions with the proposed 2023 dredging works in place. Model runs applying a morphology speedup factor have simulated 3 months of sand transport under existing and proposed dredge conditions, as detailed in sections 6.9.1 and 6.9.2.

Figure 7-9 presents a differential plot of bed level change at the end of each simulation (post-development 2023 minus baseline 2023). This plot highlights that significant differentials in bed level change are limited to the dredge navigation channel, and the immediate vicinity. This indicates that the longshore transport of sand along the eastern face of the spit will continue unaffected by the proposed 2023 dredge. The modelling highlights that whilst the north-western intertidal and subtidal build out of the spit will continue to the east of the dredged navigation channel, the channel will act as a trap to the further westward transport of sediment.

To the west of the new channel the results indicate that the remaining intertidal and subtidal head of the spit will be subject to ongoing erosion, with sand predominantly being transported further west into the present location of the former dredged navigation channel, and across the north-eastern fringe of Whiteness Sands, in line with present day processes.

Due to the large volume of sediment currently available within the local coastal system, it is considered that the removal of the proposed dredge budget to land 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 localised in extent. It is considered that the longshore feed of sediment along the spit will continue, with change limited to the footprint and immediate vicinity of the dredge channel, and the north-eastern fringe of Whiteness Sands.

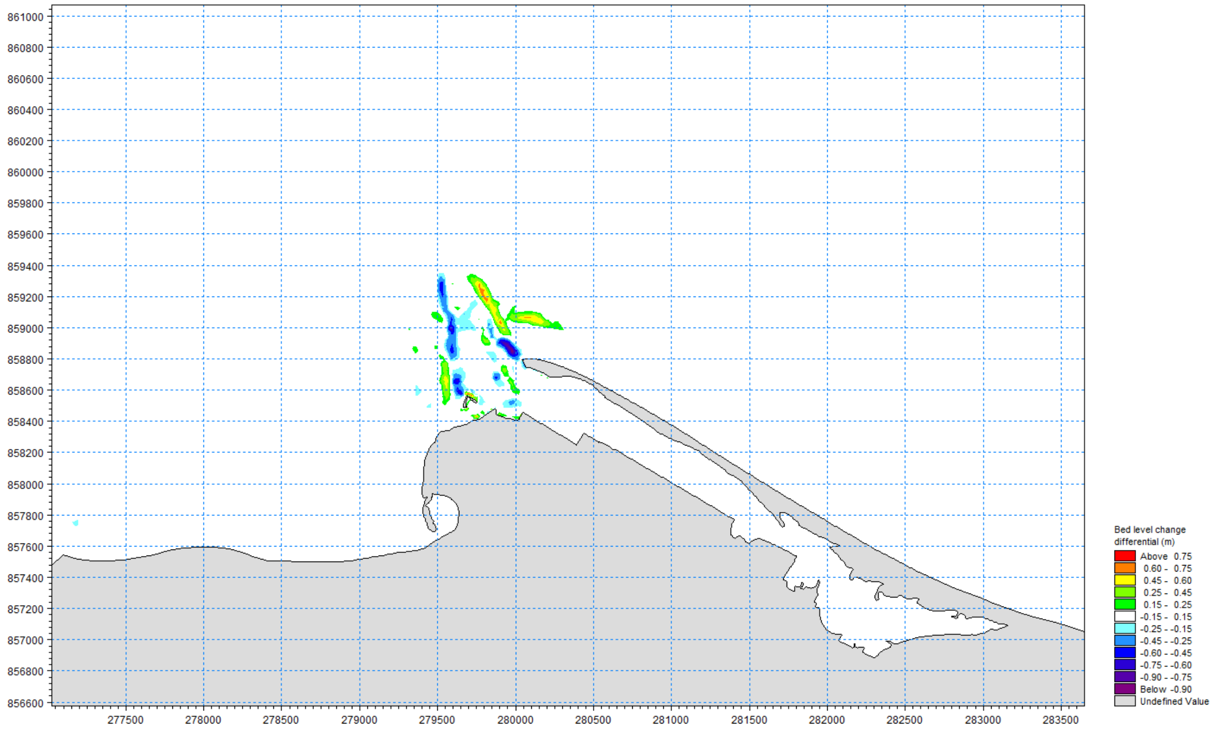


Figure 7-9: 2023 Post-Development Versus 2023 Baseline – Bed Level Change Differential

2023 Post-Development Versus 2018 Post-Development

Comparison has been undertaken between sand transport model results for the proposed 2023 dredge variation versus the consented 2018 dredge extent. Figure 7-10 presents a differential plot of bed level change at the end of each simulation (post-development 2023 minus post-development 2018). This plot highlights that differentials are limited to the dredge extent and immediate surrounds. Some of these differences may be attributed to changes in bathymetry between 2018 and 2023 input survey datasets, however primarily they relate to the change in dredge channel extent and the position of the channel tie-in slopes.

