REPORT

Dover Harbour Board: Outer Wave Screen

Environmental Screening Report

Client: Dover Harbour Board

Reference: PB1552-RHD-ZZ-XX-RP-Z-0003

Status: Final/P01.03

Date: 18 June 2021

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APPENDIX 2 - HR Wallingford, 2021. Dover Marina: Wave reduction modelling. Report number DEM8459-RT003-R02-00

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1 INTRODUCTION

1.1 Background to the DWDR Scheme

In March 2016, Dover Harbour Board (DHB) was granted a Marine Licence consenting the construction of the Dover Western Docks Revival (DWDR) Scheme. The DWDR Scheme takes forward the vast majority of the marine works within the Terminal 2 (T2) Dover Harbour Revision Order (HRO), granted in 2012 and will provide the fundamental infrastructure required to transform Dover's waterfront. It includes the construction of a new marina pier and curve as well as the relocation of Dover's cargo terminal and distribution centre and will provide vast economic development not only for the Dover area, but for the UK's trade and prosperity links with the European Union (EU), as well as greatly enhancing employment and recreation opportunities for Dover's local community.

The construction phase of the DWDR Scheme is being undertaken in stages and many of the activities have already been completed, including all elements of Stage 1, Stage 1A and Stage 2. This includes the dredging, reclamation and construction works necessary for creating Berths A and C and the new marina and associated structures.

Once the construction of the marina and adjacent pier was completed (under construction Stage 2, as above), DHB identified an unexpected situation whereby wave heights within the new marina under south-westerly storm conditions, in combination with high water, were leading to unacceptable movement of the floating pontoons within the marina. In an attempt to rectify this problem, in November 2020 DHB successfully procured a variation to the existing DWDR Scheme Marine Licence (L/2016/00056/8) to include the construction of a 14.4m long inner wave screen at the entrance to the marina, in the aperture between the Marina Curve and the new Marina Pier, to limit the propagation of reflected waves into the marina. The inner wave screen was successfully constructed in 2020.

1.2 The Requirement for the Outer Wave Screen

Following a review of the performance of the recently-constructed inner wave screen, it has been determined that, as a result of the nature of the incident waves and the limited reduction in wave height arising from more frequent events, further wave attenuation measures are required. It is proposed to construct an outer wave screen (OWS) of approximately 70m in length which is designed to protect the entrance to the marina from wave energy reflected from the north-eastern corner of the harbour at high water. The construction of the wave screen will comprise contiguous tubular steel piles similar to those used to construct the inner wave screen. The final design is still being developed, but it is now anticipated that approximately 61 piles will be required, with a diameter of approximately 1.1m. Due to the location the piles will be driven from a floating or jack-up barge.

1.3 Purpose of this Report

It is DHB's intention to apply to the Marine Management Organisation (MMO) for a Harbour Revision Order (HRO) under Section 14 of the Harbours Act 1964 (as amended) (HA 1964) to authorise construction of the proposed scheme. As the proposed HRO would authorise a 'project', DHB must submit 'notice of their intention to make the application' to the MMO under the requirements of Paragraph 3, Schedule 3 of the HA 1964. This will also allow the MMO to 'screen' the notice for the purposes of Environmental Impact Assessment (EIA) (i.e. provide an EIA Screening Opinion). This report therefore provides the information required under Annex IIA to the EIA Directive[1] to allow the MMO to form such an opinion.

---

[1] L_2014124EN.01000101.xml (europa.eu)

Under Part 4 of the Marine and Coastal Access Act, 2009 ('MCAA (2009)') a marine licence from the Marine Management Organisation (MMO) will also be required for the construction of the proposed scheme. Therefore, this report is also submitted to the MMO in request of a Screening Opinion under the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended[2])(MWRs). It is expected that the MMO will be able to defer its Opinion under the MWR's to that made under the HA 1964.

1.4 Report Structure

A description of the proposed scheme is provided in Section 2 of this report. The legislative background to the consenting regime is provided in Section 3. Section 4 provides a description of potential environmental impacts arising from the proposed scheme, with conclusions presented in Section 5.

2 SCHEME DESCRIPTION

The proposed scheme consists of installing a 'wall' of tubular piles to create an OWS of approximately 70m in length at the entrance to the marina, designed to protect the marina from wave energy reflected from the north-eastern corner of the harbour at high water. The General Arrangement drawing for the proposed scheme is presented in **Appendix 1** to this report.

2.1 Site Location

The Proposed Works area falls outside the DWDR Scheme boundary and is approximately 20m west of the existing breakwater at the marina entrance and aligned in a NW-SE direction (**Figure 2-1**). As such, it is considered necessary to apply for a HRO in addition to the requirement for a marine licence.

2.2 Proposed Layout of Outer Wave Screen

Following modelling by HR Wallingford of potential options for protecting the Marina from reflected waves, the preferred option is to install a detached vertical wave screen in an area of reduced depth, outside the commercial navigation area (as shown in the navigation chart in **Figure 2-2 and Figure 2-3**). The OWS will be located approximately 20m west of the existing breakwater at the Marina entrance and angled so that it is approximately along a radial line from the tip of the existing extension to the marina curve breakwater (**Figure 2-1**). The modelling shows that this will limit reflected waves entering the harbour whilst ensuring that any waves diffracting from the marina curve breakwater tip will run straight past the marina entrance, instead of being reflected into the marina.

Section 5.1 presents further information on the modelling to inform the proposed location of the OWS.

2.3 Construction Methodology

The OWS will be approximately 70m in length and will lie in a NW-SE orientation, approximately 20m west of the existing breakwater. It will be constructed from approximately 61 tubular steel piles of a maximum diameter of approximately 1.1m, driven contiguously by either a jack-up barge or floating barge held in position by spud legs and anchors. The top of the piles will be +9.5m Chart Datum (CD) and the toe is expected to be around –17m CD. The marine footprint of the OWS is restricted to the plan area of the piles – resulting in a maximum total area of approximately 58m^2. Two square platforms will be installed on each end of the OWS for access and placement of navigational lighting.

Piles may be delivered by road or by sea, depending on the final procurement strategy, and will be stored on an adjacent quayside and transferred to the piling location by barge. Piles will be driven as far as possible

[2] The Marine Works (Environmental Impact Assessment) Regulations 2007 (legislation.gov.uk)

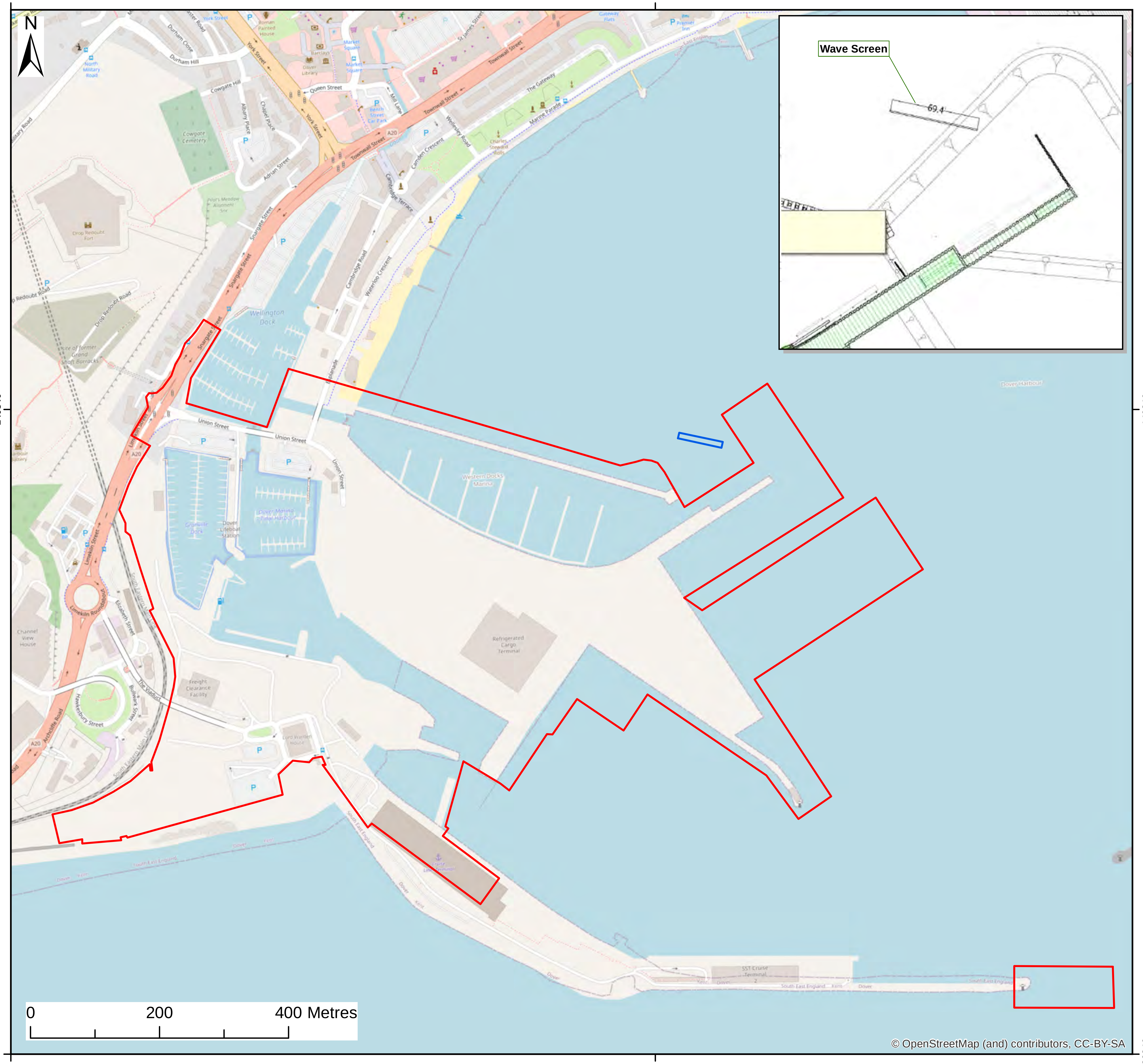
using a vibratory hammer, but it is expected that driving to the final elevation will require the use of a percussive hammer; however, percussive piling will be limited to the absolute minimum.

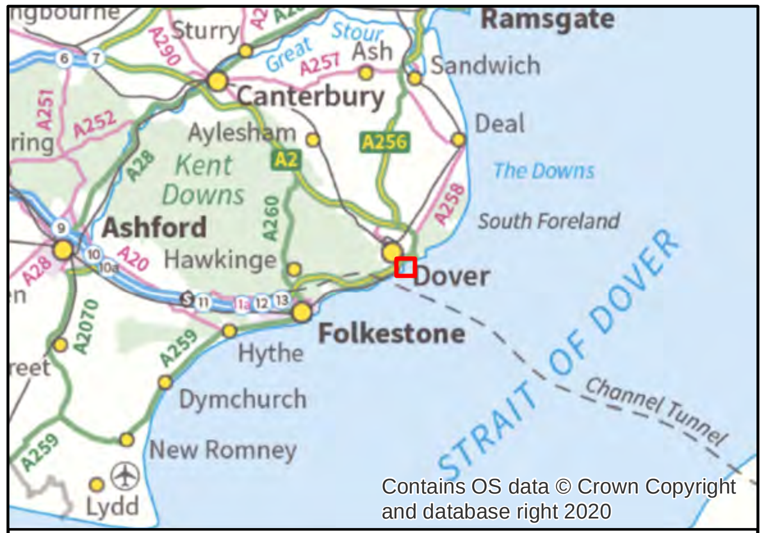
All piling works will be carried out in accordance with Condition 5.2.12 of the marine licence for the DWDR Scheme (L/2016/00056/8):

> *"During the construction phase piling operations, soft-start procedures must be used, as set out in Piling Method Statement (v1) in Schedule 7 [of L/2016/00056/8]. Should changes to this methodology be required, a revised Piling Method Statement must be developed in consultation with Natural England and submitted to the MMO at least 4 weeks prior to the proposed commencement of the piling activities. Piling activities must not re-commence until written approval of the revised Piling Method Statement is provided by the MMO.*
>
> *Licensed activities must be undertaken in accordance with the agreed Piling Method Statement."*

2.4 Programme of Works

It is anticipated that the piling works will take place in Q1 2022 over a period of approximately four weeks. Piling activity will only be permitted between 0800 and 1800 Monday to Friday and 0800 to 1230 on Saturdays.





Legend:

- DWDR Scheme Boundary
- Outer Wave Screen

Client: Dover Harbour Board	Project: DWDR Outer Wave Screen

Title: Location of the Outer Wave Screen

Figure: 2.1 | Drawing No: PB1552-RHD-ZZ-ZZ-YE-0006

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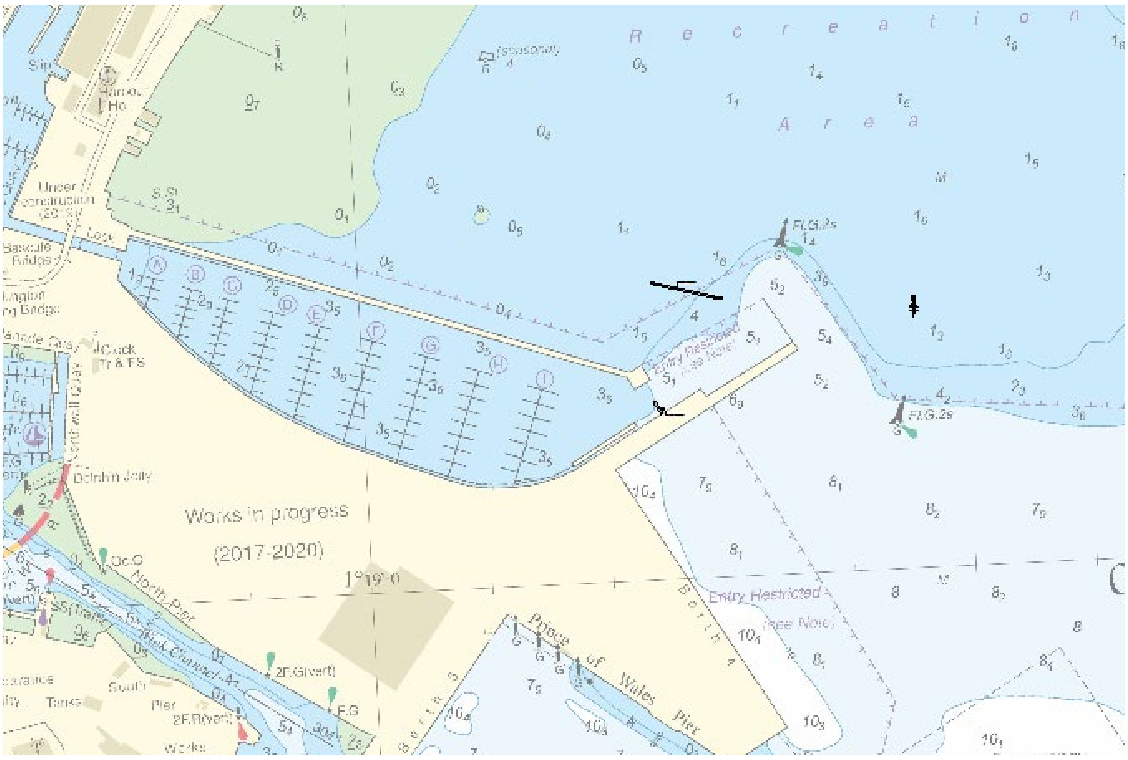

Figure 2-2 *Dover Harbour navigation chart and OWS*

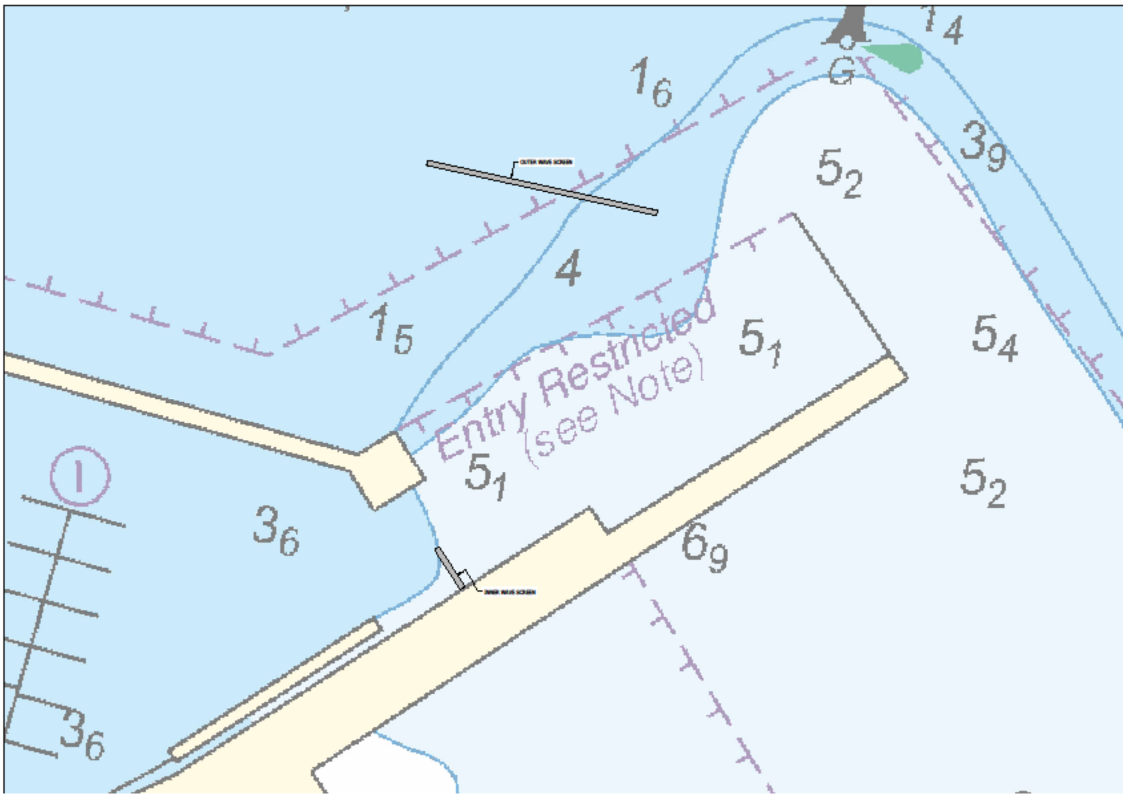

Figure 2-3 *Dover Harbour navigation chart and OWS*

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3 LEGISLATION AND RELEVANT POLICY

This section describes the legislative and policy context of the proposed scheme.

On 31 December 2020, the UK left the EU and consequently, there have been several amendments to legislation and policy. Largely these changes involve transferring functions from the European Commission to the UK government and its devolved administrations so that processes in the original regulations remain unchanged and existing guidance is still relevant.

3.1 The Harbours Act 1964 (as amended)

Under the requirements of the HA 1964 the MMO is responsible for the determination of applications for 'Harbour Orders' in England. Harbour Orders which authorise the carrying out of development works are known as 'works orders'.

Section 14 of the HA 1964 allows for the MMO to make a HRO *"in relation to a harbour which is being improved, maintained or managed by a harbour authority in the exercise and performance of statutory powers and duties…for achieving all or any of the objects specified in Schedule 2"*.

Section 14 also requires an application to be made in writing to the MMO by *"the authority engaged in improving, maintaining or managing it or by a person appearing to him to have a substantial interest or body representative of persons appearing to him to have such an interest"*. DHB is the Statutory Harbour Authority (SHA) for the Port of Dover.

3.2 Environmental Impact Assessment Directive

Directive 2014/52/EU (the 'EIA Directive') is implemented by Schedule 3 of the HA 1964 (as amended) in respect of applications for Harbour Orders. An EIA is required for all projects which fall under Annex I of the EIA Directive, and also those projects (known as 'relevant projects') which fall under Annex II of the EIA Directive and the following criteria are met:

- The area of the works is > 1ha;
- Any part of the works will be undertaken in a sensitive area; or
- The Secretary of State (SoS) believes that the project falls within Annex II.

According to Annexe IIA of the EIA Directive, the information to be provided to the MMO in request of a Screening Opinion must contain the following:

> *"1. A description of the project, including in particular:*
>
> > *(a) a description of the physical characteristics of the whole project and, where relevant, of demolition works;*
> >
> > *(b) a description of the location of the project, with particular regard to the environmental sensitivity of geographical areas likely to be affected.*
>
> *2. A description of the aspects of the environment likely to be significantly affected by the project.*
>
> *3. A description of any likely significant effects, to the extent of the information available on such effects, of the project on the environment resulting from:*
>
> > *(a) the expected residues and emissions and the production of waste, where relevant;*
> >
> > *(b) the use of natural resources, in particular soil, land, water and biodiversity.*

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4. The criteria of Annex III shall be taken into account, where relevant, when compiling the information in accordance with points 1 to 3."

The proposed scheme will be less than 1 ha, and is not being undertaken within a 'sensitive' area.

As a Marine Licence will also be required to allow construction of the proposed scheme, an EIA Screening Opinion is also requested from the MMO under the requirements of the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended).

3.3 The Marine and Coastal Access Act (2009)

Part 4 of The Marine and Coastal Access Act 2009, as amended by the Marine Environment (Amendment) (EU Exit) Regulations 2018, (hereafter referred to as 'MCAA 2009'), provides a framework for the marine licensing system for works below the level of MHWS tides. The MMO is the regulatory authority for most marine licensing in English inshore and offshore waters. A marine licence is required for the proposed scheme.

Part 5 (section 116(1)) of the MCAA 2009 provides a framework for the designation and protection of Marine Conservation Zones (MCZs) around the coasts of England and Wales.

Under Section 126 of the MCAA (*'Duties of public authorities in relation to certain decisions'*), duties are placed on the MMO in relation to marine licence decision making and the consideration of MCZs as outlined below:

"(1) This section applies where –

a) A public authority has the function of determining an application (whenever made) for authorisation of the doing of any act, and

b) The act is capable of affecting (other than insignificantly) –

i. The protected features of an MCZ;

ii. Any ecological or geomorphological process on which the conservation of any protected feature of an MCZ is (wholly or in part) dependent alone or in-combination with other plans or projects."

The MMO's guidance '*Marine conservation zones and marine licensing*' (MMO, 2013) provides information on the three sequential stages for undertaking a MCZ assessment to assess the potential impacts of operations or activities occurring within, or in close proximity to, an MCZ.

There are five MCZs within the vicinity of the proposed scheme; Further information on the identification of potential impacts on MCZs body is presented in **Section 6**.

3.4 The Conservation of Habitats and Species Regulations (2017)

Until 31st December 2020, The Conservation of Habitats and Species Regulations (2017) underpinned the designation of formerly EU-protected sites otherwise known as the Natura 2000 network or sites of European importance, which were comprised of SPAs, potential SPAs (pSPAs), Special Areas of Conservation (SACs) and candidate SACs (cSACs). This legislation requires an Appropriate Assessment be undertaken for any plan or project, not connected with the management of the site, but which is likely to have a significant effect on the site either alone or in-combination with other plans or projects (Habitat Regulations Assessment). This function was also extended to any listed Ramsar site within the vicinity for the purpose of considering development proposals affecting them.

Following the UK's exit from the EU, the UK government amended this legislation on the 1st January 2021 so that it is now known as The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 which merges formerly EU-protected sites into a new 'national site network'. Largely these changes involve transferring functions from the European Commission to the UK government and its devolved administrations so that processes in the 2017 regulations remain unchanged and existing guidance is still relevant.

Consideration to this legislation has been given for the proposed scheme however a HRA is not considered necessary as there is no pathway for any impacts to any sites in the national site network, the closest (Dover to Kingsdown Cliffs SAC), being located approximately 1.4km from the proposed scheme (**Figure 3-1**).

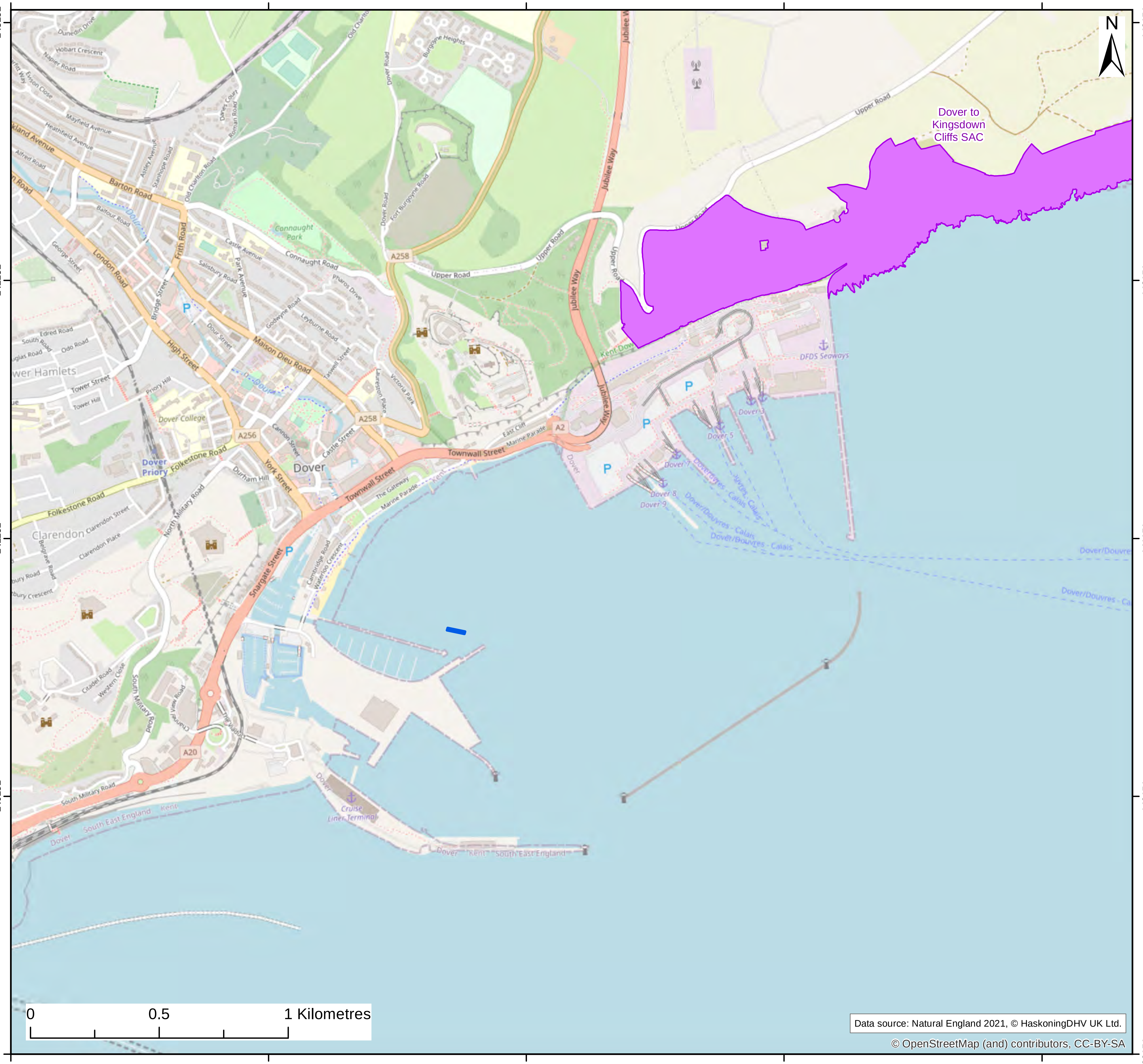
3.5 The Water Framework Directive

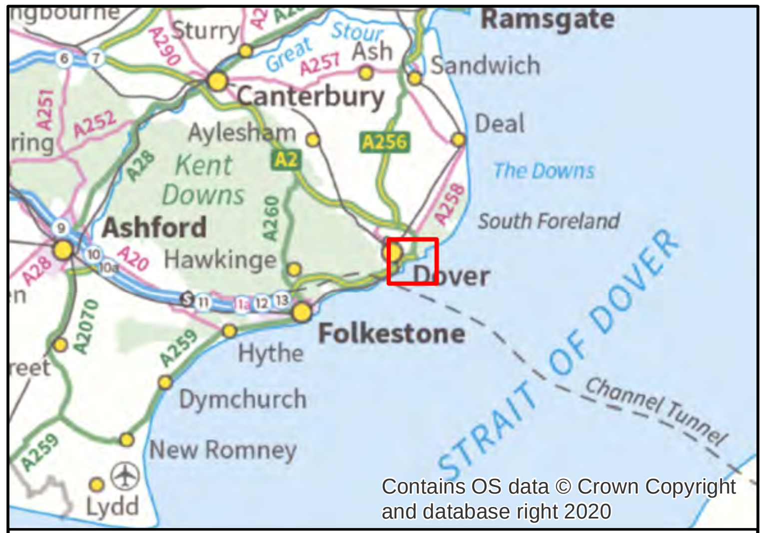
The Water Framework Directive (Council Directive 2000/60/EC) (WFD), establishes a legal framework to protect and restore clean waters across Europe to ensure long-term, sustainable use. The WFD applies to coastal waters out to one nautical mile from the baseline from which territorial waters are drawn.

The WFD requires that all EU Member States must prevent deterioration and protect and enhance the status of aquatic ecosystems. This means that Member States must ensure that new schemes do not adversely impact upon the status of aquatic ecosystems, and that historical modifications that are already impacting it need to be addressed.

The Water Environment (WFD) (England and Wales) Regulations 2017, as amended by the Floods and Water (Amendment etc.) (EU Exit) Regulations 2019 transposes the WFD into UK Law and requires WFD to be considered at all stages of the planning and development process in England and Wales.

The proposed scheme is within the Kent South WFD water body. Further information on the identification of potential impacts on WFD parameters for this water body is presented in **Section 5.2.**





Legend:

- Outer Wave Screen
- Special Areas of Conservation (SAC)

Client: Dover Harbour Board	Project: DWDR Outer Wave Screen

Title: Dover to Kingsdown Cliffs SAC and the Location of the Outer Wave Screen

Figure: 3.1 Drawing No: PB1552-RHD-ZZ-ZZ-YE-0007

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3.6 Ancient Monument and Archaeological Areas Act (1979)

Under the terms of this Act, an archaeological site or historic building of national importance can be designated as a Scheduled Monument and is registered with the Department of Culture, Media and Sport (DCMS). Any development that might affect either the Scheduled Monument or its setting is subject to the granting of Scheduled Monument Consent. This act is further supported by a Scheduled Monuments and nationally important but non-scheduled monuments Policy Statement which sets out the Government's current policy on the identification, protection, conservation and investigation of nationally important ancient monuments.

An application for Scheduled Monument Consent must be made to the Secretary of State for Digital, Culture, Media and Sport before any work can be carried out which might affect a monument either above or below ground level. Historic England gives advice to the government on each application and administers the consent system.

There are two Scheduled Monuments in the Port of Dover:

- Fairburn-type crane, Wellington Dock (List UID: 1004193); and
- Admiralty Pier Turret (List UID: 1004209).

However, both are located a sufficient distance from the proposed scheme so that impacts will not occur. An identification of all potential impacts of the scheme on archaeology and heritage is presented in **Section 5.7**.

3.7 Relevant Policy: Marine Plans

Part 3 of the MCAA 2009 provides a framework for marine planning. In England, the MMO is the planning authority for the marine environment, and the inshore and offshore waters have been split into 11 plan areas. The Proposed Works' are located within the South East Inshore Marine Plan area and which stretches from Felixstowe in Suffolk to near Folkestone in Kent, covering approximately 1,400 kilometres of coastline, taking in a total of approximately 3,900 square kilometres of sea. The draft plan was consulted upon between January 2020 and April 2020 and is now being reviewed by the MMO.

The proposed scheme is also located 1.7km north of the South Inshore Marine Plan area, which was adopted in July 2018.

Marine plans are prepared under the policy framework provided by the Marine Policy Statement, and together they underpin the marine planning system for England. The Marine Policy Statement builds on the shared UK wide high-level marine objectives, and provides an overview of relevant national policy, including the National Planning Policy Framework and associated National Policy Statements.

3.7.1.1 Compliance with the Marine Plans

The implementation of the Marine Plans for the South East Inshore region and South Inshore region are not anticipated to conflict with the proposed scheme, which has been designed to follow principles which compliment those on which marine planning is based. The proposed scheme is located within a busy port setting subject to regular commercial vessel movements. Marine plans for this region recognise the industrial character of the Port of Dover in order to support the development of well-regulated human activity in the area. Therefore, the proposed scheme is considered to be in full accordance with the Draft South East Inshore and South Inshore Marine Plans.

4 CONSULTATION

DHB recognises the importance of stakeholder consultation and hosts a number of regular consultation forums, including the following which are of particular relevance to this application and at which the OWS was discussed:

- Leisure Zone Management Consultation – 31 March 2021;
- Marina Berth Holders meeting – 25 March 2021; and
- Public Annual Consultative Meeting – 26 May 2021.

In addition, the proposals were discussed in detail with the Royal Yachting Association on 19 May 2021.

5 DESCRIPTION OF POTENTIAL ENVIRONMENTAL IMPACTS

This section provides an overview of the potential impacts that could arise as a result of the proposed scheme and, where applicable, describes measures that have been identified to date to avoid or mitigate these impacts throughout the development of the project.

Given the nature and location of the scheme, the following aspects are considered relevant:

1. Coastal processes
2. Water and sediment quality
3. Marine ecology
4. Marine and coastal ornithology
5. Shipping and navigation
6. Landscape and visual impacts
7. Migratory and resident fish
8. Marine mammals
9. Archaeology and cultural heritage
10. Accidents and disasters
11. Climate change
12. Water Framework Directive
13. Cumulative impacts

The proposed scheme is not within or close to any sites designated for their nature conservation value and due to the localised nature of the construction and operation of the OWS, there is no impact pathway that would lead to a disturbance to the habitats or species within any designated sites. It was therefore concluded that there would be no impact on designated sites; therefore, a HRA is not required.

Due to the location of the proposed scheme entirely within the inner harbour and the fact that that the OWS is a new structure which does not constitute a replacement, the following additional topics are not considered to be of relevance to the currently proposed scheme:

1. Flood and coastal defence
2. Waste and use of natural resources
3. Terrestrial and coastal ecology
4. Shellfish resource
5. Traffic and transport
6. Commercial fisheries
7. Tourism and recreation
8. Impacts to human receptors (noise and vibration, air quality and human health)

In addition to any measures set out in the following sections to avoid or mitigate any adverse effects that could arise as a result of the proposed scheme, industry good practice guidance will be adhered to throughout the programme of works, such as:

- Environment Agency guidelines, in particular Pollution Prevention Guidelines – works in, near or liable to affect watercourses: PPG 5 (these were withdrawn in 2015 but are still used by industry and still recognised by the Environment Agency as best practice within their consultation responses);
- CIRIA Coastal and Marine Environmental Site Guide (second edition) (CIRIA report C744); and,
- International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL 73/78).

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5.1 Coastal processes

The primary purpose of the installation of the OWS is to modify the wave climate within the Marina. Following a review of the performance of the recently-constructed inner wave screen, it has been determined that, whilst the wave climate has been significantly improved in line with modelled predictions, the nature of the incident waves and the limited reduction in wave height arising from more frequent events, further wave attenuation measures are required to protect the marina entrance from wave energy reflected from the north-eastern corner of the harbour at high water. **Figure 5-1** shows the modelling of significant wave height (m) in the Marina **under the existing configuration** (with the inner wave screen in place).

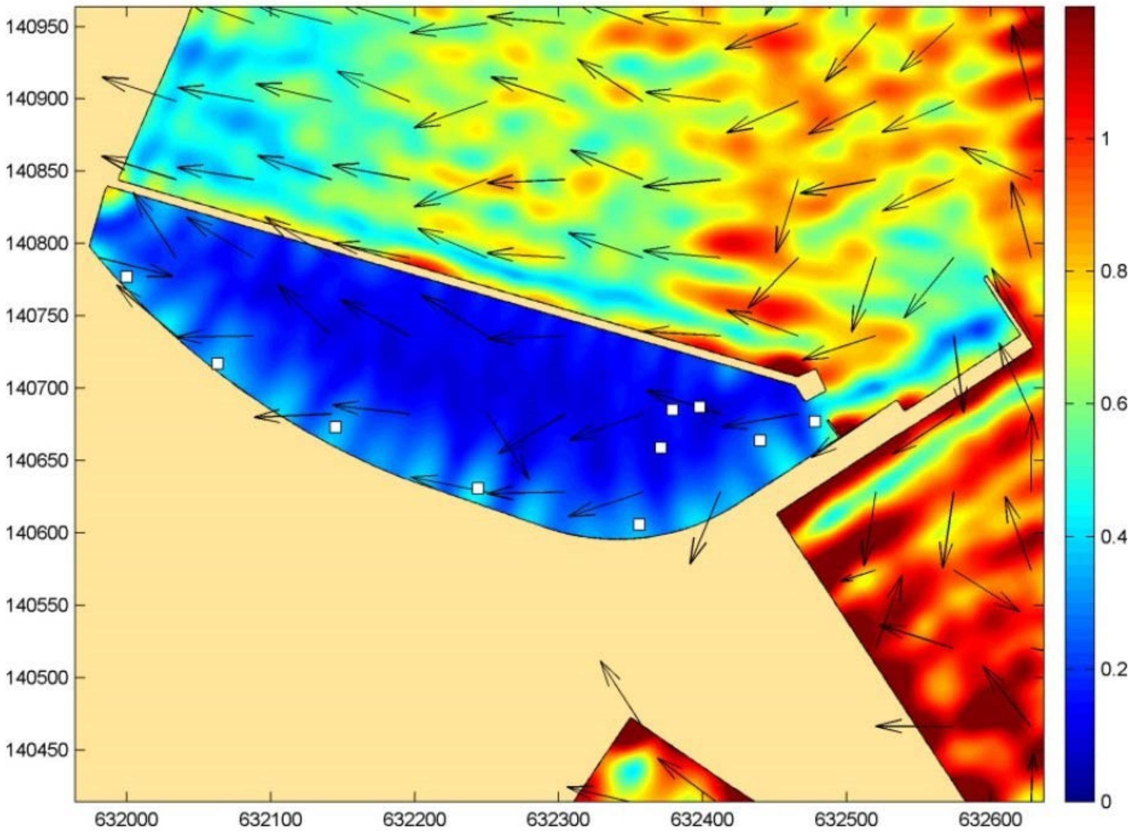


***Figure 5-1** Modelling of significant wave height (m) in the Marina under the existing configuration (including inner wave screen) (HR Wallingford, 2021)*

5.1.1 Impacts during construction of the wave screen

Given the very limited marine footprint (approximately 58m^2), the construction activities associated with the wave screen are not anticipated to have any significant effects on local or regional hydrodynamic processes.

5.1.2 Impacts during operation of the wave screen

5.1.2.1 Changes to wave activity

The purpose of the OWS is to limit the reflection of waves into the Marina, thereby reducing wave heights **within the marina** during adverse conditions. This is demonstrated by the ARTEMIS wave model run by HR Wallingford (2021) (**Appendix 2**) with the proposed OWS installed under incident boundary significant wave heights (SWH) of both 3.8m and 5.14m, representing the once in 1 year an once in 50 years events.

The modelled effects remained valid during further sensitivity testing (i.e. for a variety of boundary wave directions) as demonstrated in **Appendix 2**.

Immediately outside the marina the wave pattern is slightly changed and there is a general reduction in wave energy in the dredged approach to the marina entrance. However, the modelling also indicated that the standard wave pattern along the marina curve extension results in a localised increase in wave heights along the parts of the quay wall in the vicinity of the proposed berths for port vessels and shows a concentration of wave energy and corresponding increase in wave height of around 0.2m immediately against the outer (NE) face of the wave screen (**Figure 5-2** and **Figure 5-3**), but this is very localised and the wave height remain significantly less than the waves existing in other parts of the outer harbour (**Figure 5-4**).

