Addendum to the
Natura Impact Statement

NISA
North Irish Sea Array

Volume 2: Appendices

Appendix A12
Supporting Assessment Sensitivity Studies

North Irish Sea Array (NISA) Offshore Wind Farm

Appendix A12: Supporting Assessment Sensitivity Studies

Marine Geology, Oceanography and Physical Processes

3 June 2026

MetOceanWorks Reference:

GoBe_C00002_R01_RFI_Marine_Processes

Commercial in Confidence

Andrew Watson MSc CSci CMarSci MIMarEST

Senior Metocean Consultant & Director

andrew.watson@metoceanworks.com

Contact +44 (0)7763 896635

MetOceanWorks Ltd is Registered in England and Wales, Company Number 8078702

Revision	Description	Prepared	Reviewed	Date
RO2	Final	Jamie Hernon and Bill Cooper	Bill Cooper and Jamie Hernon	3 June 2026
R01	Draft	Jamie Hernon and Bill Cooper	Bill Cooper and Jamie Hernon	8 May 2026

Disclaimer

Table of contents

1 Introduction 4

1.1 Summary of issues and report structure 4

2 Approach to Marine Processes Assessment 5

2.1 Background - knowledge, experience and guidance 5

2.2 Background - evidence base 5

2.3 Background - design assumptions for EIA versus as-built design 5

2.4 Background - the role for modelling 5

2.5 EIA approach for the proposed development 6

2.6 Sensitivity studies 6

3 Wind Blockage 7

3.1 Overview 7

3.2 NISA wind turbine generator parameters 7

3.3 EIA assumptions related to wind-blockage 8

3.4 Wind-wake modelling 8

3.5 Sensitivity studies 16

4 Morphodynamic Modelling 30

4.1 Overview 30

4.2 Baseline understanding 30

4.3 Wave blockage background 30

4.4 Assessment of morphological response 30

4.4.1 South-south-easterly waves 31

4.4.1.1 P50 - SSE 32

4.4.1.2 1 in 1 year Return Period - SSE 33

4.4.1.3 1 in 10 year Return Period - SSE 34

4.4.1.4 1 in 50 year Return Period - SSE 35

4.4.2 East-north-east waves 36

4.4.2.1 P50 - ENE 37

4.4.2.2 1 in 1 year Return Period - ENE 38

4.4.2.3 1 in 10 year Return Period - ENE 39

4.4.2.4 1 in 50 year Return Period - ENE 40

4.4.3 Summary of sensitivity test for morphodynamic impacts 41

5 Climate Change 42

6 Interdependency Between Marine Processes 61

6.1 The effect of currents on waves 62

6.2 The effect of waves on hydrodynamics 66

7 Conclusion 71

References 72

List of Figures

Figure 3.1: Waked wind field for p50 waves from 68°N. 9
Figure 3.2: Waked wind field for p50 waves from 156°N. 10
Figure 3.3: Waked wind field for 1 in 1 year waves from 68°N. 11
Figure 3.4: Waked wind field for 1 in 1 year waves from 156°N. 12
Figure 3.5: Waked wind field for 1 in 10 year waves from 68°N. 13
Figure 3.6: Waked wind field for 1 in 10 year waves from 156°N. 14
Figure 3.7: Waked wind field for 1 in 50 year waves from 68°N. 15
Figure 3.8: Waked wind field for 1 in 50 year waves from 156°N. 16
Figure 3.9: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 17
Figure 3.10: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 17
Figure 3.11: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 18
Figure 3.12: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 18
Figure 3.13: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 19
Figure 3.14: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 19
Figure 3.15: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 20
Figure 3.16: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 20
Figure 3.17: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 21
Figure 3.18: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 21
Figure 3.19: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 22

Figure 3.20: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 22
Figure 3.21: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 23
Figure 3.22: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 23
Figure 3.23: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 24
Figure 3.24: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 24
Figure 3.25: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 25
Figure 3.26: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 25
Figure 3.27: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 26
Figure 3.28: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 26
Figure 3.29: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 27
Figure 3.30: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 27
Figure 3.31: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 28
Figure 3.32: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only. 28
Figure 4.1: Predicted change in 1 in 50-year wave height for waves arriving from the south-south-east with nearshore sites for assessing significance of impacts along the coastline. 32
Figure 4.2: Predicted change in 1 in 50-year wave height for waves arriving from the east-northeast with nearshore sites for assessing significance of impacts along the coastline. 37
Figure 5.1: Location of UKCP sea level rise grid cell centre. 43
Figure 5.2: IPCC predictions of sea level rise at Dublin. 44

Figure 5.3: Difference in water surface elevation caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with. 45
Figure 5.4: Difference in current speed caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with. 45
Figure 5.5: Difference in current direction caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with. 46
Figure 5.6: Difference in water surface elevation caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with. 46
Figure 5.7: Difference in current speed caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with. 47
Figure 5.8: Difference in current direction caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with. 47
Figure 5.9: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 48
Figure 5.10: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 49
Figure 5.11: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 49
Figure 5.12: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 50
Figure 5.13: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 50
Figure 5.14: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 51
Figure 5.15: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 51
Figure 5.16: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 52
Figure 5.17: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 52
Figure 5.18: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 53
Figure 5.19: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 53
Figure 5.20: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 54

Figure 5.21: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 54

Figure 5.22: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 55

Figure 5.23: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 55

Figure 5.24: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 56

Figure 5.25: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 56

Figure 5.26: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 57

Figure 5.27: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 57

Figure 5.28: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 58

Figure 5.29: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise. 58

Figure 5.30: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 59

Figure 5.31: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 59

Figure 5.32: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise. 60

Figure 6.1: Proposed development induced difference in significant wave height during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents. 62

Figure 6.2: Proposed development induced difference in mean zero-crossing wave period during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents. 63

Figure 6.3: Proposed development induced difference in peak wave period during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents. 63

Figure 6.4: Proposed development induced difference in mean wave direction during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents. 64

Figure 6.5: Proposed development induced difference in significant wave height during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents. 64
Figure 6.6: Proposed development induced difference in mean zero-crossing wave period during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents. 65
Figure 6.7: Proposed development induced difference in peak wave period during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents..............................65
Figure 6.8: Proposed development induced difference in mean wave direction during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents..............................66
Figure 6.9: Proposed development induced difference in surface elevation during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 67
Figure 6.10: Proposed development induced difference in current speed during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 67
Figure 6.11: Proposed development induced difference in current direction during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 68
Figure 6.12: Proposed development induced difference in surface elevation during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 68
Figure 6.13: Proposed development induced difference in current speed during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 69
Figure 6.14: Proposed development induced difference in current direction during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees. 69

List of Tables

Table 1.1: Issues addressed and locations in this document. 4
Table 4.1. Comparison of leeward wave conditions for P50 event - SSE 33
Table 4.2. Comparison of leeward wave conditions for 1 in 1 year event - SSE 34
Table 4.3. Comparison of leeward wave conditions for 1 in 10 year event - SSE 35
Table 4.4. Comparison of leeward wave conditions for 1 in 50 year event - SSE 36
Table 4.5. Comparison of leeward wave conditions for P50 event - ENE 38
Table 4.6. Comparison of leeward wave conditions for 1 in 1 year event - ENE 39
Table 4.7. Comparison of leeward wave conditions for 1 in 10 year event - ENE 40
Table 4.8. Comparison of leeward wave conditions for 1 in 50 year event - ENE 41
Table 6.1: Coupled Modelling Scenarios. 61

North Irish Sea Array Windfarm Ltd (NISA, hereafter referred to as 'the Developer') has been considering the Request for Further Information (RFI) issued by An Bord Pleanála (now An Coimisiún Pleanála) as well as the third-party submissions received following public consultation. At An Coimisiún Pleanála's behest, the Developer has also continued to consult with stakeholders in respect of the 2024 planning application throughout 2024-2026. The Developer has refined elements of the design to respond to the third-party submissions, the continued public and stakeholder consultation and the RFI. Full details of consultation undertaken can be found in Appendix A2 of the SISAA.

For the purposes of clarity, this document shall be read in conjunction with the Appendix A11 submitted as part of the 2024 NIS.

Any cross reference to a chapter, section, table, image, figure or appendix within this document is to another location within the Addendum to the EIAR or NIS unless explicitly stated otherwise. Any cross reference to anything included in the 2024 EIAR or NIS will be clearly labelled as such.

The RFI Response Document identifies where topics relevant to Marine Geology, Oceanography and Physical Processes are responded to. In summary:

- **Topics 7 (g), (h), and (i) (part) are addressed in the amendment to Chapter 10: Marine Geology, Oceanography and Physical Processes.**
- **Topic 7 (f) and (q) (part) are addressed in Appendix A10.1: Marine Processes Review of Project Options of the EIAR.**
- **Topics 7 (a), (b), (c), (d), (i) (part), (l) and (p) are addressed in Appendix A11: Marine Physical Processes Numerical Modelling of the NIS.**
- **As dredging is no longer proposed, topics 7 (m), (n) and (o) no longer apply and Appendix 10.3 of the 2024 EIAR is removed.**
- **Topics 7 (e), (j), (k) and (q) (part) are addressed in Appendix A12 Supporting Assessment Sensitivity Studies providing details of sensitivity tests to justify the present modelling approach.**

The sections relevant to Appendix A12 in the RFI are included below.

RFI Section	RFI	Relevance to Chapter
1 (b)	The scientific information provided as part of the planning application documentation should be based on up-to-date survey reports and data. Accordingly, the applicant is requested to confirm/provide justification/verification that the information submitted in support of the planning application remains relevant and appropriate at the point of submitting further information or to update same as required.	The timeframes associated with the RFI have necessitated a review of the datasets previously used in the 2024 EIAR and NIS to ensure any necessary updates to the baseline environment are captured. Therefore, a review of the marine physical processes modelling baseline resources has been undertaken to comply with RFI 1 (b).
7 (e)	The applicant is requested to characterise the existing environment in terms of the sediment transport regime in the form of coupled wave, wind, hydrodynamic and sediment transport modelling. As indicated in Appendix 10.2, the SWAN model was utilised for the assessment of waves and theMIKE21FM (Flexible Mesh) 2D modelling package was utilised for hydrodynamic modelling. The separation of the wave, hydrodynamics and wind influences does not allow for a comprehensive assessment of the impact of the proposed development on marine processes. The applicant is requested to submit a coupled model in order to demonstrate the interaction between waves, hydrodynamics and wind influences. The applicant is also requested to undertake a greater range of sensitivity runs to examine the coupled model performance. Model scenarios should include an assessment of extreme events e.g. 10%, 5%, 2%, 1%, 0.5%, 0.2% annual exceedance probability (AEP) events and joint probability occurrences of tidal, surge and wave conditions. The applicant is requested to assess these probabilities in modelling scenarios and provide for climate change.	The matters raised are addressed in Section 4 (Morphodynamic and Coupled Modelling), Section 5 (Climate Change) and Section 6 (Interdependency Between Marine Processes) which provides the technical basis supporting the conclusions set out in Chapter 10.

7 (j)	The applicant is requested to include the impact of wind blocking on coastal processes. It is requested that this be addressed through site specific wake and wind field modelling, considering the entire windfarm layout.	The impact of wind-blocking on coastal processes is assessed, with the inclusion of the proposed development's WTG parameters, the assumptions applied to wind-blockage, and the associated wind-wake modelling and sensitivity studies is addressed in Section 3 of this document.
7 (k)	The applicant is requested to use coupled modelling of the leeward environments between the proposed array and the coastal zone to assess the combined impact of tidal, wind and wave blockage.	Section 4 describes the modelling proposed development of impacts arising from the proposed development on coastal sediment transport. See also response to 7 (e) for a response to coupled modelling.
7 (q)	The longer term morphodynamic impact of the development including cable armouring, scour protections and wind turbine foundations is not assessed. This requires coupled wind, wave, hydrodynamic, and sediment transport modelling. The applicant is requested to submit modelling of the morphodynamic response of the coastline to the proposed development. Morphodynamic Modelling should be extended over a series of longer time horizons, operational plus decommissioning, ie 40+ years, and compared with the non-developed scenario for the same time period.	In Section 3, 4 and 6 of this report, the assessment examines whether the wind-wake effect has a significant additional impact on wave conditions, whether this effect could modify coastal processes in a way that would influence the morphological response of the coastline, and whether coupled wave and hydrodynamic modelling produces a significantly different blockage result to single process models.

1 Introduction

This document responds to Section 7 - Marine Geology, Oceanography and Physical Processes of Schedule - Further Information Request issued by An Bord Pleanála (now An Coimisiún Pleanála) in respect of application Ref. ABP-319866-24 and specifically the issues discussed at the meeting on 6th November 2025 (Meeting under Art. 5(6)(c) of the Planning & Development (Maritime Department) Regulations, 2023.

In brief, Section 7 - Marine Geology, Oceanography and Physical Processes of Schedule - Further Information Request refers to:

- clarifications related to information previously provided which is based on well-established approaches and supported by current industry guidance; and

- suggestions to provide alternative approaches which appear to go beyond well-established approaches and are not represented in current industry guidance.

The former set of issues are addressed within the relevant set of addenda for Chapter 10 – Marine Geology, Oceanography and Physical Processes whereas the latter set of issues are responded to in this document.

1.1 Summary of issues and report structure

The specific RFIs addressed in this document cover 7e, 7j, 7k, and 7q. The locations within this document where each response can be found is described in Table 1.1.

Table 1.1: Sections relevant to Appendix A12 in the RFI

RFI	Description	Location in this document
7j	Request to analyse the impact of wind blocking on coastal processes	Section 3
7k and 7e	Request to utilise coupled wave, wind, hydrodynamic, and sediment transport modelling, and use coupled modelling of the leeward environments	Section 4
7e	Provide for climate change	Section 5
7q	Longer term morphological impacts over 40+ years	Section 4

2 Approach to Marine Processes Assessment

2.1 Background - knowledge, experience and guidance

The development of offshore windfarm projects has matured over the last 25 years with many North European countries being early adopters. Compliance with EU legislation for Environmental Impact Assessment (EIA) has been successfully demonstrated with multiple developments. The delivery of these developments has been well-supported from several thematic programmes providing technical guidance and evidence reviews which includes the topic of marine and coastal process. Relevant publications include [1], [2], [3], [4], [5], [6], [7], [8], and new guidance from Scottish Government due to be published later in 2026, amongst others. Importantly, over the last 25 years the latest technical guidance remains relevant as bigger projects move further offshore into deeper water with adaptations in design (e.g., floating offshore wind) and changes in environmental conditions (e.g., stratification). In addition, the emerging evidence base adds value to the overall assessment approach.

2.2 Background - evidence base

Notably, there have been no reported cases to date where an EIA for an offshore windfarm, or an operating project, has identified or reported a significant impact on any marine and coastal processes receptor. In addition, presently available monitoring evidence has upheld assertions made within the associated marine and coastal processes assessment (i.e., monitoring evidence has not identified any greater effects than those assessed within an EIA).

The portfolio of existing projects, and associated monitoring, has developed an important evidence base for marine process issues (e.g., [3], [4], [6] and [7], amongst others) which supports the evidence-based approach.

2.3 Background - design assumptions for EIA versus as-built design

The design and construction assumptions assessed for an EIA typically represent the maximum parameters (i.e., largest size, amount or number of items, etc.) of possible options in order to retain design flexibility through the consenting process, whereas the as-built project is required not to exceed this consented design and is expected to lead to lesser environmental impacts than those presented in the EIA. Inherently, the EIA adopts necessary conservatisms in design which also help to manage residual uncertainties (e.g., design assumptions, data, methods, etc.).

2.4 Background - the role for modelling

Modelling has been applied to support the EIA related marine processes assessment; however, not all issues require modelling. All relevant sources of potential impact are initially assessed and their effects conceptualised. Where these effects can be supported by relevant evidence or are deemed to remain close to source, small-scale and with no risk to any associated receptor then modelling is not considered necessary or appropriate (e.g., potential effects from pre-grapnel runs do not require modelling due to localised, small-scale and temporary effects, etc.). Where these effects are likely to spread further afield and risk an impact on a receptor then these effects are investigated with appropriate modelling tools (e.g., the spread of sediment plumes, etc.). These investigations are based on scenarios that target representative conditions expected to occur within the development lifecycle and locations which are likely to place the greatest risk to an associated environmental receptor. This is a well-understood, standard and targeted approach to marine physical processes assessment which remains practical, achievable and relevant to an EIA and is the basis of the present method of assessment.

2.5 EIA approach for the proposed development

The delivery of the marine and coastal processes assessment for the proposed development adopts recognised best practice, latest technical guidance (e.g., [1], [2], [3], [4], [5], [6], [7], [8], as well as making consideration to new guidance from Scottish Government due to be published later in 2026), and is based on proven technical methods. A baseline overview is presented which identifies key processes and potential interactions. As a part of our baseline understanding, we identify that there is low potential for process interactions (i.e., waves interacting with tides, or tides interacting with waves). Furthermore, the array area falls within a relatively low flow environment where fines deposit and form the wider area known as the Western Irish Sea Mud Belt. There is no evidence of bedforms indicative of a mobile sandy seabed. Water depths across the array area are considered sufficient to prevent the majority of wave conditions having any influence on the seabed. The adjacent coastline is drift-aligned[1] to prevailing waves from the south-south-east which also represents the wave direction with the longest fetch. Baseline metocean data [9] for waves and currents also supports effective calibration of wave and tidal models as independent processes. If wave and tidal processes were strongly dependent on each other then, this level of model calibration would not be possible and a coupled approach would need to be considered, however, this is demonstrated not to be the case.

2.6 Sensitivity studies

In general, the RFI suggests approaches that go beyond well-established practice. In our view, these approaches would introduce a range of unnecessary complexities, as well as additional uncertainties which would likely weaken the robustness of the assessment. Nevertheless, a range of sensitivity tests associated with the issues raised in the RFI have been performed to help justify our existing approach. This approach was presented to ACP at the meeting held on the 6 November 2025.

The test for any issue being sensitive to the alternative approaches suggested in the RFIs is where there is a distinct change from the outcome presented in Chapter 10 of the EIAR [10] based on the standard approach. The outcome of the sensitivity analyses will show one of the following two outcomes:

- A similar result with negligible difference compared to the existing approach indicates no sensitivity and the existing approach and assessments remain valid.
- A non-negligible difference indicates a level of sensitivity and existing assessments in the EIA would be required to change on this basis. Non-negligible may be indicated with a different spatial extent, magnitude or duration.

---

[1] A drift-aligned coastline is where waves strike the shore at an angle, transporting sediment along the coast via a process called longshore drift

3 Wind Blockage

3.1 Overview

Section 7 of the RFI includes a subsection on blockage modelling and specifically the impact of wind blocking on coastal processes (RFI 7j). It requests that the project addresses this issue through site specific wake and wind field modelling, considering the entire windfarm layout.

Offshore wind foundations directly interact with the passing water body whereas the support tower, hub and blades directly interact with the passing air column.

The former interactions are included within the marine processes assessment as wave-related blockage effects (i.e., due to drag, inertia, wave energy absorption, reflection, diffraction, etc.) and flow-related blockage effects (i.e., due to drag, flow wakes, flow separation, increased turbulence, etc.).

Wind-related blockage is analogous to flow-related blockage to develop turbulent wakes and a reduction in wind speed (i.e. a velocity deficit) in the air column. These wakes are most evident when the wind turbine generators (WTG) are operating, with the effect scaled to the swept area of the blades and the thrust forces acting against the incident winds. For an array of WTG, the effects can become cumulative when there is wake-wake interaction. However, WTGs do not function for 100% of wind conditions and are limited to operating above a cut-in wind speed and below a cut-out wind speed. In addition, an individual WTG will be stationary during a maintenance cycle.

3.2 NISA wind turbine generator parameters

The following details are relevant to NISA to help characterise the WTGs which will interact with incident wind conditions, leading to wind-wake blockage:

Parameter	Project Option 1	Project Option 2
number of WTG	49	35
blade (rotor) diameter (m)	250	276
swept area (m^2)	49,087	59,828
hub height (max) (m)	165	178
blade clearance to LAT (m)	40	40
cut-in wind speed (m/s)	3	3
cut-out wind speed (m/s)	32	32

Based on these details, Project Option1 will have a total swept area of 2,405,281 m^2 accounting for all WTG compared with 2,093,997 for Project Option 2.

Notably, the swept area where a wind-wake initiates is from 40 m above lowest astronomical tide (LAT) to the height of the blade. From this location, the wind-wake dissipates as an expanding cone-shape in a downwind direction which is expected to eventually touchdown on the sea surface. At this point, there is a potential for the modified wind-field to affect downwind wind-wave generation, however, this will be restricted to the footprint of the wake which will eventually fully dissipate over distance from the array of WTG.

For reference, the standard height for wind conditions used in numerical expressions for wind-wave generation is 10 m above sea level. Due to boundary effects with the sea surface, winds at the hub height will be larger than those at 10 m above sea level.

3.3 EIA assumptions related to wind-blockage

Chapter 10 of the EIAR for the proposed development [10] recognises the direct and largest effects on waves and tides is due to blockage effects created by the interaction of the in-water section of foundation structures (including surrounding scour protection). These interactions have been modelled, in line with standard practice, and adopt a level of conservatism to represent the effect of maximum design parameters.

Whilst acknowledging other interactions on waves and tides may occur (e.g. due to wind-wakes, etc.), these interactions are considered to be secondary and minor, in comparison, and are scoped out from further assessment. Furthermore, any secondary effects are also considered to be sufficiently offset by the adopted levels of conservatism (e.g., design assumptions, data, methods, etc.).

At the present time, there is also no universally-accepted approach to assessing the effects of wind-wakes, noting that presently-available models can only reproduce these effects with considerable uncertainties. Ongoing research aims to improve knowledge in this subject (e.g., EuroWindWakes and BeNEWakes) and is motivated by the need to improve assessment of energy yield and quantify apparent losses between adjacent projects.

3.4 Wind-wake modelling

For the purpose of present sensitivity tests, a computationally efficient methodology has been developed to quantify the influence of offshore windfarm wake effects on near-surface wind fields used to drive spectral wave models.

The methodology modifies spatially-uniform wind fields to account for turbine-induced flow effects, including downstream velocity deficits and upstream blockage (induction) effects. The resulting wake-modified wind fields at 10 m above sea level are used as input to the SWAN (Simulating Waves Nearshore) spectral wave model used to assess blockage effects on waves (see Appendix A11).

The approach is grounded in established engineering wake modelling frameworks, combining classical momentum-based wake theory [12] with more recent analytical Gaussian wake formulations [13], and is consistent with current industry-standard wind farm modelling practices [14], [15].

The modelling workflow consists of four principal stages:

- Definition of ambient wind field at 10 m above sea level
- Vertical extrapolation to turbine rotor (hub) height
- Application of wake and blockage models at hub height
- Transfer of wake-modified wind field back to 10 m

A key feature of the implementation is the sequential evaluation of turbines in the wind direction, ensuring that downstream turbines are influenced by the cumulative effects of upstream wakes.

A spatially uniform wind field is defined over the model domain at a reference height of 10 m above sea level. The wind field is characterised by a constant wind speed and direction and discretised onto a structured computational grid.

This simplification is appropriate for EIA-scale assessments, where the objective is to isolate wind farm-induced effects from larger-scale atmospheric variability.

The ambient wind field is extrapolated from 10 m to turbine hub height using a simple power-law wind profile. Then, wake-induced velocity deficits are calculated using the Gaussian wake model of [13]. This formulation is implemented in a manner consistent with classical momentum-based wake theory [12]. Wake expansion is parameterised using a default wake expansion coefficient, widely accepted for offshore conditions and consistent with reduced ambient turbulence environments. Overlapping wakes are combined using a root-sum-square approach. Turbines are evaluated sequentially in the wind direction. Each turbine experiences a wind field modified by all upstream wakes, reflecting cumulative wake interaction.

Synthetic aperture radar observations of wind farm wakes [11] have reported wake lengths of up to 70 km during stable atmospheric conditions (i.e., non-extreme events). During unstable atmospheric conditions (i.e., extreme events), wake lengths of up to 10 km were reported. A conservative maximum wake distance of 30 km is applied (noting that most events modelled herein feature high-energy wind events to drive extreme waves, and so atmospherically unstable conditions are likely).

The waked wind field is then transferred from hub height to 10 m assuming vertical coherence of the deficit. The resulting wake-modified wind field at 10 m is used as input to the spectral wave model SWAN.

The waked input wind fields for each scenario (each severity and direction combination) are shown in Figure 3.1 to Figure 3.8.

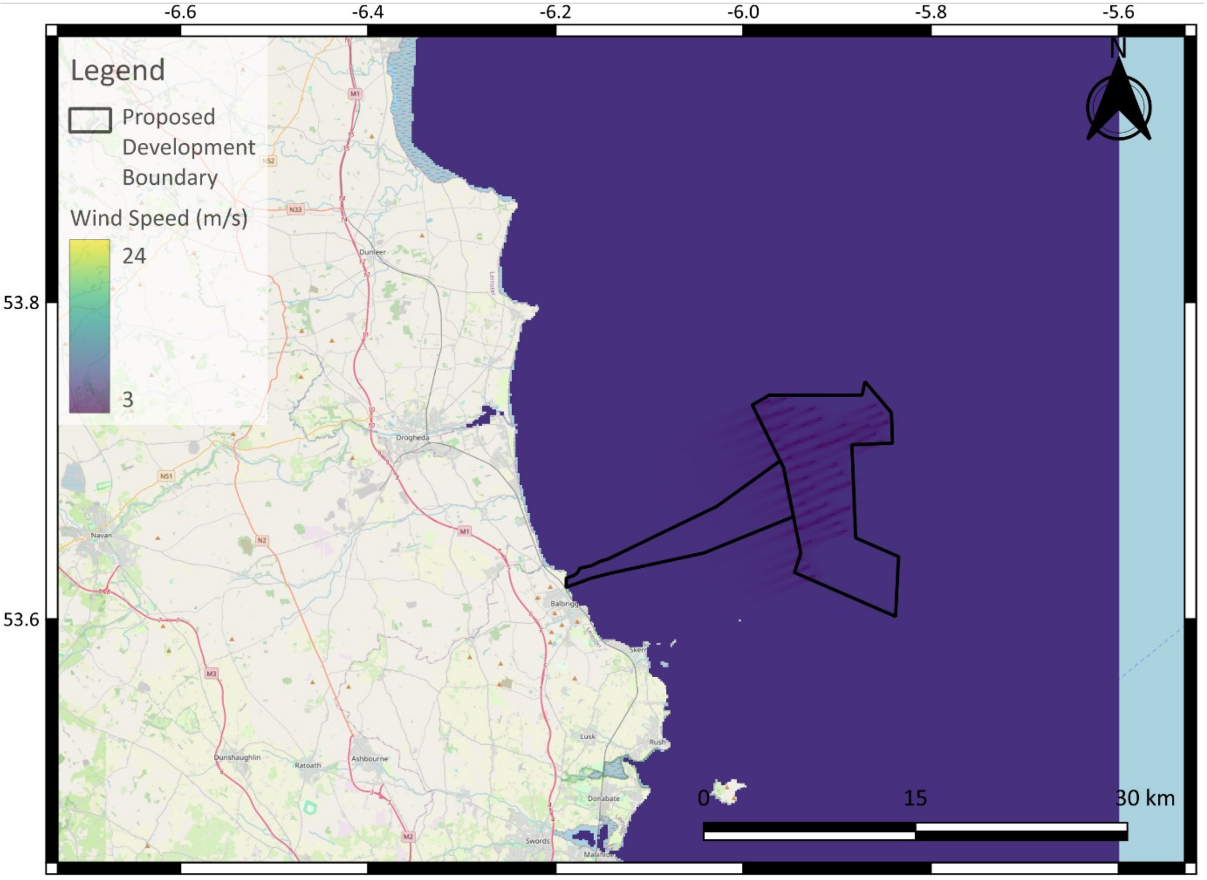

Figure 3.1: Waked wind field for p50 waves from 68°N.

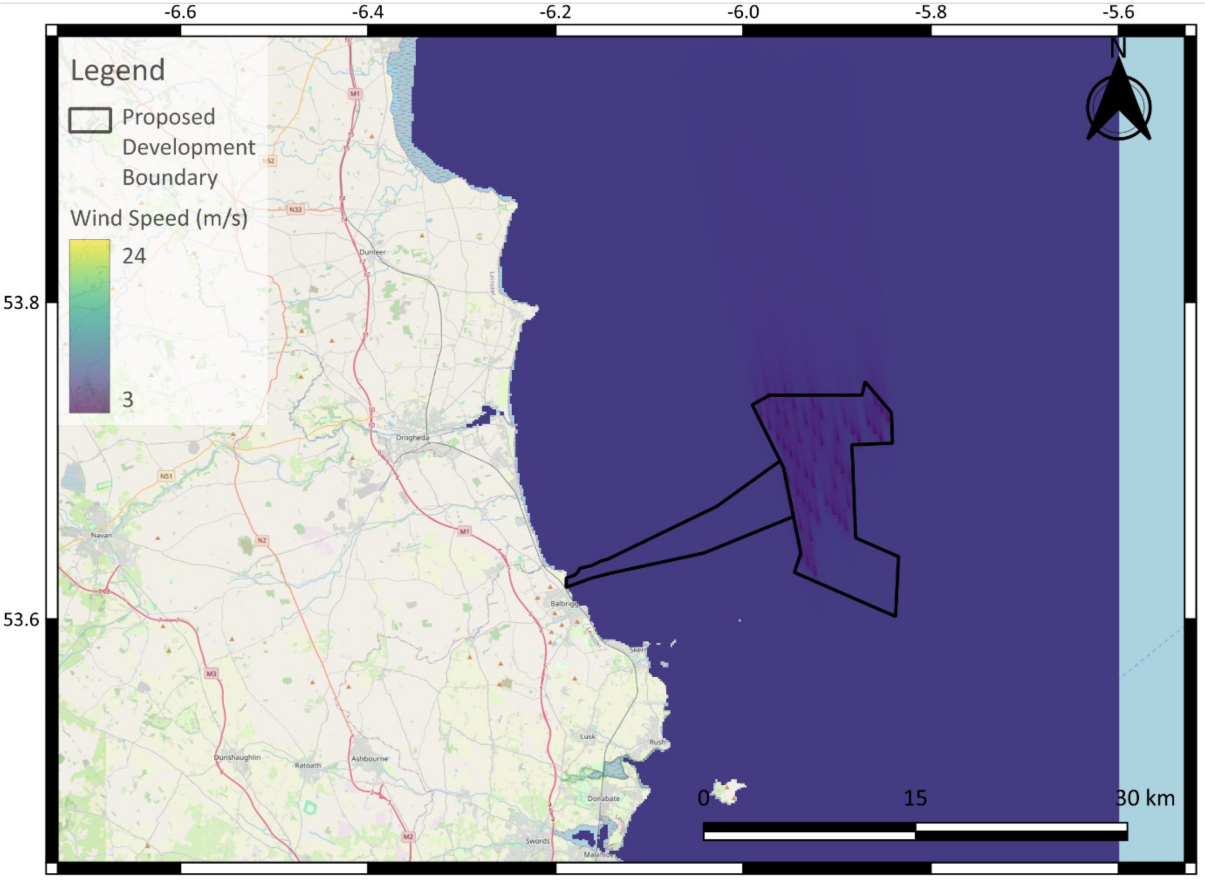

Figure 3.2: Waked wind field for p50 waves from 156°N.