Figure 7-11 presents a differential plot of bed level change at the end of each simulation (post-development 2023 minus post-development 2018) for the spit trace model scenario, which focuses on assessing transport of sand from the sand spit in the east, and immediate surrounds. This plot highlights the movement in zone of deposition between the two dredge scenarios due to the wider dredge channel in the 2023 scenario. No significant change is predicted elsewhere, and importantly no change to the west of the dredge channel. Figure 6-3 highlights that some sand transport would continue across the dredge channel, with deposition occurring around the southern margin of Whiteness sands.

Figure 7-12 presents a differential plot of bed level change at the end of each simulation (post-development 2023 minus post-development 2018) for the sands trace model scenario, which focuses on assessing transport of sand from the Whiteness Sands in the west, and immediate surrounds. The plot shows very limited and localised differential between the two scenarios.

The model results and analysis indicate that the proposed dredge variation will have only limited and localised impact to sand transport processes, versus the consented 2018 dredge extents, with these changes primarily observed within the dredge extent. The results indicate that present day processes will continue relatively unaffected by the development in the wider setting, and key sediment transport pathways between the spit and sands are not significantly affected by the variation in dredge design.

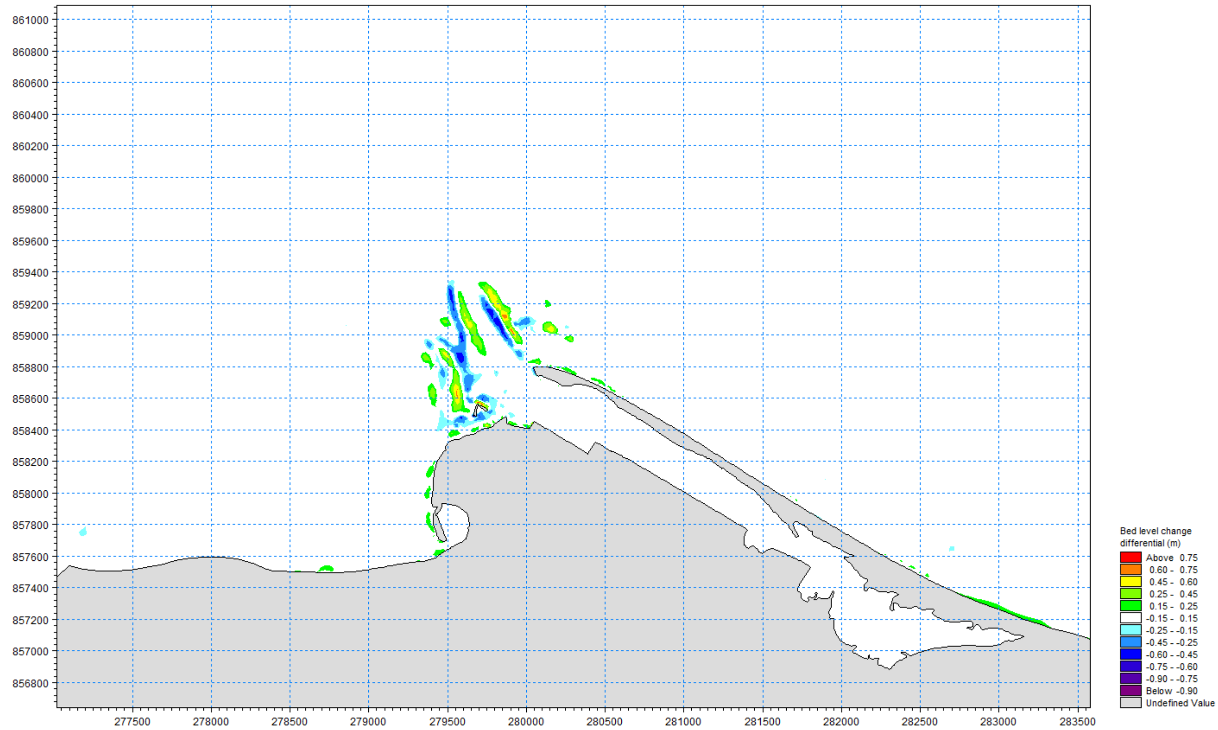


Figure 7-10: 2023 Post-Development Versus 2018 Post-Development – Bed Level Change Differential

