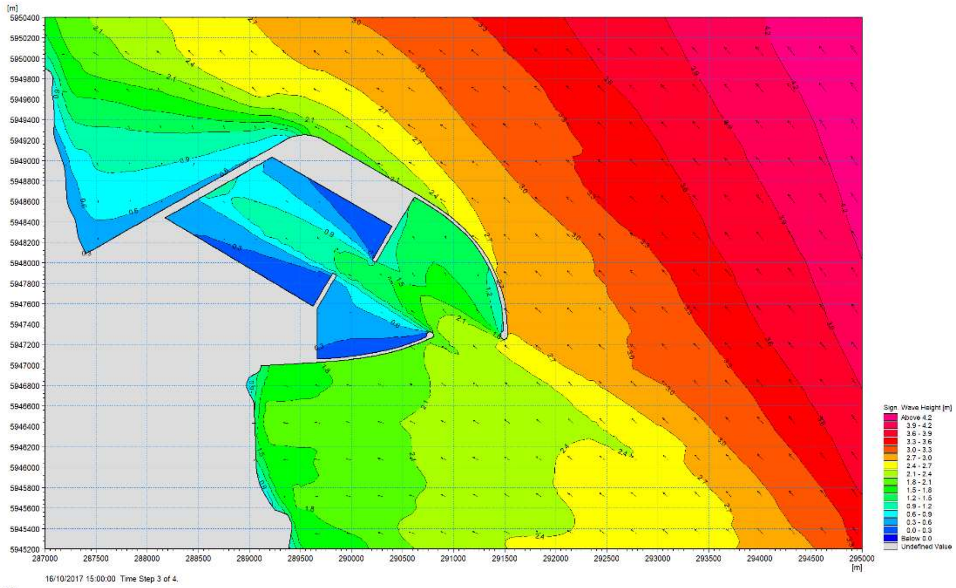
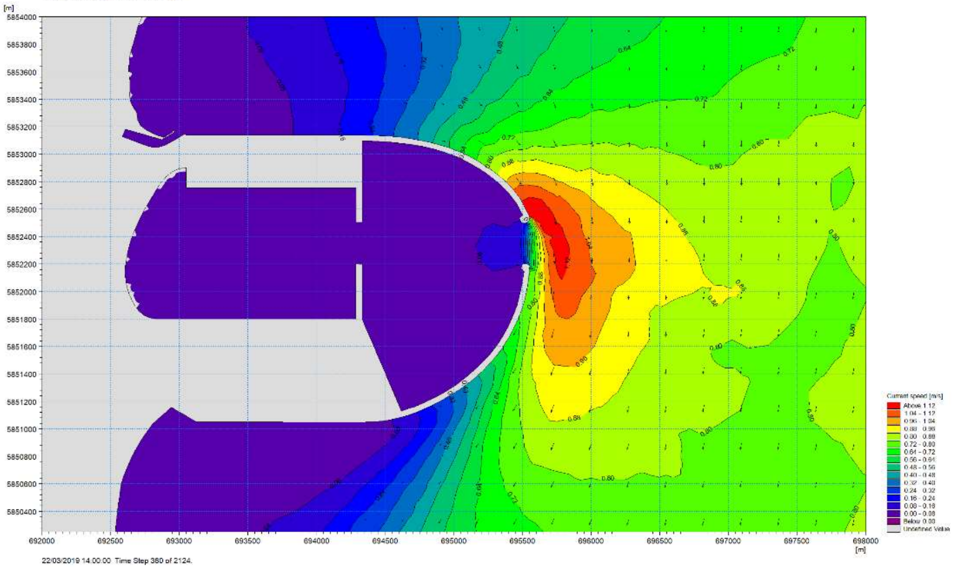
DUBLIN PORT COMPANY

DP1.5 PORT DEVELOPMENT

HYDRAULIC MODEL STUDIES





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Contents

Figures

1 INTRODUCTION

RPS has been commissioned to assist Dublin Port in the development of two conceptual plans for a port development project on the east coast of Ireland to provide additional capacity once Dublin Port reaches its capacity in 2040.

RPS was asked to take conceptual port block plans, developed by Dublin Port with assistance from Martin Mannion, and develop these into harbour layouts suitable for undertaking hydraulic modelling of the coastal processes around the areas of the proposed port development schemes.

The hydraulic modelling studies were to be undertaken to provide information for the design of the proposed port developments as well as to assist with the determination of the likely impact of the proposed scheme on the coastal processes around Bremore Point and Arklow.

RPS was also commissioned to use its coastal engineering expertise to undertake conceptual design of the breakwaters for each of the proposed port development schemes.

The DPC Masterplan 2040 documents indicate market forecasts to 2040, while further projections to 2060, 2080 and 2100 have been estimated by DPC. It is assumed that a portion of this demand will displace to other east coast ports. Therefore, the design of the satellite port will be based on a DP1.5 'Reduced' with 40 million tonnes capacity in 2080 and 58 million tonnes in 2100.

2 PORT DEVELOPMENT AT BREMORE POINT

2.1 General

The waters around Bremore Head are relatively shallow and there are beaches along the shoreline to the north and south of the Head. Rapid storm infilling of the navigation channel into Drogheda at the entrance to the Boyne Estuary has been a significant issue for Drogheda Port for many years. Dublin Port was concerned that this could be a problem for any extensive entrance channel at Bremore if it were to be located within the breaking wave zone.

Analysis of possible rapid infilling of the entrance channel and the resulting closure of the port indicated that the entrance channel to a port development at Bremore should be located to seaward of the nearshore zone. This could be achieved by locating a significant part of the port land areas between the existing coastline and the main part of the harbour basin so that the entrance channel would not cut through the storm wave surf zone.

The proposed DP1.5 port was to have a general depth of -12m CD with the approach channel dredged to -13m CD to allow for under-keel clearance with waves. The entrance channel alignment was chosen to make best use of the natural protection provided by the land to the south of the site running east out towards Skerries together with the distance from the site to deep water.

Consideration was also given to having the entrance to the port from the northeast. However, as will be seen in the following section, Figure 2.4, the largest waves approach Bremore from the sector 30^o to 90^o thus these waves would easily penetrate a harbour with a northeast facing entrance. In addition, the tidal flows in the area around Bremore run in northwest – southeast directions thus a north east facing entrance would have cross currents at the entrance further adding to the navigational difficulties for vessel entering the port. For these reasons the northeast facing entrance to the port was not considered to give an optimal layout for the new port.

2.2 Wave Climate and Water Levels

In order to provide information for the refinement of the DP1.5 layout at Bremore, RPS undertook the wave transformation of twenty years of three hourly wave climate data from an offshore point to the site for the period 1999 to 2018 inclusive. This require 58,439 simulations of a flexible mesh spectral wave model. The extent and bathymetry of the coupled wave and tidal model for the existing Bremore Point is shown in Figure 2.1.

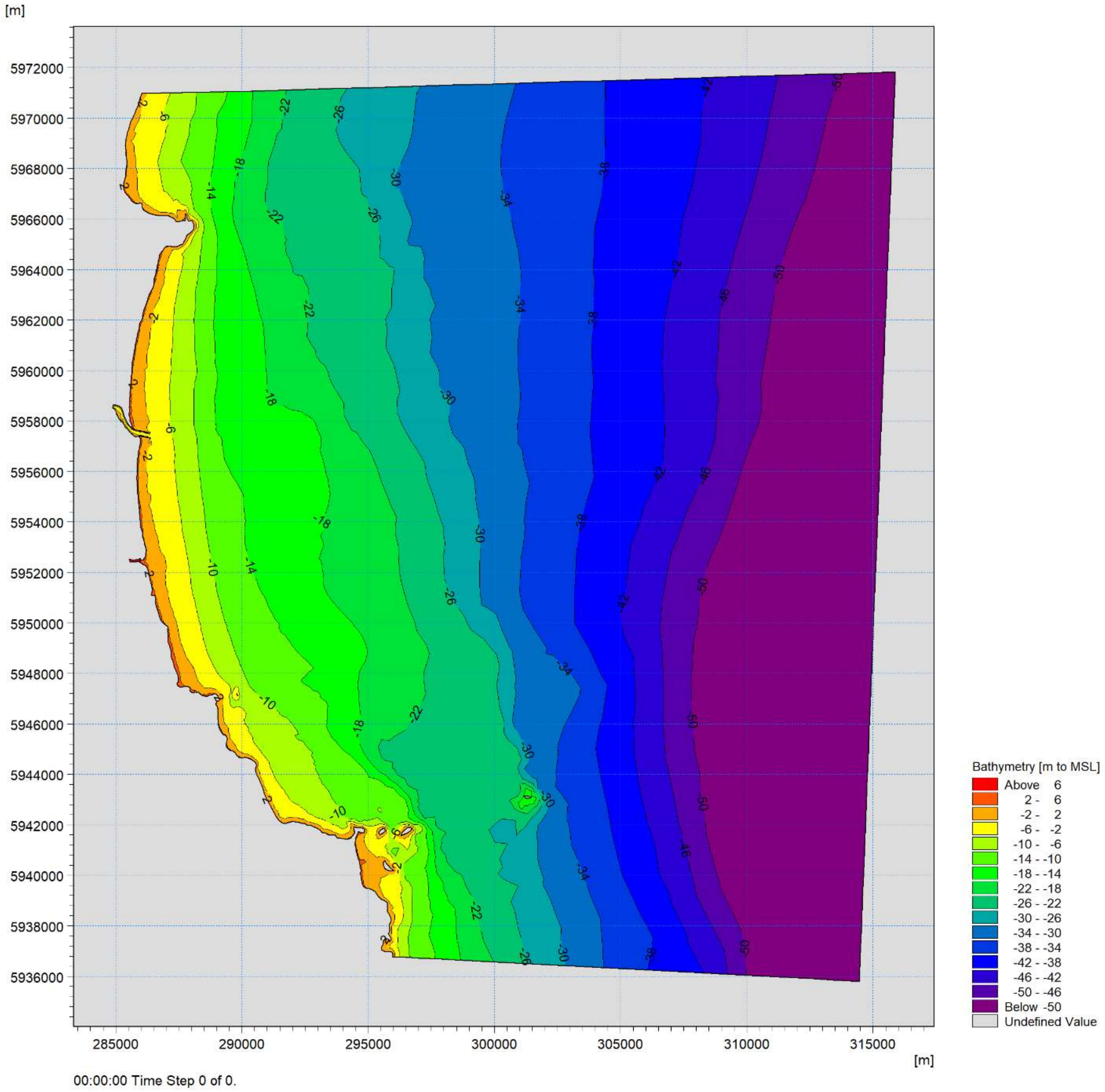


Figure 2.1 Extent of coupled wave and tidal model for Bremore Point

The offshore wave climate was taken from the 8km grid UK Met Office Wavewatch III wave model at a point 5.696°W, 53.748°N. The offshore wave rose for wave heights greater than 2m is shown in Figure 2.3

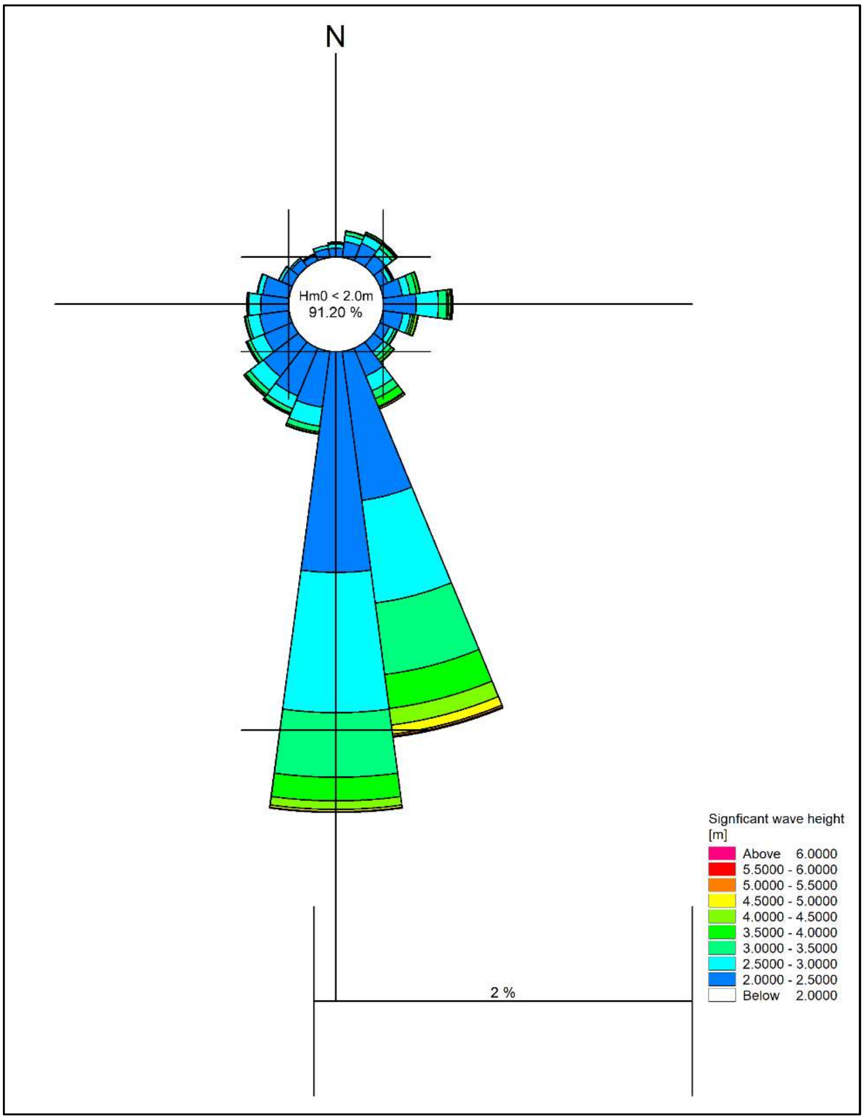


Figure 2.2 Offshore wave height rose – 3 hourly wave climate 1999 – 2018 inclusive

It will be seen from the offshore wave rose that the offshore wave climate is most active for waves from the south to south east direction but there are also large storm waves from the east and north east directions.

The wave transformation simulations were undertaken using the tidal levels which occurred at the time plus the increase in line with the High End Future Scenario (HEFS) climate change predictions for 2100. This procedure was undertaken to allow for climate change over the future port operational period.

The results of the wave transformation simulations are shown in Figures 2.3 and 2.4 in terms of the inshore wave height rose (above 1 metre) and a scatter plot of significant wave height against inshore wave direction.

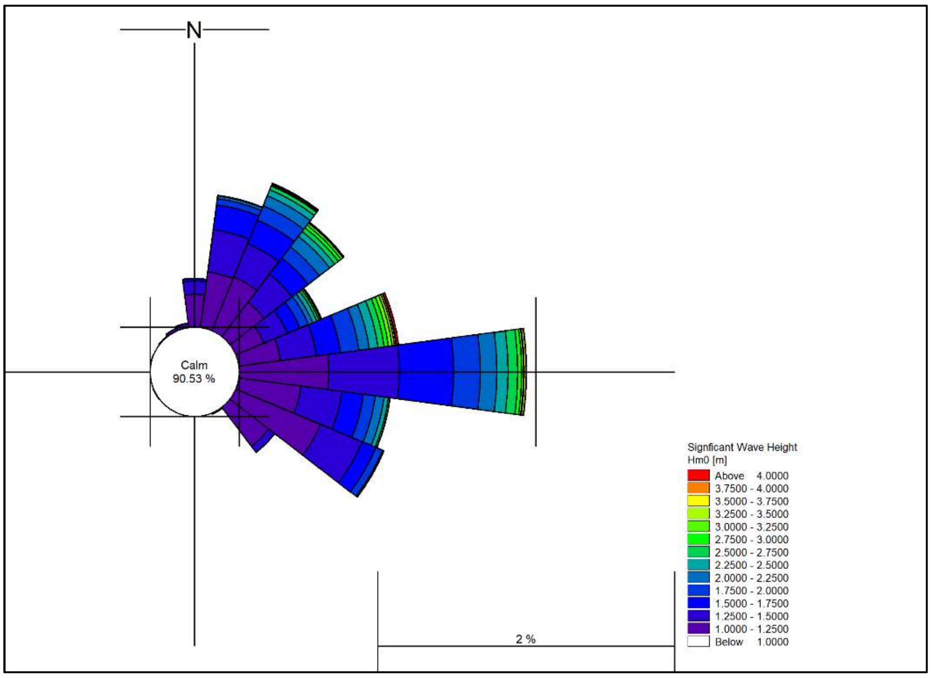


Figure 2.3 Inshore wave rose at Bremore Point – 1999 – 2018 with HEFS climate change to 2100

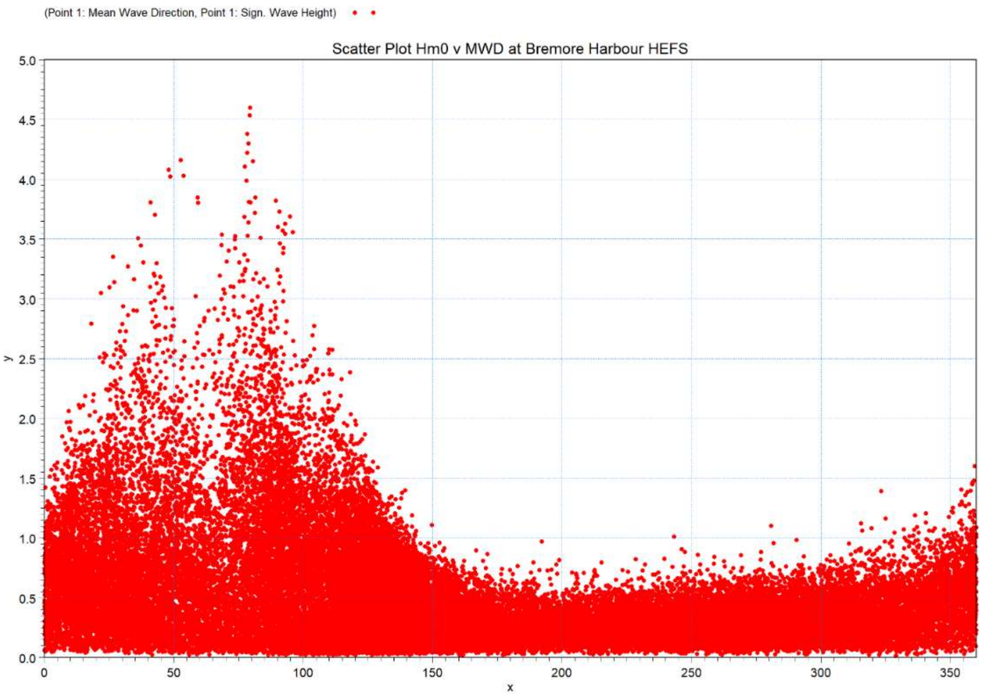


Figure 2.4 Inshore wave scatter diagram of Hm0 v MWD 1999 – 2018 with HEFS climate change to 2100

It will be seen from the results of the wave modelling that the most energetic waves in the inshore wave climate at Bremore Point come from the north to east-southeast sector. For other directions the wave heights are generally less than about 1 metre in height.

2.3 Tidal Levels and Flows

The tidal levels at the Bremore site have been calculated based on UK Admiralty data for Dublin, Howth, Balbriggan and the entrance to the River Boyne. The levels to Chart Datum are estimated to be:

HAT	5.0 m
MHWS	4.5 m
MHWN	3.7 m
MLWN	1.5 m
MLWS	0.7 m

The HEFS water level used in the wave modelling simulations for Bremore was +3.0m above msl.

The coupled wave and tidal model, Figure 2.2, was run for a month of tides to establish the tidal current regime around Bremore Point. The tidal boundary conditions for the coupled wave and tidal model of Bremore Point were taken from the RPS tidal and storm surge model of the whole of the west coast of the UK and Ireland. This model is run on 24/7 basis to provide storm surge forecast for the all the coasts of Ireland and has been extensively calibrated and validated. The extent of this tidal and storm surge model is shown in Figure 2.6.

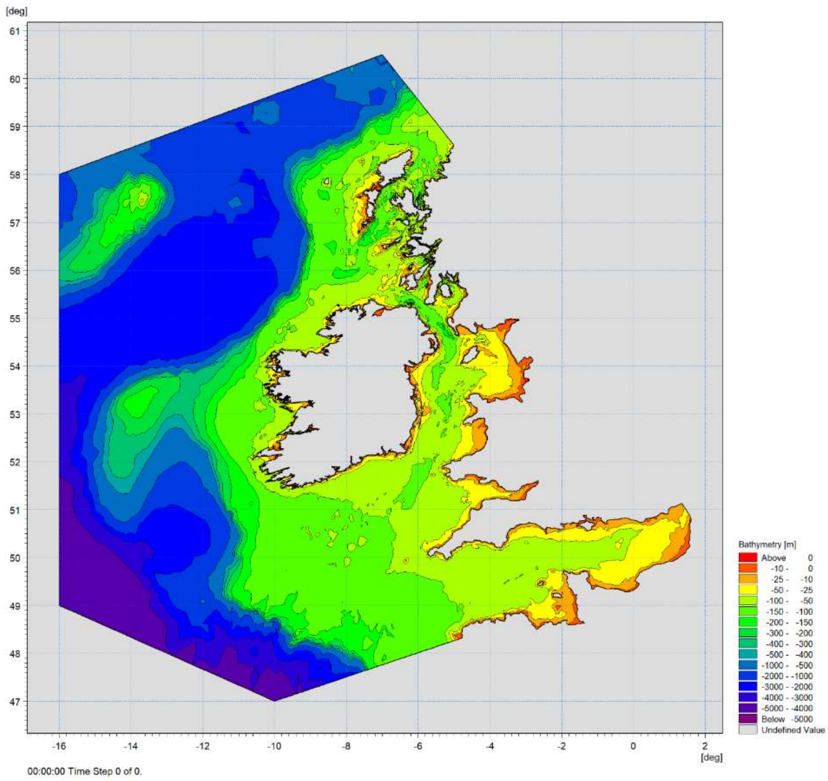


Figure 2.5 Extent of tidal and storm surge model for the west coast of the UK and Ireland

The typical flood tide and ebb tide flow regime around Bremore Point is shown in Figure 2.7 and 2.8.

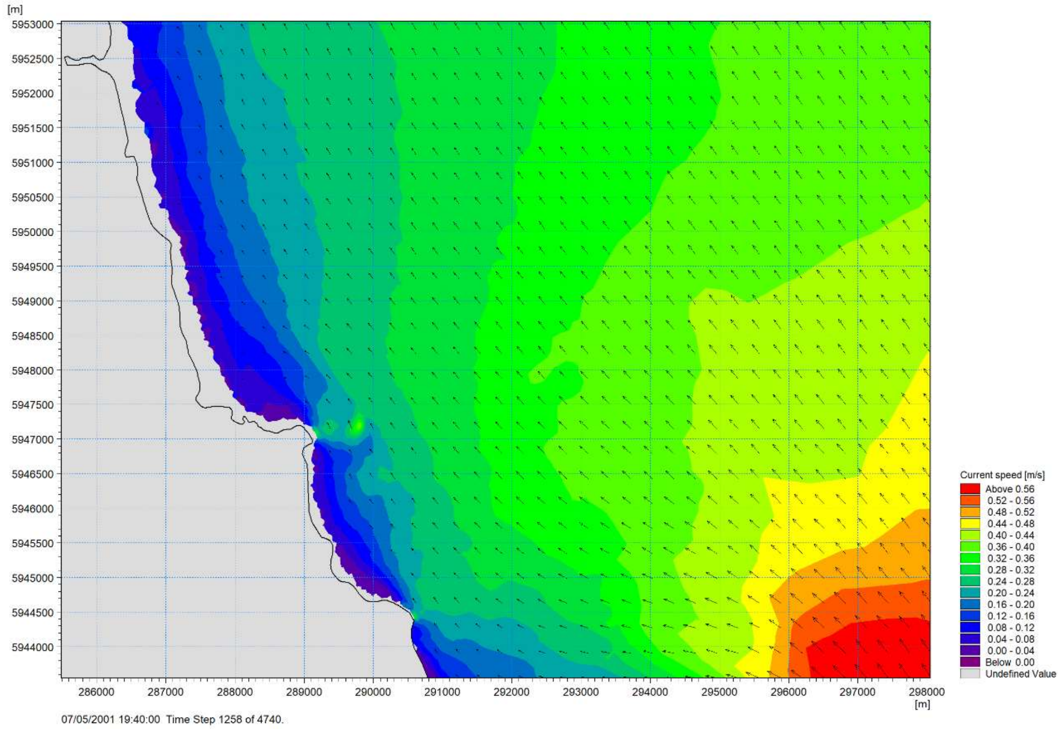


Figure 2.6 Typical spring flood tide flow conditions around Bremore Point

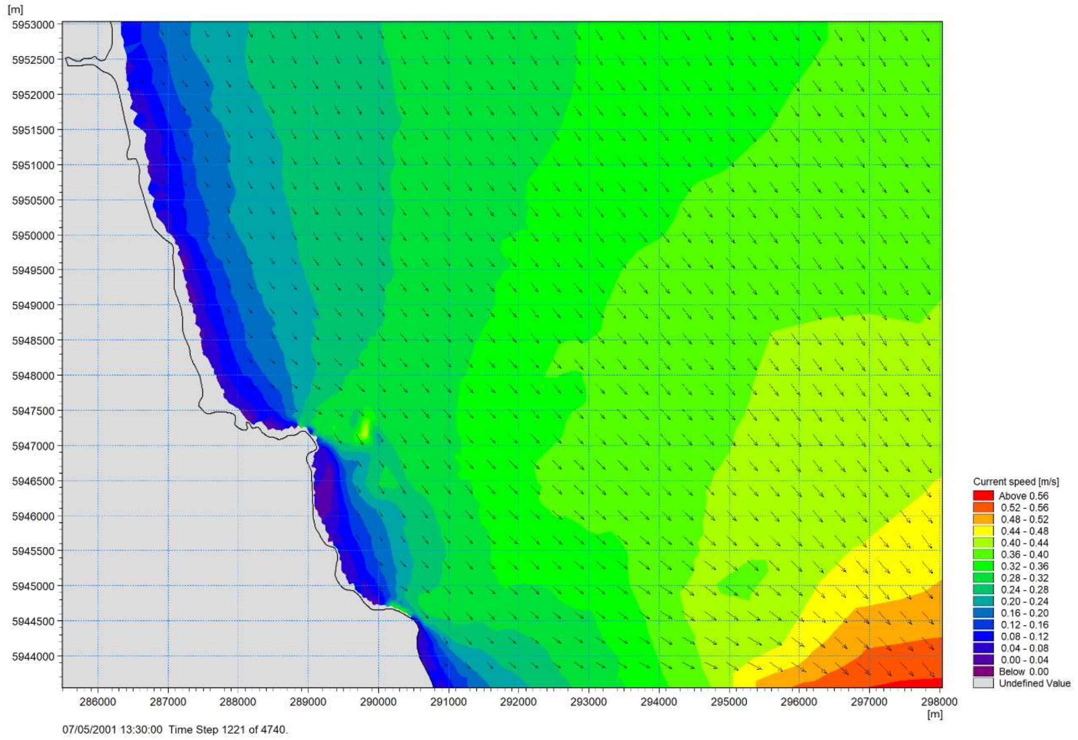


Figure 2.7 Typical spring ebb tide flow conditions around Bremore Point

2.4 Development of the DP1.5 Bremore Point Port Layout

The initial layout for the DP1.5 port at Bremore was based on the DP2 layout with reduced quay lengths as shows in the initial block concept layout for the Bremore Point area developed by Dublin Port and Martin Mannion, Figure 2.8.

