A.1 Introduction

Jacobs have developed a suite of numerical models of the project area to support the design process; these models provide the following inputs:

- Wave, water level and tidal current parameters that are essential for the design of coastal protection structures.
- Information on the historical shoreline change and predicted future shoreline change if no additional coastal protection works are undertaken.
- Modelling of key options to understand their effectiveness of reducing wave and water level impacts at the railway and any changes to how sediment circulates within the study area.

A.1.1 Phase 1 Baseline Modelling Overview

Baseline modelling was undertaken by Jacobs during Phase 1 of the project. This baseline modelling also included the effect of spatial and temporal changes in water level on waves and variable sediment transport rates.

A two-dimensional wave model of the East Coast of Ireland was set up to derive wave data at nearshore points along the study area. This model uses wind and wave data recorded in the Irish Sea by the Irish Marine Data Buoy Observation Network and the UK Met Office and bathymetry information from INFOMAR and C-MAP to predict the wave heights, periods and direction close to the shoreline.

The baseline modelling of the shoreline looked at locations of interest between Dublin Bay and Wicklow Harbour to estimate the quantity of beach sediment moving along the coast and to predict the future shoreline position in 2055 and 2100. The results of this modelling highlight the areas of the railway which are most at risk of erosion.

A.1.2 Phase 2 Modelling Overview

Under Phase 2 of the project, a Coastal Area Model (CAM) which includes the effects of two-dimensional bathymetry variation on waves, tides, associated flows and sand transport, was set up for the coastline between Bray Head and Wicklow Head to provide more detailed analysis for CCA5 and CCA6. This model was run for the present day (2025) and with an allowance for 100 years of climate change impacts. The CAM has three parts which run in parallel and provide outputs to each other: one module for waves (SW model), one for water levels (HD model) and one for sediment transport (ST model). The model extents are shown in Figure A.1-1 and Figure A.1-2 indicates how the CAM modules are inter-linked. The CAM is computationally intensive and therefore it has been run for a set of representative conditions that could be expected to occur within a normal year.

For CCA6.1, a shoreline evolution model in LITLINE has also been set up; this has been used to calculate longshore sediment transport rates and associated changes in the shoreline position in 2025, 2055 and 2100. The LITLINE model extents including nearshore wave points are shown in Figure A.1-3.

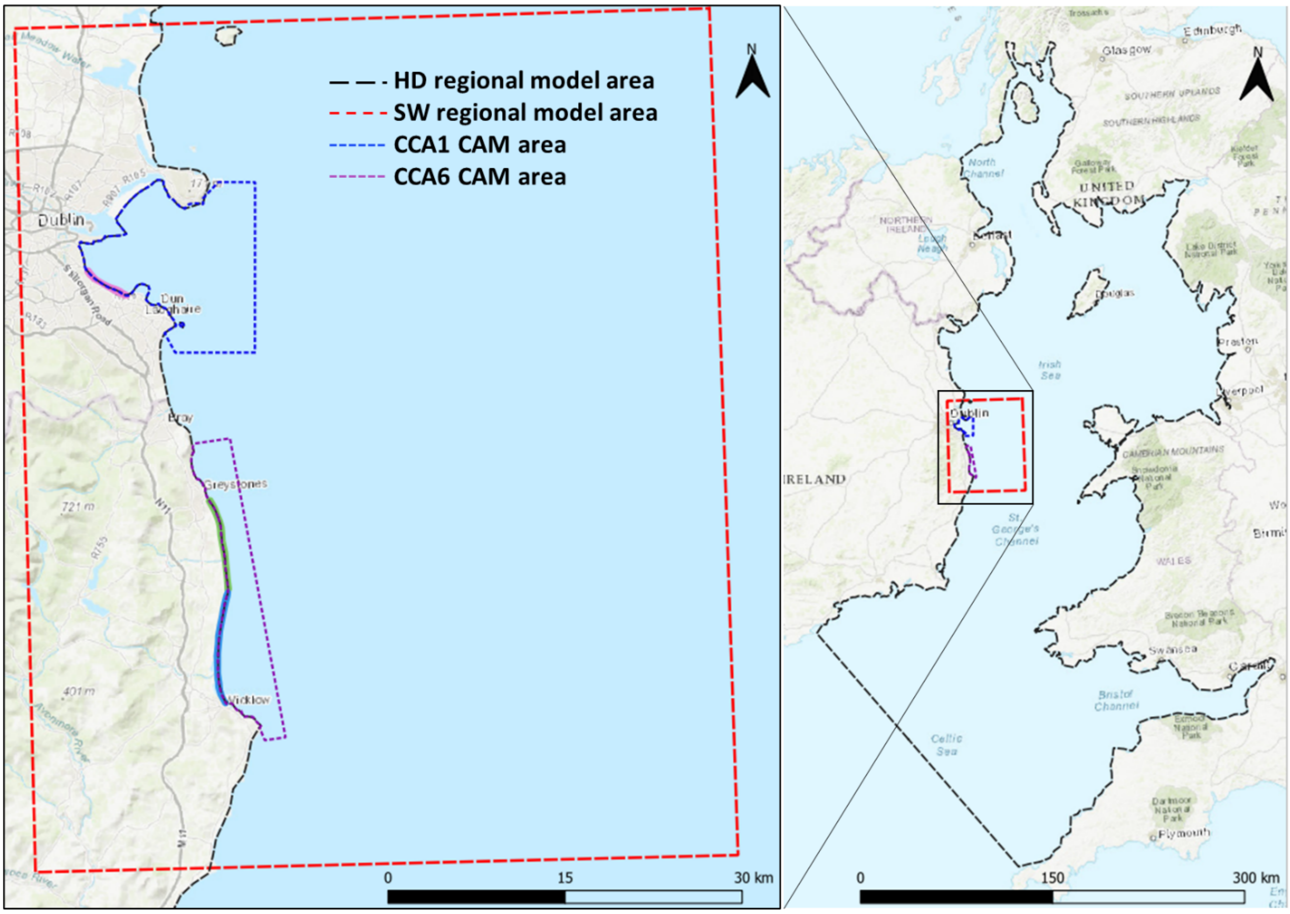


Figure A.1-1. Outlines of regional hydrodynamic model, regional wave model and local CAM.