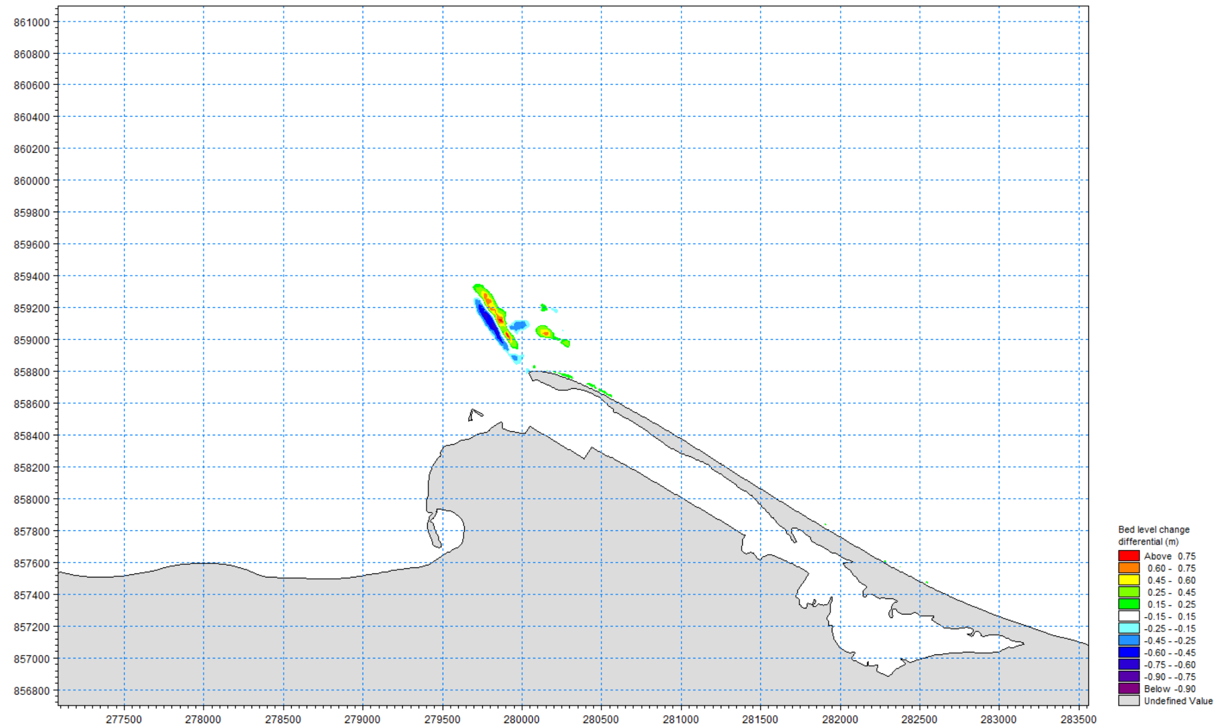


Figure 7-11: 2023 Post-Development Versus 2018 Post-Development – Bed Level Change Differential (Spit Trace)

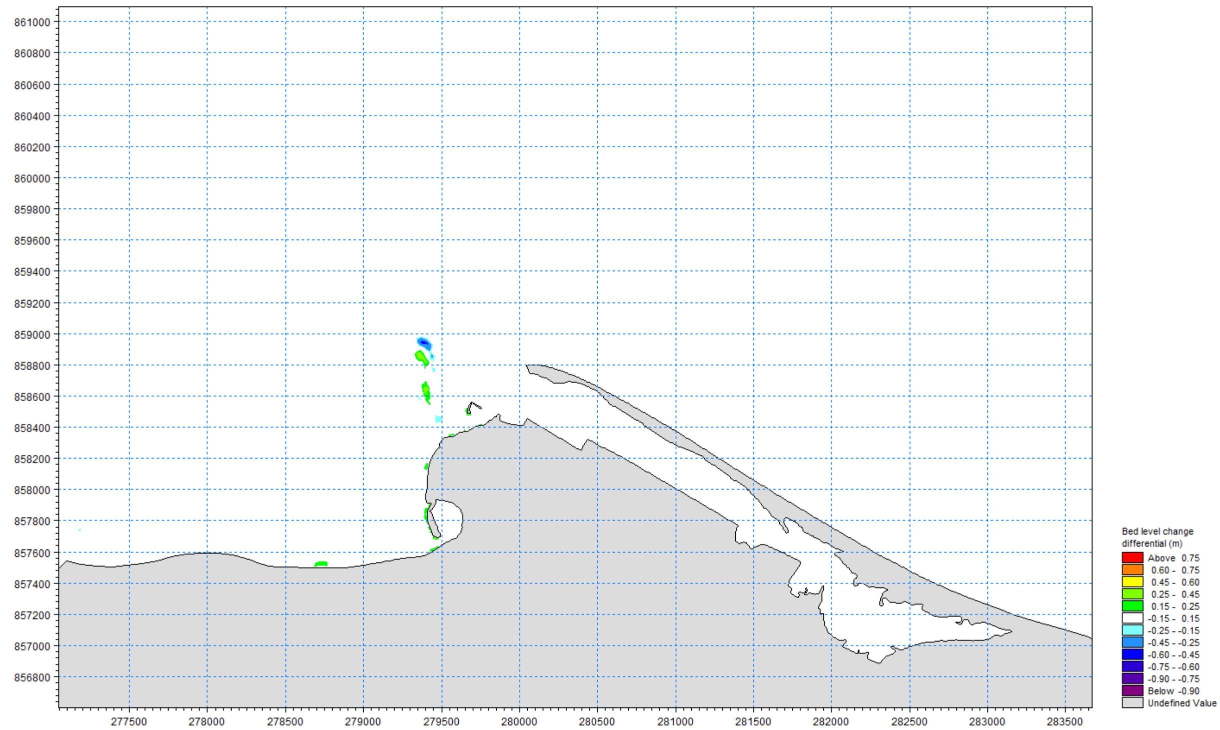


Figure 7-12: 2023 Post-Development Versus 2018 Post-Development – Bed Level Change Differential (Sands Trace)