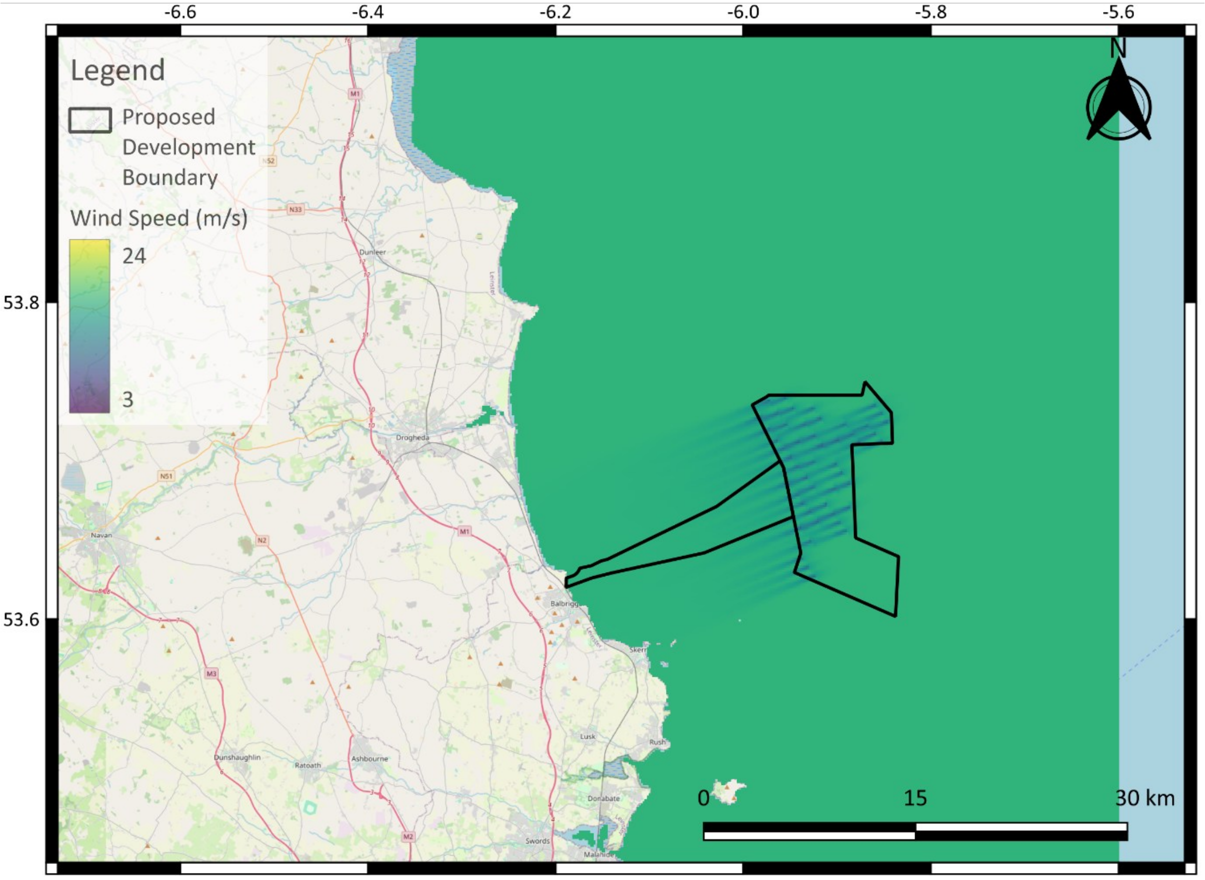

Figure 3.3: Waked wind field for 1 in 1 year waves from 68°N.

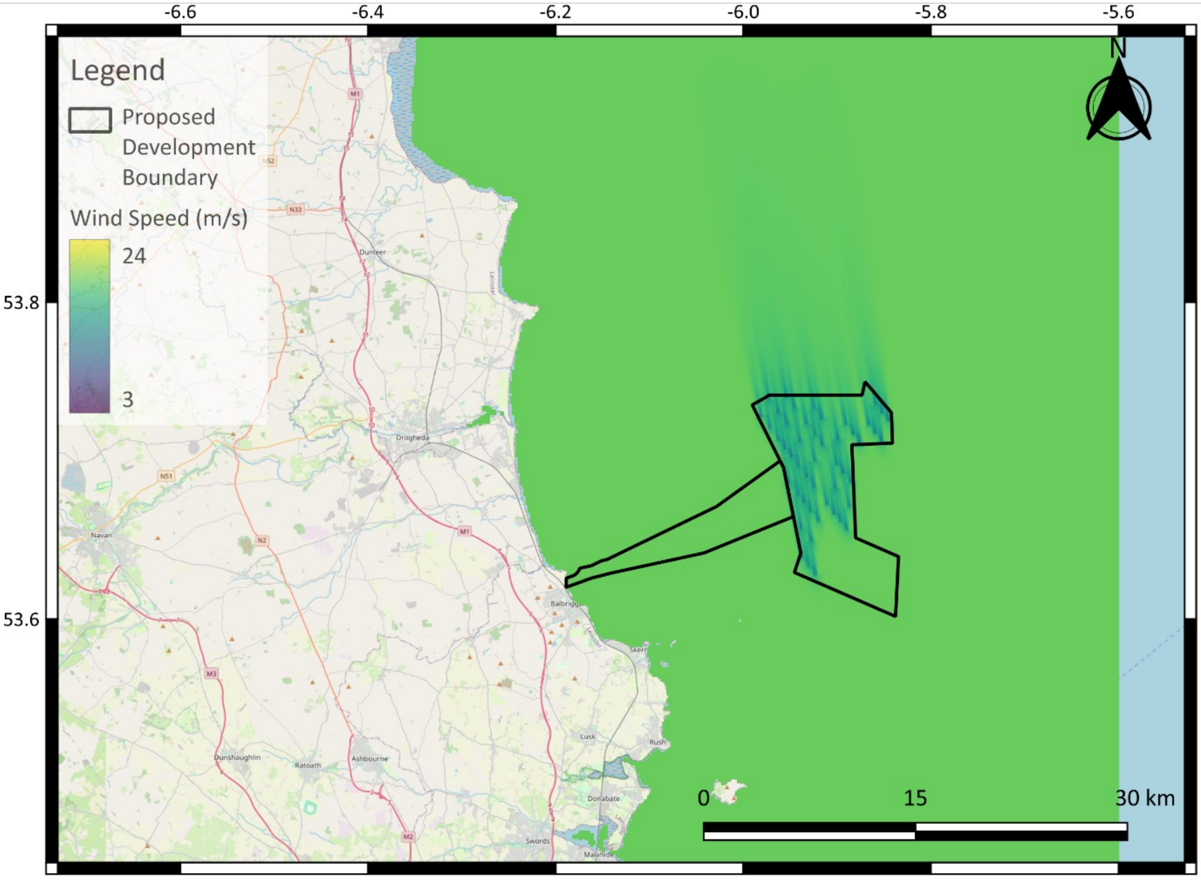

Figure 3.4: Waked wind field for 1 in 1 year waves from 156°N.

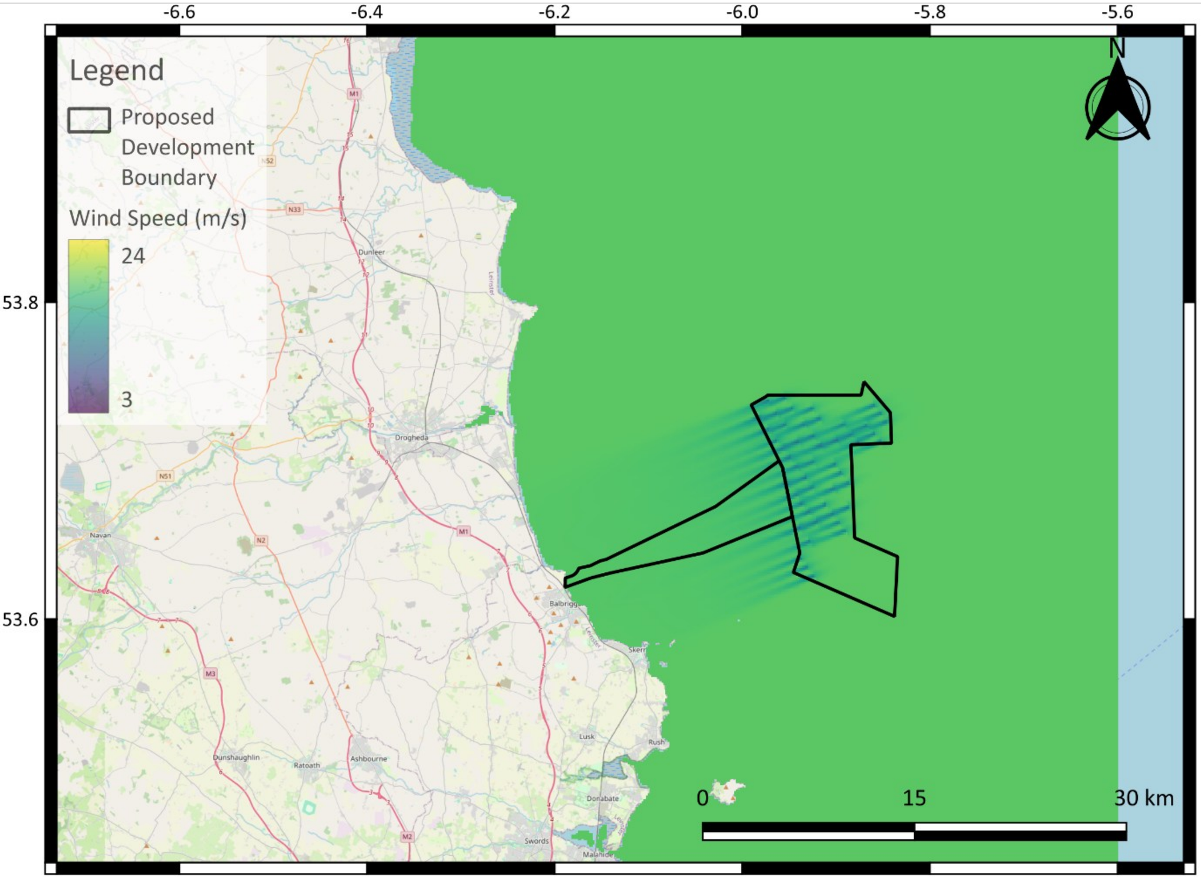

Figure 3.5: Waked wind field for 1 in 10 year waves from 68°N.

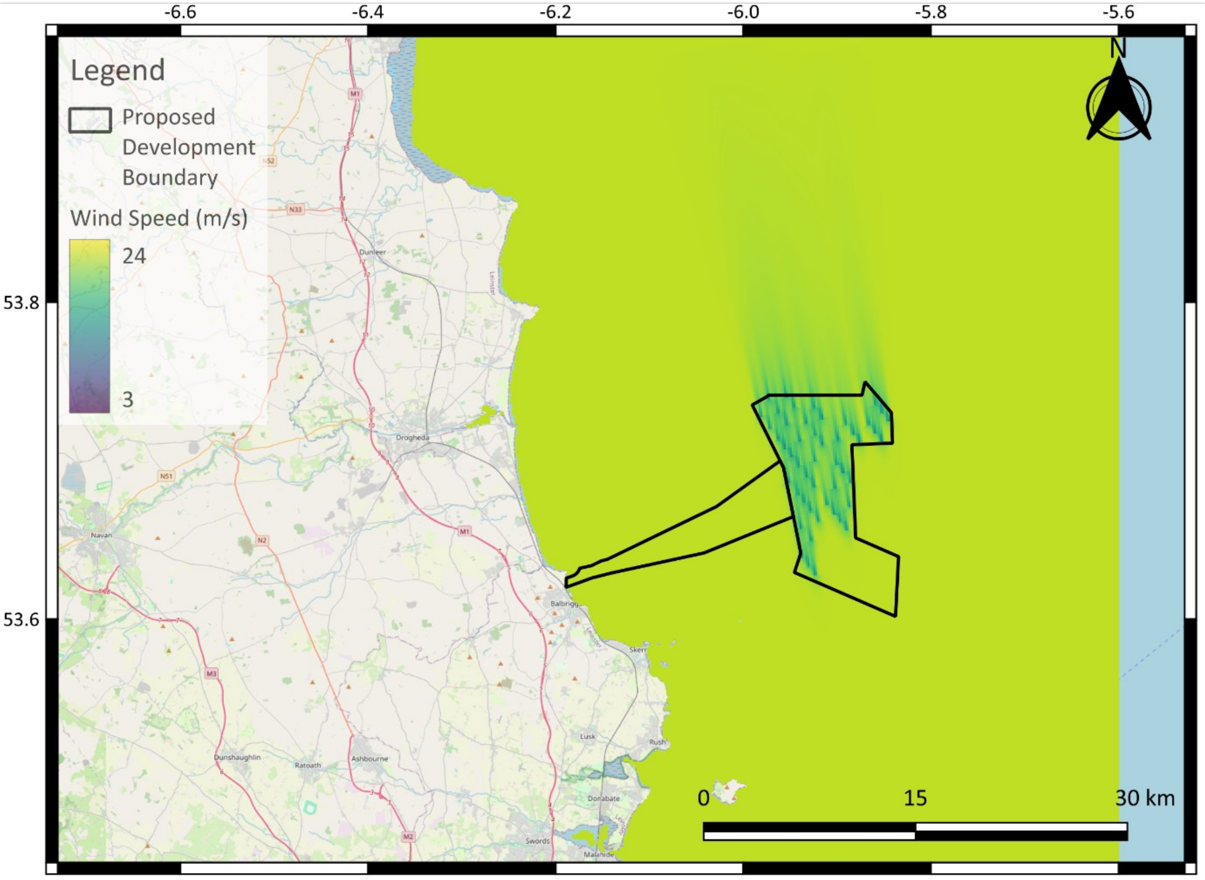

Figure 3.6: Waked wind field for 1 in 10 year waves from 156°N.

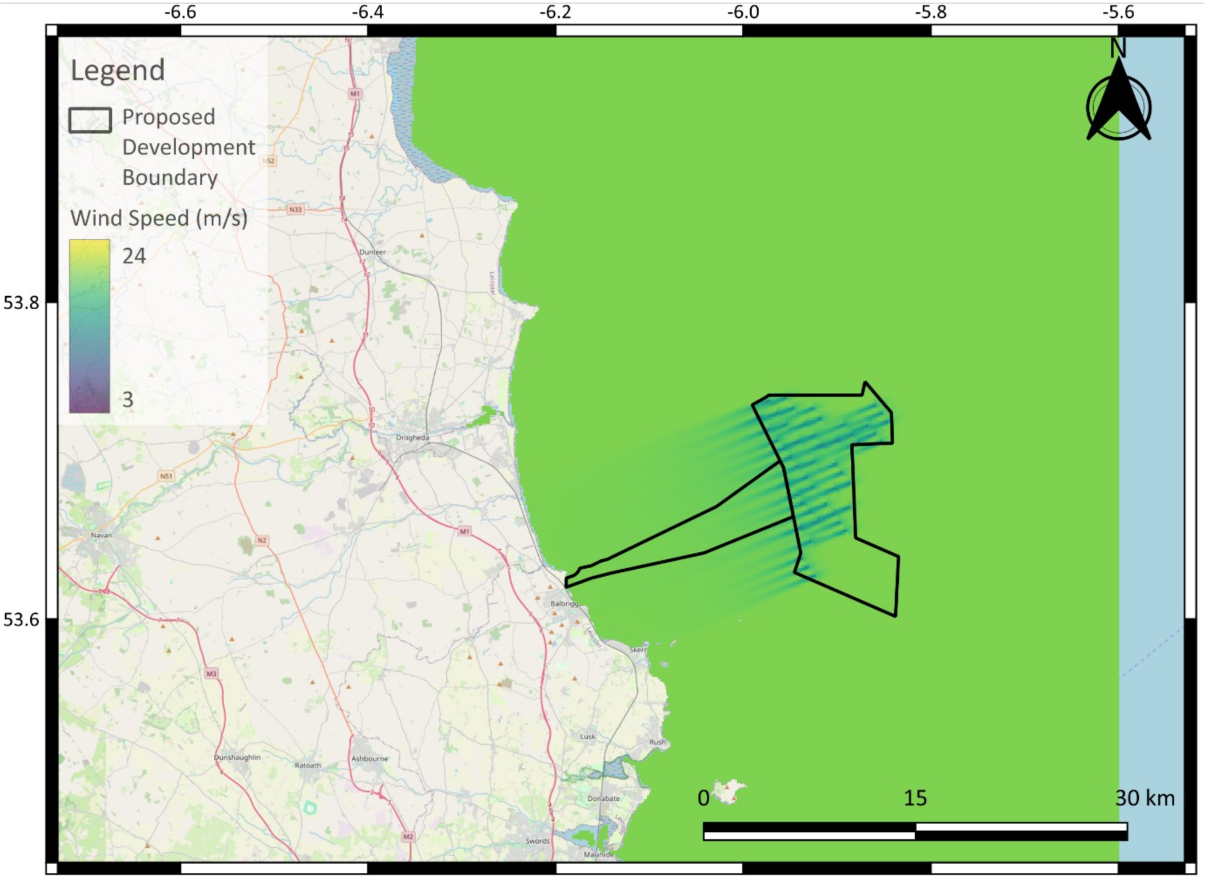

Figure 3.7: Waked wind field for 1 in 50 year waves from 68°N.

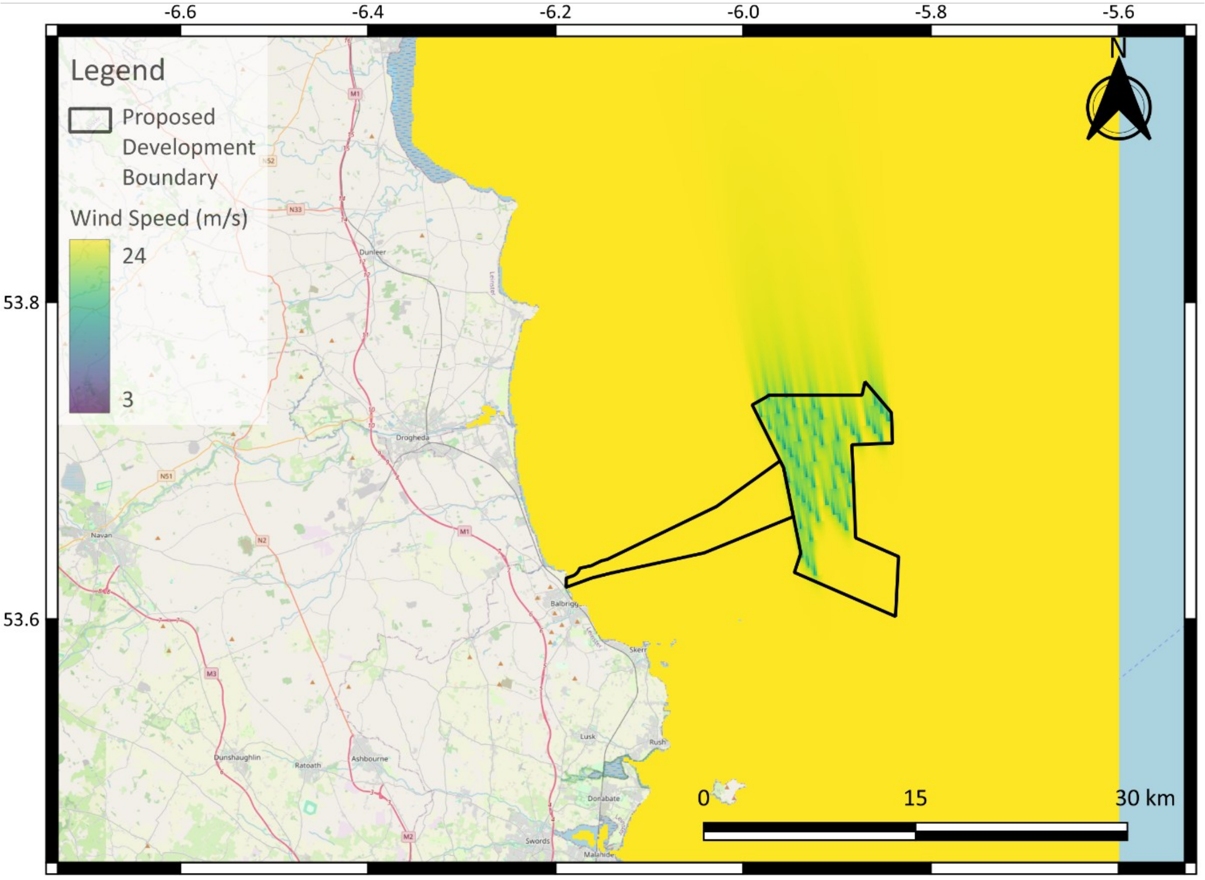

Figure 3.8: Waked wind field for 1 in 50 year waves from 156°N.

3.5 Sensitivity studies

The SWAN wave model was run for cases where the structures (i.e., WTG and OSP foundations) were included in the wave model with a uniform wind field, and where the structures were included in the wave model along with the waked wind field. The results of these two cases are shown in the following figures. In each case, the left panel includes wave model structures and wind wakes, and the right panel includes wave model structures only.

In these figures, the images are scaled and coloured to allow the reader to compare the left and right panels, to ascertain whether the influence of wind wakes make an appreciable difference to the results of the modelling. For a detailed assessment of the modelling of the impact of the proposed development on the environment, please see Section 10.5 of Chapter 10 of the EIAR [10].