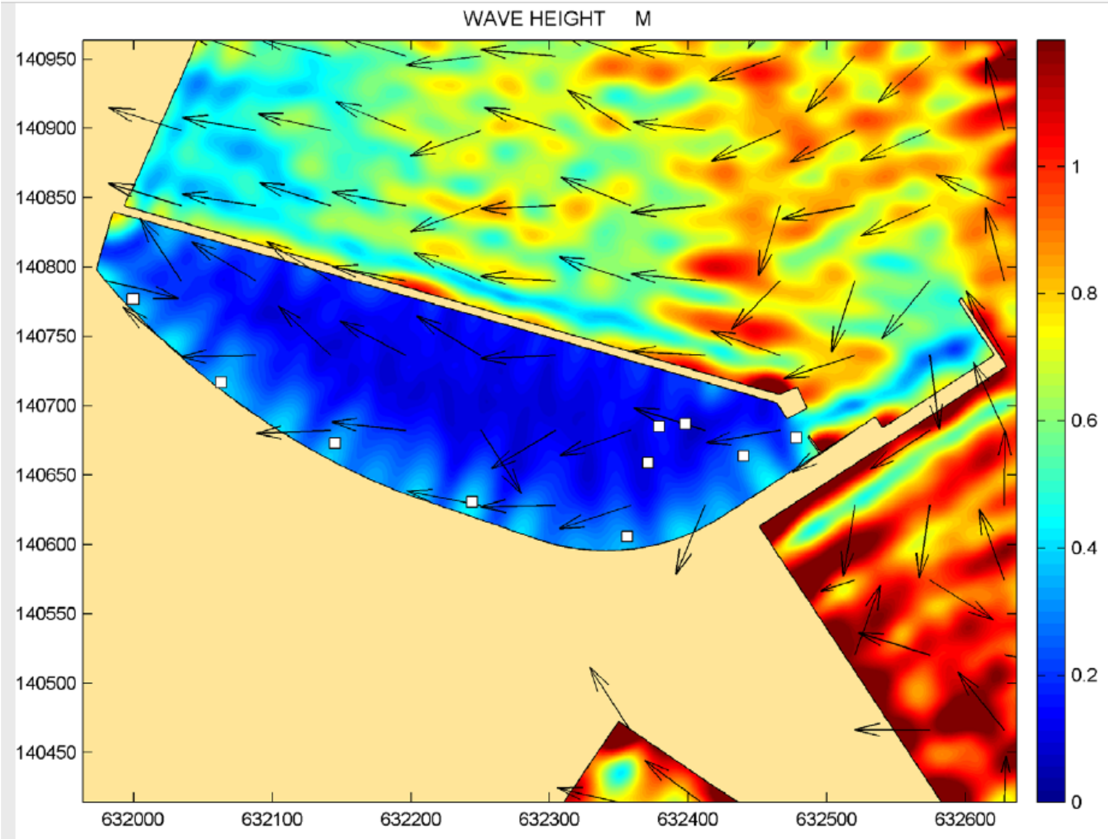


Figure 5-2 *Baseline wave conditions inside marina (including only inner wave screen) (taken from HR Wallingford, 2021)*

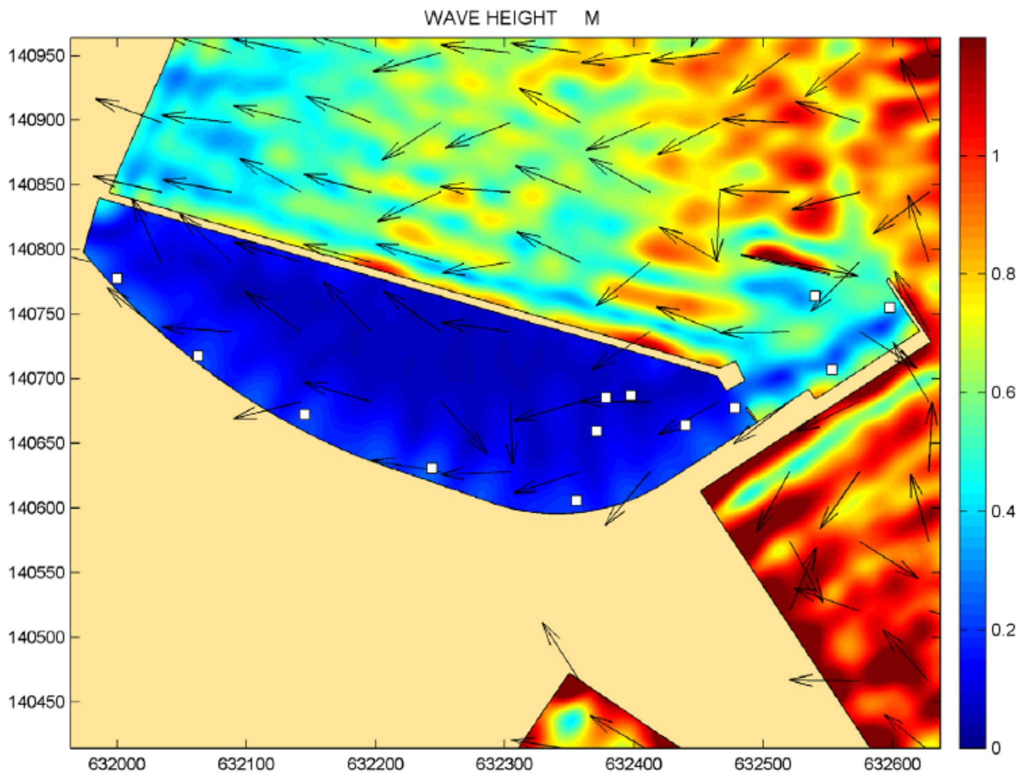


***Figure 5-3** Expected wave conditions inside marina with OWS installed (taken from HR Wallingford, 2021)*

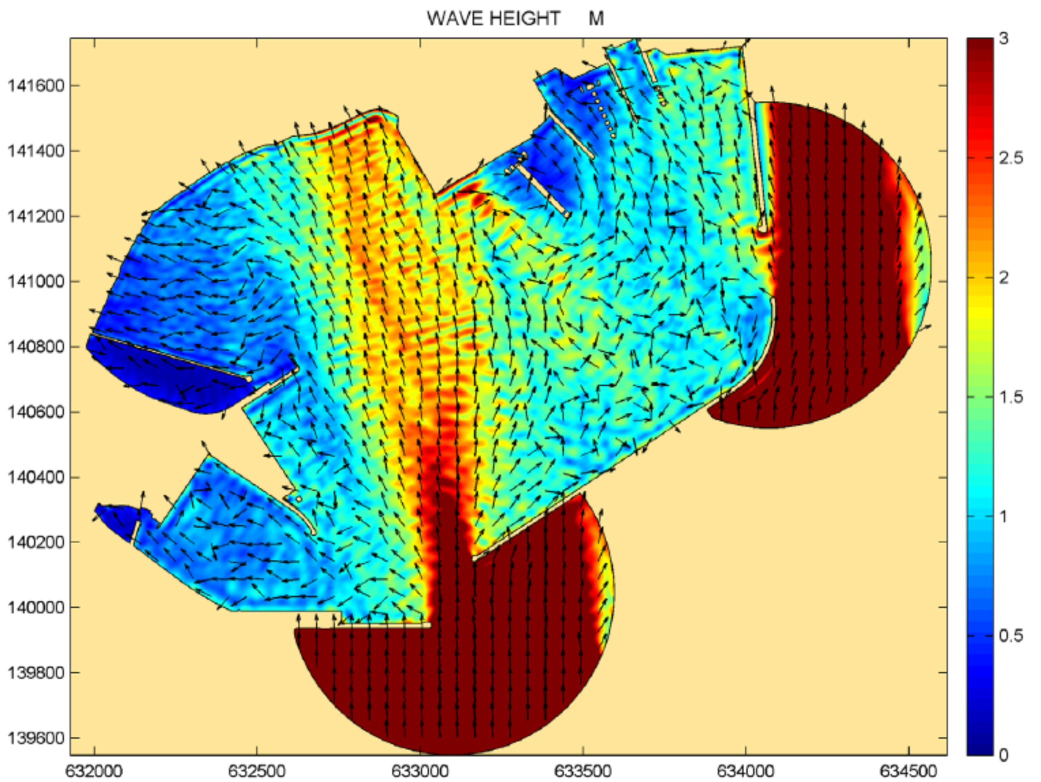


***Figure 5-4** Wave conditions inside harbour (including inner wave screen) (taken from HR Wallingford, 2021)*

As such, the operation of the OWS will have an insignificant impact on of wave activity outside of the Marina, but a significant **beneficial impact** on wave height within the Marina, which is the desired effect.

5.1.2.2 Changes to tidal flow speed and direction

The proposed scheme is minor in comparison to the overall DWDR Scheme. Considering that the DWDR Screening Opinion Report (Port of Dover, 2015) indicated that there may be only **minor** changes to tidal flow speed and direction as a result of the wider DWDR Scheme (which included, *inter alia*, the construction of the ~500m-long Marina Pier and ~100m-long Breakwater within the Outer Harbour, plus the reclamation of land within the existing tidal basin system and the creation of new berths) it can, therefore, be reasonably concluded that any further changes to tidal flow as a resulting of the proposed scheme would not be significant.

To conclude, aside from the intended positive beneficial impacts on wave reflection within the Marina, any potential adverse impacts on the hydrodynamic regime and tidal flows resulting from installation of the proposed scheme, which has a very limited footprint, are considered to be of **negligible** significance.

5.2 Water and sediment quality

The proposed scheme is located within the Kent South Coastal water body (GB640704540001) (classified as a HMWB) (**Figure 5-5**). The current overall status of the water body is Good.

An assessment to consider the proposed scheme against WFD compliance criteria in line with the 'Clearing the Waters for All guidance' (Environment Agency, 2017) will be undertaken as part of the documentation produced in support of both the HRO and marine licence applications. The proposed scheme will however be compliant with WFD requirements with regards to water and sediment quality during both the construction and operational phases as there are several in-built control measures, as below:

- Adherence to requirements of the CCEMP (which is a live document - see Appendix 4 of the DWDR Environmental Report (RHDHV, 2015a))
- All marine vessels and construction equipment will be checked for presence of invasive species before commencing operations
- All fuels, oils, lubricants and other chemicals should be stored in an impermeable bund with at least 110% of the stored capacity. Spill kits to be available always, and damaged containers should be removed from site
- Biodegradable oils should be used where possible.

Furthermore, there are no higher or lower sensitivity habitats within Dover Harbour and the proposed scheme does not pose any risks to resident or migratory fish species. This is because there will not be either physical barriers to movement (i.e. closing access to upstream locations of the Dour or entrainment/impingement risks) or non-physical barriers (i.e. significant noise or vibratory disturbances) as piling works, including any percussive driving required, will be undertaken in accordance with Condition 5.2.12 of the existing Marine Licence which ensures the use of soft-start procedures.

5.2.1 Impacts during construction of the wave screen

5.2.1.1 Impact on water quality due to releases of suspended solids and contaminants

The DWDR Screening Opinion Report (Port of Dover, 2015) indicated that the impact of suspended solids was generally anticipated to be of minor adverse significance during the wider DWDR works, which included a significant amount of dredging, due to the naturally high suspended sediment concentration (SSC) within the harbour, and the fact that the harbour is regularly exposed to SSC fluctuations from maintenance dredging operations. Furthermore, the Screening Opinion Report indicated only a temporary moderate impact on releases of suspended solids and contaminants as a result of dewatering of land reclamation material.

During construction of the OWS, driving piles into the seabed may result in disturbance of sediment into the water column in the immediate vicinity of the screen. However, the volume of material that may be disturbed is considered to be *de minimis* when set into the context of the modelled sediment plumes from capital dredging and disposal during the DWDR Scheme (HR Wallingford, 2015 and 2017). Furthermore, a maintenance disposal licence was granted to DHB in 2019 (L/2019/00401/1), supported by results of sediment sampling within the harbour undertaken in 2019, which permits offshore disposal of dredged material from within the harbour. Sampling point 12 from this plan is the closest location to the proposed scheme location, thereby indicating that the material within the harbour is sufficiently uncontaminated that it is suitable for disposal at sea, and as such, not of concern with regards to any minor temporary disturbance effects.

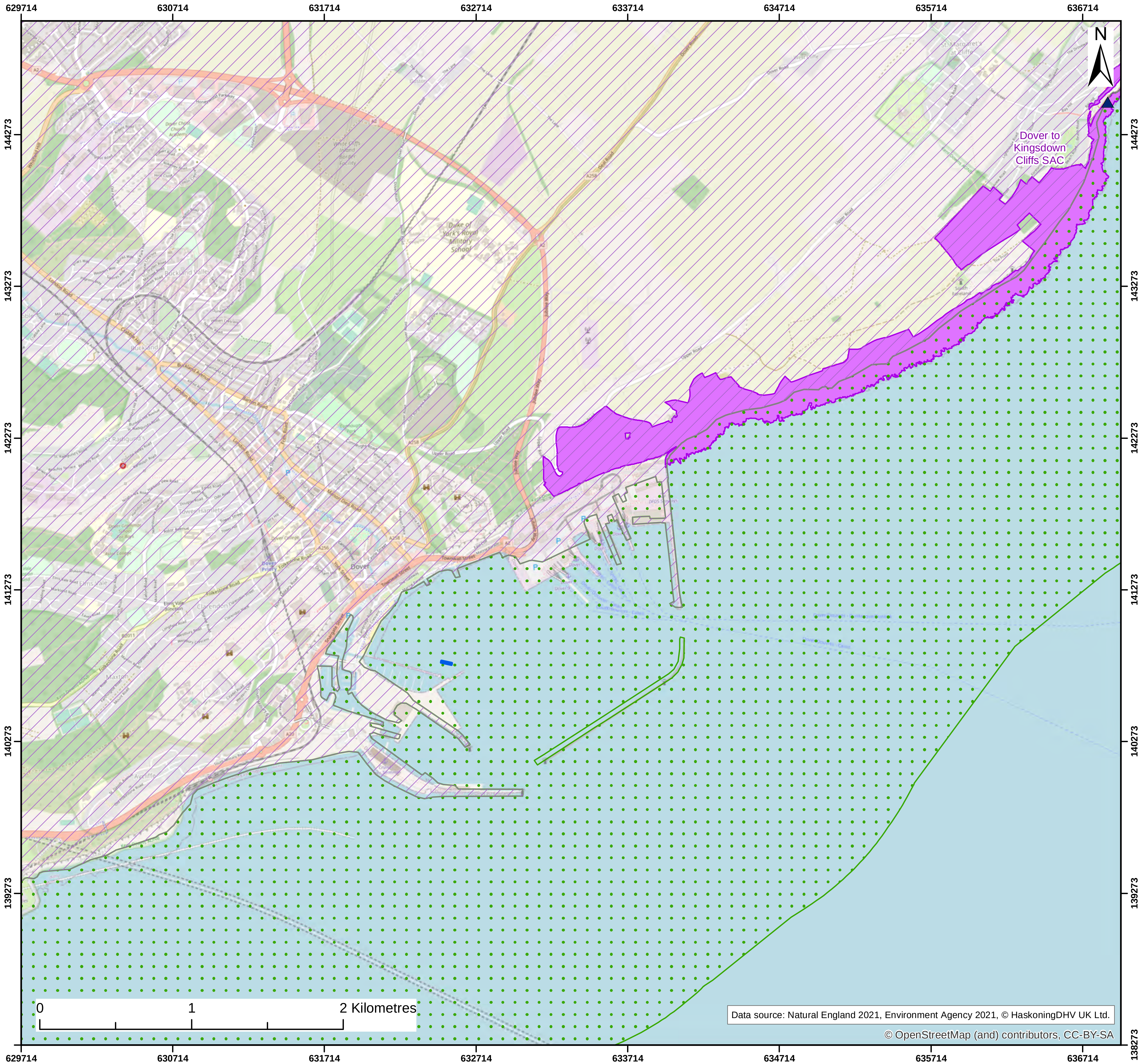
As such, temporary localised increases in SSC due to the installation of the OWS piles would be of **negligible** significance, especially when compared with the minor to moderate impacts from DWDR capital dredging/disposal activities and the dewatering of reclaimed material and the continual maintenance dredging. It should also be noted that, due to the above, this includes an impact of **negligible** significance on waters used for bathing at Dover Beach.

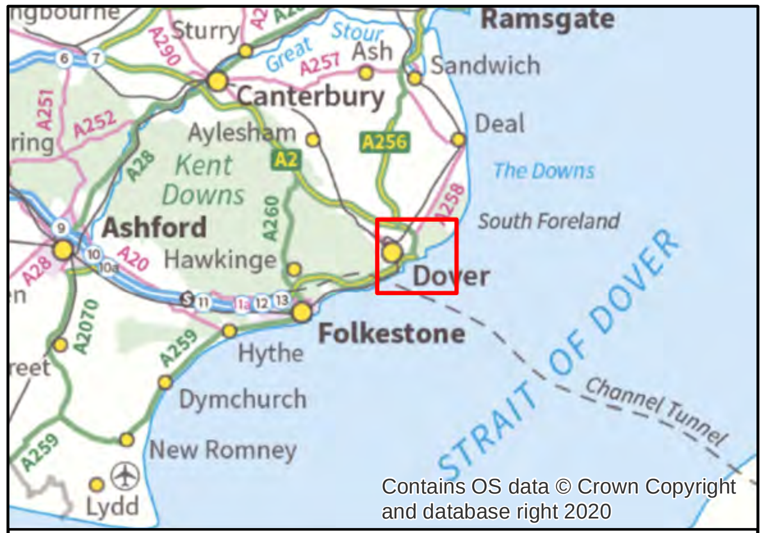
5.2.2 Impacts during operation of the wave screen

5.2.2.1 Changes to the salinity regime

The DWDR Screening Opinion Report (Port of Dover, 2015) indicated that the salinity profile through the Marina and into the Outer Harbour would be similar to that within the original basin system prior to the DWDR Scheme commencing, although with a slightly steeper dilution gradient. The impact of this change in the salinity regime was considered previously to be of minor adverse significance.

Installation of the proposed scheme will have no bearing on the diversion of the Dour since there will be no changes to the outstanding reclamation activities. As such, in the context of the wider DWDR Scheme, the presence of the proposed scheme would have **no impact** on the salinity regime driven by the output from the Dour. Therefore, **no impact** upon water and sediment quality is predicted.





Legend:

- Outer Wave Screen
- Bathing Water Locations
- WFD Groundwater Body
- WFD Coastal Water Body
- Special Areas of Conservation (SAC)

Client:	Project:
Dover Harbour Board	DWDR Outer Wave Screen

Title: WFD Water Bodies in relation to the Outer Wave Screen

Figure: 5.5 | Drawing No: PB1552-RHD-ZZ-ZZ-YE-0008

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
01	09/06/2021	GC	MJ	A3	1:25,000

Co-ordinate system: British National Grid

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5.3 Marine ecology

5.3.1 Impacts during construction of the wave screen

5.3.1.1 Direct loss and alteration of subtidal benthic invertebrate resources within the marine footprint

The DWDR Screening Opinion Report (Port of Dover, 2015) indicated that the wider DWDR Scheme would have minor to moderate adverse impacts on marine ecological receptors, such as benthic habitats and species, due to capital dredging and disposal operations across the DWDR site and the reclamation of c.130,000m^2 of subtidal/intertidal habitat (approximately 50% of which is still outstanding).

By comparison, the OWS has a footprint of approximately 58m^2 and does not require any dredging or land reclamation. Furthermore, given that the proposed scheme is located within the Marina/approaches to the Marina, is also in an area that has been subject to recent capital, and ongoing maintenance, dredging activities.

Given the above, it can be reasonably assumed that direct impacts on benthic receptors arising from the construction of the proposed scheme would be of negligible significance, particularly when considered in the context of the wider DWDR Scheme.

5.3.1.2 Remobilisation of potentially contaminated sediments and subsequent effects on the benthic communities

The DWDR Screening Opinion Report (Port of Dover, 2015) indicated that any impacts on benthic communities from the release of contaminants during the wider DWDR Scheme would be negligible, based on the fact that sediment within Dover Harbour at the time of the marine licence application was permitted for offshore disposal. Since the marine licence was granted, further sediment sampling has been undertaken within the harbour and the maintenance disposal licence (L2019/00401/1) has been renewed, with dredged material from the harbour still permitted for offshore disposal. Sampling point 12 from the supporting sediment sampling plan is the closest location to the proposed scheme location, so the sediment at the Proposed Works location is also considered to be suitable for offshore disposal, and as such, not of concern with regards to any minor temporary disturbance effects. Furthermore, the amount of sediment likely to be disturbed by installation of the proposed scheme will be insignificant when compared with the capital dredging and disposal activities that have already been undertaken for the DWDR Scheme.

Given the above, it can be reasonably assumed that the potential for impacts from released contaminants in sediment disturbed during construction of the OWS would remain of **negligible** significance, particularly when considered in the context of the wider DWDR Scheme and continual maintenance dredging.

5.3.1.3 Indirect smothering impacts on benthic habitats from deposition of suspended sediments

The DWDR Scheme included extensive capital dredging and dewatering of reclaimed material (which is approximately 50% complete), which potentially leads to suspension of sediment and eventual resettlement and, consequently, potential smothering of benthic habitats. The DWDR Screening Opinion Report (Port of Dover, 2015) assessed this impact to be temporary minor adverse, given that the benthic communities within the harbour are frequently subject to disturbance from maintenance dredging and are therefore considered to be relatively resilient to such impacts.

By contrast, construction of the OWS will result in considerably lower levels of sediment suspension, limited to areas within the vicinity of the wave screen, as described in **Section 5.2 (*Marine Water Quality – Impacts During Construction of the Wave Screen*)**. Given the limited area likely to be affected by deposition, which would be restricted to areas within the Marina and Outer Harbour where capital and maintenance dredging has occurred recently (i.e. within the previous two years), potential impacts on benthic communities in the affected areas would be of **negligible** significance, especially when set into the context of the wider DWDR Scheme and continual maintenance dredging.

5.3.2 Impacts during operation of the wave screen

5.3.2.1 Impacts on benthic communities due to redirecting the River Dour

In the DWDR Screening Opinion Report (Port of Dover, 2015) the redirection of the River Dour through the Marina as a result of the DWDR Scheme was assessed to have a minor adverse impact on benthic communities due to more brackish conditions following the freshwater throughput.

Installation of the OWS will have no bearing on the diversion of the Dour, since there would be no changes to the outstanding reclamation activities and therefore no significant obstruction of water flow from the Marina into the Outer Harbour (including freshwater from the Dour). As such, the presence of the wave screen would not alter the effects of the overall DWDR Scheme on the salinity regime and its consequent impacts on the benthic communities within the Marina.

To conclude, **no impact** on marine ecological receptors resulting from the operational phase of the proposed scheme are predicted.

5.4 Marine and coastal ornithology

5.4.1 Background

Overwintering and breeding bird surveys that were carried out in the Western Docks to inform the DWDR Screening Opinion Report (Port of Dover, 2015) demonstrated that the harbour is generally of low interest for breeding and overwintering birds. During the surveys carried out, species of interest recorded have included: 2 pairs of ringed plovers, a small roost of purple sandpiper and occasional sightings of black redstart. However, the site is dominated by gulls and supports a low diversity of species.

5.4.2 Impacts during construction of the wave screen

Displacement or significant disturbance to important species is not considered likely as a result of the construction of the proposed scheme given the context within the overall DWDR Scheme, and the lack of ornithological interests present at the site. Furthermore, the proposed scheme does not have the potential to cause the permanent loss or damage of bird breeding or foraging habitat. **No impact** upon ornithological receptors are therefore predicted.

5.4.3 Impacts during operation of the wave screen

As for the construction phase, **no impact** is predicted upon ornithological receptors as a result of the operational phase of the proposed scheme.

5.5 Shipping and navigation

5.5.1 Background

The proposed scheme consists of installing a ‘wall’ of tubular piles to create a ~70m long wave screen just outside the entrance to Dover Harbour marina within the Port of Dover, which is the busiest ro-ro ferry port in Europe and the second busiest cruise port in the UK.

The Port of Dover is located adjacent to the Dover Strait and is one of the busiest shipping channels in the world. Due to the proposed location of the OWS and that it is a detached structure, there is the potential for the proposed scheme to impact on the safe navigation of vessels and the operational requirements of nearby port facilities within the Port of Dover. Therefore, an assessment of the potential impact on shipping and navigation must be considered.

5.5.2 Impacts during construction of the wave screen

Vessel movements are anticipated during the construction of the proposed scheme as piling will be carried out from either a jack-up barge or a floating barge held in position by spud legs and anchors. In addition, piles may be delivered by road or by sea, depending on the final procurement strategy, and will be stored on an adjacent quayside before being transferred to the piling location by barge. Therefore, there is a potential impact on navigational safety during construction through the risk of collision with other vessels using the area.

No impacts are predicted on commercial navigation from construction activities, as water levels in this part of the Outer Harbour are not sufficient for such vessels to navigate, leading to a very low risk of accidental collision.

With regards to the potential for impacts upon recreational boating activities during the construction phase, DHB has restricted entry in place to certain operational areas of the Port, including the entrance to the Marina. In addition, although the location of the proposed scheme falls just outside the marine licence boundary of the DWDR Scheme (L/2016/00056/8) it is anticipated that the marine licence (once granted) for the proposed scheme will be subject to identical conditions to the existing DWDR marine licence, namely with Conditions 5.1.1 and 5.1.2, which ensures the use of mitigation measures to minimise collision risks during construction, such as use of lights, flags and Notices to Mariners.

With regards to other recreational users (e.g. the rowing club), again the construction of the proposed scheme will be taking place in an area which is already subject to restrictions on recreational use by existing control measures put in place by DHB, therefore no impacts upon such user groups is anticipated during the construction phase.

Given the commitment to suitable mitigation measures as outlined above, it is considered that any potential for impacts upon overall navigational safety during the construction phase would be of **negligible** significance.

5.5.3 Impacts during operation of the wave screen

5.5.3.1 Commercial shipping

Similarly, during the operational phase, the potential for the proposed scheme to be a collision hazard with commercial vessels is limited due to the proposed scheme lying in shallow water outside of the commercial navigation area (**Figure 2-2 and Figure 2-3**). In addition, due to the high density of ferry traffic within the Port of Dover, all vessel movements within the harbour are closely managed by the Port of Dover Vessel Traffic Service (VTS) which will ensure safe navigation around the newly installed structure. It is therefore considered that the risk of commercial vessel collisions with the proposed scheme is of **negligible** significance.

5.5.3.2 Recreational users

With regards to recreational boating traffic, the location of the proposed scheme is adjacent to the existing navigation channel into the Marina. As recreational boating traffic is already subject to controls in this location, no adverse impacts are predicted upon such vessel traffic.

The existence of a Water Safety Strategy for recreational users and new navigation lights active from sunrise to sunset to prevent danger to navigation, (in accordance with Part 3 (Works and Lands), of the original Dover Harbour Consolidation Act, 1954[3]) and the use traffic lights to manage a one-way system to manage entry/ exit from the Marina will mitigate any risks of collisions. Therefore, the risk of recreational vessel collisions with the proposed scheme is also considered to be of **negligible** significance.

The proposed scheme also extends into an area which is designated as 'restricted' for recreational activities, however this overlap is very minor in nature and again located adjacent to the entrance to the Marina, where recreational activities are already actively discouraged for safety reasons and strictly controlled by the Port's existing navigational safety measures.

Given the commitment to suitable mitigation measures as outlined above, it is considered that any potential for impacts upon navigational safety of commercial and recreational vessels during the operational phase would remain as one of **negligible** significance, whilst recognising that the proposed scheme will have an overall beneficial impact in relation to future usage of the Marina.

5.6 Landscape and visual impacts

5.6.1 Background

Dover and its surrounding area have a rich archaeology and history. The ongoing DWDR Scheme has already resulted in considerable visual changes within Dover Harbour as a result of long-term and large-scale construction activities (including demolition, dredging, piling and infilling).

5.6.2 Impacts during construction of the wave screen.

There will be no significant impact on visual impacts as a result of the construction of the proposed scheme. The scale and duration of the proposed construction activities (up to four weeks) is insignificant when compared with the scale of works associated with the ongoing and fully consented DWDR Scheme, and the ongoing presence of both construction plant and operational equipment within Dover harbour. Therefore, it can be reasonably assumed that visual impacts from the plant and equipment required for the construction phase for the proposed scheme would have **no impact**.

5.6.3 Impacts during operation of the wave screen

Once in situ, the maximum elevation of the proposed scheme (which will be permanent) will stand at the same height as other close-by piled structures, at a level of approximately +9.5m CD. Two square platforms will be installed on each end of the OWS for access and placement of navigational lighting.

When compared with tidal levels, this means that the structure will be visible at all tidal states. On average, approximately 2.7m of the structure will be visible on MHWS tides (+6.8m CD), and approximately 8.7m on MLWS tides (+0.8m CD). It is however considered that, located as it will be within an existing heavily developed port setting, this will not lead to significant impacts on existing views of, or within, Dover harbour, especially when considered in the context of the immediately adjacent quay walls and the wider DWDR

[3] 3 *https://www.legislation.gov.uk/ukla/1954/4/pdfs/ukla_19540004_en.pdf*

Scheme. The proposed scheme will therefore have an impact of negligible significance in relation to landscape and visual impacts.

5.7 Marine mammals

5.7.1 Background

Extensive vibratory and percussive piling works were required for the construction of DWDR structures such as the Marina Curve and Extension, Marina Pier and Breakwater and Berths A and C quay walls, plus the restraining piling to pontoons and berths within the Marina. Piling controls and best practice measures have been employed for all piling works undertaken as part of the DWDR Scheme - these measures are set out in the Piling Method Statement (Schedule 7 to the existing Marine Licence) and mandated by Condition 5.2.12 of the Marine Licence. The measures include (*inter alia)* soft-start procedures and the use of marine mammal observers to ensure the area is vacant of marine mammals prior to commencement.

5.7.2 Impacts during construction of the wave screen

5.7.2.1 Acoustic impacts from piling activities

Piling activities within the marine area can generate high levels of underwater sound, which may adversely affect marine mammals. However, due to the geomorphology of the harbour (i.e. the chalk and silt substrate and shallow bathymetry) and the semi-enclosed nature of the harbour, much of the sound is attenuated before travelling beyond the harbour. Similarly, given the existing use of the harbour by high vessel numbers (Dover is one of the busiest ferry ports in Europe), the existing underwater noise levels within the surrounding area are characterised by frequent anthropogenic sounds.

By comparison to the overall DWDR Scheme works, the construction of the proposed scheme requires the installation of a maximum of 61 smaller-diameter piles over area footprint of only 58m^2. Piles will be driven as far as possible using a vibratory hammer, but it is expected that driving to the final elevation will require the use of a percussive hammer. All piling mitigation measures set out in the Marine Licence condition and the Piling Method Statement will be adhered to during construction of the proposed scheme. Furthermore, the piling works will be undertaken over a short period of time (approximately four weeks) and will only be undertaken during daylight hours.

Given the above, it can be reasonably assumed that impacts on marine mammals from the piling required for the proposed scheme would be of a far lower order of magnitude than the piling activities assessed for the wider DWDR Scheme, which itself is considered to have an impact of **negligible** significance.

5.7.3 Impacts during operation of the wave screen

The operation of the OWS is not anticipated to have any significant effects on marine mammal abundance or activity, given that there will be no significant impacts on other ecological receptors (i.e. prey resources such as fish (please see **Section 5.8**). **No impact** is therefore predicted on marine mammals from the operational phase.

5.8 Migratory and resident fish

5.8.1 Background

As per the baseline set out in the DWDR Screening Opinion Report (Port of Dover, 2015), long-term records (1994 to 2013) from trawl surveys identified a total of 37 species within the harbour, including hearing specialists such as herring and diadromous species such as brown trout *Salmo trutta* and European eel

Anguilla Anguilla, which pass through the harbour during their migration up the River Dour. For trout this season is primarily November to February, while for eels it is primarily March to May.

5.8.2 Impacts during construction of the wave screen

5.8.2.1 Acoustic impacts on fish populations from piling activities

As with marine mammals, acoustic disturbance from piling activities may adversely affect migratory and resident fish species, particularly those that are considered hearing specialists and use swim bladders for hearing (and hence are more sensitive to increased sound pressure).

The DWDR Screening Opinion Report (Port of Dover, 2015) indicated that the impact of piling from the DWDR Scheme would have a temporary minor adverse impact on migratory and resident fish, given that the piling mitigation measures described above in **Section 5.4** and **Section 2.3**, notably the use of soft-start procedures, would be in place. However, as described above, the magnitude of piling works required for construction of the OWS is significantly lower than those that have been completed, or are still to be undertaken, for the overall DWDR Scheme.

Given the above it can be reasonably assumed that, with the continued adherence to the piling mitigation measures (as outlined in **Section 2.3**), the impact on fish of acoustic disturbance from the proposed piling would be of **negligible** significance in the context of the wider DWDR Scheme.

5.8.3 Impacts during operation of the wave screen

5.8.3.1 Impacts on changes to freshwater flow patterns on diadromous fish using the River Dour

Migratory fish are sensitive to changes in salinity, using visual and chemical cues, and use such changes to locate their destination. At the onset of the DWDR Scheme, the course of the Dour ran through Wellington Dock and the original marina basin system (i.e. Tidal Basin, Granville Dock and Wick Channel). Since then, the navigation channel between Wellington Dock and the Marina has been completed so the Dour now enters the Outer Harbour through the navigation channel and the Marina.

As described in the **Section 5.2 - *Water and sediment quality***, the OWS will not significantly affect the salinity profile within the lowest reaches of the diverted river course (i.e. within the Marina), beyond that already expected as part of the wider DWDR Scheme, which is assessed in the DWDR Screening Opinion Report as being of **negligible** significance. **No additional impacts** are therefore predicted from the operational phase of the proposed scheme.

5.9 Archaeology and heritage

5.9.1 Background

Although the location of the proposed scheme falls just outside the boundary of the existing DWDR Scheme marine licence (L/2016/00056/8), the marine heritage study area used in the assessment to support the marine licence application for the DWDR scheme covered the proposed location of the OWS. Therefore, survey findings for the background DWDR Scheme have been used to identify the baseline to identify the potential impacts at the location of the proposed scheme.

5.9.2 Impacts during construction of the wave screen

5.9.2.1 Impact on existing structures

Figure 5-6 shows the distribution of seabed features of archaeological interest within the area of the Western Docks. This has been informed by sidescan sonar surveys and includes magnetic anomalies as well as subsurface prehistoric assets (see Page 449 of the T2 Environmental Statement (Royal HaskoningDHV, 2009). Since the commencement of the DWDR Scheme a Heritage Steering Group (HSG), comprising Historic England, Kent County Council's (KCC) Heritage Conservation Team and Dover District Council's (DDC) Conservation Officer, has been monitoring the ongoing archaeology and heritage work packages, co-ordinated by the retained archaeologist (Royal HaskoningDHV) and DHB's internal conservation officers. All archaeological assessments and mitigation measures were set out and agreed with the HSG through a combined Written Scheme of Investigation (WSI) which addressed both onshore and offshore elements of the DWDR scheme (Royal HaskoningDHV, 2015d).

Given that it is a detached structure, the proposed scheme adjacent to the new marina curve quay wall, will have an impact of **negligible** significance upon existing structures additional to that already mitigated for by the DWDR scheme.

5.9.2.2 Impact on subsurface / potential buried structures

The screening report identified that the DWDR Scheme had potential to disturb or destroy buried features or structures of post-medieval date or earlier, and sites with potential for paleoenvironmental remains, and that mitigation would be required within the footprint of the Wellington Dock Navigation Cut.

As part of the DWDR scheme a programme of geoarchaeological assessment and subsequent archaeological monitoring and excavation was carried out by Archaeology South East (ASE) within the footprint of the Wellington Dock Navigation Cut (ASE, 2020).

The marine footprint of the proposed scheme is a maximum area of 58m^2 and is located offshore within an area already subject to capital dredging and construction. Therefore, there will be an impact of negligible significance to buried features or structures of post-medieval date or earlier additional to that already mitigated for by the DWDR scheme.

5.9.2.3 Impact on marine structures, wrecks and wreckage

In support of the T2 Development Plan at the Western Docks, an assessment of sidescan sonar, magnetometer and bathymetry data was undertaken by Marine Archaeology Limited (MAL) (2008). This was followed by a diver survey of selected geophysical anomalies undertaken by Wessex Archaeology (2009). The diver survey did not identify the presence of any archaeologically significant material at any of the identified anomaly locations and, as such, further diving investigations were not recommended.

Further Marine geophysical data was acquired for the DWDR scheme by EGS in January and February 2015, the results of which were reviewed by the retained archaeologist (Royal HaskoningDHV, 2015e). The data indicated the presence of a large number of individual items of debris although no identifiable wrecks or aircraft were identified. The majority of these items of debris were located beyond the footprint of the DWDR scheme. It was concluded that the likelihood of intact buried structures being present had been reduced by historic dredging activity and that the high levels of modern fishing and port related debris known to be present within the Western Docks area reduced the potential for identifying material of archaeological interest.

Prior to the commencement of capital dredging, in advance of the construction of the new marina, an investigation of Unexploded Ordnance (UXO) was carried out by Boskalis and a number of the identified anomalies were ground-truthed. All targets investigated as part of the UXO target were reviewed by the retained archaeologist (Royal HaskoningDHV) and, whilst the majority were found to comprise debris of no archaeological interest, 24 archaeological finds were recorded. These comprised 10 anchors, two items of historic UXO, a divers weighted boot, a glass fishing float, a railing, three railway tracks, two timber finds and four further items of metal debris. All of these finds have been addressed through the DWDR Protocol for Archaeological Discoveries and all items of wreck have been reported to the Receiver of Wreck. The DWDR Protocol, incorporated within the WSI and agreed with the HSG, has been implemented across the DWDR scheme and remains in place until the end of construction at which time a final report will be compiled setting out the significance of all discoveries encountered during the course of the development.

As the footprint of the proposed scheme is located within an area which has previously been subject to investigation and capital dredging it is anticipated that there will be an impact of **negligible** significance to marine structures, wrecks and wreckage. Together with the limited footprint of the works (maximum area of less than $58m^2$) and the nature of the works (piling) the potential for further discoveries is anticipated to be very low, since the area has already been extensively surveyed and there are no geophysical anomalies in the immediate vicinity of the proposed structure (**Figure 5-6**). Furthermore, several identified targets located within the wider vicinity of the proposed structure were investigated by Boskalis as part of the UXO investigation and clearance for DWDR and excluded from further study. Nonetheless, should an unexpected discovery be encountered during works to install the wave screen, the Protocol for Archaeological Discoveries remains in place across the DWDR scheme to ensure that all discoveries can be reported, and archaeological advice provided in a timely manner.

5.9.2.4 Impact on buried landsurfaces / palaeochannels

Geoarchaeological assessment of vibrocores and boreholes acquired for the DWDR scheme, supported by the archaeological assessment of seismic data, as well as samples acquired as part of works undertaken for the Wellington Dock Navigation Cut, has been undertaken by ASE (2016, 2020) as part of the ongoing archaeological works for the DWDR scheme.

Within the offshore areas, a marine geophysical (seismic sub-bottom) and vibrocore survey was undertaken (ASE, 2016). A deposit model was created using this data and incorporating the results of onshore borehole survey and further data points provided by Martin Bates, based upon previous work undertaken in Dover. These investigations identified Pleistocene and Holocene deposits which had the potential to preserve palaeoenvironmental remains suitable for assessment. A large palaeochannel and several channel edge locations were identified within the model. A total of six vibrocores were then selected for geoarchaeological recording and subsampling, with four being selected for assessment, which was carried out at Fugro's laboratories, Great Yarmouth. However, the results of the assessment demonstrated that successive dredging from the Tudor period up until the present day has had a detrimental effect on the preservation of deposits and that there is very low potential for the preservation of early palaeoenvironmental or archaeological remains.

Located within this previously assessed area, therefore, the proposed scheme will have an impact of **negligible** significance upon buried landsurfaces or palaeolandscape features.

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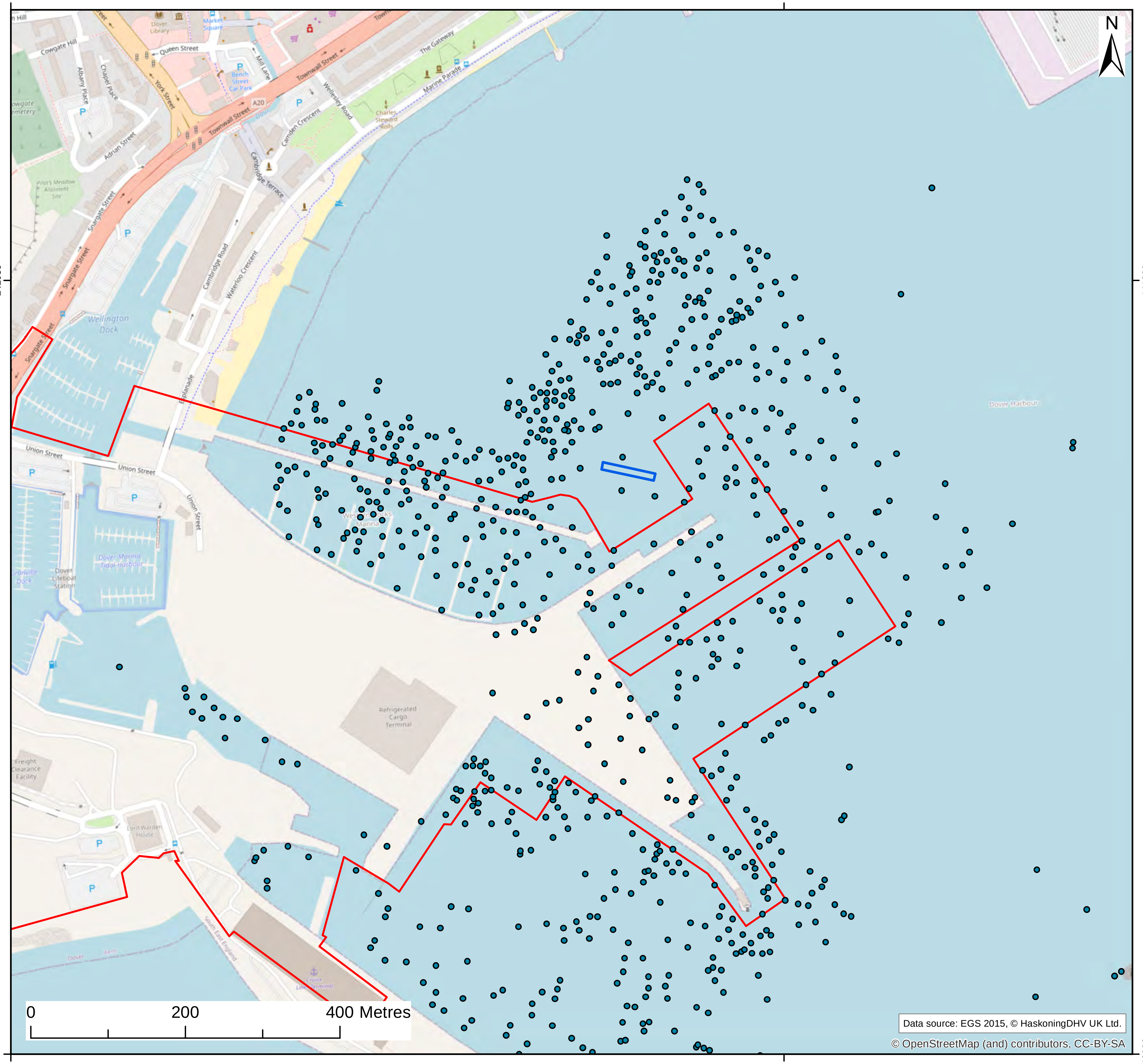

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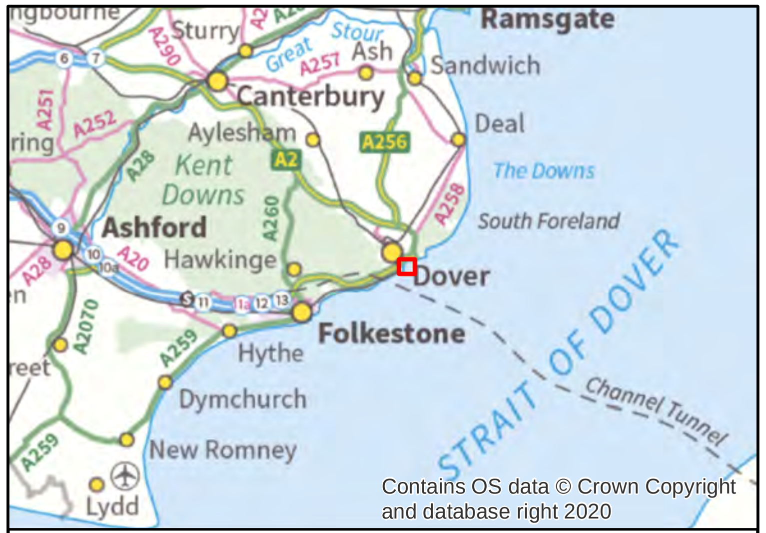

Legend:

- Outer Wave Screen
- DWDR Scheme Boundary
- EGS Magnetic Anomalies
- Assessed Palaeochannel Location (ASE)
- Assessed Vibrocores (ASE)

Client: Dover Harbour Board

Project: DWDR Outer Wave Screen

Title: Seabed Features of Archaeological Interest in the vicinity of the Proposed Wave Screen and Outstanding DWDR Scheme

Figure: 5.6

Drawing No: PB1552-RHD-ZZ-ZZ-YE-0009

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Co-ordinate system: British National Grid

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5.9.3 Impacts during operation of the wave screen

5.9.3.1 Impact on historic landscape character

The 2015 Screening Report (RHDHV, 2015c) indicated the impact on historic landscape character was anticipated to be moderate adverse due to the delivery of large commercial buildings in the DWDR Scheme. However, the proposed buildings were considered appropriate for a commercial dockside setting and mitigation by design was included to minimise the loss of historic character. Whilst the currently proposed scheme represents a further structure within the assessed historic landscape, the limited extent of the installed structure, in close proximity to the new Marina Curve, means that the OWS is not incongruous and would not change the significance of effect, over and above that previously assessed and mitigated for the DWDR scheme. As such, the impact of the proposed scheme on historic landscape character is considered to be of **negligible** significance, particularly when considered in the context of the wider DWDR Scheme.