7.2 Impact on Designations

The predicted zone of impact to coastal processes from the proposed 2018 dredge extent in relation to designated sites, as previously assessed, is identified in Figure 7.13. These impacts relate primarily to the dredging activities to reinstate the navigation channel and harbour. The extents shown are based on the conceptual understanding and supported by hydraulic modelling. Given the results of the updated coastal modelling presented in this report, it is considered that this predicted zone of impact remains true for the proposed 2023 dredge variation.

Comments in relation to the extent of the impact on the designated sites, and relative proportions of designation impacted, are provided in Table 7.1. The areas of the designated sites potentially impacted 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)

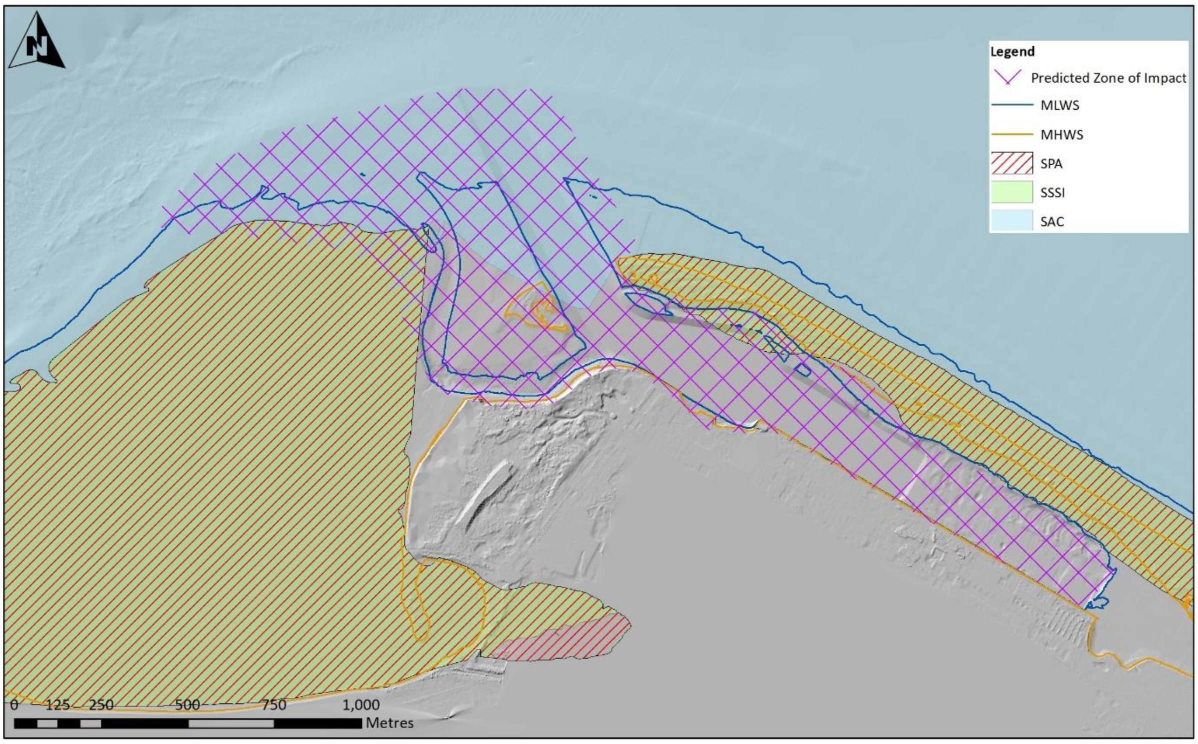


Figure 7.13: Predicted Zone of Impact in Relation to Designated Sites

Table 7.1: 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%

8 SUMMARY OF IMPACTS

In general terms, the proposed variation represents an increase in depth and width to the navigation channel as previously assessed in 2013 and 2018, while the relative positioning remains similar. The key findings of the predicted effects of the 2018 assessment have been reviewed in relation to the proposed variation and the updated modelling presented in this report, as summarised in Table 8.1.