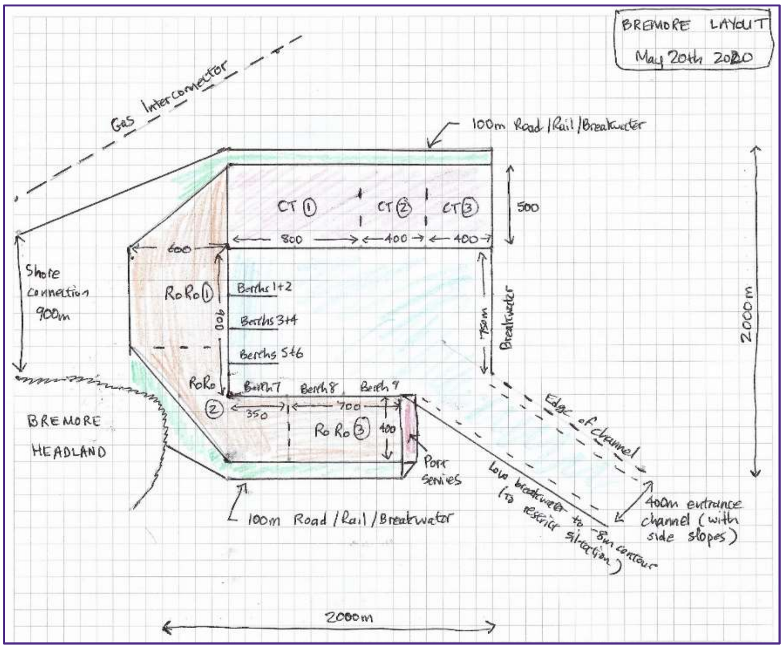


Figure 2.8 Initial block concept plan for DP1.5 at Bremore produced by Martin Mannion

The hydraulic model of this initial layout is shown in Figure 2.9 and simulations were undertaken to evaluate the hydraulic performance of the port with tidal currents and also storm wave conditions.

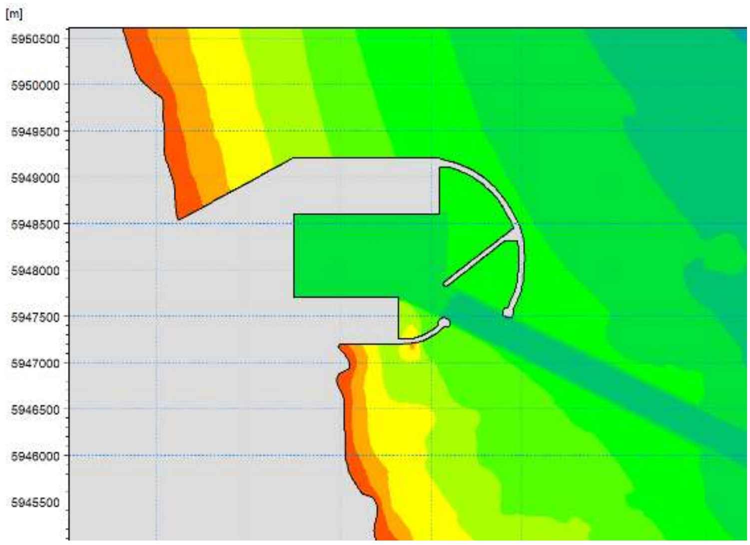


Figure 2.9 Hydraulic model bathymetry of the initial concept plan for DP1.5 at Bremore

As will be seen from Figure 2.10 the initial layout did not perform well under south easterly wave conditions and the Dublin Port Harbour Master was concerned that there would be insufficient distance from the entrance of the port to the turning circle to get tugs alongside the larger container ships and bring the container ship under control.

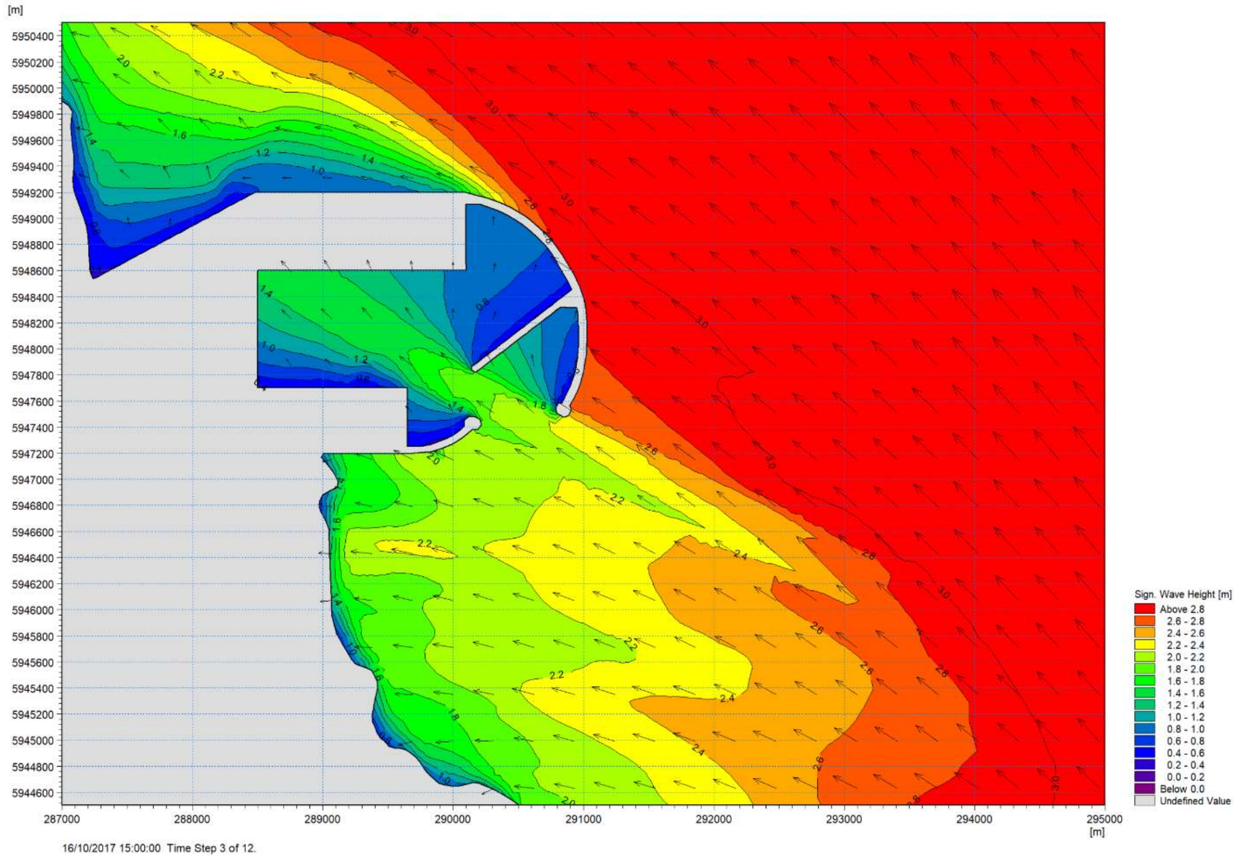


Figure 2.10 Significant wave heights and mean wave directions SSE storm at high water

Following the assessments of the initial port plan, a revised layout was devised with a curved entrance channel and a large overlap of the eastern breakwater, as shown in Figure 2.11.This arrangement was designed to see if it would improve the performance of the proposed harbour under SSE storm conditions.

As will be seen from Figure 2.12, the modelling showed that the harbour quays were still subjected to excessive wave heights and the navigational access via the curved channel was not ideal. Furthermore RPS was concerned that the large overlap of the eastern breakwater in relation to the southern breakwater could result in sedimentation in the channel in the lee of the eastern breakwater. Thus this concept for the new harbour was abandoned in favour of a layout with the container berths on outer side of the harbour basin and a spending beach on the northwest side of the basin as shown in Figures 2.13 and 2.14.

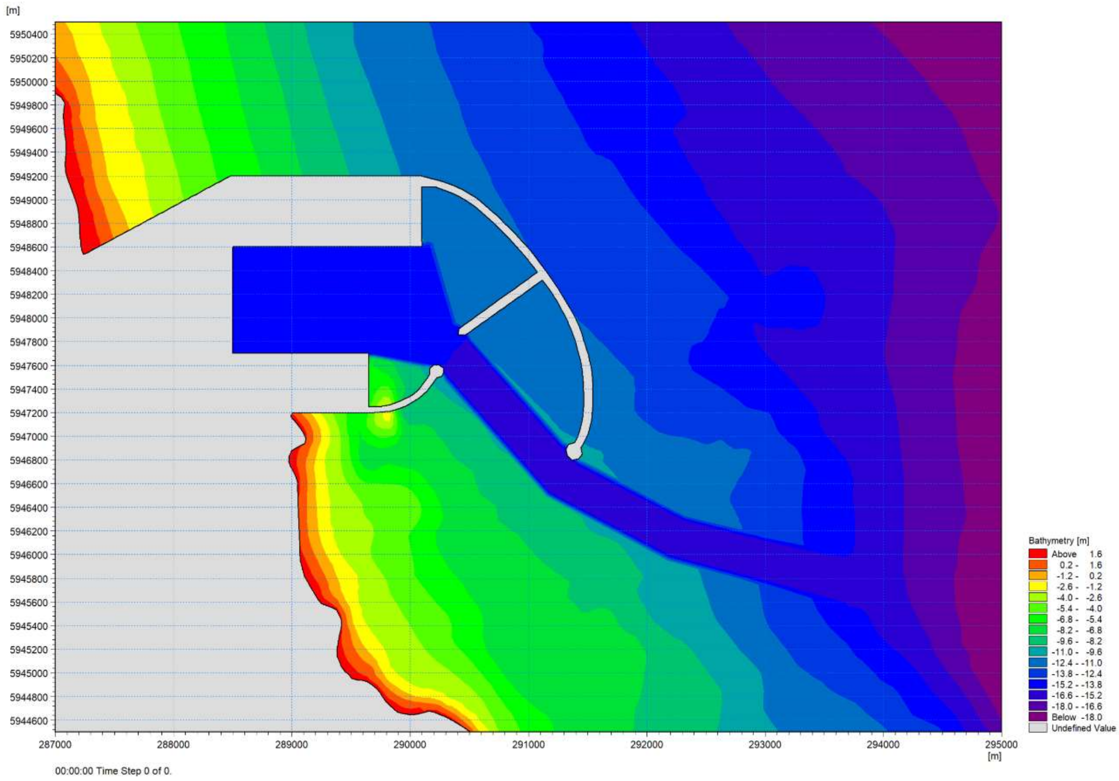


Figure 2.11 Revised DP1.5 Layout based on Martin Mannion concept 12th June 2020

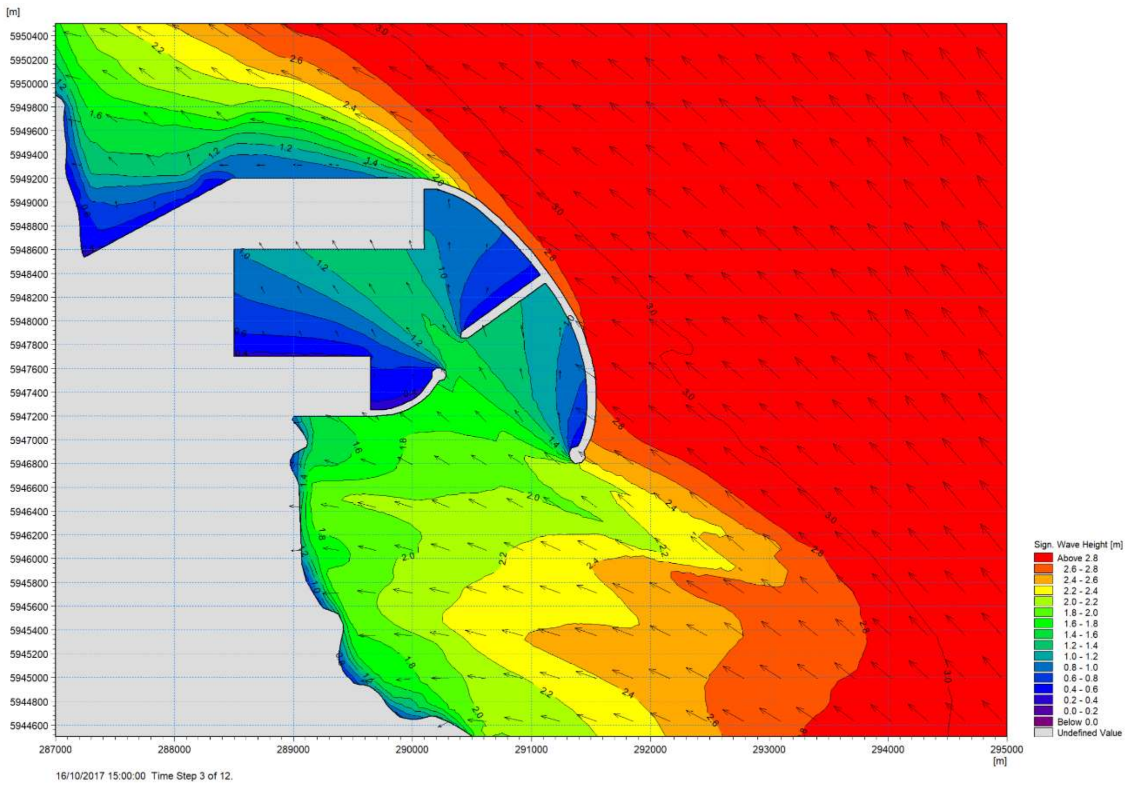


Figure 2.12 Significant wave heights and mean wave directions SSE storm at high water +surge

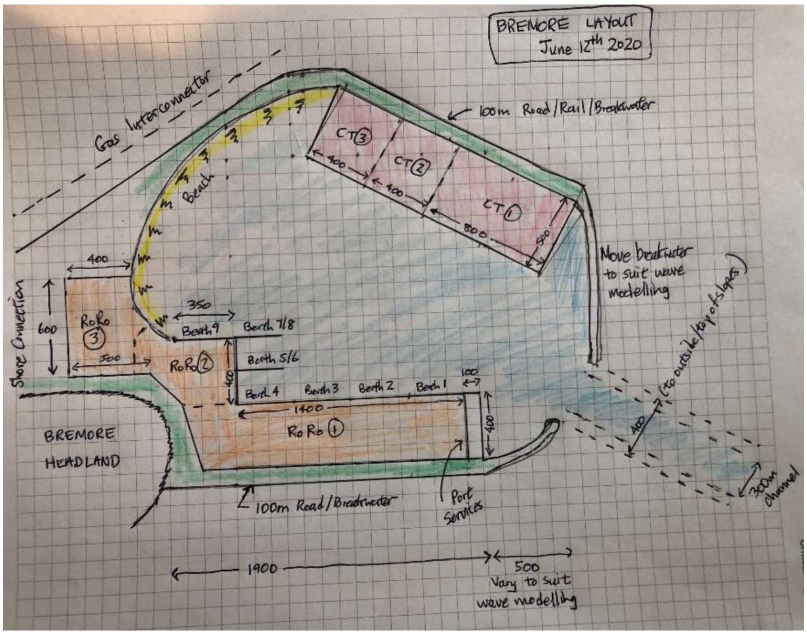


Figure 2.13 Concept plan for revised DP1.5 layout as per Martin Mannion 12th June 2020

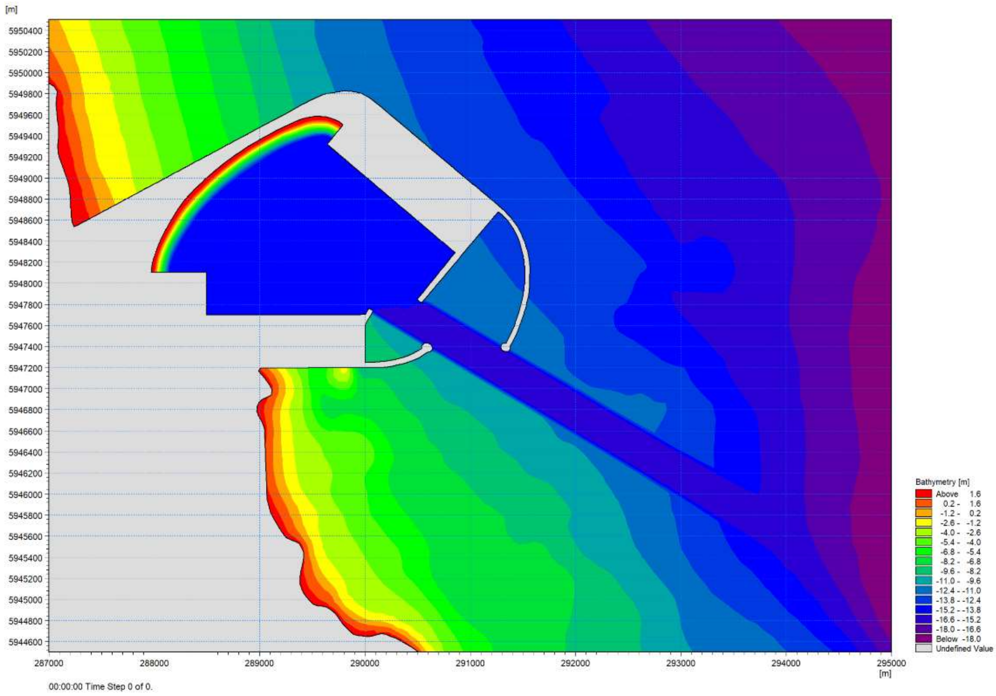


Figure 2.14 RPS model based on a refinement of Martin Mannion concept of June 2020

The model based on the revised concept plan was subjected to storm wave and tidal simulations and as can be seen from Figure 2.15, the amended harbour layout perform satisfactorily under the severe south-southeast storm which occurred during the time when ex hurricane Ophelia struck Ireland in October 2017.

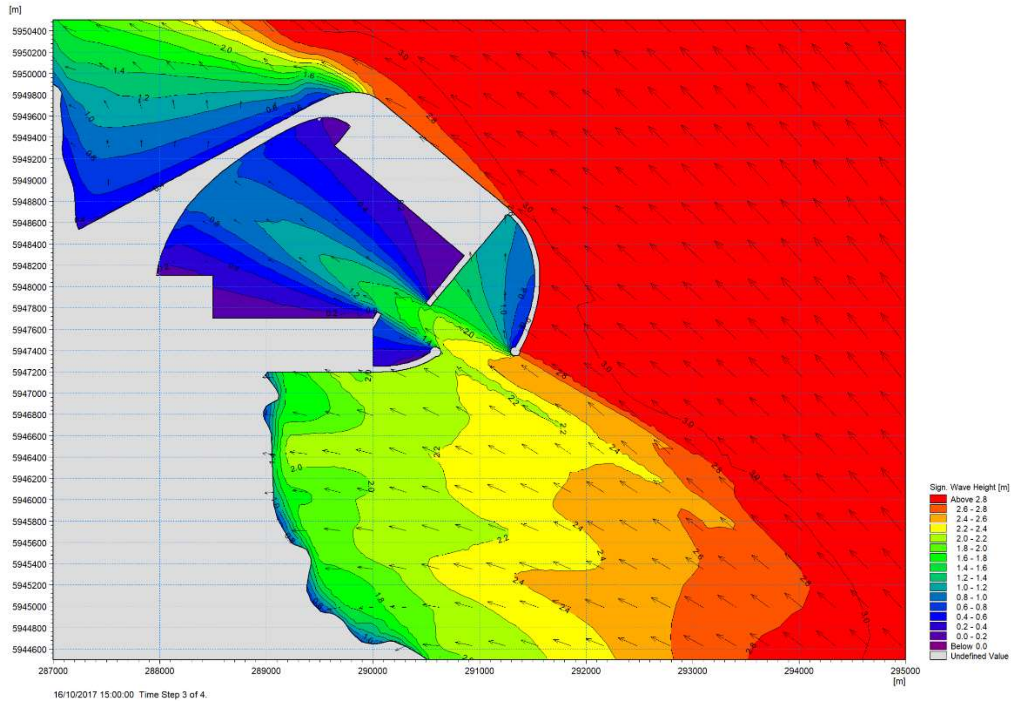


Figure 2.15 Significant wave heights and mean wave directions SSE storm at high water +surge

This concept plan was then subsequently revised and amended as the planning of the harbour was refined so that the final proposed DP1.5 harbour layout model bathymetry was as shown in Figure 2.16.

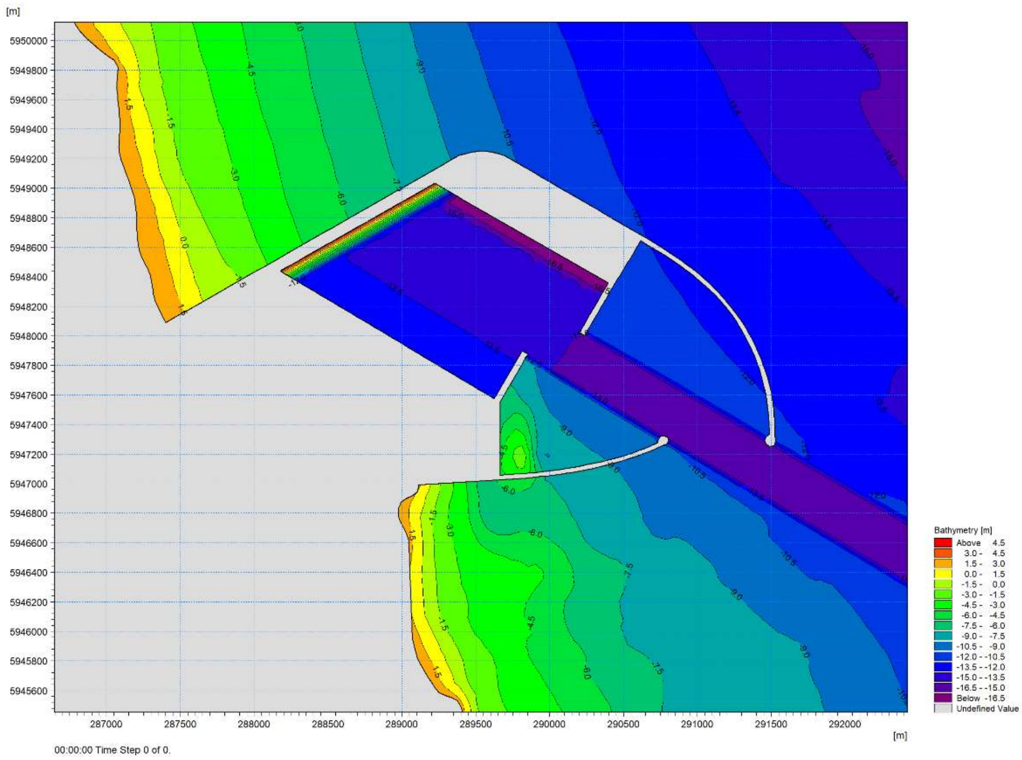


Figure 2.16 Final model bathymetry for the proposed DP1.5 harbour at Bremore Point

The performance of this layout was evaluated by simulating both storm waves events and tidal flows. Figure 2.17 shows the harbour during a SSE storm at high tide plus surge while the wave climate around the harbour during ESE and NE storms is shown in Figures 2.18 and 2.19. It will be seen from these diagrams that the wave conditions in the harbour are satisfactory under all of these conditions.