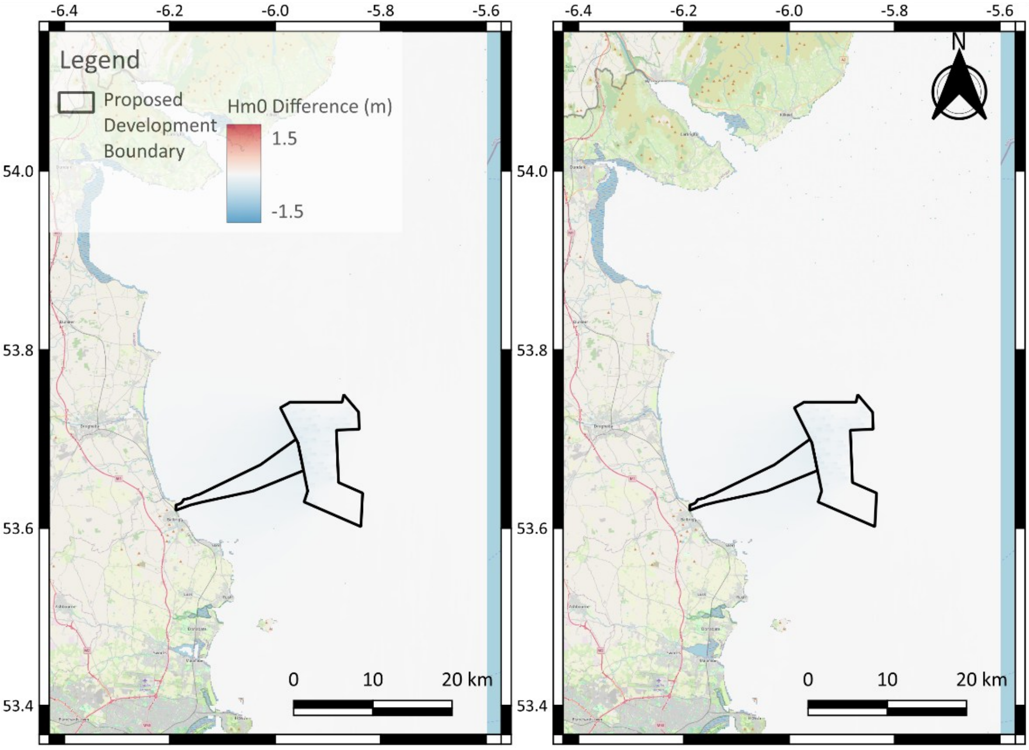

Figure 3.9: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

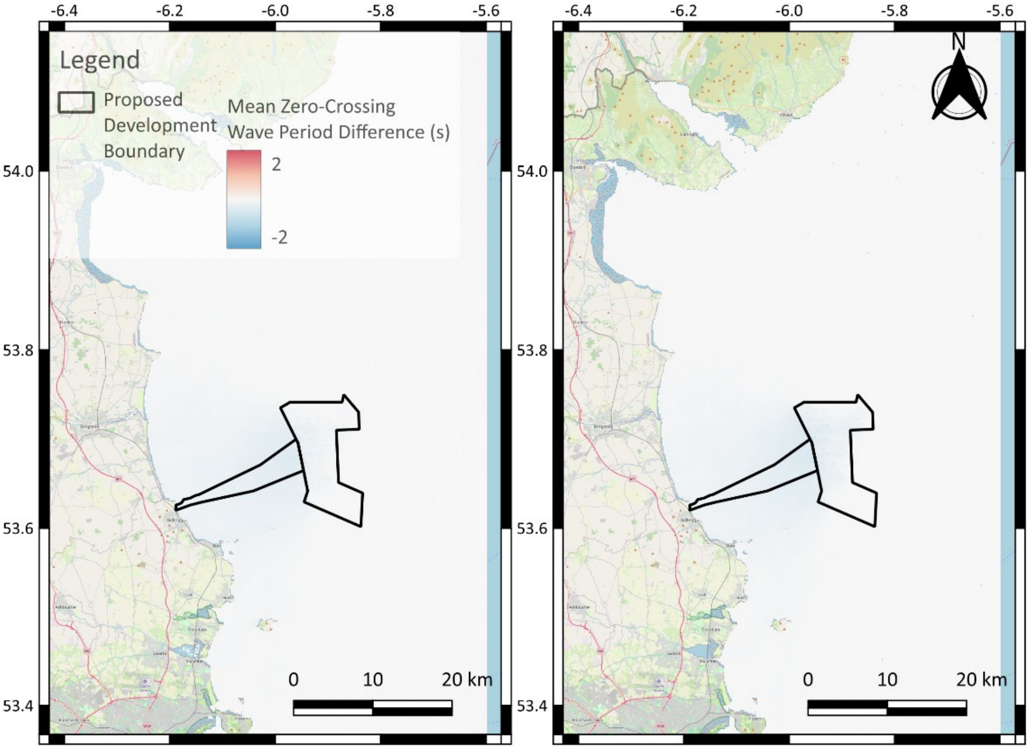

Figure 3.10: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

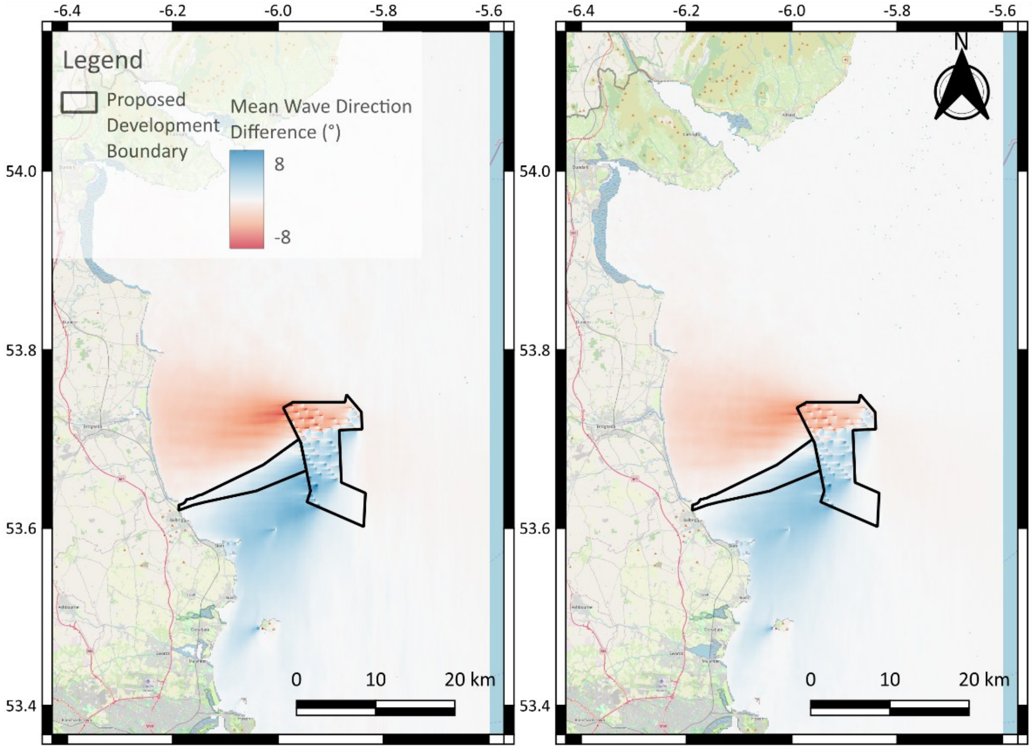

Figure 3.11: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

Figure 3.12: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

Figure 3.13: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

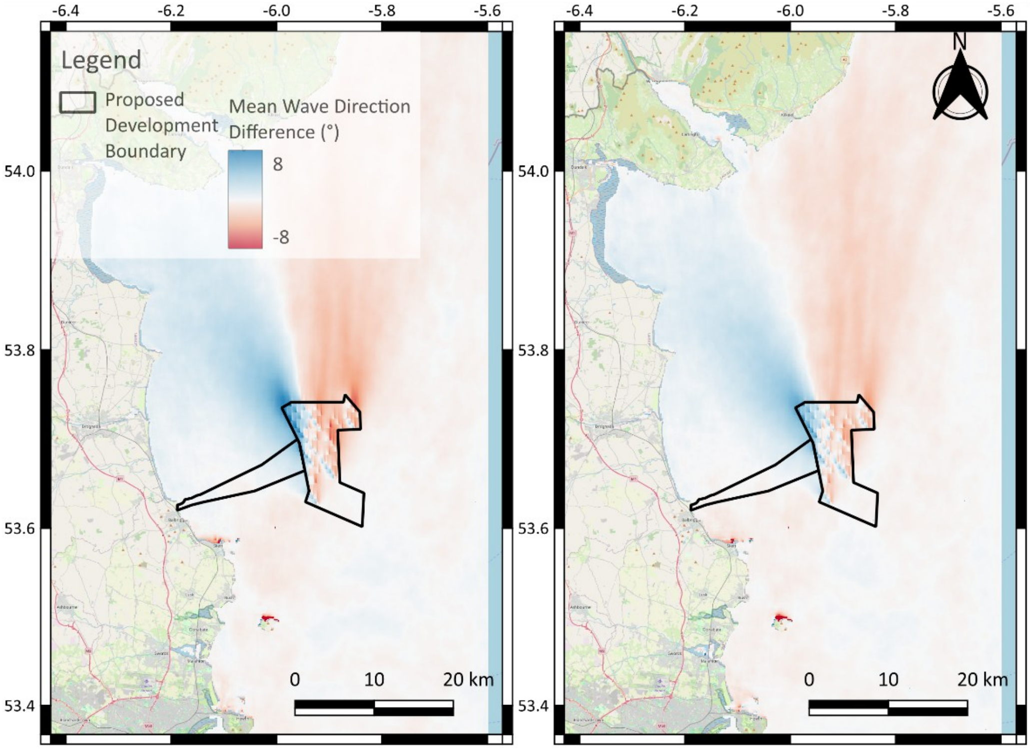

Figure 3.14: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

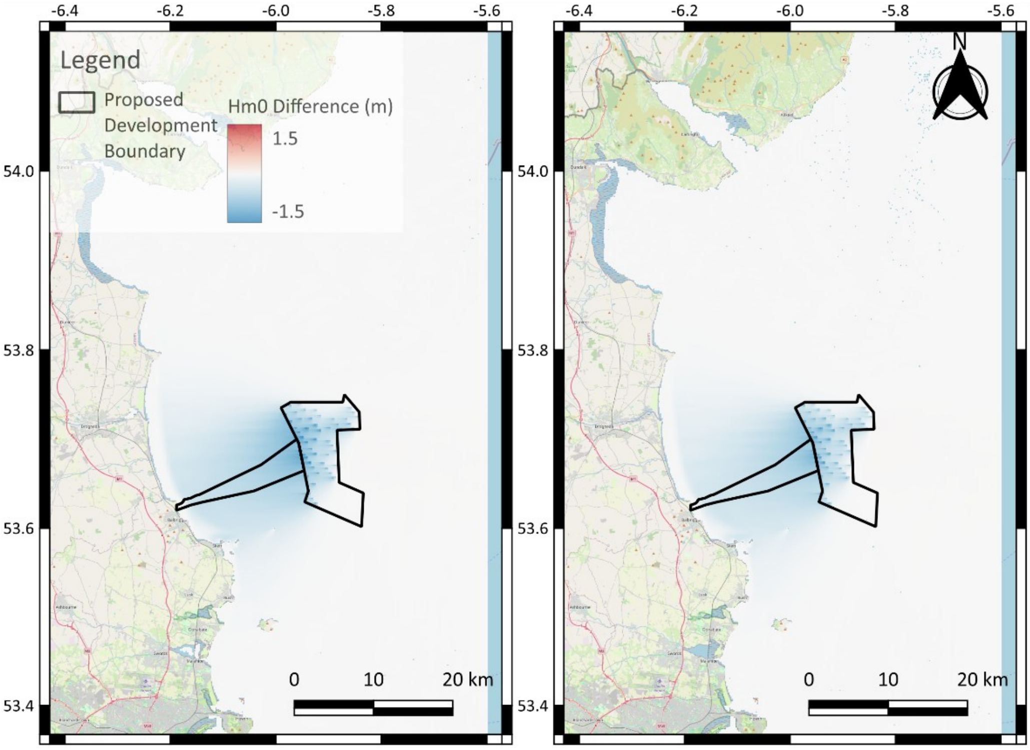

Figure 3.15: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

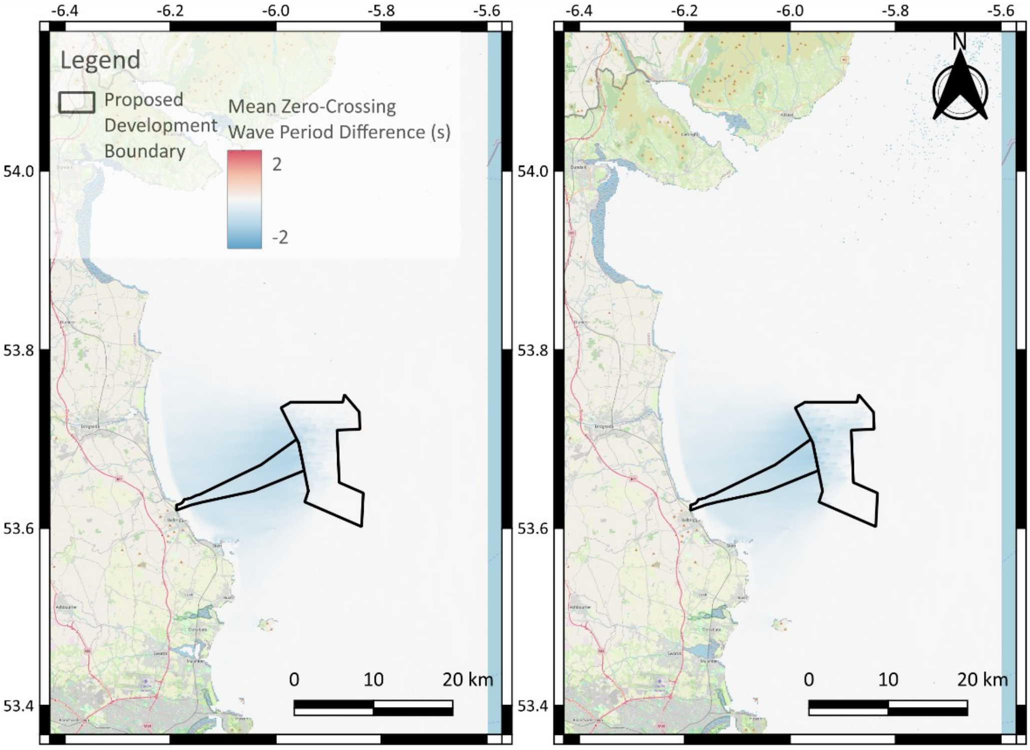

Figure 3.16: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

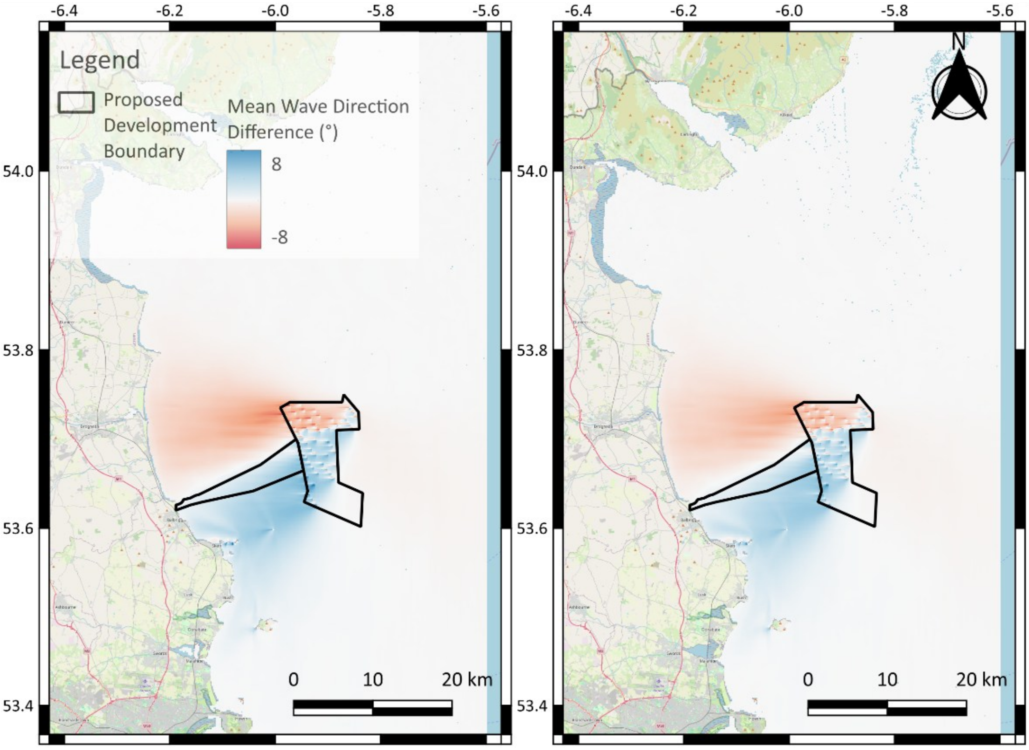

Figure 3.17: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

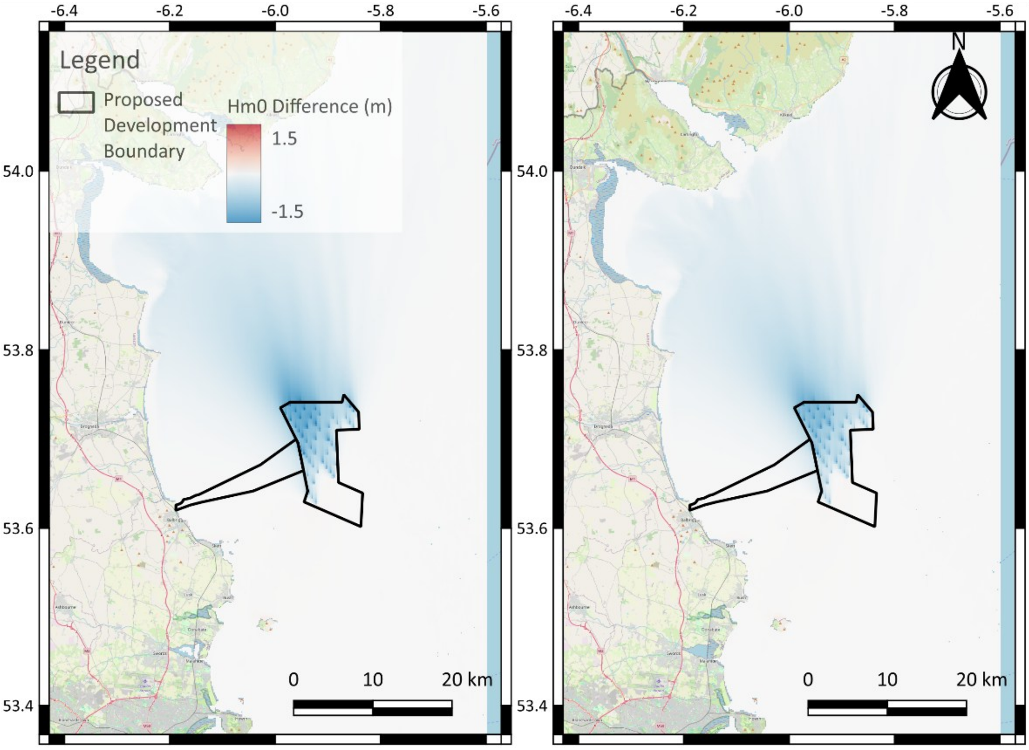

Figure 3.18: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

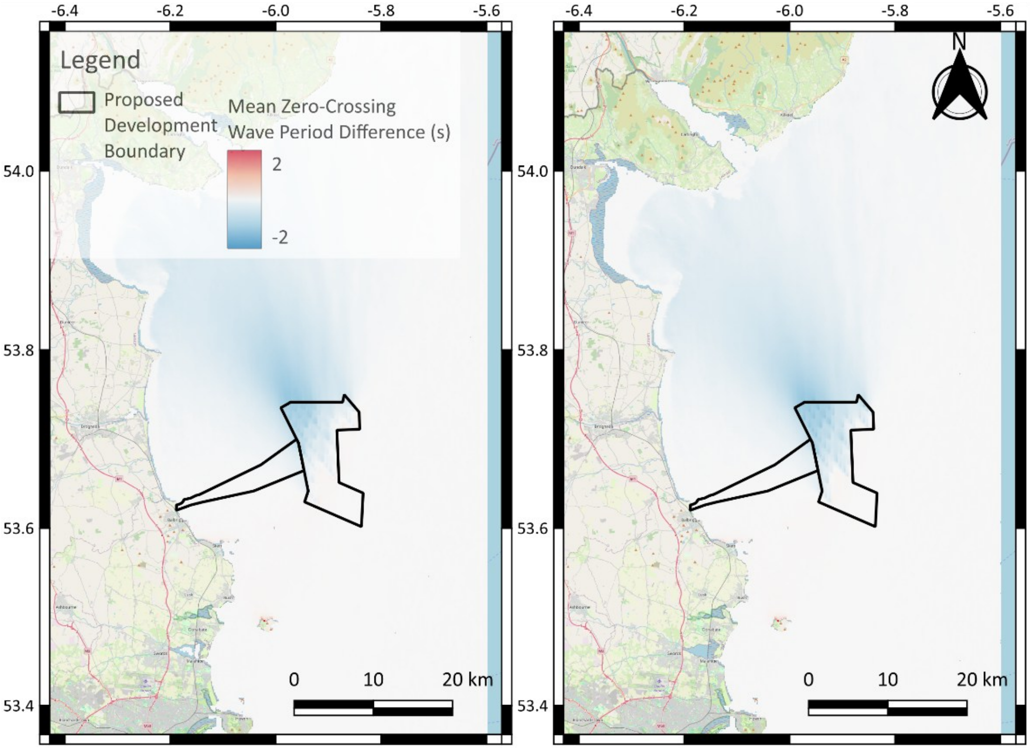

Figure 3.19: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

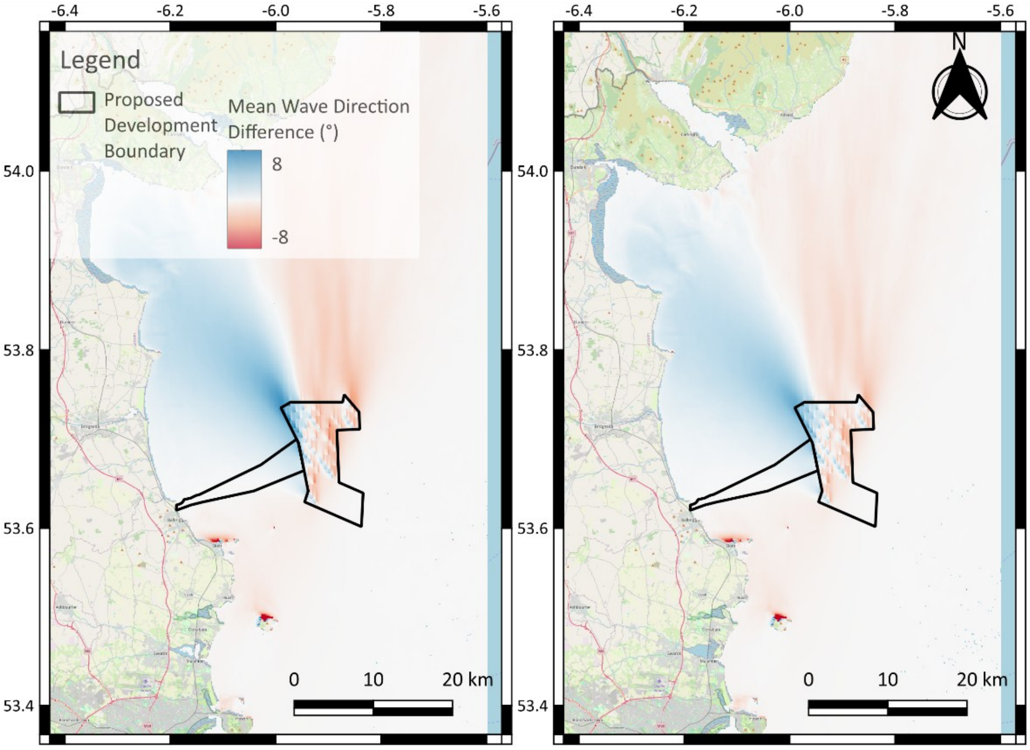

Figure 3.20: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

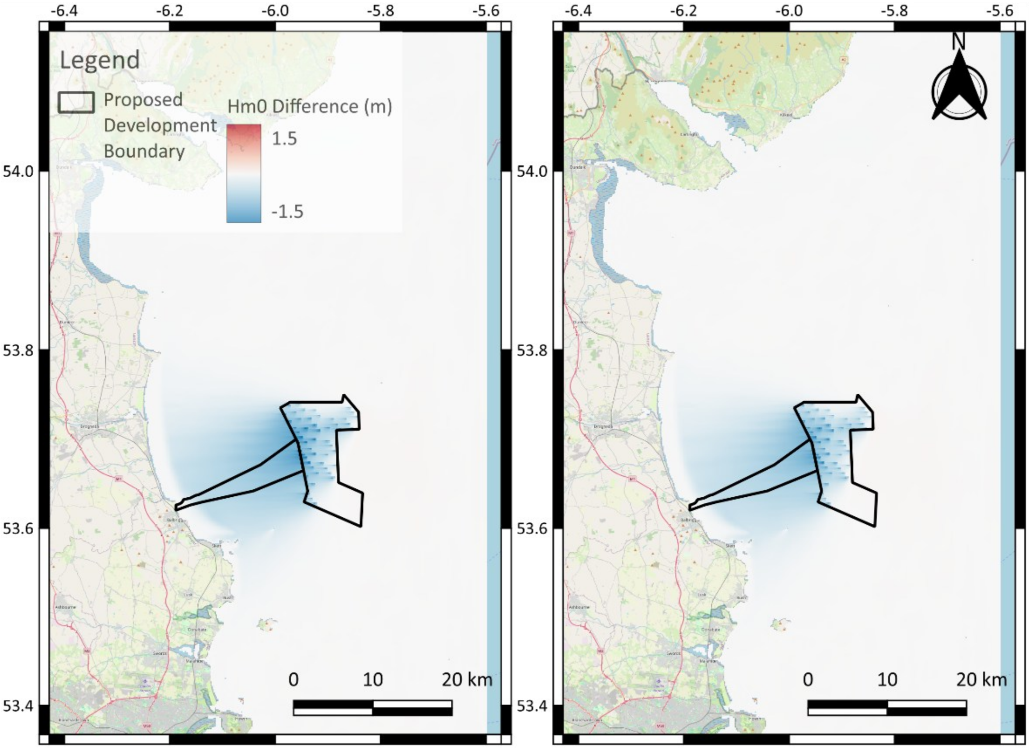

Figure 3.21: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

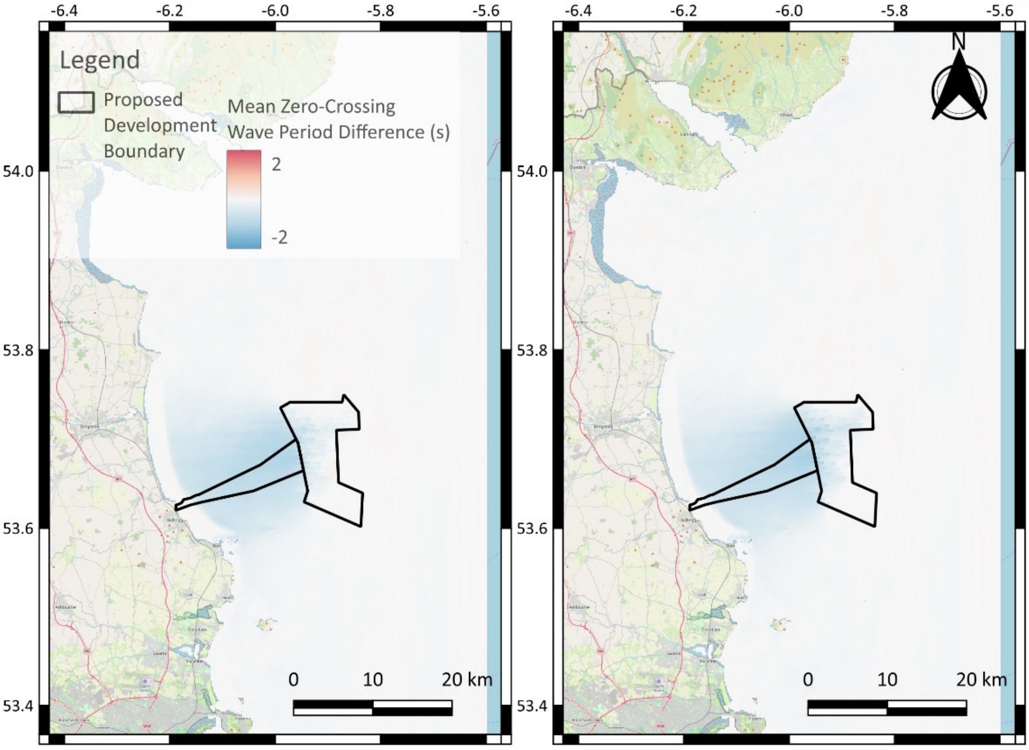

Figure 3.22: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

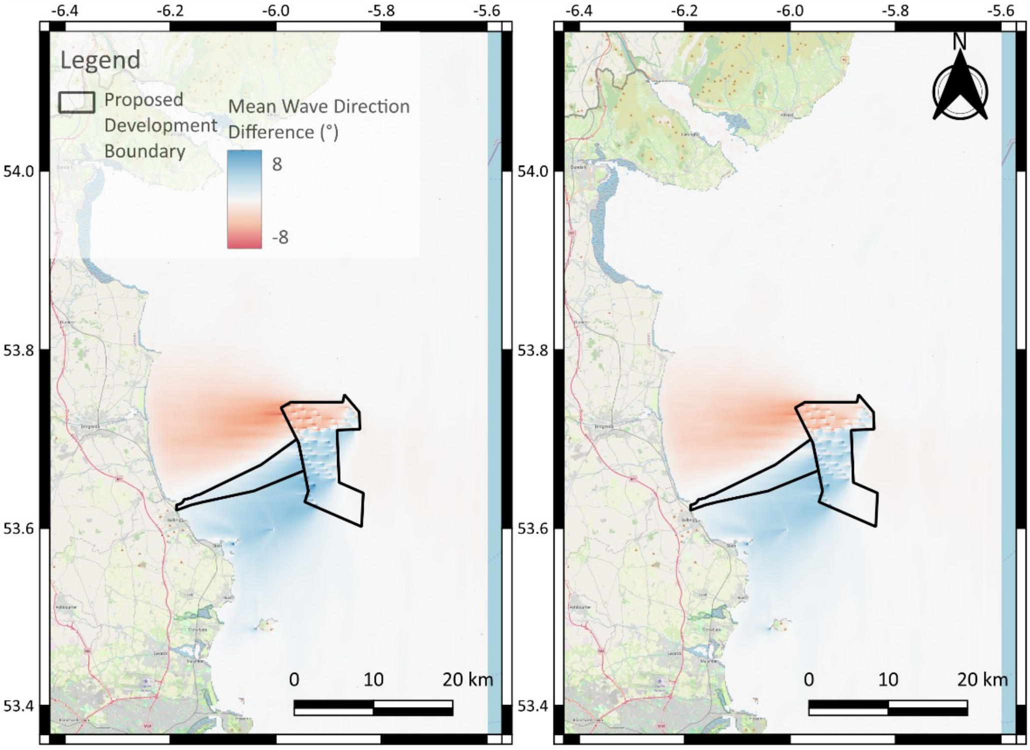

Figure 3.23: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

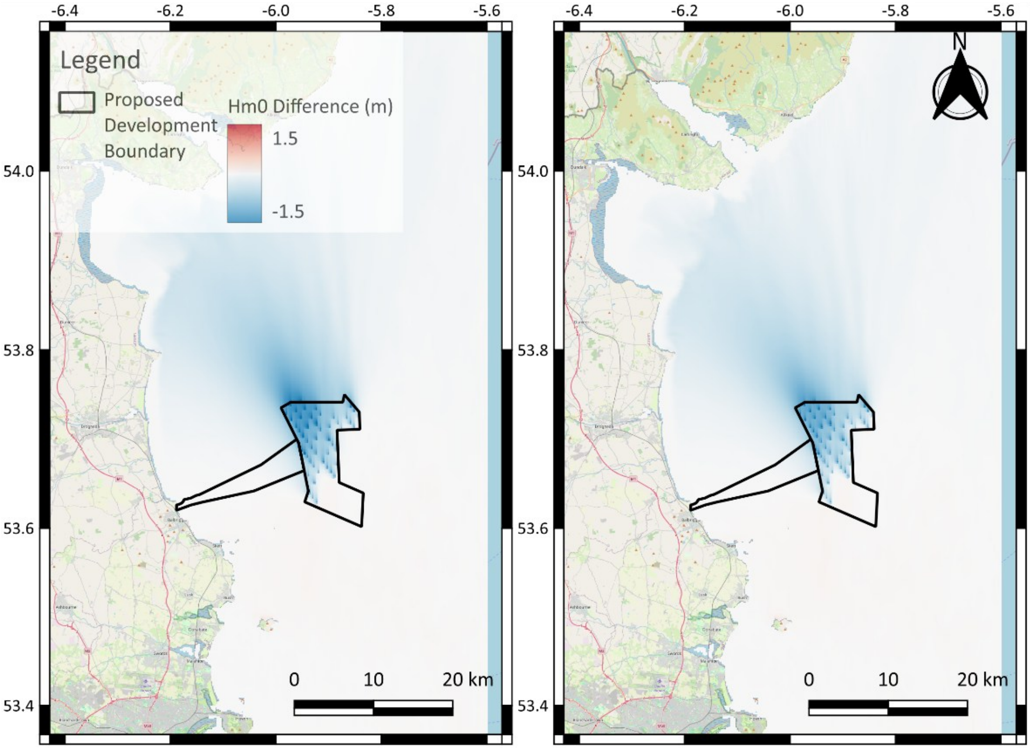

Figure 3.24: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

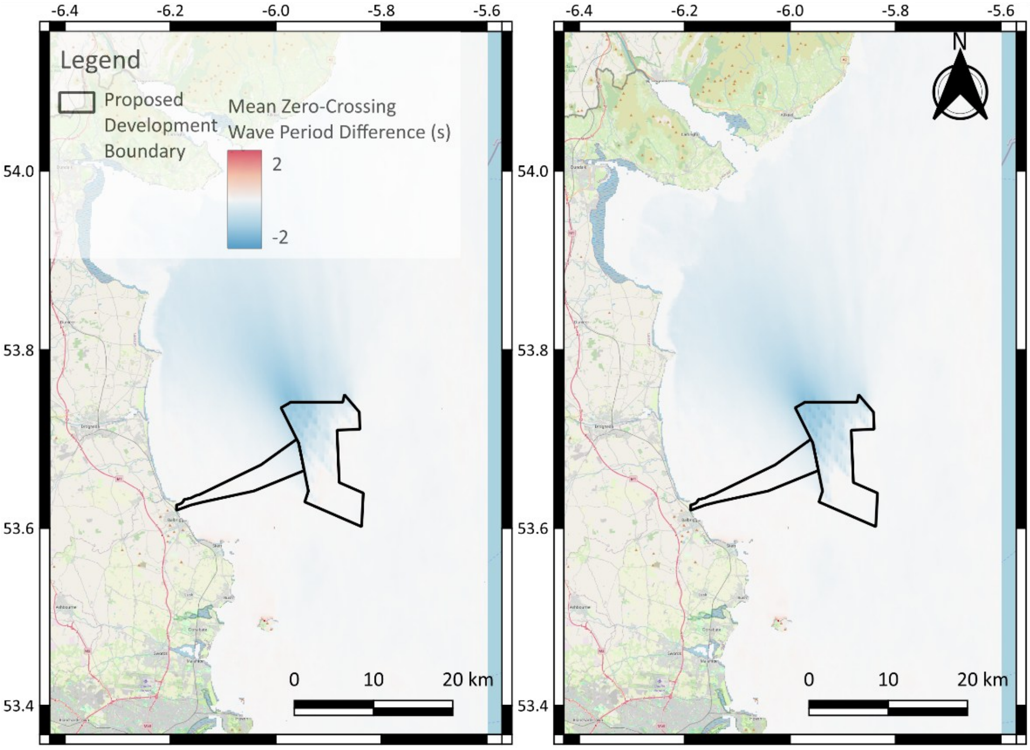

Figure 3.25: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

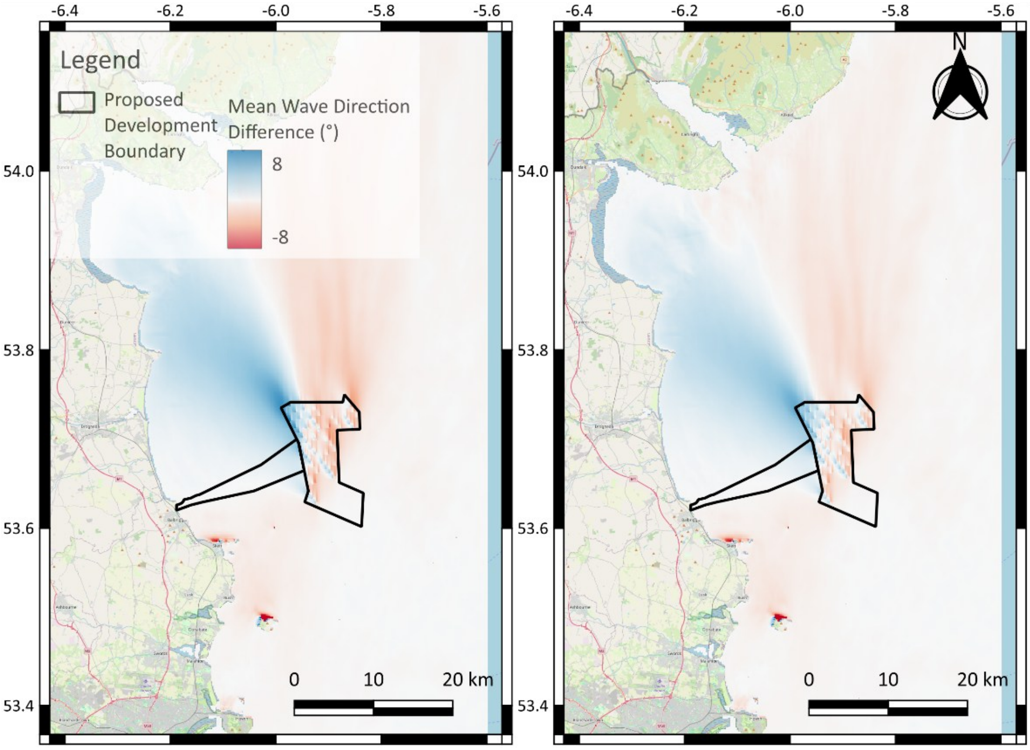

Figure 3.26: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

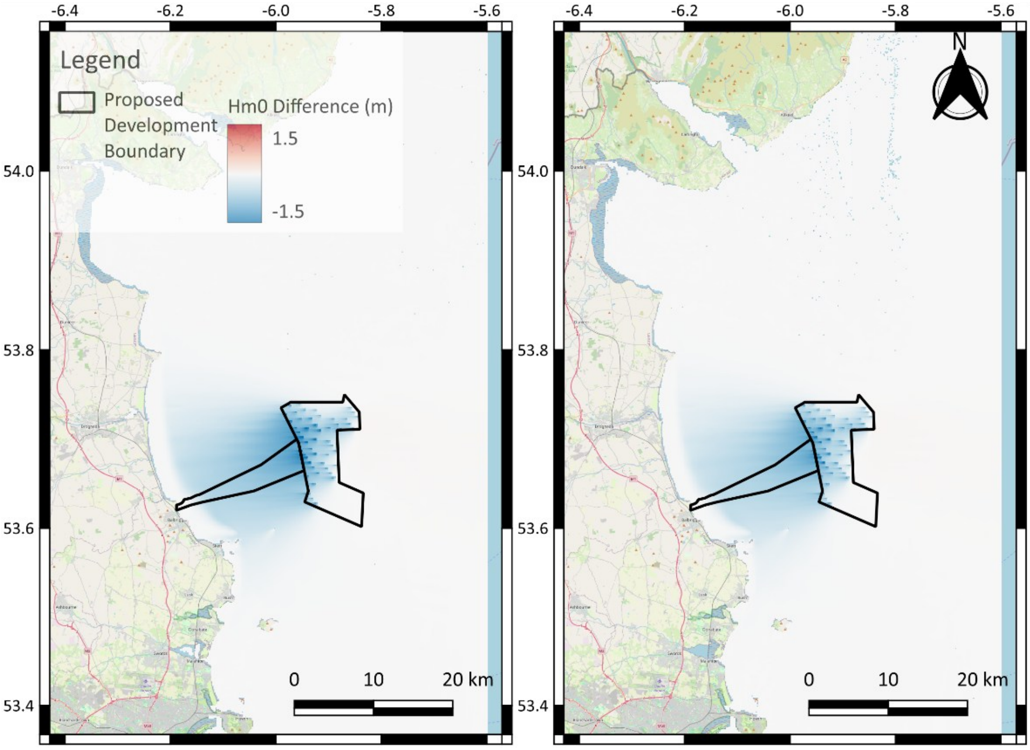

Figure 3.27: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

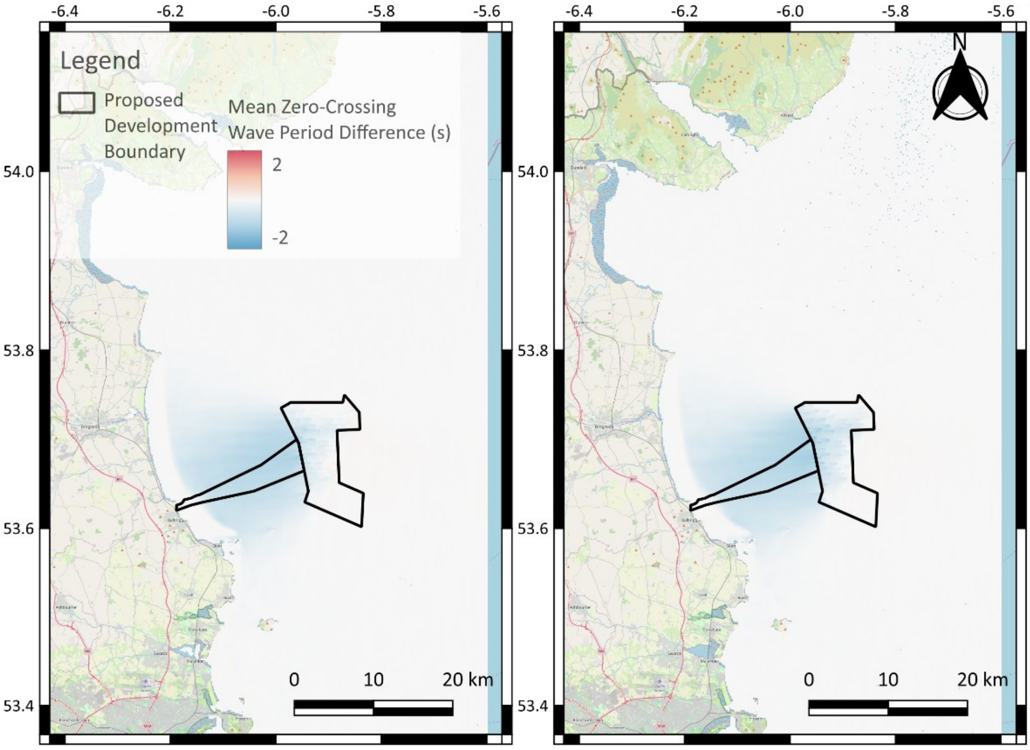

Figure 3.28: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

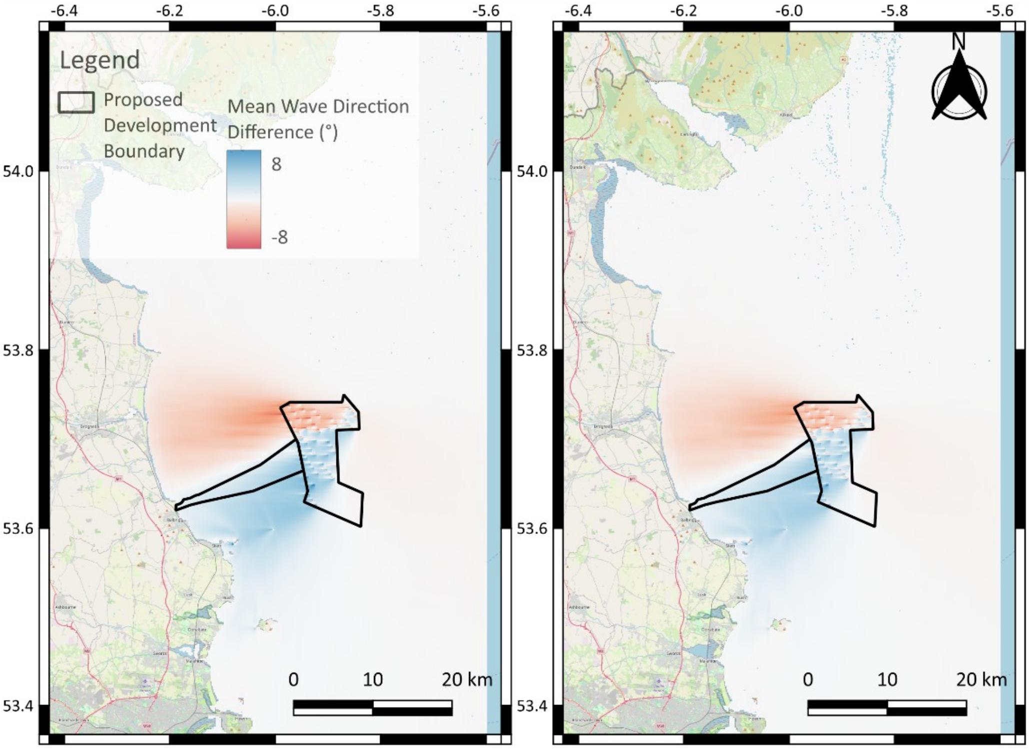

Figure 3.29: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

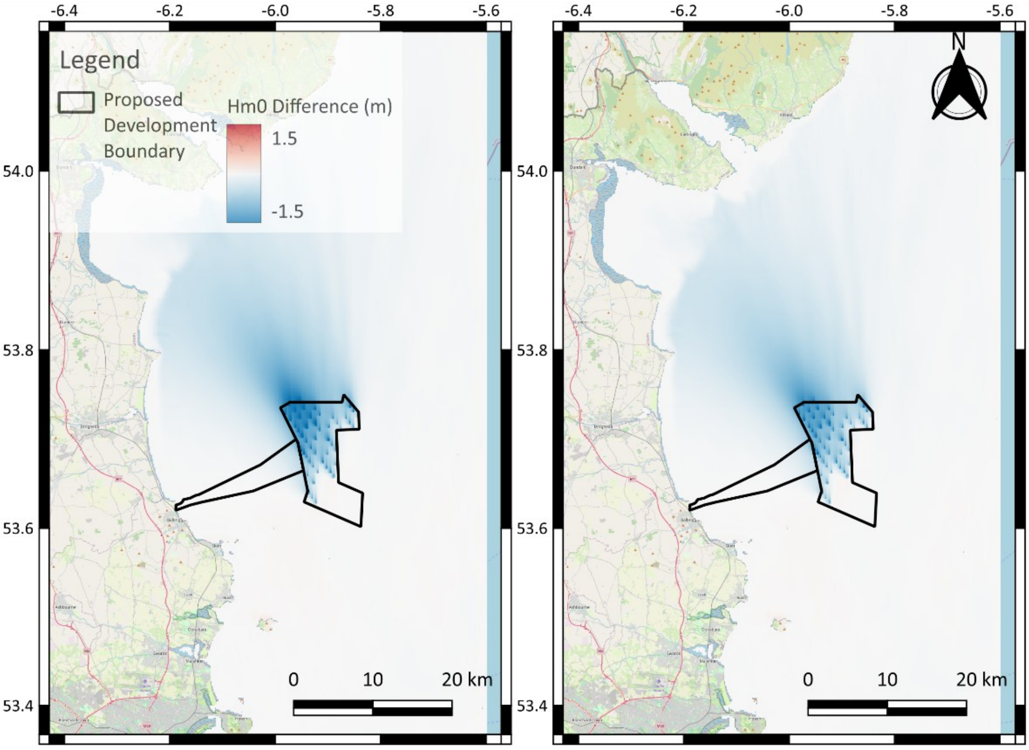

Figure 3.30: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

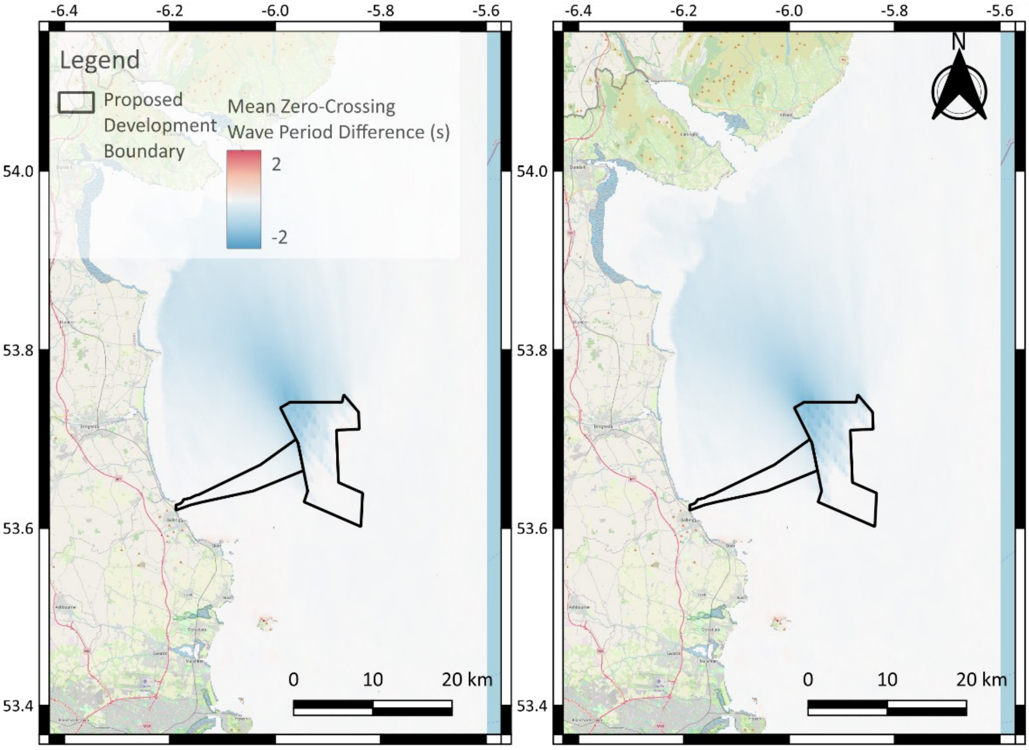

Figure 3.31: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

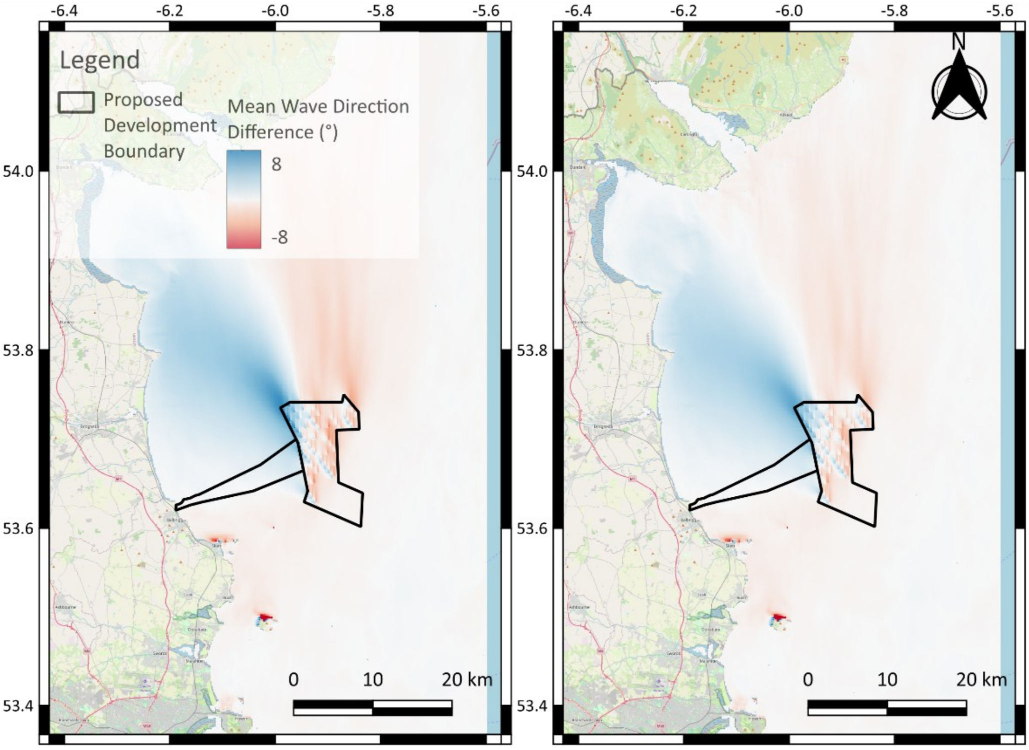

Figure 3.32: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Left panel includes wave model structures and wind wakes, right panel includes wave model structures only.

The comparisons between the left and right panels of Figure 3.9 to Figure 3.32 demonstrate that wind wakes do not make an appreciable difference to effects on leeward waves when compared against the modelling not including wind wakes, and are not considered necessary to include. In summary:

- For the p50 (median) conditions, for waves arriving from both 68°N and 156°N, the additional changes attributed to wind wakes are almost indiscernible. The most notable variations occur in the mean wave direction, where the inclusion of wind wakes results in an additional shift of approximately 1–2° in the immediate lee of the development. These effects dissipate within approximately 10 km. Changes to significant wave height are negligible for these conditions.
- For the 1 in 1 year conditions, the inclusion of wind wakes results in additional changes similar to those seen in the P50 conditions, with some variation in spatial extent.
    - Mean Wave Direction: Additional changes are smaller (typically <1° in the immediate lee) but have a slightly larger extent. For the 156°N case, the effect extends up to approximately 20 km before reducing to zero; for the 68°N case, the extent is slightly shorter.
    - Significant Wave Height: For the 156°N case, including wind wakes predicts an additional reduction in significant wave height of up to 0.2 m in the immediate lee, dissipating over approximately 20 km. For the 68°N case, the additional reduction is smaller (up to 0.1 m) and dissipates within 17 km.
- For the 1 in 10 year cases, the additional impacts of wind wakes on both mean wave direction and significant wave height for the 1 in 10 year conditions are consistent with the patterns and magnitudes described for the 1 in 1 year conditions.
- For the 1 in 50 year cases, while changes to mean wave direction remain similar to the 1 in 1 year results, the impact on significant wave height is more pronounced:
    - 156°N Case: Including wind wakes results in an additional reduction in significant wave height of up to 0.25 m in the immediate lee, dissipating over approximately 25 km.
    - 68°N Case: Additional reductions in significant wave height of up to 0.15 m are predicted in the immediate lee, dissipating over a shorter distance of approximately 13 km.

4 Morphodynamic Modelling

4.1 Overview

Morphodynamic modelling is provided to investigate the mophodynamic response of the coastline to the proposed development.

4.2 Baseline understanding

The coastline represents an important marine processes receptor with a morphology controlled by wave and tidal processes, and sediment supply. The most sensitive stretch of coastline is the drift-aligned sandy beaches to the west of the array area, which are subject to net littoral drift in a northerly direction driven by prevailing waves from the south-south-east (centred on 156 °N) [10]. As waves move into shallow water they refract, shoal, steepen and eventually break, with wave energy dissipation developing littoral currents where they arrive acute to the orientation of the beach. This process drives sand transport along the shoreline as longshore transport. In contrast, the shoreline further to the north is mainly gravelly, without sandy beaches and where prevailing waves arrive almost normal to the orientation of the coastline.

The dissipation of wave energy along the shoreface dominates over any effect from tidal currents, however, the rise and fall of tidal levels alters the cross-shore position where this dissipation occurs.

4.3 Wave blockage background

During the operational phase, the majority of each wavefront passing through a wind farm will remain unaffected, however, small sections will interact with each foundation to develop a cumulative set of interactions. This process is generally referred to as array-scale wave-blockage. The modified wave field emerging from the leeward side of the array area will incur a small reduction of wave energy represented in correspondingly small changes to wave height, wave period and wave direction. These changes spread away and dissipate over distance downwind from the windfarm.

Part of the wave recovery process in the downwind direction is due to wind-wave growth over the distance between the windfarm and the adjacent coastline. For the modelling presented in Chapter 10.3.7 of the EIAR [10], the associated wind-field is not modified as the scale of this effect was considered insignificant compared to the conservative assumptions adopted for wave-related blockage (see Section 3). For the purpose of the sensitivity tests, the wind field is modified to account for a velocity deficit due to wind-blockage created across the swept area of each WTG. To note, the leeward fetch distance is relatively short and is not likely to have a major influence on wind-wave growth.

4.4 Assessment of morphological response

In order to undertake a sensitivity test to assess potential modifications on coastal processes that may influence the morphological response of the coastline, the sensitivity test related to wind-wake blockage (Section 3) is considered.

This sensitivity test is configured as follows:

- Coupled wind, wave and tidal modelling which considers baseline conditions and the entire windfarm layout represented by Project Option 1 (see Appendix A10.1 of the EIAR for selection of the project option with the greatest potential to develop a likely significant effect. In addition, Project Option 1 has the highest overall swept area). The representation of the windfarm includes the array layout of foundations (suction bucket, scour protection, jacket) and swept area of blades.

- Cable protection (armouring) is not included in the model as this is too small-scale (e.g. up to 2 m high and width of 5 m in a trapezoidal cross-section) and is also not considered to have a large-scale or long-term influence on the seabed morphology. The assessment of cable armouring has previously been considered in Chapter 10 of the EIAR [10] on a conceptual basis as Impact 11 (See Section 10.5.3.3).

- Wind and wave conditions consider two directions; (a) the shortest distance to the coastline with winds and waves from 068 °N, and (b) the prevailing wave direction with winds and waves from south-south-west (centred on 156 °N). A range of combined wind and wave events are considered from an annual 50th percentile, and 1 year, 10 year and 50 year return periods. Accordingly, this range of events includes regular lower magnitude conditions which would expect to frequently occur over the short-term, as well as higher magnitude conditions which might expect to occur less frequently over the long-term.

- Wave results are considered for locations along the nearshore in the lee of the windfarm which are the same locations presented in Chapter 10.3.5 of the EIAR [10] (Figure 10.23 and Figure 10.24). These results are used to calculate littoral drift as an hourly rate, i.e., each wind-wave event is considered stationary for a period of one hour, noting extreme events are not expected to persist for longer than one hour and water levels will change over a longer period.

For the proposed development to create a morphodynamic response along the coastline, the development would need to significantly modify nearshore waves conditions incident along the coastline which drive longshore drift. Such modifications could include a notable change in the rate and/or direction of longshore drift.

4.4.1 South-south-easterly waves

South-south-easterly waves represent the prevailing conditions (48% of all waves arrive from this direction) shaping the adjacent coastline.

Figure 4.1 shows the effect of wave blockage for a 1 in 50-year return period wave event in terms of predicted modifications on leeward wave heights (relative to the baseline) due to wave blockage effects only.

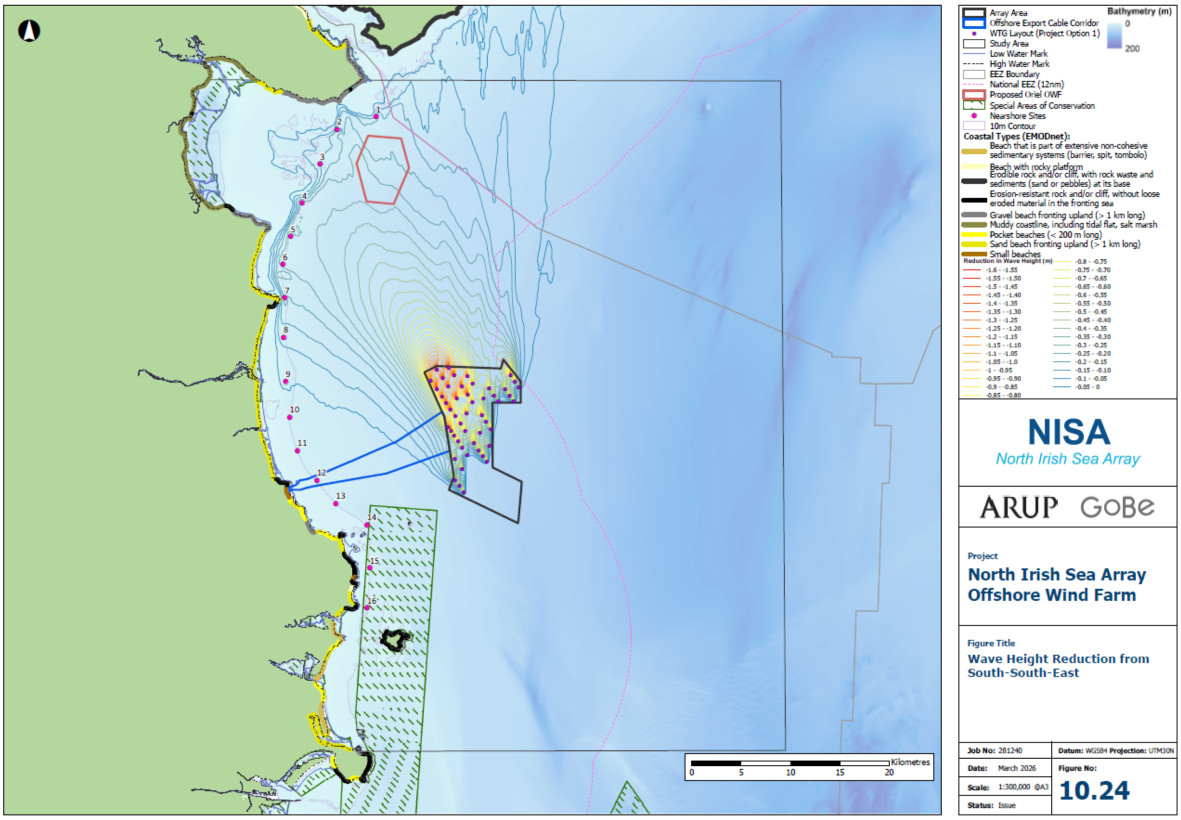

Figure 4.1: Predicted change in 1 in 50-year wave height for waves arriving from the south-south-east with nearshore sites for assessing significance of impacts along the coastline.

The relevant nearshore locations to evaluate potential effects on adjacent sandy beaches are Sites 6, 8 and 9. The coastline adjacent to Site 7 represents a rocky promontory. Site 10 to 16 are south of any moderated waves which pass through the array area, whereas Sites 1 to 5 are north of the sandy beaches.

Site 6 represents the nearshore location adjacent to a sandy beach where the highest relative level of change in downwind wave conditions is determined for incident waves arriving at array area from the south-south-east. In contrast, all other nearshore locations are considered to have a lesser scale of change.

For reference, the shortest direct distance from the array area to Site 6 is around 18 km. Waves passing through the array area gradually refract into shallower water to change direction towards the coastline. In this case, waves travel a slightly longer distance. The direction of wind-wakes is expected to remain close to incident conditions, in which case the affected leeward fetch distance relevant to Site 6 will be limited to a slightly smaller distance.

4.4.1.1 P50 - SSE

The P50 scenario represents the 50 percentile of wind and wave conditions, equivalent to median conditions over the year with 50% of conditions being lower and 50% being higher (including the extreme events).

The associated incident wind field for the P50 scenario is 6.6 m/s from 156°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.1 compares predicted P50 wave conditions at Site 6 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.1. Comparison of leeward wave conditions for P50 event - SSE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	0.58	0.57	0.57
	Difference (m)	-	-0.01	-0.01
Wave period	Absolute value (s)	2.60	2.57	2.56