5.9.3.2 Impact of hydrodynamic changes on wrecks and historical landsurfaces

The wider DWDR Scheme is assessed to have no significant impact on wrecks and historical landsurfaces as a result of long-term hydrodynamic changes. Such an impact from the proposed scheme, when considered within the context of the wider scheme, is therefore considered to be of **negligible** significance.

5.10 Accidents and disasters

The main accident or disaster risk relating to the proposed scheme is associated with collision risk with commercial or recreational vessel use, both during the construction and operational phases, as the proposed works are in areas of boat use. However, as discussed in **Section 5.5**, the adoption of best practice measures by DHB harbour master, in addition to the expected inclusion of conditions to minimise the risk of collisions (as per the existing DWDR Scheme marine licence), it is considered that the risk of accidents and disaster are extremely low.

Specific conditions that relate to these risks include Conditions 5.1.1 and 5.1.2 which ensure the use of mitigation measures to minimise collision risks during construction (such as use of lights, flags and Notices to Mariners); and the use of a VTS whereby entry and exit from the marinas are managed using a one-way system controlled by traffic lights. Further measures to reduces these risks are through, the use of a Water Safety Strategy for recreational users and new navigation lights active from sunrise to sunset to prevent danger to navigation, (in accordance with Part 3 (Works and Lands), of the original Dover Harbour Consolidation Act, 1954). As such, **no impacts** relating to accidents and disasters are anticipated.

5.11 Climate change

The construction works have the potential to result in the release of greenhouse gases due to the vessel movements that are anticipated during piling from either a jack-up barge or a floating barge. In addition, piles may be delivered by road or by sea, depending on the final procurement strategy. However, the works are very small scale in nature, and if delivered by road, given there are only 61 piles to be installed it is expected this would result in an insignificant number of additional HGV movements, when placed in the context of daily traffic volumes experienced within the Port of Dover. In addition, the operation of the proposed scheme will not lead to an increase in greenhouse gas emissions as it is a passive structure with minimal maintenance requirements predicted involving infrequent replacement of galvanic anodes and since navigation lights will be solar powered with a long life expectancy. Therefore, **no impacts** relating to climate change are anticipated.

6 MARINE CONSERVATION ZONE ASSESSMENT

There are five MCZs within the vicinity of the proposed scheme:

- Dover to Folkestone MCZ;
- Dover to Deal MCZ;
- Folkestone Pomerania MCZ;
- Goodwin Sands MCZ; and
- Foreland MCZ.

Figure 6-1 shows the location of these MCZs.

An MCZ Assessment will be completed in support of the marine licence application for the proposed scheme. This will include the potential for impacts from both the construction and operational phases of the proposed scheme. It will follow the two-staged approach set out in the MMO's existing guidance 'Marine Conservation Zones and Marine Licensing' (MMO, 2013). This approach is further outlined below.

Stage 1 MCZ Assessment

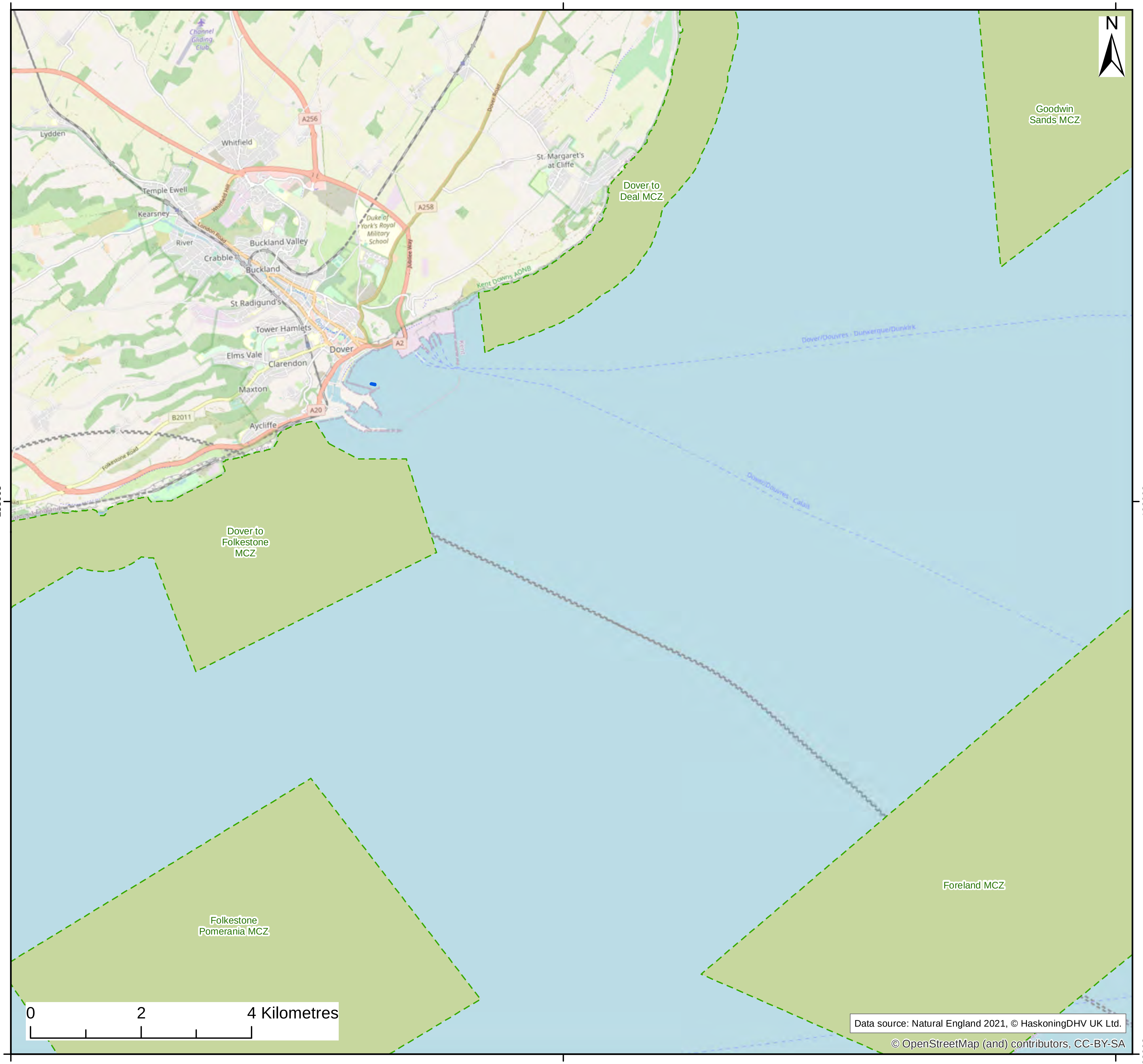
The Stage 1 MCZ Assessment will consider the extent of the potential impact of the proposed scheme on the relevant MCZs in more detail. At this stage the conservation objectives for the MCZs need to be considered. The conservation objectives for MCZs are high level criteria describing the desired condition of the MCZ features. There are two objectives for features within an MCZ, namely whether the features are in the desired favourable condition and need to be maintained in this condition, or, whether the features are not in the desired favourable condition and need to be recovered to that condition. The Stage 1 MCZ Assessment will look at whether the proposed scheme could potentially affect these objectives; that is, impact the site so that the features are no longer in favourable condition, or prevent the features from recovering to a favourable condition. The MMO also needs to be satisfied that it can meet its requirements under the MCAA to further the conservation objectives for the site. This requirement sits with the MMO as the licensing authority to ensure that the condition of the site is improved and enhanced wherever possible. The MMO will use information supplied by the applicant with the licence application, advice from the Statutory Nature Conservation Bodies (SNCBs) and any other relevant information to determine whether (as set out in MMO guidance).

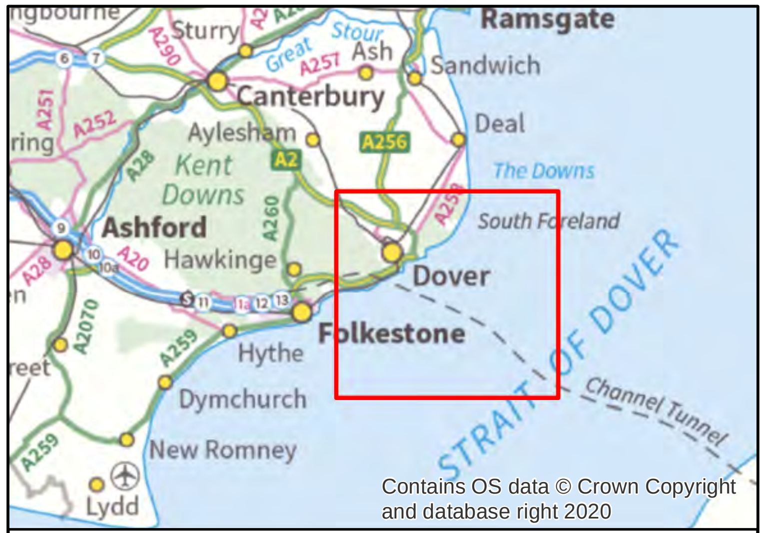
Given the very limited extent of any potential adverse impacts arising from the installation of the proposed scheme there is no impact-receptor pathway for any of the features of the Folkestone Pomerania, Goodwin Sands and Foreland MCZs. However, given the closer proximity of Dover to Deal and Dover to Folkestone MCZs to the proposed scheme, assessments of the potential for impacts is required. The relevant pressures (from piling) that will be assessed in these MCZ Assessments are:

1. Direct impacts on the surface and substrate of the seabed (i.e. abrasion, habitat loss/alteration and disturbance)
2. Changes in SSC and subsequent smothering and siltation
3. Underwater noise changes
4. Visual disturbance
5. Contaminant release
6. Hydrodynamic/sedimentary changes

Where there is a possibility that feature(s) of the MCZs may be affected by construction or operation activities associated with the proposed scheme, the sensitivity of the feature(s) will be considered as per

Natural England's 'Advice on Operations' (Natural England 2021a, 2021b). However, due to the limited size of the proposed scheme, it is expected that any potential impacts will be very limited, particularly when taken into the context of the wider DWDR Scheme. It is therefore considered unlikely that a Stage 2 MCZ Assessment will be required. This will be fully documented in the Environmental Report to be submitted as supporting information of the HRO and marine licence applications.





Legend:

- Outer Wave Screen
- Marine Conservation Zones (MCZ)

Client:	Project:
Dover Harbour Board	DWDR Outer Wave Screen

Title:

MCZs in the Vicinity of the Works

Figure:	6.1	Drawing No:	PB1552-RHD-ZZ-ZZ-YE-0010		
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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7 CUMULATIVE IMPACT ASSESSMENT

7.1 Background to cumulative impact assessment

There is no legislation that specifically applies to cumulative impact assessment (CIA) or that outlines how such assessment should be undertaken. However, the EIA Directive and associated EIA Regulations require consideration of direct impacts and any indirect, secondary and cumulative effects of a project. In their Guidelines for EIA (2004), IEMA define cumulative impacts as:

> *"the impacts on the environment which result from incremental impacts of the action when added to other past, present and reasonably foreseeable future actions …"*

CIA assesses the potential impacts of a proposed development with other past, present (current) and reasonably foreseeable (proposed) plans and projects.

With respect to 'past' projects, a useful ground rule in CIA is that the environmental impacts of schemes that have been completed should be included within the environmental baseline; as such, these impacts are already taken into account in the EIA process for a development. Consequently, generally completed projects can be excluded from the scope of CIA. However, the environmental impacts of recently completed projects may not be fully manifested and, therefore, the potential impacts of such projects should be taken into account.

Projects that are currently being constructed or that are in the planning process (where sufficient information is publicly available), as well as on-going activities that have the potential to influence the same environmental parameters as the proposed scheme, are the focus of CIA.

7.2 Potential for cumulative impacts

Of particular importance in defining likely cumulative impacts are the following aspects, all of which are important in deriving the overall cumulative impact significance:

- The temporal and geographic (spatial) boundaries of the effects of each project;
- The interactions between relevant activities of each project and the overall environment/ecosystem; and
- The thresholds of sensitivity of the existing environment.

Generally, measures to avoid or minimise significant adverse impacts at the project level will also tend to reduce or avoid the potential for any accumulation of impact with other plans or projects.

The outstanding construction activities associated with the remainder of the DWDR Scheme have the potential for a pathway for in-combination effects with the proposed scheme, however given the location and scale of works remaining, only some limited piling activities relating to port vessel berths at the mouth of the marina are located in the same vicinity as the proposed scheme. Piling required for both the proposed scheme and the remaining DWDR works will also be short-term in nature, and subject to the commitments with regards to mitigation measures as outlined in Condition 5.2.12 of the existing marine licence for the DWDR Scheme (L/2016/00056/8) (see **Section 2.3** of this report). As such, no significant cumulative effects are predicted between the proposed scheme and the remaining works related to the DWDR scheme.

Table 1 presents a list of ongoing projects in the vicinity of the proposed scheme, according to the MMO's Explore Marine Plans[4] interactive mapping tool. The projects have the potential to have a cumulative impact with the Proposed Works.

***Table 1** Projects relevant to cumulative impact assessment*

MLA and Licence	Status	Project Name	Description	Distance from Proposed Works	Timescales
MLA/2015/00420/8 L/2016/00056/8	Ongoing construction	DWDR Scheme	Outstanding construction activities	0km	Due to be completed by December 2023
MLA/2019/00055 L/2019/00401/1	Ongoing maintenance	Maintenance Disposal Activities Port of Dover	Disposal of dredged material removed from within Dover Harbour for the purposes of maintaining port operations and safe navigation	0.6km	November 2029
MLA/2019/00027	Ongoing maintenance	Southern Water Coastal Outfalls Maintenance	Southern Water undertake crucial maintenance on their coastal discharge outfalls. This maintenance licence allows Southern Water to carry out low impact activities without the need for repeated applications for 10 years.	0km	December 2029
MLA/2019/00116 L/2020/00093/1	Ongoing demolition	Dover Harbour Board Berth 1 removal	Demolition and removal of the redundant roll-on / roll-off (RORO) linkspan structure (Berth 1) in Dover Harbour. This is part of a wider project to demolish Dover Cargo Terminal	1.7km	Due to be completed by December 2021

The projects noted in **Table 2** all include mitigation measures to reduce potential impacts to sensitive receptors.

It is concluded that with the inclusion of suitable mitigation measures, no significant cumulative impacts would be expected. There is limited potential for further indirect impacts from the works. As noted previously, a WFD assessment will be undertaken to support any marine licence application for the proposed scheme. As part of this assessment, specific cumulative impact assessments will be undertaken to consider the potential for in-combination impacts to water quality, designated sites and protected species.

As noted in **Section 5**, there will be no significant increase in expected construction or operational impacts beyond those already assessed and mitigated for in the DWDR Scheme. Given that minimal environmental impacts have been predicted as a result of the proposed scheme, it is concluded that there would be no potential for significant cumulative impacts with other planned and proposed plans and projects.

[4] *https://explore-marine-plans.marineservices.org.uk/*

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8 SUMMARY AND NEXT STEPS

The information in this Environmental Screening Report is provided to support a request to the MMO for a Screening Opinion in relation to the potential impacts of the proposed scheme.

Given the conclusions reached in this report, it is considered that the proposed scheme does not constitute a Relevant Project for the purposes of EIA. Once confirmed by the MMO, it is proposed that a HRO application will be submitted to the MMO with an accompanying application for a marine licence. These applications will be supported by an Environmental Report and all necessary Drawings, as well as a Statement in Support for the HRO, using the MMO's recommended template.

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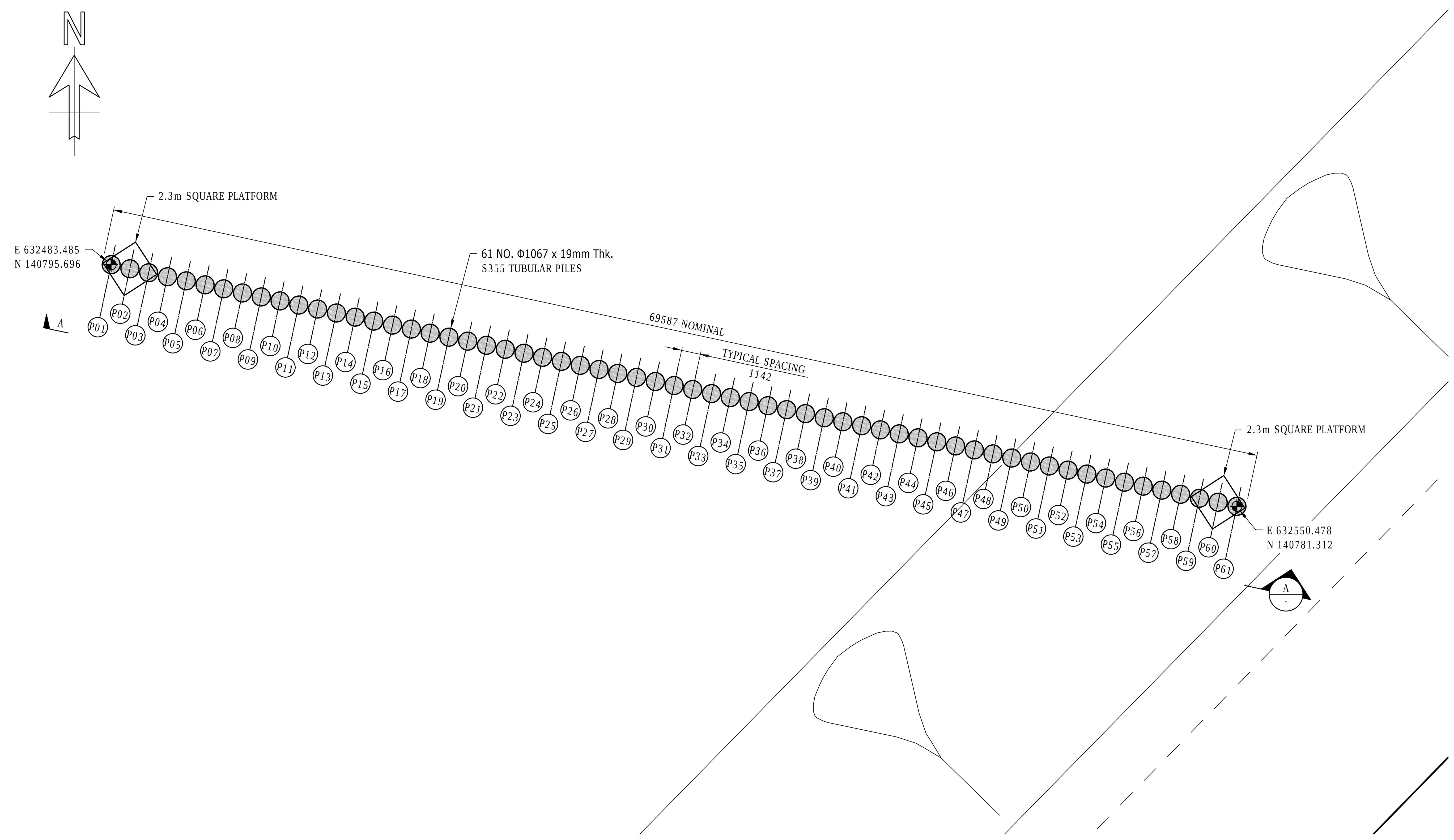
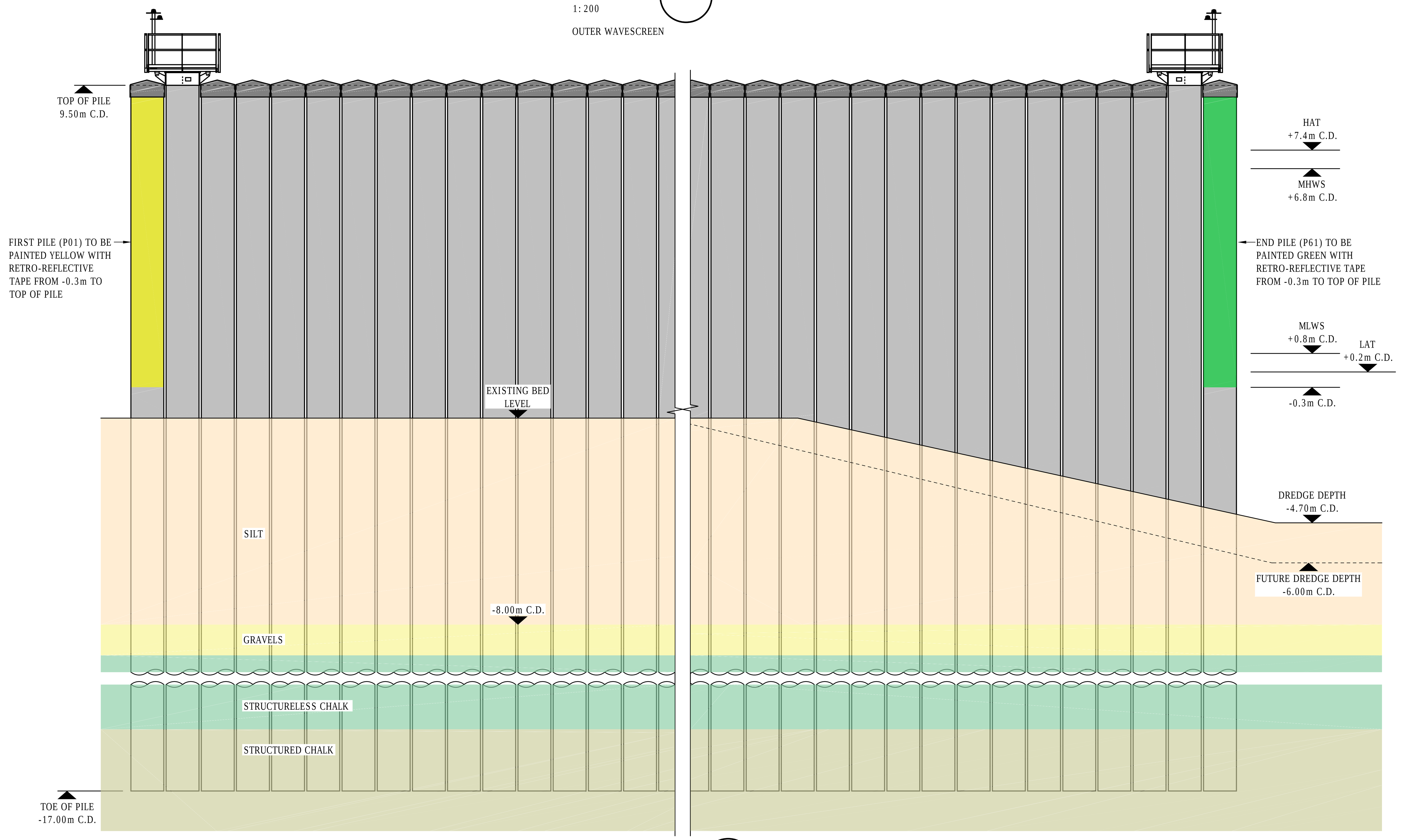
APPENDIX 1 - 11690-RAM-ZZ-XX-DR-CM-00201 - Outer Wavescreen - General Arrangement



PLAN

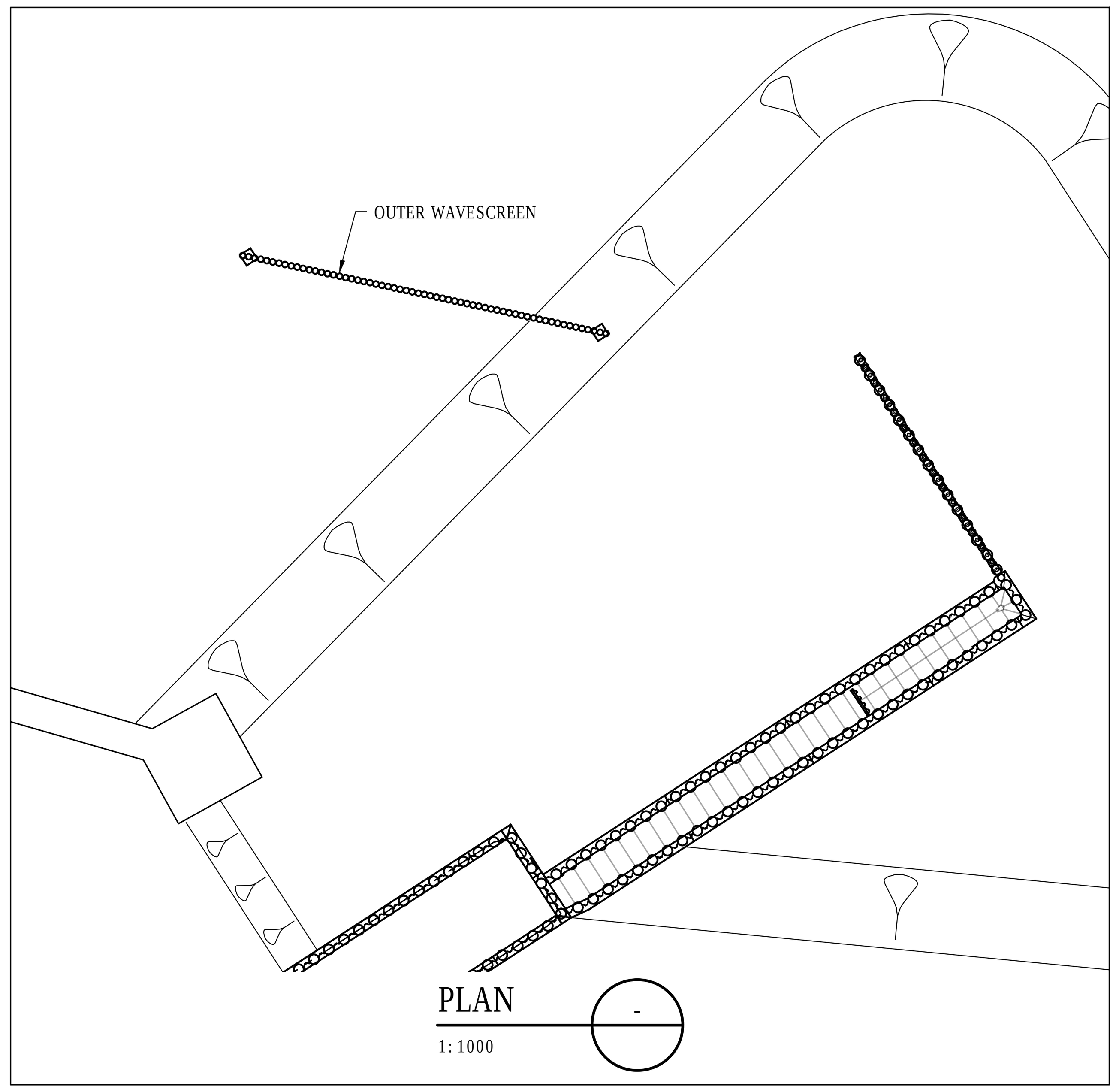
1: 200

OUTER WAVESCREEN



ELEVATION A-A

1: 100



PLAN

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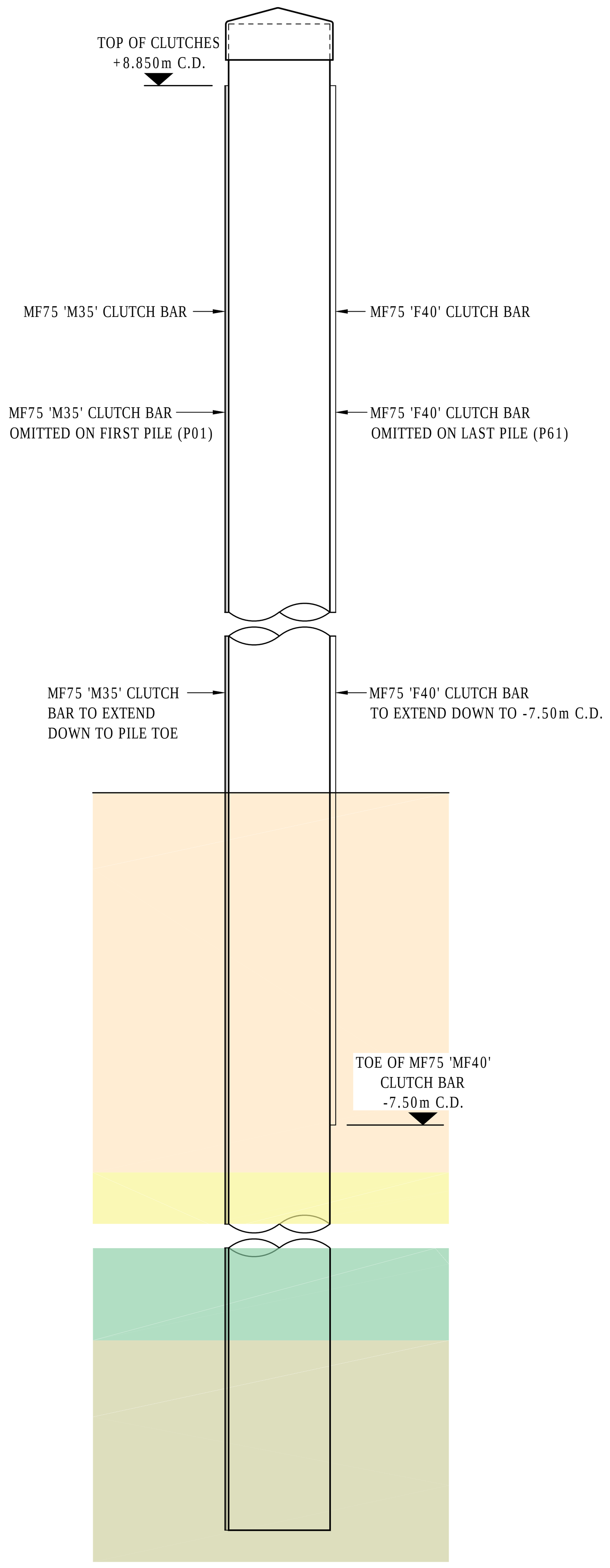
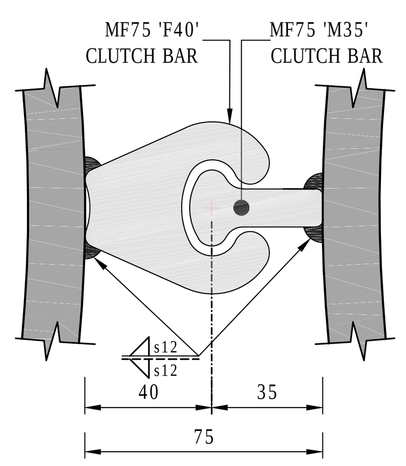


ELEVATION

1: 50

TYPICAL PILE



DETAIL 01

1: 2

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

NOTES BELOW ARE ADDITIONAL TO HAZARDS/RISKS NORMALLY ASSOCIATED WITH THIS TYPE OF WORK. FOR DETAILS REFER TO CDM RISK REGISTER...

CONSTRUCTION (INCLUDING DEMOLITION AND REMOVAL OF EXISTING STRUCTURAL COMPONENTS)

ACTIVITIES ADJACENT TO WATERS EDGE.

OPERATIONS, MAINTENANCE

VESSEL COLLISION.

BED LEVEL DIFFERENCE SHOULD NOT EXCEED 1m ON EITHER SIDE OF WAVESCREEN.

DISMANTLING / DEMOLITION (FUTURE)

REFER TO GENERAL NOTES & THE PRINCIPAL CONTRACTOR FOR MORE INFORMATION ABOUT THE RISKS ASSOCIATED WITH THIS WORK.

Notes

General Notes

1. DO NOT SCALE FROM THIS DRAWING .
2. ALL DIMENSIONS ARE IN MILLIMETRES U.N.O.
3. ALL LEVELS ARE IN METERS RELATIVE TO CHART DATUM U.N.O.
4. ALL MATERIALS AND WORKMANSHIP WILL BE DEFINED AS IN THE SPECIFICATION UNLESS NOTED OTHERWISE.
5. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS.
6. FOR THE RELATIONSHIP BETWEEN THE CHART DATUM AND ORDNANCE DATUM REFER TO THE DIAGRAM BELOW:

00.000m OD

3.667m

00.000m CD

TRANSFORMATION FORMULAE

PSEUDO GRID TO NATIONAL GRID	NATIONAL GRID TO PSEUDO GRID
NGE = (PGE - 162.4962)*1.00025694044)	PGE = (NGE / 1.00025694044) + 162.4962)
NGN = (PGN - 36.3221)*1.00025694044)	PGE = (NGE / 1.00025694044) + 36.3221)

TIDAL LEVELS

TIDAL LEVEL DESCRIPTION	ABBREVIATION	LEVEL
HIGHEST ASTRONOMICAL TIDE	HAT	+7.4m C.D.
MEAN HIGH WATER SPRINGS	MHWS	+6.8m C.D.
MEAN HIGH WATER NEAPS	MHWN	+5.3m C.D.
MEAN SEA LEVEL	MSL	+3.8m C.D.
MEAN LOW WATER NEAPS	MLWN	+2.1m C.D.
MEAN LOW WATER SPRINGS	MLWS	+0.8m C.D.
LOWEST ASTRONOMICAL TIDE	LAT	+0.2m C.D.

7. GRADES OF STEEL:
   TUBULAR PILES - S355
   MF CLUTCH - S355
   ALL OTHER STEELWORK TO BE S355.
8. STEEL STRUCTURES PROVIDED WITH 50 YEAR CORROSION ALLOWANCE BASED ON EN 1993-5 CORROSION RATES
9. CATHODIC PROTECTION PROVIDED TO PREVENT CORROSION (INCLUDING ALWC/MIC) IN SUBMERGED REGIONS.
10. FOR PROPOSED DREDGING ZONES REFER TO DRAWINGS:
    1620003182-DWDR-RAM-XXX-00-DR-CW-10005
    1620003182-DWDR-RAM-XXX-00-DR-CW-10006
    1620003182-DWDR-RAM-XXX-00-DR-CW-10007
11. THE FOLLOWING SPECIFICATIONS SHOULD BE REFERRED TO:
    - 03182-RAM-XXX-R-SP-00100 - MATERIALS AND WORKMANSHIP SPECIFICATION - GENERAL
    - 03182-RAM-XXX-R-SP-00104 - MATERIALS AND WORKMANSHIP SPECIFICATION - PILING

Rev.	Description	Date	By / Chk'd	App'd
P01	PRELIMINARY	21/04/21	LH / PE	GW

PRELIMINARY

DOVER WESTERN DOCKS REVIVAL

NEW MARINA OUTER WAVESCREEN GENERAL ARRANGEMENT

Project No:	Scale (@A1):	Drawn:	Date:
1620011690	AS SHOWN	LH	APR. 2021

Drawing No.: 11690-RAM-ZZ-XX-DR-CM-00201

Rev: P01

APPENDIX 2 - HR Wallingford, 2021. Dover Marina: Wave reduction modelling. Report number DEM8459-RT003-R02-00

HR Wallingford
Working with water

Dover Marina

Wave reduction modelling

DEM8459-RT003-R02-00

May 2021

Document information

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Project name	Dover Marina
Report title	Wave reduction modelling
Report number	RT003
Release number	R02-00
Report date	May 2021
Client	Dover Harbour Board
Client representative	Mark Hill
Project manager	Nigel Tozer
Project director	Nigel Bunn

Document authorisation

Prepared	Approved	Authorised

Document history

Date	Release	Prepared	Approved	Authorised	Notes
11 May 2021	02-00	NPT	NPB	NPB	Incident only wave conditions at Breakwaters G and B added.
03 Feb 2021	01-00	NPT	NPB	NPB	Sensitivity tests expanded and review of conditions observed within Marina during December 2020
26 Nov 2020	00-07	NPT	NPB	NPB	Sensitivity tests added
24 Jul 2020	00-06	NPT	NPB	NPB	Layout G+B+H1 results added
09 Jul 2020	00-05	NPT	NPB	NPB	Layout G2+B+J1 results added
08 Jun 2020	00-04	NPT	NPB	NPB	Layout G+B results included
19 May 2020	00-03	NPT	NPB	NPB	Layout G+A1 results included
04 May 2020	00-02	NPT	NPB	ICC	Layout G results included
17 Mar 2020	00-01	NPT	NPB	ICC	Issued for discussion

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1. Introduction

The construction of the Dover Western Docks Revival (DWDR) development within Dover Harbour is nearing completion. The new marina has not opened, but conditions within the new marina occasionally lead to adverse movement of the floating pontoons. HR Wallingford was commissioned by Dover Harbour Board (DHB) to update the existing ARTEMIS wave disturbance model with a view to better understanding the wave conditions that lead to the pontoon movement and then potentially consider possible ways to reduce wave conditions such that pontoon movement is reduced to acceptable levels e.g. as per the published guidance.

This report describes the wave disturbance modelling carried out to assess the performance of a range of potential different mitigation measures with the aim of reducing wave heights within the marina and at the outer berths down to acceptable levels.

2. Methodology

The wave modelling study described in this report follows previous work to calibrate an existing ARTEMIS of Dover Harbour against measured wave conditions within the recently constructed Marina (HR Wallingford, 2020). The ARTEMIS model incorporates the latest bathymetric survey data and uses boundary wave conditions derived using a SWAN model, which in turn is forced with offshore wave and wind conditions from the Met Office.

A range of mitigation measures for reducing wave heights within the marina were originally discussed during a workshop held in Wallingford in December 2019. This workshop was attended by representatives from DWDR, HR Wallingford and DWDR's supervising engineer from Royal Haskoning DHV.

Without significantly altering the layout of the marina, the two agreed concepts for reducing wave conditions within the marina were beach renourishment and a range of breakwater solutions. The aim of the beach renourishment is to reduce wave reflections back towards the marina entrance and the breakwater solutions to have a more direct role of blocking wave energy propagating into the marina entrance. A wide range of breakwater solutions discussed during the workshop, and some of those layouts were taken forward and refined as part of the current study, through ongoing discussion at each stage with the client.

In order to complete the work efficiently, model tests were carried out for a limited set of important wave conditions with estimated return periods of 1 and 50 years.

3. Partial beach renourishment

By causing incoming waves to break and dissipate energy, the shingle beaches in Dover harbour provide a natural and effective source of wave damping. The shingle beaches up against the seawall along the eastern parts of Marine Parade (Sections A, B and C as shown in Figure 3.1) are at some of their lowest levels in recent times. For example, beach profiles 4 and 5, from the Channel Coast Observatory as plotted in Figure 3.2 show a significant reduction in levels since 2015. Because of this, wave reflection from the defences behind the beaches is relatively high, particularly at high water levels. Historically this has not been a problem, but it appears that reflection from the defences along Marine Parade is one of the primary mechanisms for wave energy to propagate into the marina.

Figure 3.1: Seawall Sections and Beach Profiles “4” and “5”

Source: Google Earth

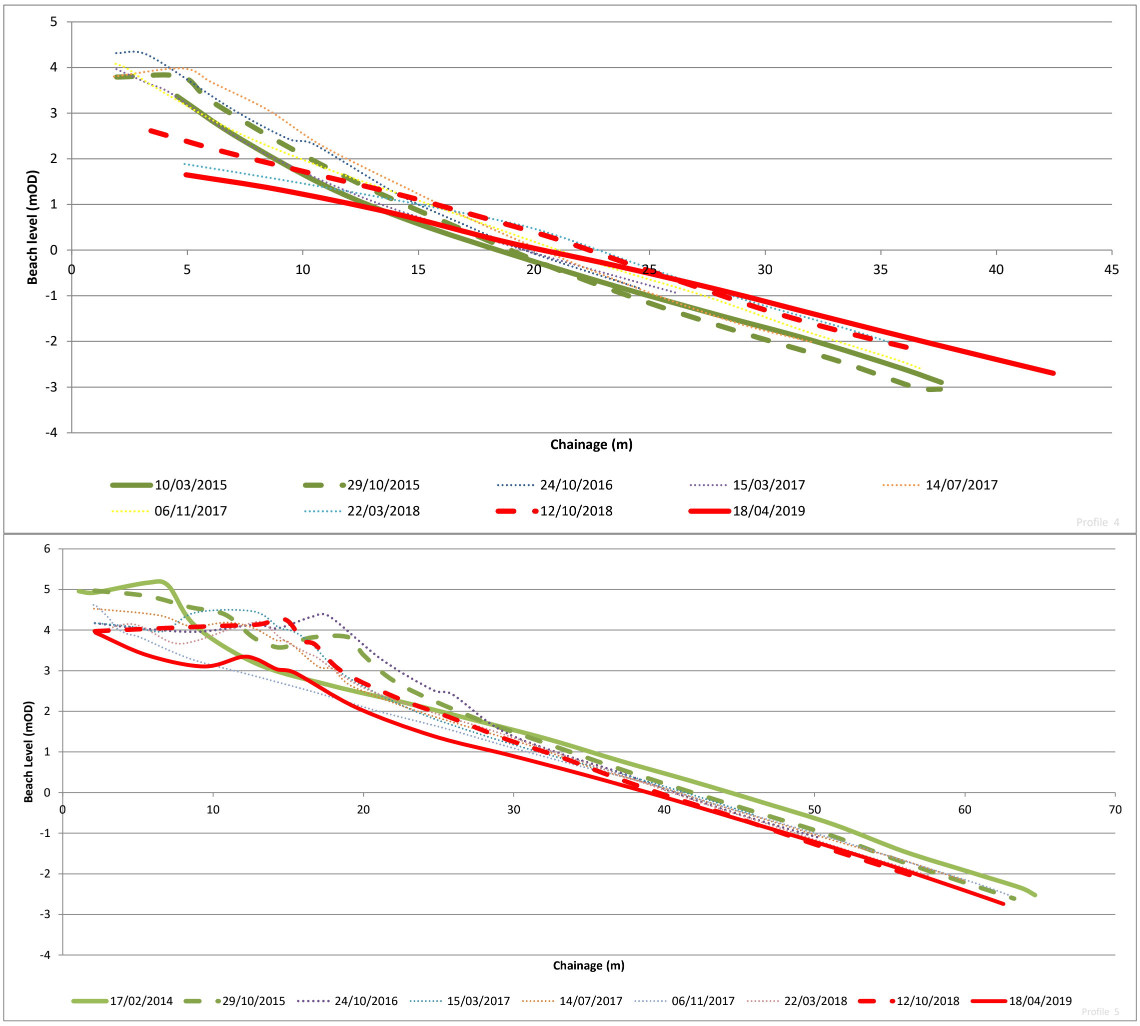

Figure 3.2: Beach levels (Profiles 4 and 5) (m OD)

Source: Channel Coast Observatory.