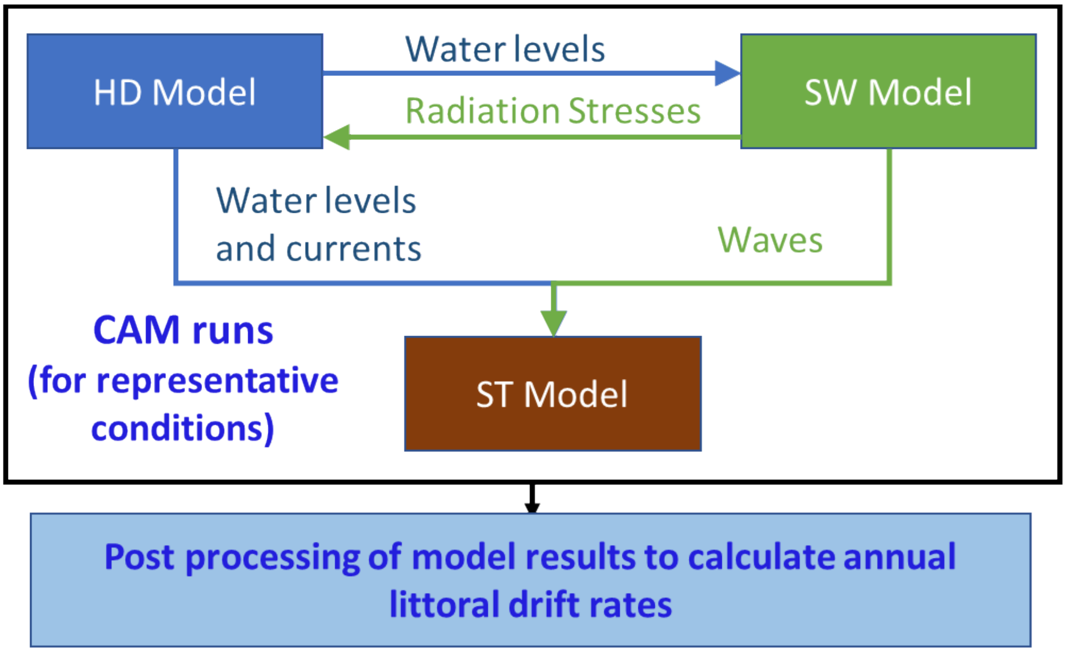


Figure A.1-2. Overview of Coastal Area Modelling (CAM) methodology

Figure A.1-3. LITLINE model extents showing baseline, hard defences (revetments), profile and nearshore wave and water level locations for CCA6.1.

A.2 Waves and Water Levels

A.2.1 Waves

Figure A.2-4 provides the CAM wave module results for offshore waves approaching from the north to south sectors. The largest waves at the nearshore points are generated for waves approaching from 75°N.

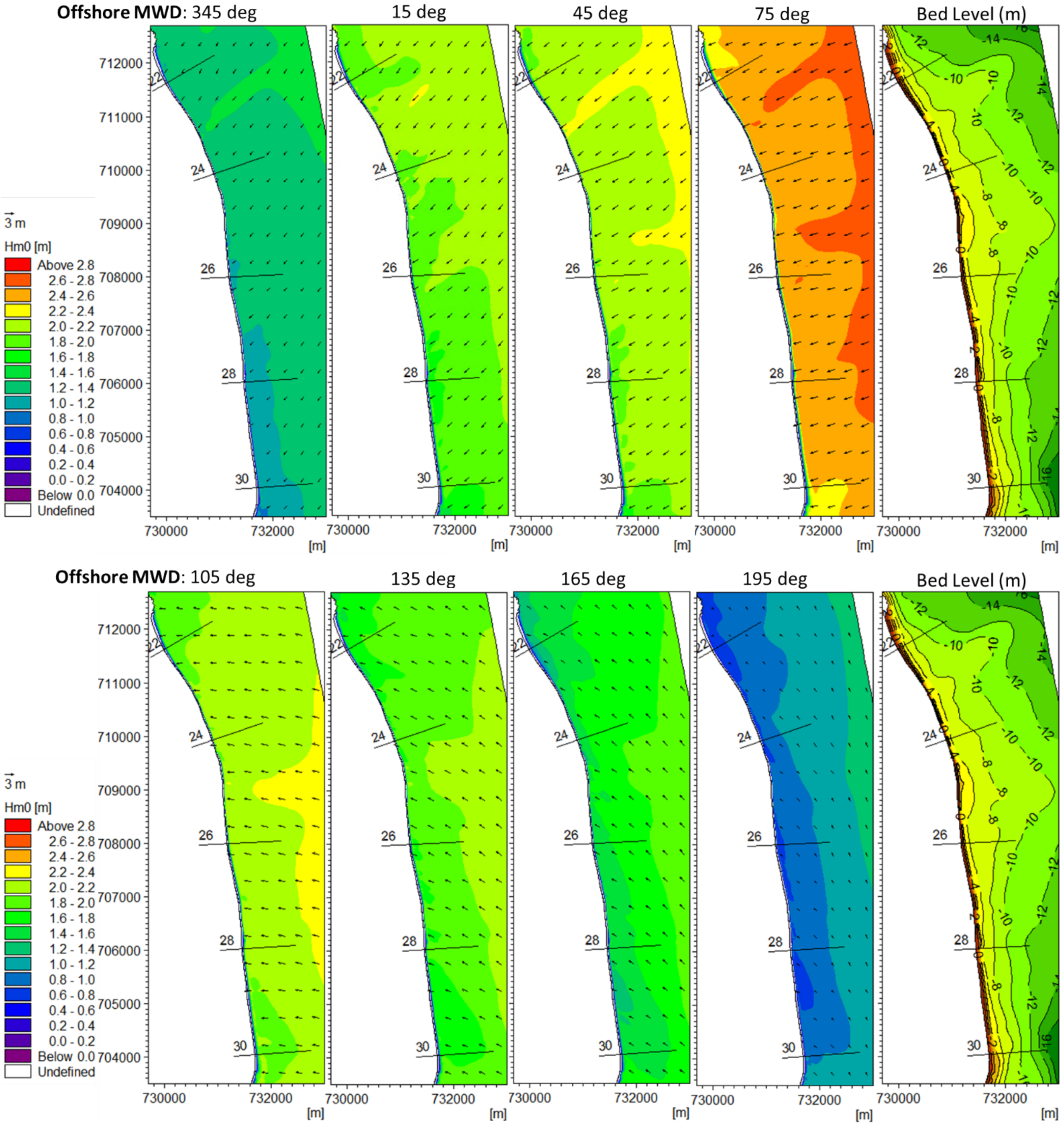


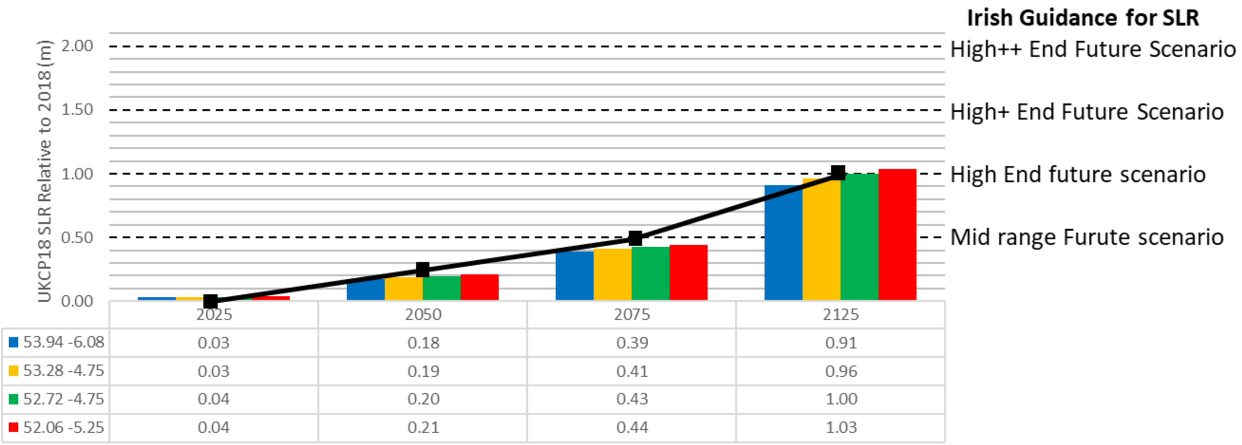
Figure A.2-4. Representative wave heights from a range of different offshore wave directions

A.2.2 Water Levels

A.2.2.1 Sea Level Rise

The following sea level rises have been adopted on consideration of Irish (OPW) and UKCP18 guidance. These are plotted against the guidance in Figure A.2-5.