Table 8.1: Review of Coastal Processes Impacts (2018) to 2023 Variation Change

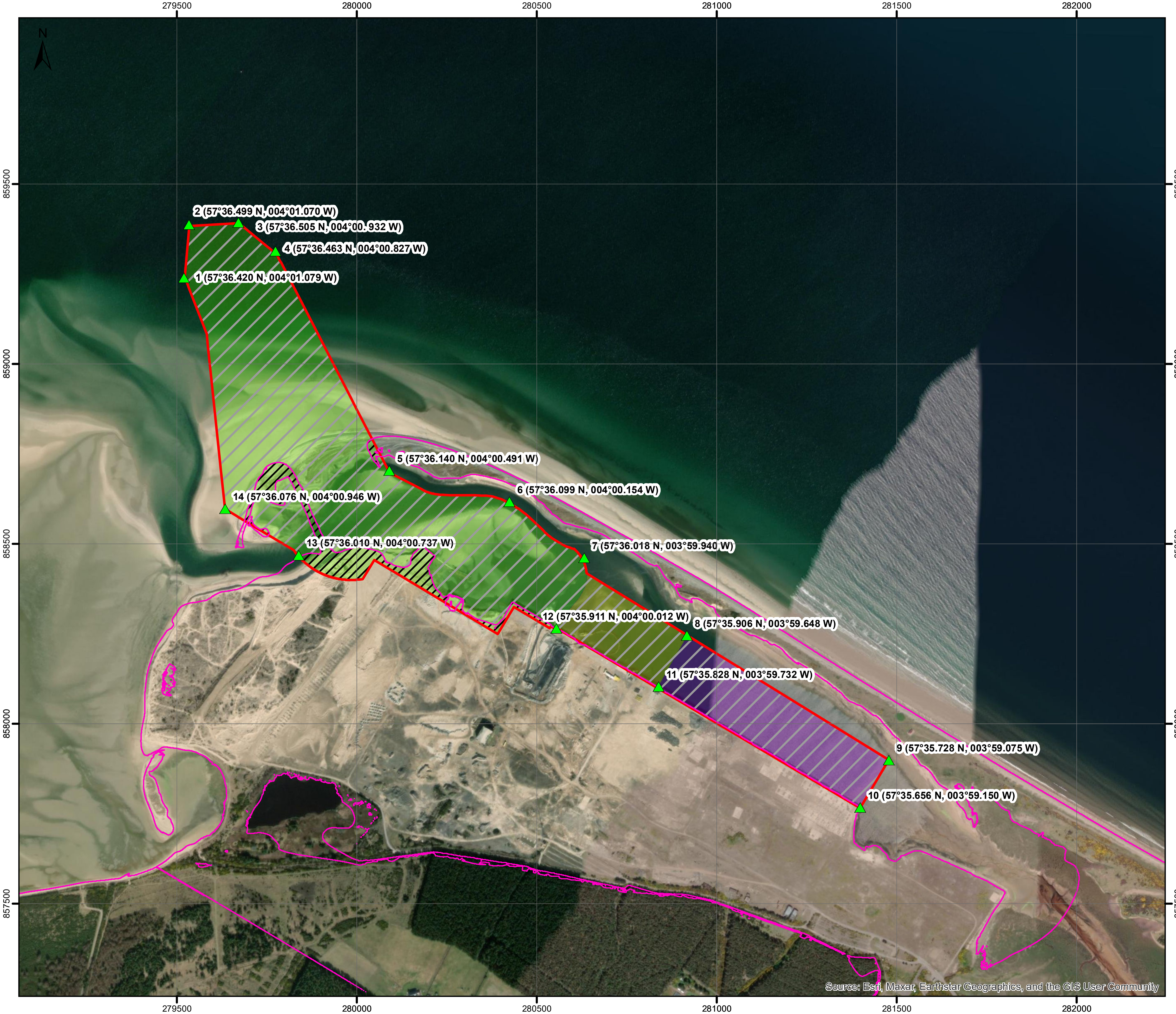
Coastal Process	2018 Assessment Findings	2023 Proposed Variation Conditions
Tides	No significant impact on tidal levels.	No Change.
	Low water tidal range will increase within dredge zone.	No Change.
	Localised reductions in tidal velocities within the immediate vicinity of dredge zone.	Further reduction due to increased depth and width of dredge zone.
	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 zone and waves able to penetrate into the harbour via the dredge channel.	Further increases in wave height in dredge channel and penetration into outer harbour / quay.
	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 significant change to process, position of initial deposition moves with dredge extents.
	Immediately west of the navigation channel dredge zone, the remaining intertidal and subtidal head of the spit 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.	Process will remain similar. Increase in area of subtidal bed exposed to erosion.
	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 footprint and immediate vicinity of the dredge channel and the north-eastern fringe of Whiteness Sands	No change.
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.

This updated assessment has reviewed the findings of the 2018 coastal processes assessment, in the context of a now proposed deeper and wider dredge within the same corridor, finds similar impacts would be anticipated. Where changes have been identified, these are predominantly within the immediate vicinity of the dredge zone, becoming less beyond this zone. Where changes are expected versus existing conditions, these are anticipated to be of a similar magnitude to those previously assessed in 2018 for the consented dredge design.

The overall impact of the proposed deeper dredge on the local conditions and processes is therefore not predicted to significantly change the overall findings of the 2018 assessment.