The full renourishment of these sections of beach is expected to lead to a significant reduction in reflection and therefore wave heights with the marina, but the associated cost is expected to be expensive and may involve a lengthy planning application. Partial renourishment back to pre-2015 levels is a more viable option, as would be in line with routine maintenance in order to protect these important sea defences.

The following modelling work was to model wave conditions within the marina due to partial renourishment of the beaches (Sections A+B, and Sections A+B+C, as shown in Figure 3.1).

3.1. Model bathymetry

The bathymetry of the calibrated ARTEMIS model was updated along the beaches to incorporate the 2018 topographic survey data (DHB drawing *2018_A_114 Beach Survey (Nversion)_elev25cm_res100cm_size20_DSM (Final)*) (Figure 3.3). This survey includes the beach but also the sloping and stepped seawall structures. The baseline bathymetry shown in Figure 3.4 represents the seabed and beach bathymetry up until the toe of the seawall structure (which is modelled by a reflection coefficient rather than in the bathymetry). Where there is a full height beach and the reflection coefficient is set at 0.2 to be representative of a shingle beach, the bathymetry has been set to ensure a water depth of 4m to at the toe of the beach. To model the partial beach renourishment of Sections A, B and C, the beach levels in the model were raised by 1m. Figure 3.5 and Figure 3.6 show the bathymetries in these models.

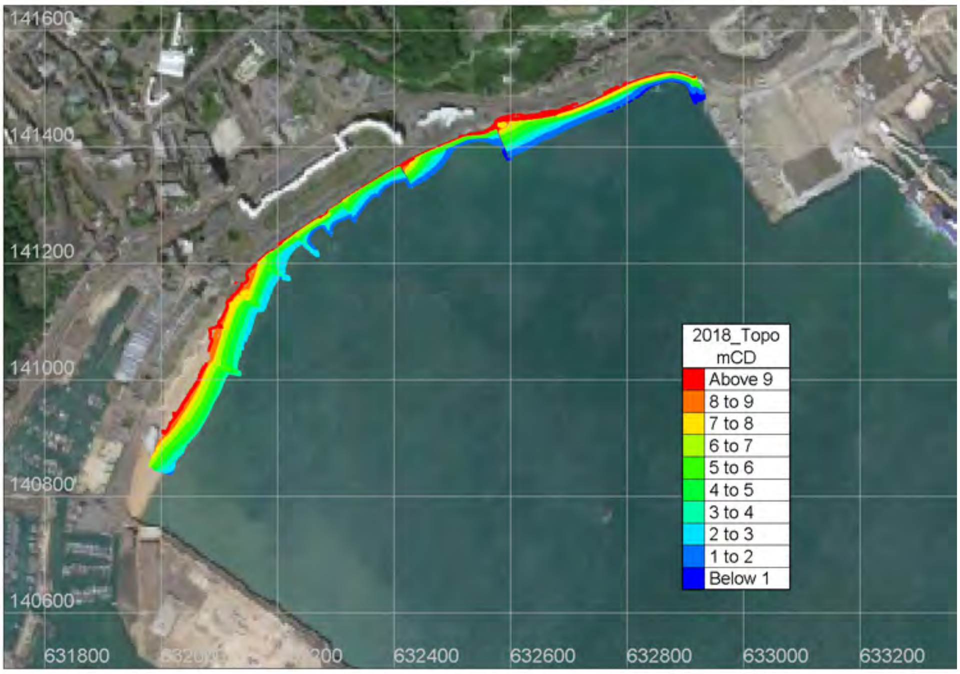

Figure 3.3: 2018 Topographic Survey data

Source: DHB

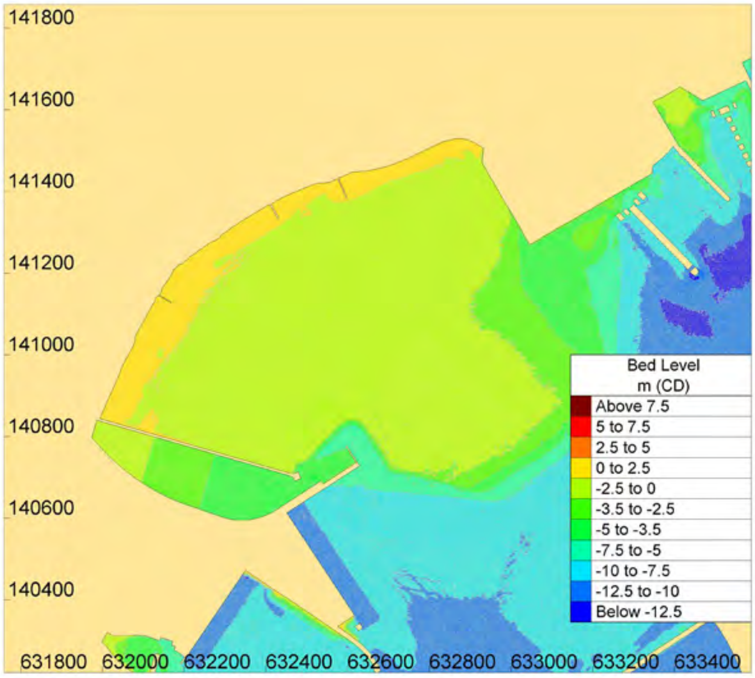

Figure 3.4: ARTEMIS model depths around Dover Harbour (m relative to CD) – Baseline (including Pier F)

Source: HR Wallingford

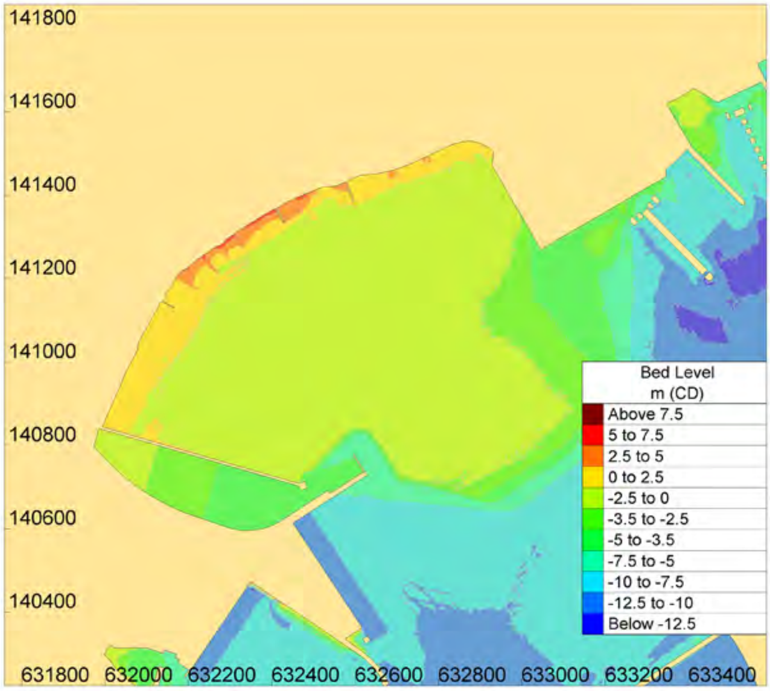

Figure 3.5: ARTEMIS model depths around Dover Harbour (m relative to CD) – 2018 beach levels + Sections A+B raised by 1m

Source: HR Wallingford

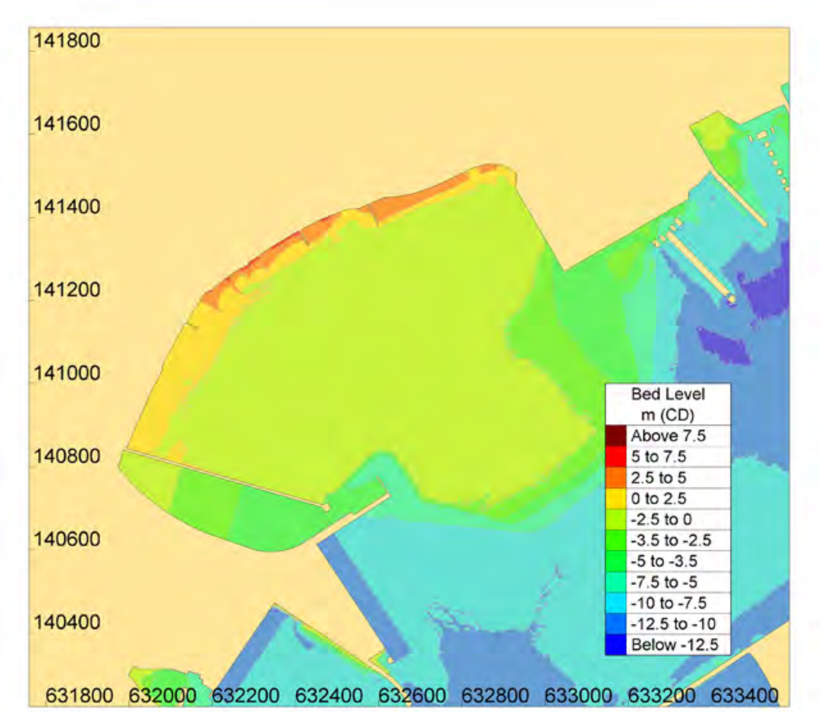

Figure 3.6: ARTEMIS model depths around Dover Harbour (m relative to CD) – 2018 beach levels + Section A+B+C raised by 1m

Source: HR Wallingford

3.2. Reflection coefficients

Along sections where the beach was renourished sufficiently to prevent direct impact of the waves on the seawall, model reflection coefficients were reduced to a reflection coefficient of 0.2 (corresponding to a well-nourished shingle beach). Elsewhere, and including where the waves meet the hard defences along Marine Parade, the reflection coefficients were unchanged from the calibrated values represented in Ref 1 (reproduced below). The reflection coefficients applied are shown in Figure 3.7 to Figure 3.10.

Figure 3.7: Reflection Coefficients (Calibrated model (Storm 6h)

Source: HR Wallingford

Figure 3.8: Reflection Coefficients (with Pier F model)

Source: HR Wallingford

Figure 3.9: Reflection Coefficients (Sections A+B partially renourished)

Source: HR Wallingford

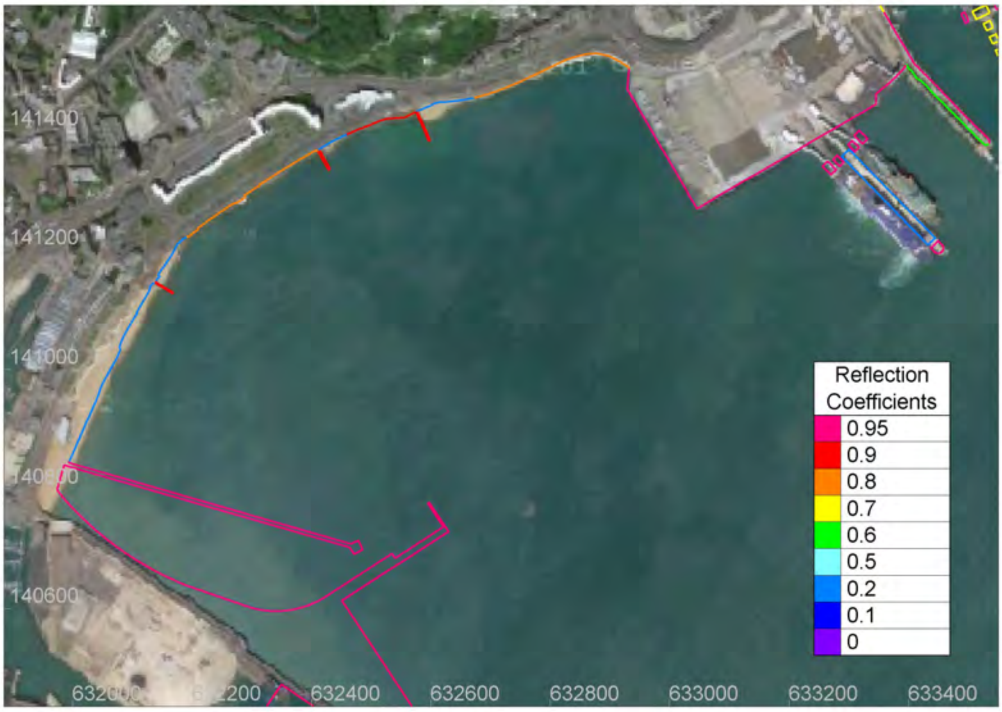

Figure 3.10: Reflection Coefficients (Sections A+B+C partially renourished)

Source: HR Wallingford

3.3. Model test conditions

The ARTEMIS models were run for one test condition referred to in Reference 1 as Storm 6. This wave condition corresponds with conditions around high water on 2 November 2019 when severe wave conditions within the marina were observed. This wave condition has an estimated return period of approximately 1 year. The wave condition applied in ARTEMIS is summarised in Table 3.1.

Table 3.1: Incident wave conditions applied in ARTEMIS

Storm Number	Significant wave height Hs	Peak Period Tp (s)	Mean wave Direction (°N)	Tide Level (mCD)	Tide Level (mOD)
6	3.8	8.7	178	+6.0	+2.33

Source: HR Wallingford SWAN model

3.4. Model results

Model results are presented as colour contour plots of significant wave height with vectors showing mean wave direction. Model results for the calibrated Baseline layout, partial renourishment along beach Sections A+B, and partial renourishment along Section A+B+C are presented. Figure 3.11 to Figure 3.13 show the model results within the harbour and Figure 3.14 to Figure 3.16 within the marina.

Figure 3.11 and Figure 3.12 show that nourishing the beach results in lower wave heights to the north of the marina, slightly lower wave heights in the area of more direct wave penetration between the western entrance and the eastern end of Marine Parade. Figure 3.12 shows a small increase in wave height along the west facing side of the Freight Services Area. This is expected to be because of a slight increase in wave reflection along Section C due to the change in bathymetry in this area between the baseline and the models incorporating the 2018 bathymetry.

Figure 3.13 shows that extending the partial renourishment to also include Section C leads to further reduction in wave heights, most notably in the area of more direct wave penetration.

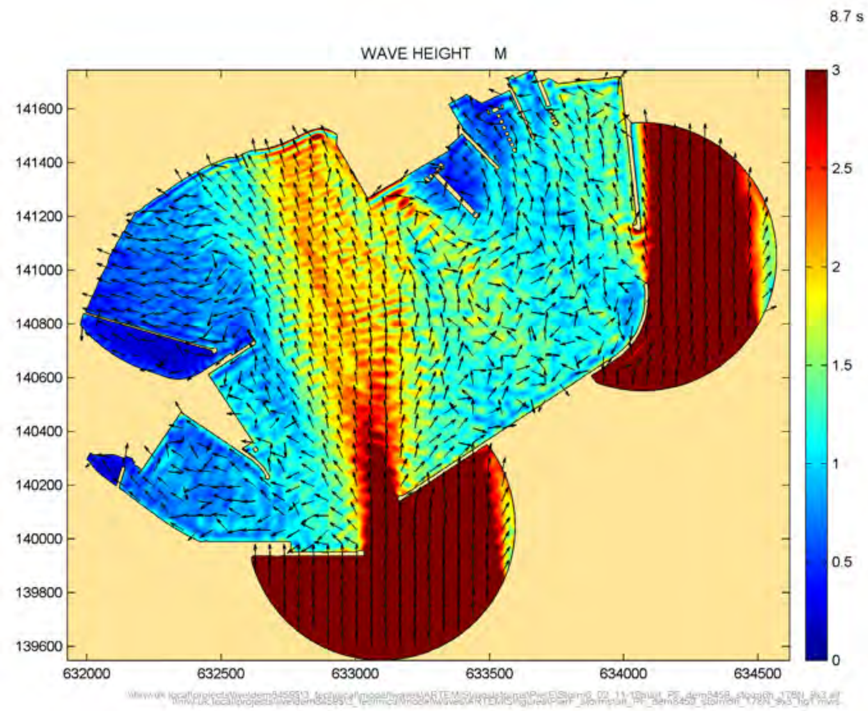

Figure 3.11: Wave conditions inside harbour (Baseline: Storm 6)

Source: HR Wallingford

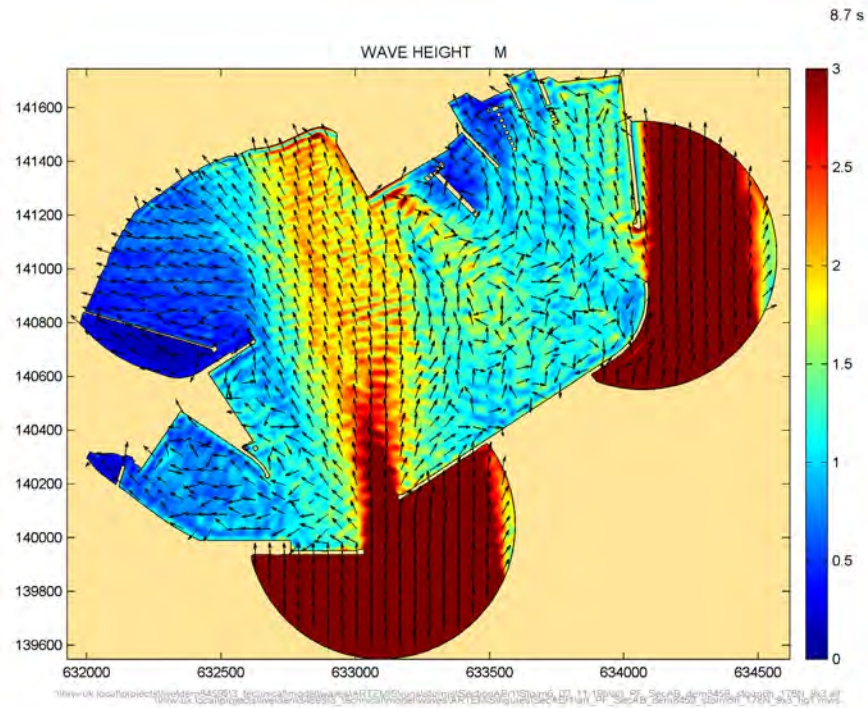

Figure 3.12: Wave conditions inside harbour (Sections A+B: Storm 6)

Source: HR Wallingford

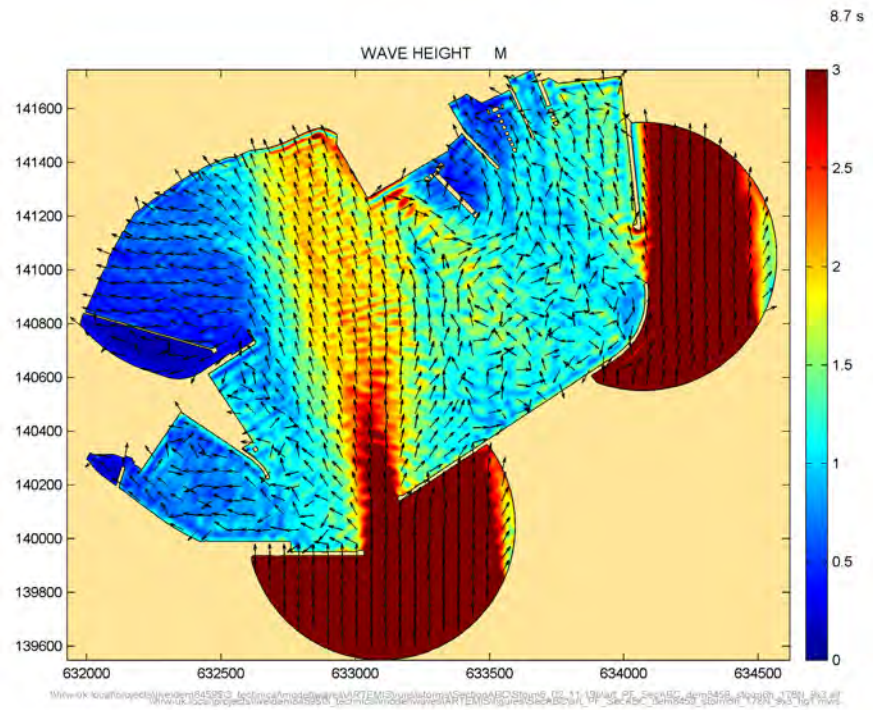

Figure 3.13: Wave conditions inside harbour (Sections A+B+C: Storm 6)

Source: HR Wallingford

Figure 3.14 to Figure 3.16 show the model results within the marina. The results show a noticeable reduction in wave height due to the partial renourishment of Section A+B, and a further reduction when also partially renourishing Section C.

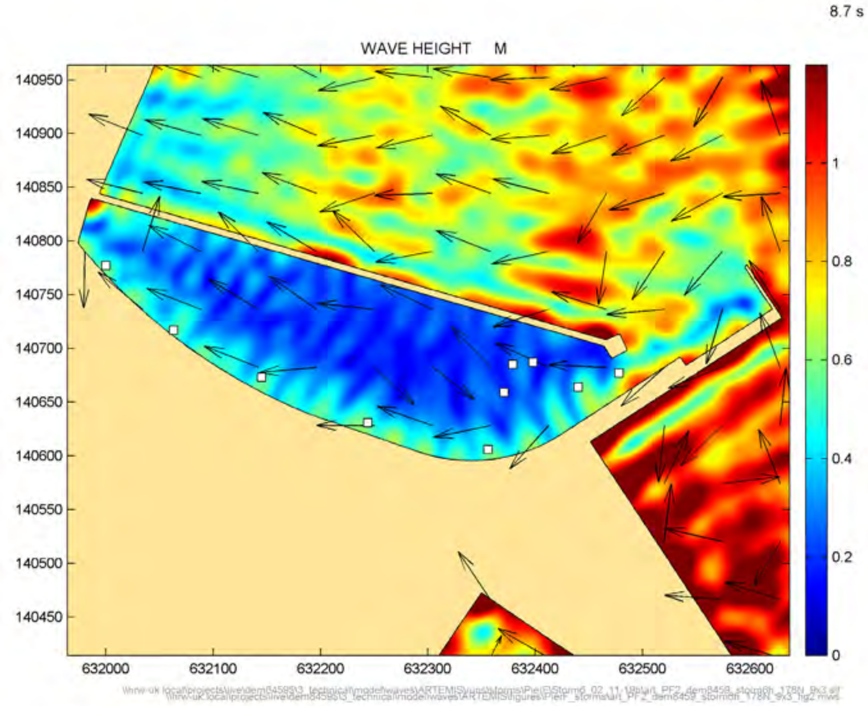

Figure 3.14: Wave conditions inside marina (Baseline: Storm 6)

Source: HR Wallingford

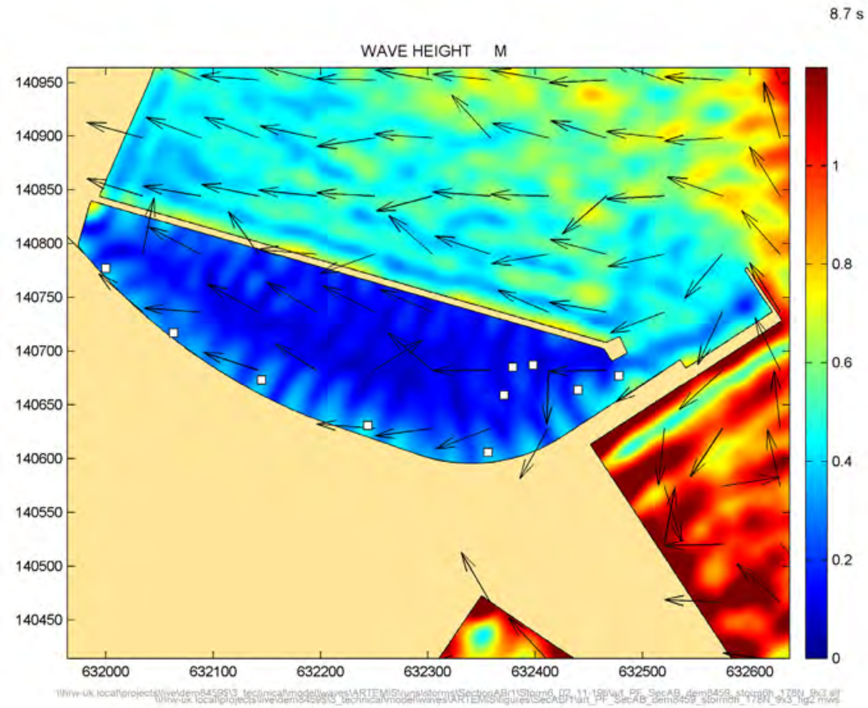

Figure 3.15: Wave conditions inside marina (Sections A+B: Storm 6)

Source: HR Wallingford

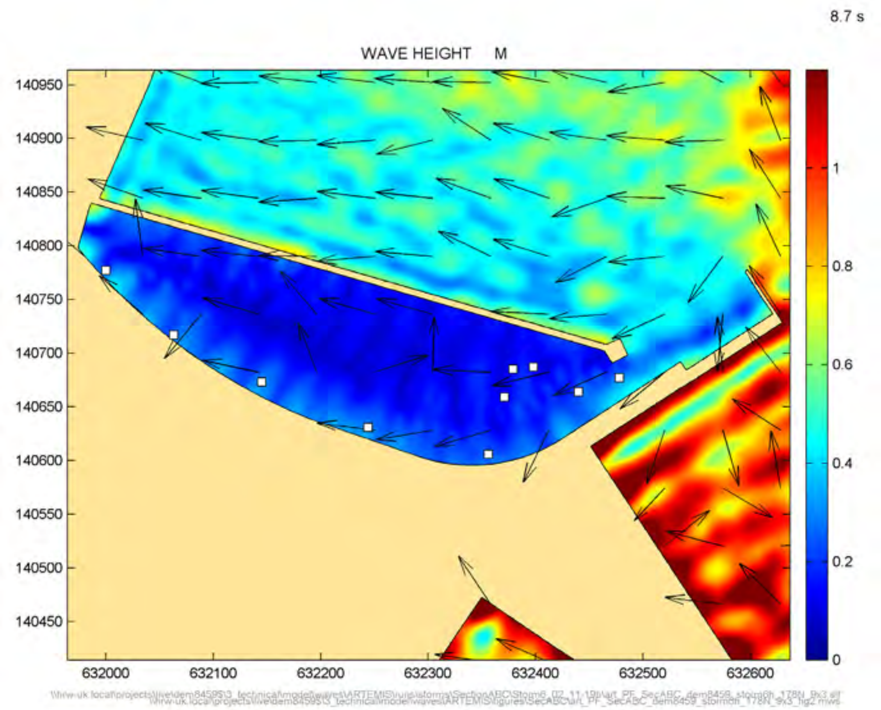

Figure 3.16: Wave conditions inside marina (Sections A+B+C: Storm 6)

Source: HR Wallingford

Model results are also extracted at the points (as shown in Figure 3.17) within the marina. The results are summarised in the histogram shown in Figure 3.18. This figure quantifies the reduction in wave heights due to the partial renourishment of beach Sections A+B and Sections A+B+C, respectively.

Figure 3.18 shows that the baseline case, representative of the beach condition during the autumn of 2019, for Storm 6 gives wave heights at most points greater than 0.3m as given in the guidelines for good wave climates in marinas (Ref. 3). Figure 3.18 shows that the partial renourishment of Section A+B results in lower wave heights within the marina, but several locations where the significant wave heights are over 0.3m with significant wave heights of 0.5m predicted at the buoy location, i.e. higher than the recommended heights. The results also show that the recommended wave heights for good conditions are slightly exceeded with the partial renourishment of Sections A+B+C, with predicted wave heights between 0.3 and 0.4m at some of the point locations.

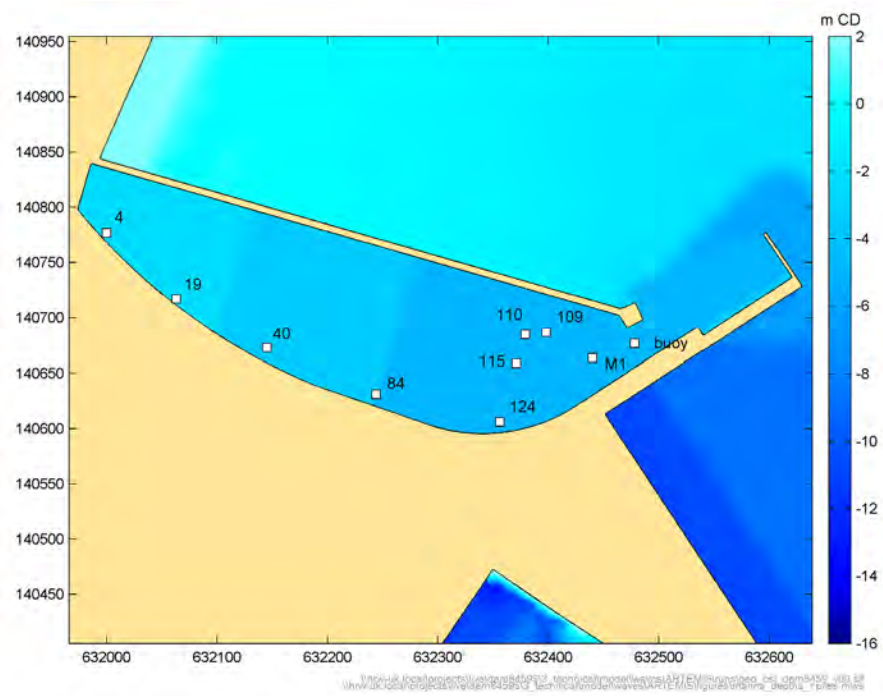

Figure 3.17: Model depths within Marina and output locations

Source: HR Wallingford

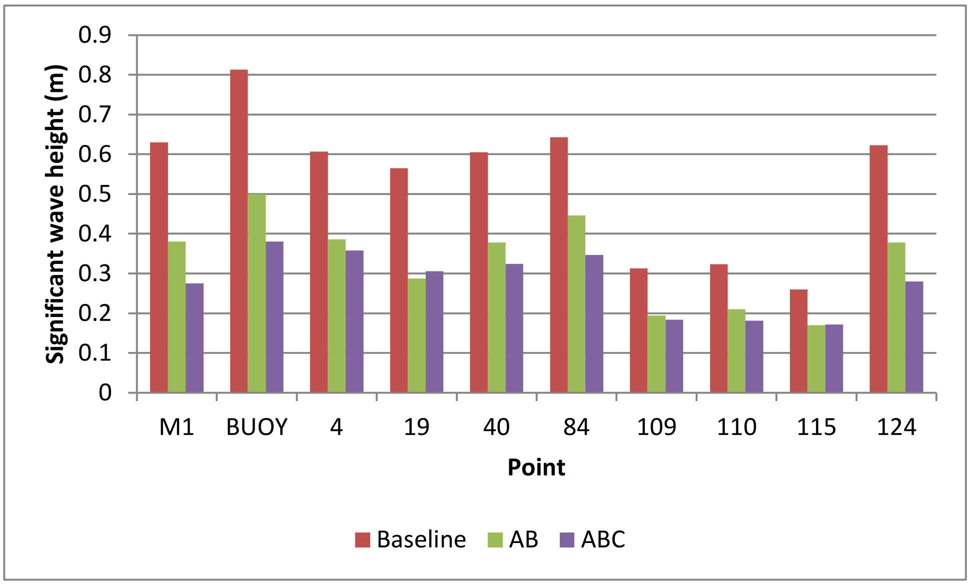

Figure 3.18: Predicted wave height variation within marina

Source: HR Wallingford

4. Layout G

Several breakwater options were discussed during a workshop held at HR Wallingford during December 2019. This included a vertical screen breakwater referred to as Layout G, across the marina entrance, as indicated in Figure 4.1. This breakwater was modelled in ARTEMIS with a length of approximately 14m leaving a marina entrance width/aperture of approximately 18m.

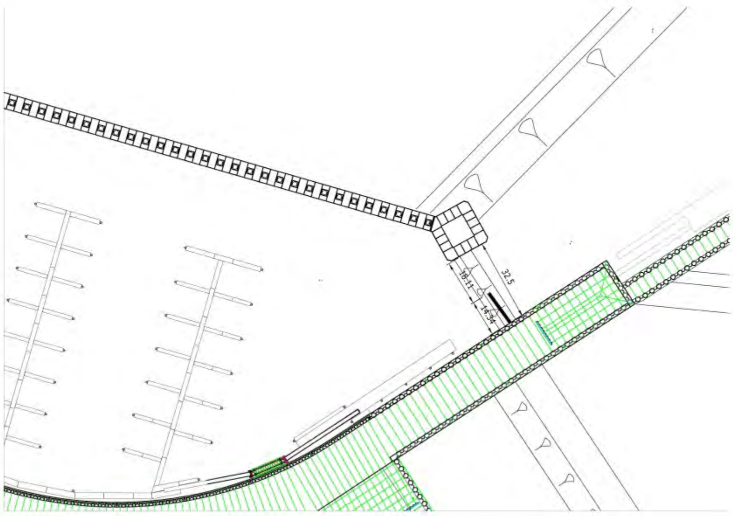

Figure 4.1: Breakwater G

Source: HR Wallingford/DHB

It should be noted that HR Wallingford has not assessed Option G from a navigational perspective. HR Wallingford has drawn some of the international standards to the attention of Dover Port noting they indicate slightly larger widths than provided by Option G. However, it is understood that the Harbour Master at Dover Port has assessed the Option G layout and is content with the width which will help maintain a one-way traffic system into and out of the marina.

4.1. Model bathymetry

The model bathymetry for Layout G is exactly the same as for the baseline case (including Pier F) as shown in Figure 4.2.

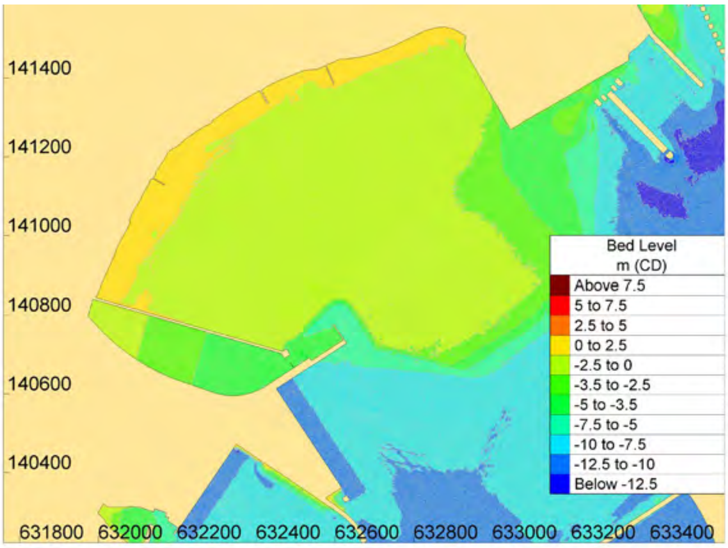

Figure 4.2: ARTEMIS model depths around Dover Harbour (m relative to CD) – Layout G

Source: HR Wallingford

4.2. Reflection coefficients

The reflection coefficients applied for Layout G used are exactly the same as used for the baseline case (including Pier F) as shown in Figure 4.3. A reflection coefficient of 0.95 was used for Breakwater G and this wave screen was assumed to extend to the seabed allowing no wave transmission underneath.

Figure 4.3: Layout G: Reflection Coefficients

Source: HR Wallingford

4.3. Model test conditions

The ARTEMIS model was run for one test condition referred to above as Storm 6 as summarised in Table 3.1.

4.4. Model results

The model results for Layout G are presented with the results for the Baseline case (including Pier F). Figure 4.4 and Figure 4.5 shows the results throughout the harbour and Figure 4.6 and Figure 4.7 show the results within the marina, for the baseline and layout G, respectively.

The results show a noticeable reduction in wave height within the marina due to the inclusion of Breakwater G, The standing wave pattern along the marina curve remains noticeable, but the heights are lower for Layout G. Wave conditions at the outer berths (see Figure 4.8) also appear to be slightly lower compared with the baseline case and there are some small differences in the wave pattern around the marina entrance (including some increase in wave conditions at the entrance).

Model results were extracted at the points within the marina shown in Figure 4.8. The results at these locations are summarised in Figure 4.9, which also shows the results from the baseline case (including Pier F) and the partial beach renourishment results for reference. Figure 4.9 shows that incorporating Breakwater G leads to a noticeable reduction in wave heights at the points within the marina, with significant wave heights below the target of 0.3m at points 109,110 and 115, and below 0.4m at points M1, 4, 19, 40, and 124. The buoy location remains above 0.5m, but is close to the marina entrance.

In general, incorporating Breakwater G is predicted to have about the same wave height reducing effect as the partial beach renourishment of beach sections A and B as described in Section 3, and is not quite effective enough on its own to reduce wave heights to below 0.3m at all points within the marina.