	Difference (s)	-	-0.03	-0.04
Wave direction	Absolute value (°N)	143	144	144
	Difference (°)	-	+1	+1
Longshore transport rate, Qt	Absolute value (m^3/hr)	+32	+31	+31
	Difference (m^3/hr)	-	-1	-1

+ve values of baseline Qt rates relate to northerly directed transport

In summary, there are no discernible changes in P50 wave conditions at Site 6 between the baseline and either the wave blockage scenario or the wind and wave blockage scenario, and no discernible changes in longshore drift rates.

4.4.1.2 1 in 1 year Return Period - SSE

The 1 in 1 year return period (RP) event represents a condition which, on average, would be expected to occur once per year.

The associated incident wind field for the 1 in 1 year RP scenario is 19.2 m/s from 156°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.2 compares predicted 1 in 1 year RP wave conditions at Site 6 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates using on the internationally-recognised CERC formula from USACE [16]. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.2. Comparison of leeward wave conditions for 1 in 1 year event - SSE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	3.10	2.96	2.94
	Difference (m)	-	-0.14	-0.16
Wave period	Absolute value (s)	5.77	5.56	5.56
	Difference (s)	-	-0.21	-0.21
Wave direction	Absolute value (°N)	129	131	131
	Difference (°)	-	+2	+2
Longshore transport rate, Qt	Absolute value (m^3/hr)	+1,609	+1,510	+1,491
	Difference (m^3/hr)	-	-99	-118

+ve values of Qt relate to northerly directed transport

In summary, there are very small changes in 1 in 1 year RP wave and longshore drift conditions at Site 6 between the baseline and the wave blockage scenario (a small reduction of 99 m^3/hr), and a very similar level of change between the baseline and the wind and wave blockage scenario (a small reduction of 118 m^3/hr). Importantly, the 1 in 1 year RP event is an infrequent condition that is only likely to occur once a year, on average, and last for a limited period)

4.4.1.3 1 in 10 year Return Period - SSE

The 1 in 10 year return period (RP) event represents an extreme condition with a 10% chance of occurrence within a year, which, on average, would be expected to occur once every ten years.

The associated incident wind field for the 1 in 10 year RP scenario is 22.0 m/s from 156°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.3 compares predicted 1 in 10 year RP wave conditions at Site 6 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.3. Comparison of leeward wave conditions for 1 in 10 year event - SSE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	3.82	3.60	3.58
	Difference (m)	-	-0.22	-0.24
Wave period	Absolute value (s)	6.51	6.27	6.25
	Difference (s)	-	-0.24	-0.26
Wave direction	Absolute value (°N)	126	128	128
	Difference (°)	-	+2	+2
Longshore transport rate, Qt	Absolute value (m^3/hr)	+2,417	+2,243	+2,233
	Difference (m^3/hr)	-	-174	-184

+ve values of Qt relate to northerly directed transport

In summary, there are small changes in 1 in 10 year RP wave and longshore drift conditions at Site 6 between the baseline and the wave blockage scenario (a small reduction of 174 m^3/hr), and a very similar level of change between the baseline and the wind and wave blockage scenario (a small reduction of 184 m^3/hr). Importantly, the 1 in 10 year RP event is an infrequent condition that has a 10% chance of occurring every, on average, and will last for a limited period.

4.4.1.4 1 in 50 year Return Period - SSE

The 1 in 50 year return period (RP) event represents an extreme condition with a 2% chance of occurrence within a year, which, on average, would be expected to occur once every 50 years.

The associated incident wind field for the 1 in 50 year RP scenario is 24.0 m/s from 156°N at 10 m above sea level. This wind speed is above the cut-in conditions, however, the wind speed at hub height is expected to be close to or above the cut-off wind speed for the turbine to be operating. The scenario presented below assumes the turbine to remain in operation for illustrative purposes.

Table 4.4 compares predicted 1 in 50 year RP wave conditions at Site 6 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.4. Comparison of leeward wave conditions for 1 in 50 year event - SSE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	4.35	4.08	4.05
	Difference (m)	-	-0.27	-0.30
Wave period	Absolute value (s)	7.06	6.74	6.74
	Difference (s)	-	-0.32	-0.32
Wave direction	Absolute value (°N)	125	126	127
	Difference (°)	-	+1	+2
Longshore transport rate, Qt	Absolute value (m^3/hr)	+3,120	+2,886	+2,867
	Difference (m^3/hr)	-	-234	-253

+ve values of Qt relate to northerly directed transport

In summary, there are small changes in 1 in 50 year RP wave and longshore drift conditions at Site 6 between the baseline and the wave blockage scenario (a small reduction of 234 m^3/hr), and a very similar level of change between the baseline and the wind and wave blockage scenario (a small reduction of 253 m^3/hr). Importantly, the 1 in 50 year RP event is an infrequent condition that has a 2% chance of occurring every, on average, and will last for a limited period.

4.4.2 East-north-east waves

East-north-east waves represent the direction with the shortest leeward distance onto the adjacent coastline; however, these waves represent around 9% of all conditions.

Figure 4.2 shows the effect of wave blockage for a 1 in 50-year return period wave event in terms of predicted modifications on leeward wave heights (relative to the baseline), due to wave blockage effects only.

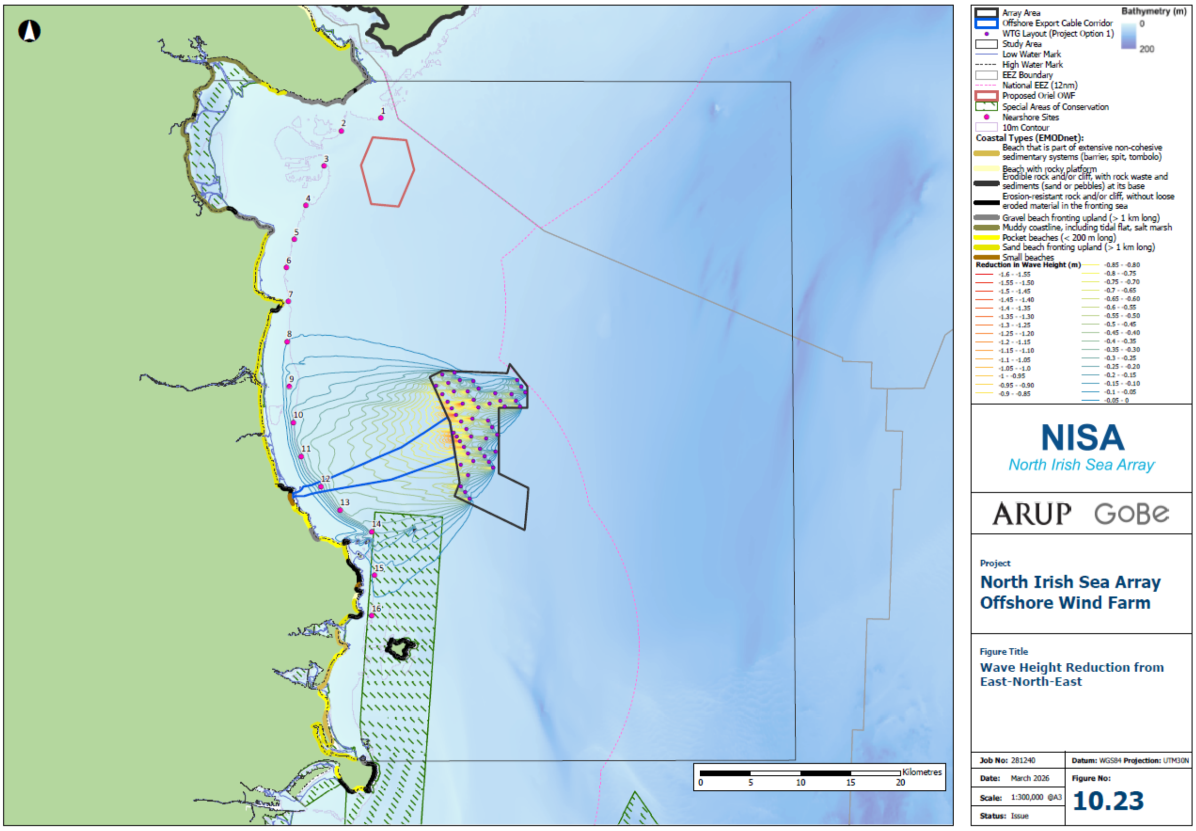

Figure 4.2: Predicted change in 1 in 50-year wave height for waves arriving from the east-northeast with nearshore sites for assessing significance of impacts along the coastline.

The relevant nearshore locations to evaluate potential effects on adjacent sandy beaches are Sites 8 to 15. The coastline adjacent to Sites 12, 14 and 15 represents rocky promontories. Site 16 is south of any moderated waves which pass through the array area, whereas Sites 1 to 7 are north of any moderated waves.

Site 11 represents the nearshore location adjacent to a sandy beach where the highest relative level of change in downwind wave conditions is determined for incident waves arriving at array area from the east-north-east. In contrast, all other nearshore locations are considered to have a lesser scale of change.

For reference, the shortest direct distance from the array area to Site 11 is around 15 km. Waves passing through the array area from the east-north-east are already close to shore normal and experience minimal refraction as they approach the coastline. The direction of wind-wakes is expected to remain close to incident conditions, in which case the affected leeward fetch distance relevant to Site 11 will have an equivalent distance.

Longshore drift occurs when wave arrive obliquely on a sandy coastline. Waves that arrive close to shore normal do not lead to well-developed longshore drift.

4.4.2.1 P50 - ENE

The P50 scenario represents the 50th percentile of wind and wave conditions, equivalent to median conditions over the year with 50% of conditions being lower and 50% being higher (including the extreme events).

The associated incident wind field for the P50 scenario is 6.0 m/s from 68°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.5 compares predicted P50 wave conditions at Site 11 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.5. Comparison of leeward wave conditions for P50 event – ENE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	0.69	0.66	0.66
	Difference (m)	-	-0.03	-0.03
Wave period	Absolute value (s)	2.84	2.79	2.78
	Difference (s)	-	-0.05	-0.06
Wave direction	Absolute value (°N)	68	67	67
	Difference (°)	-	-1	-1
Longshore transport rate, Qt	Absolute value (m^3/hr)	-17	-18	-18
	Difference (m^3/hr)	-	+1	+1

+ve values of Qt relate to northerly directed transport

In summary, there are no discernible changes in P50 wave conditions at Site 11 between the baseline and either the wave blockage scenario or the wind and wave blockage scenario, and no discernible changes in longshore drift rates.

4.4.2.2 1 in 1 year Return Period - ENE

The 1 in 1 year return period (RP) event represents an extreme condition, which, on average, would be expected to occur once per year.

The associated incident wind field for the 1 in 1 year RP scenario is 16.8 m/s from 68°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.6 compares predicted 1 in 1 year RP wave conditions at Site 11 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.6. Comparison of leeward wave conditions for 1 in 1 year event – ENE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	3.82	3.63	3.57
	Difference (m)	-	-0.19	-0.25
Wave period	Absolute value (s)	6.60	6.35	6.31
	Difference (s)	-	-0.25	-0.29
Wave direction	Absolute value (°N)	69	69	69
	Difference (°)	-	0	0
Longshore transport rate, Qt	Absolute value (m^3/hr)	-1,067	-1,009	-991
	Difference (m^3/hr)	-	-58	-76

+ve values of Qt relate to northerly directed transport

In summary, there are very small changes in 1 in 1 year RP wave and longshore drift conditions at Site 11 between the baseline and the wave blockage scenario, and a very similar level of change between the baseline and the wind and wave blockage scenario. Importantly, the 1 in 1 year RP event is an infrequent condition that is only likely to occur once a year, on average.

4.4.2.3 1 in 10 year Return Period - ENE

The 1 in 10 year return period (RP) event represents an extreme condition with a 10% probability of occurrence within a year, which, on average, would be expected to occur once per decade.

The associated incident wind field for the 1 in 10 year RP scenario is 18.65 m/s from 68°N at 10 m above sea level. This wind speed is above the cut-in conditions for the turbine to be operating.

Table 4.7 compares predicted 1 in 10 year RP wave conditions at Site 11 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the CERC formula [16]. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.7. Comparison of leeward wave conditions for 1 in 10 year event – ENE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	4.64	4.38	4.31
	Difference (m)	-	-0.26	-0.33
Wave period	Absolute value (s)	7.46	7.12	7.11
	Difference (s)	-	-0.34	-0.35
Wave direction	Absolute value (°N)	70	70	69
	Difference (°)	-	0	-1
Longshore transport rate, Qt	Absolute value (m^3/hr)	-1,545	-1,449	-1,419
	Difference (m^3/hr)	-	-96	-126

+ve values of Qt relate to northerly directed transport

In summary, there are small changes in 1 in 10 year RP wave and longshore drift conditions at Site 11 between the baseline and the wave blockage scenario, and a very similar level of change between the baseline and the wind and wave blockage scenario.

4.4.2.4 1 in 50 year Return Period - ENE

The 1 in 50 year return period (RP) event represents an extreme condition with a 2% probability of occurrence within a year, which, on average, would be expected to occur once every 50 years.

The associated incident wind field for the 1 in 50 year RP scenario is 20.0 m/s from 68°N at 10 m above sea level. This wind speed is above the cut-in conditions and also below the cut-off wind speed for the turbine to be operating.

Table 4.8 compares predicted 1 in 50 year RP wave conditions at Site 11 for baseline, wave blockage and wind and wave blockage scenarios, along with predicted longshore transport rates based on the USACE CERC formula. For the purpose of this calculation the duration of the wave conditions is assumed to last for one hour. All differences are made to baseline values [difference = baseline – scenario].

Table 4.8. Comparison of leeward wave conditions for 1 in 50 year event – ENE

Descriptor		Baseline	Wave blockage	Wind and wave blockage
Wave height	Absolute value (m)	5.09	4.86	4.80
	Difference (m)	-	-0.23	-0.29
Wave period	Absolute value (s)	7.74	7.51	7.49
	Difference (s)	-	-0.23	-0.25
Wave direction	Absolute value (°N)	70	70	70
	Difference (°)	-	0	0
Longshore transport rate, Qt	Absolute value (m^3/hr)	-1,860	-1,792	-1,780
	Difference (m^3/hr)	-	-68	-80

+ve values of Qt relate to northerly directed transport

In summary, there are small changes in 1 in 50 year RP wave and longshore drift conditions at Site 11 between the baseline and the wave blockage scenario, and a very similar level of change between the baseline and the wind and wave blockage scenario.