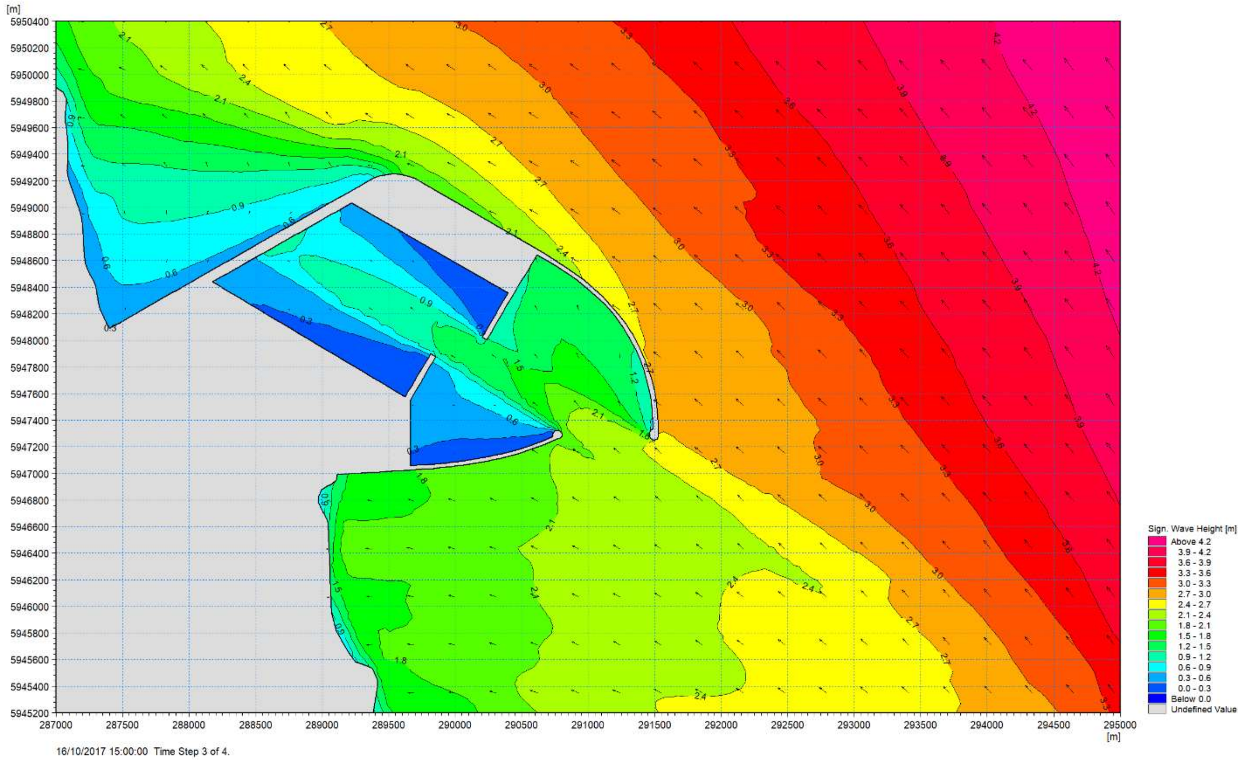


Figure 2.17 Significant wave heights and mean wave directions SSE storm at high water +surge

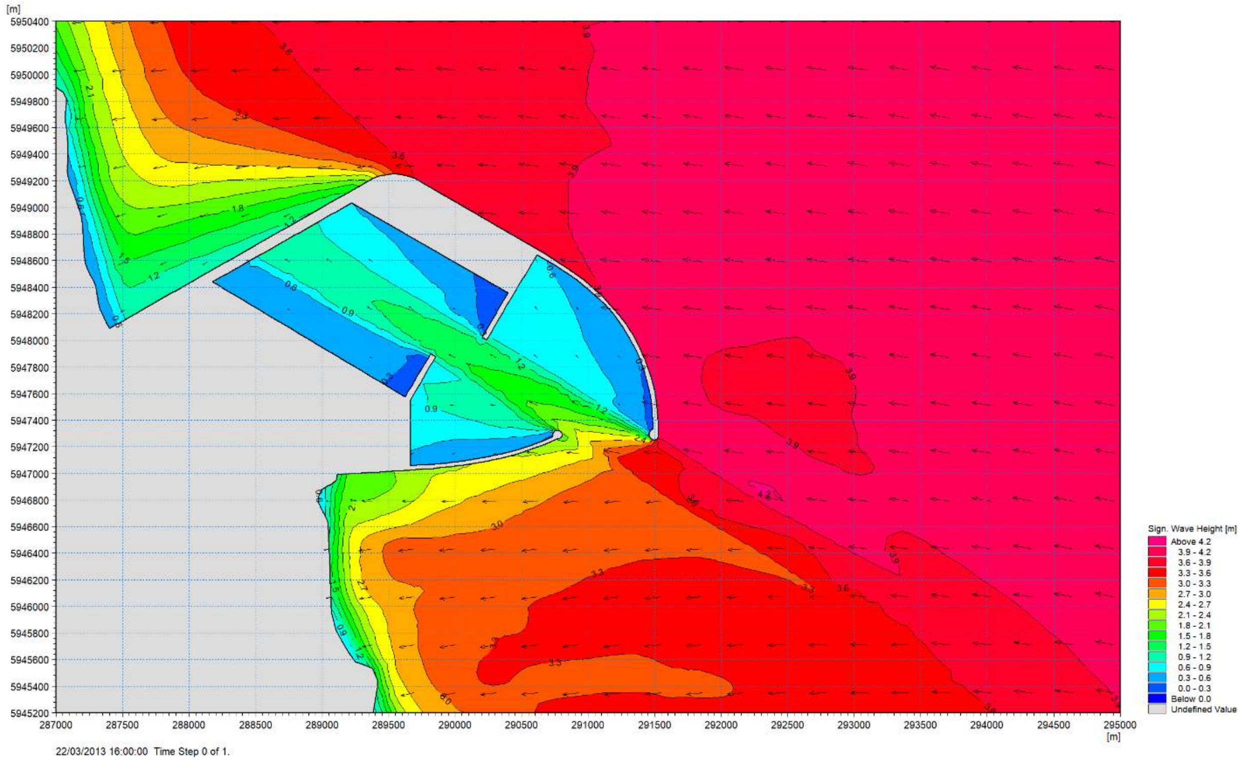


Figure 2.18 Significant wave heights and mean wave directions ESE storm at high water

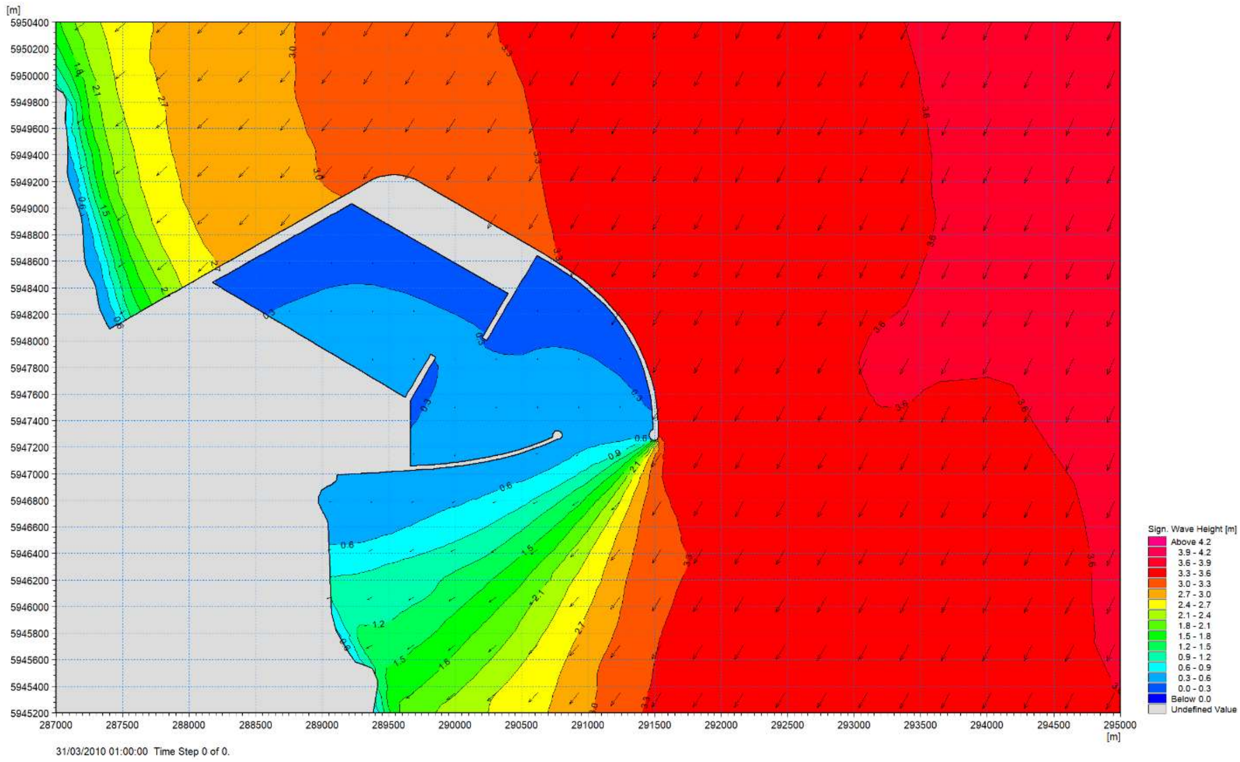


Figure 2.19 Significant wave heights and mean wave directions NE storm at high water

The mean flood and ebb tidal flows around the proposed harbour are shown in Figures 2.20 and2.21. While the new harbour will accelerate the tidal flows in the vicinity of the harbour, the highest flow velocities are on the north eastern side of the harbour and do not impinge on the entrance area to the port. Thus the change in tidal flows will not have any significant impact for navigation into or out of the port.

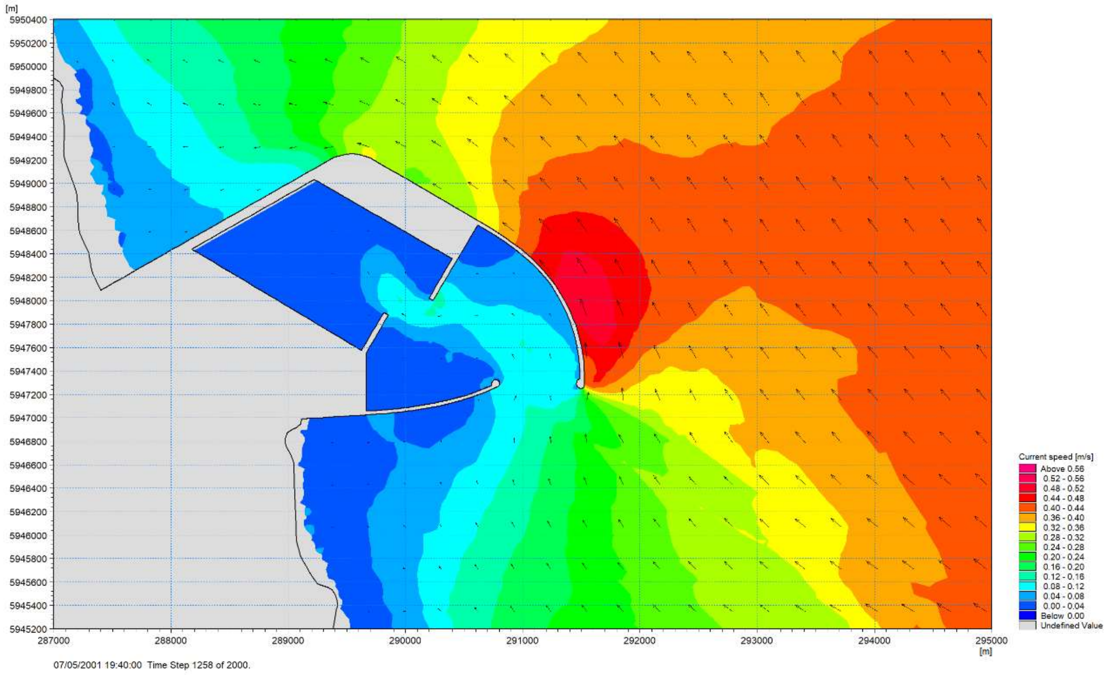


Figure 2.20 Flood tidal flow around proposed DP1.5 Bremore harbour

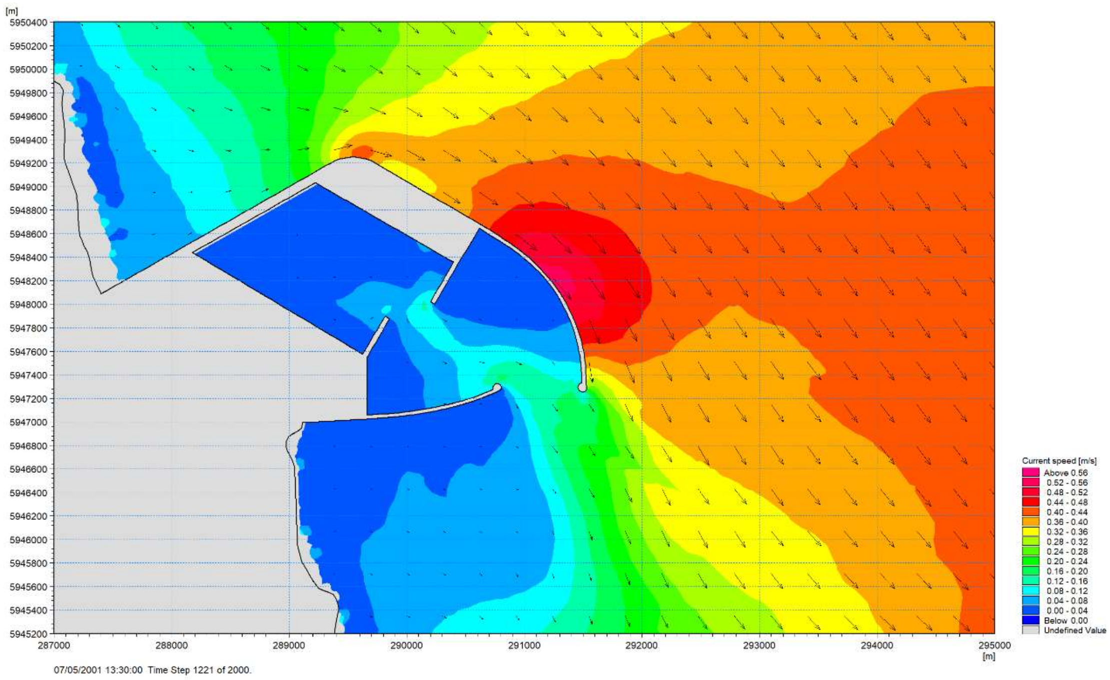


Figure 2.21 Ebb tidal flow around proposed DP1.5 Bremore harbour

2.5 Bremore Point Port – Impact on Adjoining Coasts

2.5.1 Tidal flows

Figure 2.22 shows the spring flood tidal flow around Bremore and the adjoining coasts for the model with the proposed port (left) and with the existing bathymetry (right). Similarly Figure 2.23 show the tidal flows for a spring ebb tide.

Examination of these diagrams indicates that the proposed Bremore Port development would reduce the tidal velocities along the coast for about 5 kilometres to the north and south of the proposed development. However, there is a significant increase in the tidal flow velocities at the outer boundary of the proposed port development.

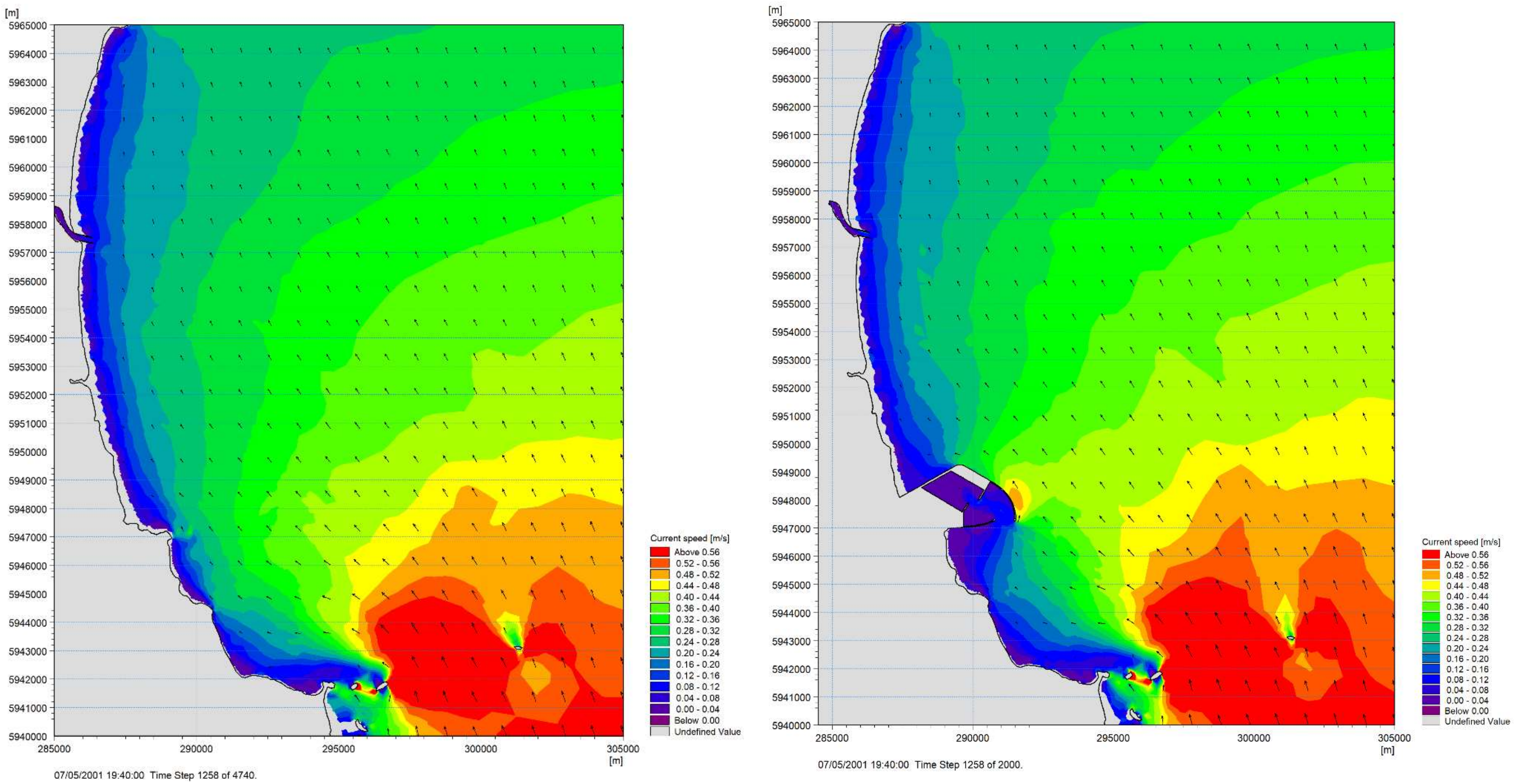


Figure 2.22 Spring tide flood current flows — Existing Bremore layout (left) –Proposed Bremore layout (right

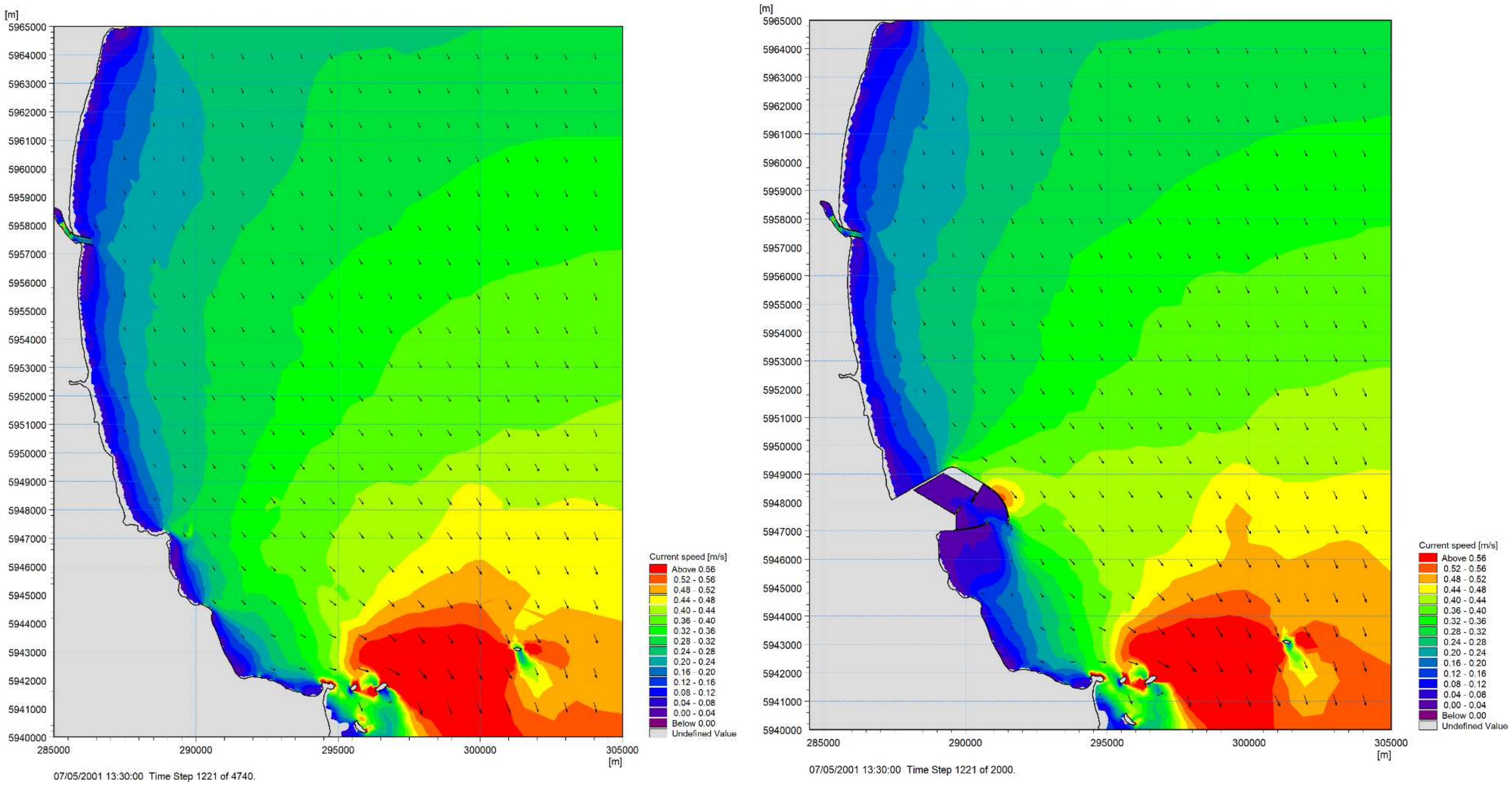


Figure 2.23 Spring tide ebb current flows — Existing Bremore layout (left) –Proposed Bremore layout (right)

2.5.2 Wave Climate

Figures 2.24 and 2.25 show the effect of the proposed port on the wave climate along the adjoining coast.

With north to northeast storms, Figure 2.24, the effect of the projection of the port from the shoreline will be to shelter about 3 kilometres of coastline to the south of the development. Similarly, with south to southeast storms, the projection of the port will reduce the wave climate for about 3 to 4 kilometres north of the northern boundary of the proposed development.