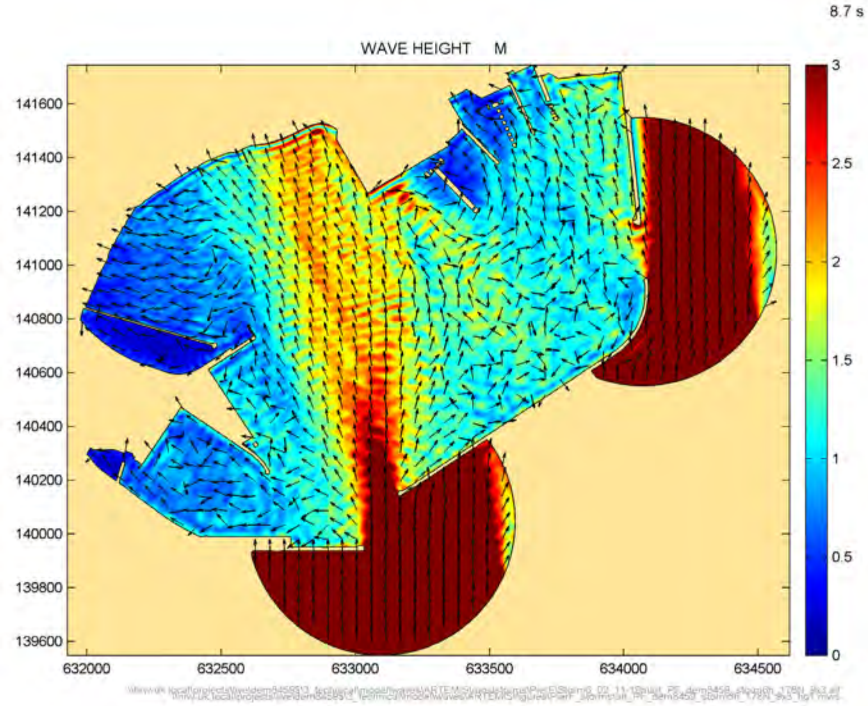

Figure 4.4: Wave conditions inside harbour (Baseline: Storm 6)

Source: HR Wallingford

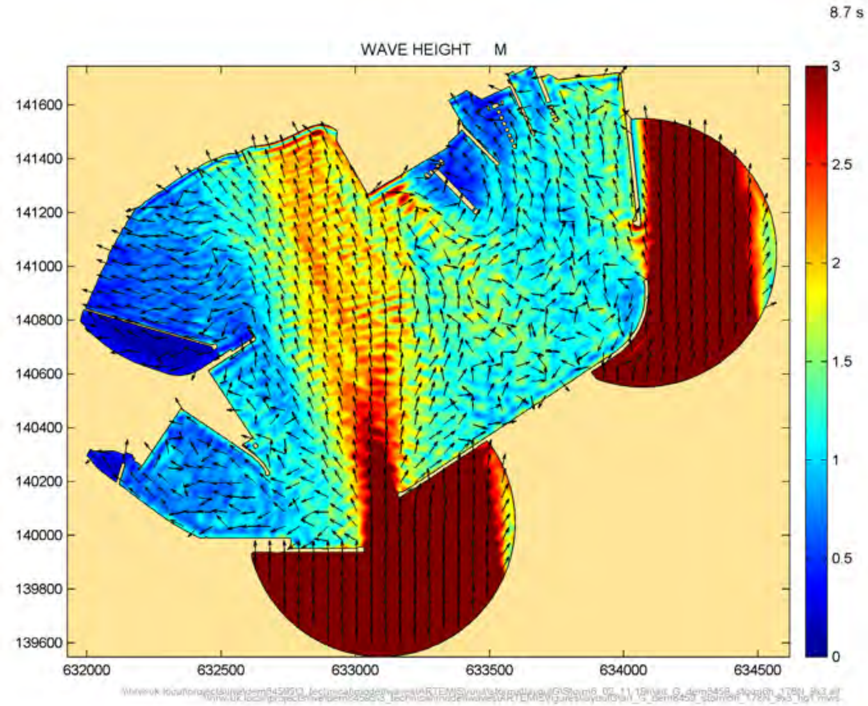

Figure 4.5: Wave conditions inside harbour Layout G: Storm 6)

Source: HR Wallingford

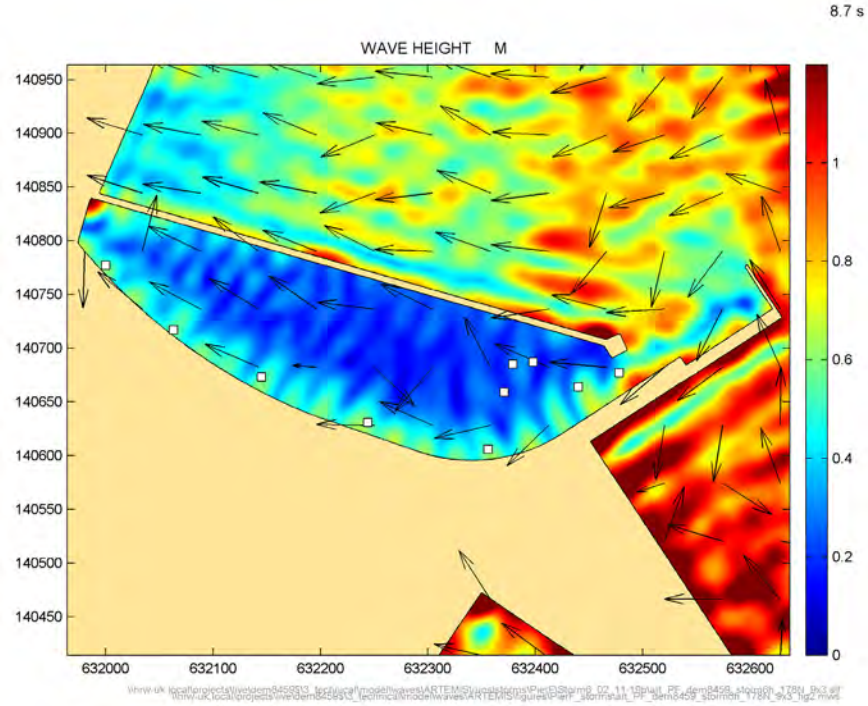

Figure 4.6: Wave conditions inside marina (Baseline: Storm 6)

Source: HR Wallingford

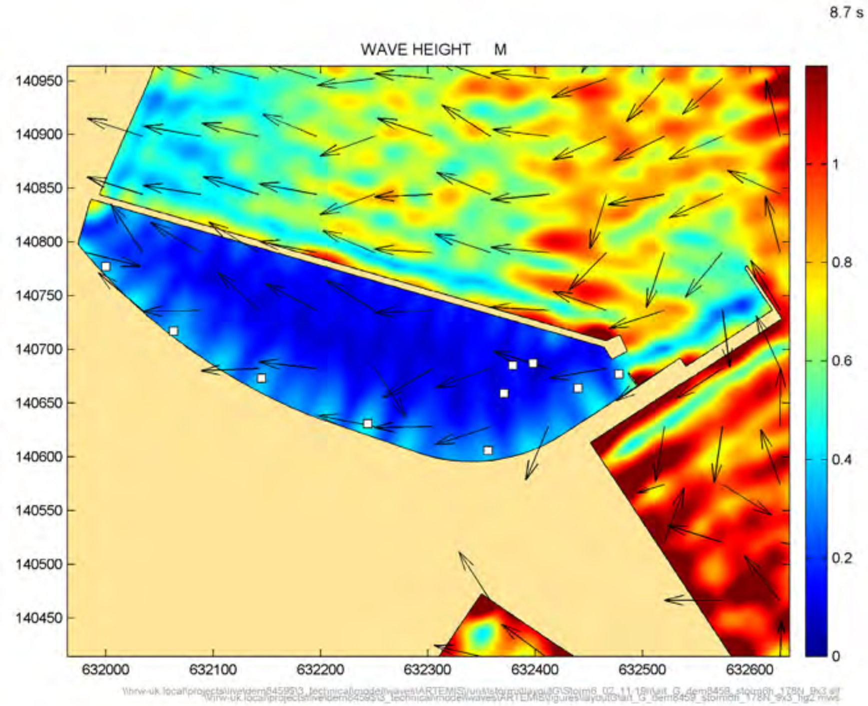

Figure 4.7: Wave conditions inside marina (Layout G: Storm 6)

Source: HR Wallingford

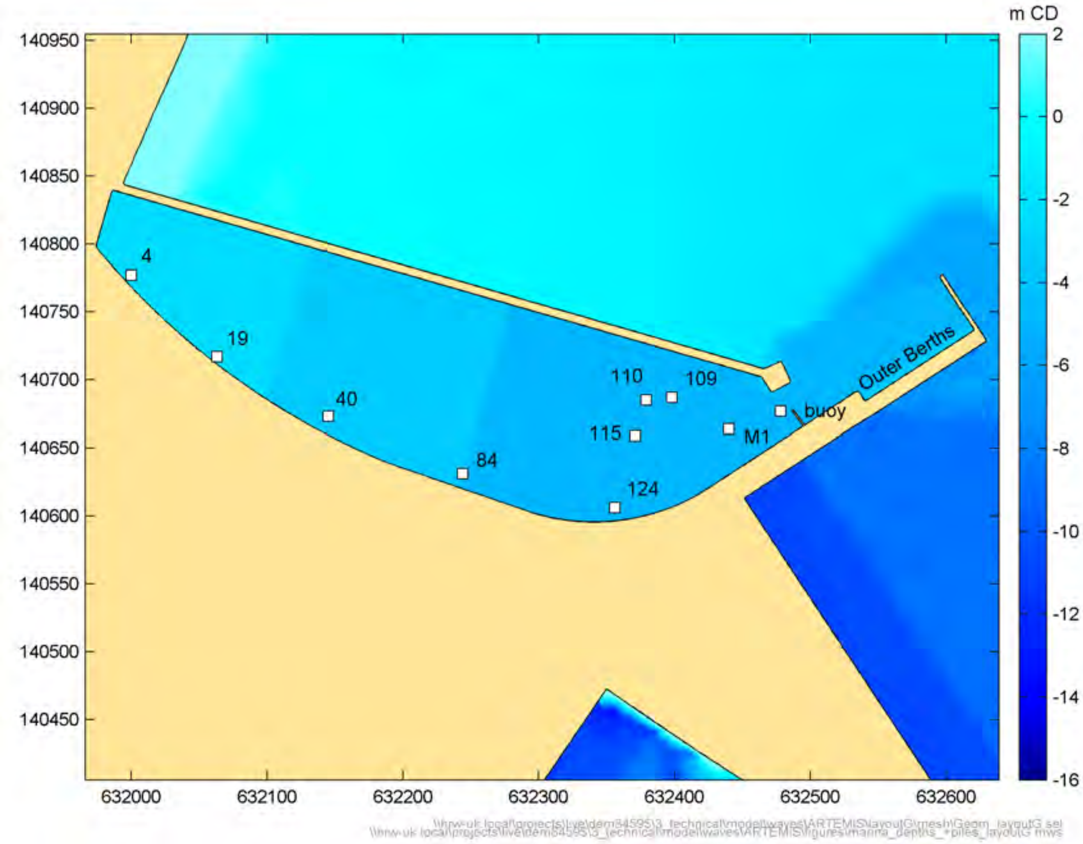

Figure 4.8: Layout G: Model depths within Marina and output locations

Source: HR Wallingford

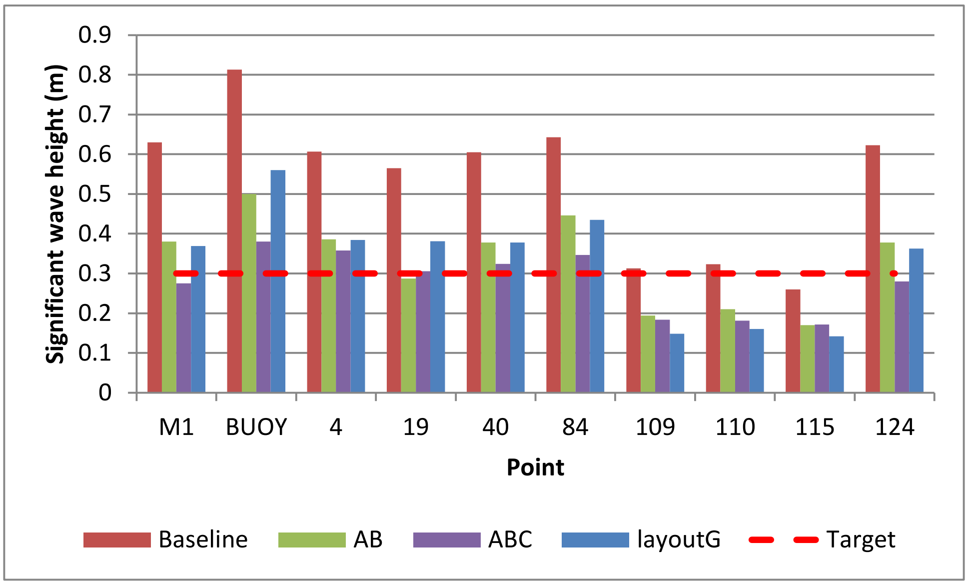

Figure 4.9: Predicted wave height variation within marina

Source: HR Wallingford

5. Layout G+A1

Layout G, on its own, does not quite provide enough shelter to meet guidance for a good wave climate within the marina. In order to reduce wave conditions within the marina and at the outer berths, an extension to the marina curve breakwater was proposed. Rather than the full length Breakwater A of over 70m as originally proposed during the workshop, a shortened breakwater of approximately 36m was initially considered as shown in Figure 5.1. As illustrated, the construction of this breakwater will also require further dredging to accommodate the extension to the marina curve breakwater.

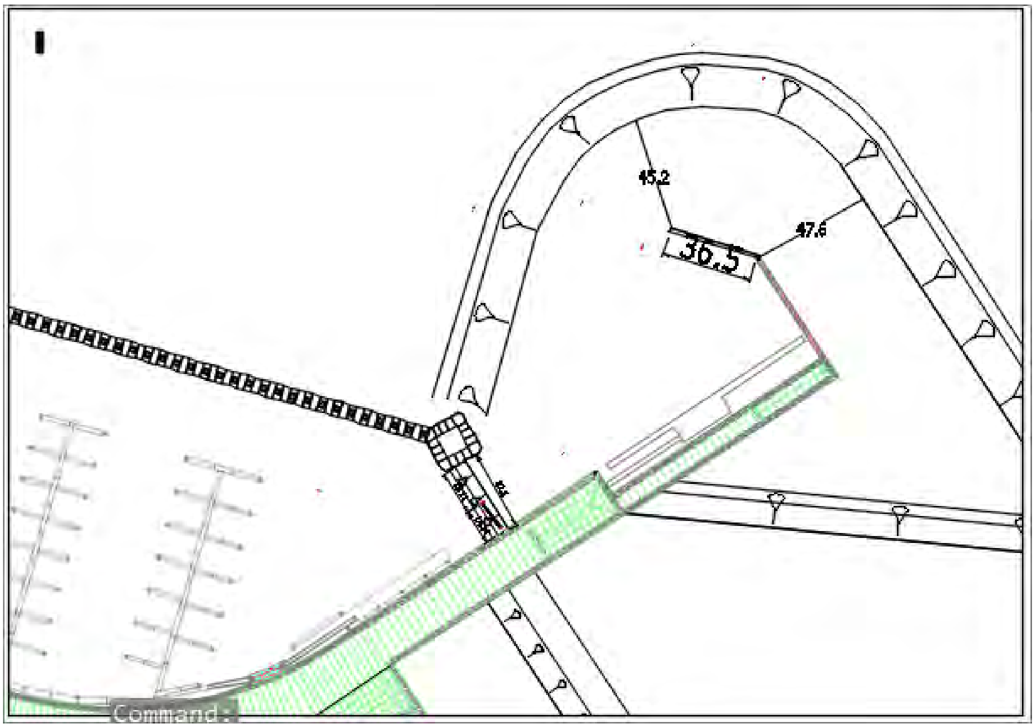

Figure 5.1: Marina Curve breakwater extension A1.

5.1. Model bathymetry

The model bathymetry was updated to accommodate the revised dredged approach channel (see Figure 5.2). As shown in Figure 5.1 the proposed approach channel has a minimum width of approximately 45m, a depth of 5m below CD, and side slope of approximately 10degrees i.e. a slope of 1:5 to 1:6.

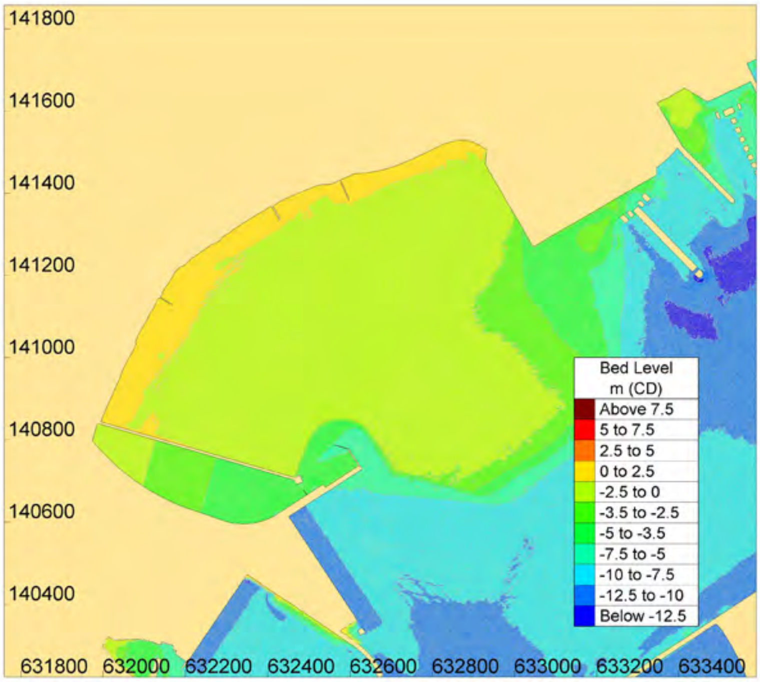

Figure 5.2: Layout G+A1 Model depths

5.2. Reflection coefficients

The reflection coefficients applied (as shown in Figure 5.3) for Layout G+A1 are the same as used for the baseline case (including Pier F) and Layout G. A reflection coefficient of 0.95 was used for Breakwater A1 and this wave screen / breakwater was assumed to extend to the seabed allowing no wave transmission underneath.

Figure 5.3: Layout G+A1 Reflection coefficients

5.3. Model test conditions

The ARTEMIS model was initially run for one test condition referred to previously as Storm 6 as summarised in Table 3.1. This has an approximate return period of 1 year. A second model run was also carried out by scaling up the boundary significant wave height of Storm 6 to 5.14m and is representative of a 50 year return period offshore wave condition (as previously reported).

5.4. Model results

Model results are presented as colour contour plots throughout the harbour and within the marina area in Figure 5.4 and Figure 5.5 for Storm 6 and Figure 5.6 and Figure 5.7 for the 50 year condition. The plots show that, compared with Layout G, little further reduction in wave height is predicted inside the marina by incorporating Breakwater A1. This further supports the notion that the majority of energy entering the marina is due to waves reflecting from Marine Parade. Outside the marina the wave pattern is slightly changed and there is a reduction in wave energy at the outer berths, most likely due to moving the diffraction point further NW. Clearly the existing marina curve breakwater return is already providing shelter from the direct waves from the harbour entrance and the results demonstrate that it is the reflected component from Marine Parade that is the problem.

Waves for the 1 year condition as quoted in Figure 5.9, at the points shown in Figure 5.8, show that inside the marina the predicted significant wave heights at points M1, 4, 40, 84 and 124 remain above the 0.3m guidelines. The 50-year condition gives very similar results within the marina to the Storm 6 condition within the marina most likely because of wave breaking reducing the wave height to the same for both conditions before reflecting back from the Marine Parade. The results show the predicted 50 year conditions in the marina are below the 0.6m quoted for 50 year conditions in the guidelines.

The originally proposed length of Breakwater A was chosen to give shelter at the marina entrance from the waves reflected from Marine Parade. Breakwater A1 provides some shelter at the outer berth, but unfortunately, these results show that the shorter Breakwater A1 does not provide much additional sheltering within the marina. Therefore a longer length Breakwater A or detached Breakwater B as proposed during the workshop may be required to meet the guidelines for good conditions in a 1 year event.

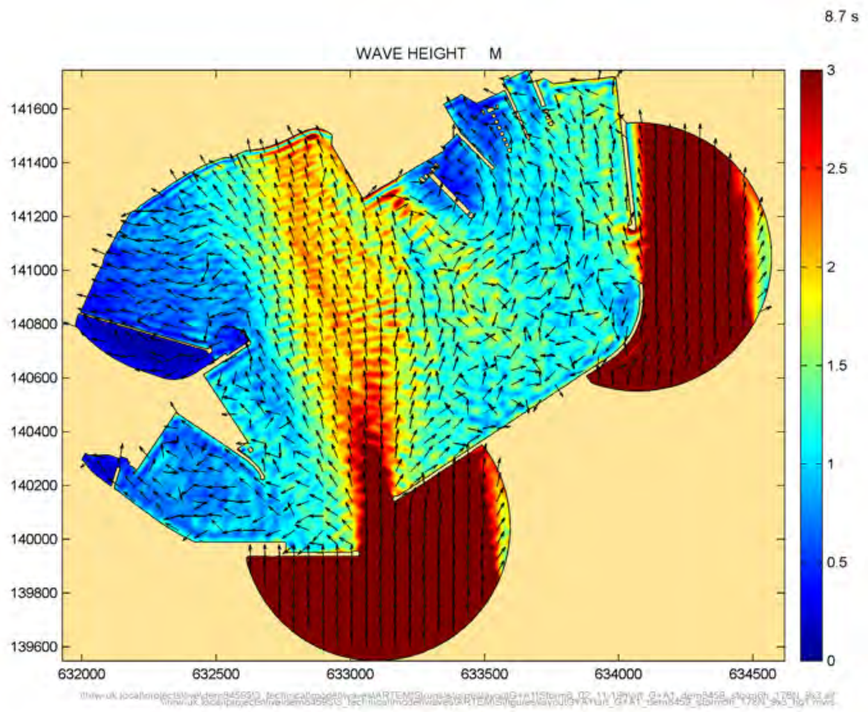

Figure 5.4: Wave conditions inside harbour (Layout G+A1: Storm 6)

Source: HR Wallingford

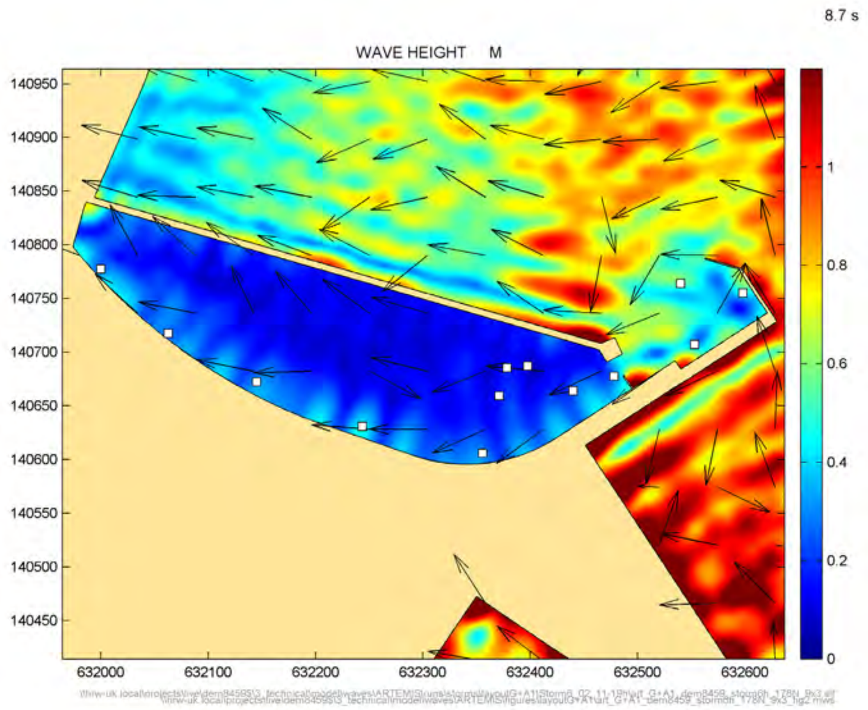

Figure 5.5: Wave conditions inside marina (Layout G+A1: Storm 6)

Source: HR Wallingford

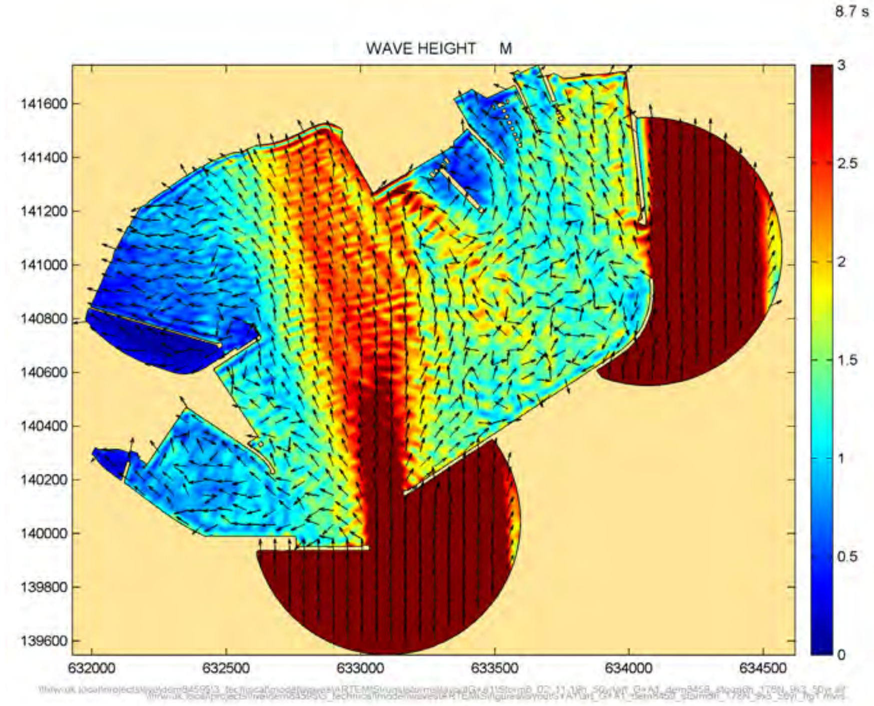

Figure 5.6: Wave conditions inside harbour (Layout G+A1: 50 Year)

Source: HR Wallingford

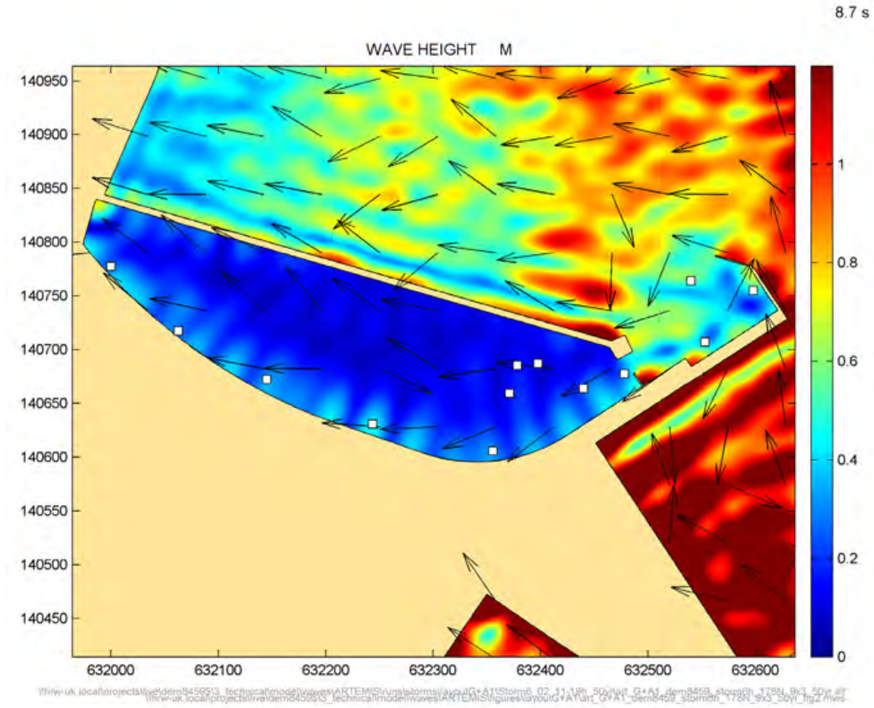

Figure 5.7: Wave conditions inside marina (Layout G+A1: 50 Year)

Source: HR Wallingford

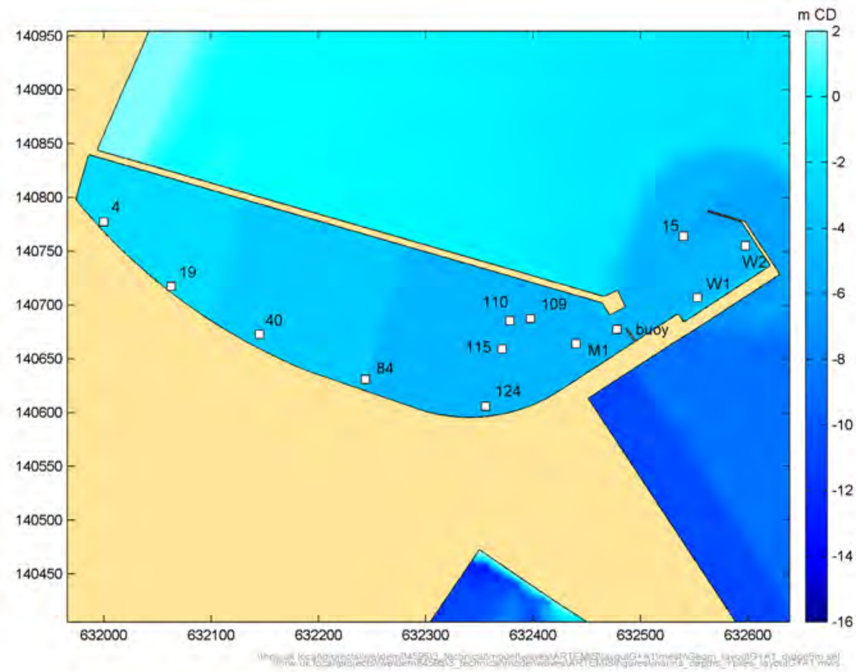

Figure 5.8: Layout G+A1: Model depths within Marina and output locations

Source: HR Wallingford

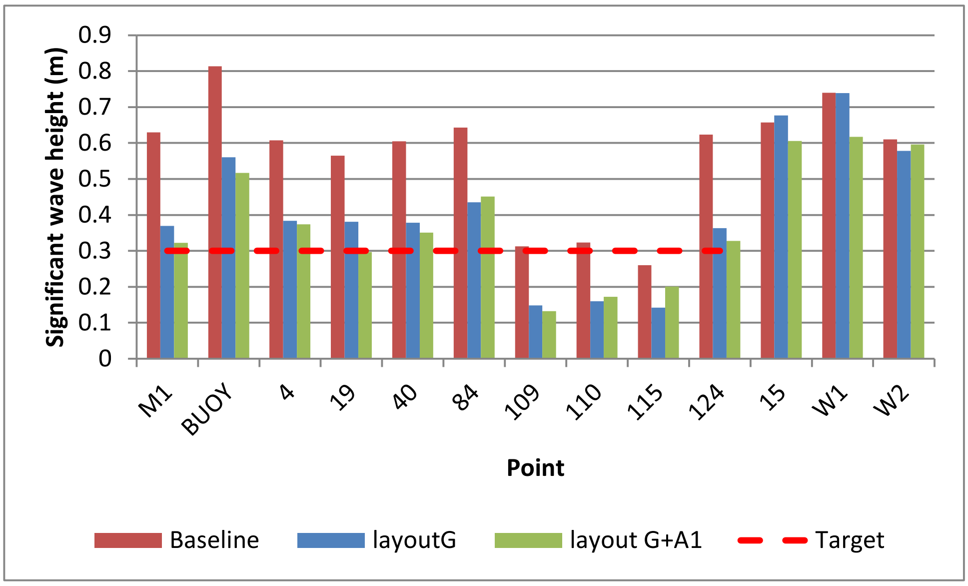

Figure 5.9: Predicted wave height variation within marina: Storm 6

Source: HR Wallingford

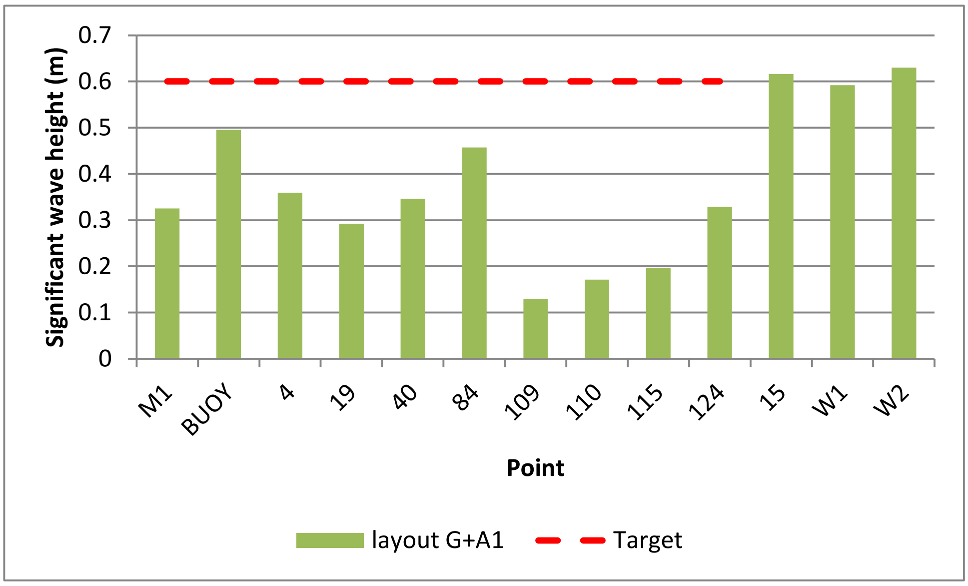

Figure 5.10: Predicted wave height variation within marina: Storm 6 - 50yr

Source: HR Wallingford

6. Layout G+B

As shown in Section 5.4, Layout G+A1, also does not provide enough shelter to meet guidance for a good wave climate within the marina so Breakwater A1 would need to be lengthened. Alternatively, in order to reduce wave conditions within the marina, a detached breakwater was proposed during the December 2019 workshop. This breakwater, referred to as Breakwater B, was angled so that it is approximately along a radial line from tip of the existing extension to the marina curve breakwater, so that waves diffracting from the marina curve breakwater tip should run straight past and not get reflected back into the marina. This breakwater is also approximately perpendicular to the reflected waves from Marine Parade and with a length of approximately 70m, as shown in Figure 6.1, provides a small overlap with the marina pier so is expected to be reasonably effective in providing shelter to waves reflecting from the more reflective parts of beach.

No additional dredging should be required for this layout.

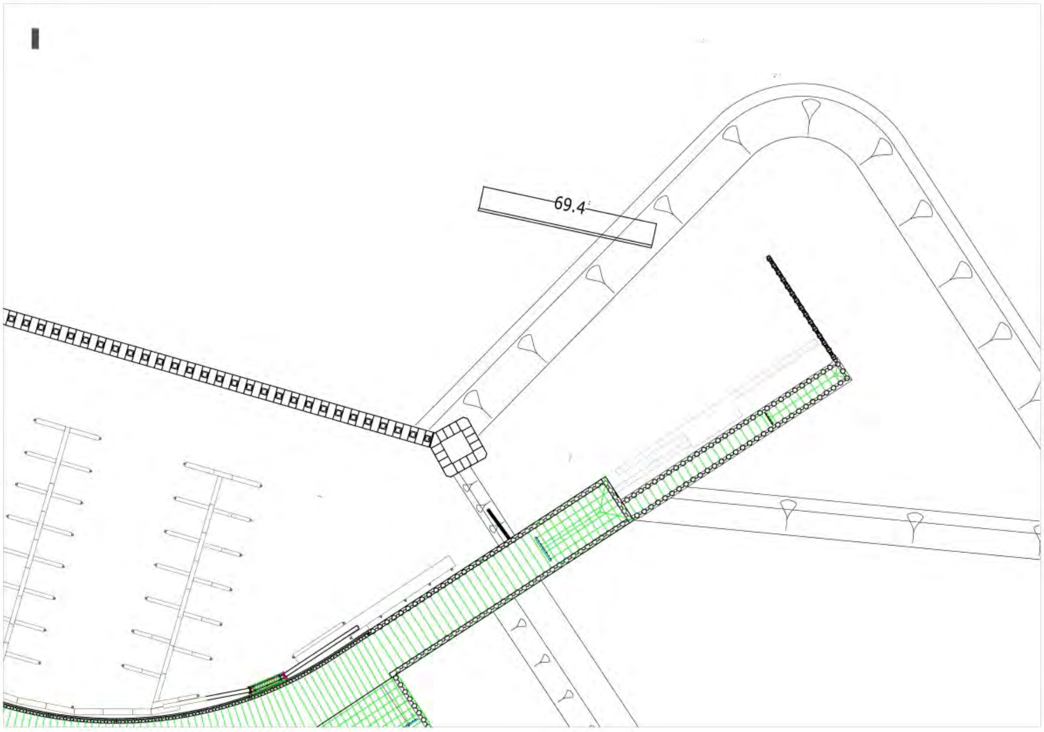

Figure 6.1: Layout G+B

6.1. Model bathymetry

The model bathymetry was identical to that used for previous layouts (baseline and Layout G), i.e. excluding Layout G+A1 that required additional dredging.

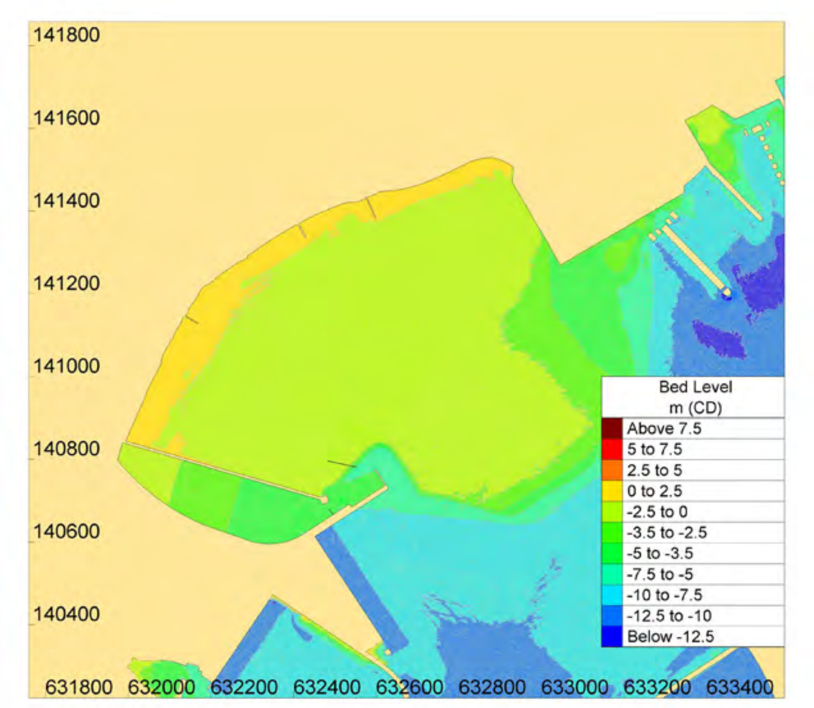

Figure 6.2: Layout G+B Model depths

6.2. Reflection coefficients

The reflection coefficients applied (as shown in Figure 5.3) for Layout G+B are the same as used for the baseline case (including Pier F) and Layout G. A reflection coefficient of 0.95 was used for Breakwater B and this wave screen / breakwater was assumed to extend to the seabed allowing no wave transmission underneath.

Figure 6.3: Layout G+B Reflection coefficients

6.3. Model test conditions

The ARTEMIS model was initially run for one test condition referred to previously as Storm 6 as summarised in Table 3.1. This has an approximate return period of 1 year. A second model run was also carried out by scaling up the boundary significant wave height of Storm 6 to 5.14m and is representative of a 50 year return period offshore wave condition (as previously reported).

6.4. Model results

Model results for Layout G+B are presented as colour contour plots throughout the harbour, within the inner and outer marina areas in Figure 6.4 to Figure 6.6 for Storm 6 and Figure 6.7 to Figure 6.9 for the 50 year condition. Note the directions plotted as vectors are vector mean wave directions so can be difficult to interpret where there are two or more wave components/directions. The wave height plots show that, compared with Layouts G and G+A1, wave heights within the marina are noticeably reduced. Similarly, outside the marina the wave pattern is slightly changed and there is a general reduction in wave energy at the outer berths compared with previous layouts, although the apparent node/antinode standing wave pattern along the marina curve extension results in high wave heights along the parts of the quay wall where the pontoons are to be positioned. This standing wave pattern, which is a function of wave period and water depth, needs to be accounted for in the selection of pontoons to be installed and the planned use of the berths during such events.

Waves for the 1 year condition at the points shown in Figure 6.10 as quoted in Figure 6.11, show that the predicted significant wave height at the buoy location just inside the entrance is approximately 0.3m, and at the other points within the marina are below 0.3m. The 50-year condition gives very similar results within the marina. Figure 6.12 shows the predicted 50 year conditions inside the marina are close to 0.3m at the buoy location and below 0.3m at the other points i.e. within the 1 year condition given in the guidelines.

Wave conditions at the berth locations outside the marina (positions W1 and W2) are similar to Layout G+A1 and noticeably higher than inside the marina. Significant wave heights at W1 and W2 are predicted to be between 0.5 to 0.65m for the Storm 6 and 50 year conditions, but as shown in Figure 6.6 and Figure 6.9 there are areas along the marine extension where the pontoons are to be located with higher wave heights of up to approximately 0.9m for the 50 year condition.