- Present day (2025) = +0.00 m
- Year 2055(P + 30 yrs) = +0.30 m
- Year 2075 (P + 50 yrs) = +0.50 m
- Year 2125 (P +100 yrs) = +1.0 m



	2025	2050	2075	2125
🟦 53.94 -6.08	0.03	0.18	0.39	0.91
🟨 53.28 -4.75	0.03	0.19	0.41	0.96
🟩 52.72 -4.75	0.04	0.20	0.43	1.00
🟥 52.06 -5.25	0.04	0.21	0.44	1.03

Figure A.2-5. Comparison of UKCP18 sea level rise projections and Irish Guidance. Proposed SLR curve shown with black line

A.2.2.2 Tidal Levels

Admiralty TotalTide (ATT, 2023) water levels have been extracted for the Irish Sea covering the extent of the modelled area (Figure A.2-6). The levels for Dublin North Wall and Wicklow Harbour are summarised in Table A.2-1.

It should be noted that the tidal range decreases from north to south through CCA6; this is due to the increasing proximity to an amphidromic point near Cahore Point (Co. Wexford) where the tidal range is very small.

Table A.2-1. Tide levels for Dublin North Wall

Tidal Level	Dublin North Wall (mODM)	Wicklow Harbour (mODM)
Highest Astronomical Tide	+1.99	
Mean High Water Springs	+1.59	0.19
Mean High Water Neaps	+0.89	-0.21
Mean Sea Level	-0.11	
Mean Low Water Neaps	-1.01	-1.41
Mean Low Water Springs	-1.81	-1.81
Lowest Astronomical Tide	-2.61	

Figure A.2-6. Admiralty Total Tide data locations and model area; Cahore Point is included for reference

A.2.2.3 Extreme Water Levels

Extreme water levels are available along the Irish coast from the Irish Coastal Wave and Water Level Modelling Study (ICWWS, 2018), and along the Welsh coast from the Coastal Flood Boundary (CFB, 2018) dataset. Both sets of data are used to provide boundary conditions to the general ECRIPP model. Water levels at 39 locations from Dublin Bay to Wicklow Harbour have been extrapolated using these input data.

A.2.3 Joint Probability of Waves and Water Levels

Joint probability analysis combines the likelihood of two different variables occurring at the same time. In the design of coastal structures, it is common to use joint probability pairs of wave heights and water levels; this provides the design team with several different inputs which have the same chance of occurrence to fine-tune the design against. Figure A.2-7 shows the joint probability results for the 1 in 2 and 1 in 200 year return period conditions in the present day, 2055, 2100 and 2125. The left hand panel contains the conditions at nearshore point 26 and the right hand panel contains the offshore conditions.

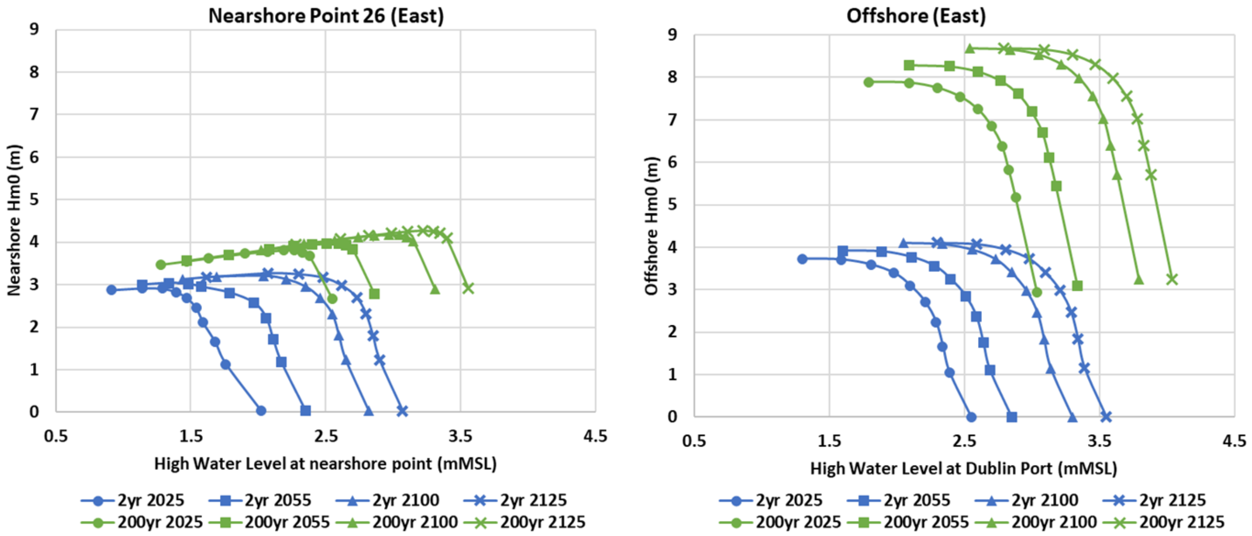


Figure A.2-7. Joint probability plots of wave height (y-axis) and water level (x-axis) at nearshore point 26 and offshore for the 1 in 2 and 1 in 200 return period conditions in the present day and with sea level rise.

A.3 Currents

Two dimensional plots of current speeds at low tide and at peak flood (highest currents on the rising tide) are shown in Figure A.3-8. Figure A.3-9 shows the currents speeds at high tide and at peak ebb (highest currents on the falling tide). These plots show that the tidal currents along the CCA6.1 frontage are low (< 0.2 m/s) at all stages of the tide.

Current flows northward along CCA6.1 during the rising tide and southward on the falling tide. Tidal currents are moderate (0.6 - 1.4 m/s) and are greatest across the shallow area between wave points 24 and 26. Currents close to the shoreline are at the lower end of this range.