4.4.3 Summary of sensitivity test for morphodynamic impacts

The existing modelling approach correctly identifies the primary source (wave-blockage) and pathway for impacts which could affect the adjacent coastline receptor.

The modelling approach includes a range of representative conditions which cover both typical and extreme events which might be expected to occur over the operational period.

Whilst wind-wake blockage has a theoretical influence on leeward wave conditions, the scale of this effect is shown by the sensitivity modelling to be secondary to wave-blockage related effects and not at a scale that changes the outcome of the EIA assessment. See Section 10.5 of Chapter 10 of the EIAR [10].

The further consequence of modified waves acting on the coastline has been considered in terms of longshore drift showing modifications are effectively nil for typical wave conditions and small or very small for less frequent extreme conditions. These outcomes are shown to be the same whether wind-blockage effects are included or not.

5 Climate Change

Section 4 of this document provides sensitivity studies and assessments that respond to the request of coupled modelling. RFI 7e requests that in addition to this, the modelled scenarios should account for climate change.

The project metocean report [17] provides a comprehensive overview of climate change research and predictions relevant to the design criteria for the site. In summary;

- Strong winds and extratropical storms are projected to have a slightly increasing frequency and amplitude in the future, off the European coasts under Representative Concentration Pathway (RCP) 8.5 by the end of the century (medium confidence), due to the increase in intensity of extratropical storms at a 2 °C or above global warming scenario. n.b., Representative Concentration Pathways (RCPs) are standardised scenarios that model how different levels of greenhouse gas concentrations will affect the Earth's energy balance. They provide a common framework for scientists to predict future global warming and its environmental impacts.
- In general, the models predict a reduction in mean significant wave height of around 0.07 m, and an increase in the mean annual maximum significant wave height of around 0.25 m, in the vicinity of the project site under RCP8.5, by the end of this century. This is consistent with the predictions of increases in magnitude of extreme wind events in the vicinity of the study site.
- Mean sea level change is expected to be the dominant source of increase in total water levels.
- Marine currents are unlikely to substantially change as a direct result of climate change.

Taken together, these predictions are generally associated with low levels of confidence or are small/negligible changes. The exception to this is mean sea level rise.

Mean sea level change is not investigated in the project metocean report, and so a short *precis* of the current research and predictions on this topic are provided here.

Whilst the IPCC Sixth Assessment Report provides predictions of global mean sea level change, detailed high-resolution predictions are not provided. Therefore, herein we use UKCP18 as a primary data source for our analysis of the impacts of climate change at the site (since many of the analyses also pertain to the island of Ireland, and because the site is geographically close to UK waters, where predictions are provided by UKCP18. Because the information is regional-scale, we do not expect differences between the position chosen, and the location of the proposed development). The UKCP18 projections incorporate a range of potential outcomes based on different greenhouse gas emission scenarios (RCPs), reflecting the inherent uncertainty in climate sensitivity and future global mitigation efforts. Our analysis considers the probabilistic distributions provided within these scenarios to ensure that the assessment accounts for the higher-magnitude, low-probability events required for a precautionary approach.

A grid cell was extracted from the UK Climate Projects User Interface, from the nearest grid cell centre, 21 km north of the site. The location relative to the site is shown in Figure 5.1.

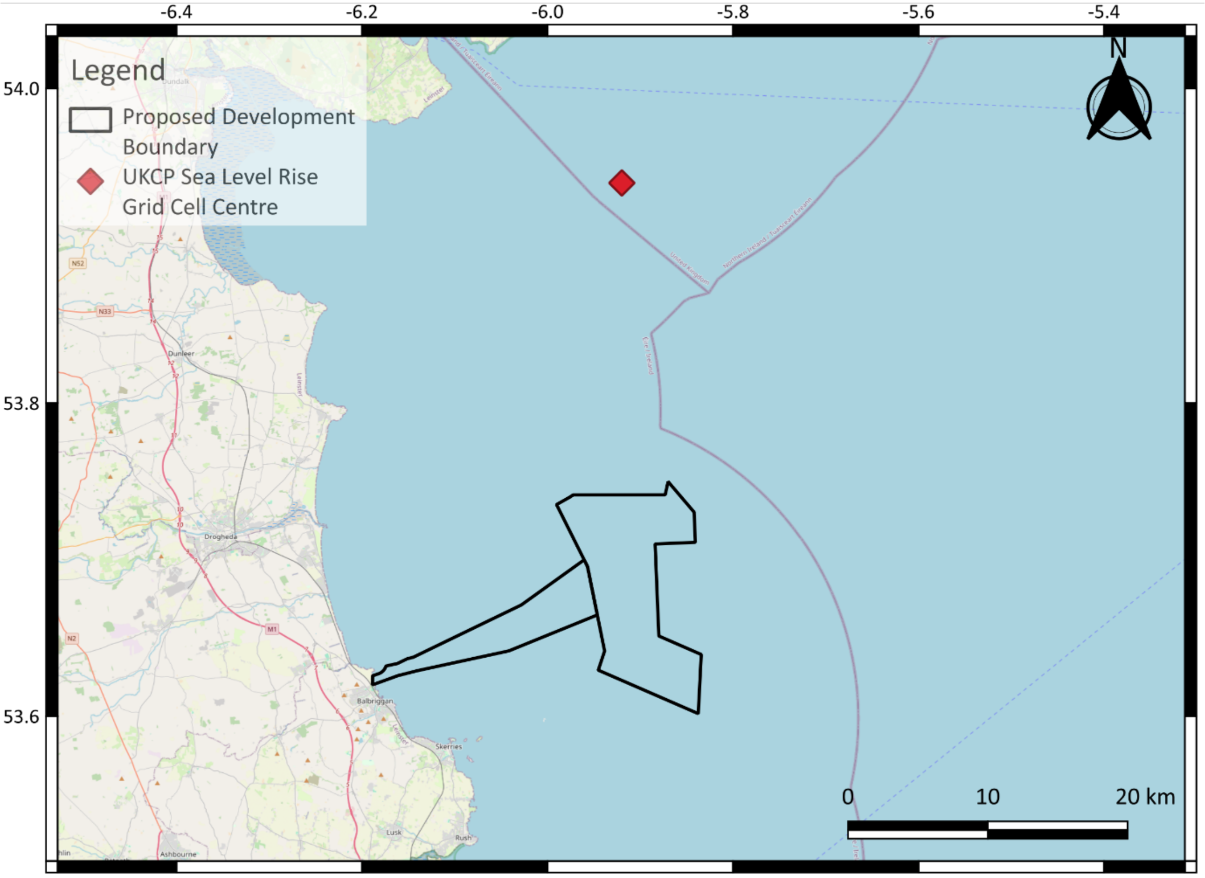

Figure 5.1: Location of UKCP sea level rise grid cell centre.

In line with typical approaches adopted in the UK offshore wind industry, predictions of mean sea level rise for the 50th percentile of the climate scenario RCP 8.5 were extracted, and the prediction was extracted for the year 2068 (equivalent to the lifespan of the proposed development post-construction). The value is 0.35 m. These data were then checked against IPCC predictions for Dublin, and the level of match was deemed acceptable.

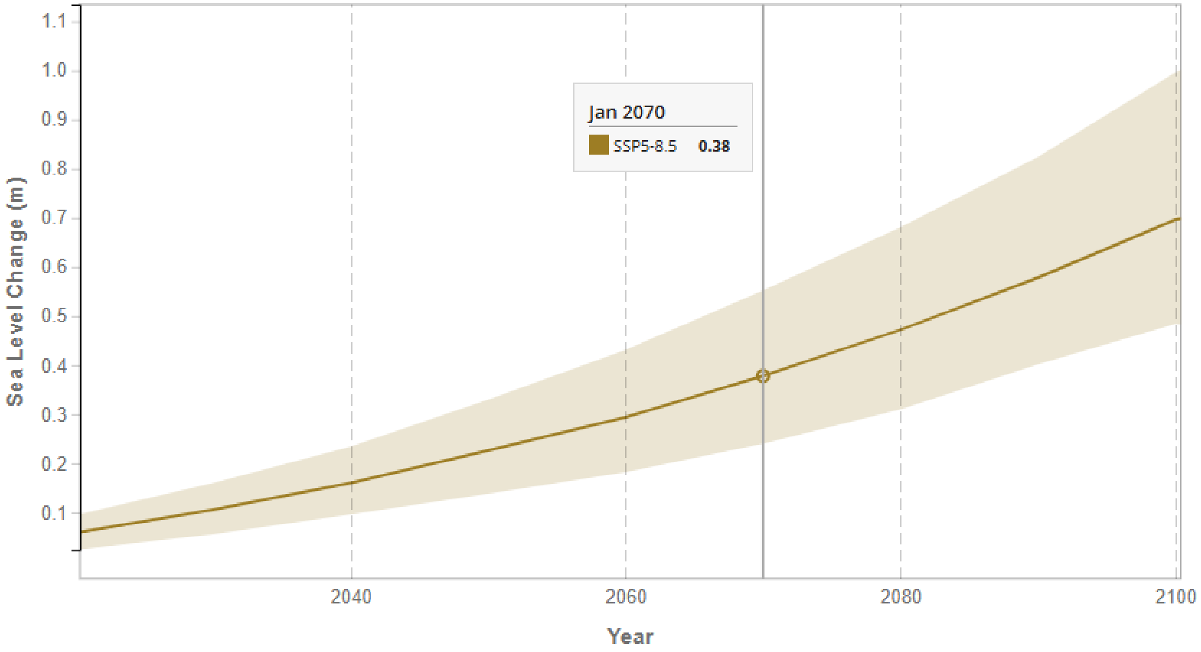

Figure 5.2: IPCC predictions of sea level rise at Dublin.

The hydrodynamic blockage model, accounting for the effects of Project Option 1, was then run for each high flow scenario, but with the water level increased by 0.35 m in each case. These outcomes are then compared against the same results without the water level increase, in Figure 5.3 to Figure 5.8. In these figures, the images are scaled and coloured to allow the reader to compare the left and right panels, to ascertain whether the influence of climate change makes an appreciable difference to the results of the modelling. For a detailed assessment of the modelling of the impact of the proposed development on the environment, please see Section 10.5 of Chapter 10 the EIAR [10].

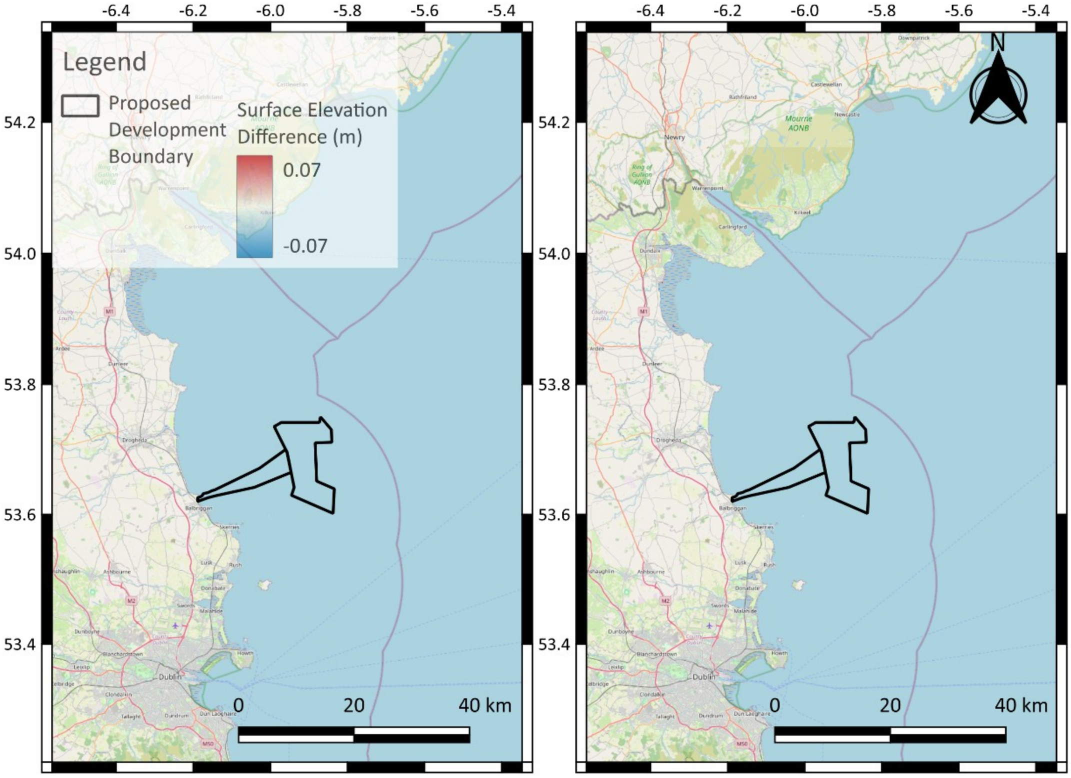

Figure 5.3: Difference in water surface elevation caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with.

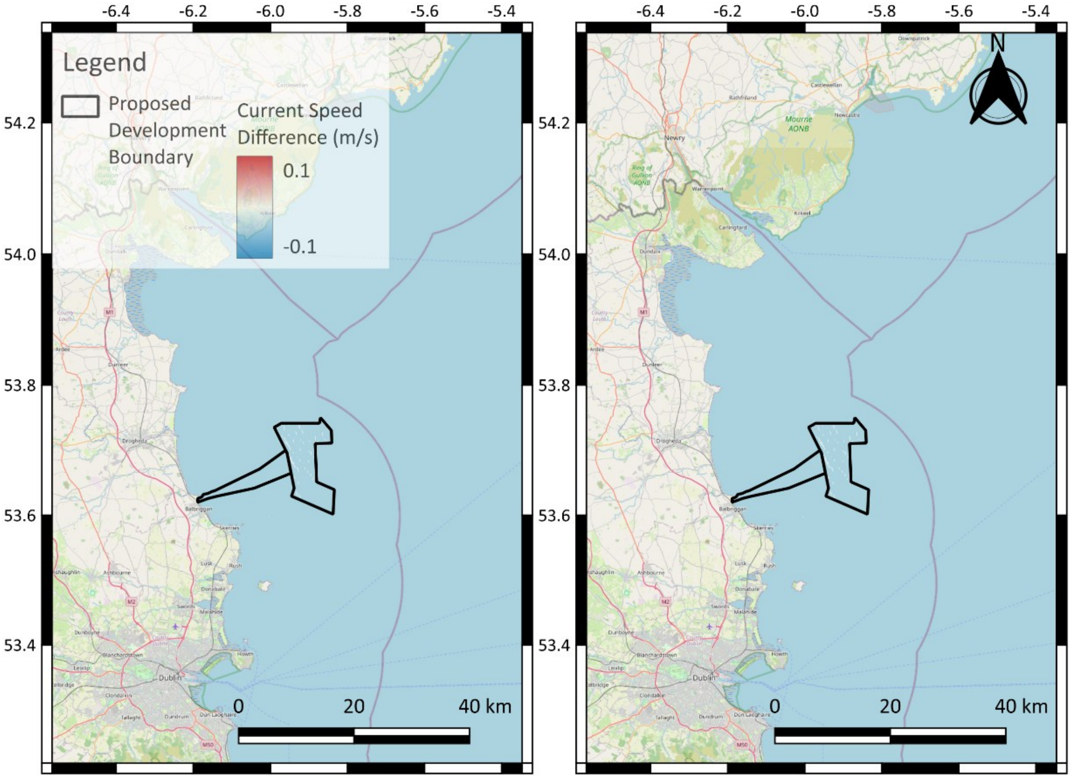

Figure 5.4: Difference in current speed caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with.

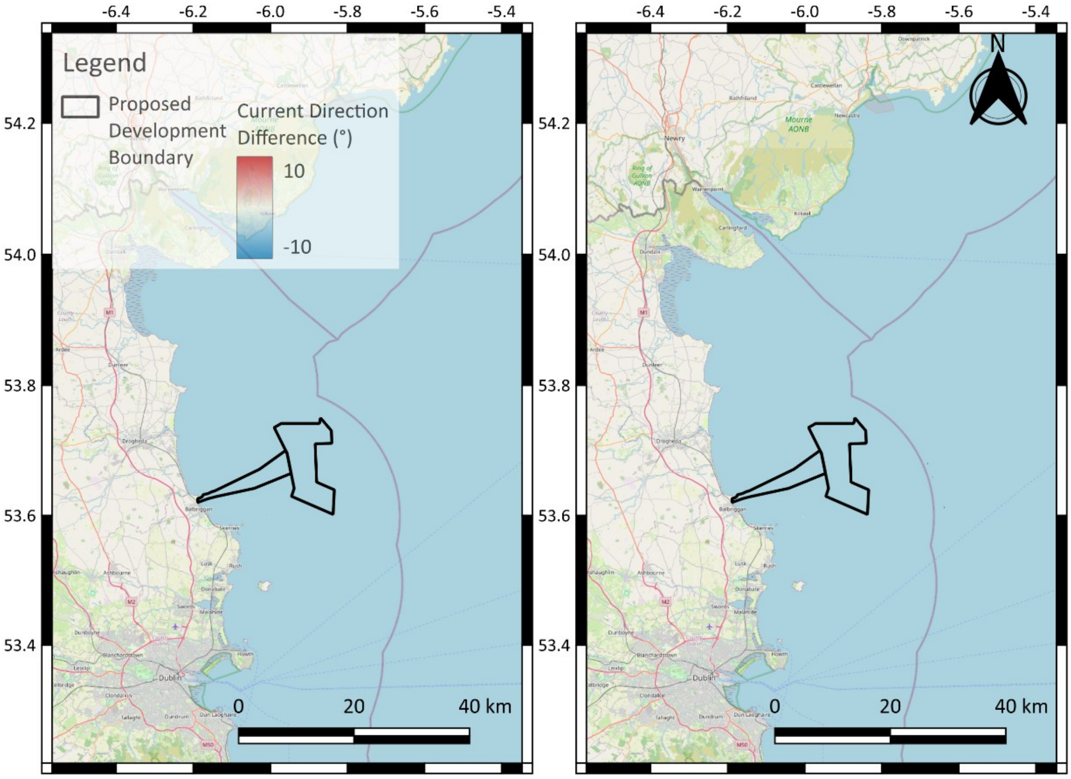

Figure 5.5: Difference in current direction caused by the wind farm during a high northerly current event. Left panel without climate change induced water level increase, right panel with.

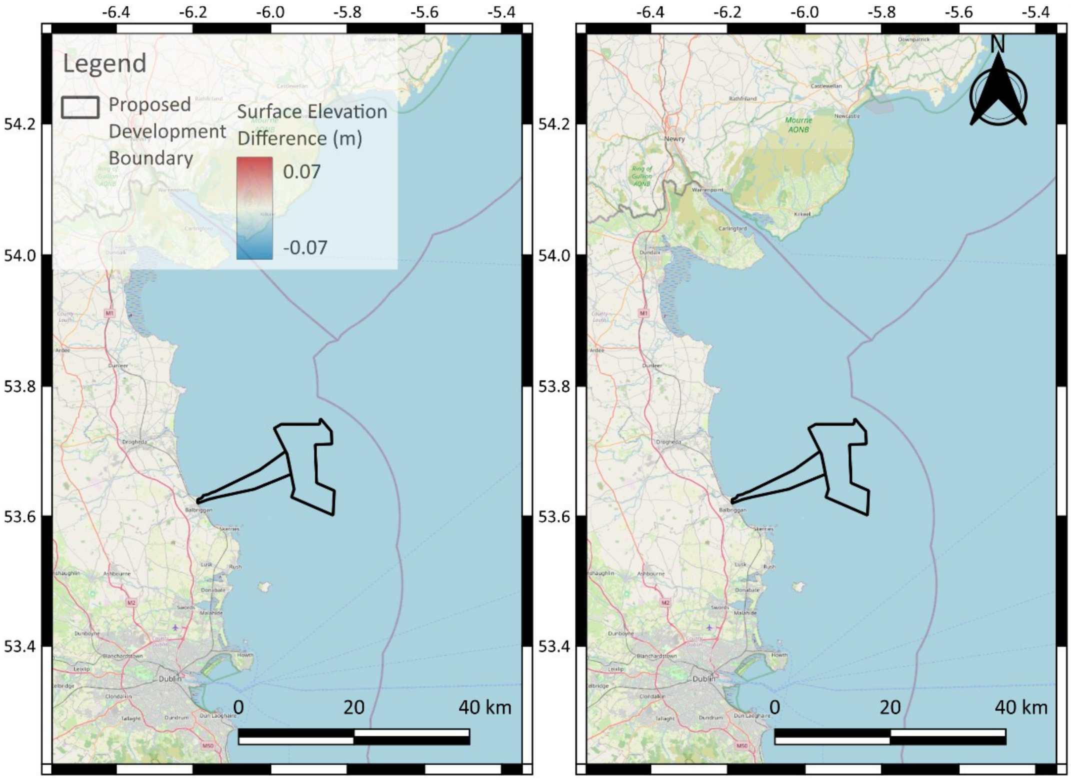

Figure 5.6: Difference in water surface elevation caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with.

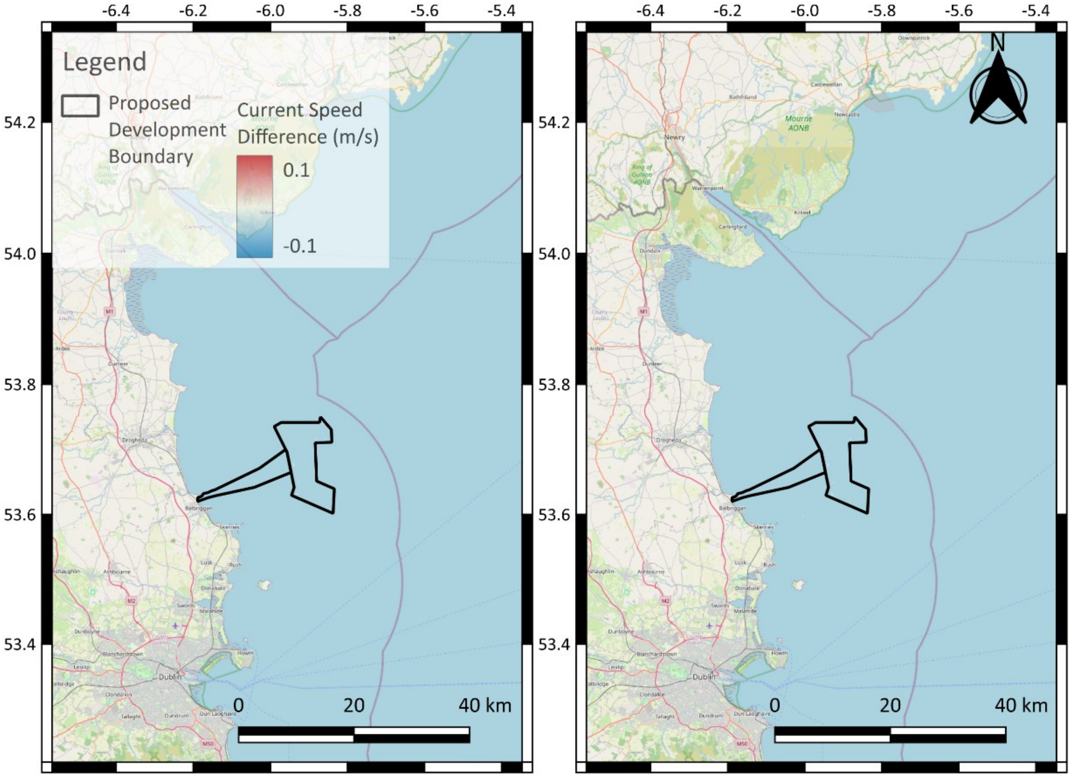

Figure 5.7: Difference in current speed caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with.

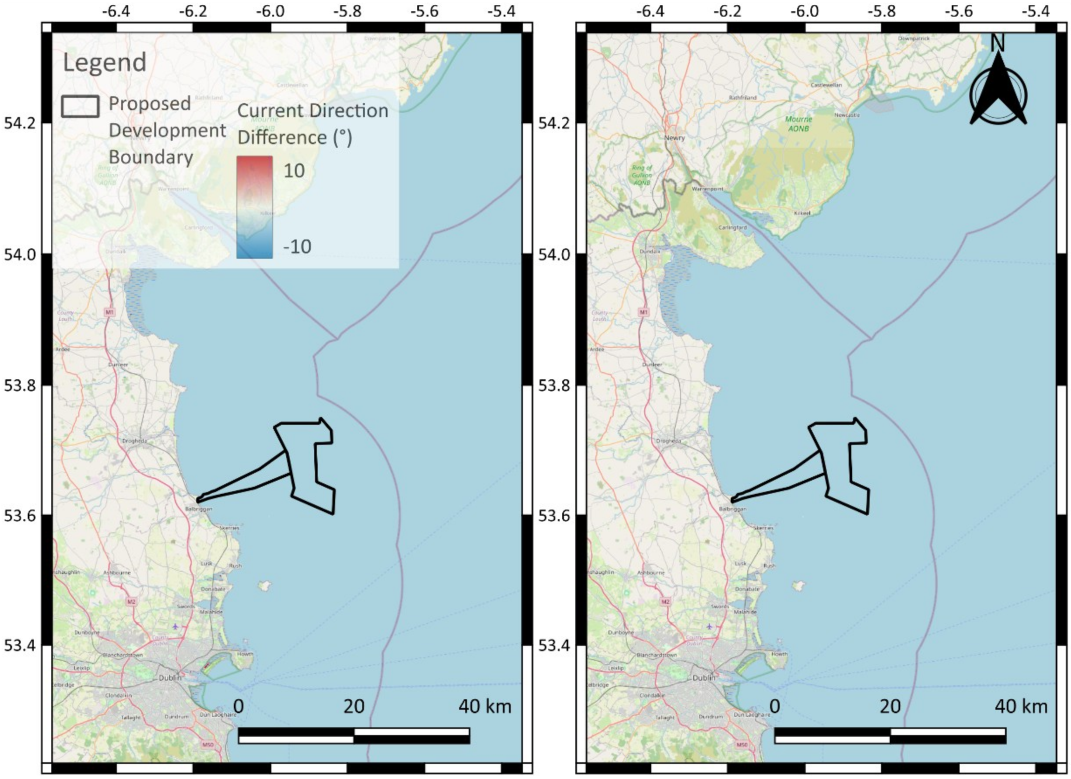

Figure 5.8: Difference in current direction caused by the wind farm during a high southerly current event. Left panel without climate change induced water level increase, right panel with.

Figure 5.3 to Figure 5.8 demonstrate that the differences in hydrodynamics caused by the wind farm are not appreciably affected by climate change, with all changes caused by climate change well within the measurement accuracy of typical instrumentation (i.e., not physically measurable).

Similarly, the wave blockage model was then run for each scenario, but with the water level increased by 0.35 m in each case. These outcomes are then compared against the same results without the water level increase in Figure 5.9 to Figure 5.32.

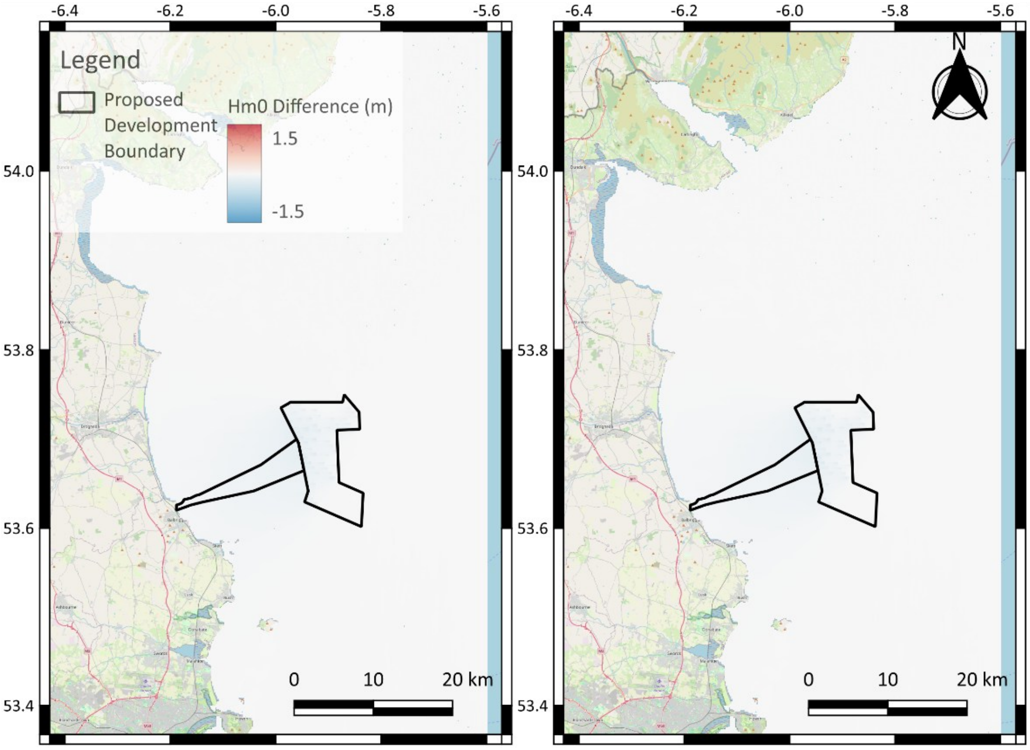

Figure 5.9: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

Figure 5.10: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

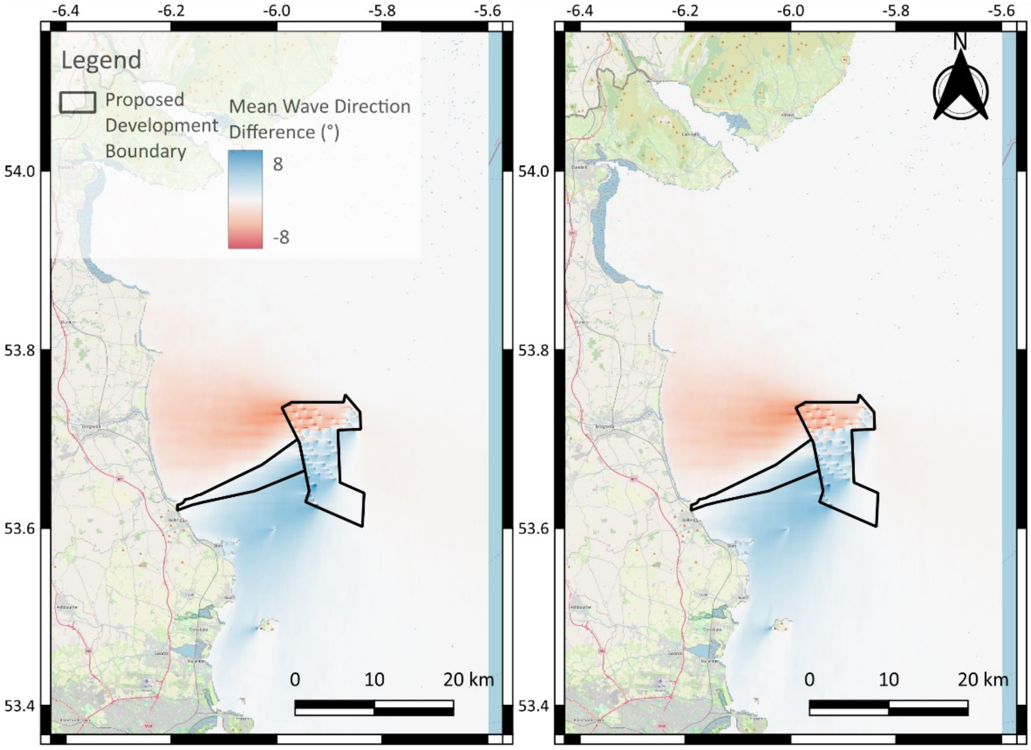

Figure 5.11: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

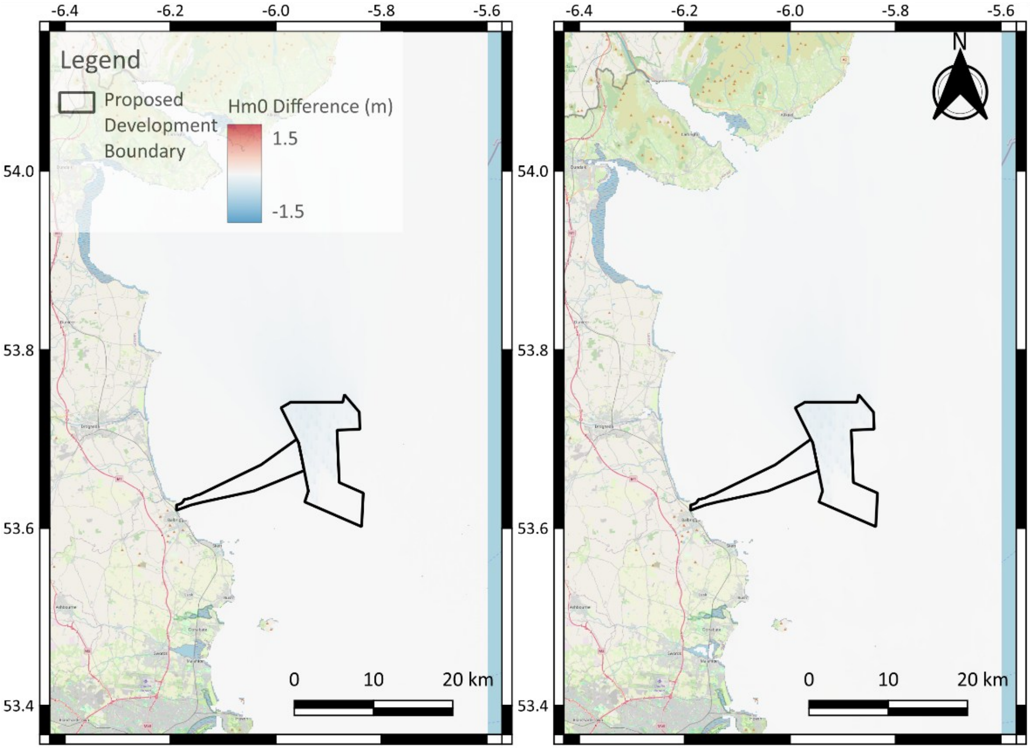

Figure 5.12: Predicted difference in significant wave height due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