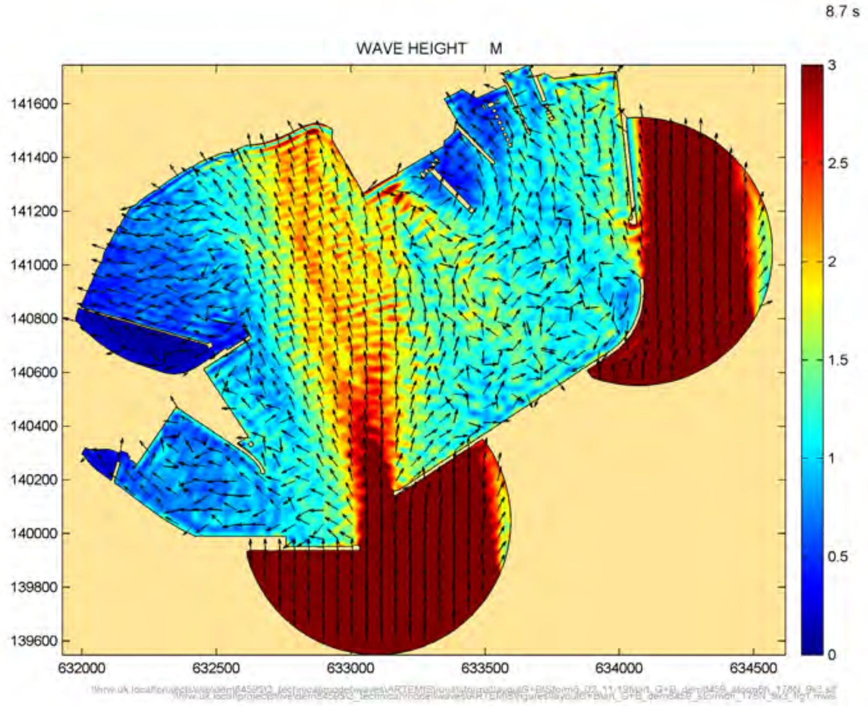

Figure 6.4: Wave conditions inside harbour (Layout G+B: Storm 6)

Source: HR Wallingford

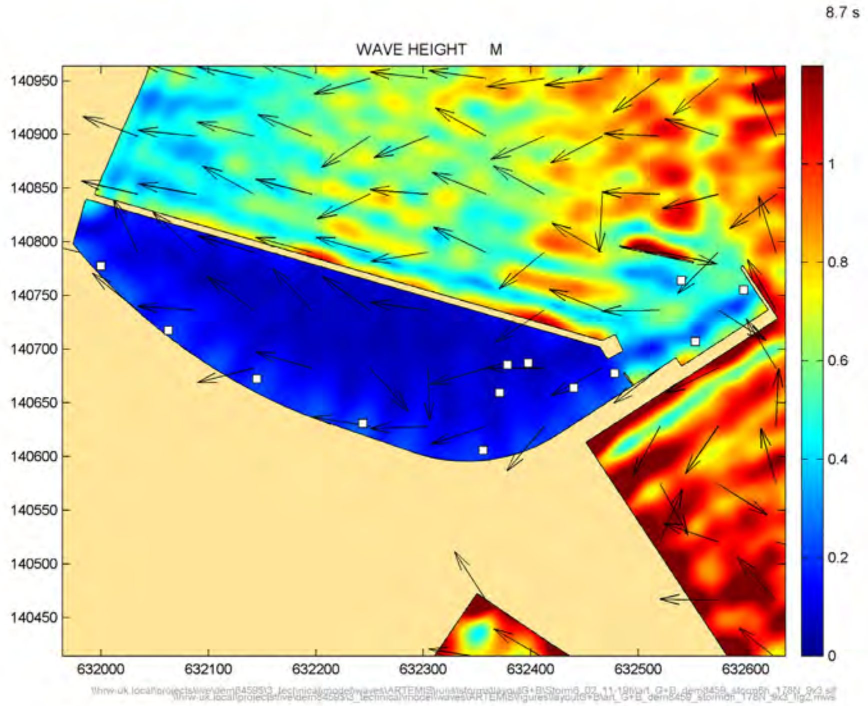

Figure 6.5: Wave conditions inside marina (Layout G+B: Storm 6)

Source: HR Wallingford

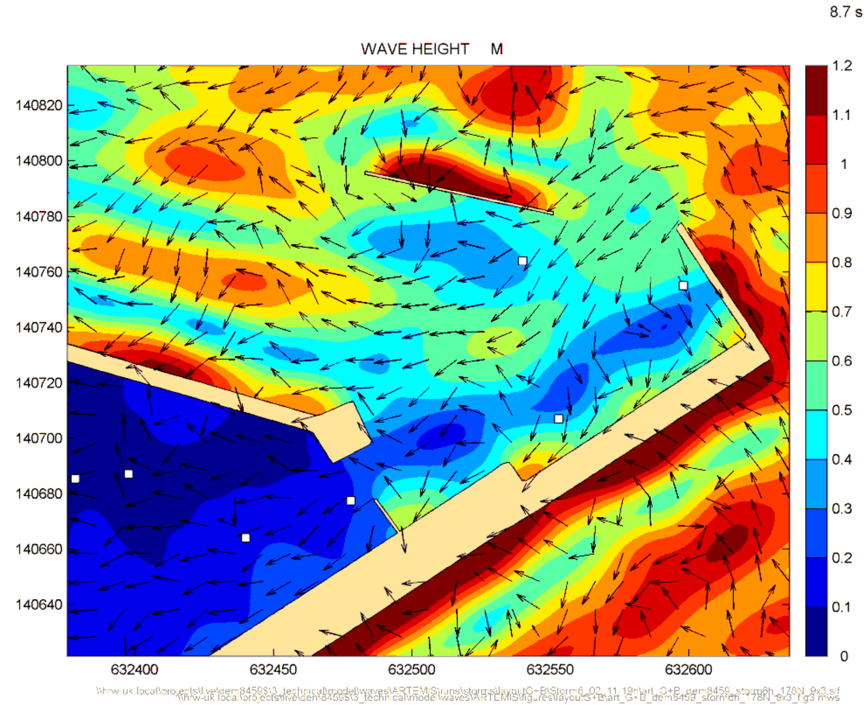

Figure 6.6: Wave conditions outside marina (Layout G+B: Storm 6)

Source: HR Wallingford

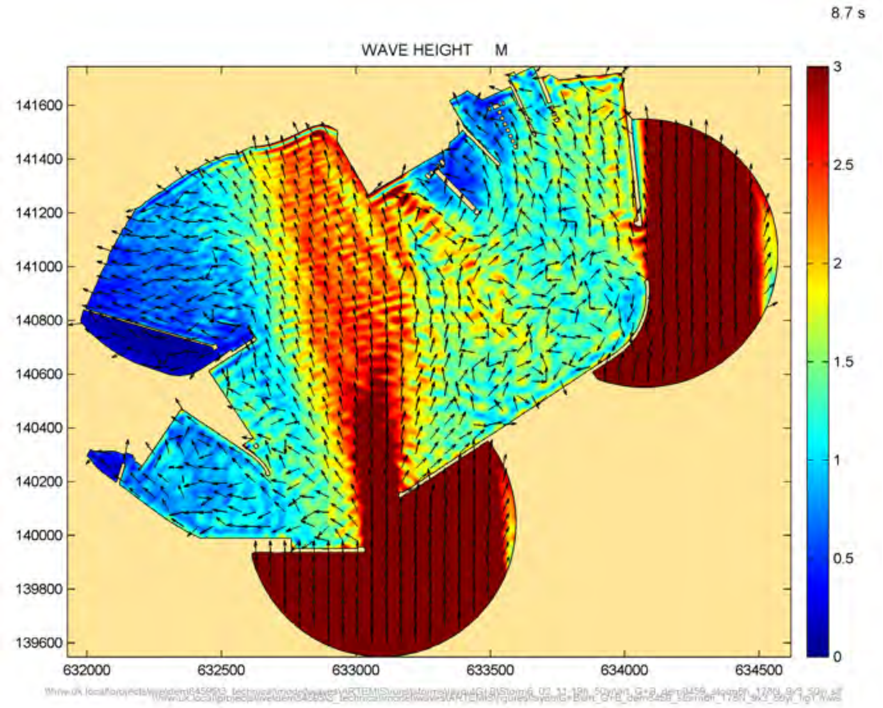

Figure 6.7: Wave conditions inside harbour (Layout G+B: 50 Year)

Source: HR Wallingford

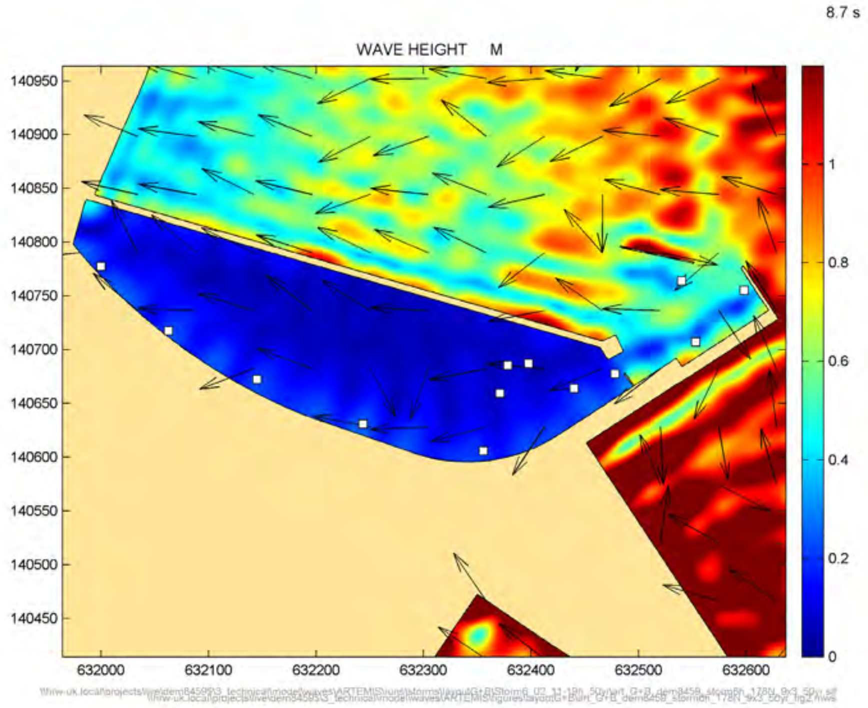

Figure 6.8: Wave conditions inside marina (Layout G+B: 50 Year)

Source: HR Wallingford

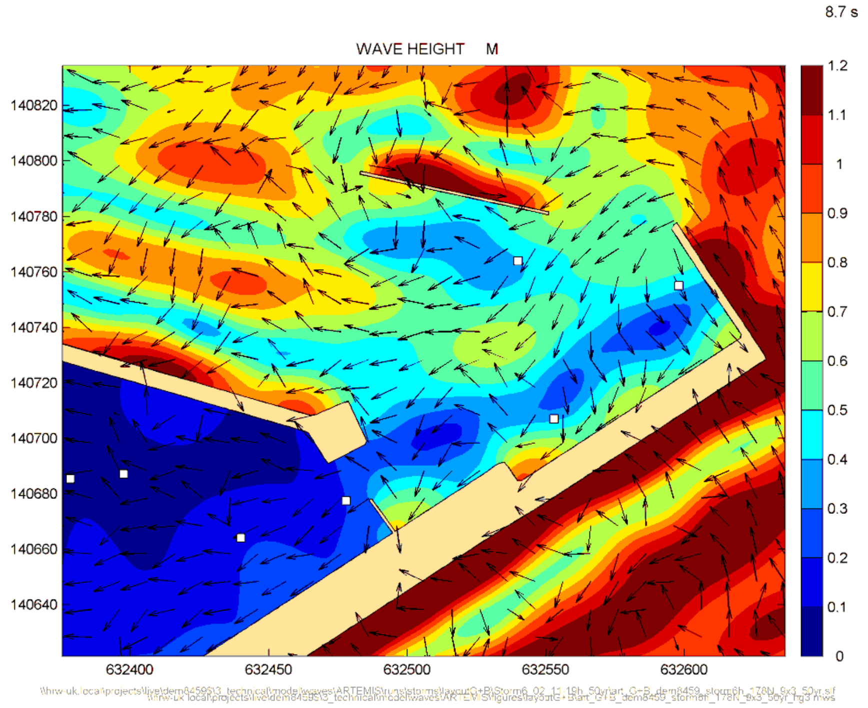

Figure 6.9: Wave conditions outside marina (Layout G+B: 50 Year)

Source: HR Wallingford

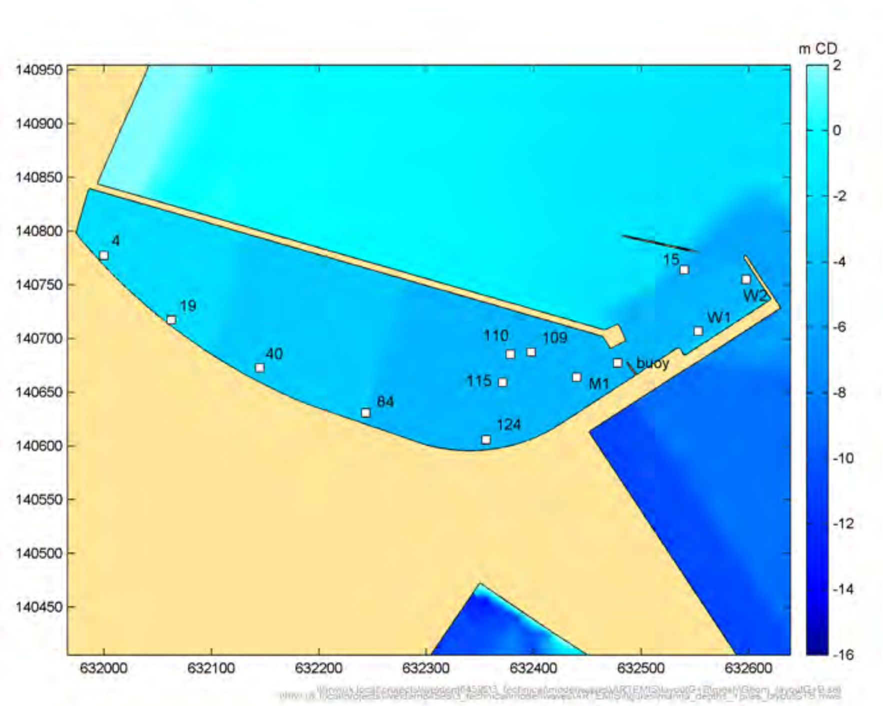

Figure 6.10: Layout G+B: Model depths within Marina and output locations

Source: HR Wallingford

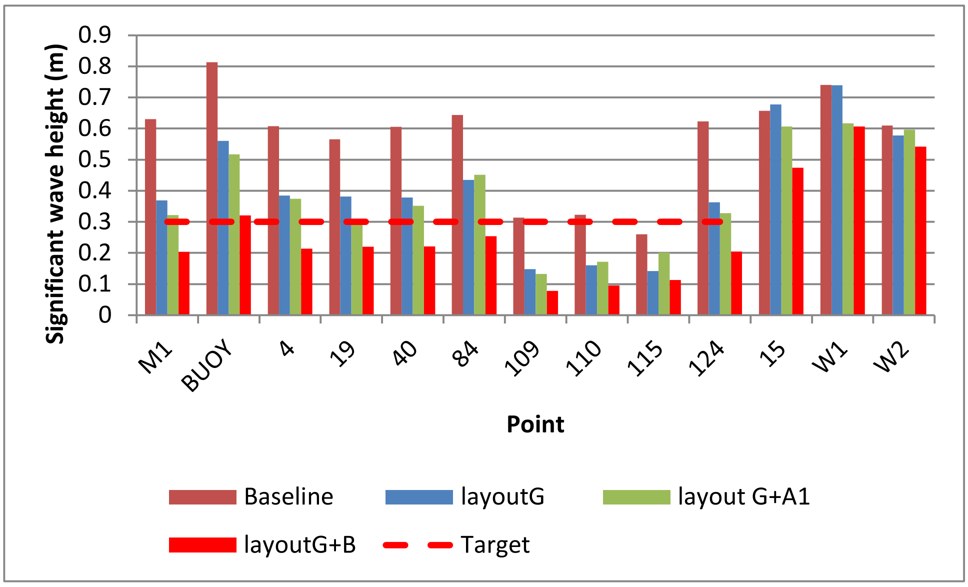

Figure 6.11: Predicted wave height variation within marina: Storm 6

Source: HR Wallingford

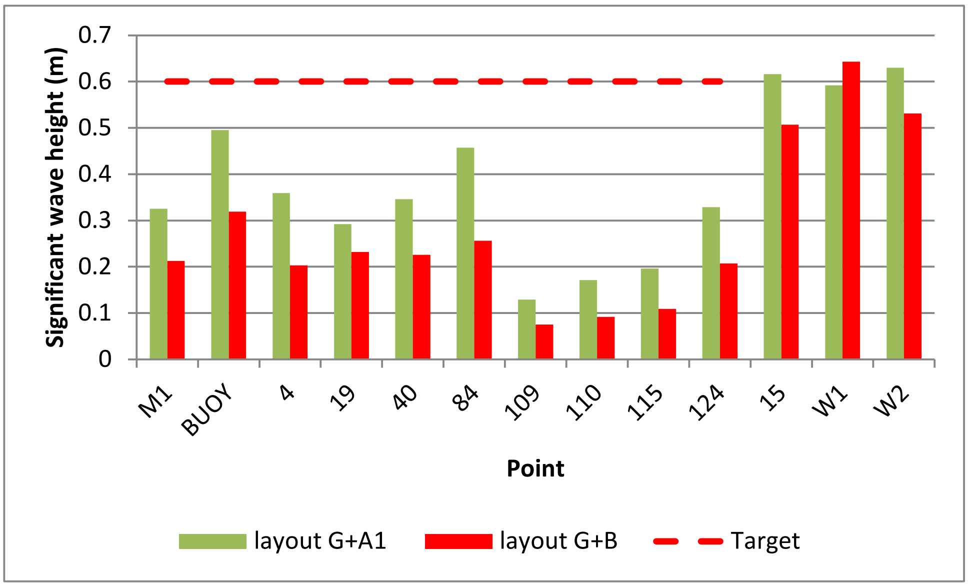

Figure 6.12: Predicted wave height variation within marina: Storm 6 - 50yr

Source: HR Wallingford

7. Layout G2+B+J1

Layout G+B appears to be effective in reducing wave heights within the marina such that they are predicted to meet the criteria for good conditions. However, at the tug and dredger berths immediately outside the marina entrance, wave conditions are substantially higher with a standing wave giving significant wave heights up to 0.9m for the 50 year conditions. In order to reduce wave conditions in this area, Breakwater J1 of length 50.6m is proposed. In addition, in order to reduce localised standing wave heights in the corner of Breakwater G and the Marina Curve, Breakwater G2 is aligned at 70° to the Marina Curve with the aim of reflecting waves back towards the gap between the Marina Curve extension and proposed Breakwater B. Breakwater G2 is also moved slightly east to avoid re-reflections into the marina from the Marina Pier.

No additional dredging is required for this layout.

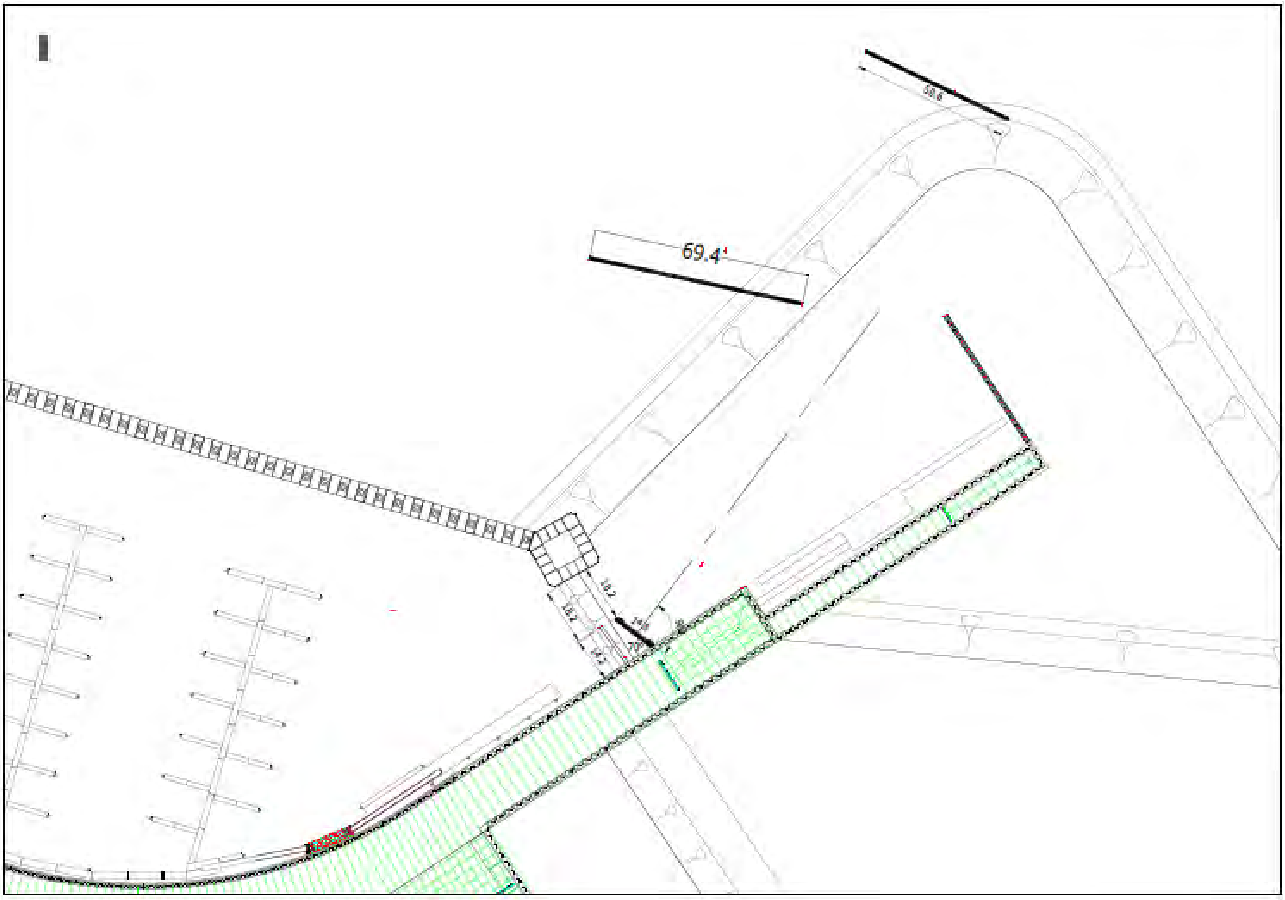

Figure 7.1: Layout G2+B+J1

7.1. Model bathymetry

The model bathymetry was identical to that used for previous layouts (baseline and Layout G), i.e. excluding Layout G+A1 that required additional dredging.

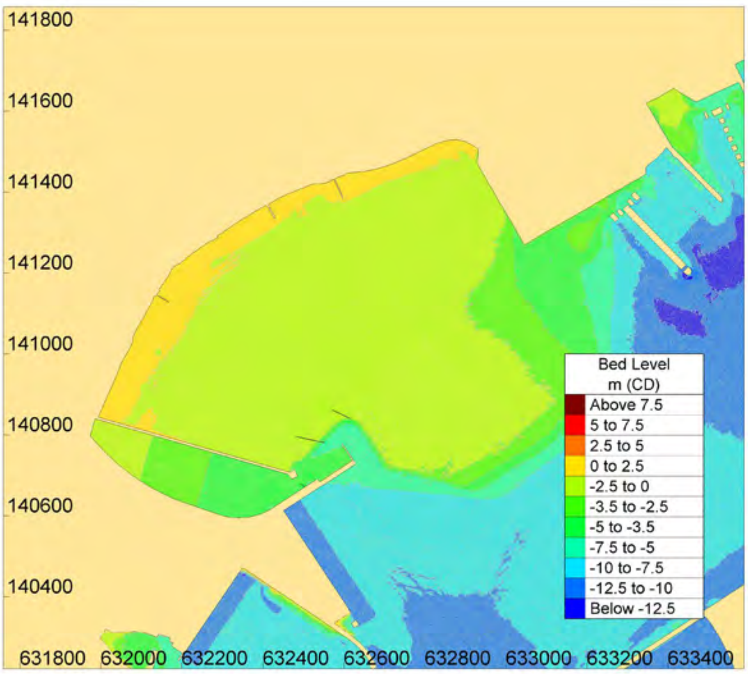

Figure 7.2: Layout G2+B+J1 Model depths

7.2. Reflection coefficients

The reflection coefficients applied (as shown in Figure 5.3) for Layout G2+B+J1 are the same as used for the baseline case (including Pier F) and Layout G. A reflection coefficient of 0.95 was used for Breakwater J1 and this wave screen / breakwater was assumed to extend to the seabed allowing no wave transmission underneath.

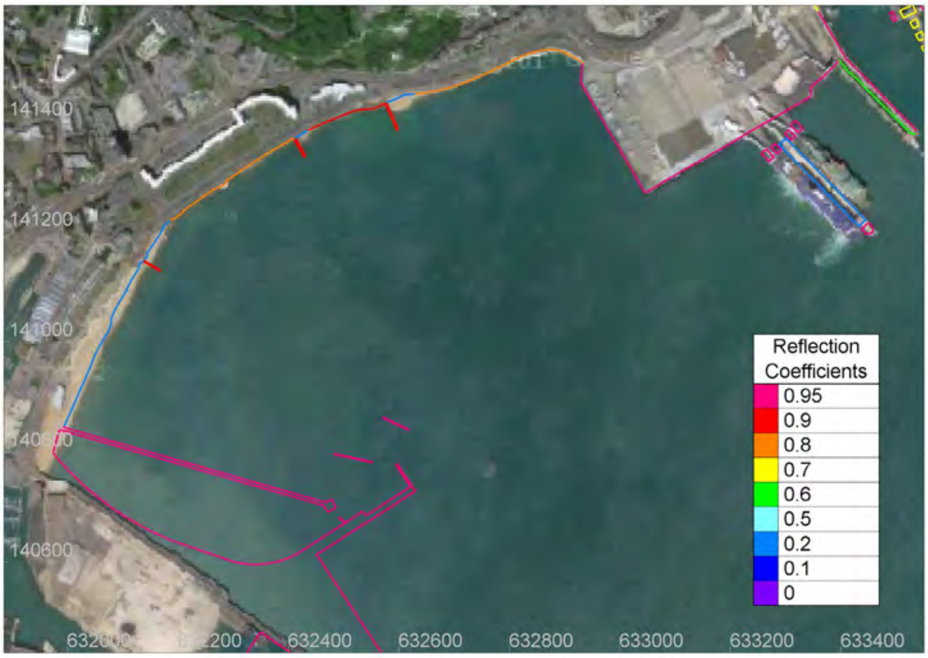

Figure 7.3: Layout G2+B+J1 Reflection coefficients

7.3. Model test conditions

The ARTEMIS model was initially run for one test condition referred to previously as Storm 6 as summarised in Table 3.1. This has an approximate return period of 1 year. A second model run was also carried out by scaling up the boundary significant wave height of Storm 6 to 5.14m and is representative of a 50 year return period offshore wave condition (as previously reported).

7.4. Model results

The model results for Layout G2+B+J1 show that significant wave heights for the 1 and 50 year conditions meet the criteria for good conditions inside the marina. For the 50 year condition significant wave heights are predicted to be just below the threshold of the proposed pontoons at the outer berths (0.78m) so this layout can be considered a minimum length option for this type of scheme. Ideally the pontoons would not be placed directly in the corners or along the wall but it would be better if they were further out so they were not at an antinode of the standing wave pattern.

It can be observed from the contour plots that waves approaching from the harbour entrance reflect off Breakwater J1 hit the outside of B and are reflected away towards the beach, so the alignment of Breakwater J1 and B are considered to be near optimal. Further refinement of the position and length of Breakwater J may help improve conditions further in the outer berths.

It is interesting in the bar charts (Figure 7.11 and Figure 7.12), comparing the layouts considered to date, that waves at W2 are slightly higher for Layout G2+B+J1 than for the G+B layout. This is due to a slight shift in the standing wave pattern. The outer berths are now dominated by this wave reflecting directly off the berth creating the standing wave. This is possibly due to wave energy reflecting from the beach Section A (see Figure 3.1). To provide shelter to these waves would require much longer breakwaters, possibly moving Breakwater J1 to the north west or could be improved with beach renourishment along beach Section A.

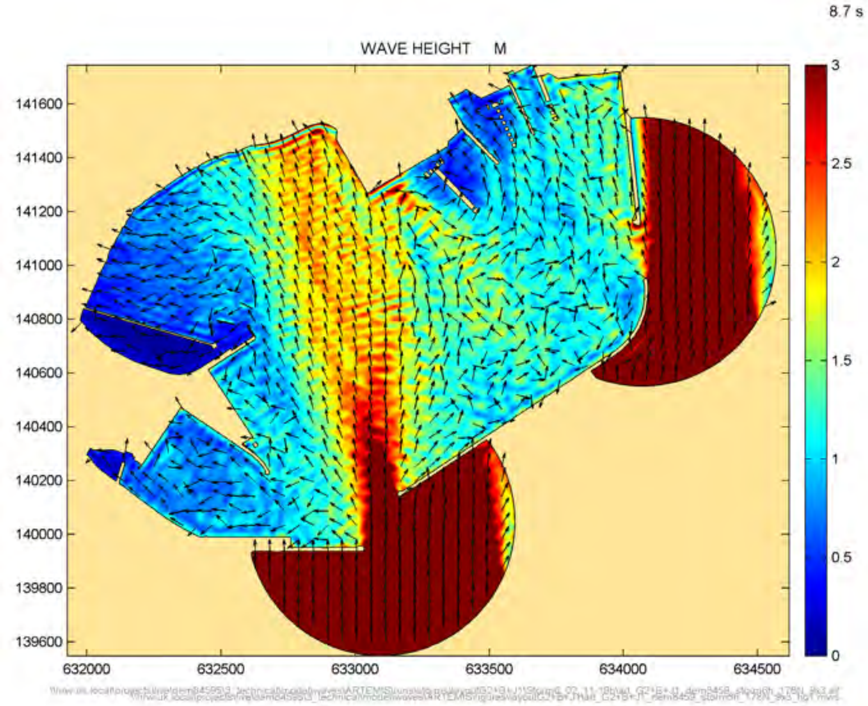

Figure 7.4: Wave conditions inside harbour (Layout G2+B+J1: Storm 6)

Source: HR Wallingford

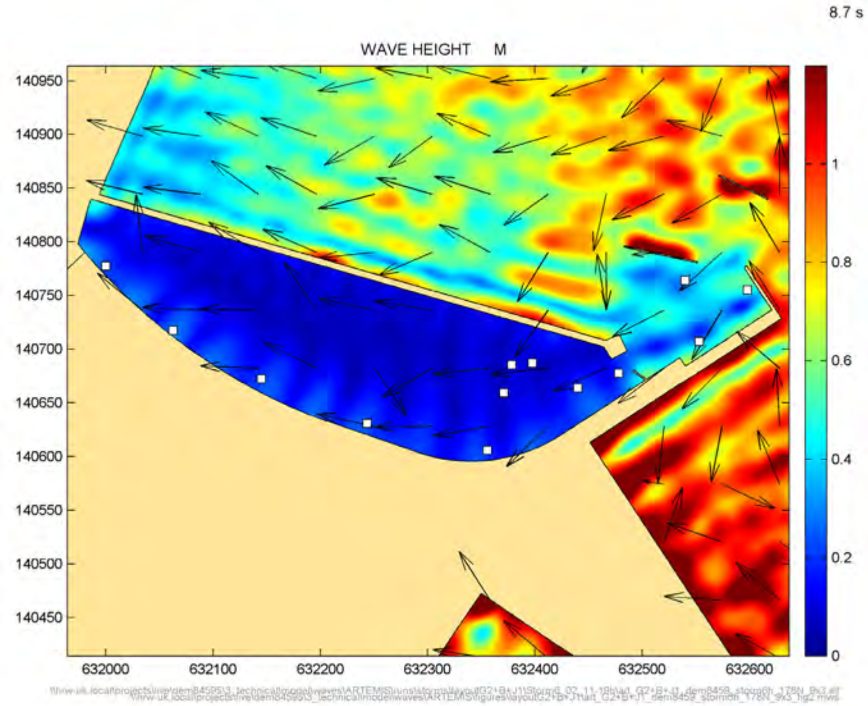

Figure 7.5: Wave conditions inside marina (Layout G2+B+J1: Storm 6)

Source: HR Wallingford

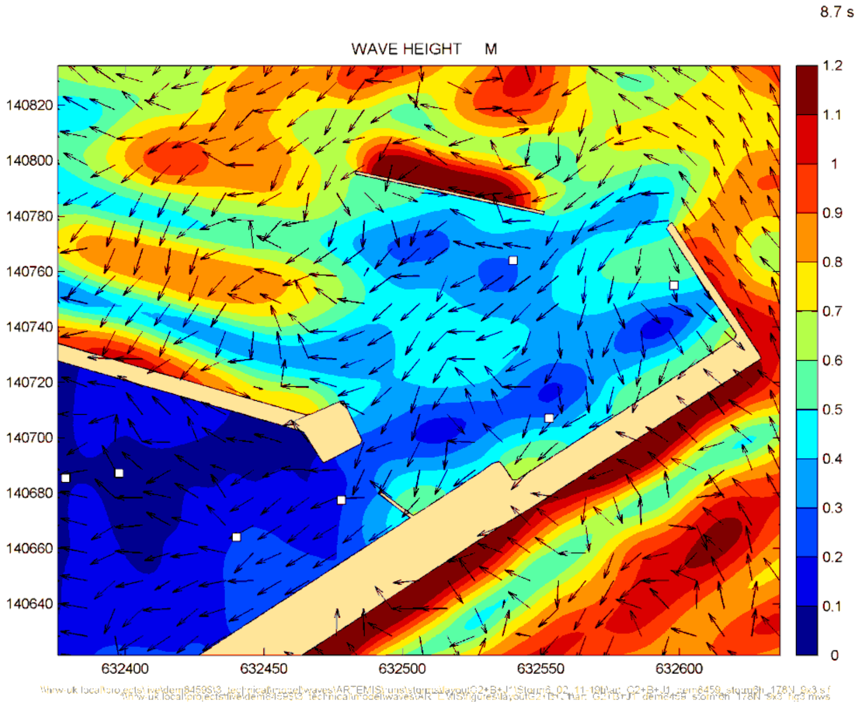

Figure 7.6: Wave conditions outside marina (Layout G2+B+J1: Storm 6)

Source: HR Wallingford

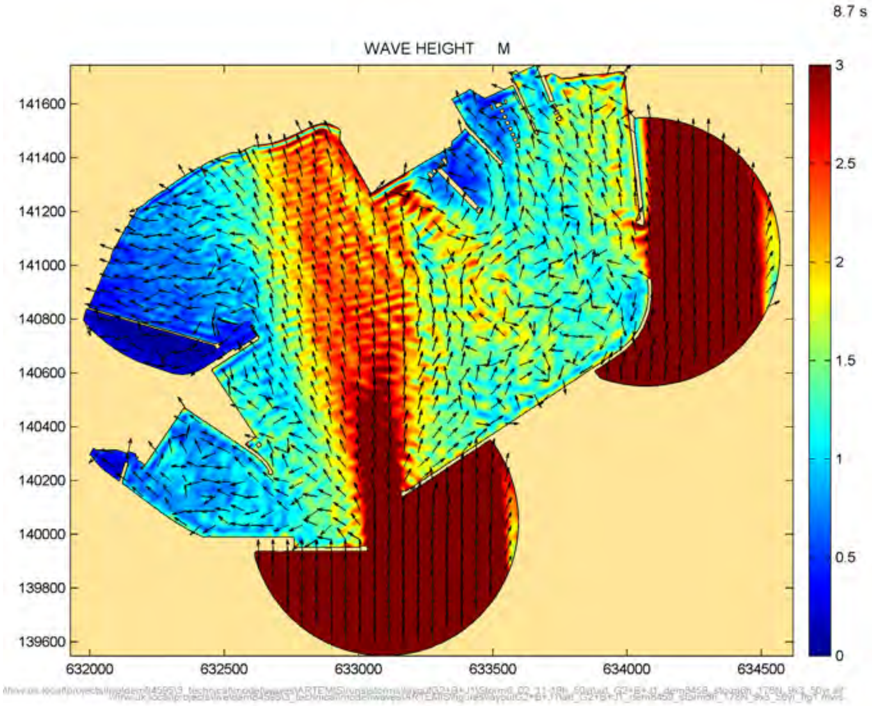

Figure 7.7: Wave conditions inside harbour (Layout G2+B+J1: 50 Year)

Source: HR Wallingford

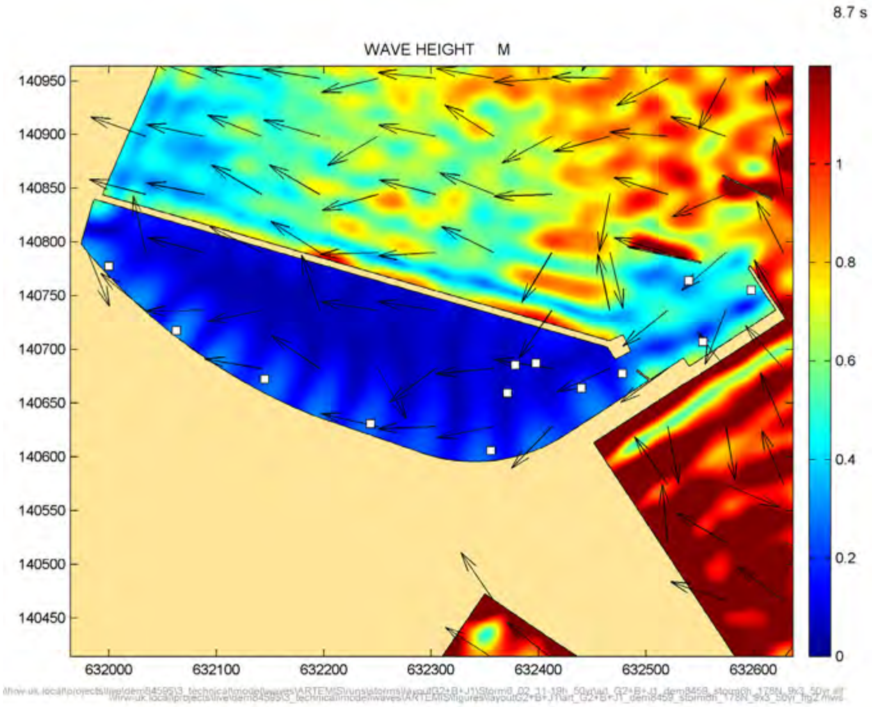

Figure 7.8: Wave conditions inside marina (Layout G2+B+J1: 50 Year)

Source: HR Wallingford

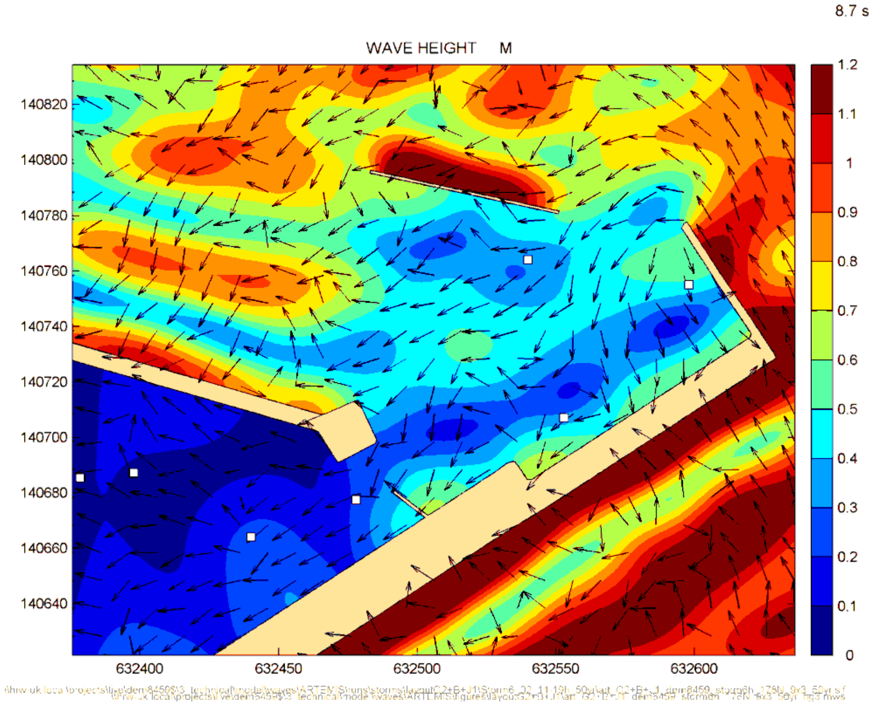

Figure 7.9: Wave conditions outside marina (Layout G2+B+J1: 50 Year)

Source: HR Wallingford

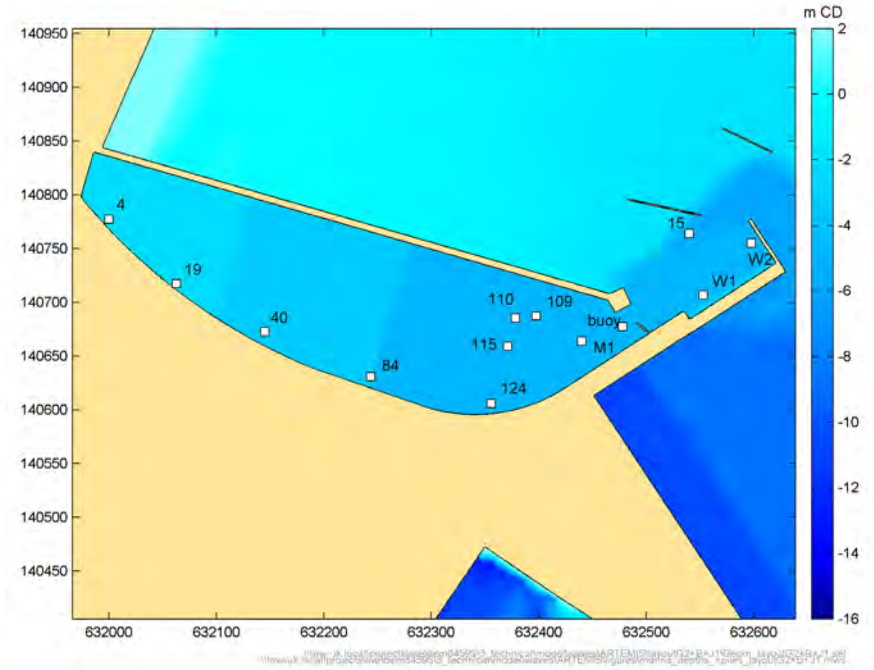

Figure 7.10: Layout G2+B+J1: Model depths within Marina and output locations

Source: HR Wallingford

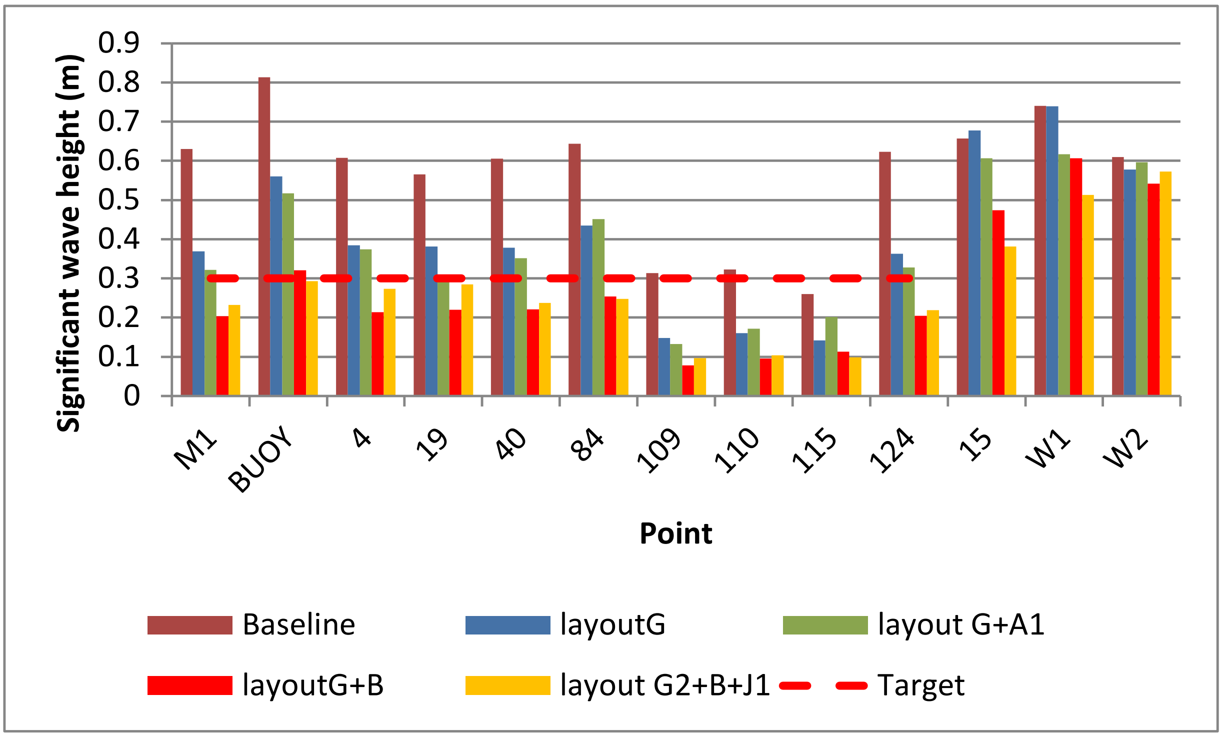

Figure 7.11: Predicted wave height variation within marina for Layout G2+B+J1: Storm 6

Source: HR Wallingford

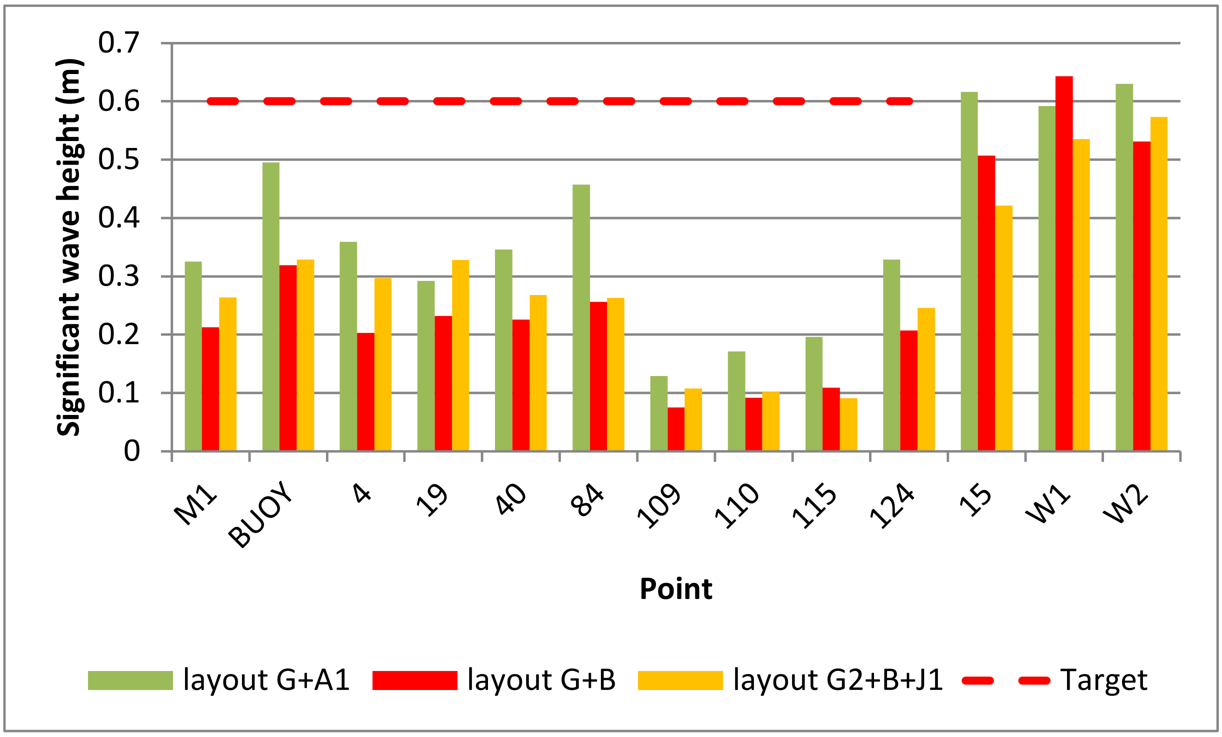

Figure 7.12: Predicted wave height variation within marina for Layout G2+B+J1: Storm 6 - 50yr

Source: HR Wallingford

8. Layout G+B+H1

The model results for Layout G2+B+J1 indicated that this layout meets the target wave heights inside the marina and at the outer berths. However, compared with Layout G+B, there is predicted to be a small increase in wave heights within marina, and the length of Breakwater J1 is considered to be long for the added shelter it provides at the outer berths.