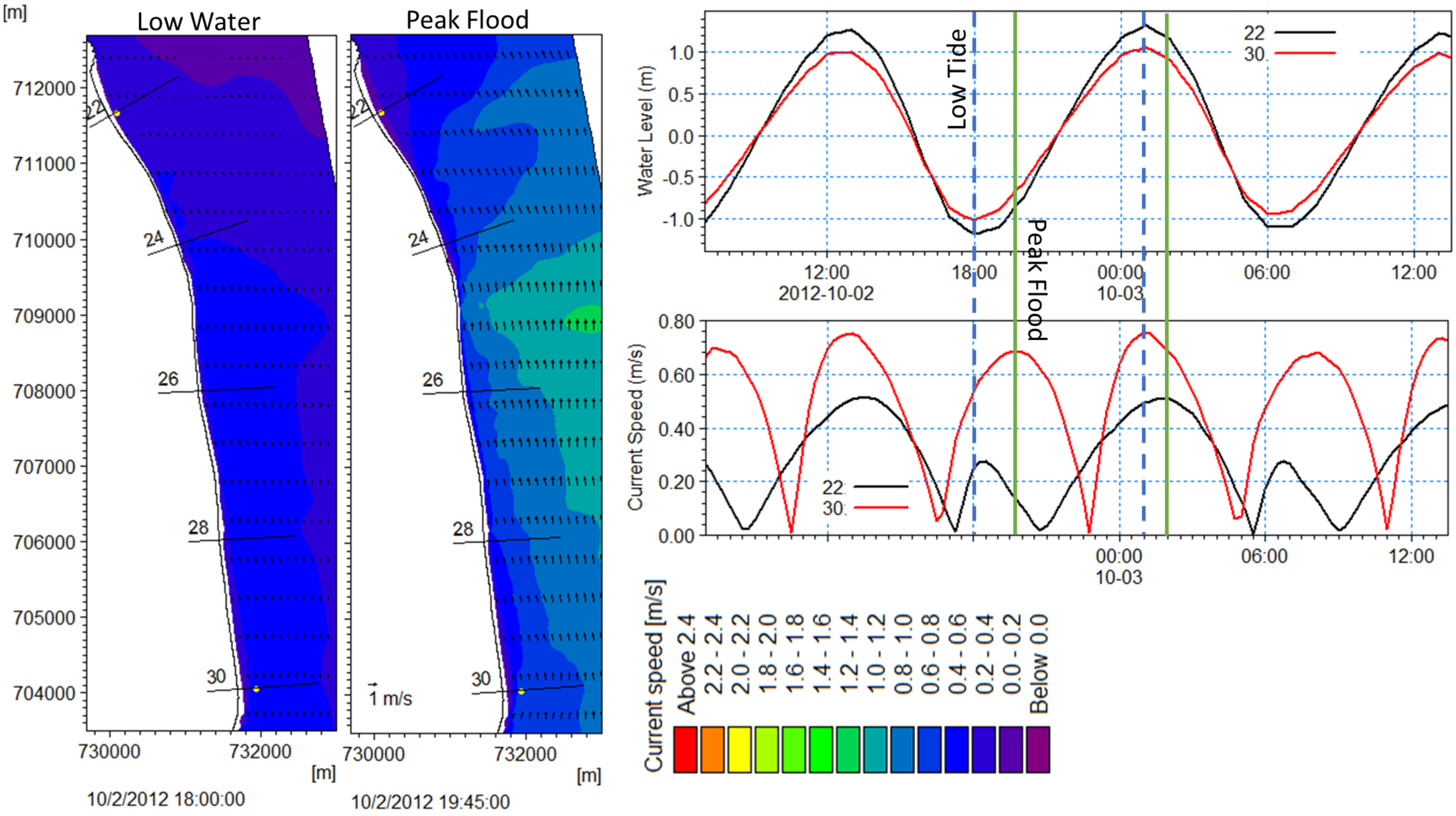


Figure A.3-8. Tidal currents across CCA6.1 at low water and peak flood (approximately 1.5 hours after low water)

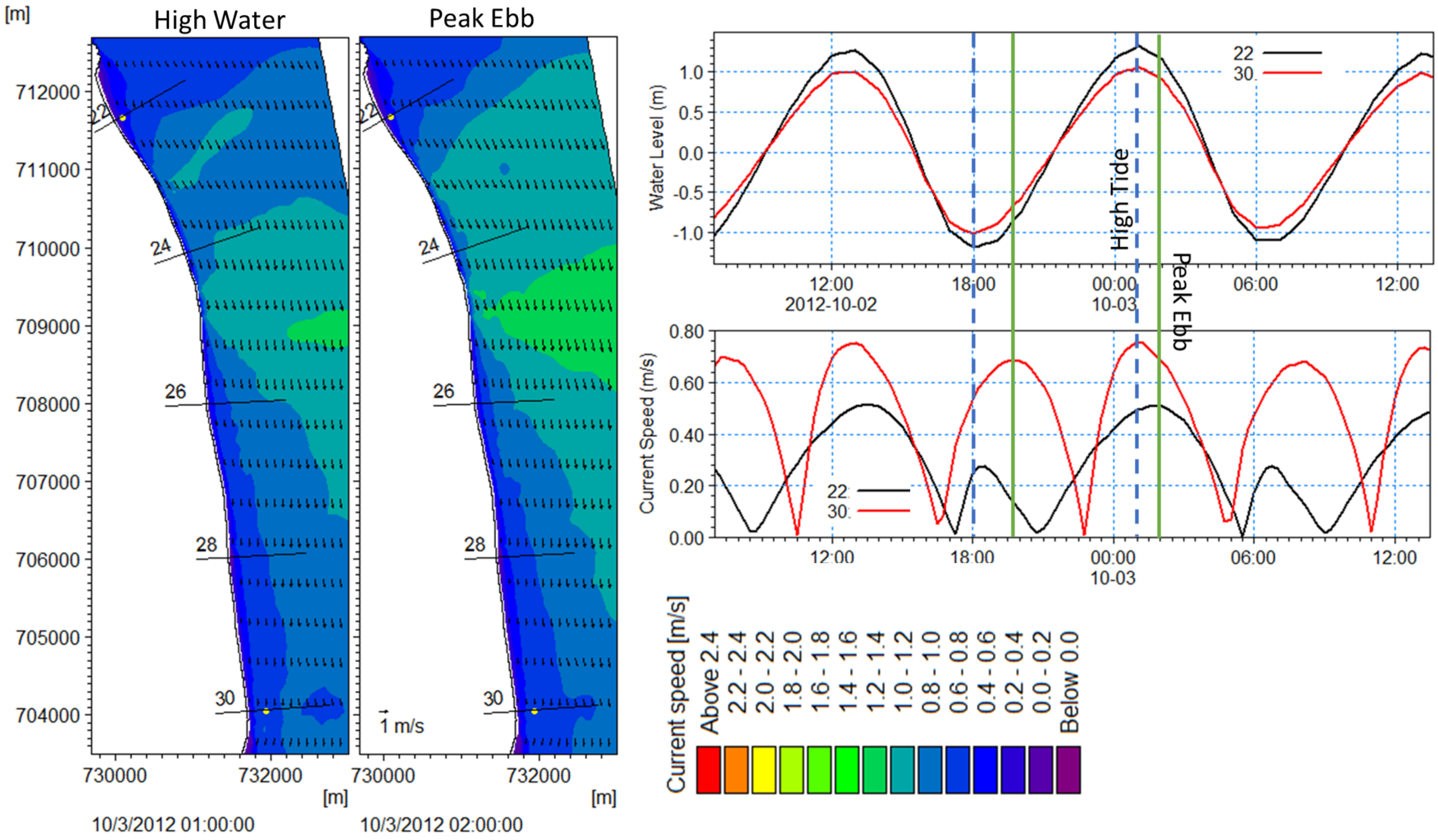


Figure A.3-9. Tidal currents across CCA6.1 at high water and at peak ebb (approximately 1 hour after high water)

A.4 Shoreline Change

A.4.1 Historical Shoreline Change

The initial shoreline used in the LITLINE shoreline change model is the high water mark; this was extracted from OSI mapping data. The OSI dataset was updated in May 2022 and therefore, is assumed to be representative of the 2022 shoreline position. Historical shoreline analysis was undertaken using georeferenced OSI maps (1830, 1900, 1940) and aerial imagery (1995, 2000, 2005, 2012 2017) to estimate a long-term historical erosion rate of up to 0.3m/year.