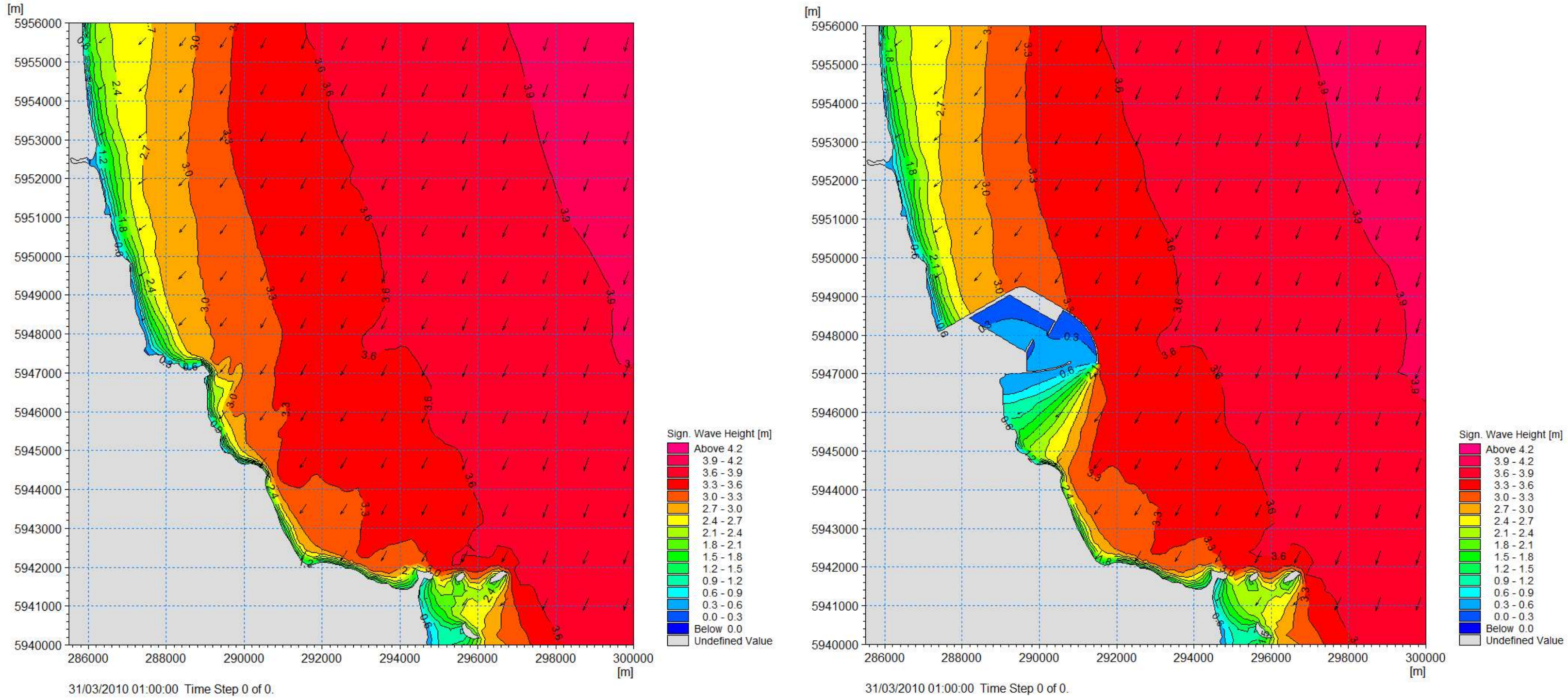


Figure 2.24 Northeast storm wave heights – Existing Bremore layout (left) –Proposed Bremore layout (right)

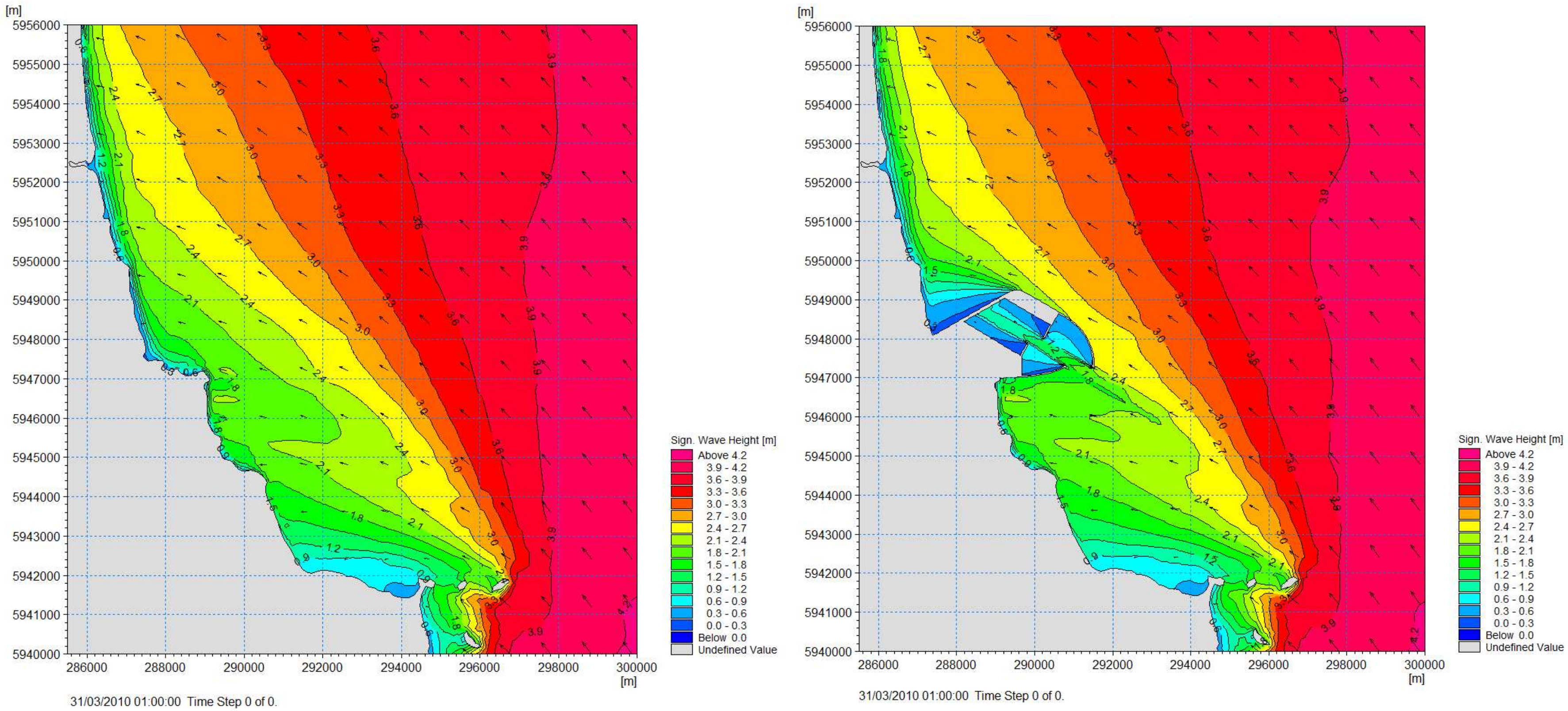


Figure 2.25 South to southeast storm wave heights – Existing Bremore layout (left) –Proposed Bremore layout (right)

2.5.3 Sediment Transport

In 2012 RPS undertook a detailed study of the sediment transport into the sediment cell around Drogheda. This study used a number of sources including studies into the stability of the entrance to the Boyne and its adjoining beach undertaken by Kirk McClure Morton for Drogheda Port and Meath County Council between 2001 and 2005, a study by DHI (unpublished) into the hydraulics of a proposed port at Bremore Point (2008), and a study by MarCon Computations International titled "Morphodynamic Modelling in the Irish Sea" which reported in March 2008.

The 2012 RPS study examined the pathway of the sediments feeding the beaches within the Drogheda sediment cell and examined the sediment transport rates along the beaches and around Bremore Point. RPS reviewed the 2012 study in 2018 and concluded that there had been no material changes which would have significantly changed the results of the 2012 report.

As can be seen from Figure 2.26, taken from the "Morphodynamic Modelling in the Irish Sea", the sediment moving into the cell around Drogheda comes from the south east and moves past Bremore Point in a north-northwest direction.

The figures from the RPS 2012 report indicates that on average some 175,000 m^3 of sand sediment will move both north-northwest and south-southeast past Bremore Point per annum with a net movement of rate of about 60,000 m^3 /year in a north-northwest direction.

As the proposed port development at Bremore projects out into the Irish Sea, it will effectively block a considerable proportion of the sediment which currently passes Bremore Point. Active sediment by-passing will be required to avoid a build-up of sand on either side of the port and this will be particularly important on the southern side of the port as a build-up of sand in this area could lead to rapid infilling of the entrance channel during extreme storm conditions. There will also be a trend for both the entrance channel and parts of the port area to silt up over time as the proposed port will act as sediment trap and thus regular maintenance dredging will be required to keep the port and channel to the required depth.

As the proposed port will create a current flow and wave shadow along the coastline on either side of the port, it is unlikely that a simple sediment by-passing operation will be able to fully mitigate the effect of the port on the sediment regime of the adjoining shorelines. Allowance should be made in the estimated running costs for a sophisticated system of physical redistributing of sediments along the adjoining coastlines.

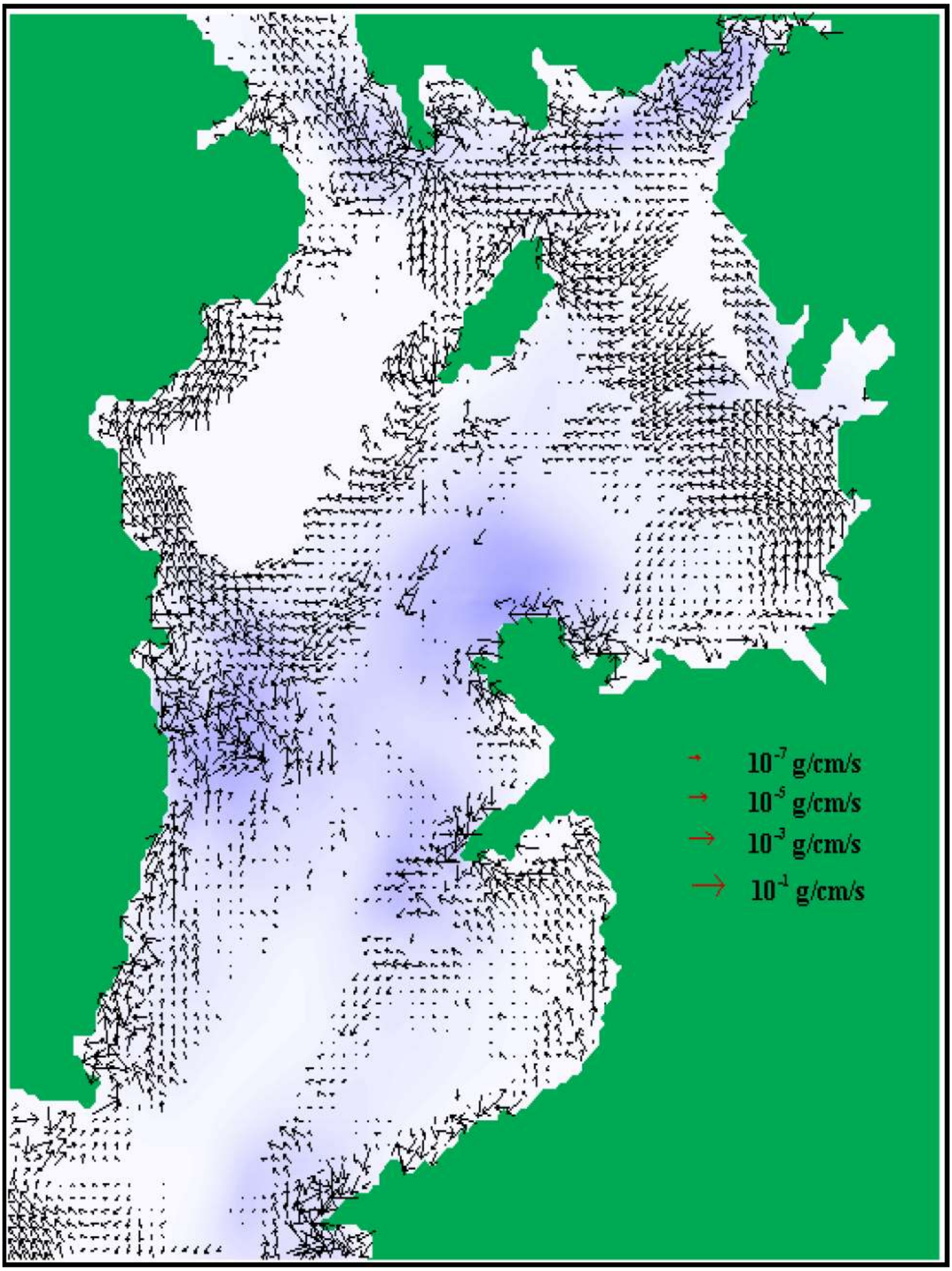


Figure 2.26 Predicted average monthly net bed-load transport vectors (after Bagnold) from MarCon study

2.6 Preliminary Design of Breakwaters

An extreme value analysis, using the MikeZero EVA toolbox, was undertaken on the 20 years of inshore wave climate to establish the 1 in 200-year return period storm wave climate for the preliminary design of the main breakwaters and revetments required for the protection of the proposed port at Bremore Point. Figure 2.27 shows the EVA wave height probability curve and confidence limits lines (plus/minus a standard deviation) for all wave directions with HEFS water levels.

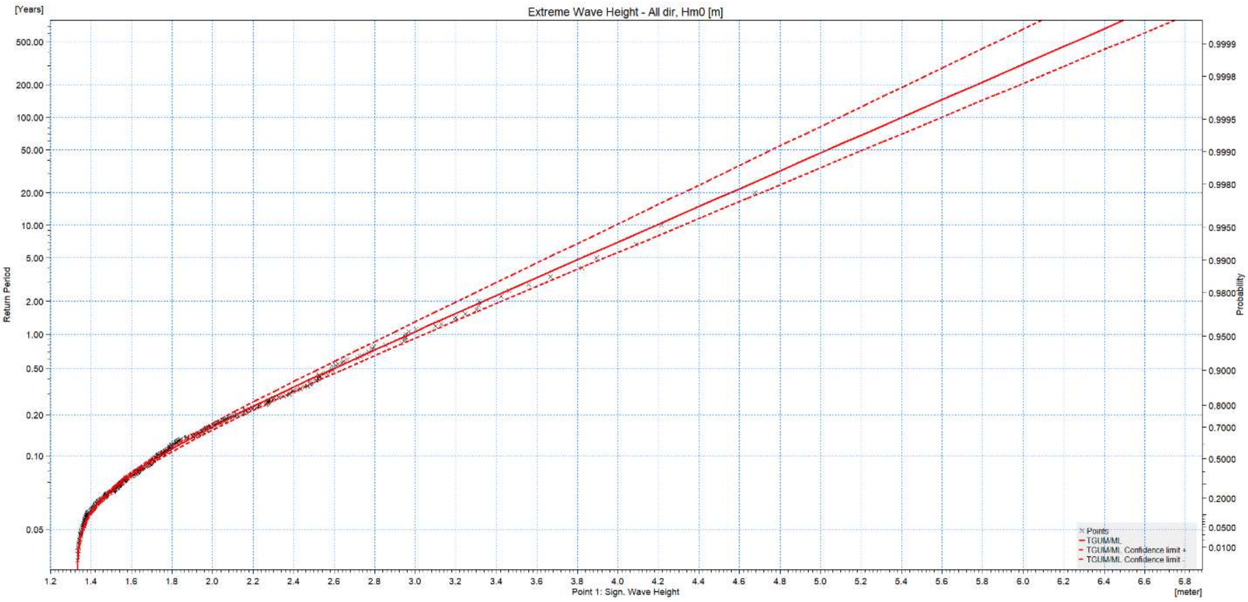


Figure 2.27 Inshore wave height Extreme Value Analysis curve for all wave directions

The directional EVA analysis and the results of the wave transformation modelling were used to establish the incoming wave heights and periods for the design of each section of the breakwaters and revetments.

The breakwaters were mostly of a rubble mound form with the main deck level being taken as +5.6m OD to allow for future sea level rise. The variation in the breakwater design for each part of the port structure is indicated in Figures 2.28. Details of the breakwater sections are given in Appendix 1.

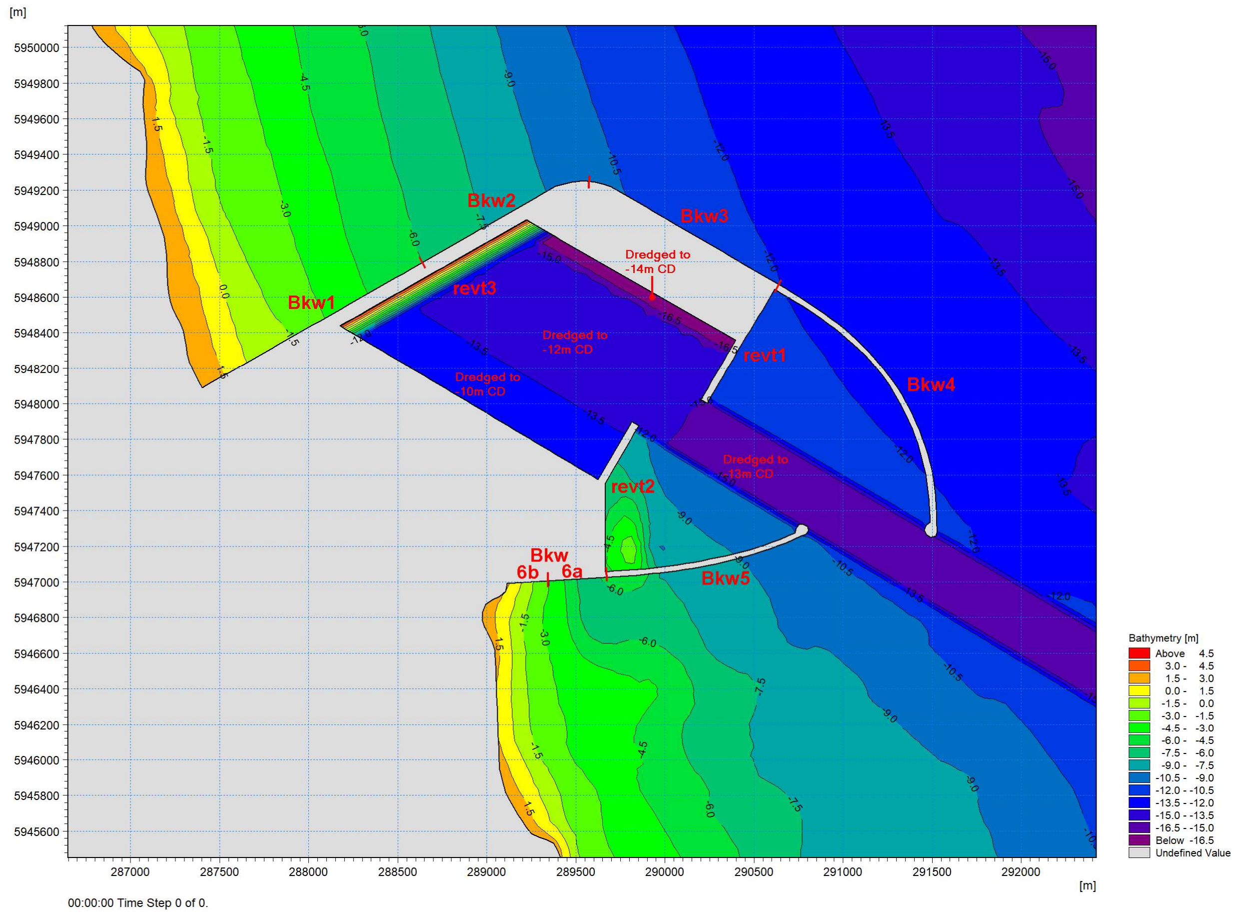


Figure 2.28 Proposed Bremore DP1.5 layout – Breakwater and revetment references

3 PORT DEVELOMENT AT ARKLOW

3.1 General

Figure 3.1 shows the coastline at Arklow. The initial site selected for the proposed Arklow Port development has a relatively short coastline of about 1.8 kilometres extending from the mouth of the Avoca River to the breakwater at the quarry site. To the south of the breakwater is the designated bathing beach at Clogga.

Figure 3.1 Coastline around the potential location for the DP1.5 port at Arklow

3.2 Wave Climate and Water Level

In order to provide information for the refinement of the DP1.5 layout at Arklow, RPS undertook the wave transformation of twenty years of three hourly wave climate data from an offshore point to the site for the period 1999 to 2018 inclusive. This require 58,439 simulations of a flexible mesh spectral wave model. The extent and bathymetry of the coupled wave and tidal model for the existing bathymetry at Arklow is shown in Figure 3.2.

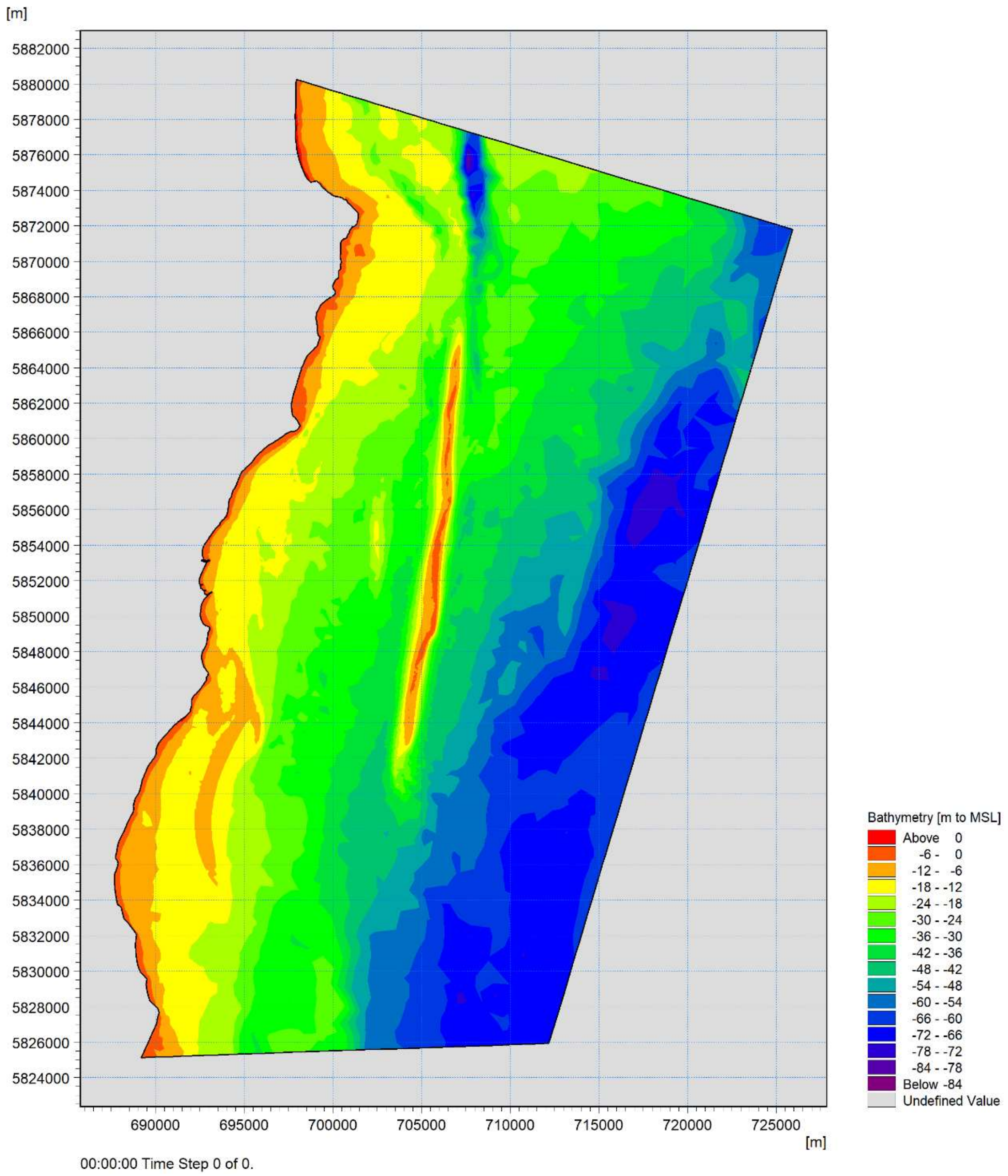


Figure 3.2 Extent and bathymetry of coupled wave and tidal model for Arklow

The offshore wave climate was taken from the 8km grid UK Met Office Wavewatch III wave model as a combination of data from two points at 5.637°W, 52.948°N and at 5.871°W, 52.542°N. The offshore wave rose for wave heights greater than 2m is shown in Figure 3.3

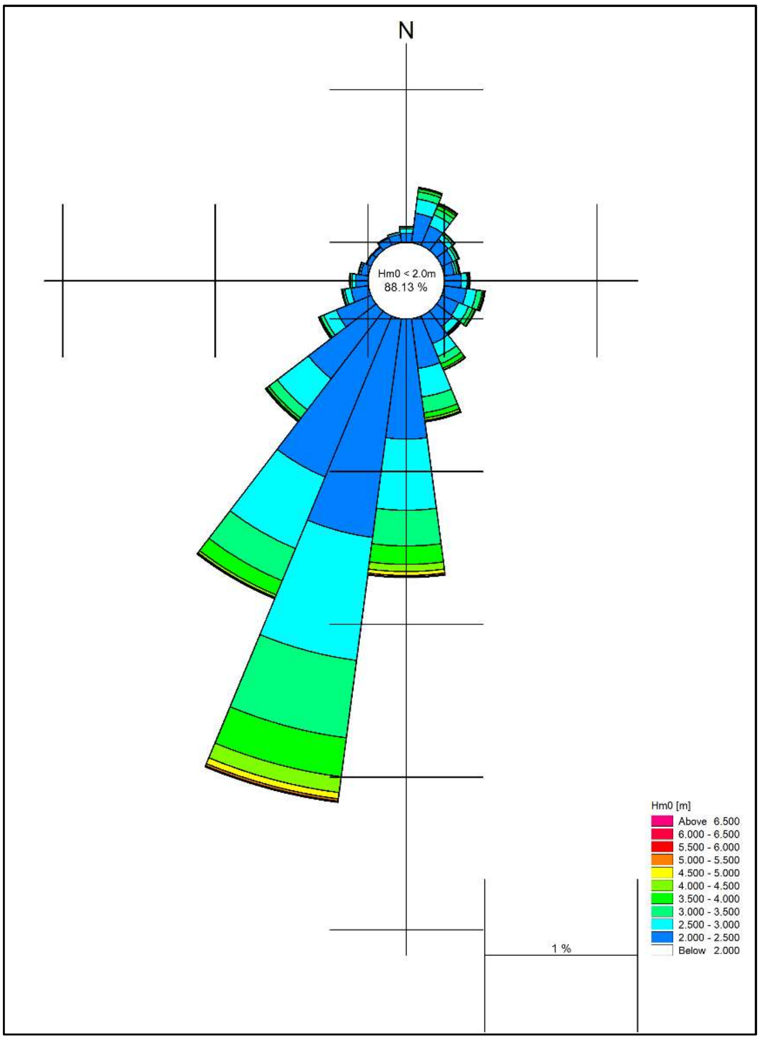


Figure 3.3 Offshore wave height and direction rose for significant wave heights > 2.0m

It will be seen from the offshore wave rose that the offshore wave climate is most active for waves from the south to south-southwest direction but there are also large storm waves from the southeast and north-northeast directions.

The wave transformation simulations were undertaken using the tidal levels which occurred at the time increased in line with the High End Future Scenario (HEFS) climate change predictions for 2100 so as to allow for the time frame for the operation of this future port.

The results of the wave transformation simulations are shown in Figures 3.4 and 3.5 in terms of the inshore wave height rose and a scatter plot of inshore significant wave height against inshore wave direction.