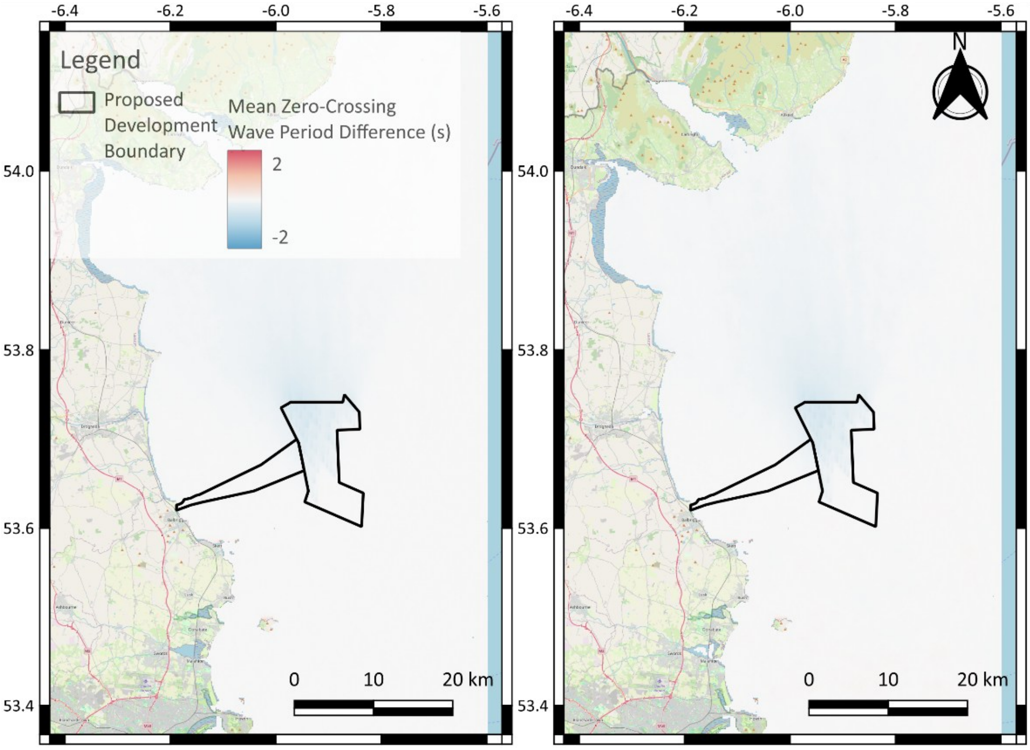

Figure 5.13: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

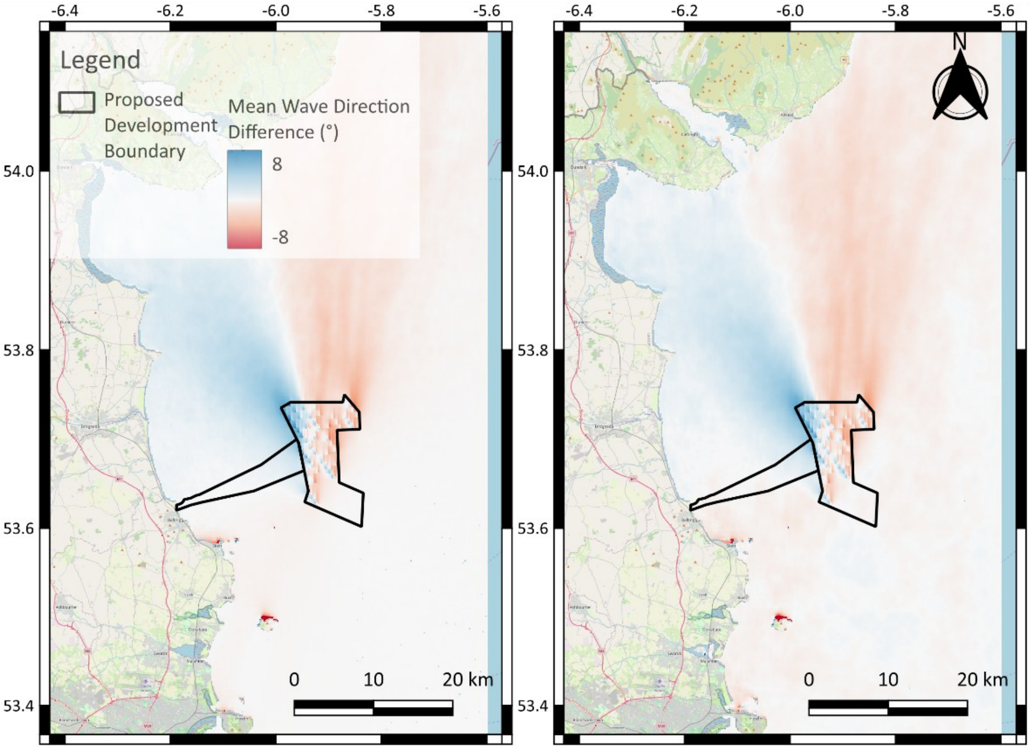

Figure 5.14: Predicted difference in mean wave direction due to the imposition of the proposed development during p50 waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

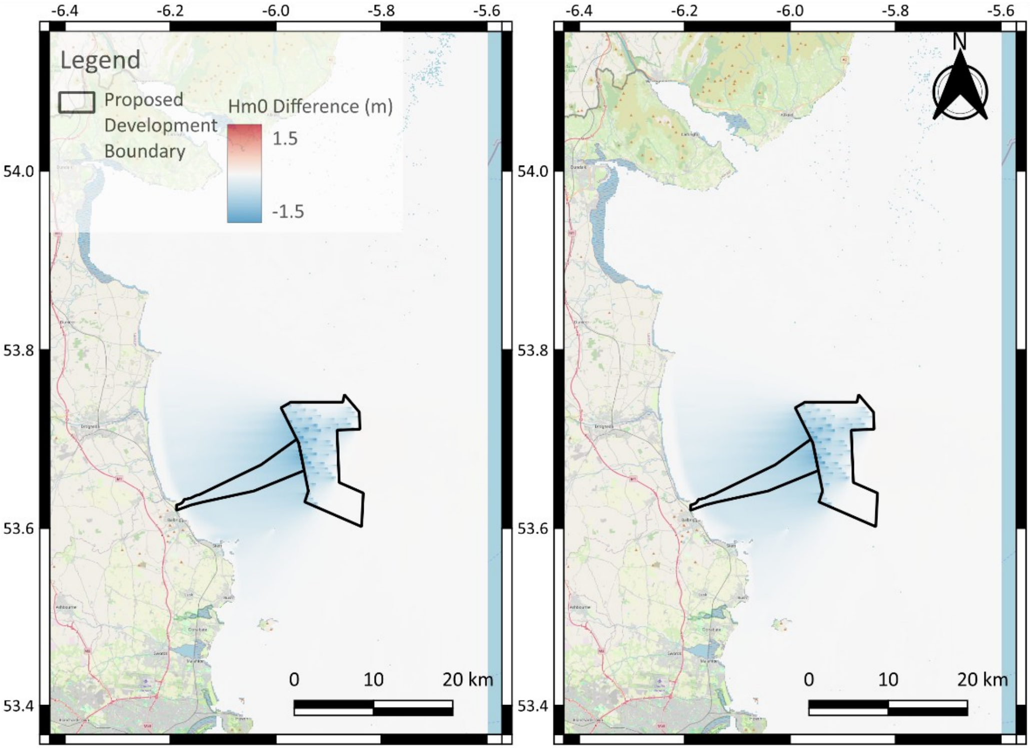

Figure 5.15: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

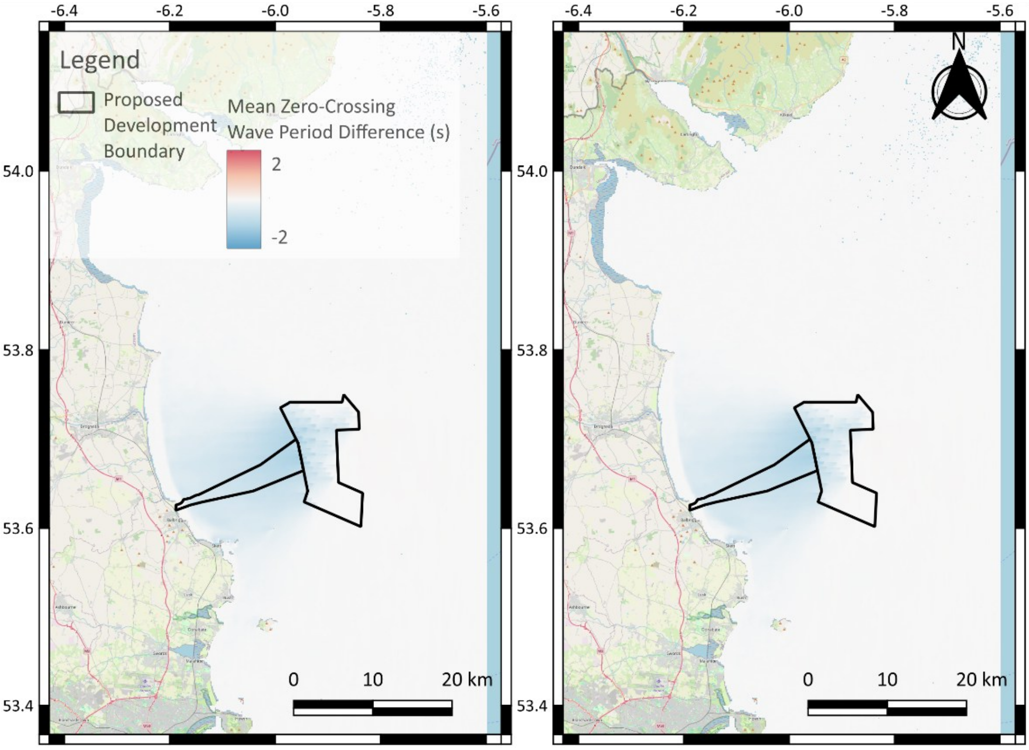

Figure 5.16: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

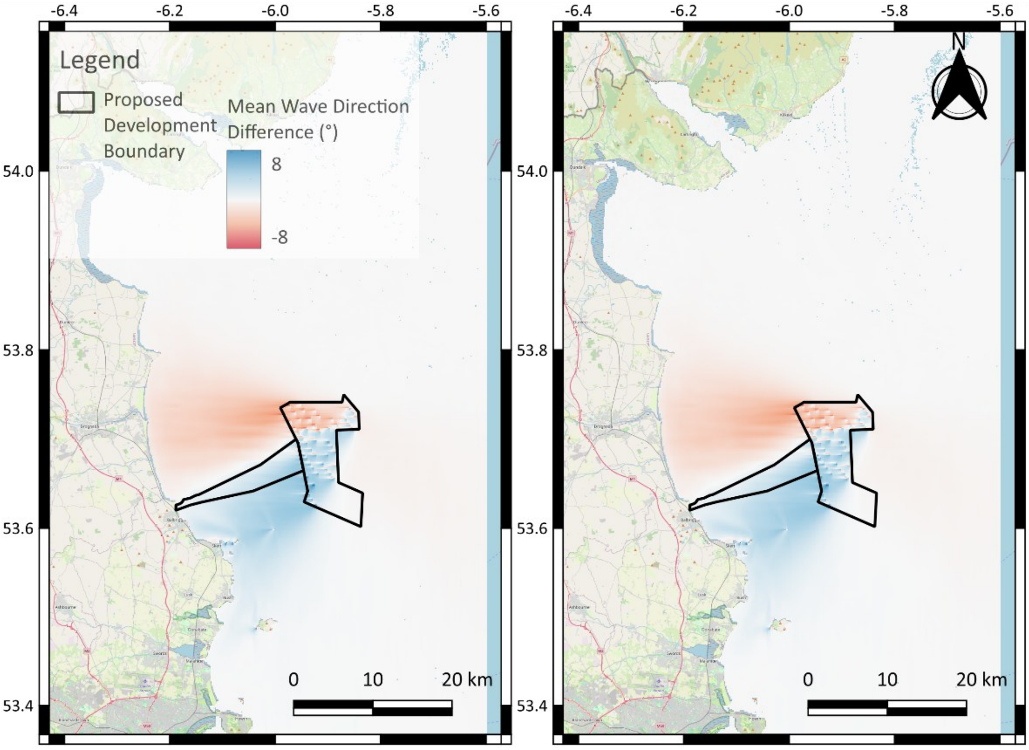

Figure 5.17: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

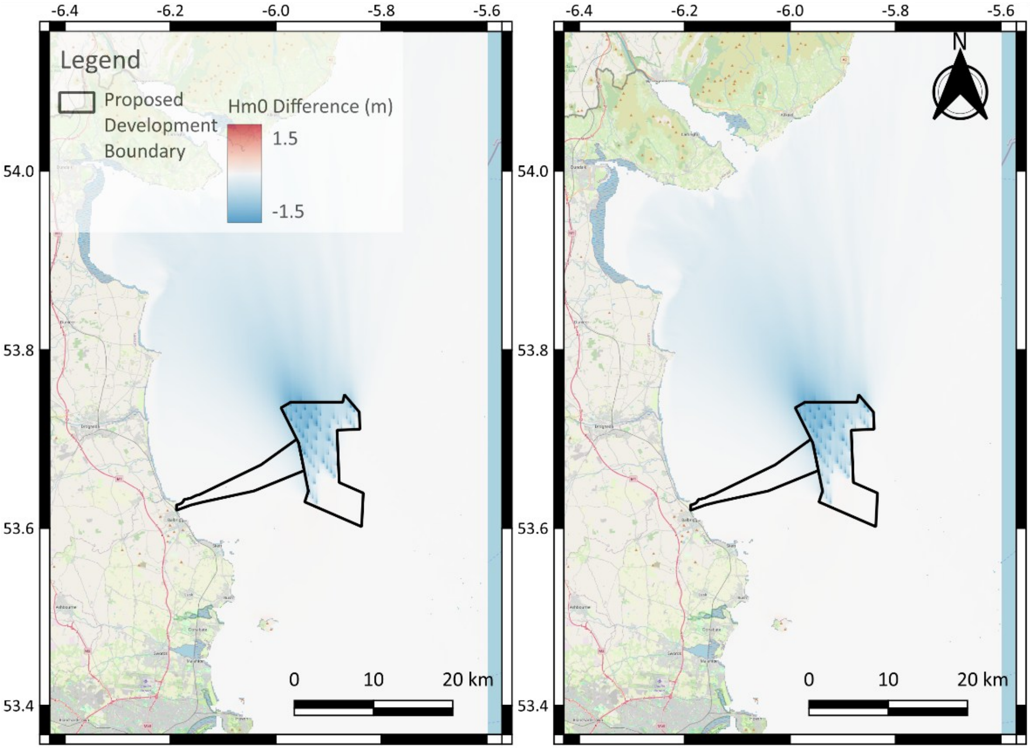

Figure 5.18: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

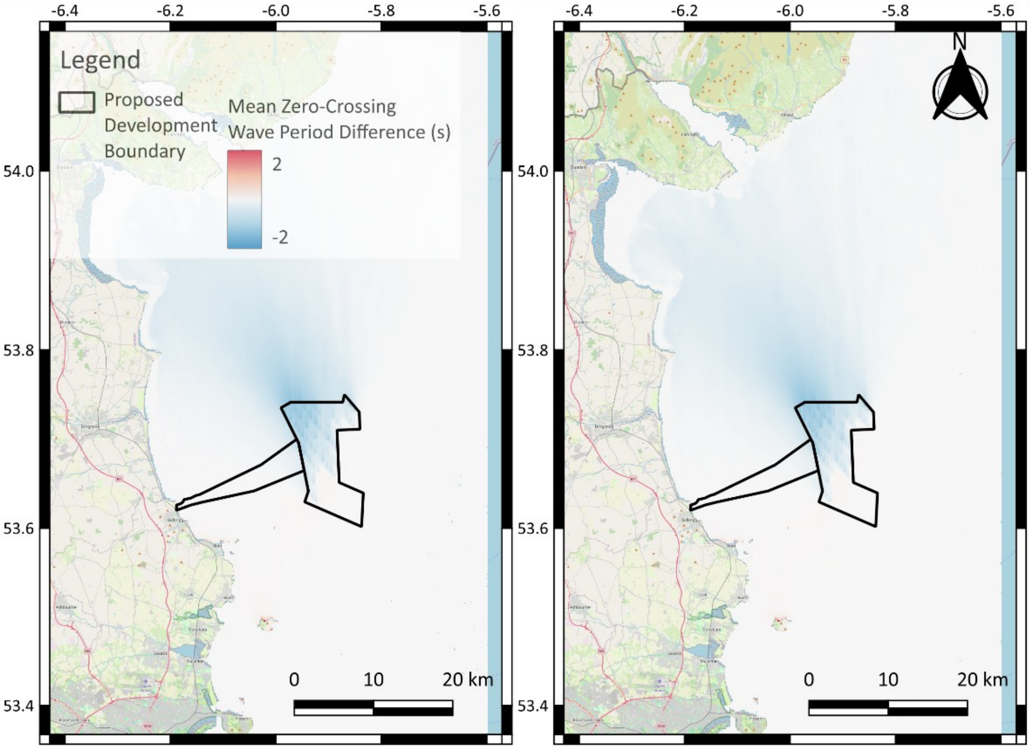

Figure 5.19: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

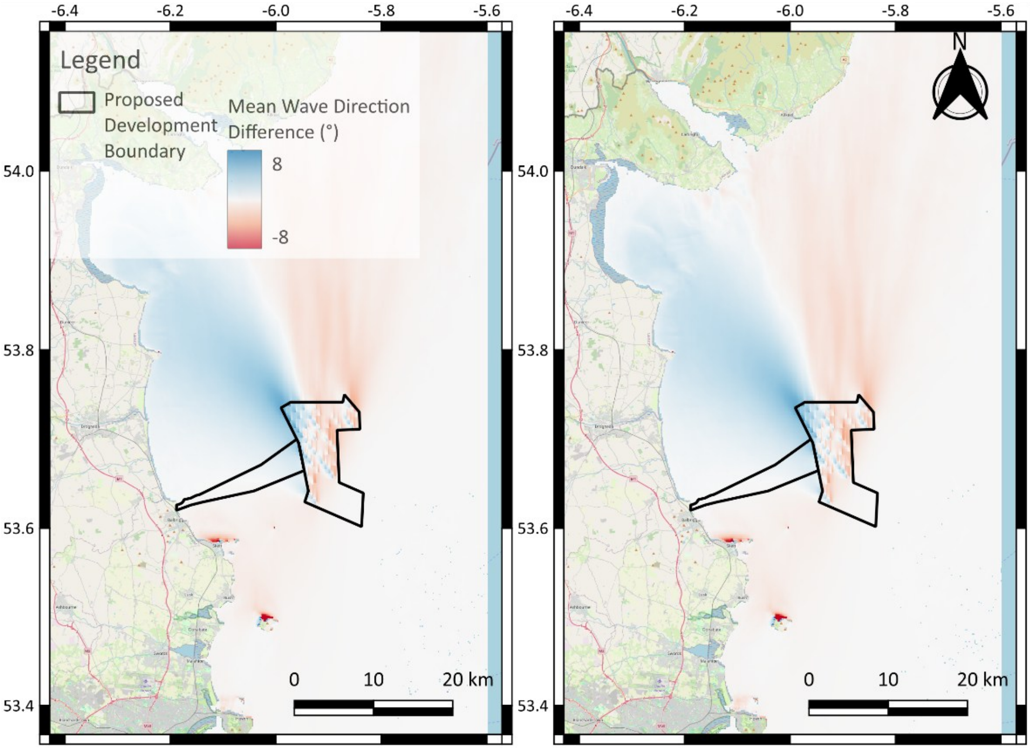

Figure 5.20: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 1 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

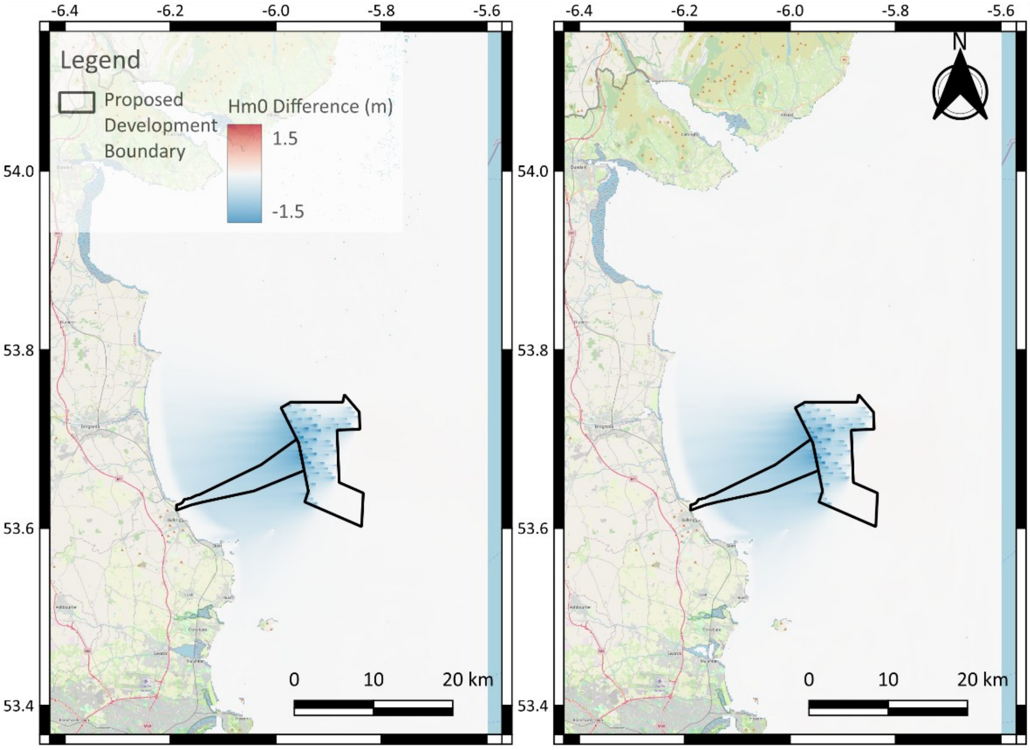

Figure 5.21: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

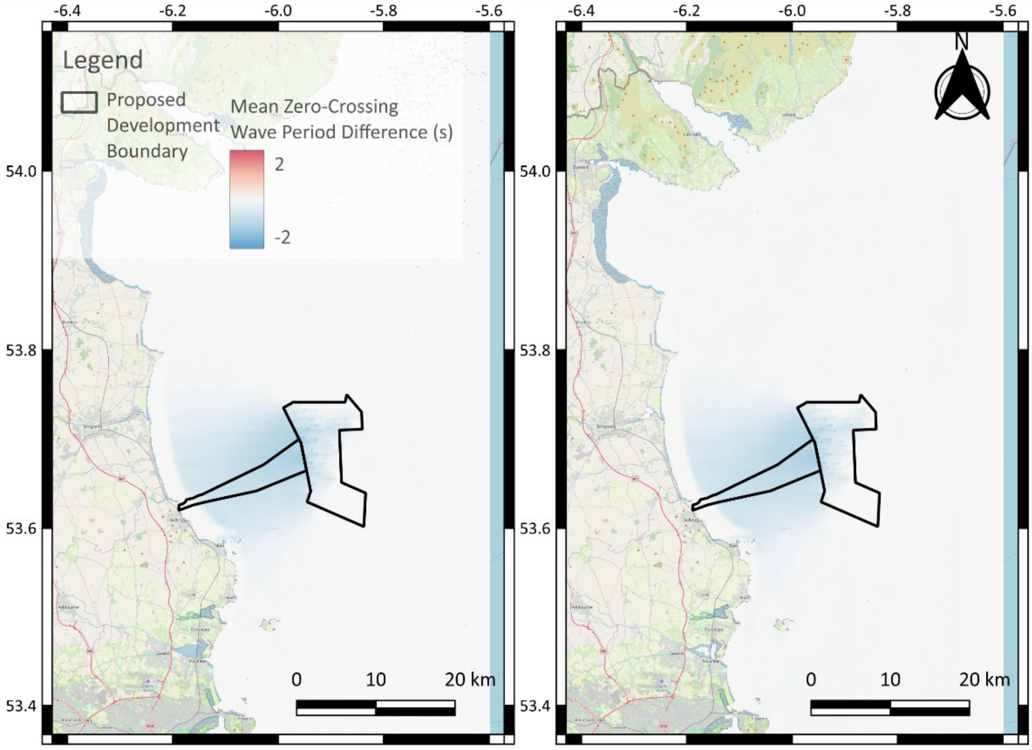

Figure 5.22: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

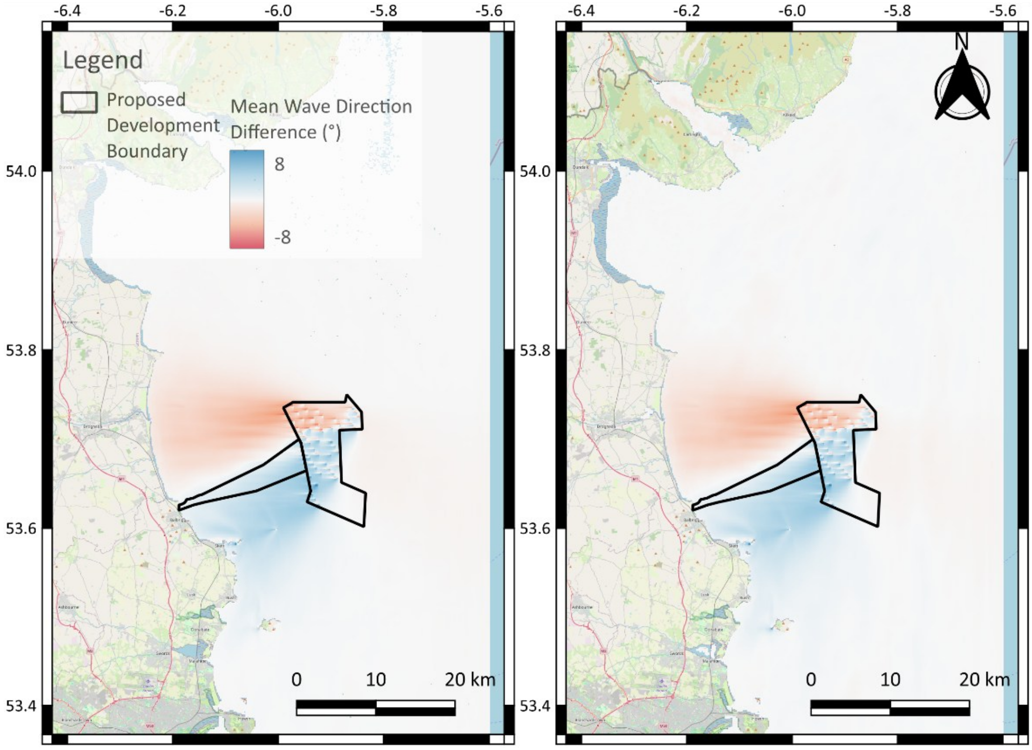

Figure 5.23: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

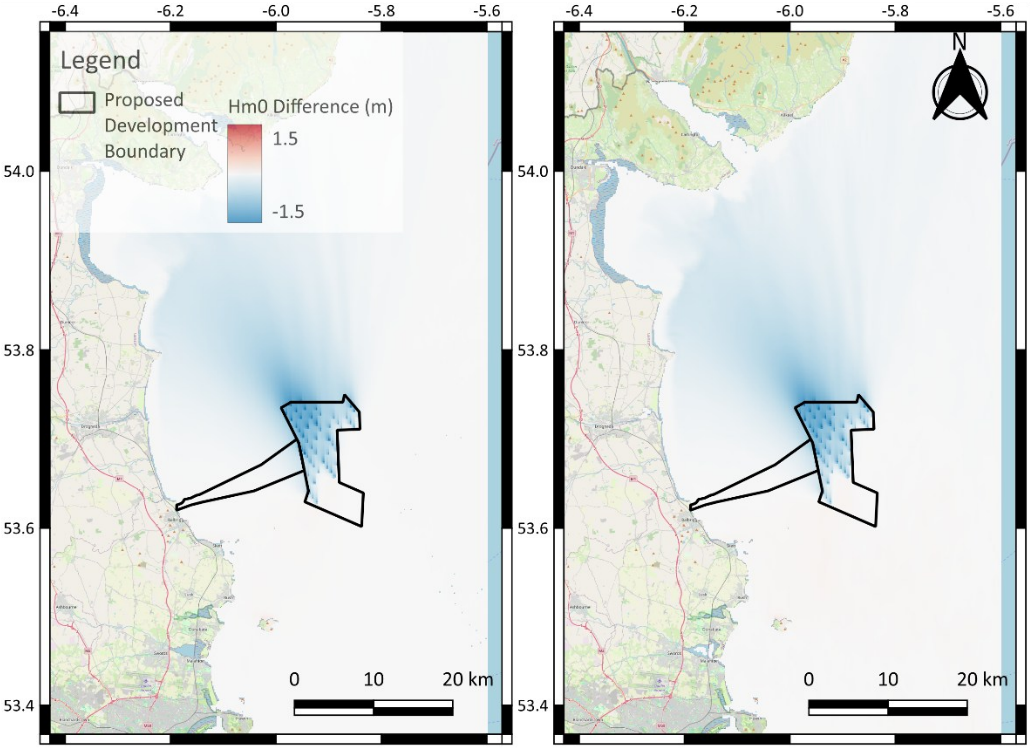

Figure 5.24: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

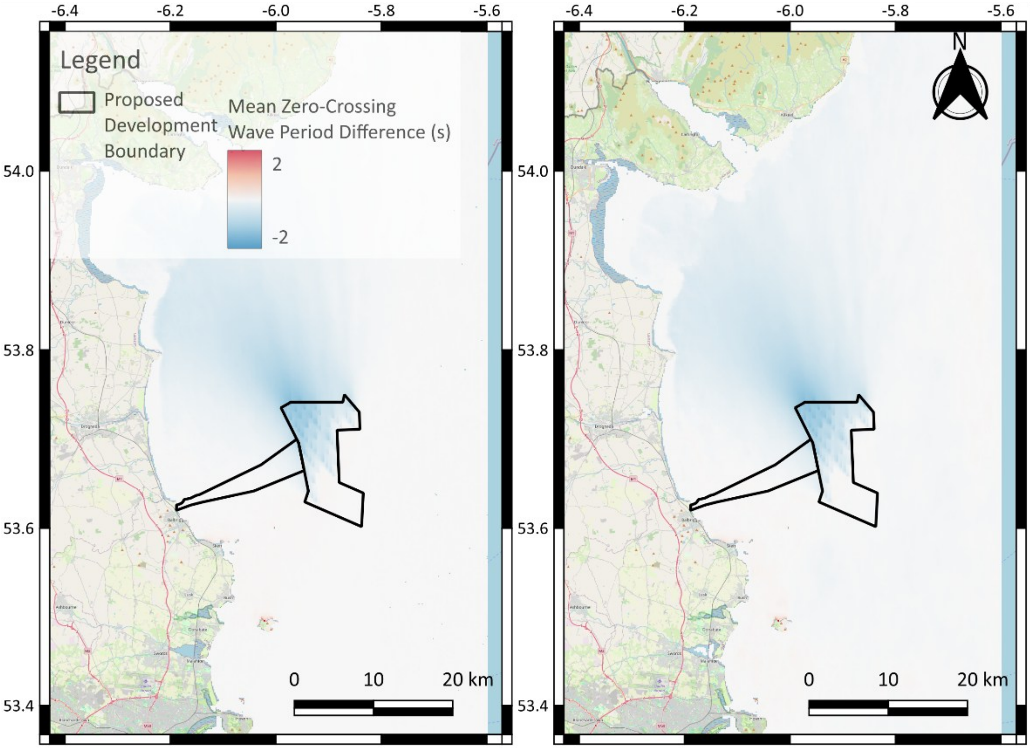

Figure 5.25: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

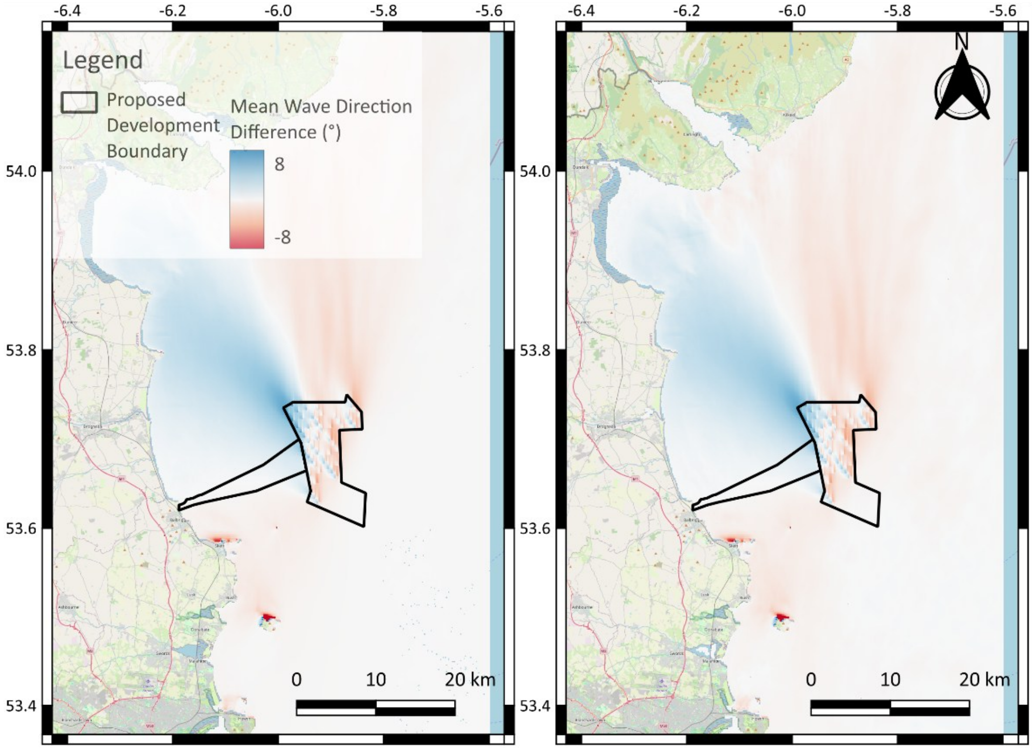

Figure 5.26: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 10 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