APPENDICES

A DREDGE DESIGN AND EXTENT



Legend

- Project Extent
- Mean High Water Springs (MWHS)
- Dredge Point Co-ordinates
- Areas Above MHWS for Removal
- Dredge Area Below MHWS

Dredge Depth (mCD)

- -3.0
- -6.5
- -12.9

Note: MWHS is 4.2mCD digised from CainTech UAV Survey undertaken in 2023

Do not scale this map

Client
Ardersier Port (Scotland) Ltd.

Project
Ardersier Port Dredge

Title
Revised Dredge Boundary 2023

Status
FINAL

Drawing No.	Revision	Date
676693-GIS006	B	10 Oct 2023
Drawn	**Checked**	**Approved**
MN	CCAS	CCAS

Scale
1:10,000 @A3
0 50 100 200 300 Metres

Rev	Date	Amendment	Initials
A	25/10/23	MHWS added and co-ordinates updated	JAS
B	02/11/23	Labels updated	JAS

envirocentre

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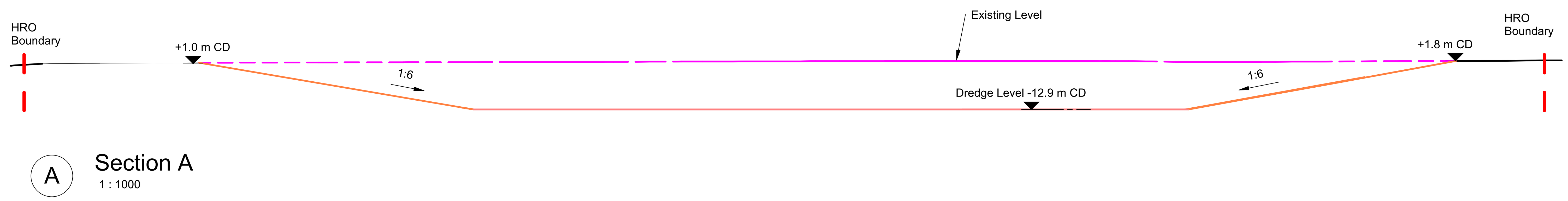