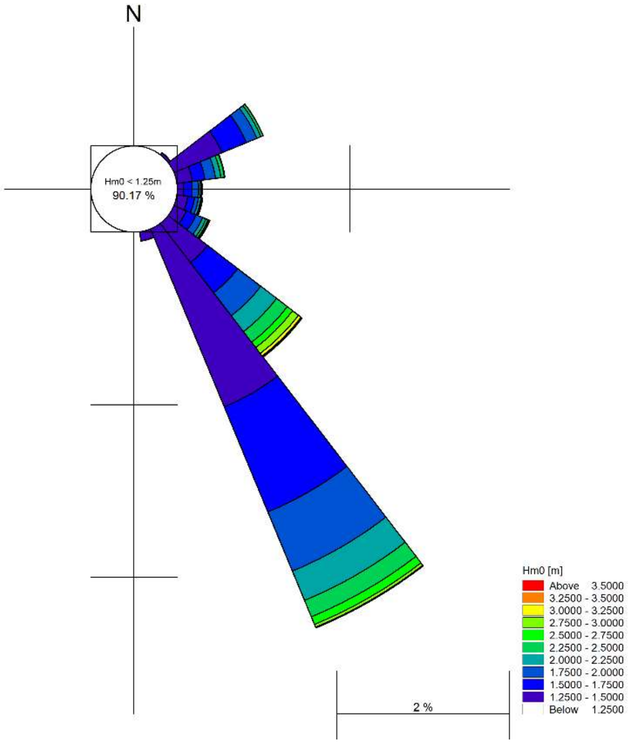


Figure 3.4 Inshore wave rose at Arklow – 1999 – 2018 with HEFS climate change to 2100

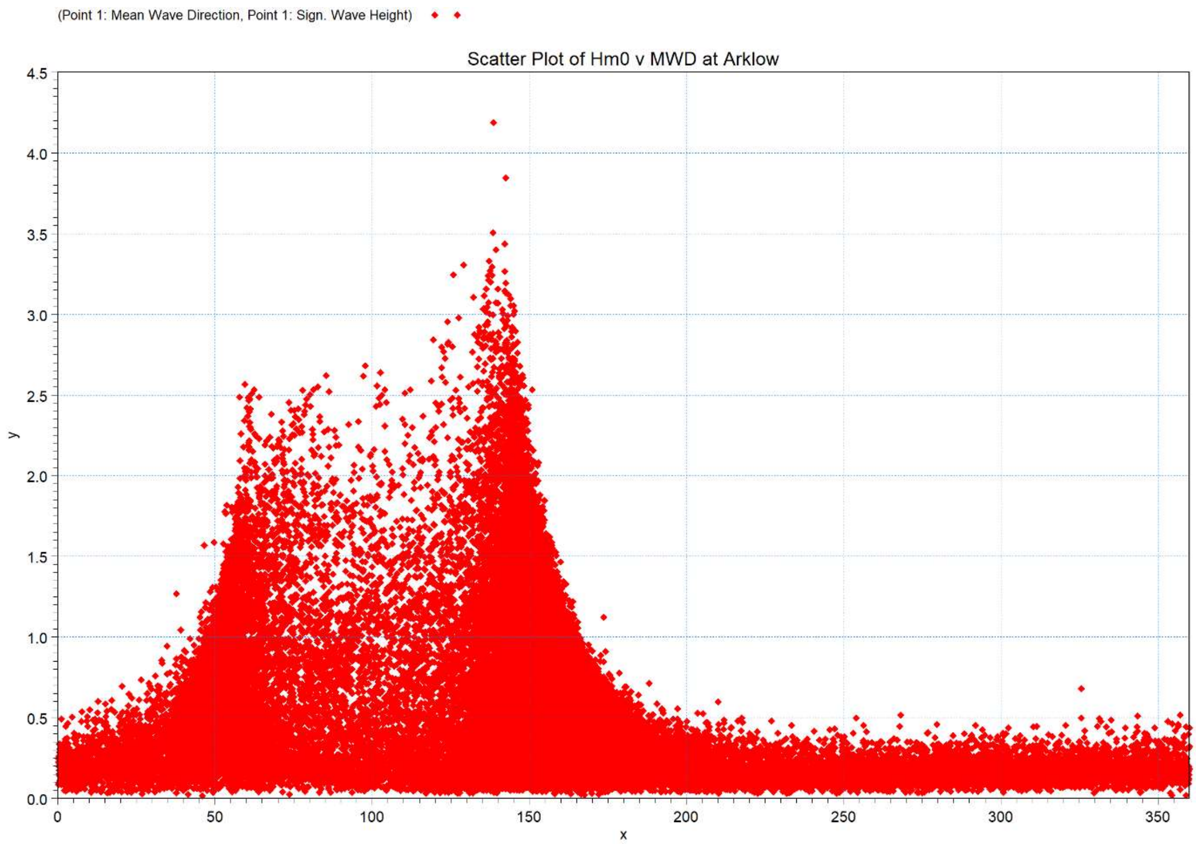


Figure 3.5 Inshore wave scatter diagram of Hm0 v MWD 1999 – 2018 with HEFS climate change to 2100

It will be seen from Figures 3.4 and 3.5 that large waves approach the proposed site from the 50° to 150°N sector. The largest waves and most frequent large waves approach from the 125° to 150°N range although there is a secondary peak in the scatter diagram at around 60°N.

An extreme value analysis on the inshore wave heights has been undertaken and the probability curve and confidence lines (plus and minus one standard deviation) is show in Figure 3.6. It will be noted that the largest inshore wave height at about 4.3m is an "outlier" in the distribution and would effectively be a 1 in 50-year return period event. This large wave occurred during ex Hurricane Ophelia on 16 October 2017.

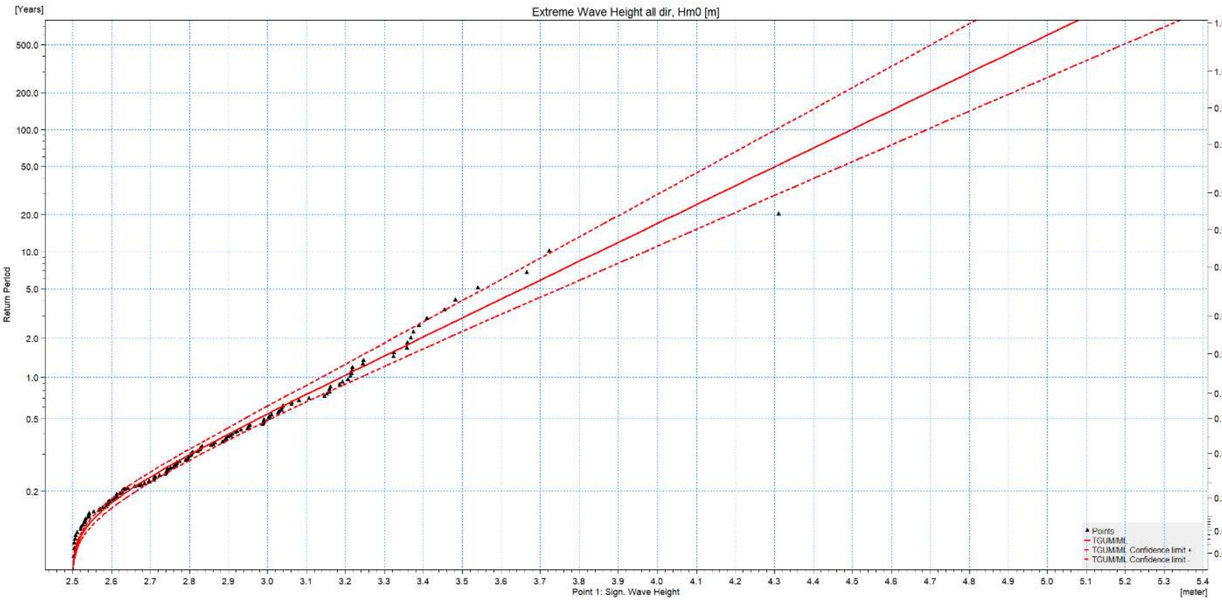


Figure 3.6 Inshore wave height Extreme Value Analysis all wave directions

The tidal range at Arklow is relatively small as it is close to the amphidromic point at Courtown. The spring tidal range at Arklow is 0.8m and HAT is about +0.6m OD. The HEFS water level used in the analysis for Arklow was +1.6m above mean sea level.

3.3 Tidal flows

The coupled wave and tidal model, Figure 3.2, was run for a month of tides to establish the tidal current regime around Arklow. The tidal boundary conditions for the coupled wave and tidal model of Arklow were taken from the RPS tidal and storm surge model of the whole of the west coast of the UK and Ireland. This model is run on 24/7 basis to provide storm surge forecast for the all the coasts of Ireland and has been extensively calibrated and validated. The extent of this tidal and storm surge model is shown in Section 2.3, Figure 2.5.

The typical flood tide and ebb tide flow regime around Arklow is shown in Figures 3.7 and 3.8. Figure 3.9 shows the tidal current speeds at a point in the middle of the proposed Arklow port site. The current speeds at the point about 1 kilometre out from the coast varies from about 0.6m/s during springs to 0.33 m/s at neaps. The spring tidal current at about 2 kilometres out from the coast will be about 0.7 m/s.

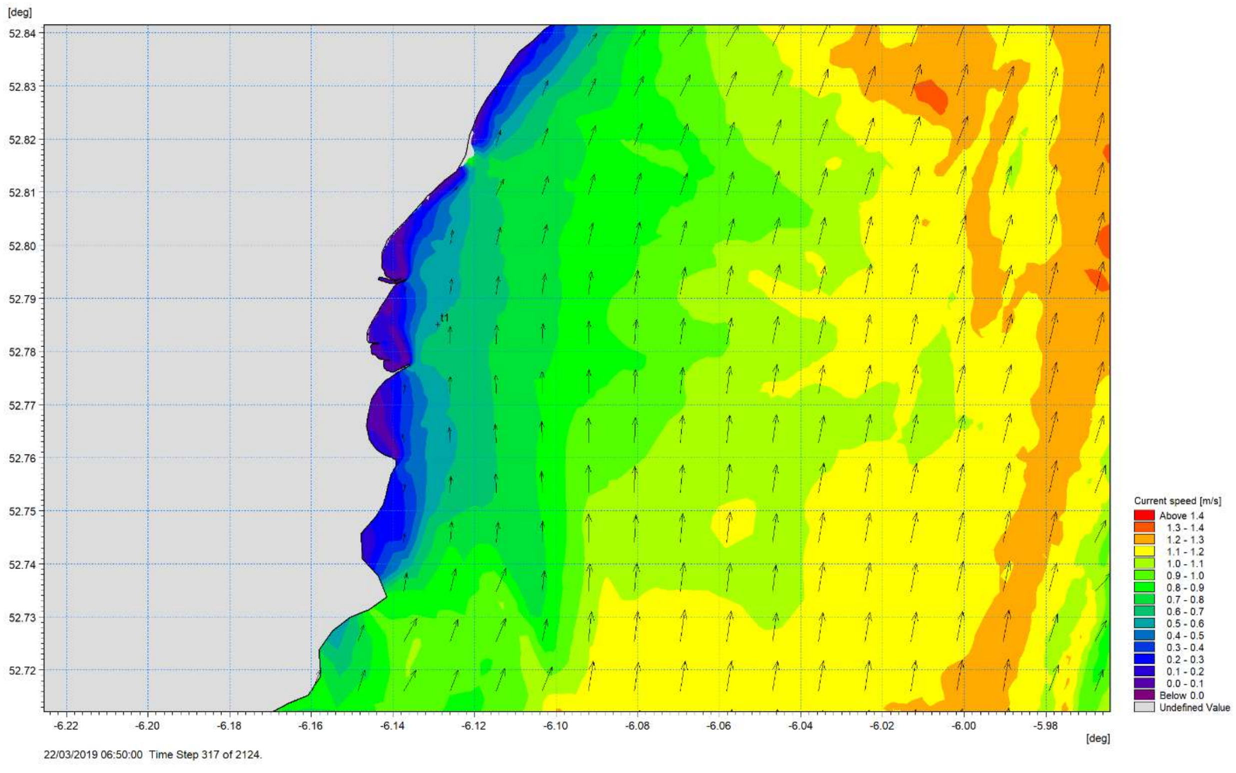


Figure 3.7 Typical spring tide flood flow regime around Arklow

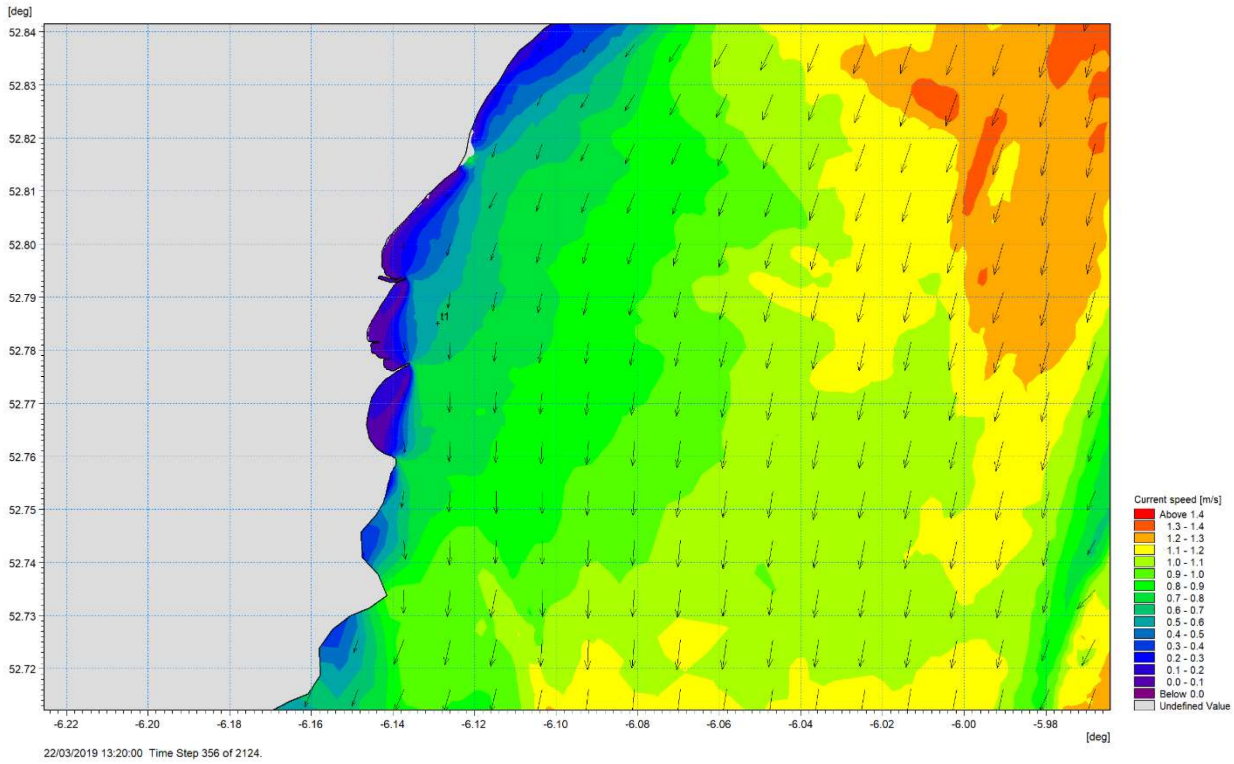
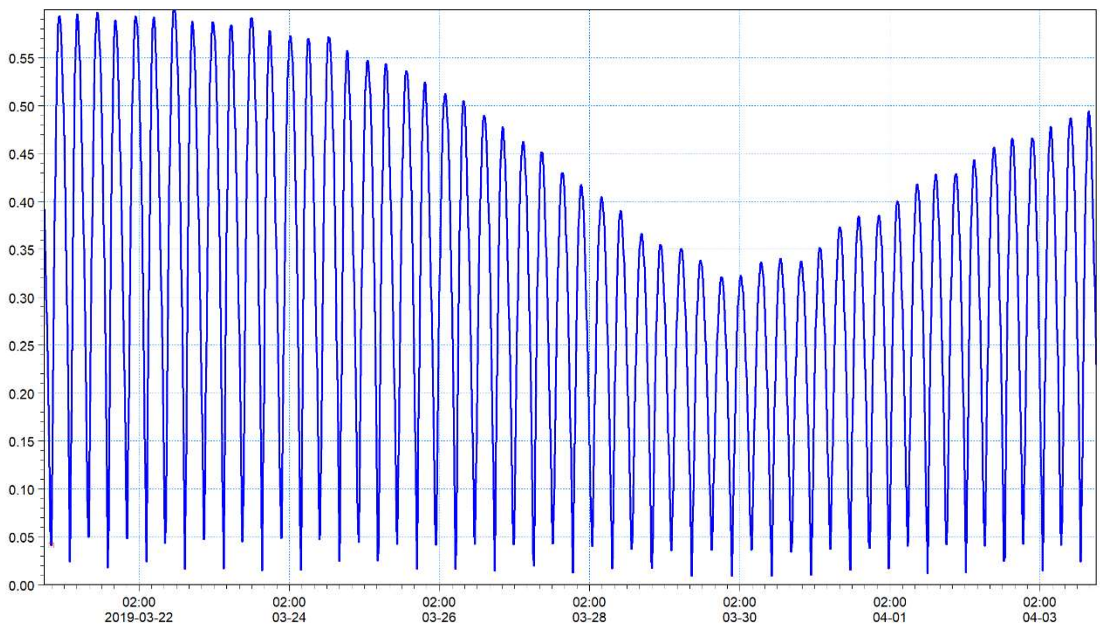


Figure 3.8 Typical spring tide ebb flow regime around Arklow



-Figure 3.9 Current speeds at Arklow port site over a spring neap cycle

3.4 Development of the DP1.5 Arklow Port Layout

Figure 3.10 shows the initial block concept layout for DP1.5 at Arklow prepared for Dublin Port by Martin Mannion based on the DP2 layout with reduced quay lengths.

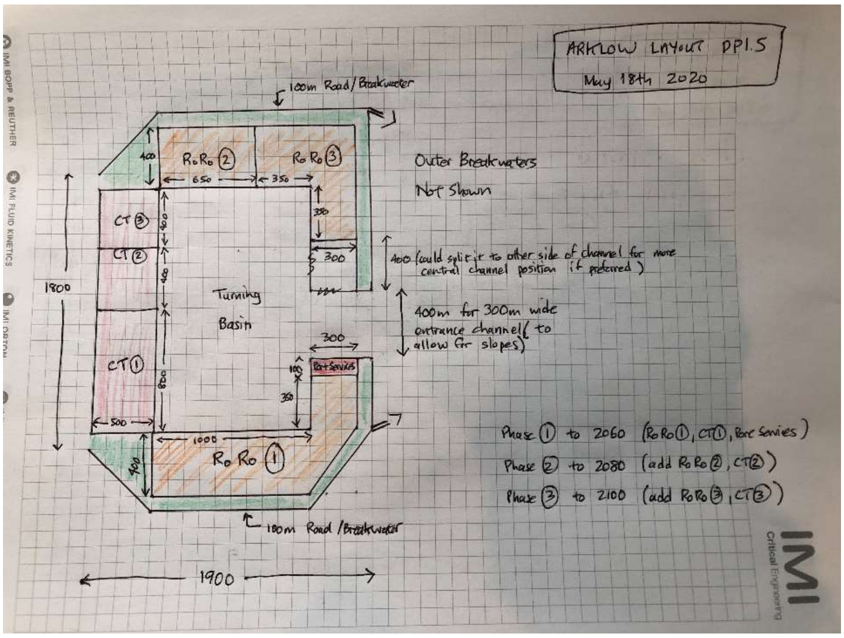


Figure 3.10 Initial block concept layout for DP1.5 at Arklow prepared by Martin Mannion

Following an initial assessment this was amended to the layout shown in Figure 3.11

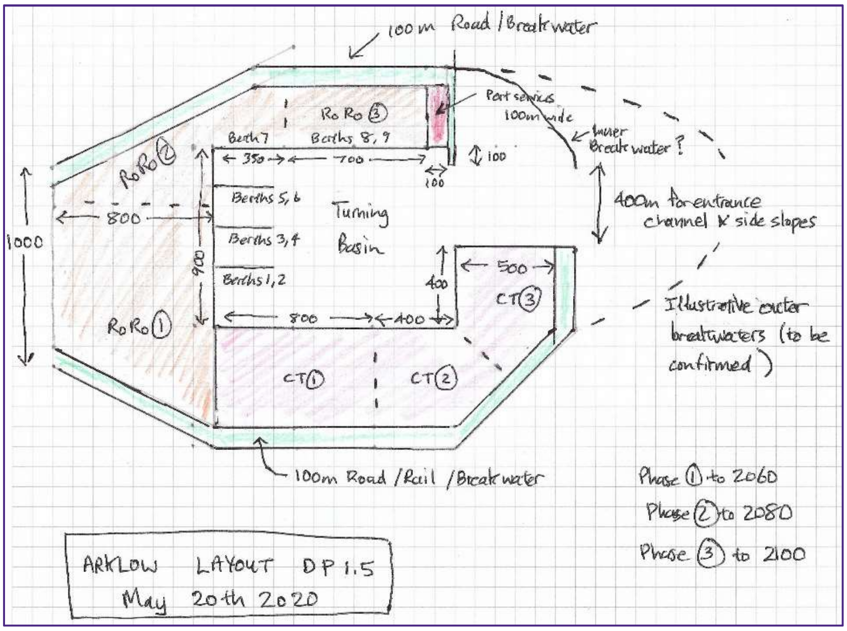


Figure 3.11 Revised concept layout for DP1.5 at Arklow

Hydraulic wave modelling showed that these initial concept layouts suffered from excessive wave heights during easterly storms due to wave reflections from the internal harbour structures. This resulted in a fundamental change in the layout of the basin in which the berths were placed on the northern and southern sides of the basin with a wave absorbing area along western side of the basin as shown in Martin Mannion's alternative concept drawing of September 2020, Figure 3.12.

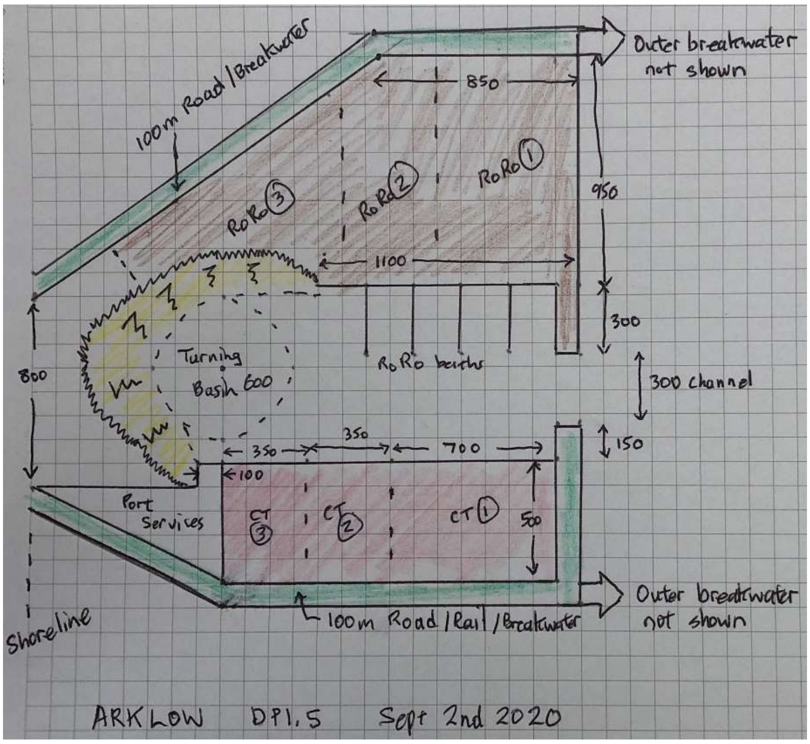


Figure 3.12 Alternative concept Layout for DP1.5 Port at Arklow

RPS used this alternative concept layout to develop further hydraulic models of the harbour with an east facing entrance with the outer breakwaters positioned to give the required navigational distance from the harbour entrance to the turning circle. An outline of one of these models is shown on top of an aerial picture of Arklow in Figure 3.13. At this time consideration was also given to a plan for a harbour with a northeast facing entrance, the model of which is shown in Figure 3.14.

It was found that in both case the alignment of the harbour risked throttling the Avoca River outflow so RPS revised the model layout by switching the Ro-Ro and Container berths from north to south and south to north to provide a harbour layout which did not extend north across the line of the mouth of the Avoca River as shown in Figure 3.15.