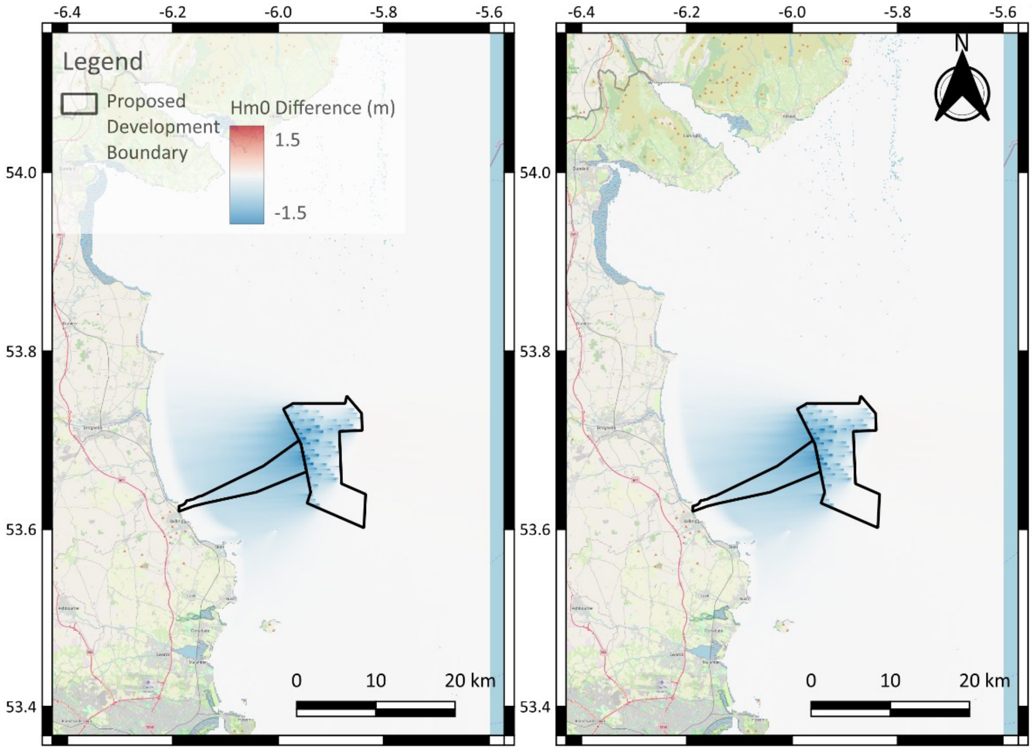

Figure 5.27: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

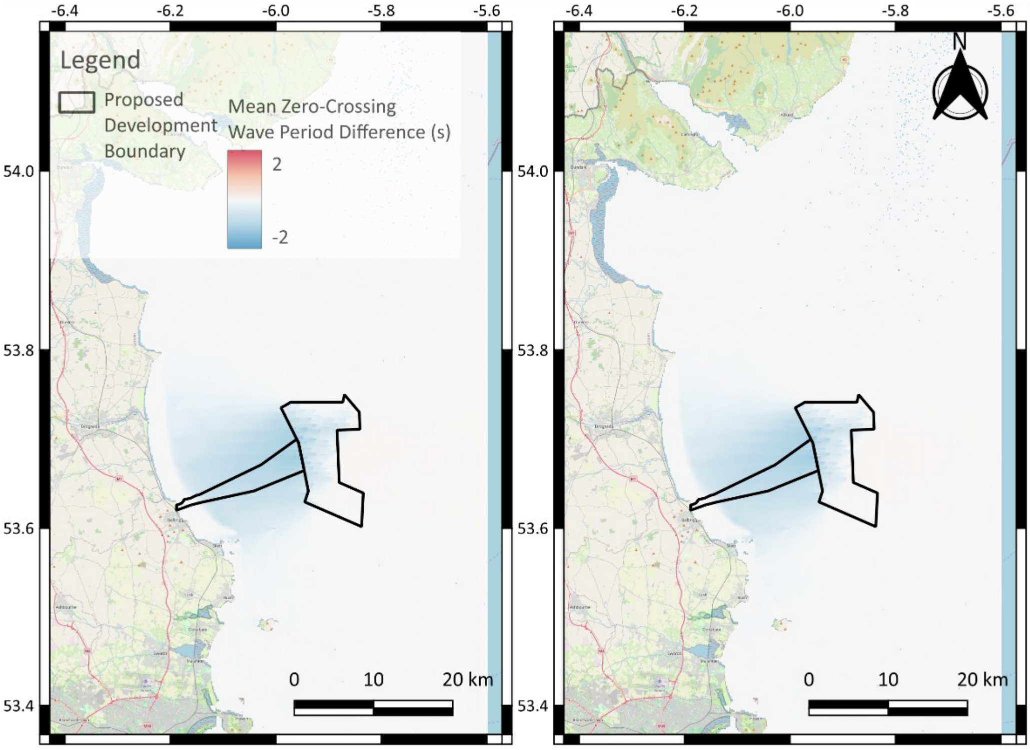

Figure 5.28: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

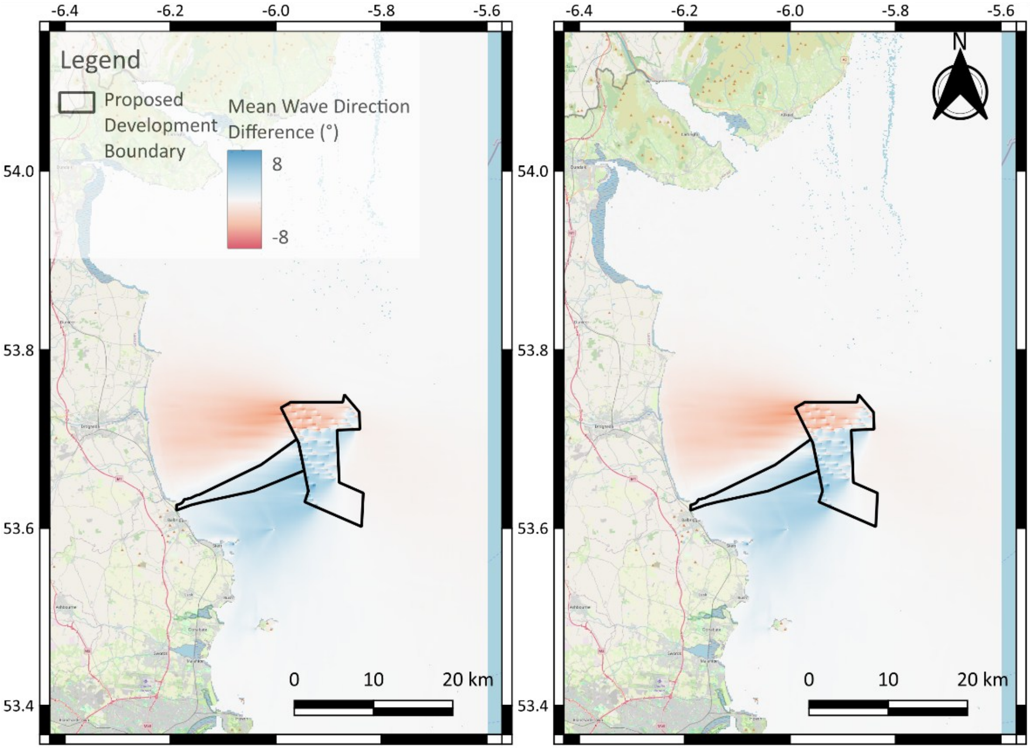

Figure 5.29: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 68°N. Right panel uses present day water level, left panel includes sea level rise.

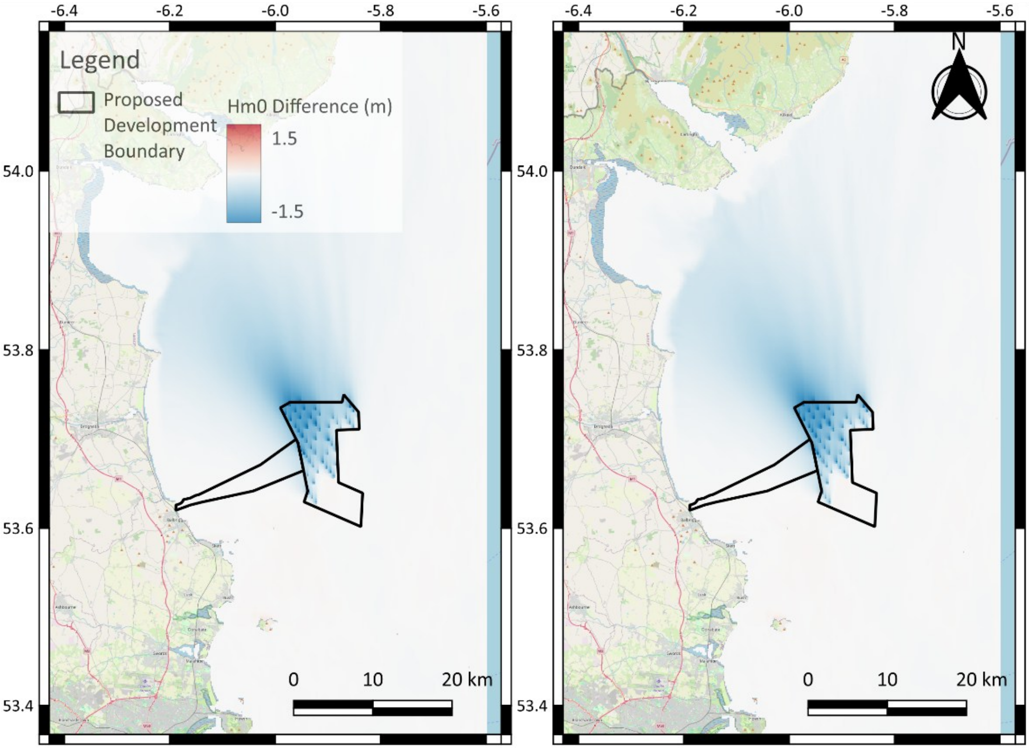

Figure 5.30: Predicted difference in significant wave height due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

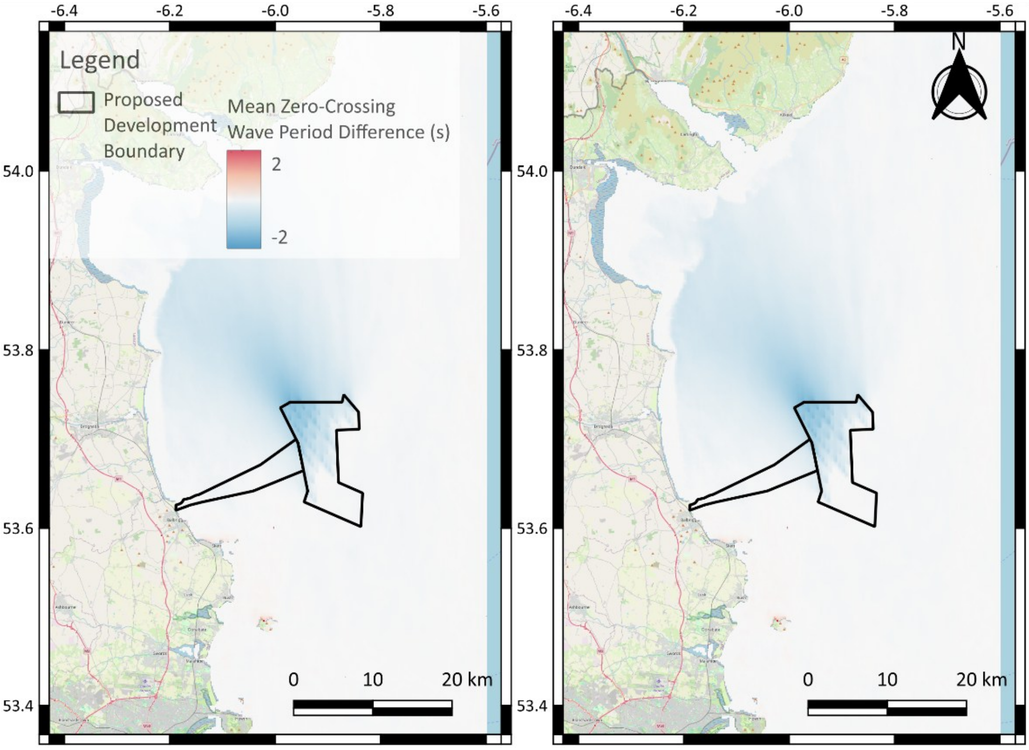

Figure 5.31: Predicted difference in mean zero-crossing wave period due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

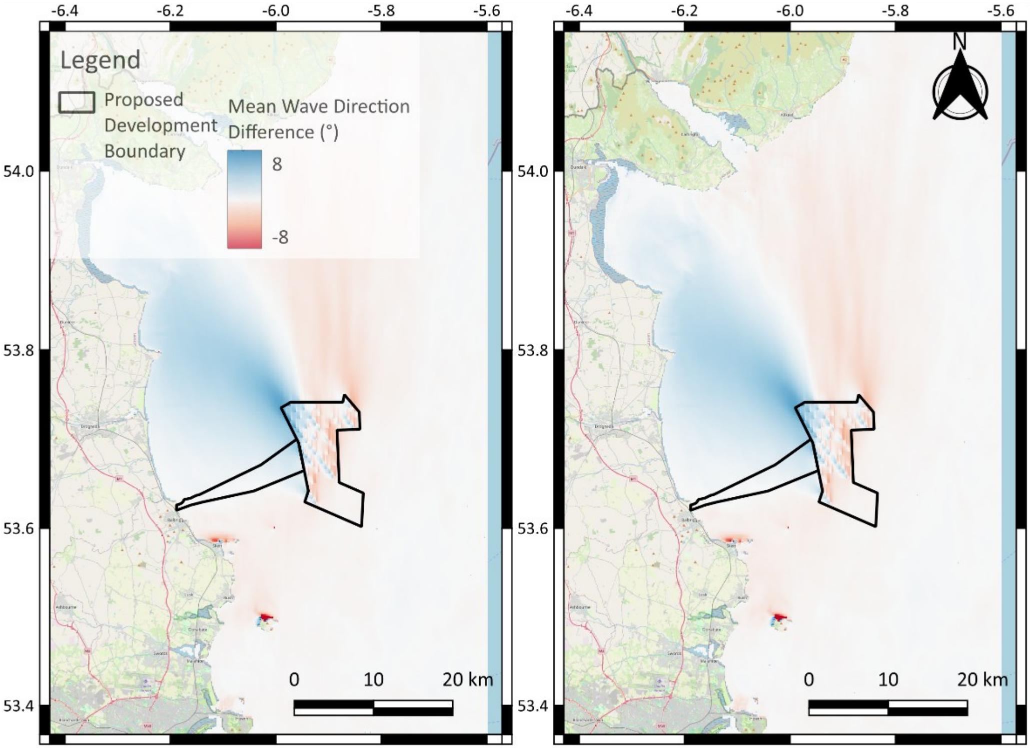

Figure 5.32: Predicted difference in mean wave direction due to the imposition of the proposed development during 1 in 50 year waves from 156°N. Right panel uses present day water level, left panel includes sea level rise.

The comparisons between the left and right panels of Figure 5.3 to Figure 5.32 demonstrate that climate change induced sea level rise will not exacerbate the impacts of the proposed development. In some cases, the impact of the proposed development will be marginally reduced by climate change induced sea level rise. Climate change is not typically considered in the modelling of marine physical processes for offshore wind developments owing to its negligible impacts on the results of the assessment.

6 Interdependency Between Marine Processes

In Appendix A10.2 of the 2024 EIAR, hydrodynamic processes (currents and water levels) and waves are treated separately. In common with well-established approaches and current industry guidance, the assertion is then made that if the processes that drive sediment transport (currents and waves) are not significantly changed, then sediment transport would also not be significantly changed. Also, in common with well-established approaches and current industry guidance, wind waking effects have not been assessed.

Nonetheless, RFI 7e states:

"The applicant is requested to characterise the existing environment in terms of the sediment transport regime in the form of coupled wave, wind, hydrodynamic and sediment transport modelling. As indicated in Appendix 10.2, the SWAN model was utilised for the assessment of waves and the MIKE21FM (Flexible Mesh) 2D modelling package was utilised for hydrodynamic modelling. The separation of the wave, hydrodynamics and wind influences does not allow for a comprehensive assessment of the impact of the proposed development on marine processes. The applicant is requested to submit a coupled model in order to demonstrate the interaction between waves, hydrodynamics and wind influences. The applicant is also requested to undertake a greater range of sensitivity runs to examine the coupled model performance. Model scenarios should include an assessment of extreme events e.g. 10%, 5%, 2%, 1%, 0.5%, 0.2% annual exceedance probability (AEP) events and joint probability occurrences of tidal, surge and wave conditions. The applicant is requested to assess these probabilities in modelling scenarios and provide for climate change."

Moreover, RFI 7k states:

"The applicant is requested to use coupled modelling of the leeward environments between the proposed array and the coastal zone to assess the combined impact of tidal, wind and wave blockage."

As discussed in Section 3, the effect of wind blocking on wave processes is negligible. Therefore, the effect of the wind blocking on hydrodynamics is also negligible (since surface winds have only a very minor effect on hydrodynamic processes). Thus, we investigate the interdependency between hydrodynamics (currents) and waves herein. A fully-coupled MIKE21 model of waves and hydrodynamics was run for both scheme (including the proposed development) and baseline (without proposed development) cases, for each of the following scenarios:

Table 6.1: Coupled Modelling Scenarios.

Wave Severity	Wave Direction	Flow Condition
1 in 50	68	High Northerly
1 in 50	68	High Southerly
1 in 50	156	High Northerly
1 in 50	156	High Southerly

The effect of different current conditions (high northerly and southerly flows) on waves is examined in Section 6.1, before the effect of waves on different current conditions is examined in Section 6.2.

6.1 The effect of currents on waves

Figure 6.1 to Figure 6.8 show the difference in wave conditions caused by the imposition of the proposed development. In the left panel, the difference in wave conditions during a high current event where currents are flowing from the north are shown, whilst in the right panel, the difference in wave conditions during a high current event where currents are flowing from the south are shown.

In these figures, the images are scaled and coloured to allow the reader to compare the left and right panels, to ascertain whether the influence of currents makes an appreciable difference to the results of the modelling of waves. For a detailed assessment of the modelling of the impact of the proposed development on the wave environment, please see Section 10.5 of Chapter 10 of the EIAR [10].

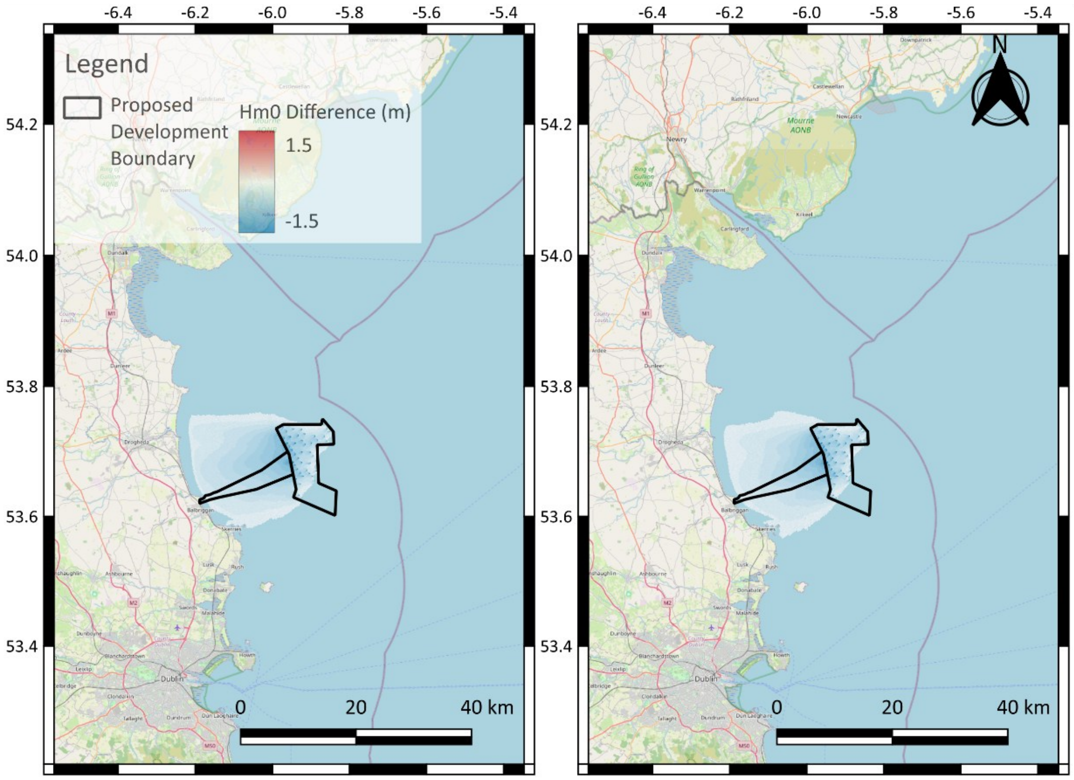

Figure 6.1: Proposed development induced difference in significant wave height during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents.

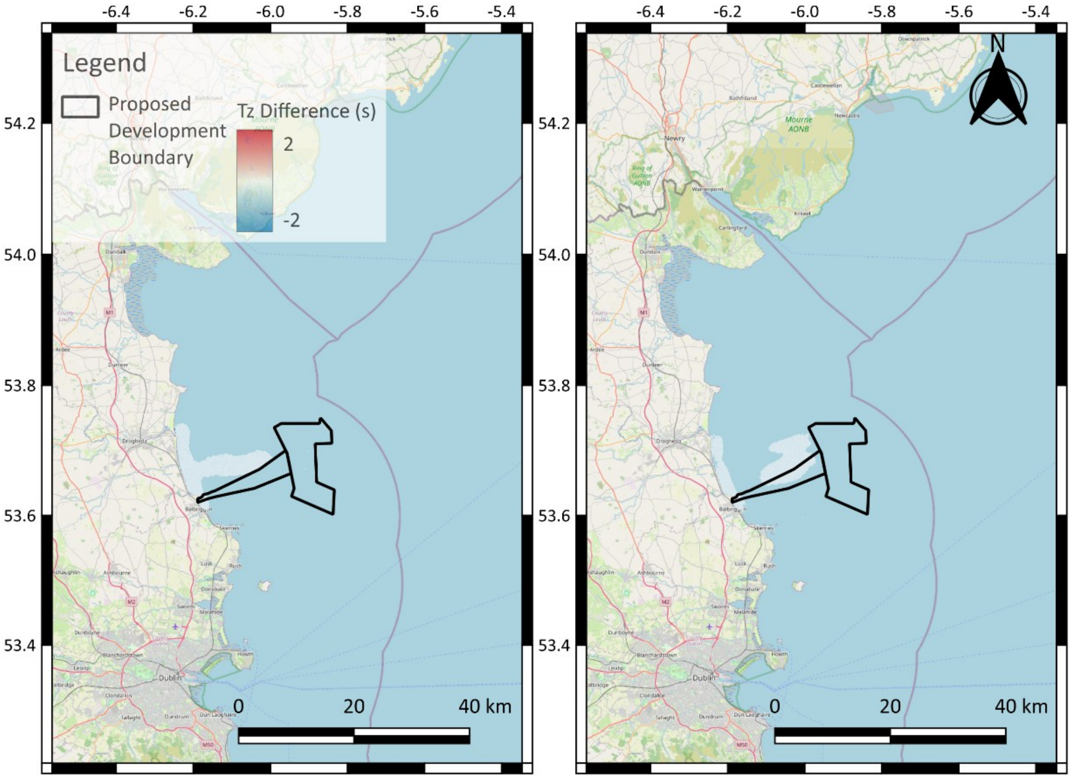

Figure 6.2: Proposed development induced difference in mean zero-crossing wave period during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents.

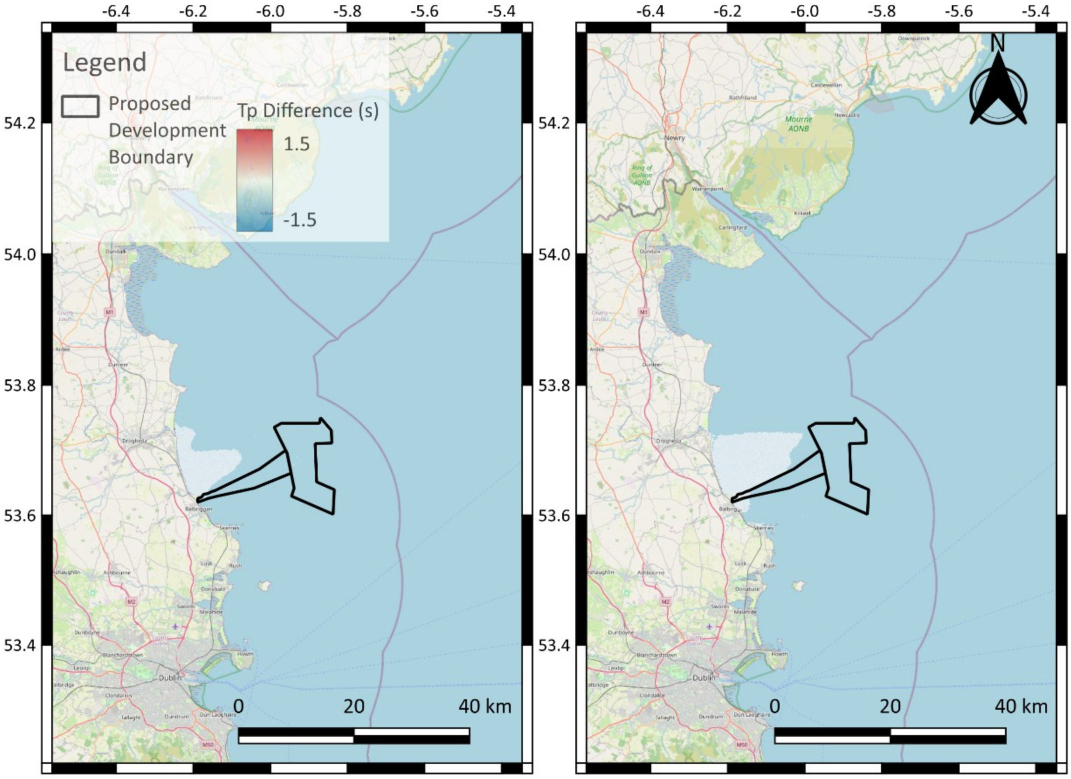

Figure 6.3: Proposed development induced difference in peak wave period during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents.

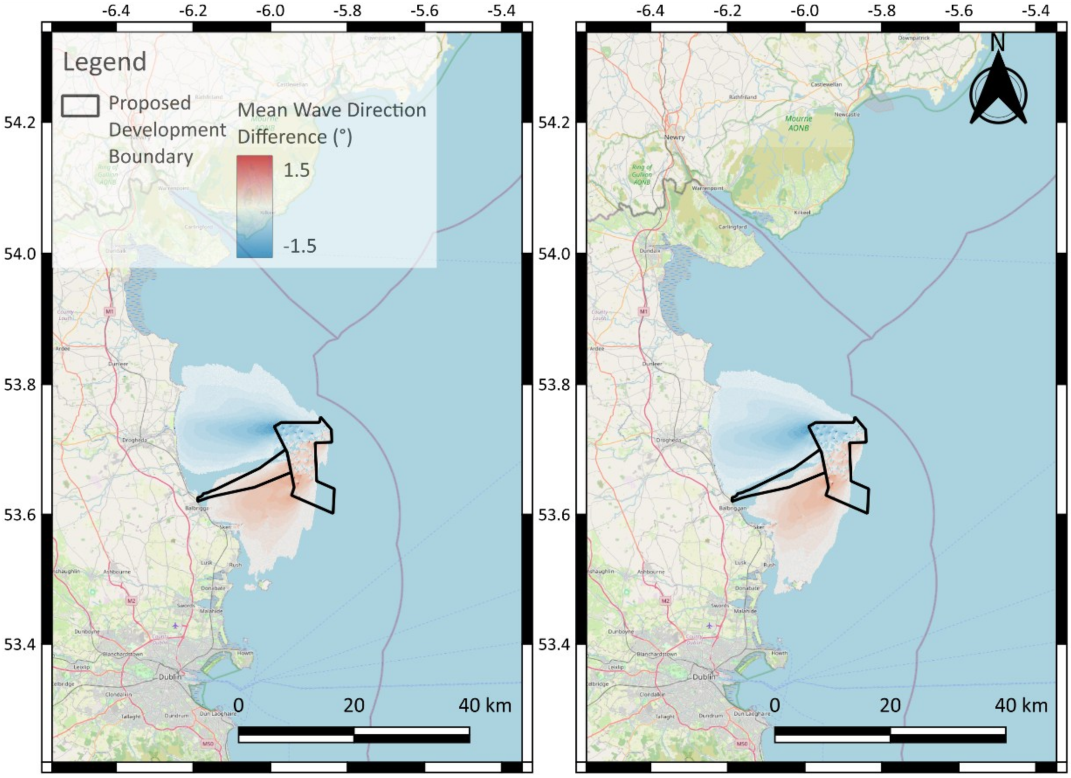

Figure 6.4: Proposed development induced difference in mean wave direction during 1 in 50 year storm waves from 68 degrees. Left panel high northerly currents, right panel high southerly currents.