The model was run from January 1988 to December 2021 using historical water levels and wave conditions for this period; the model predicts variable responses along the frontage, ranging from accretion of up to 1.5m/year at Greystones South Beach and erosion of up to 2m/year at Newcastle. The results are compared with the long-term historical rates in Figure A.4-10. The differences in the rate of shoreline changes are probably due to:

- Differences in the wave conditions during the period of historical shoreline change analysis and the modelled period. The historical analysis is based on analysis from 1830-2021, while the shoreline evolution model is forced with wave data from 1988 to 2021, starting with the 2022 shoreline position.
- Uncertainties in the sediment characteristics. The sediment data available was from only one location along this frontage. It has been assumed that this data is representative for the entire frontage.
- Uncertainties in the nearshore profile. The nearshore profiles use an interpolated bed level between the LiDAR and the bathymetry.

Given the above uncertainties, it is considered best to use the model as is, to provide an estimate of future coastline changes.

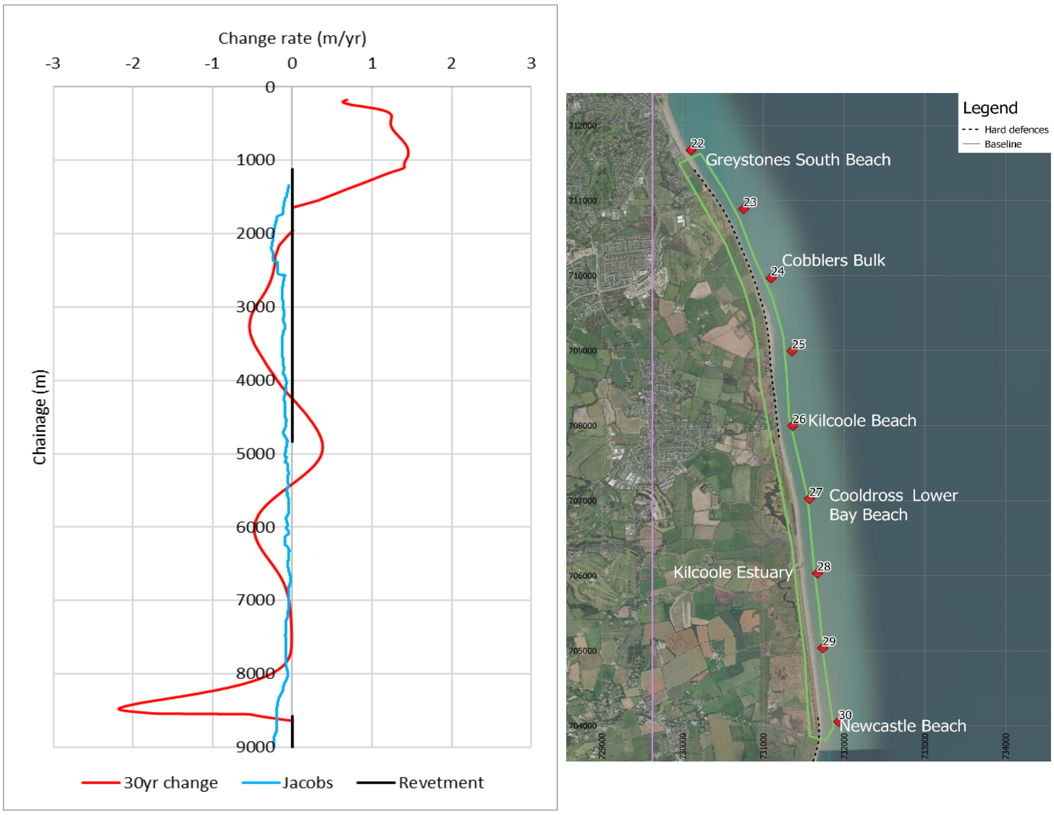


Figure A.4-10. CCA6.1 Annual shoreline changes from the numerical model (red line) and historical shoreline change analysis (blue line)

A.4.2 Future Shoreline Change

Using the LITLINE model the year end and minimum coastline position over time have been calculated for Year 2025, 2055 and 2100. The minimum coastline position is the most landward position of the coastline during the time period modelled and is not necessarily the final coastline position.

Using the modelled minimum coastline positions the minimum distance between the railway line and the coastline (MHWS shoreline) has been calculated. Figure A.4-11 shows the minimum distance to the coastline during selected time periods. Using this analysis, sections of the railway line at risk from erosion can be identified along with the period when the coastline comes within a threshold distance from the railway line. The model results show:

- The area immediately north of the revetment at Newcastle (ch 7000 m to ch 8500 m) is likely to be at a high risk of erosion to the railway line by Year 2100.
- North of the revetment at Newcastle the coastline at this location comes within 10m of the railway during 2030. It should be noted that the coastline in this area is already very close (< 30 m) to the railway line.
- From 2030 onwards further sections of railway line come under threat with 560 m of railway line within 10 m of the coastline by 2055. By 2100 1.9 km of railway comes within 10 m of the coastline.

The minimum distance between the railway line and the modelled coastline is generally less than 30 m along the frontage from Newcastle northwards to ch 800 m by Year 2100. North of ch 800 m, the minimum distance to the railway line is greater than 30 m.