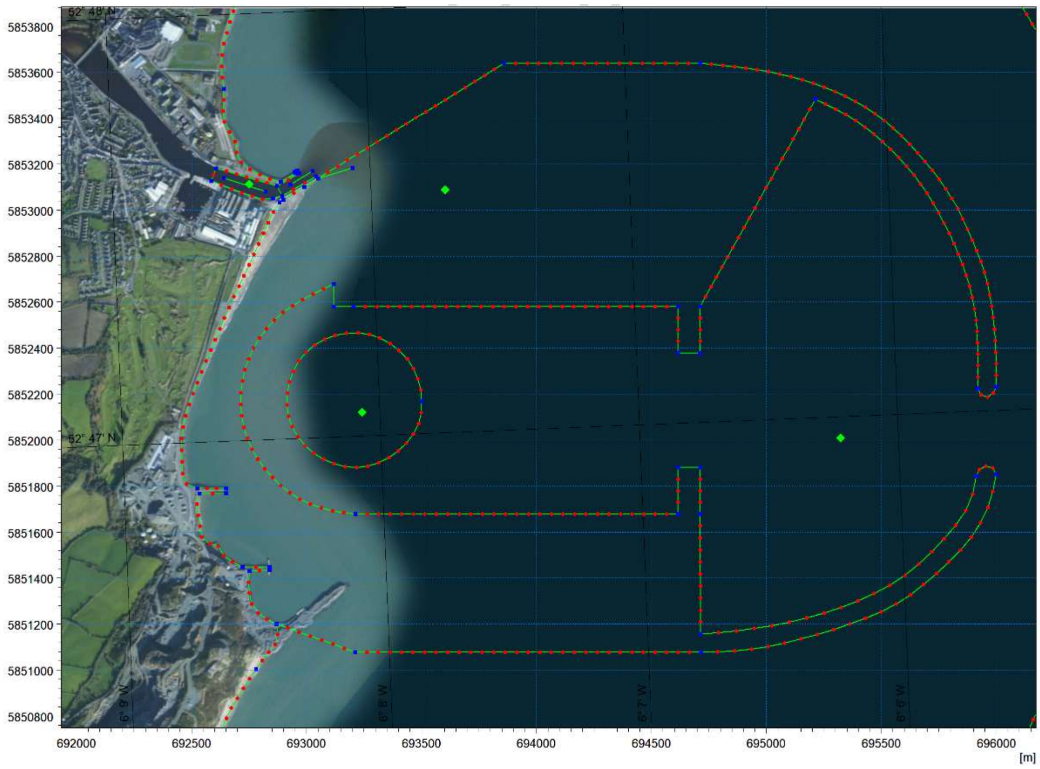


Figure 3.13 Model of alternative concept with east facing harbour entrance

Figure 3.14 Model of alternative concept with northeast facing harbour entrance

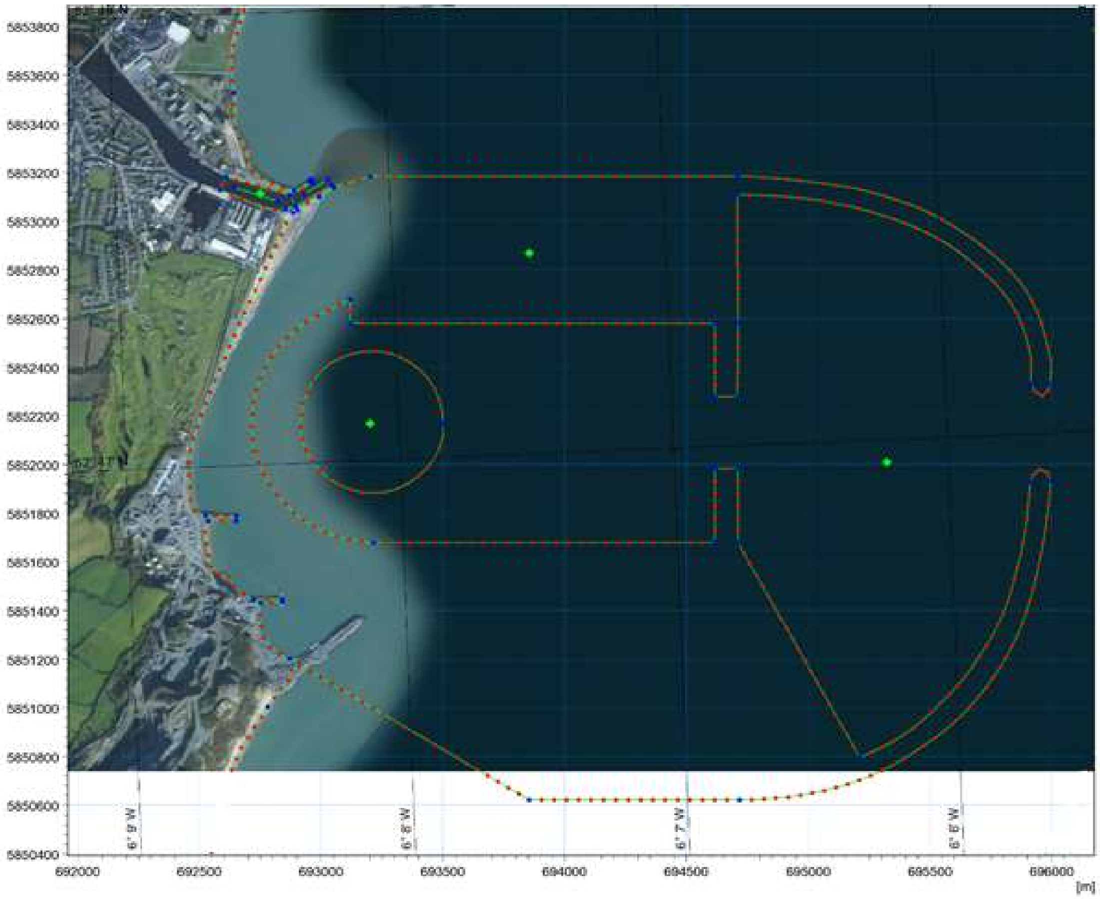


Figure 3.15 Model of the revised alternative concept with east facing harbour entrance

The hydraulic model simulations with this revised alternative concept harbour layout showed that the proposed harbour would provide adequate shelter at the berths during storm events. Following a period of optimisation of the berth lengths and harbour storage areas, the revised alternative layout was further refined to reduce the footprint of the overall harbour to give the final harbour layout shown in Figure 3.16. The model bathymetry to mean sea level of this final layout is shown in Figure 3.17.

The performance of the final harbour layout under storms from the east, northeast and south-southeast directions at high water, including sea level rise due to climate change, are shown in Figures 3.18, 3.19 and 3.20. It will be seen from these three diagrams that the proposed harbour should provide sufficient shelter at the berths for all storm directions.

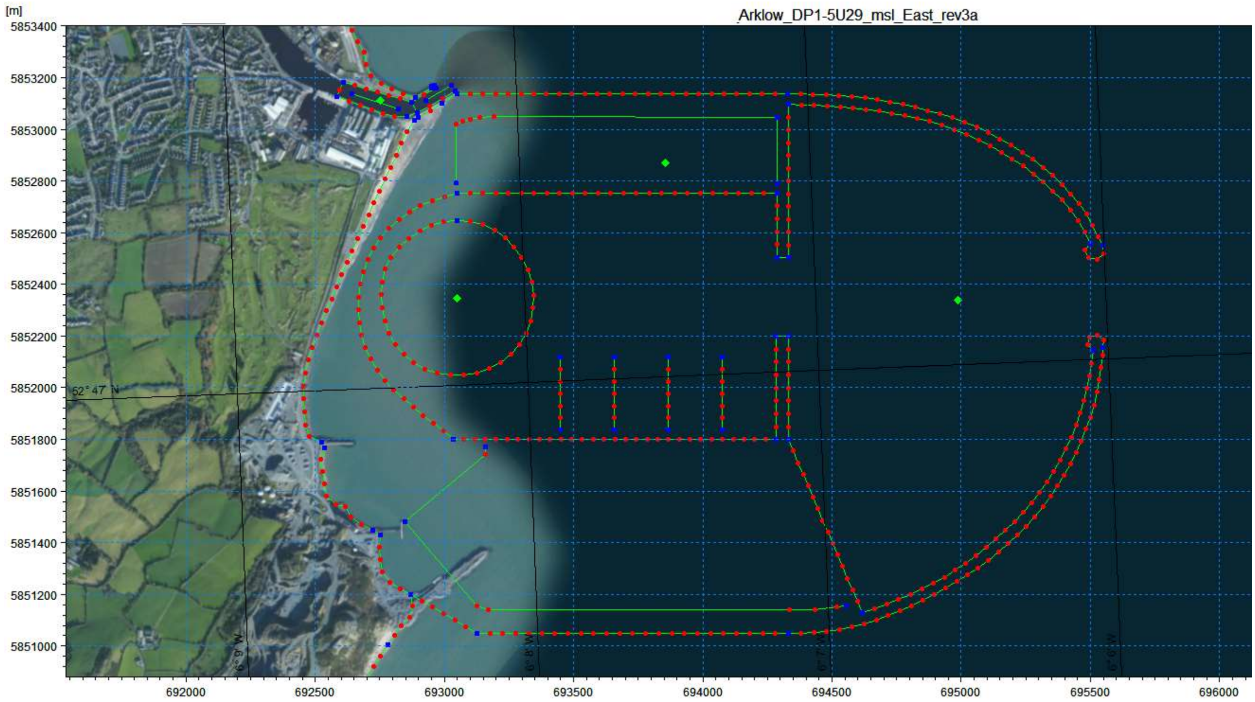


Figure 3.16 Outline of model of final DP1.5 harbour layout with east facing harbour entrance

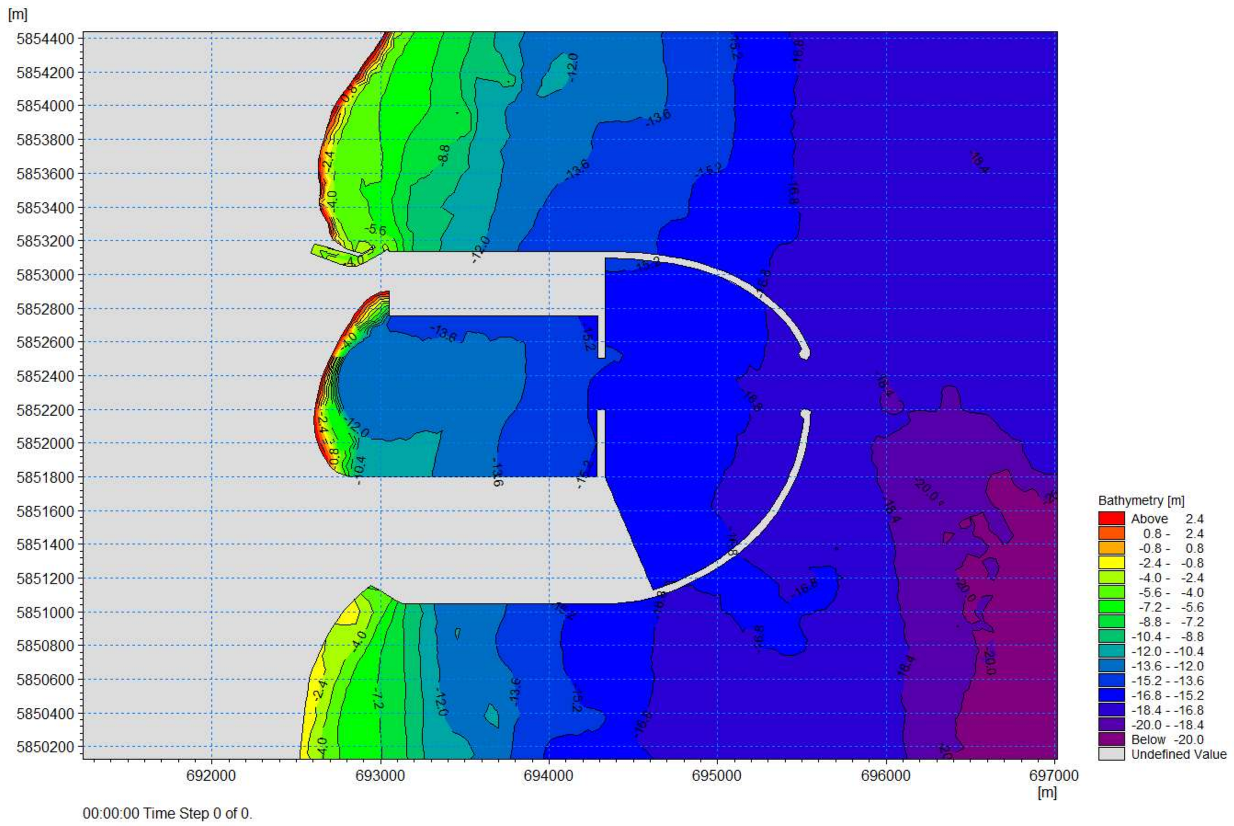


Figure 3.17 Model bathymetry of final DP1.5 Arklow harbour layout

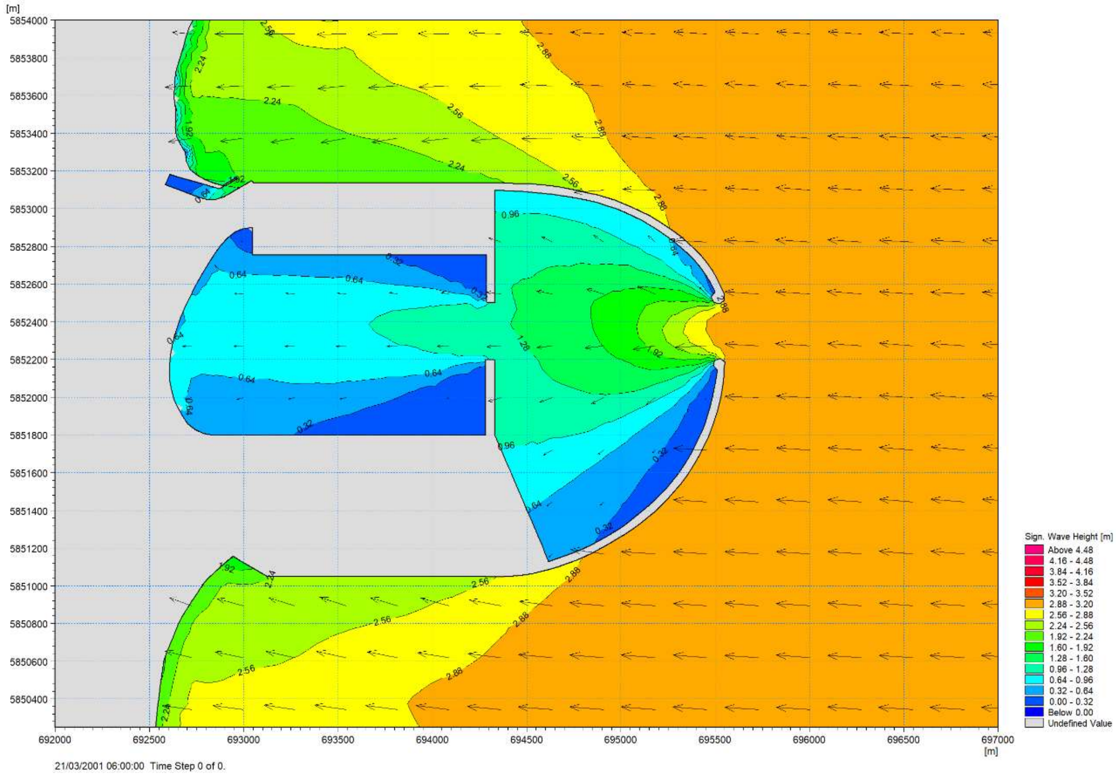


Figure 3.18 Significant wave height and mean wave direction – Easterly storm

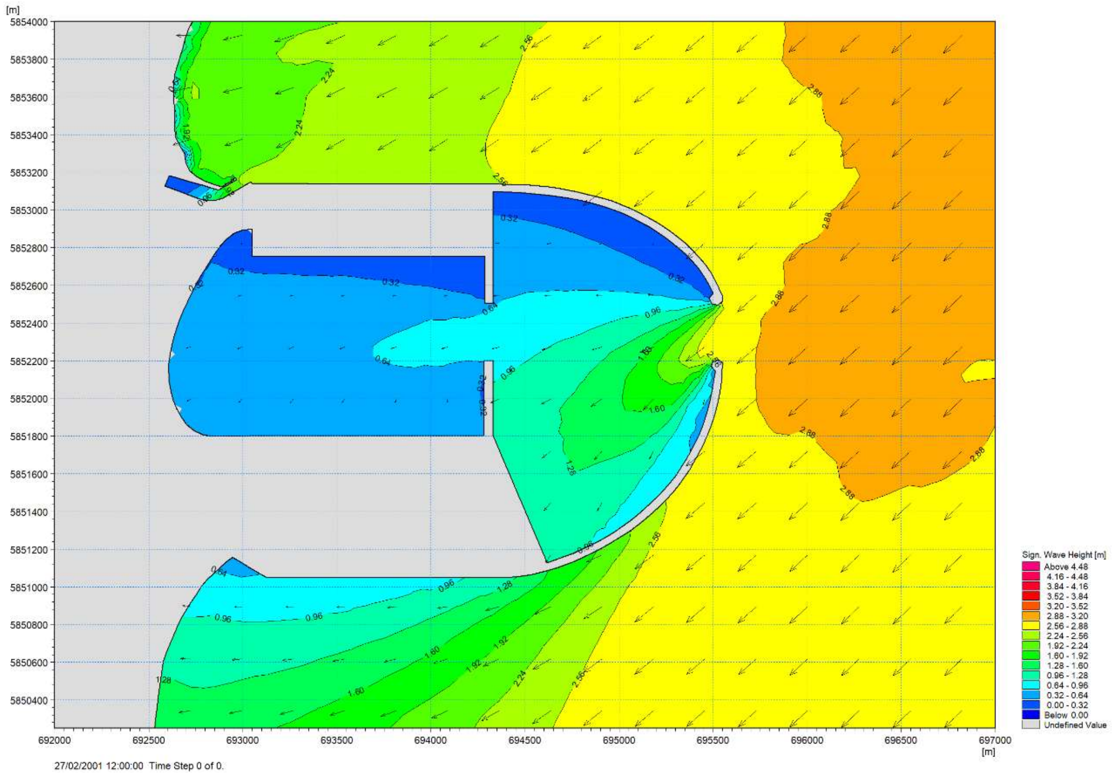


Figure 3.19 Significant wave height and mean wave direction – North easterly storm

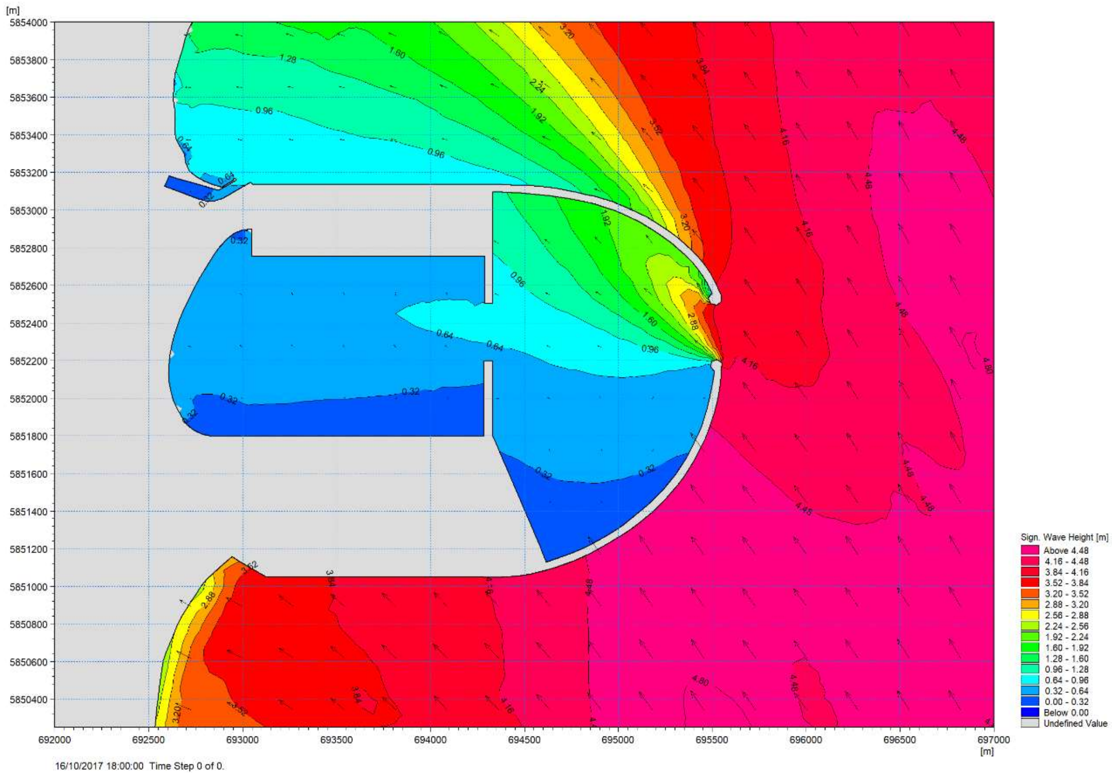


Figure 3.20 Significant wave height and mean wave direction - South south easterly storm

The tides flow approximately north-south at Arklow with the flood going north and the ebb going south at about 0.7 m/s in the area of the proposed harbour entrance. As the proposed harbour projects out from the coastline by more than 2.5 kilometres, the tidal flow will be pushed out around the harbour and will tend to accelerate across the harbour entrance.

Figures 3.21 and 3.22 show the ebb and flood current speeds at spring tides across the proposed DP1.5 harbour entrance. It will be noted from these diagrams that a ship entering the port during mid ebb or mid flood will experience a cross current of about 1.15 m/s running across the harbour entrance. This will tend to slew the ship to port or starboard as the ship enters the harbour because, at some point the bow of the ship will be in no current while the stern will be going sideways at over 2 knots. This will mean that the ships will have to enter the port at a relatively high speed to avoid being carried onto the heads of the breakwaters. Subject to detailed navigation studies, it may be necessary to include some groyne structures on the outside face of the breakwaters to deflect the increase tidal current out from of the port entrance so that the change in tidal velocity is not as abrupt as shown in Figure 3.21 and 3.22

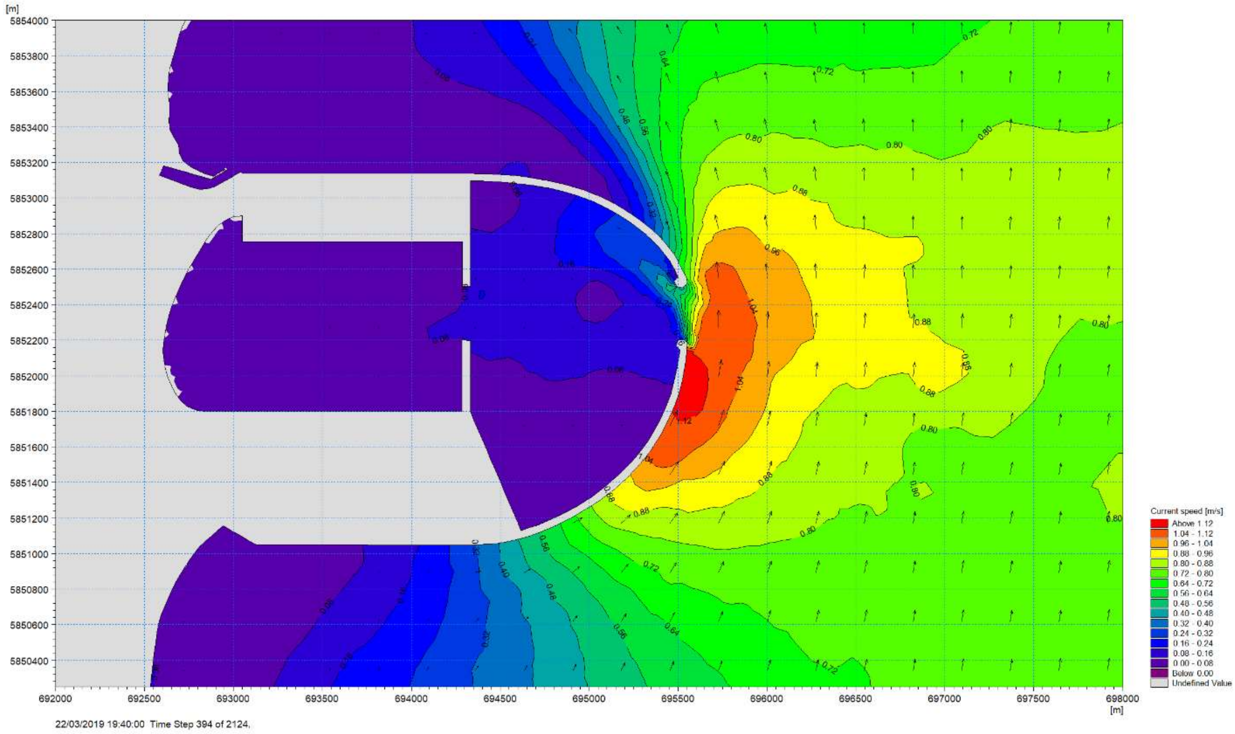


Figure 3.21 Spring flood tidal flow across the entrance to the proposed DP1.5 Port at Arklow

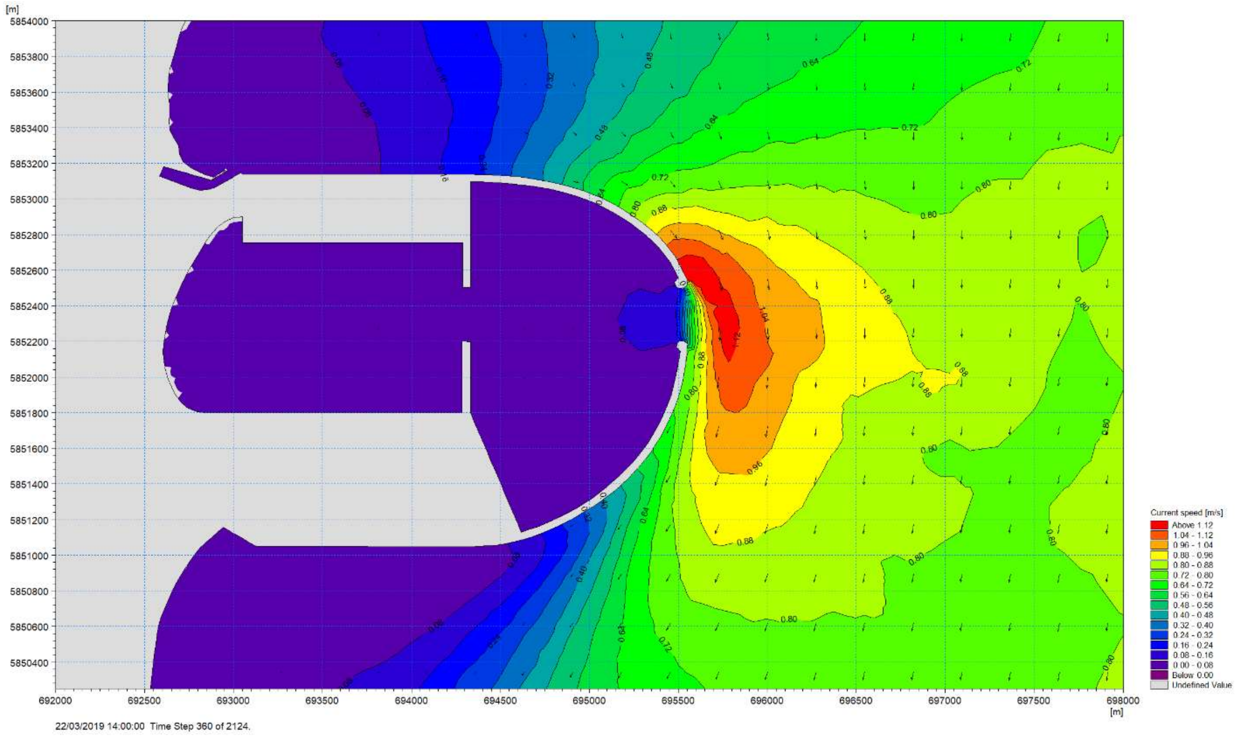


Figure 3.22 Spring ebb tidal flow across the entrance to the proposed DP1.5 Port at Arklow

3.5 DP1.5 Arklow Port – Impact on Adjoining Coasts

3.5.1 Tidal Flows

Figure 3.23 shows the spring flood tidal flow around Arklow and the adjoining coasts for the model with the existing bathymetry (left) and proposed port (right). Similarly, Figure 3.24 show the tidal flows for a spring ebb tide.

Examination of these diagrams indicates that the proposed refined port development would reduce the tidal velocities along the coast for about 6 kilometres to the north and south of the proposed development. However, there is a significant increase in the tidal flow velocities across the entrance to the proposed port development.