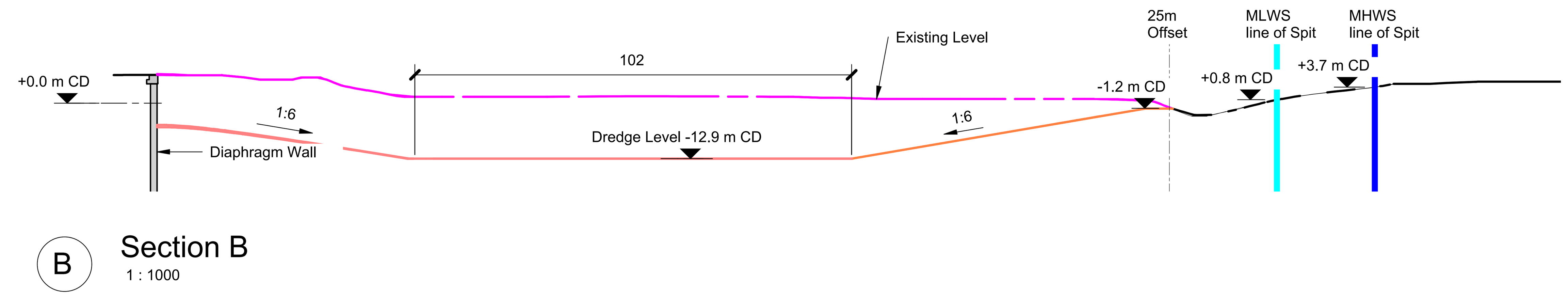

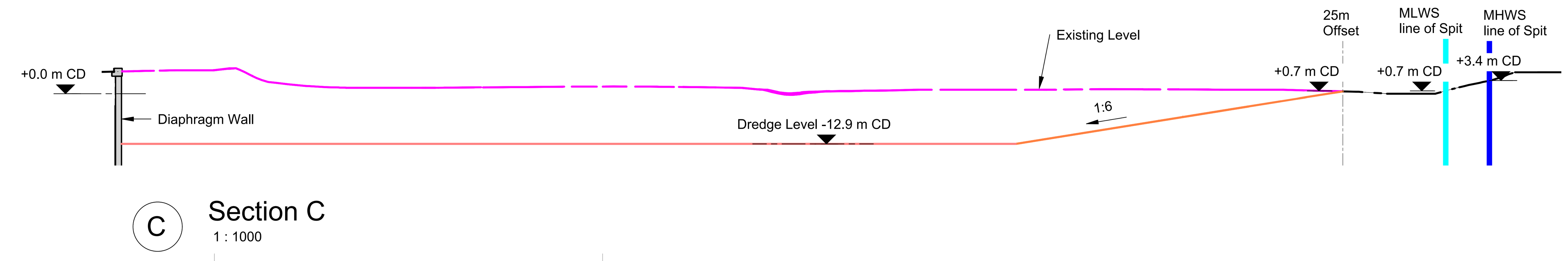

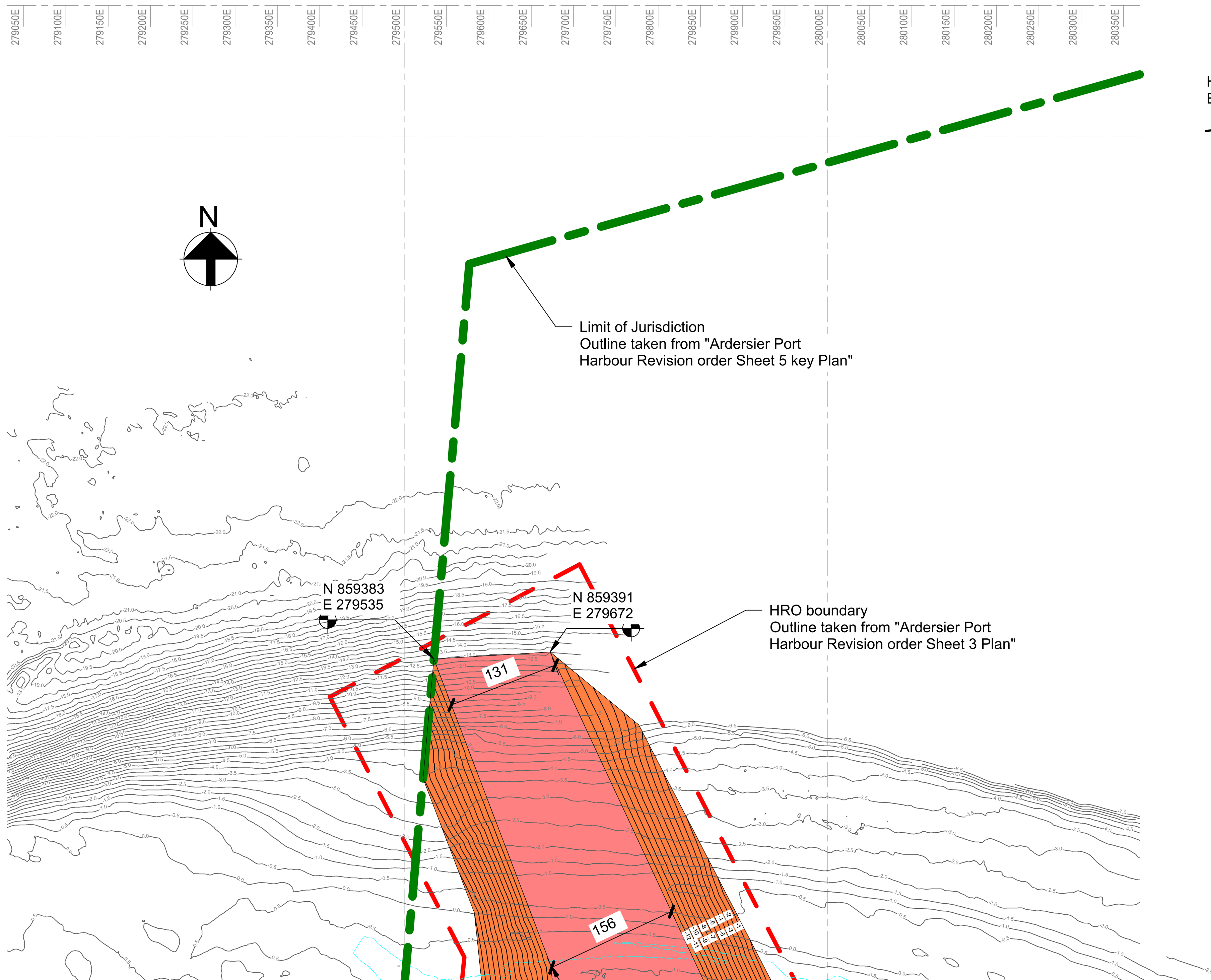
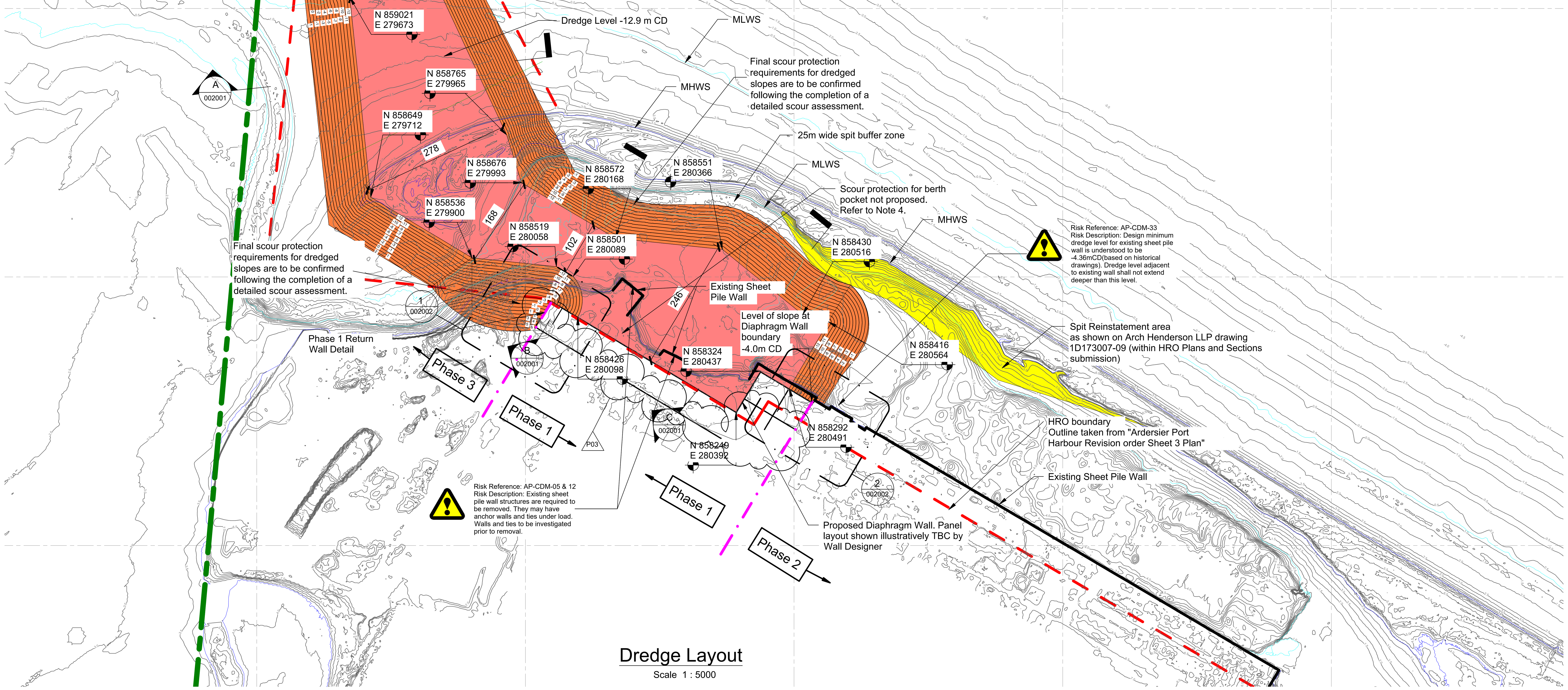