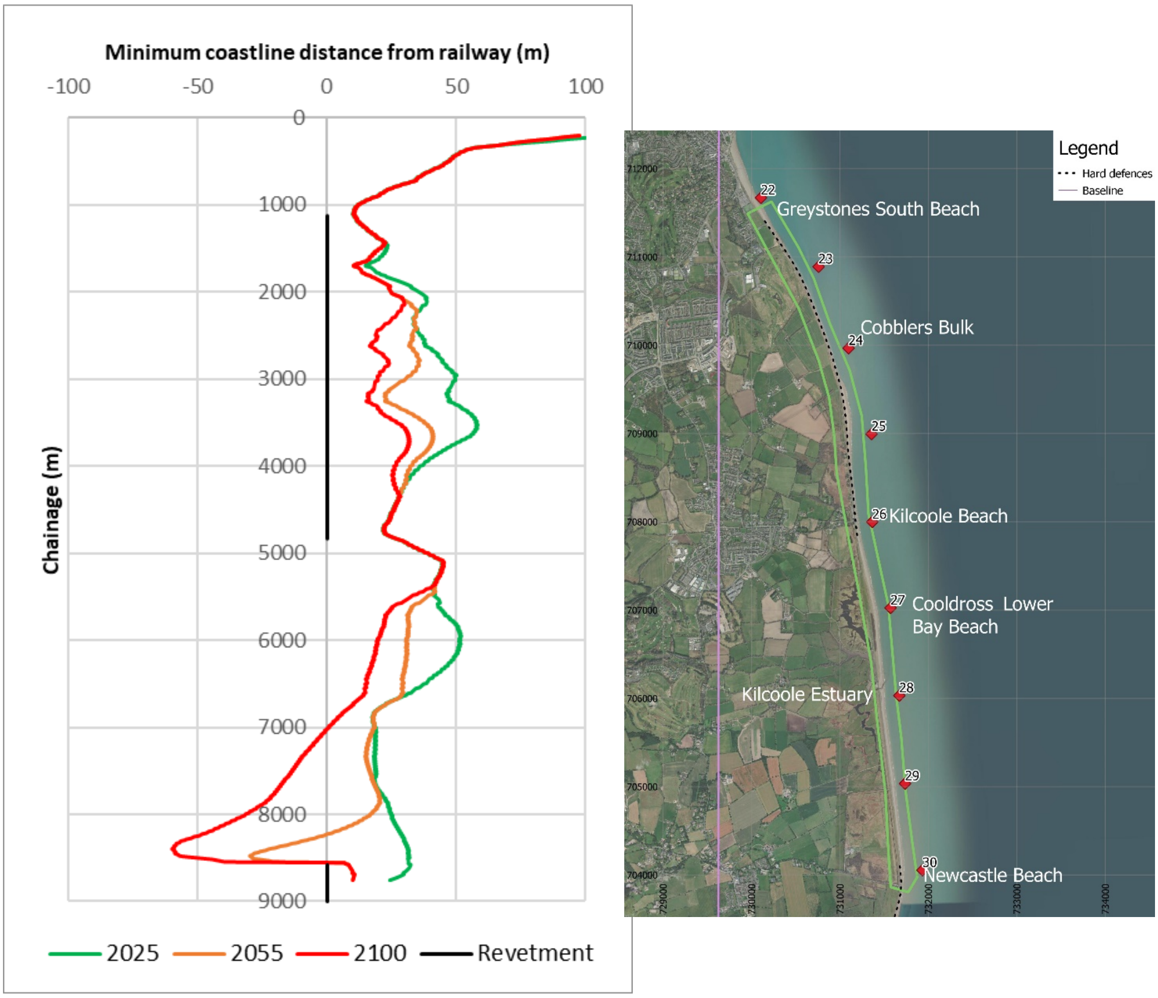


Figure A.4-11. CCA6.1 minimum coastline distance from railway

A.5 Sediment Transport

Snapshots of the sediment transport with and without waves at high tide are shown in Figure A.5-12, and Figure A.5-13 and Figure A.5-14. Figure A.5-12 shows that at high tide, sediment transport moves southward and is highest between wave points 24 and 26. Figure A.5-13 shows that under northerly waves, sediment transport is southward and Figure A.5-14 shows that under southerly waves, sediment transport is northward.

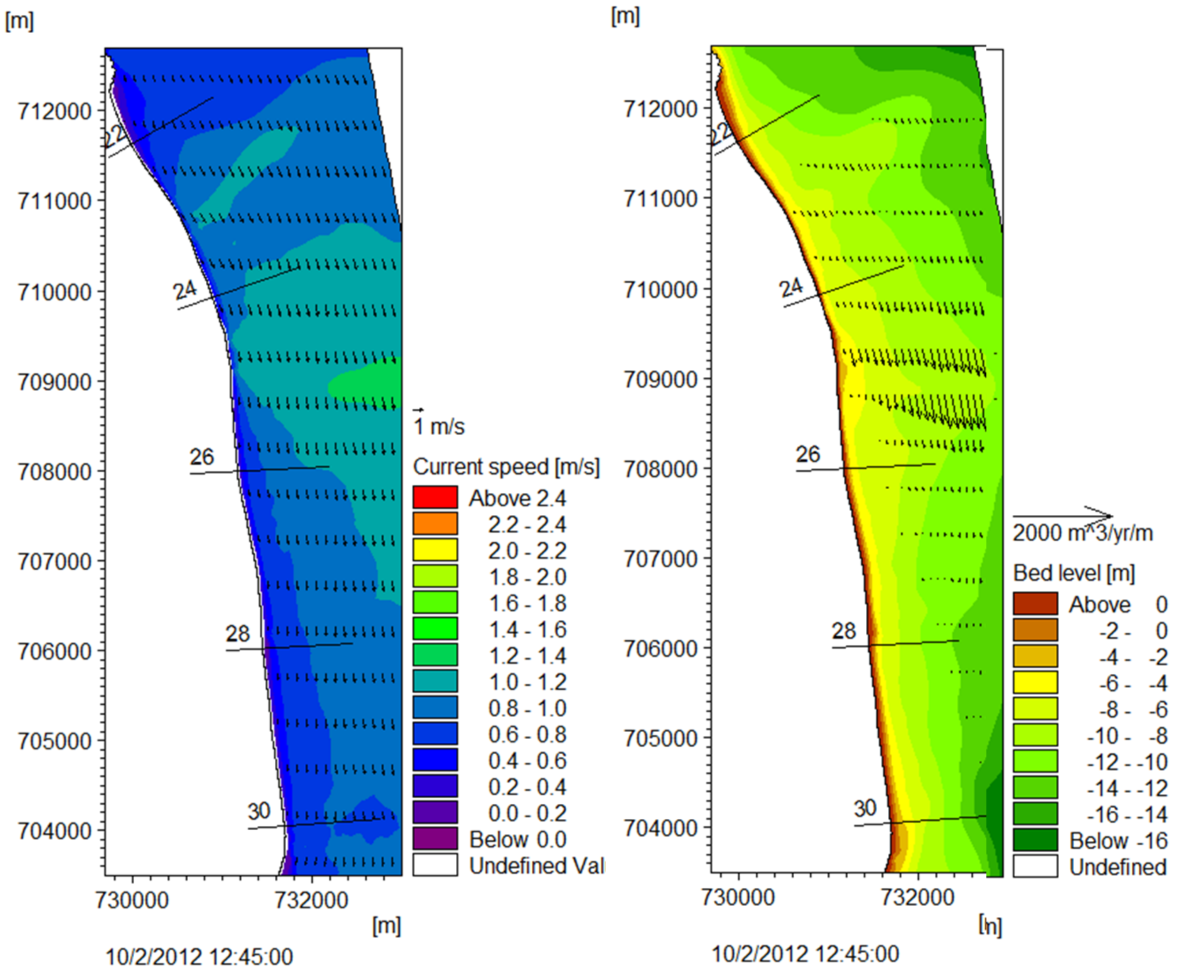


Figure A.5-12. Snapshot of CAM results for sediment transport under tidal currents only at high tide; showing currents (left panel) and sediment transport (right panel)