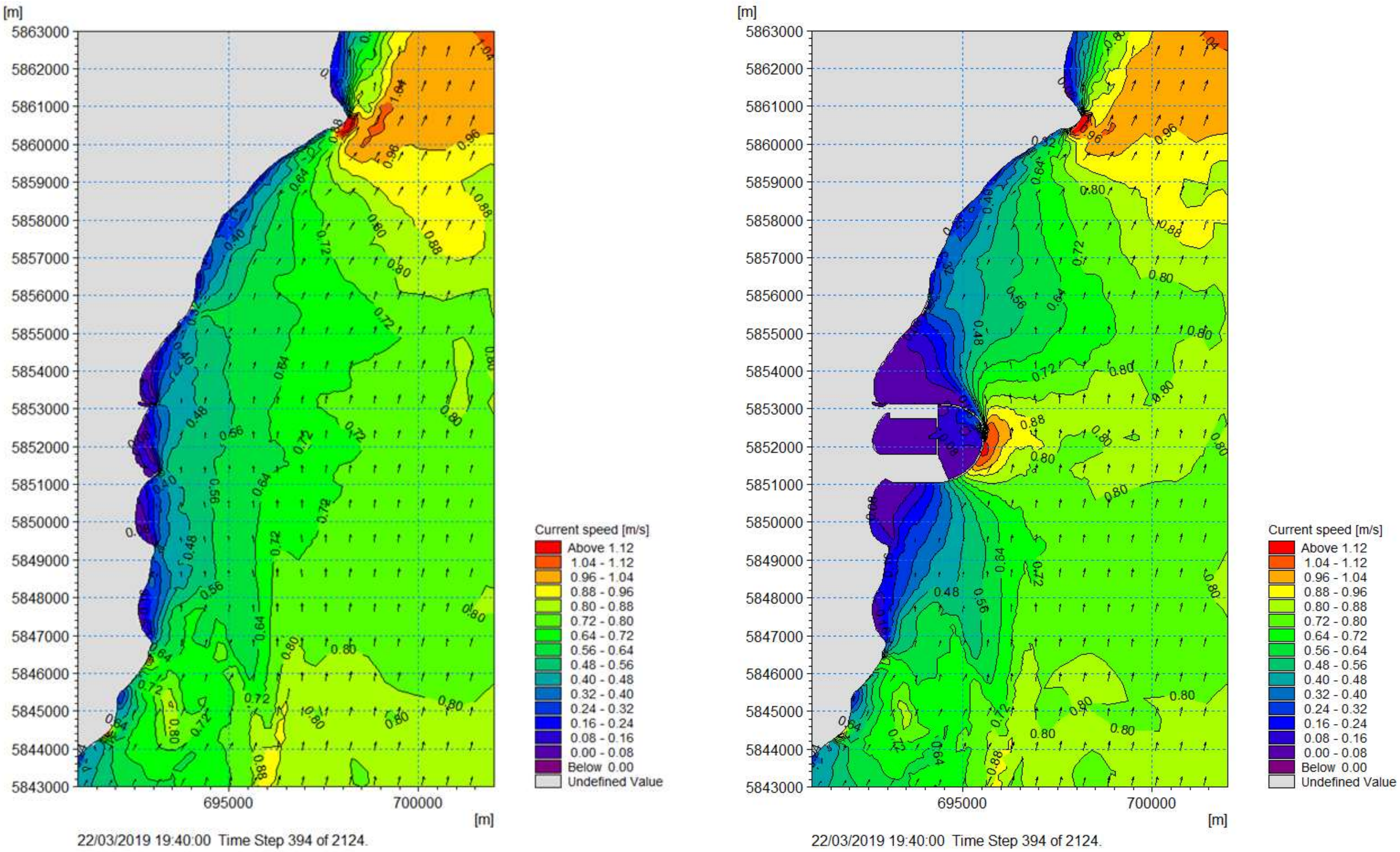


Figure 3.23 Spring tide flood current flows — Existing Arklow layout (left) –Proposed Arklow layout (right)

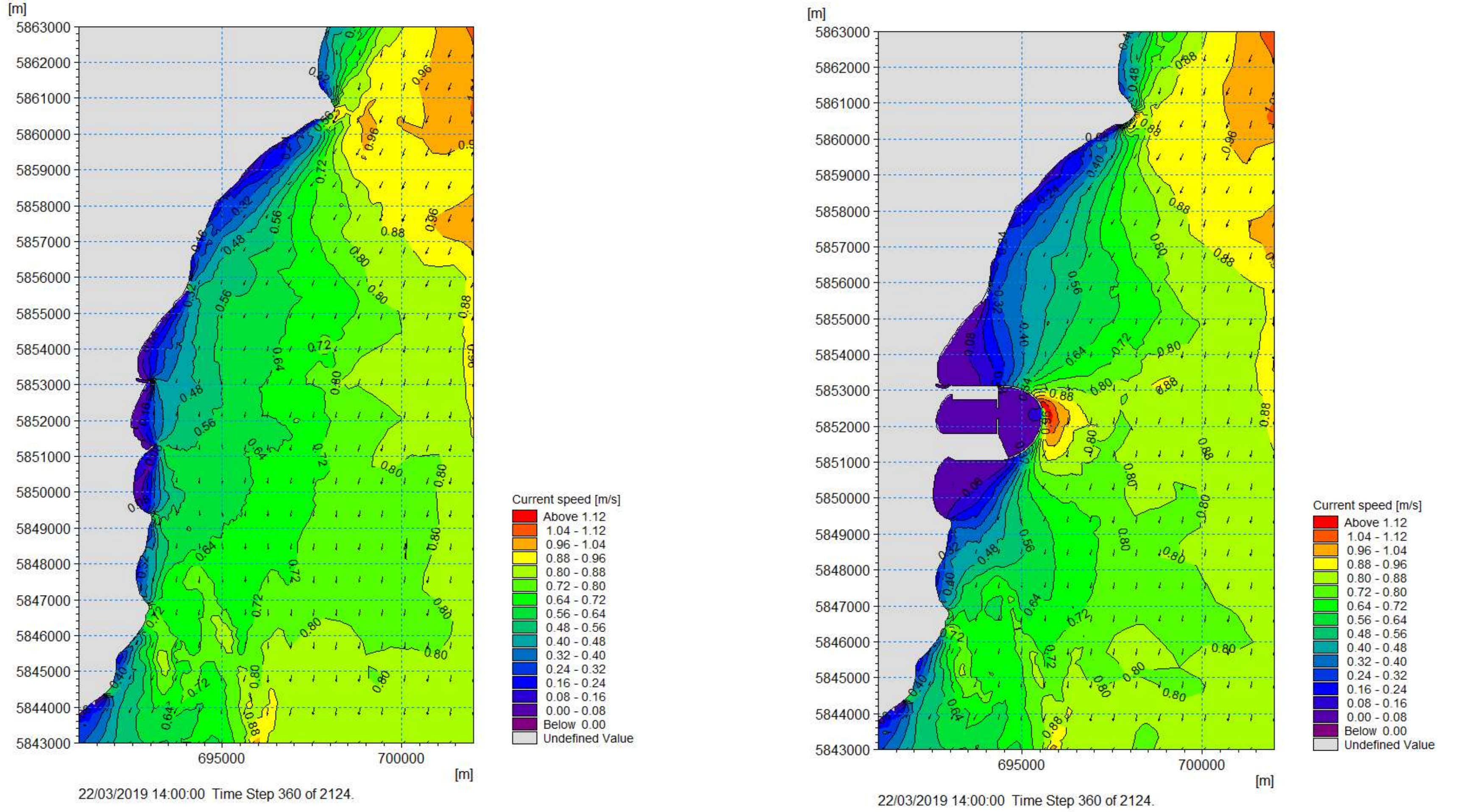


Figure 3.24 Spring tide ebb current flows — Existing Arklow layout (left) –Proposed Arklow layout (right)

3.5.2 Wave Climate

Figure 3.25 shows the distribution of wave heights and mean wave directions around the existing bathymetry (left) and the proposed port layout (right) during a south-southeast storm. The proposed port layout (right) reduces the wave climate along the coast to the north of the development for about 5 kilometres

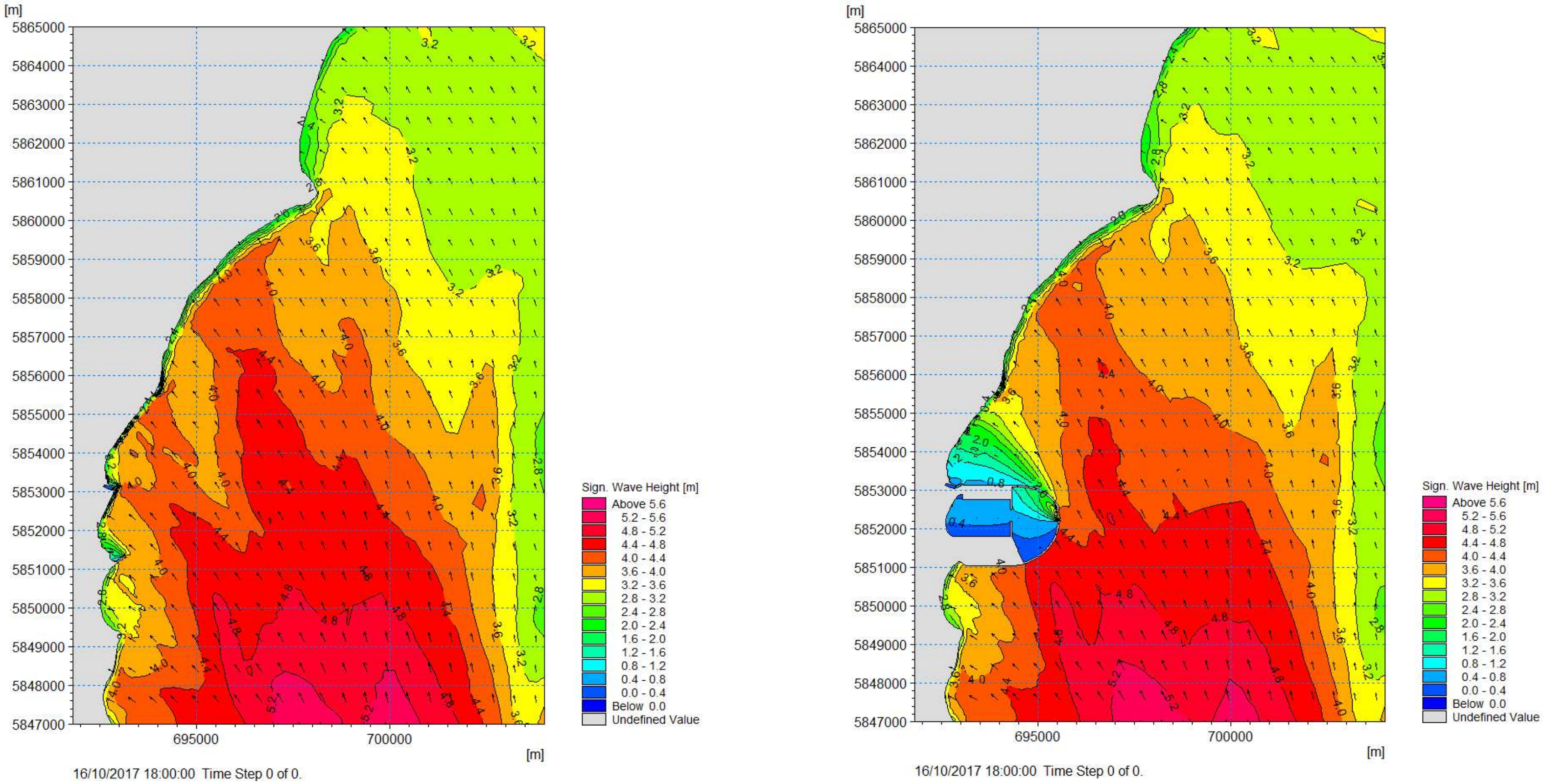


Figure 3.25 South to southeast storm wave heights – Existing Arklow layout (left) –Proposed Arklow layout (right)

Figure 3.26 shows the impact of the port on the wave climate along the coast to the south of the port during northeast storms. The proposed port layout (right) reduces the wave climate along the coast to the south of the development for about 5 kilometres.

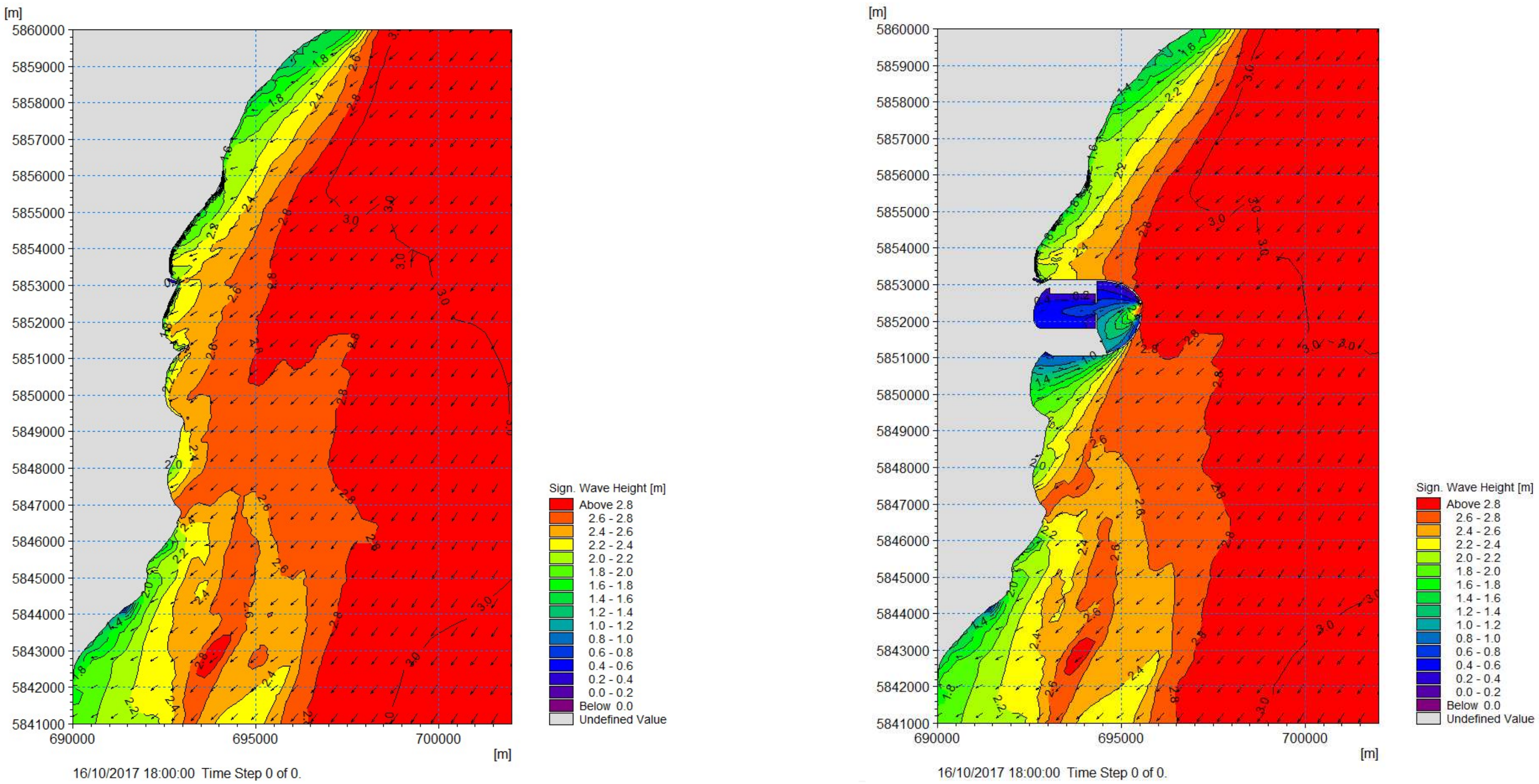


Figure 3.26 Northeast storm wave heights – Existing Arklow layout (left) –Proposed Arklow layout (right)

3.5.3 Sediment Transport

RPS has recently completed sediment transport studies for other projects around the Arklow area of the Irish Sea and adjoining coastlines. These studies show that around Arklow itself the sediment transport is driven by wave induced currents and thus the main sediment transport occurs in the nearshore area. Figure 3.27 shows the net transport during a typical 1 in 1-year storm from the south.

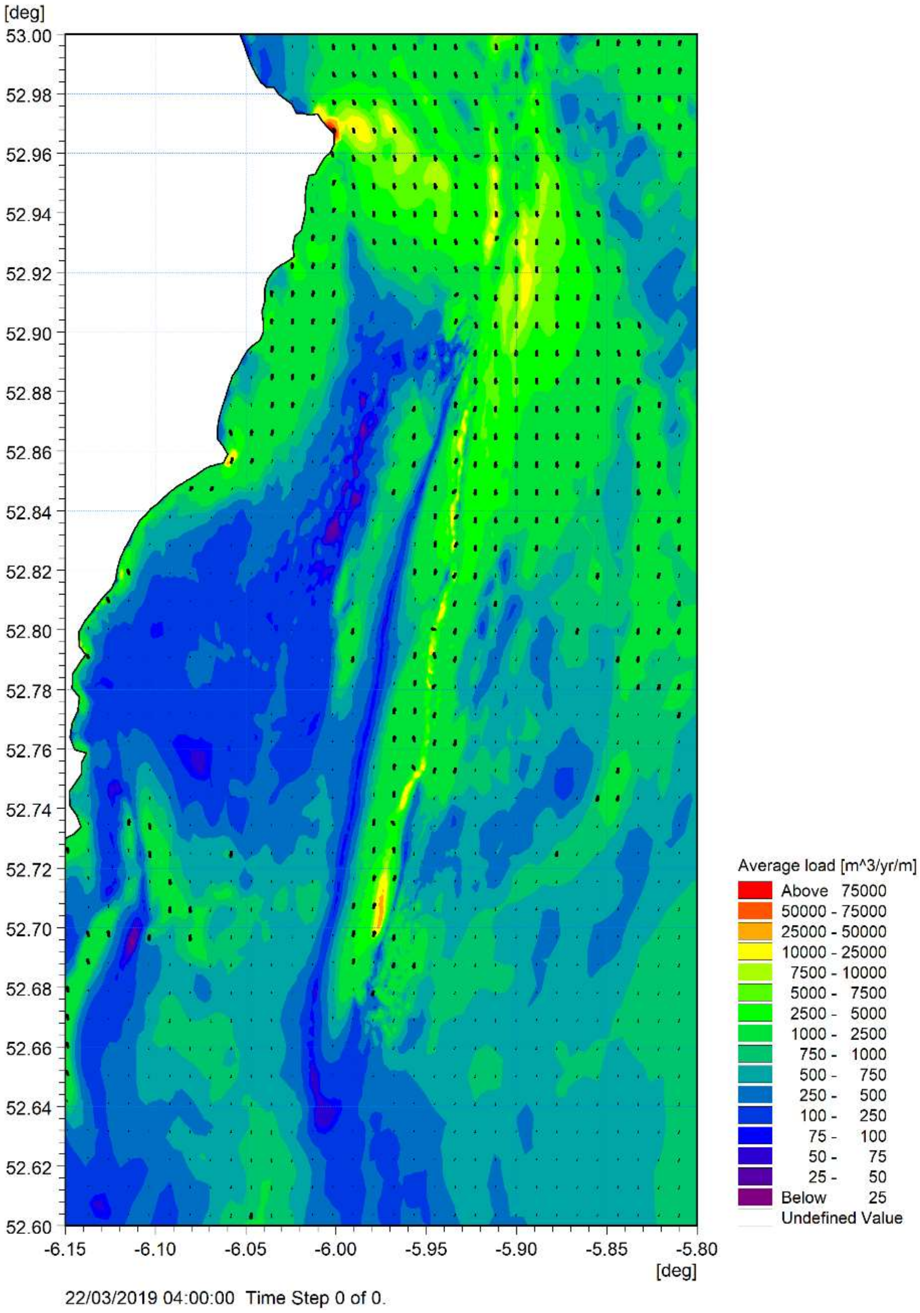


Figure 3.27 Annual sediment transport rates around Arklow during 1 in 1-year southerly storm

The results of the sediment transport studies indicate that the main transport occurs within 0.5 kilometres of the coast with rates of about 50,000 m^3 at the proposed port development site. The majority of the sand moves from south to north along the coast. However, the drift direction can reverse during events with waves from the north to east sector.

As the proposed port at Arklow projects out into deep water, the port structures will completely block the movement of sand moving both north and south along the coast. This loss of supply of sand to the beaches to the north of Arklow would be particularly serious as there is already an ongoing issue with beach level dropping in this area. Positive by-passing and ongoing beach nourishment will be required as part of the operation of the proposed new port. Particular attention will need to be paid to the risk of rapid bar formation at the entrance to the Avoca River during north easterly storm events. In addition, there is a new WWTW, including a long sea outfall, to be built on the north side of the river mouth. It is likely that the proposed new port will interfere with the dispersion of effluent from this outfall.

3.6 Arklow Port – Preliminary Design of Breakwaters

An extreme value analysis, using the MikeZero EVA toolbox, was undertaken of the 20 years of inshore wave climate to establish the 1 in 200-year return period storm wave climate for the preliminary design of the main breakwaters and revetments required for the protection of the proposed port at Arklow.

The extent of the type of breakwater design for each part of the port structure is indicated in Figure 3.28.

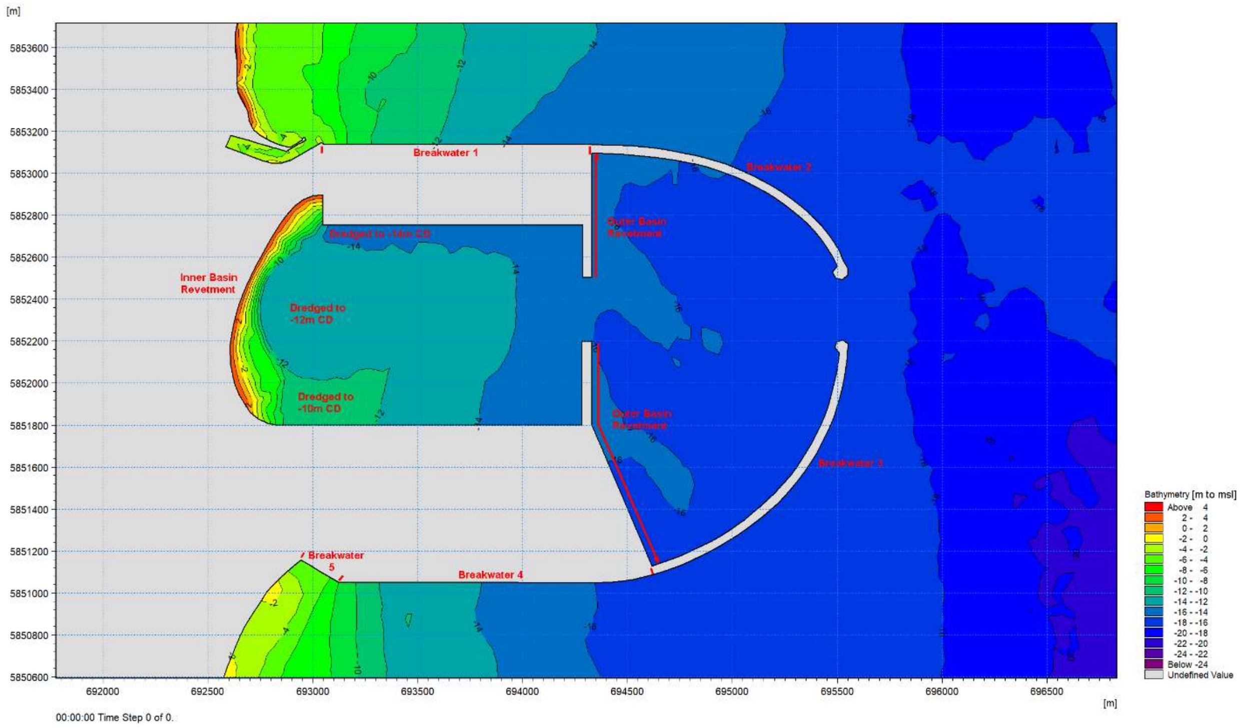


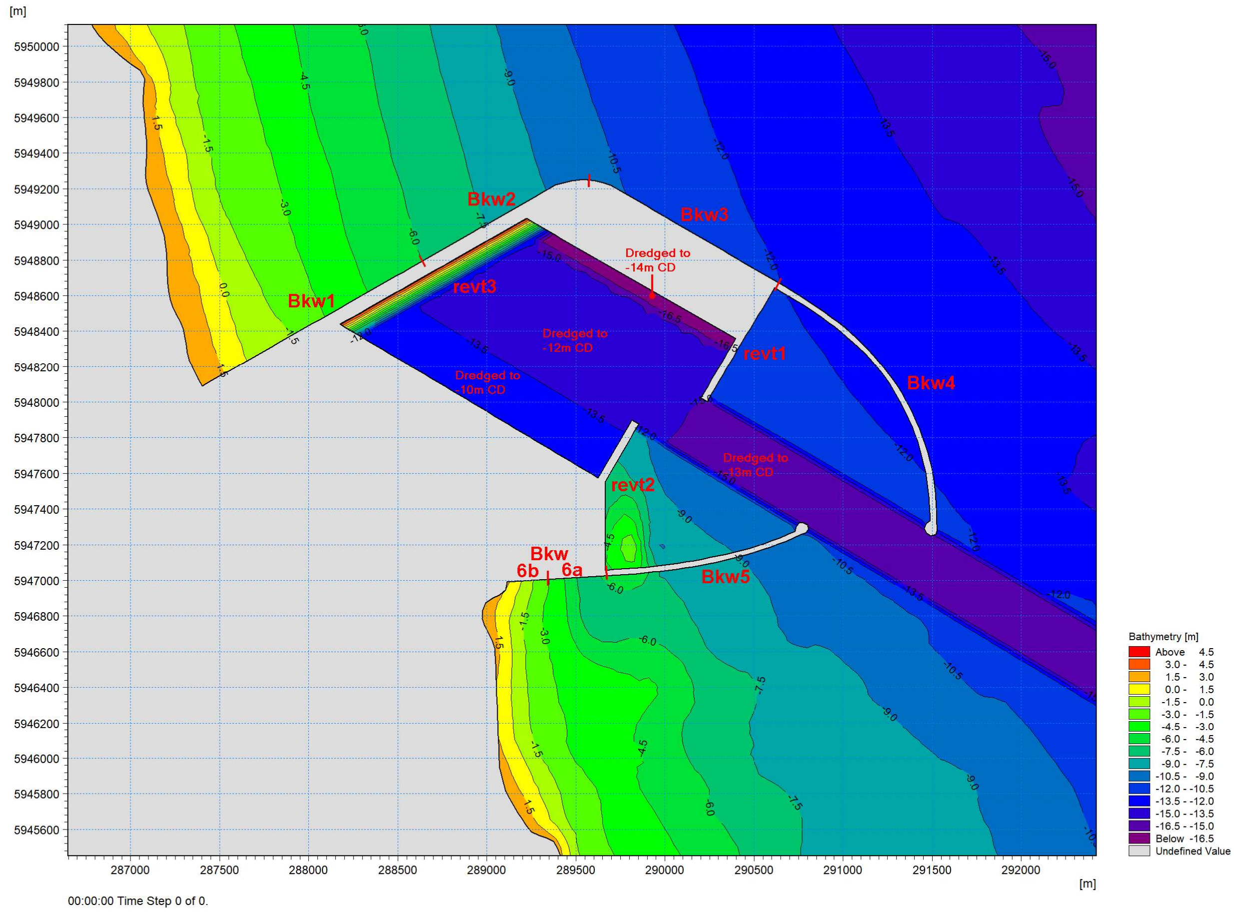
Figure 3.28 Location of Breakwater design sections for Arklow Port

The north and south breakwaters are proposed to be of rubble mound construction armoured with a single layer pattern placed concrete armour unit on a slope of 1 to 1.333. As the southern breakwater is more exposed, 10 Tonne units are required for the main armour on this structure whereas 7.5 Tonne units can be used on the face of the northern breakwater.