Following a discussion with the client, they decided to revert to the Layout G+B but in order to try to reduce wave conditions at the outer berths, it was agreed to model an angled fillet in the corner between the marina curve and the protrusion (see Figure 8.1). The aim of this fillet is to reflect waves back towards the gap between the existing marina curve extension and Breakwater B and reduce standing waves along this section of the marina curve breakwater, particularly in this corner where waves are highest.

No additional dredging is required for this layout.

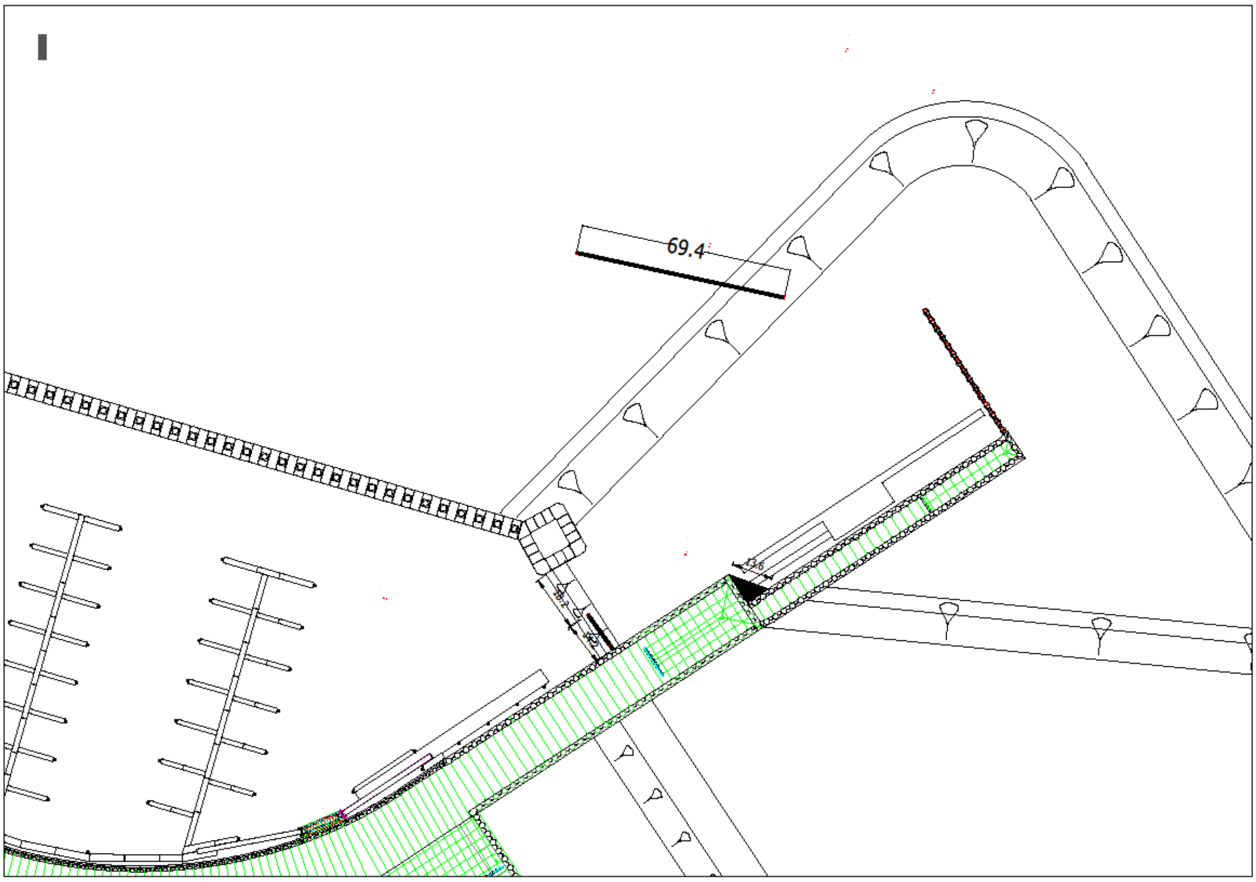

Figure 8.1: Layout G+B+H1

8.1. Model bathymetry

The model bathymetry was identical to that used for previous layouts (baseline and Layout G), i.e. excluding Layout G+A1 that required additional dredging.

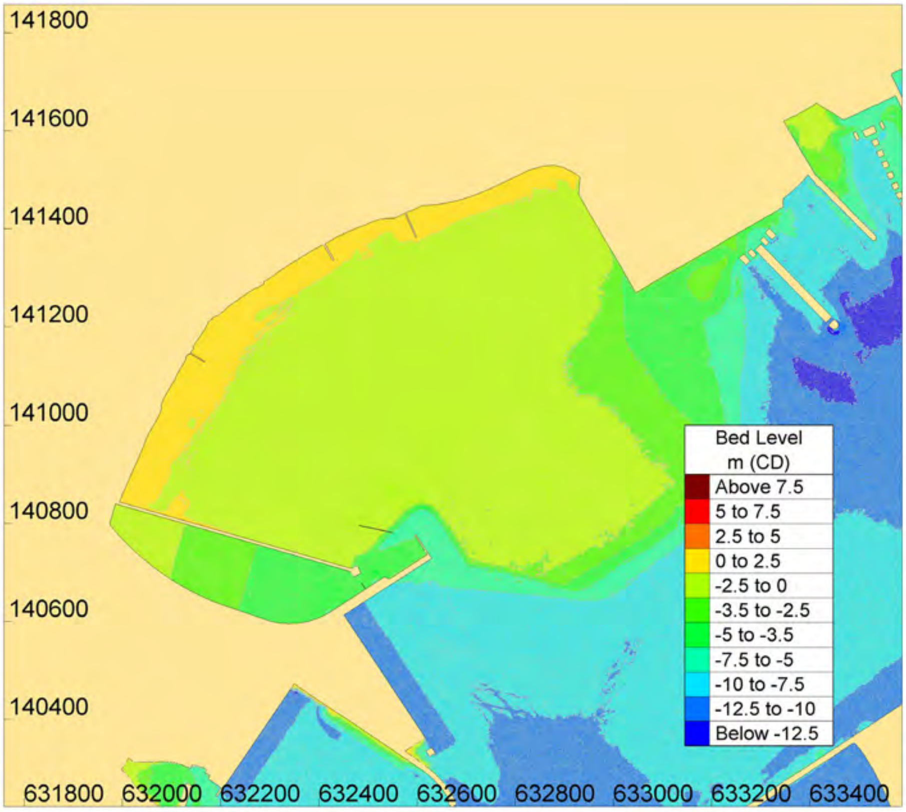

Figure 8.2: Layout G+B+H1 Model depths

8.2. Reflection coefficients

The reflection coefficients applied (as shown in Figure 5.3) for Layout G+B+H1 are the same as used for the baseline case (including Pier F) and Layout G+B. A reflection coefficient of 0.95 was used for Breakwater H1 and this wave screen / breakwater fillet was assumed to extend to the seabed allowing no wave transmission underneath.

Figure 8.3: Layout G+B+H1 Reflection coefficients

8.3. Model test conditions

The ARTEMIS model was initially run for one test condition referred to previously as Storm 6 as summarised in Table 3.1. This has an approximate return period of 1 year. A second model run was also carried out by scaling up the boundary significant wave height of Storm 6 to 5.14m and is representative of a 50 year return period offshore wave condition (as previously reported).

8.4. Model results

The model results for Layout G+B+H1, show that the effect of Breakwater H1 is a very localised effect, with generally very similar wave heights predicted within the marina and outer berths as given for Layout G+B.

According to the tabulated results quoted in Figure 8.11 and Figure 8.12, the results for Layout G+B+H1 are very slightly higher than Layout G+B inside the marina and outside at points W1 and W2. Similarly, the contour plots (Figure 8.6 and Figure 8.9) show that Breakwater H1 results in only a small reduction in wave height in this corner (H1), with significant wave heights still slightly above the target 0.78m in the 50 Year event. It seems likely that the change at H1 is too small relative to the wavelength to have much effect. It appears that a small amount of wave energy spills around the corner of H1 but will then reflect from Breakwater G so the main standing wave between Breakwater G and the Marina extension return is still very similar to before.

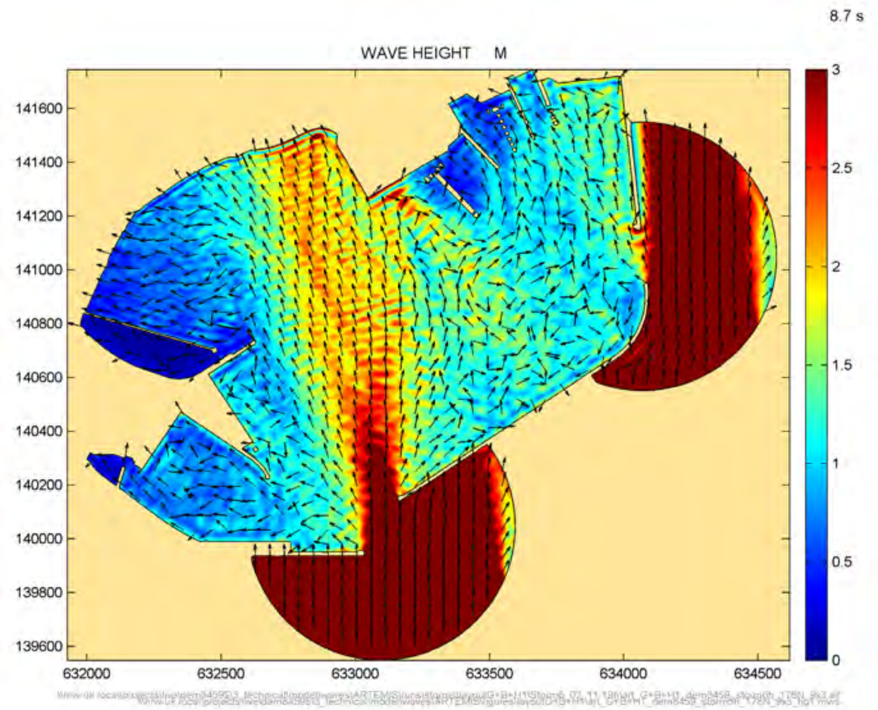

Figure 8.4: Wave conditions inside harbour (Layout G+B+H1: Storm 6)

Source: HR Wallingford

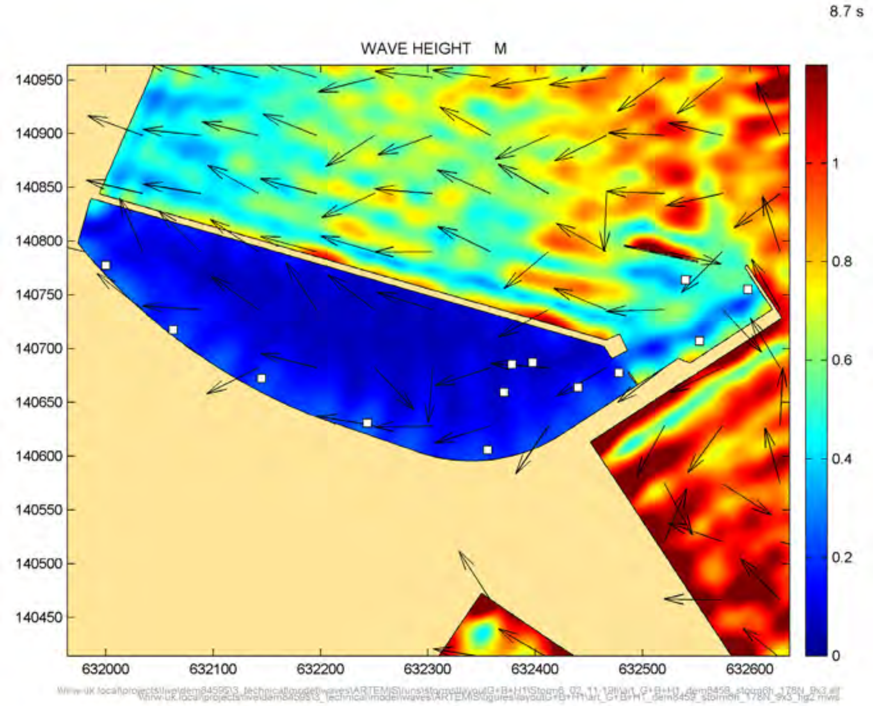

Figure 8.5: Wave conditions inside marina (Layout G+B+H1: Storm 6)

Source: HR Wallingford

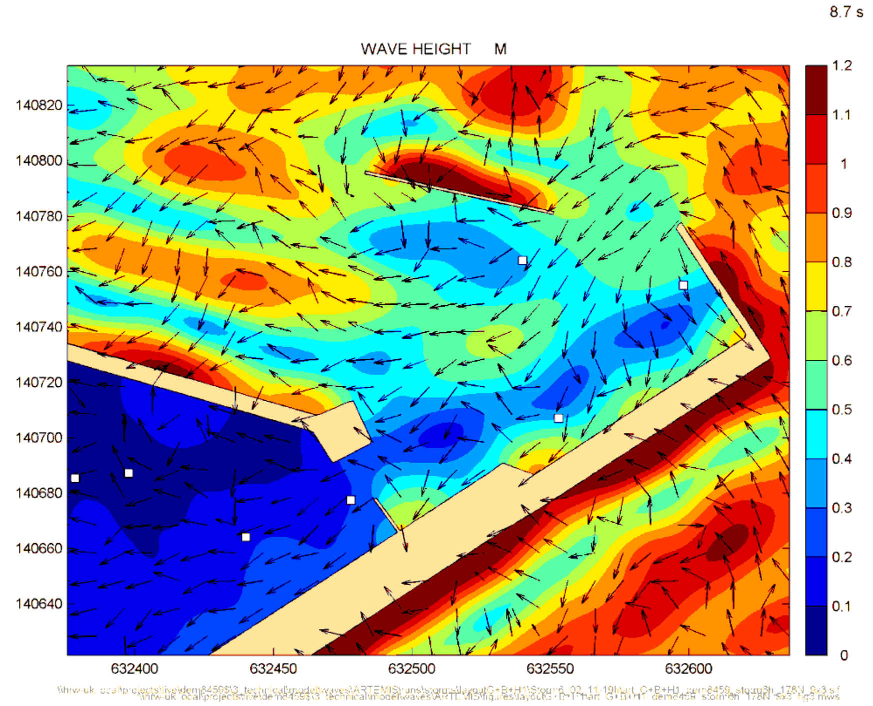

Figure 8.6: Wave conditions outside marina (Layout G+B+H1: Storm 6)

Source: HR Wallingford

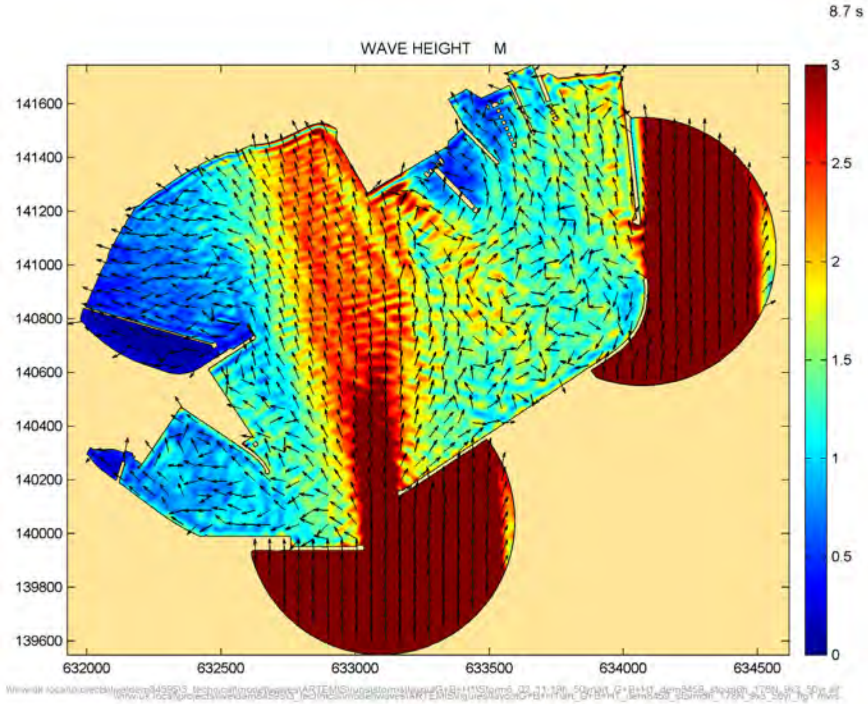

Figure 8.7: Wave conditions inside harbour (Layout G+B+H1: 50 Year)

Source: HR Wallingford

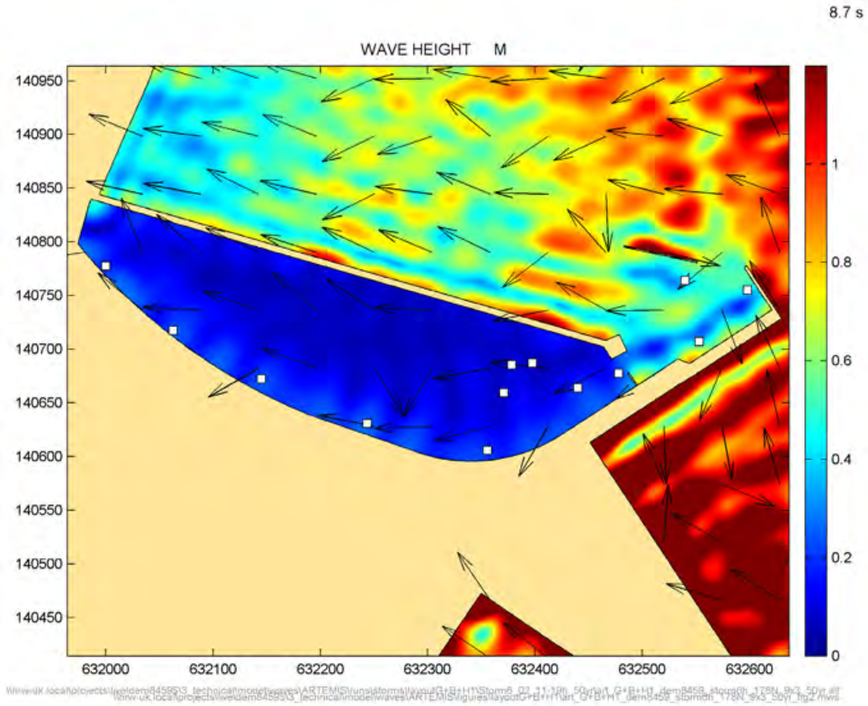

Figure 8.8: Wave conditions inside marina (Layout G+B+H1: 50 Year)

Source: HR Wallingford

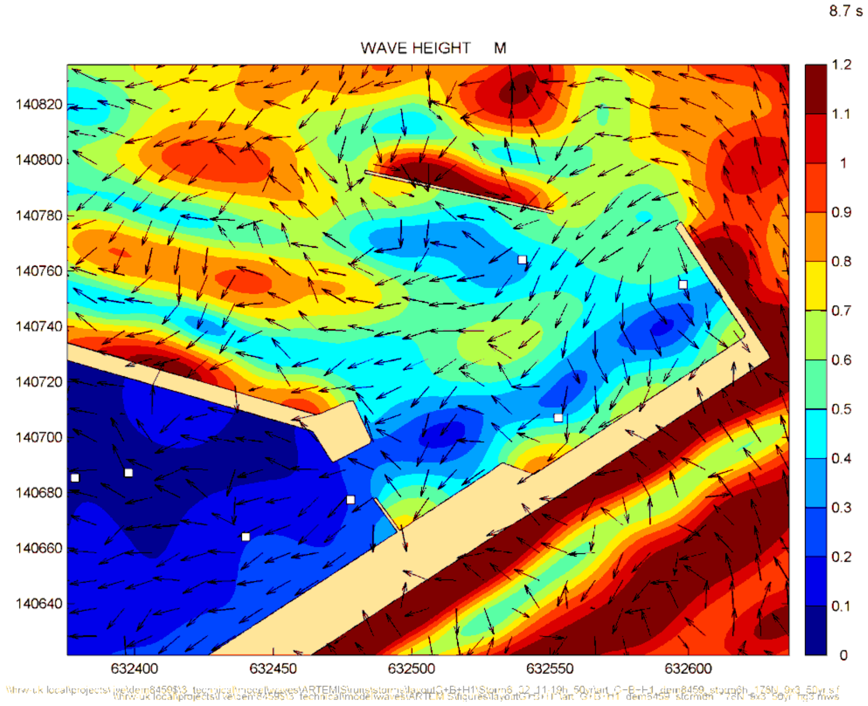

Figure 8.9: Wave conditions outside marina (Layout G+B+H1: 50 Year)

Source: HR Wallingford

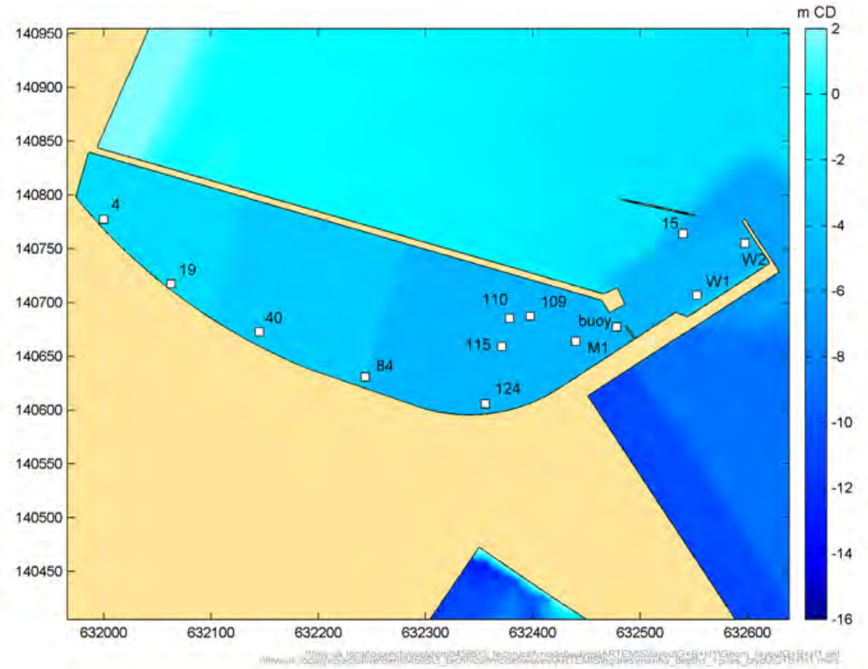

Figure 8.10: Layout G+B+H1: Model depths within Marina and output locations

Source: HR Wallingford

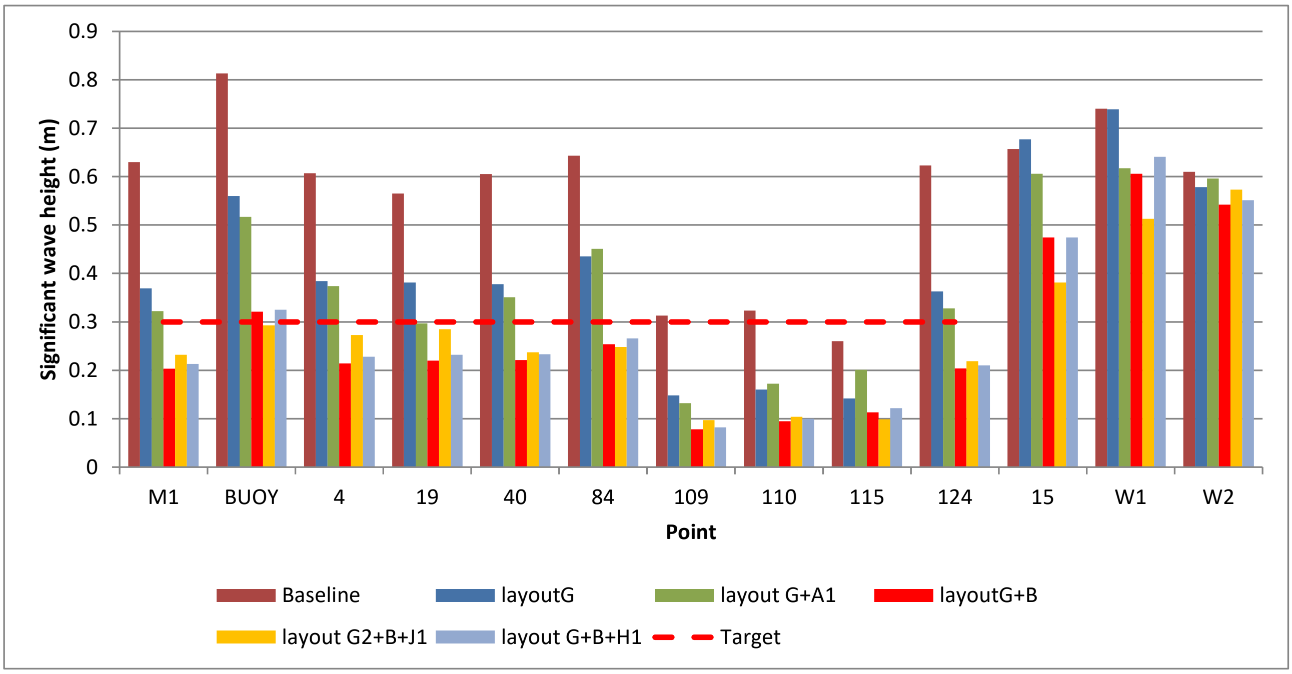

Figure 8.11: Predicted wave height variation within marina for Layout G+B+H1: Storm 6

Source: HR Wallingford

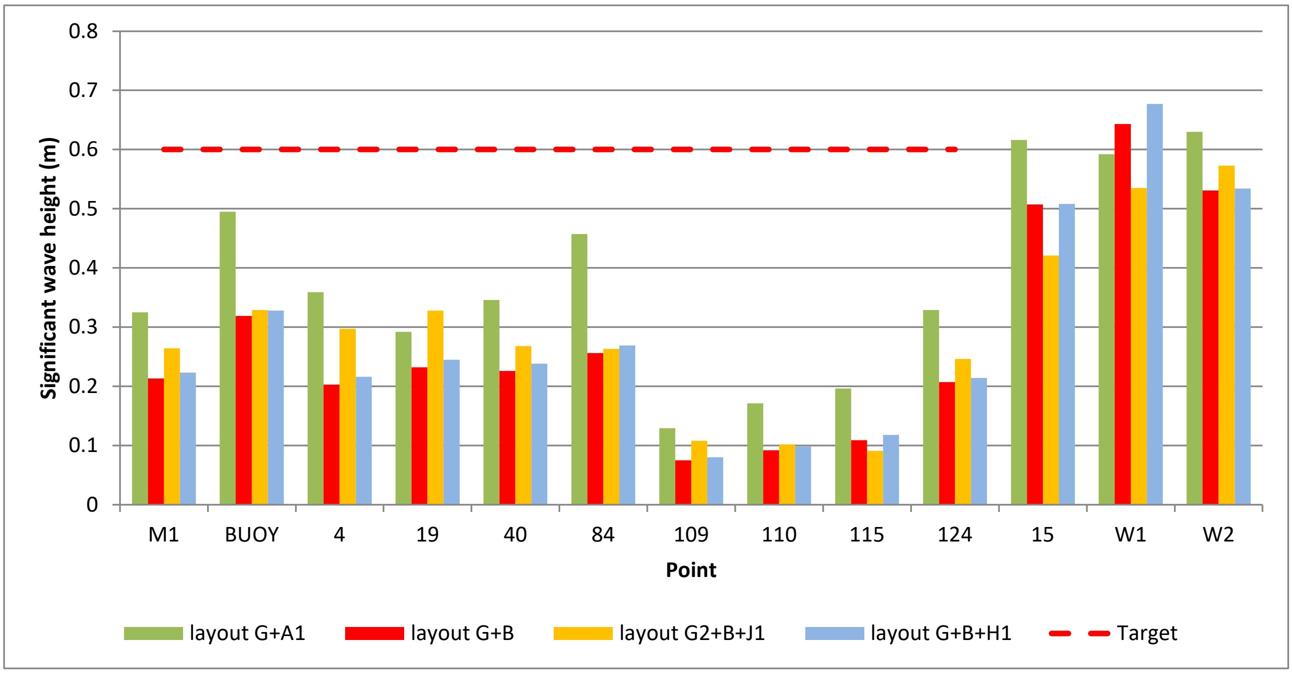

Figure 8.12: Predicted wave height variation within marina for Layout G+B+H1: Storm 6 - 50yr

Source: HR Wallingford

9. Layout G+B sensitivity tests and period scan results

Following a review with DHB of the results for the various different layouts considered, Layout G+B (see Section 6) was taken forward as the preferred layout. Because of the uncertainty associated with the boundary wave directions, further sensitivity tests of the model predictions for Layout G+B using slightly different boundary wave directions were carried out for the Storm 6 (1 year) and 50 year condition previously modelled. These conditions were both originally run with a boundary mean wave direction of 178°N, so additional runs were carried out using boundary wave directions of 173°N and 183°N, i.e. +/-5 degrees either side of the original mean wave direction applied along the model boundaries.

All model runs for the 1 and 50 year conditions were previously carried out using the water level that occurred with Storm 6: +6.0mCD. An initial analysis, reported in HR Wallingford Report DEM8459-RT002, showed that maximum wave heights measured within the marina occurred after high water. This is believed to be due to a combination of the stronger tidal currents after high water that refract waves more directly into the harbour and the time required for wave heights to build up within marina, before the tide starts to drop and reflections from Marine Parade start to reduce with lower water levels. A further analysis of the measured wave conditions and water levels within the marina and harbour was subsequently carried out based on waves measured within the marina and harbour. Appendix B and C show the time series of water levels and wave conditions around the time of the highest ten peaks of significant wave height recorded to date. Note, there is no overlap between measurements from inside the marina (at the buoy location shown in Figure 9.1) and in the harbour (at the location shown in Figure 9.2) as the same device was used. The time series plots in Appendix B and C show that, in general, the highest wave heights within the marina and harbour occur after high water, as was previously concluded. However, there are a few cases when the highest wave heights also occur at high water. Therefore, in order to check the sensitivity of the predicted wave conditions within the marina, model runs were repeated using a water level of +6.8mCD (present day MHWS). The associated model results are presented in Section 9.3 and 9.6.

Model runs were also carried out accounting for future Sea Level Rise (SLR). Current Environment Agency guidance (2020) for assessing flood risk of coastal projects recommends using the 70th percentile prediction from the RCP8.5 emissions scenario in UKCP18. This guidance also recommends an increase of 10% on offshore waves, but at this stage we are only testing the sensitivity of the predicted wave conditions to SLR. Predictions from UKCP18 for climate change predictions of a wide range of variables are available from The Met Office (2020) The relevant water level data for the Dover area was downloaded. The base levels are the average of 1981-2000 levels. Correcting to 50 years from 2020, the 70th percentile prediction is 0.41m above present day water levels. So model runs, including the sensitivity to boundary mean wave direction were carried out at a still water level of 7.21m (= MHWS+SLR = 6.8mCD+0.41m). The associated model results are presented in Section 9.4 and 9.7 for the 1 and 50 year conditions, respectively.

9.1. Discussion of sensitivity test results

The model results are presented as a series of colour contour plots, with the previous model results reproduced in this section for completeness. Figures are presented showing the predicted wave conditions across the whole model, within the marina and at the outer berths, with results presented for the three wave directions considered.

Model results were also extracted at the points of interest within the marina and outside the marina at the points shown in Figure 9.1. The predicted significant wave height results at the points of interest for Storm 6 (1-year condition) and the 50 year condition are presented as histograms in Figure 9.21, Figure 9.31, Figure 9.50 and Figure 9.60, respectively.

The colour contour plots show that the effect of changes of 5° in the boundary mean wave direction leads to small differences in wave conditions in the harbour and marina, with waves from 173°N appearing to result in the higher wave conditions in the marina and entrance to the marina. Possibly more noticeable from the plots is the difference when accounting for increased tidal level and SLR which appears to show a broader spread of waves from the western entrance and higher waves within the marina and most noticeably at the outer berthing area. This is expected to be partly due to increased wave energy diffracting around the marina breakwater, but also increased wave energy reflecting back towards the marina from the Marine Parade seawalls, due to less wave breaking in the shallow water and beach areas in front of the seawalls.

Similarly, the histograms show that the effect of changes of 5° in the boundary mean wave directions leads to relatively small changes to the wave conditions at the prediction points. However, the model results, show that particularly at the outer berths locations W1 and W2 the wave heights are sensitive to the water level, with increases in predicted significant wave height at these locations most notably when using a water level of 7.21m, compared with a still water level of +6.0mCD that occurred during Storm 6.

Figure 9.21 shows that the target for 1-year significant wave height of 0.3m is exceeded at points 4 and 19 when run at MHWS, whereas accounting also for SLR, Figure 9.31 shows that within the marina at the Buoy location and points 4, 19 and 84, the wave heights are above the target and by a more noticeable amount. For the 50 year condition, even accounting for SLR, the results within the marina are predicted to be below the recommended threshold of 0.6m.

These results assume existing beach levels. It is expected that, as sea level rises in future years, some maintenance of the beaches will be required to raise their levels to maintain existing standards of flood protection. This will help mitigate against the additional wave reflections shown in the modelling of the effects of SLR.

The model results presented all show a relatively low wave height region outside the marina, approximately parallel to the proposed outer berths. This is typical of a standing wave pattern with areas of higher waves at anti-nodal points, and lower wave heights at nodal points and is due to the interference between incident and reflected waves. Wave heights at nodal locations will be lower than at anti-nodal points; however it is worth noting that the associated, oscillating wave induced currents will be higher at nodal points. This information will be important in the position and design of the outer berth mooring arrangements.

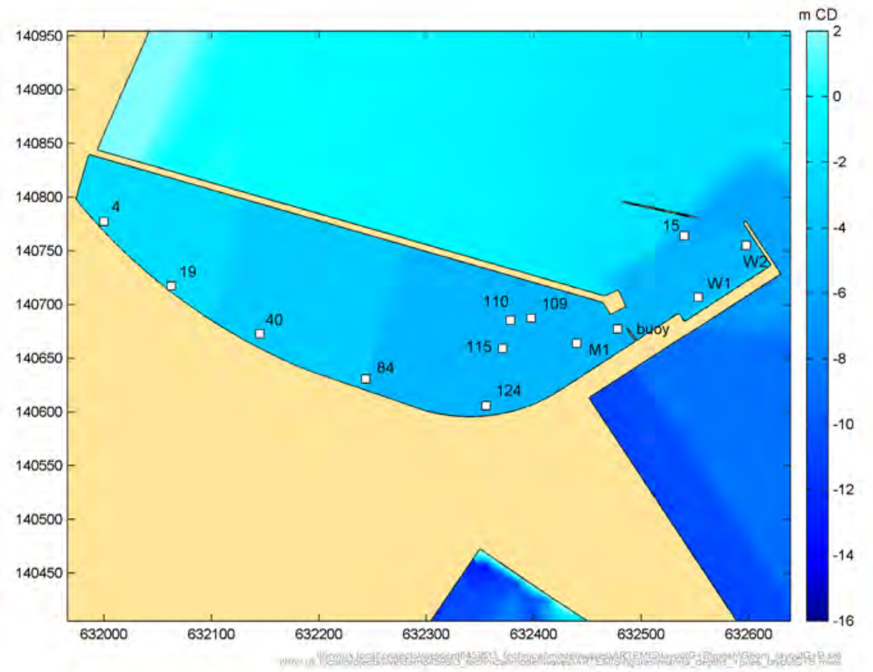

Figure 9.1: Layout G+B: Model depths within Marina and output locations

Source: HR Wallingford

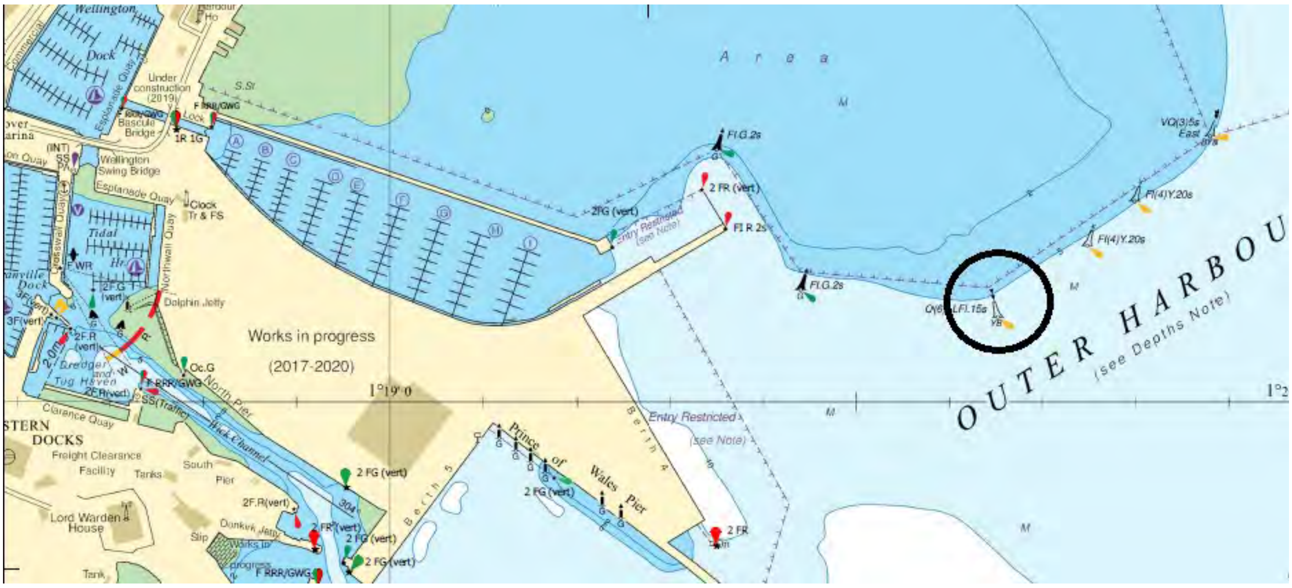

Figure 9.2: Location of wave buoy device in harbour

Source: DHB

9.2. Sensitivity to boundary wave direction (1-year condition)

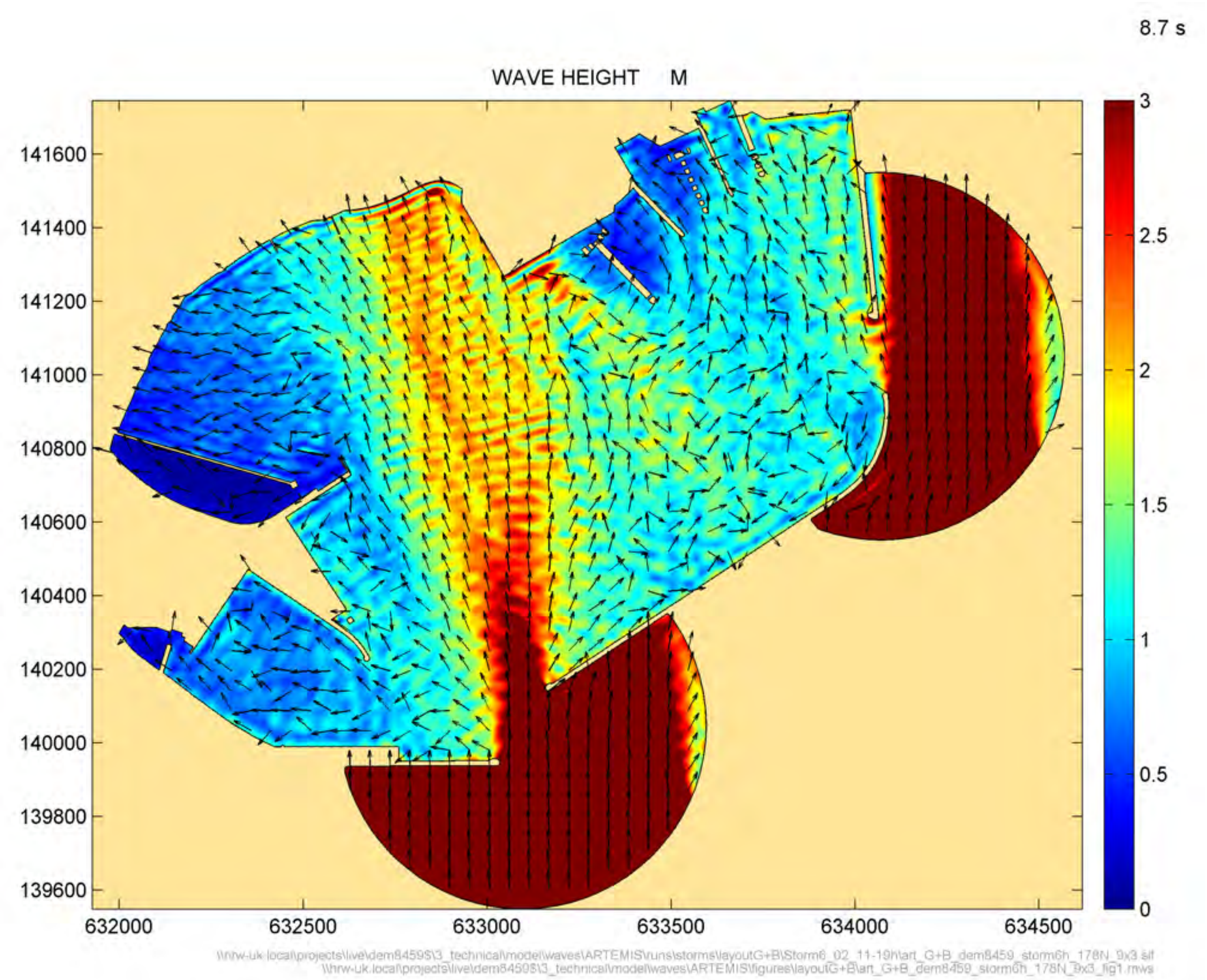

Figure 9.3: Wave conditions inside harbour (Layout G+B: 1 Year 178°N)