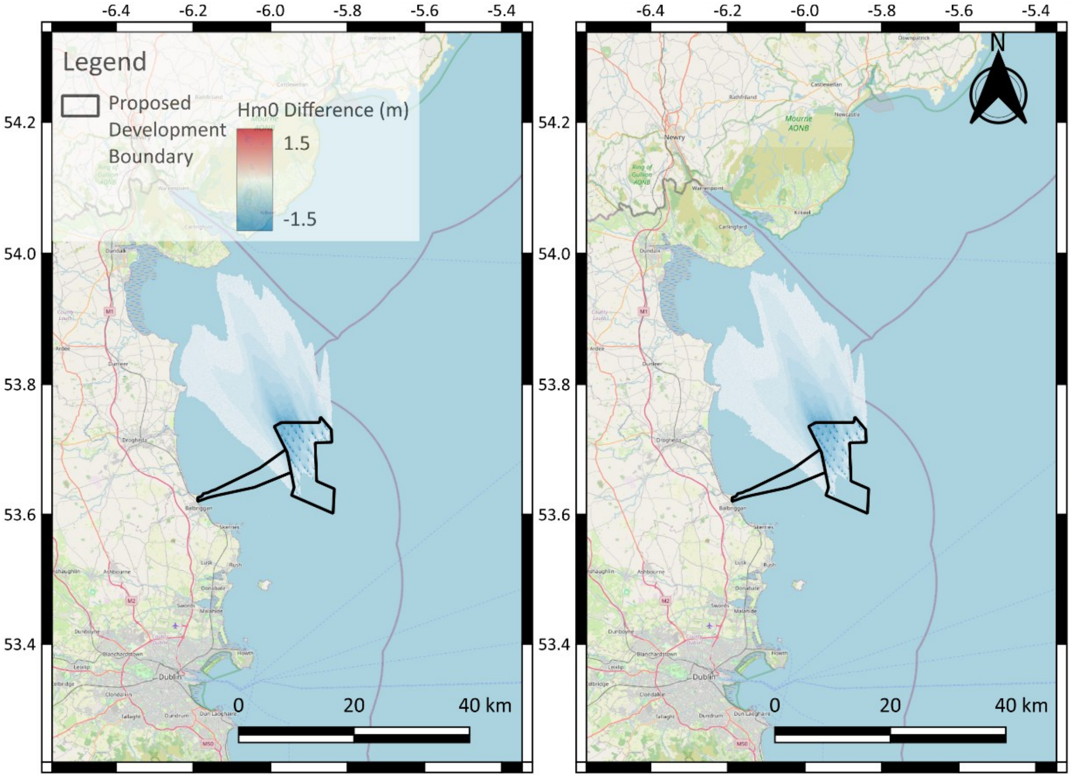

Figure 6.5: Proposed development induced difference in significant wave height during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents.

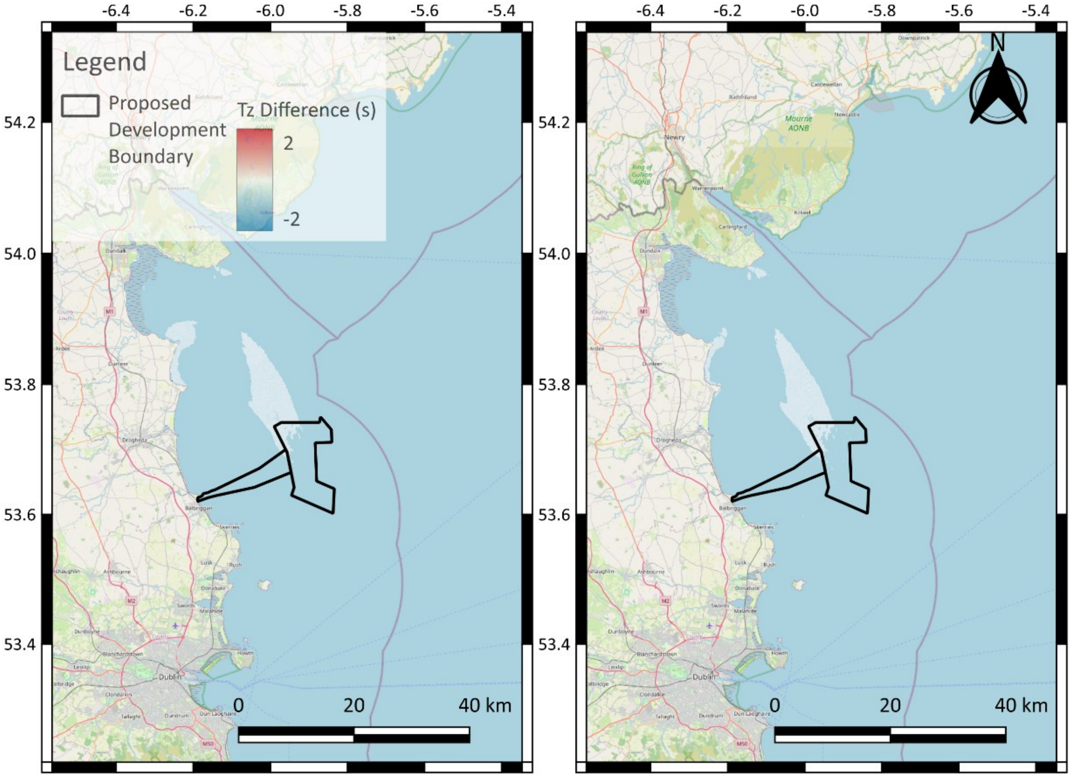

Figure 6.6: Proposed development induced difference in mean zero-crossing wave period during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents.

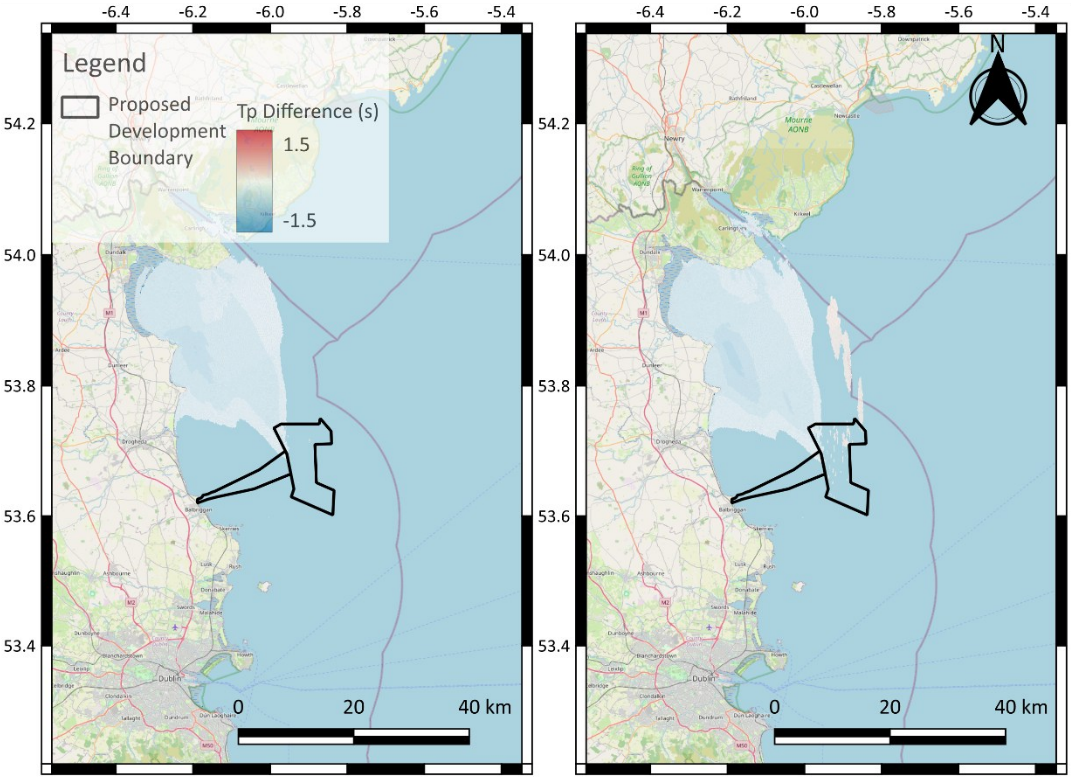

Figure 6.7: Proposed development induced difference in peak wave period during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents.

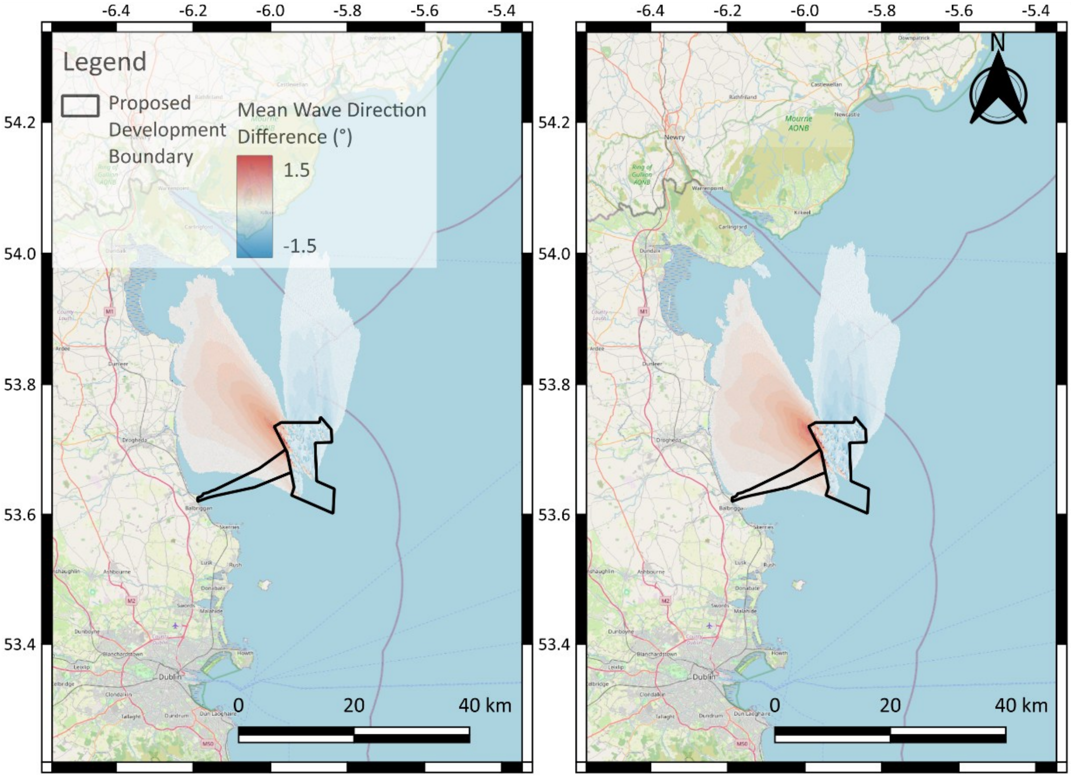

Figure 6.8: Proposed development induced difference in mean wave direction during 1 in 50 year storm waves from 156 degrees. Left panel high northerly currents, right panel high southerly currents.

In each image, the differences between the left and right panels are negligible, indicating that the effect of currents on wave differences is minimal.

6.2 The effect of waves on hydrodynamics

Figure 6.9 to Figure 6.14 show the difference in hydrodynamic (water surface elevation, current speed and current direction) conditions caused by the imposition of the proposed development, during a high current event (either northward or southward flowing). In the left panel, the difference in hydrodynamic conditions during 1 in 50 year storm waves from 68°N is shown, whilst in the right panel, the difference in hydrodynamic conditions during 1 in 50 year storm waves from 156°N is shown.

In these figures, the images are scaled and coloured to allow the reader to compare the left and right panels, to ascertain whether the influence of waves makes an appreciable difference to the results of the modelling of hydrodynamics. For a detailed assessment of the modelling of the impact of the proposed development on the hydrodynamic environment, please see Section 10.5 of Chapter 10 of the EIAR [10].

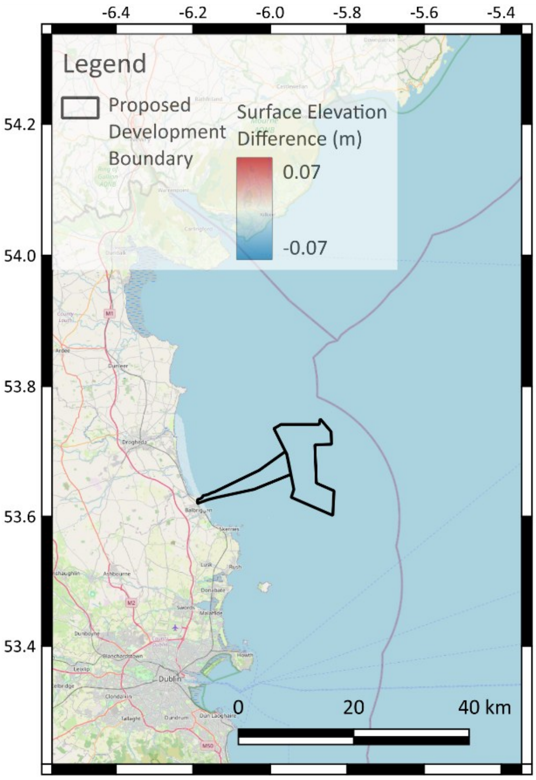

Figure 6.9: Proposed development induced difference in surface elevation during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

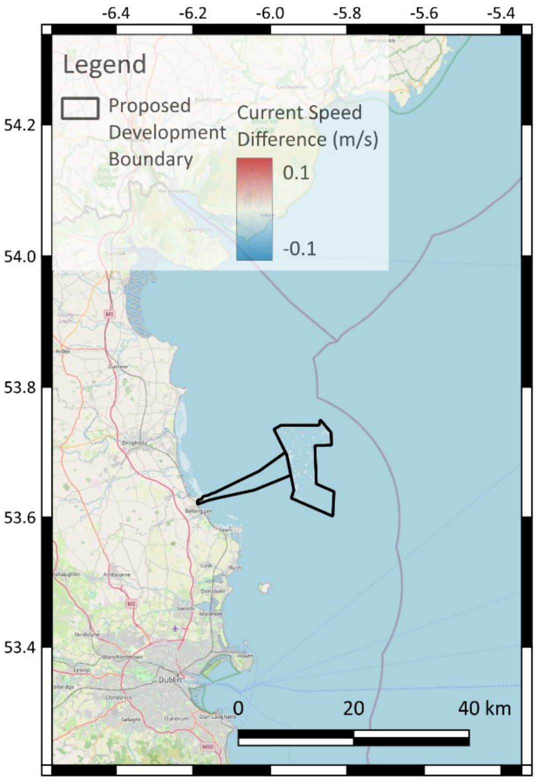

Figure 6.10: Proposed development induced difference in current speed during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

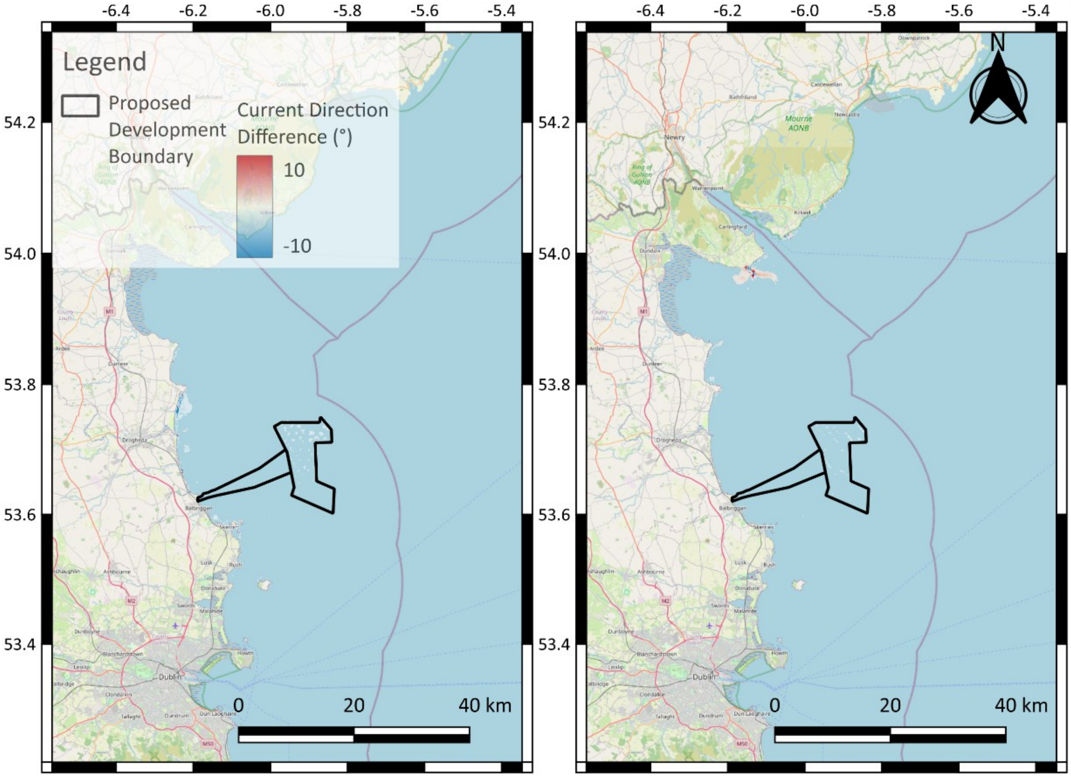

Figure 6.11: Proposed development induced difference in current direction during high northerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

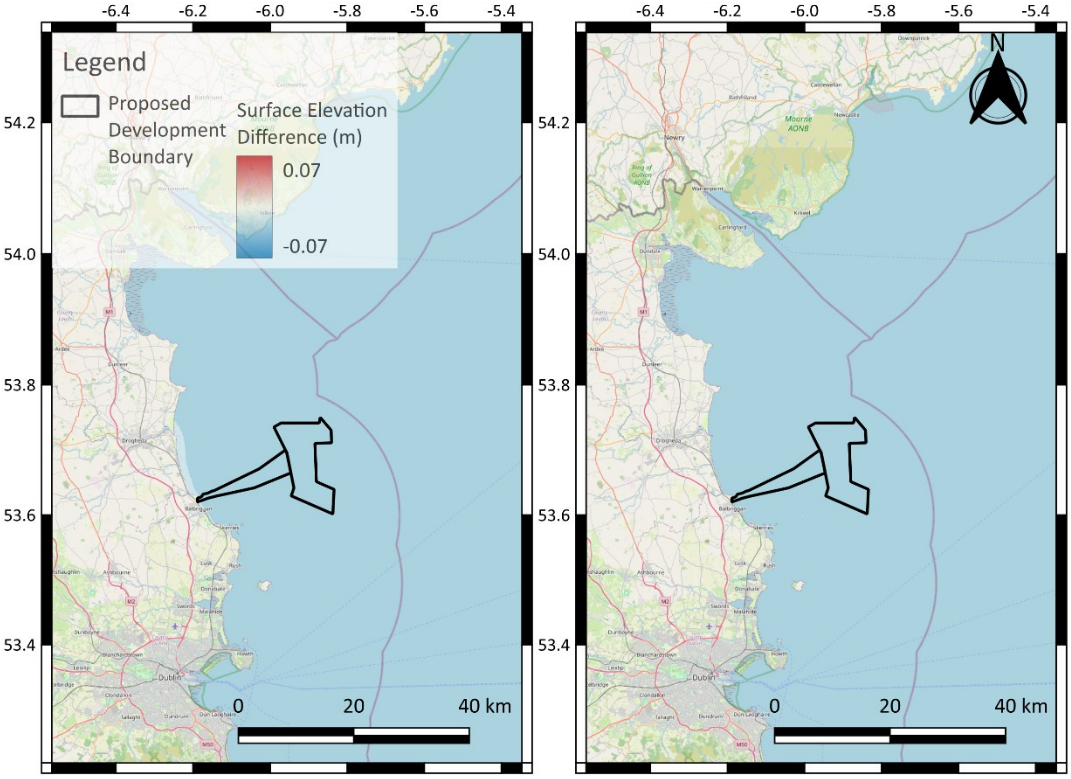

Figure 6.12: Proposed development induced difference in surface elevation during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

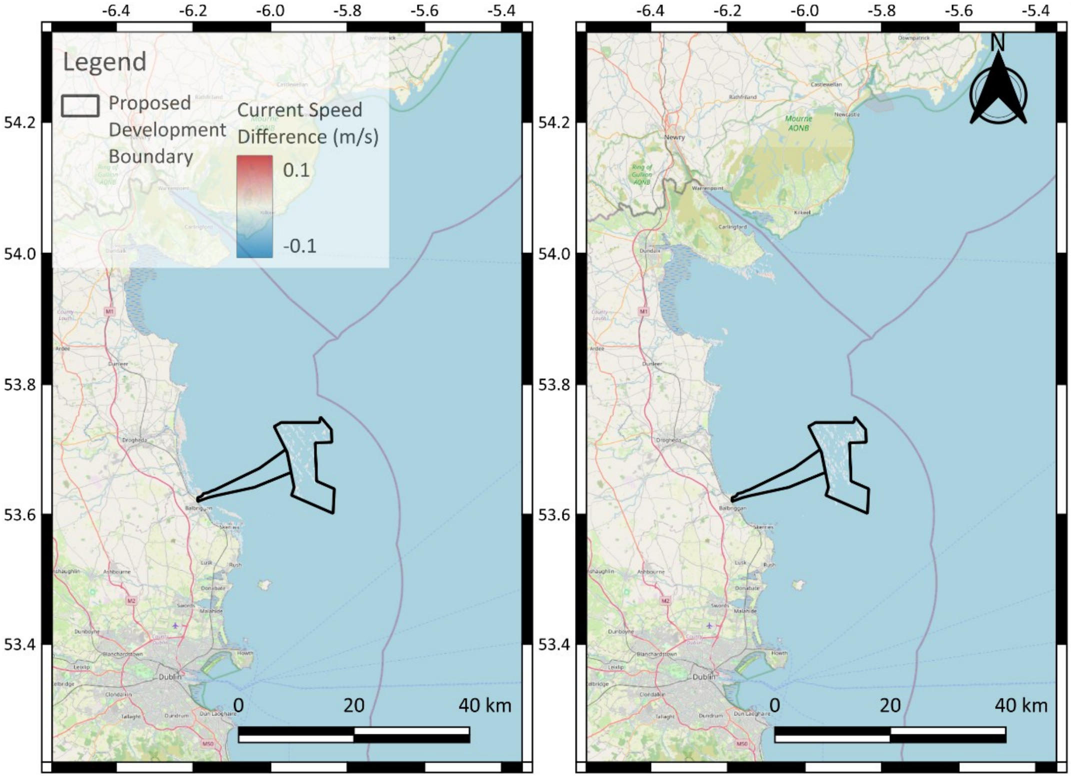

Figure 6.13: Proposed development induced difference in current speed during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

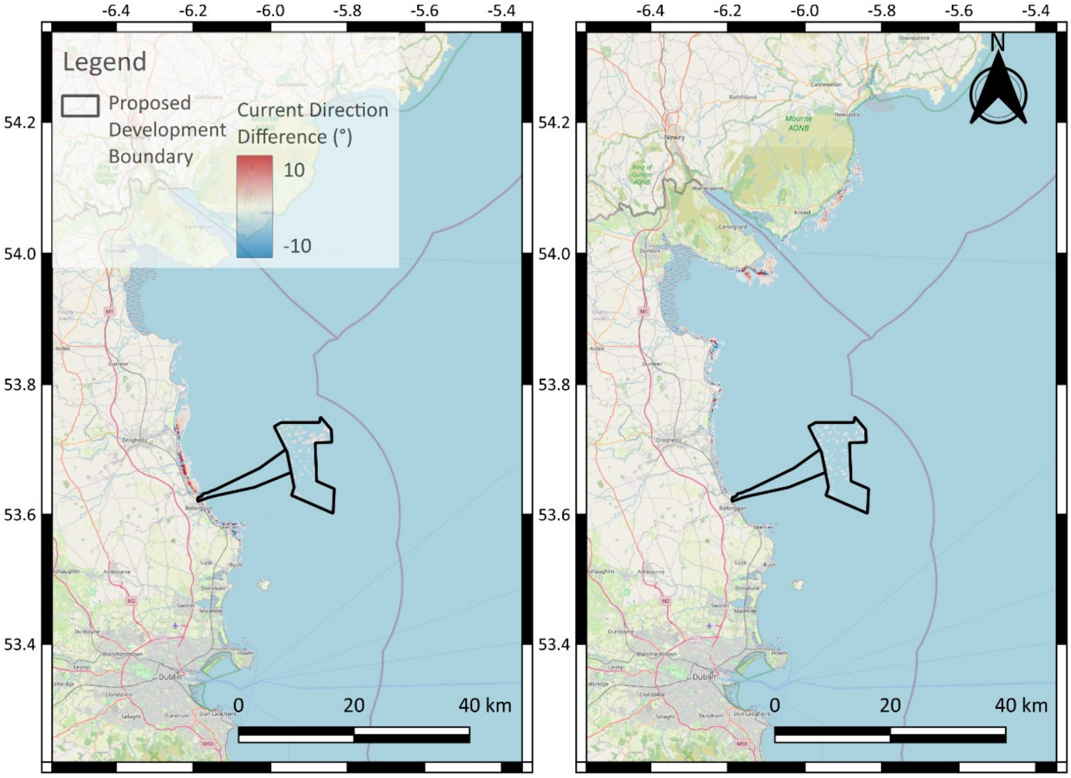

Figure 6.14: Proposed development induced difference in current direction during high southerly currents and 1 in 50 year storm waves. Left panel waves from 68 degrees, right panel waves from 156 degrees.

In each image, the differences between the left and right panels are negligible, indicating that the effect of waves on hydrodynamic differences is minimal.

Moreover, as waves propagate into shallower coastal waters, they increasingly interact with the seabed. In these shallower depths, typically within the closure depth[2] or the breaker zone[3], wave-induced orbital velocities become the dominant force for sediment mobilisation, superseding tidal currents. This transition triggers littoral processes, including longshore drift and cross-shore sediment transport, which are the primary drivers of morphological change at the coastline. Because the extent of the effect of the structures does not extend into this active littoral zone, the proposed development does not significantly modify the wave environment required to alter these nearshore processes. Consequently, the littoral regime remains governed by the existing natural wave climate, rather than by the presence of the proposed development.

Assessments of marine physical processes impacts for offshore wind developments typically make use of single process models (e.g. a tidal model) because of the clarity of result that such models provide. Where multiple processes are coupled together (e.g. wave and tidal interactions), it becomes increasingly difficult to distinguish between cause and effect of each process. Based on the results of the sensitivity analysis, it is clear the modelling approach applied to support the EIA is robust and appropriate as there is no discernible difference when processed are coupled together. Therefore, there are no changes are required in relation to RFI 7 (k) and (e).

---

[2] Closure depth corresponds to the depth where the influence of wave action on cross-shore sediment transport is on average insignificant compared to other influences.

[3] Breaker zone corresponds to the shallow water inshore location where waves steepen by shoaling to become unstable and cause wave breaking leading to wave energy dissipation on the seabed.

7 Conclusion

The additional sensitivity tests presented in this report to respond to RFI 7 (e), (j), (k) and (p) confirm that the primary interactions required for Chapter 10 of the EIAR [10] have been correctly identified and characterised. It is established that an EIA can be usefully supported by modelling where it helps to identify the magnitude and duration of a potential impact to a marine receptor. However, such an approach must be based on a conceptual understanding developed from a robust baseline. Our baseline understanding, alongside the sensitivity tests presented here, confirms that the standard modelling approach applied for the EIA captures the scale of all relevant changes. While further interactions, such as wind-blockage or climate change variables, were considered in these tests, they are shown to be secondary issues that do not act at a scale which would change any of the existing EIA outcomes.

If a conceptual understanding identifies a need to account for important process interactions, then a coupled approach should be considered; however, if processes can be demonstrated to act independently, then coupling is unnecessary. The results of these sensitivity tests demonstrate that the inclusion of these additional processes makes no appreciable difference to the results of the assessment. Furthermore, complicated modelling approaches introduce additional uncertainties which do not necessarily add value to the EIA. In contrast, the existing EIA approach inherently errs towards several levels of conservatism— e.g. adopted from outline design information, interpretation of baseline data, and the setup of modelling scenarios—which effectively manage various uncertainties without the need for excessive model complexity.

The reader should avoid viewing the results of these sensitivity tests as standalone findings, as they are intended solely as comparative exercises designed to address specific RFIs; consequently, we are precluding them from the formal EIA assessment. For the definitive results, the reader should refer to Section 10.5 of Chapter 10 of the EIAR [10].

In summary, the sensitivity tests presented in this document serve to demonstrate the existing approach applied to model and assess likely effects on marine and coastal processes is sufficient and robust and therefore no changes to the modelling approach are required.

References

[1] ABP Marine Environmental Research Ltd (ABPmer); Beiboer, F.; Cooper, B., “Potential Effects of Offshore Wind Developments on Coastal Processes (Report No. ETSU W/35/00596/00/REP),” UK Department of Trade and Industry (DTI), 2002.

[2] Centre for Environment, Fisheries and Aquaculture Science (Cefas), “Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements (Version 2),” Prepared on behalf of the Marine Consents and Environment Unit (MCEU), 2004.

[3] Department of Energy and Climate Change (DECC), “Review of Round 1 Sediment Process Monitoring Data - Lessons Learnt (SED01),” A report by HR Wallingford, CEFAS, and ABPmer for DECC, 2008.

[4] Department of Energy and Climate Change (DECC), “Dynamics of scour pits and scour protection (SED02) – Synthesis report and recommendations (Milestones 2 and 3),” Final Report prepared by HR Wallingford Ltd, ABP Marine Environmental Research Ltd and Centre for Environment, Fisheries and Aquaculture Science for the Research Advisory Group., 2008.

[5] D. O. Lambkin, J. M. Harris, W. S. Cooper and T. Coates, “Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guide,” COWRIE Ltd (Collaborative Offshore Wind Research Into the Environment), 2009.

[6] COWRIE, “A Further Review of Sediment Monitoring Data - COWRIE ScourSed-09,” A report by HR Wallingford, ABPmer, and Cefas for COWRIE Ltd., 2010.

[7] Marine Management Organisation (MMO), “Review of Environmental Data Associated with Post-Consent Monitoring of Licence Conditions of Offshore Wind Farms (MMO Project No. 1031),” 2014.

[8] Natural Resources Wales (NRW), “Scoping an Environmental Impact Assessment for Marine Developments,” 2018.

[9] Partrac, “NISA Offshore Wind Farm. Metocean Campaign. Final Data Report. Version 3,” 2023.

[10] Statkraft / NISA Ltd., “North Irish Sea Array (NISA) Offshore Wind Farm Environmental Impact Assessment Report (EIAR). Submitted to An Bord Pleanála (Case Ref: 319866),” Ove Arup & Partners Ireland Ltd., 2024.

[11] A. Platis, S. K. Siedersleben, J. Bange, R. Lückerath, B. Djath, J. Schulz-Stellenfleth, B. Djath, B. Cañadillas, T. Neumann and A. Lampert, “First in situ evidence of wakes in the far field behind offshore wind farms,” *Scientific Reports,* vol. 8, no. 1, p. 2163, 2018.

[12] Jensen, N. O., “A note on wind generator interaction.,” Risø National Laboratory, Denmark, 1983.

[13] M. Bastankhah and F. Porté-Agel, “A new analytical model for wind-turbine wakes.,” *Renewable Energy,* vol. 70, pp. 116-123, 2014.

[14] A. Crespo, J. Hernández and S. Frandsen, “Survey of modelling methods for wind turbine wakes and wind farms.,” *Wind Energy,* vol. 2, no. 1, pp. 1-24, 1999.

[15] R. J. A. M. Stevens and C. Meneveau, “Flow structure and turbulence in wind farms.,” *Annual Review of Fluid Mechanics,* vol. 49, pp. 311-339, 2017.

[16] U.S. Army Corps of Engineers, “Shore Protection Manual (4th ed., Vols. 1–2),” Coastal Engineering Research Center, Waterways Experiment Station, U.S. Government Printing Office, 1984.

[17] MetOceanWorks, “Metocean Data Overview - North Irish Sea Array Wind Farm,” MetOceanWorks Limited, 2025.

[18] G. J. Komen, L. Cavaleri, M. Donelan, K. Hasselmann, S. Hasselmann and P. A. E. M. Janssen, Dynamics and Modelling of Ocean Waves, Cambridge, UK: Cambridge University Press, 1994.

[19] SWAN team, Delft University of Technology, “Swan cycle III version 40.91 ABC - Scientific and Technical Documentation,” 2013.

[20] DHI, “MIKE 21 Flow Model FM: Hydrodynamic and Transport Module; Scientific Documentation,” DHI A/S, Denmark, 2021.

[21] DHI, “Mike 21 Flow Model FM: Hydrodynamic Module: User Guide,” DHI A/S, Denmark, 2021.

[22] AVISIO, “GLOBAL TIDE - FES,” 01 February 2023. [Online]. Available: https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/global-tide-fes.html. [Accessed 01 February 2023].

[23] The European Marine Observation and Data Network, “Bathymetry | European Marine Observation and Data Network (EMODnet),” The European Marine Observation and Data Network, 01 February 2023. [Online]. Available: http://www.emodnet-bathymetry.eu. [Accessed 01 February 2023].

[24] MetOceanWorks, “Preliminary Metocean Design Criteria - NISA South West,” MetOceanWorks, 2020.

[25] Cooper Marine Advisors, “North Irish Sea Array. Annex A: Determination of Marine Processes Worst-Case Scenarios,” Cooper Marine Advisors, 2023.

[26] Cooper Marine Advisors, “North Irish Sea Array. Annex C: Assessment of Spoil Mounds,” Cooper Marine Advisors, 2023.

[27] Fugro, “Geophysical Survey Results Report | Ireland, Irish Sea,” Fugro Mercator, 2022.

[28] N-Sea, “North Irish Sea Array Windfarm Ltd. Interim Geophysical Survey Results Report,” 2023.