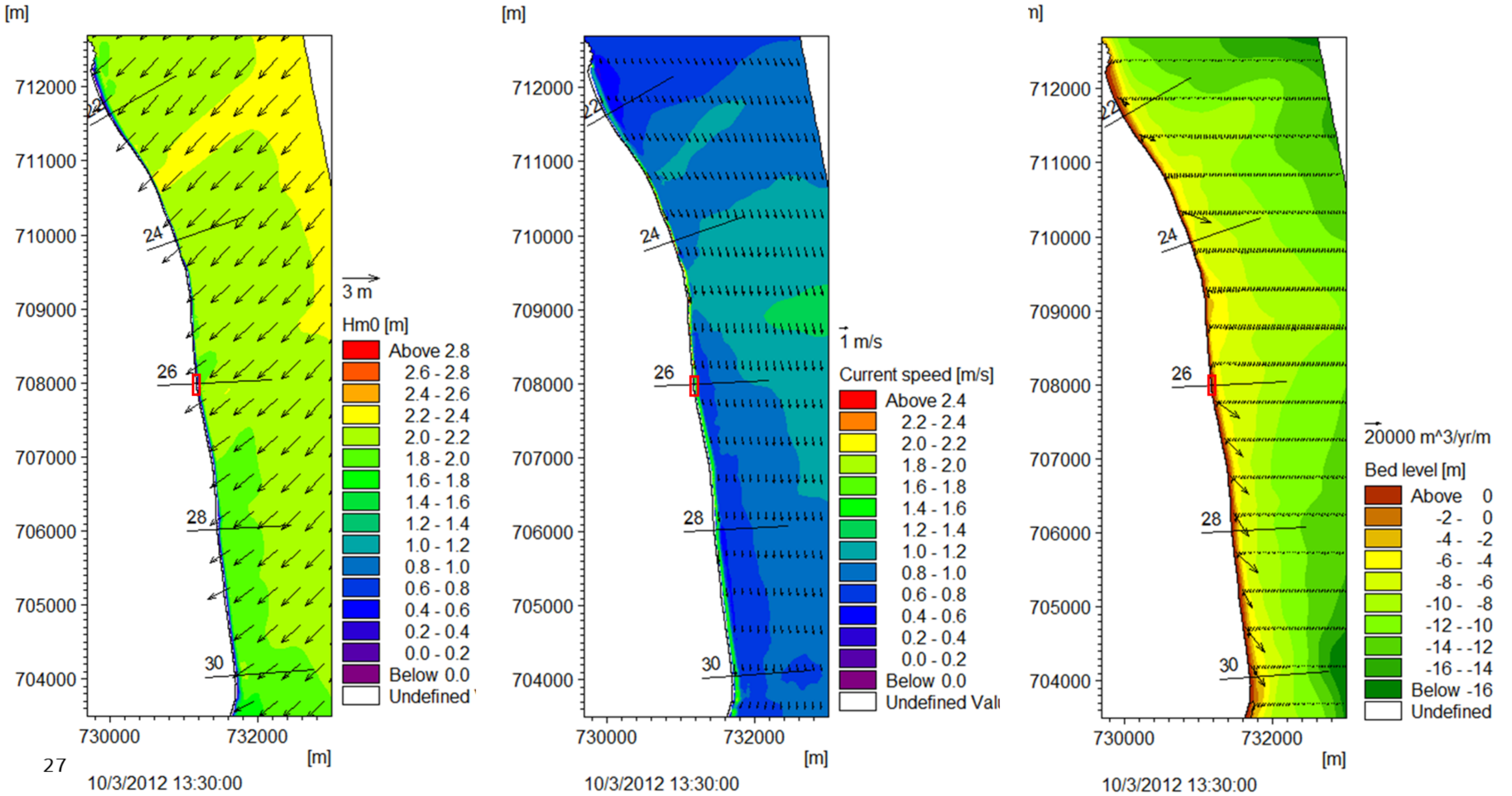


Figure A.5-13. Snapshot of CAM results for waves from 25 deg at ERA5 pt1 at high tide. Showing waves (left), currents (middle) and sediment transport (right).