Legend

- Dredge Slope 1:6
- Spit Reinstatement area

SAFETY, HEALTH & ENVIRONMENT

Notes below are additional to hazards normally associated with this type of work which a competent Contractor using safe methods of working should be aware of. Consult Arup Designer Risk register (Ref: "AP-CDM") for assessment of hazards at this stage of design. Additional hazards (including any associated with construction, operation, maintenance, or removal / demolition) are to be determined by Temporary Works Designer.

1. Ref: AP-CDM-05 — Existing sheet piles at likely to have associated anchor walls which are not recorded on surveys.
2. Ref: AP-CDM-12 — Contractors to be aware of the risk of unrecorded buried obstructions or services.
3. Ref: AP-CDM-20 — Potential risk of encountering UXO during excavations / dredging.
4. Ref: AP-CDM-21 & Ref: AP-CDM-31 — Contaminated ground.
5. Ref: AP-CDM-25 — Excessive diaphragm wall movement.
6. Ref: AP-CDM-34 — Unexpected ground conditions / obstructions.
7. Refer to specific risks highlighted on sheet.

Not for Construction

Notes:

1. All levels are in m above Chart Datum (mCD).
2. Coordinates are shwon to OS National Grid.
3. Details shown are based on concept design calculations and information. All details are subject to detailed design.
4. Phase 1 dredge levels are proposed on the basis that no scour protection is constructed, however, the berthing pocket will be monitored for signs of scour and reinstated if scour is observed. Bathymetric surveys shall be undertaken as follows:
   a) following construction of the works but prior to operation of the port;
   b) 2 weeks after the port becomes operational or after the first three vessels have used the port, whichever is first;
   c) every two months following the first operational survey;
   d) after any significant event which may have caused scour (e.g. after vessels of greater than 200m length or vessels which have a under keel clearance of 2m or less have used the port).

   The frequency of survey shall be reviewed after 12 months.
5. Assumed design life for sheet piles and tie rods is 60 years. TBC as part of detailed design.

Issue	Date	
P03	14/07/2023	Updated in line with Bauer Diaphragm and Anchor wall confirmation
P02	21/06/2023	Updated for Concept design stage submission.
P01	18/05/2023	First Issue

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Client: Ardersier Port

Project Title: Ardersier Port

Drawing Title: Phase 1 Proposed Dredging Layout Sheet 1

Scale at A1	As indicated
By / Chkd / Appd	JDW/AR/PST
Role	Civil - Geotechnical
Status	S2 - Suitable for Information -
Arup Job No	294067-00
Rev	P03
ID	294067-ARUP-XX-XX-DR-CG-002001

Do not scale

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