The main deck level for the breakwaters has been taken as +4.0m OD to allow for future sea level rise. The details of the breakwater sections are given in Appendix 2.

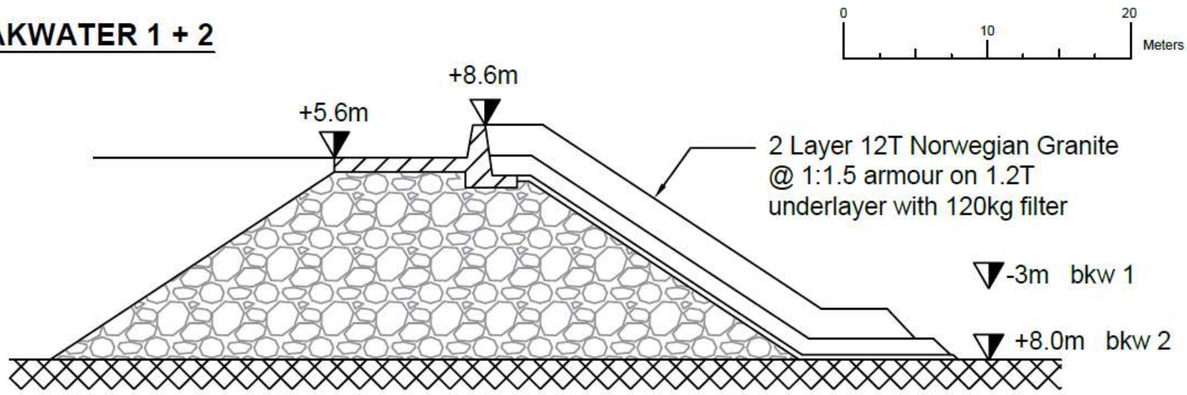
APPENDIX 1

Details of Breakwater Sections for Bremore Port

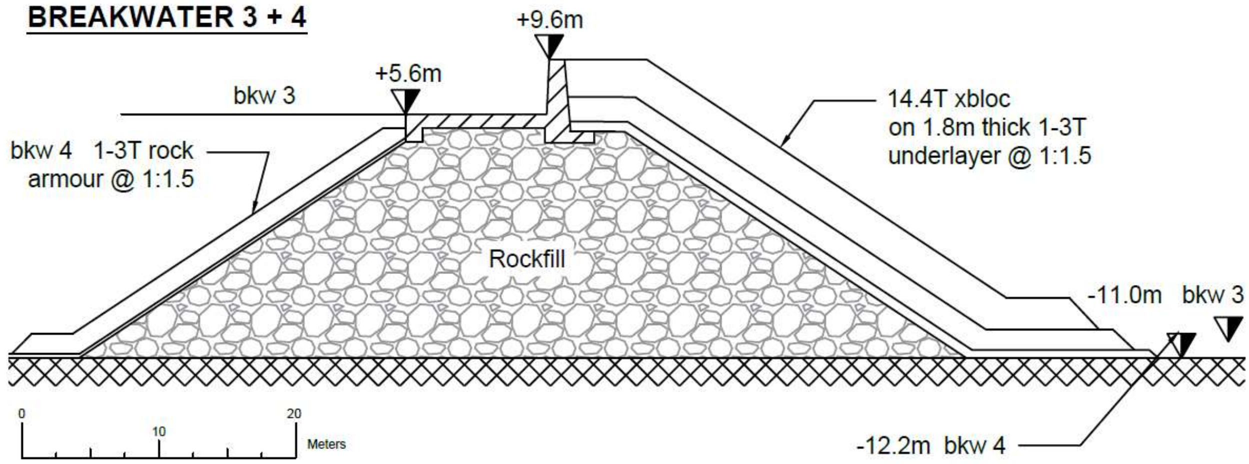


DP1.5 Bremore Final Layout – Breakwater reference labels.

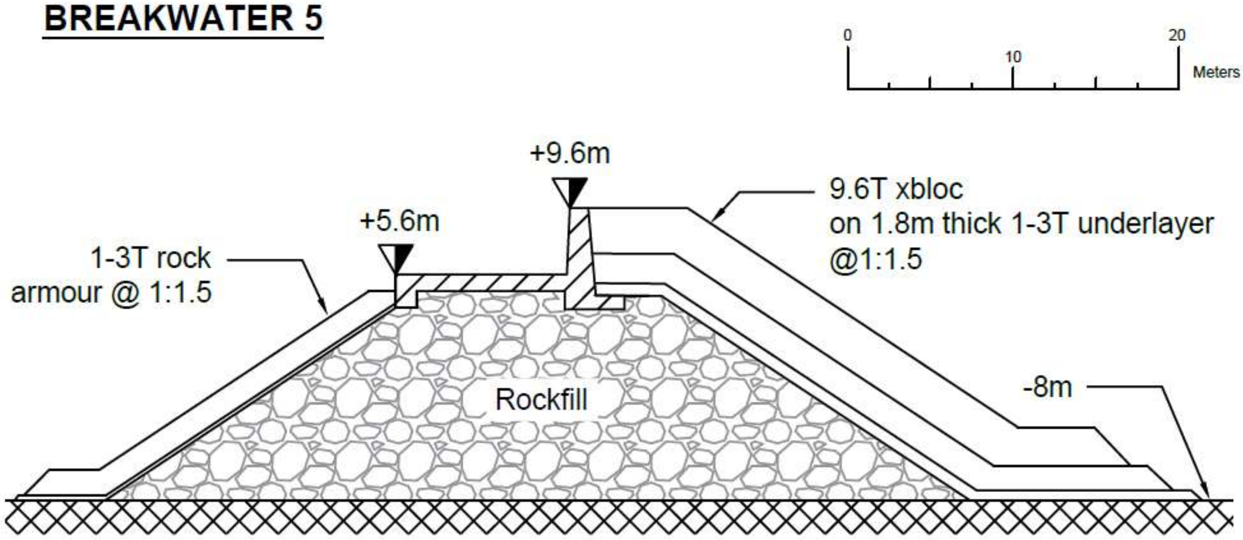
BREAKWATER 1 + 2



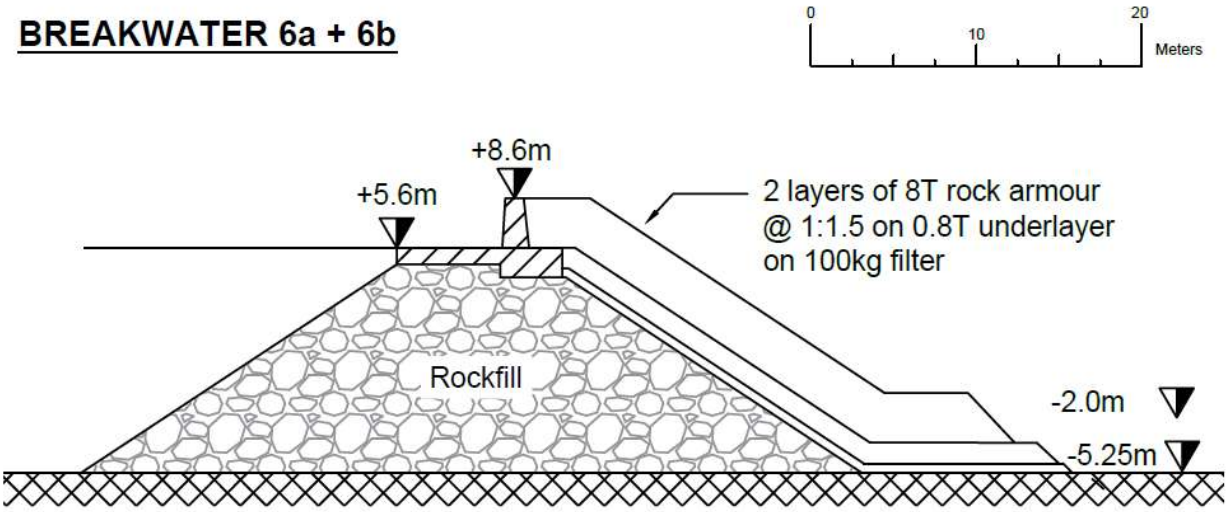
BREAKWATER 3 + 4



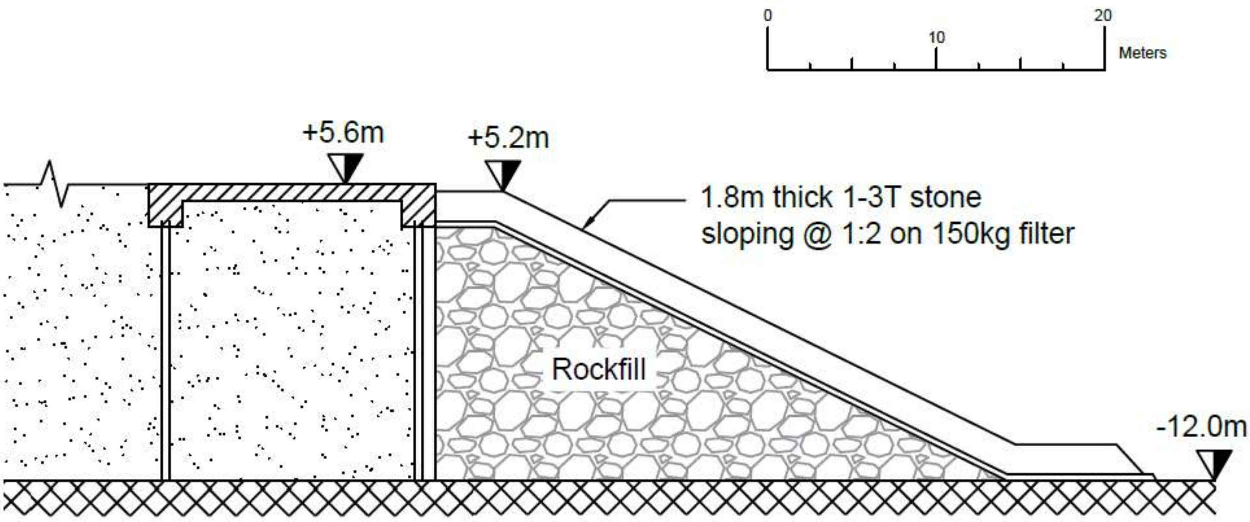
BREAKWATER 5



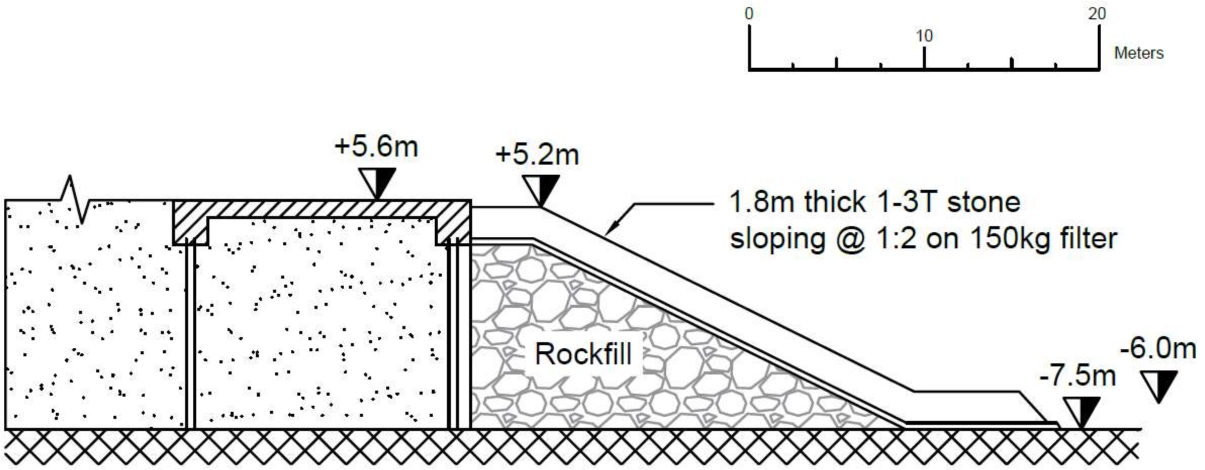
BREAKWATER 6a + 6b



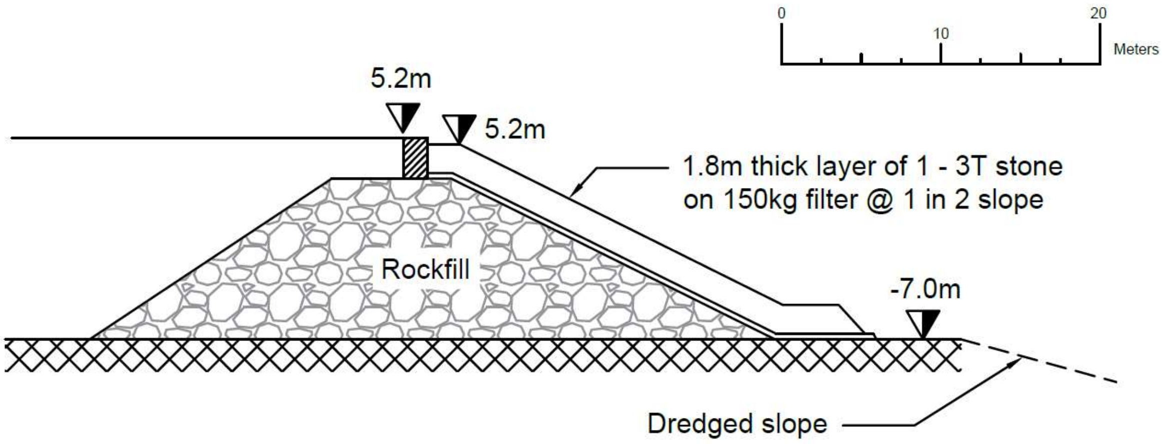
REVETMENT 1



REVETMENT 2a + 2b

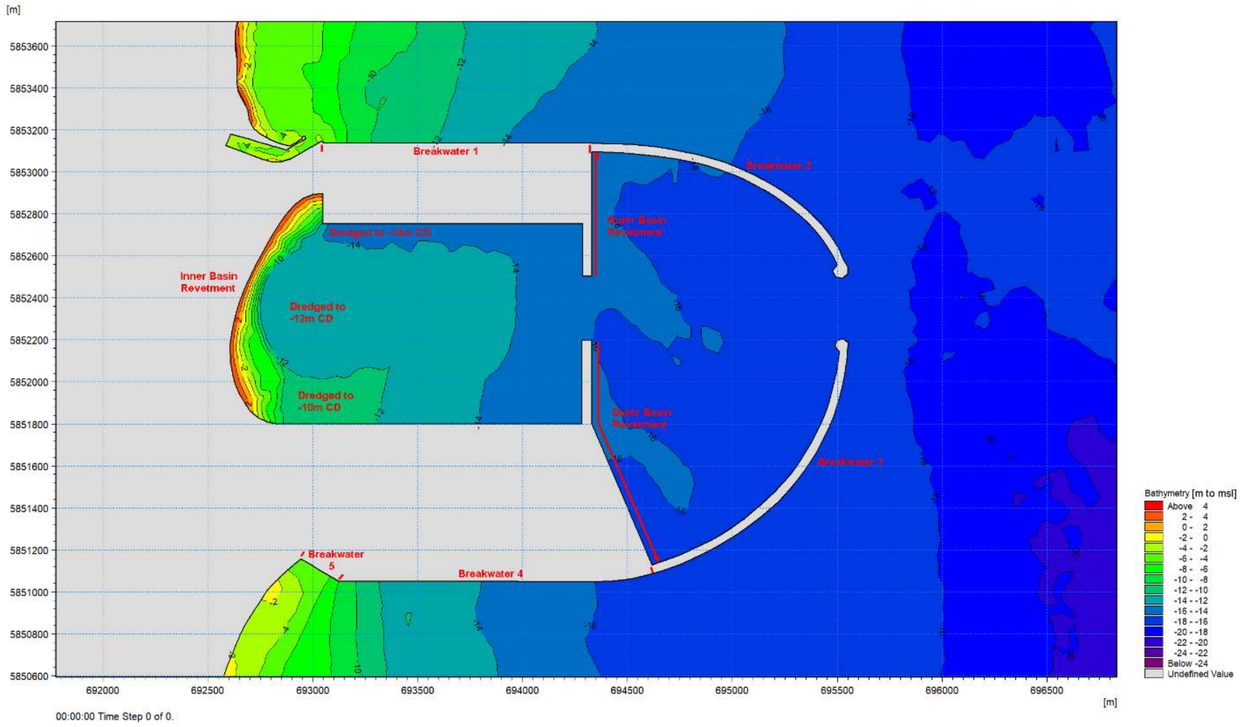


REVETMENT 3



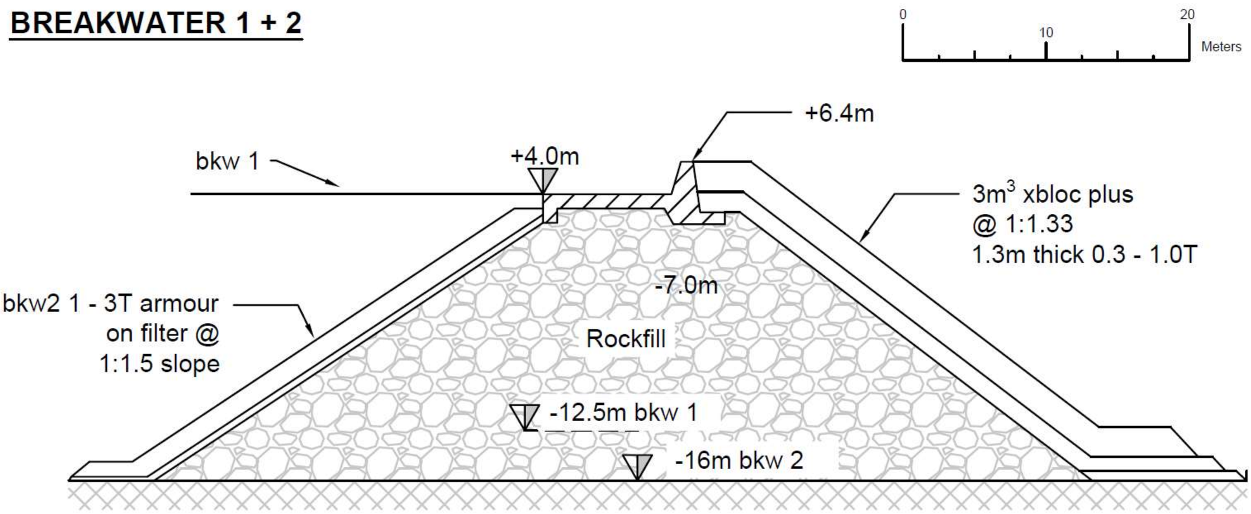
APPENDIX 2

Details of Breakwater Sections for Arklow Port

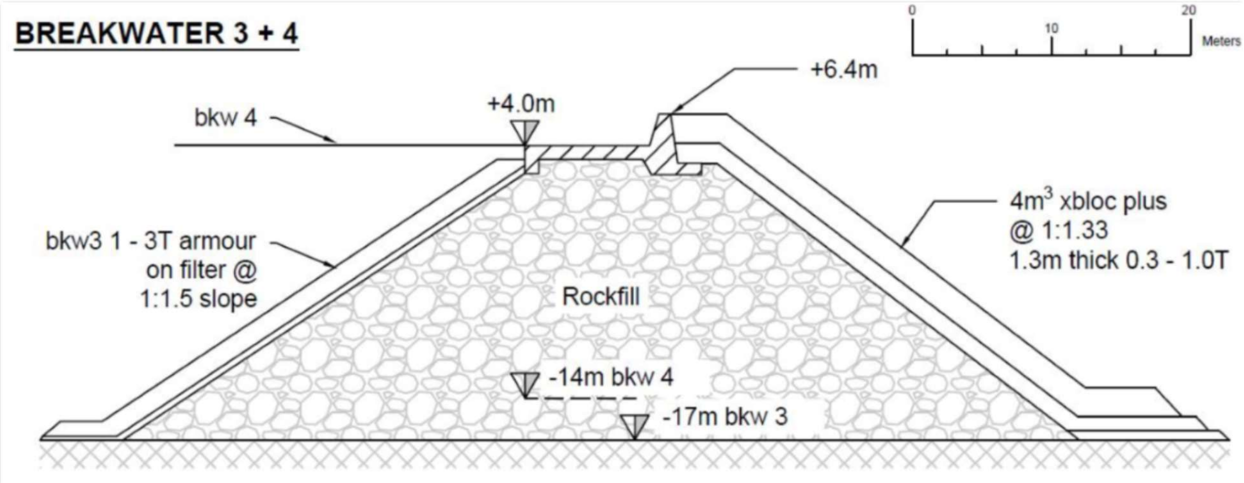


DP1.5 Arklow Final Layout – Breakwater reference labels.

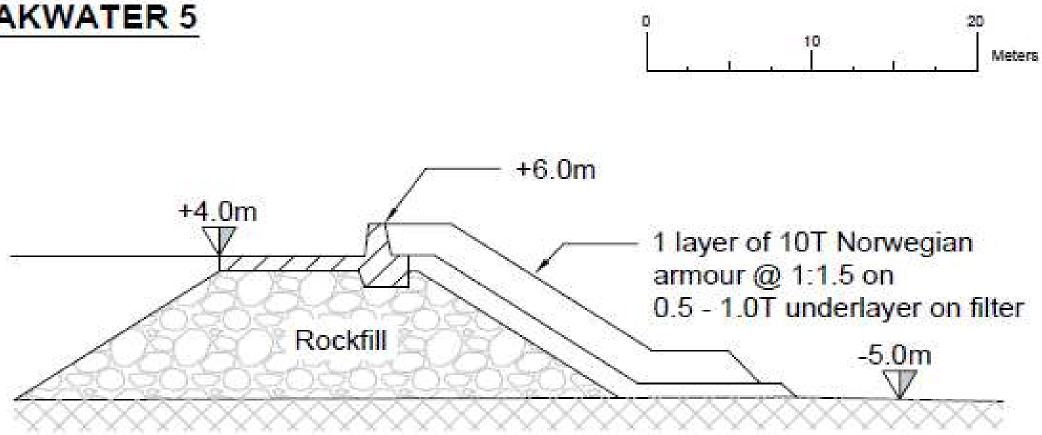
BREAKWATER 1 + 2



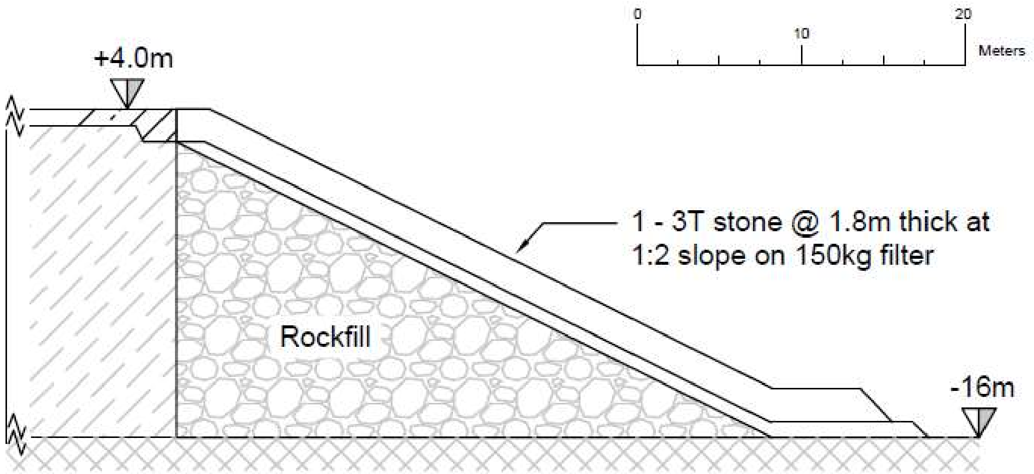
BREAKWATER 3 + 4



BREAKWATER 5



OUTER BASIN REVETMENTS



INNER BASIN REVETMENTS