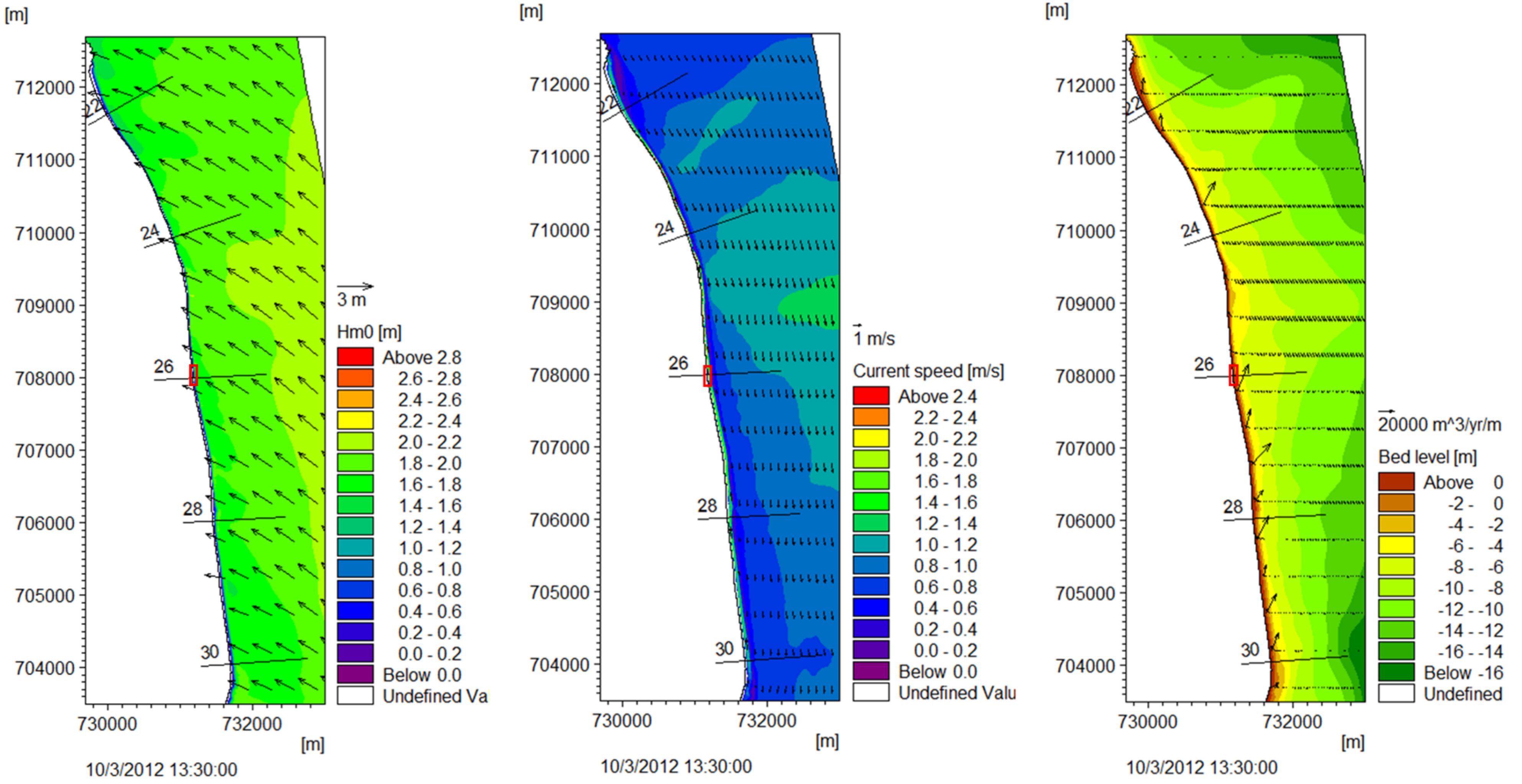


Figure A.5-14. Snapshot of CAM results for waves from 145 deg at ERA5 pt1 at hightide. Showing waves (left), currents (middle) and sediment transport (right)

A.5.1 Annual sediment transport rates

Net annual transport in CCA6.1 is northward except for a small area around wave point 24 where the net transport is marginally southward. The annual sediment transport rates are moderate, in the region of up to 10,500m³/year. As the sediment size in CCA6.1 is greater than the maximum sediment size available in the CAM sediment module, the model results were scaled to 30% of the original values.

Most of the sediment transport is occurring within 125m of the shoreline (see Figure A.5-15). Climate change moves the distribution across the shoreline further up the beach and therefore further inland. The volume of sediment transport increases slightly to up to 13,000m³/year

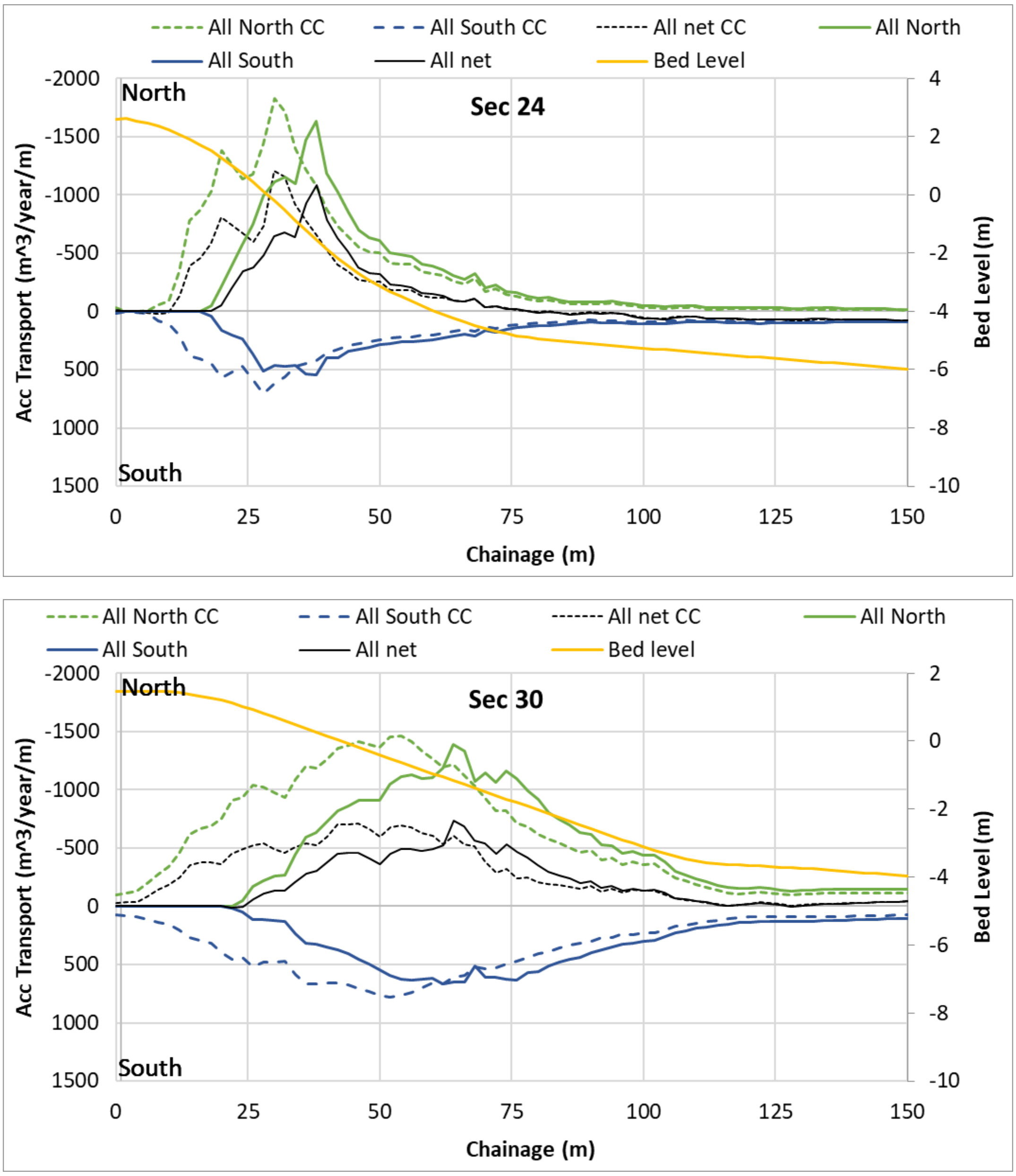


Figure A.5-15. Sediment transport rates along the bed (chainage 0 is the shoreline) at Cobblers Bulk (point 24) and Newcastle (point 30) for present day (solid lines) and with 100 years' climate change (dashed lines).

A.6 Summary

Waves within CCA6.1 are moderate, with wave heights of up to 2.8m expected at the nearshore wave points. With climate change, small increases in wave height are predicted. Sea level rise of 1m over 100 years is expected; this will have a significant effect on the design of options as the railway is very low-lying and close to the shoreline along most of CCA6.1.

Currents within CCA6.1 are moderate, typically 0.6 to 1.4m/s at all stages of the tide. This is unlikely to impact the design of revetment structures.

Sediment moves from south to north along the frontage except for an area around point 24 (Cobblers Bulk) where there is some southward transport. With climate change, the transport in area is expected to switch to northward sediment movement.

The potential sediment transport is highest in the 125 m closest to the defence. The transport rates calculated are moderate (up to 10,500m^3/year), increasing to up to 13,000m^3/year with climate change.

The areas identified as having high erosion potential generally coincide with the location of existing revetments; therefore, it is reasonable to expect that these areas will see continued beach erosion leading to potential undermining of the existing structures. Erosion of the foreshore in front of existing defences will also allow larger waves to reach the revetment and is likely to lead to greater wave overtopping.

At one of the currently undefended areas (north of Newcastle), significant erosion is expected, with up to 1.5km of the railway potentially breached by 2100 (see Figure A.4-11).