Source: HR Wallingford

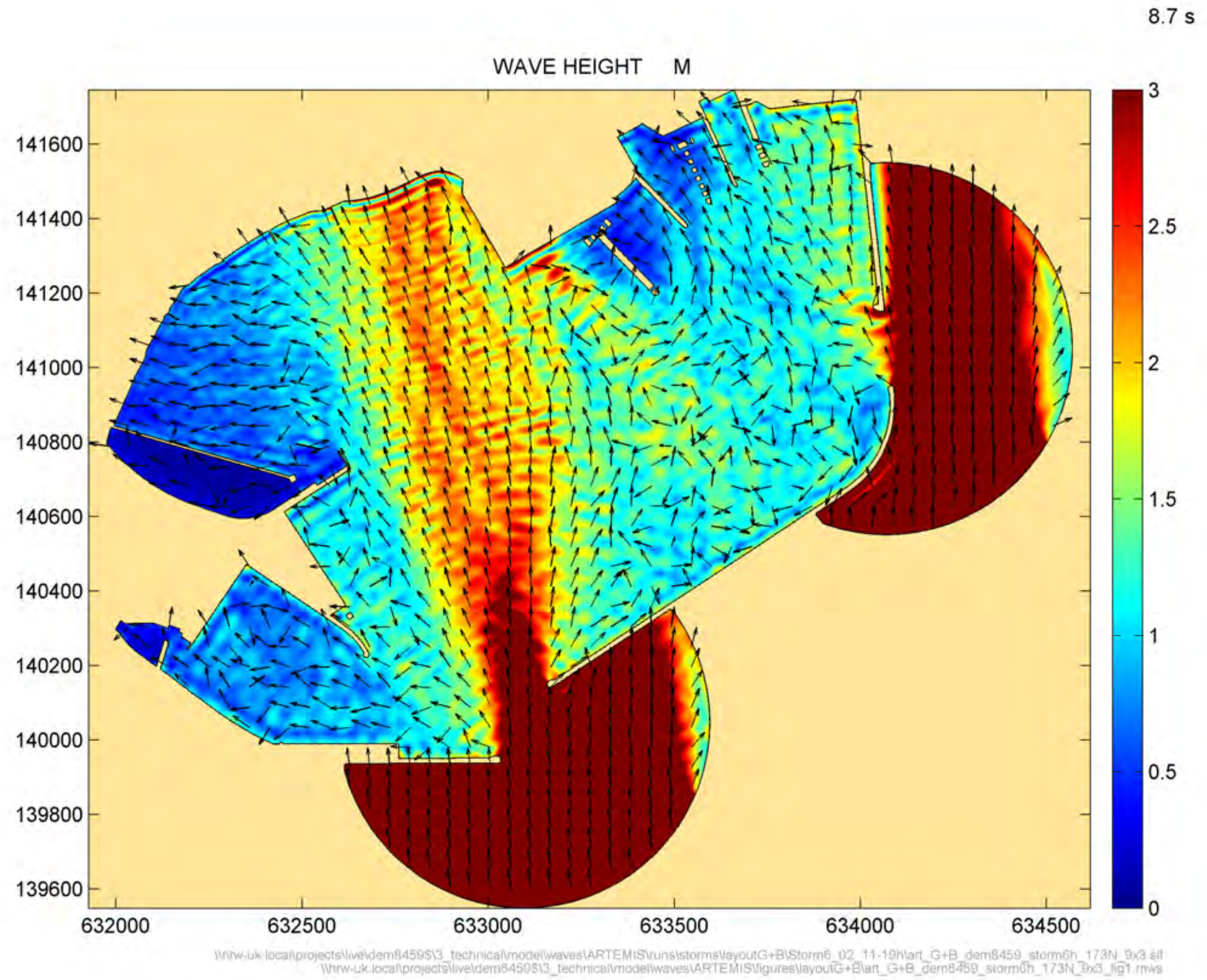

Figure 9.4: Wave conditions inside harbour (Layout G+B: 1 Year 173°N)

Source: HR Wallingford

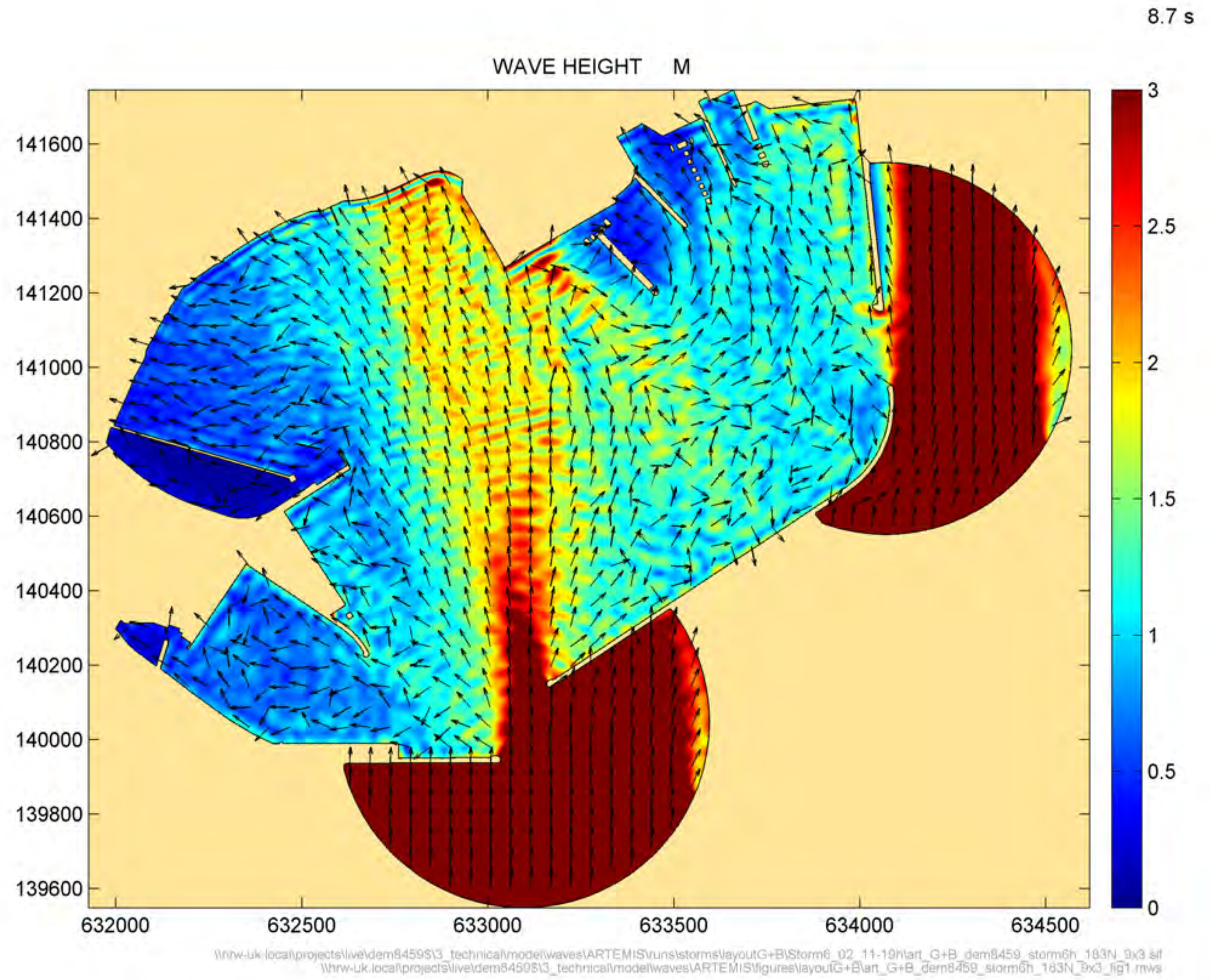

Figure 9.5: Wave conditions inside harbour (Layout G+B: 1 Year 183°N)

Source: HR Wallingford

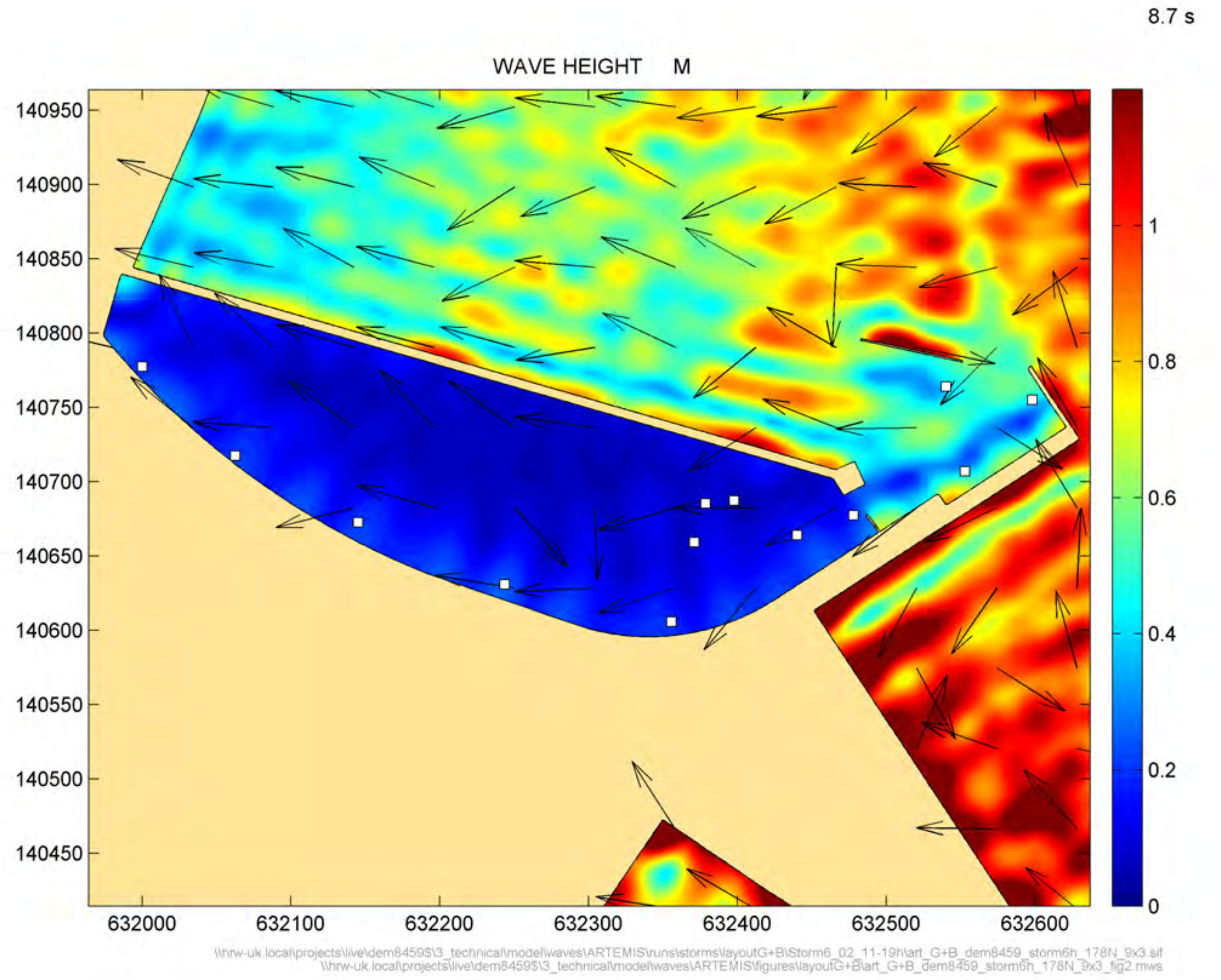

Figure 9.6: Wave conditions inside marina (Layout G+B: 1 Year 178°N)

Source: HR Wallingford

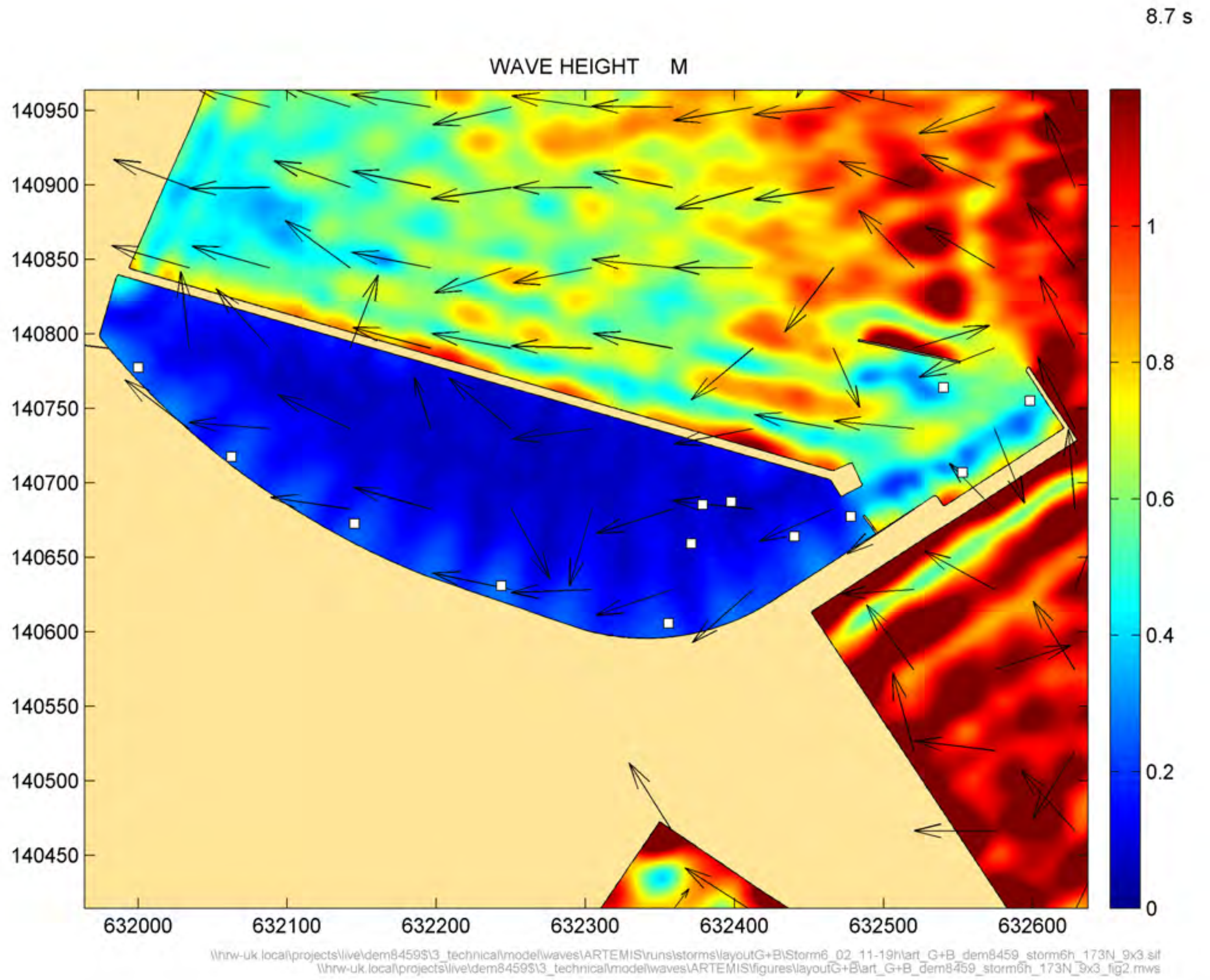

Figure 9.7: Wave conditions inside marina (Layout G+B: 1 Year 173°N)

Source: HR Wallingford

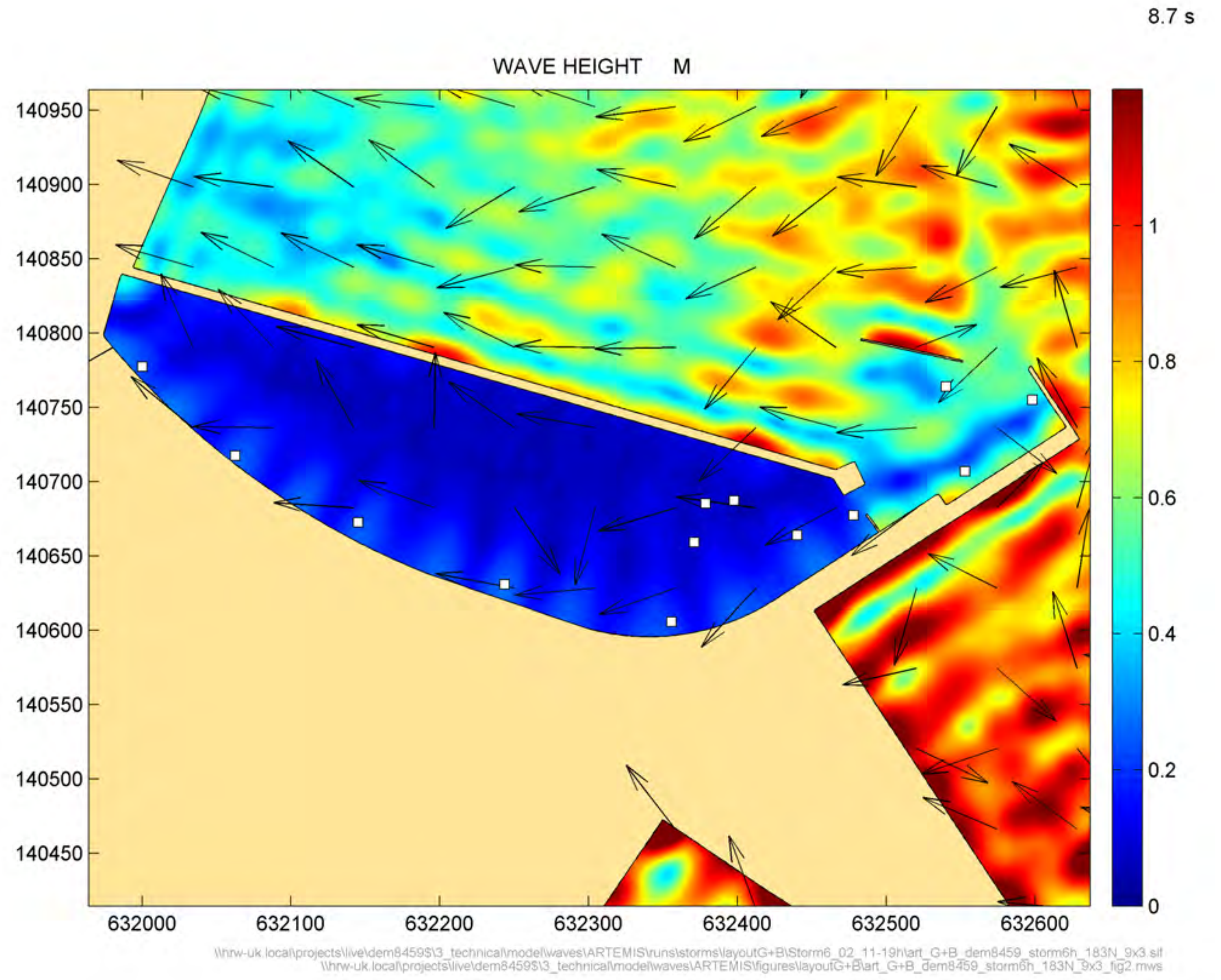

Figure 9.8: Wave conditions inside marina (Layout G+B: 1 Year 183°N)

Source: HR Wallingford

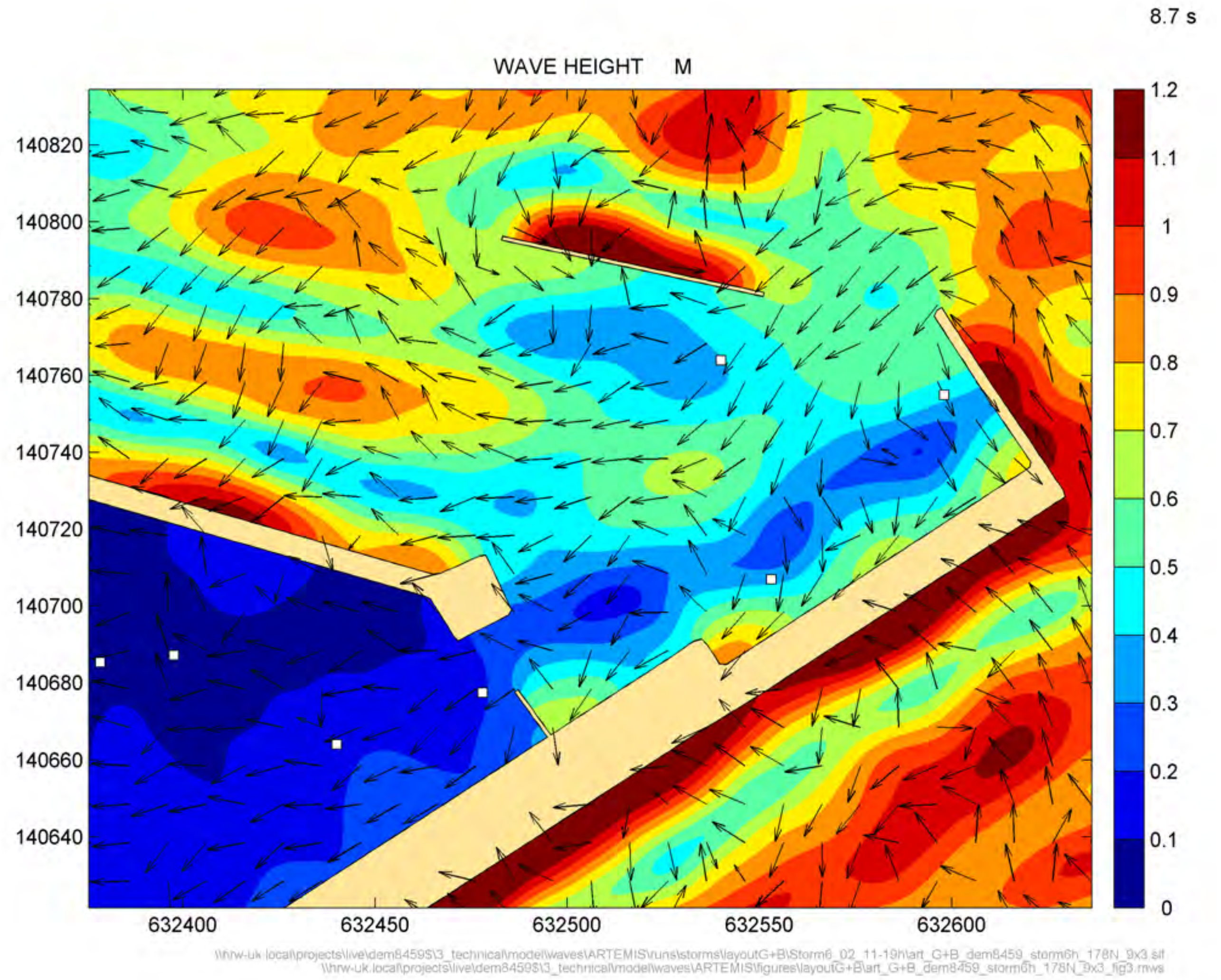

Figure 9.9: Wave conditions outside marina (Layout G+B: 1 Year 178°N)

Source: HR Wallingford

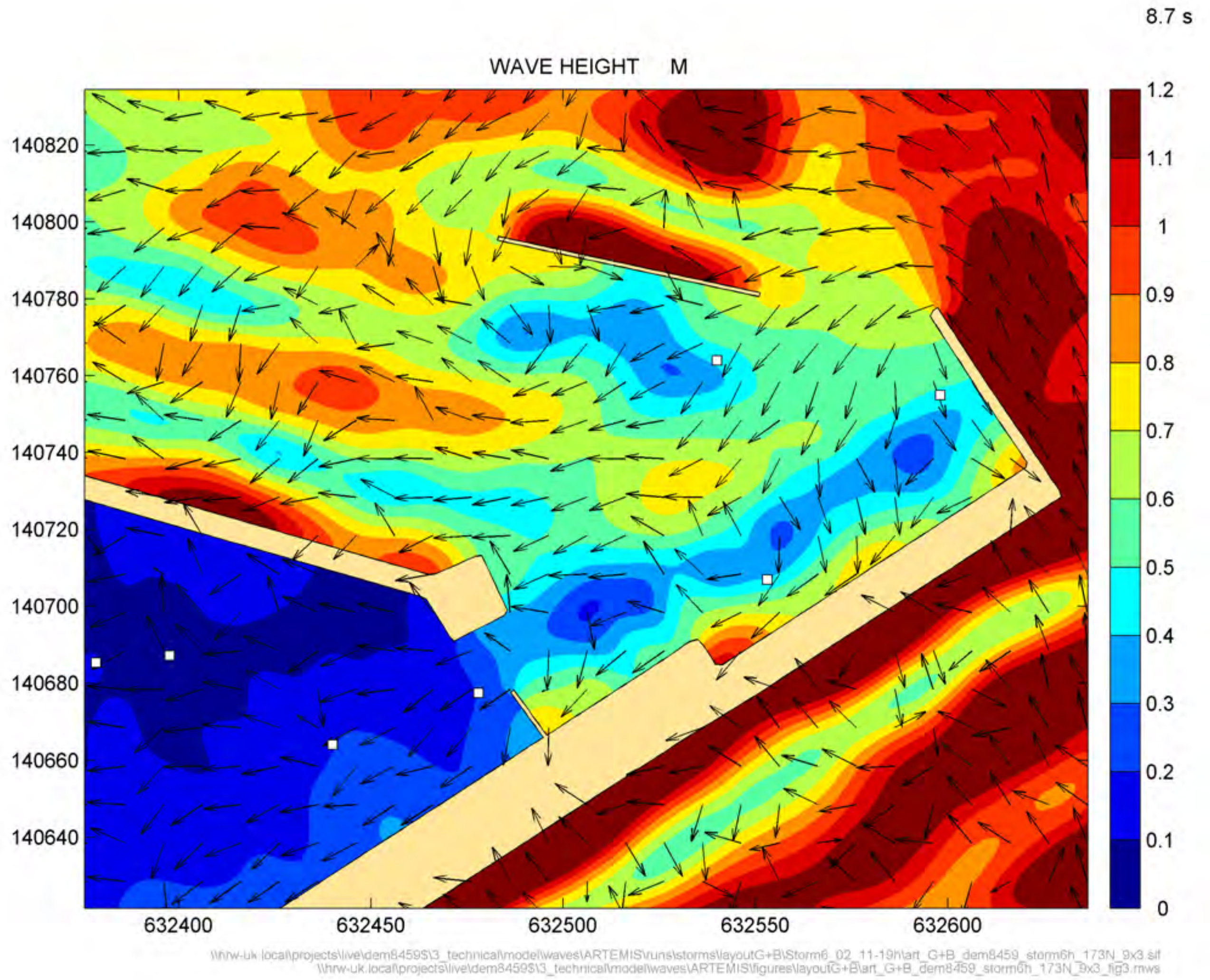

Figure 9.10: Wave conditions outside marina (Layout G+B: 1 Year 173°N)

Source: HR Wallingford

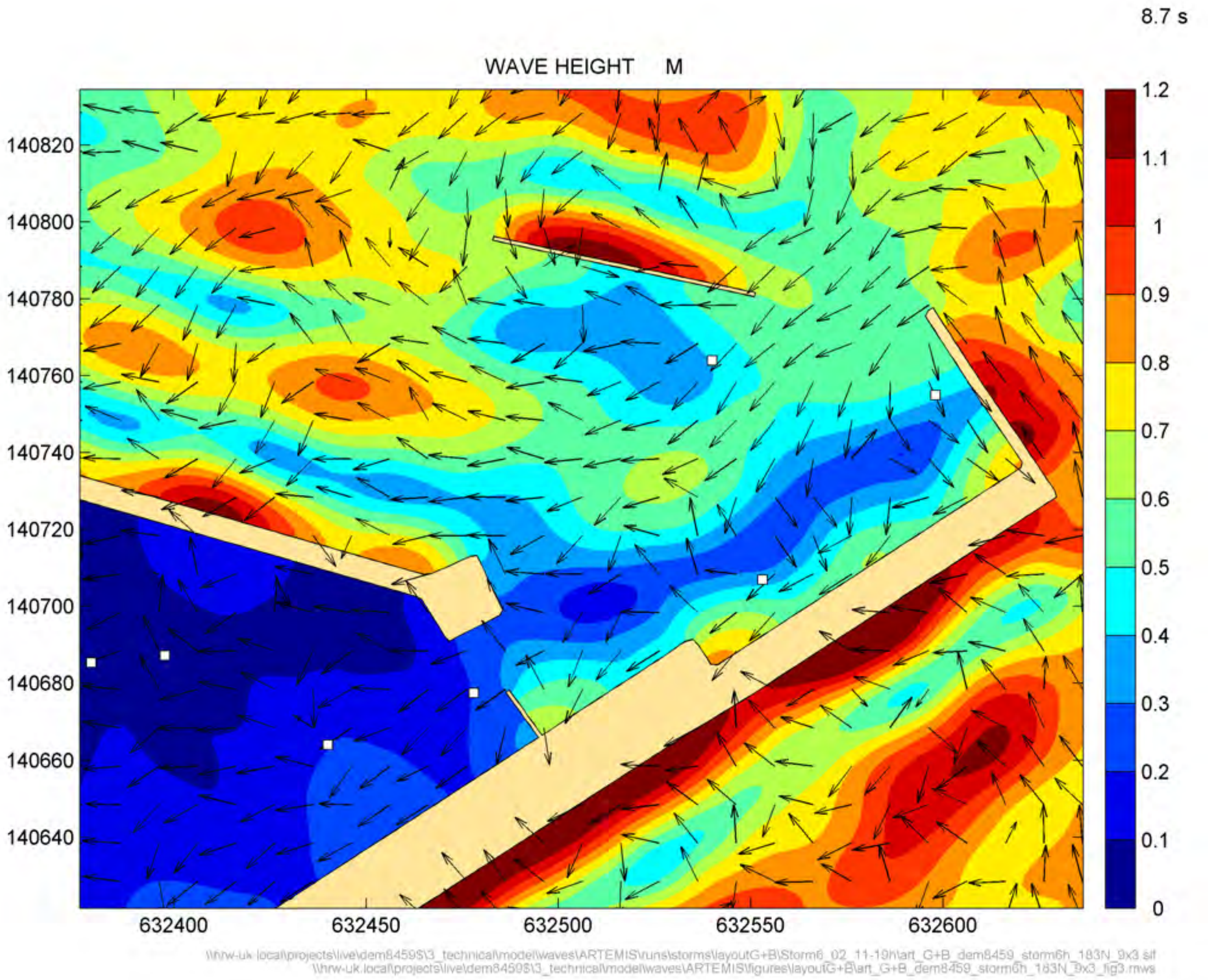

Figure 9.11: Wave conditions outside marina (Layout G+B: 1 Year 183°N)

Source: HR Wallingford

9.3. Sensitivity to boundary wave direction at MHWS (1-year condition)

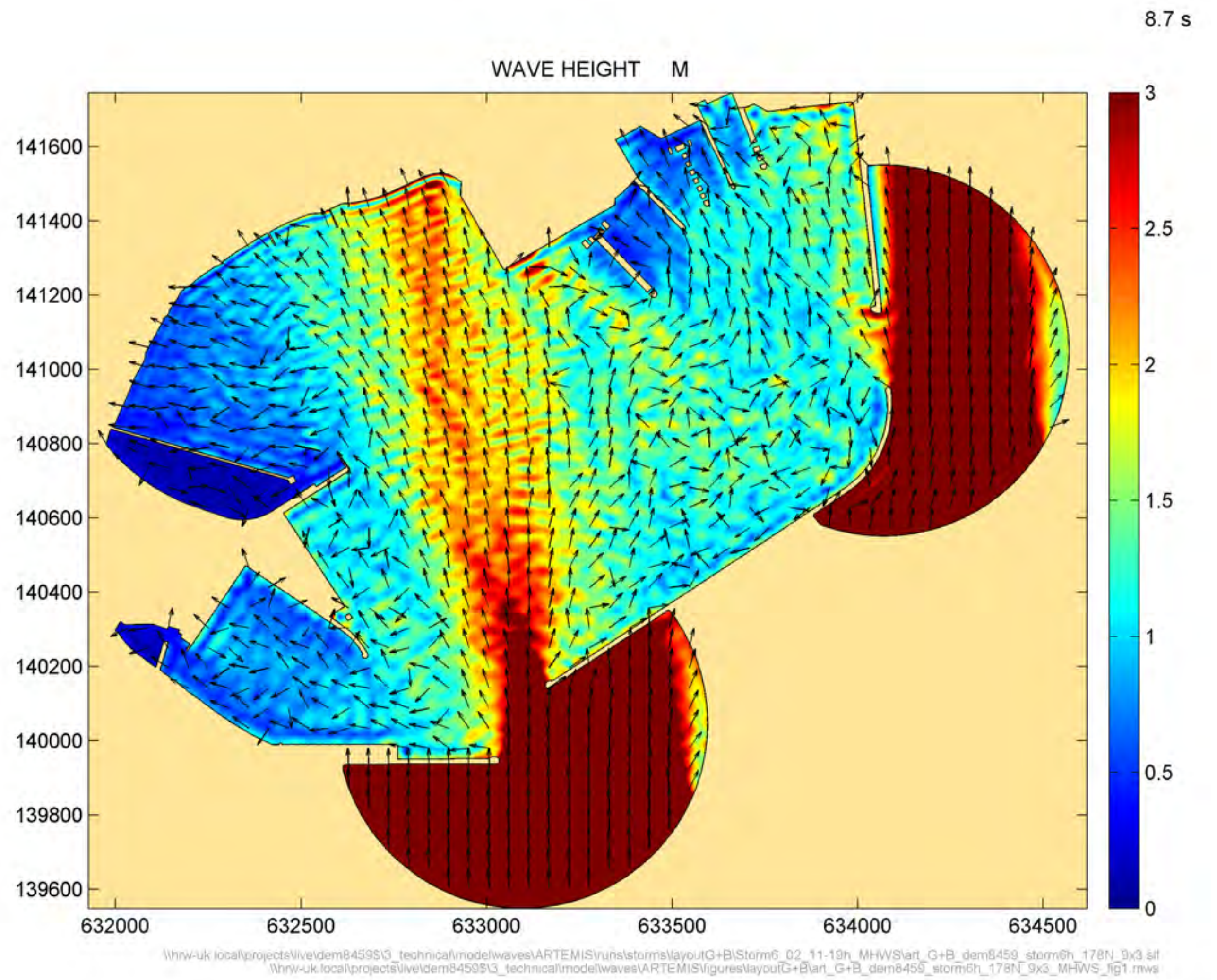

Figure 9.12: Wave conditions inside harbour (Layout G+B: 1 Year 178°N + MHWS)

Source: HR Wallingford

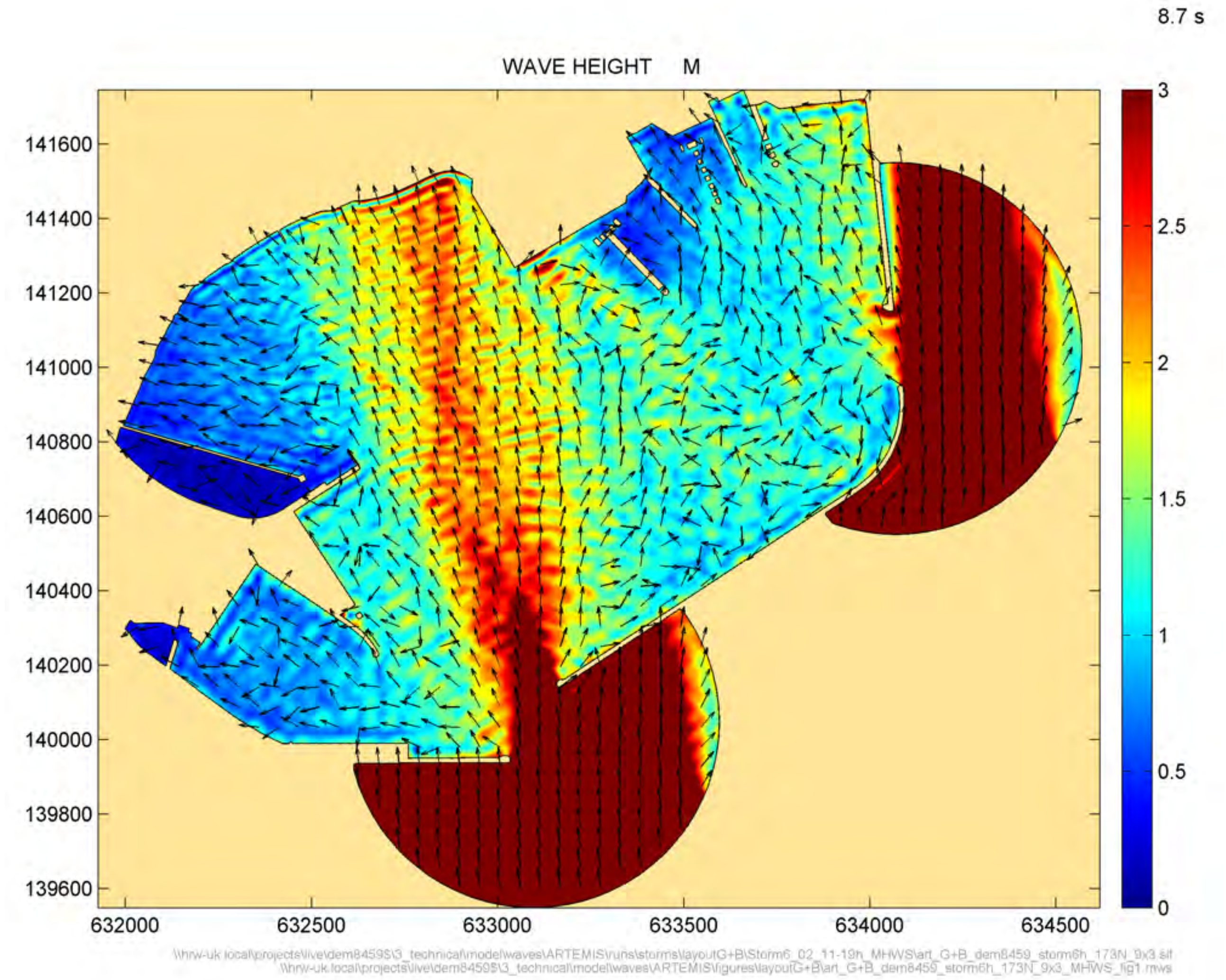

Figure 9.13: Wave conditions inside harbour (Layout G+B: 1 Year 173°N + MHWS)

Source: HR Wallingford

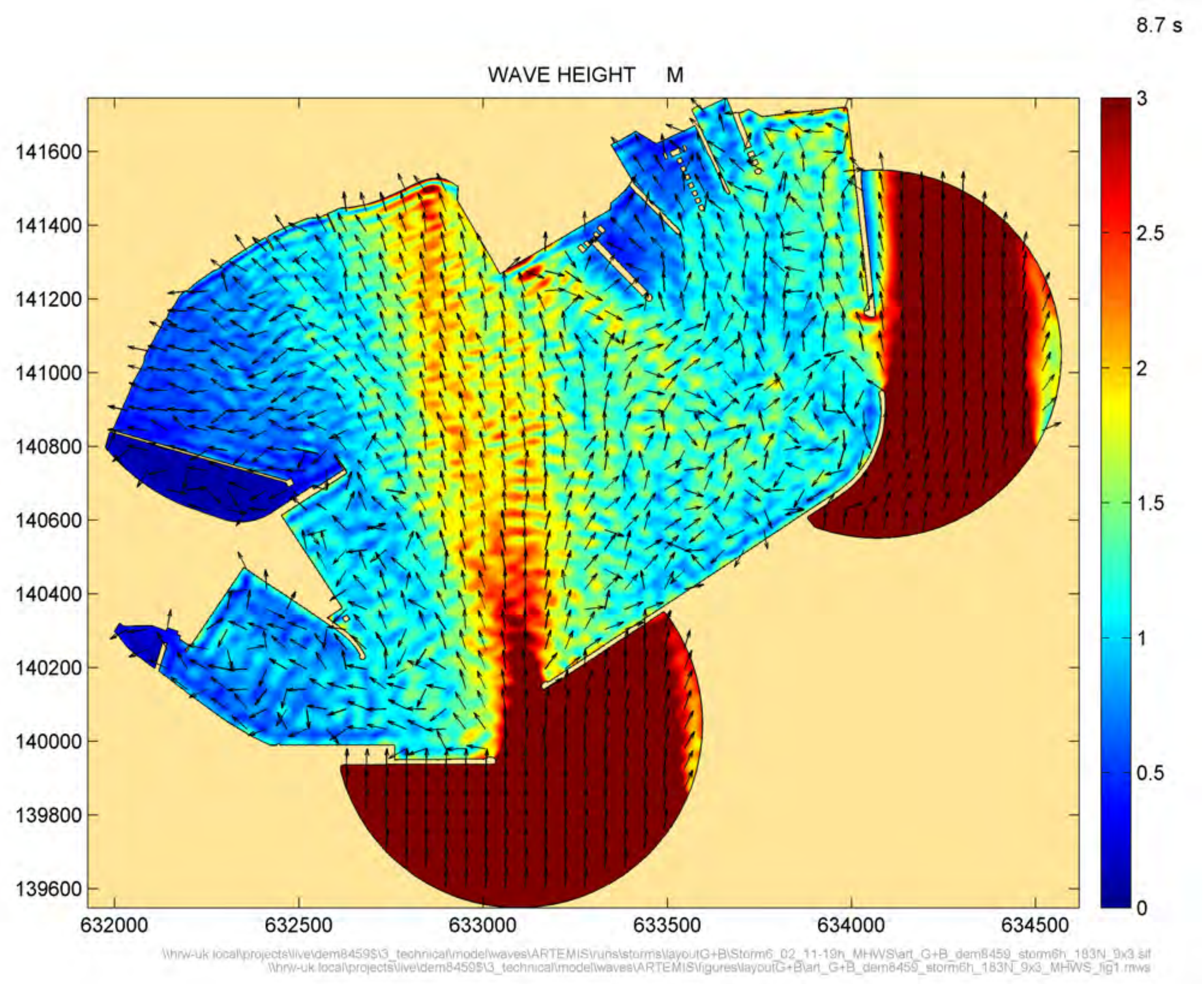

Figure 9.14: Wave conditions inside harbour (Layout G+B: 1 Year 183°N + MHWS)

Source: HR Wallingford

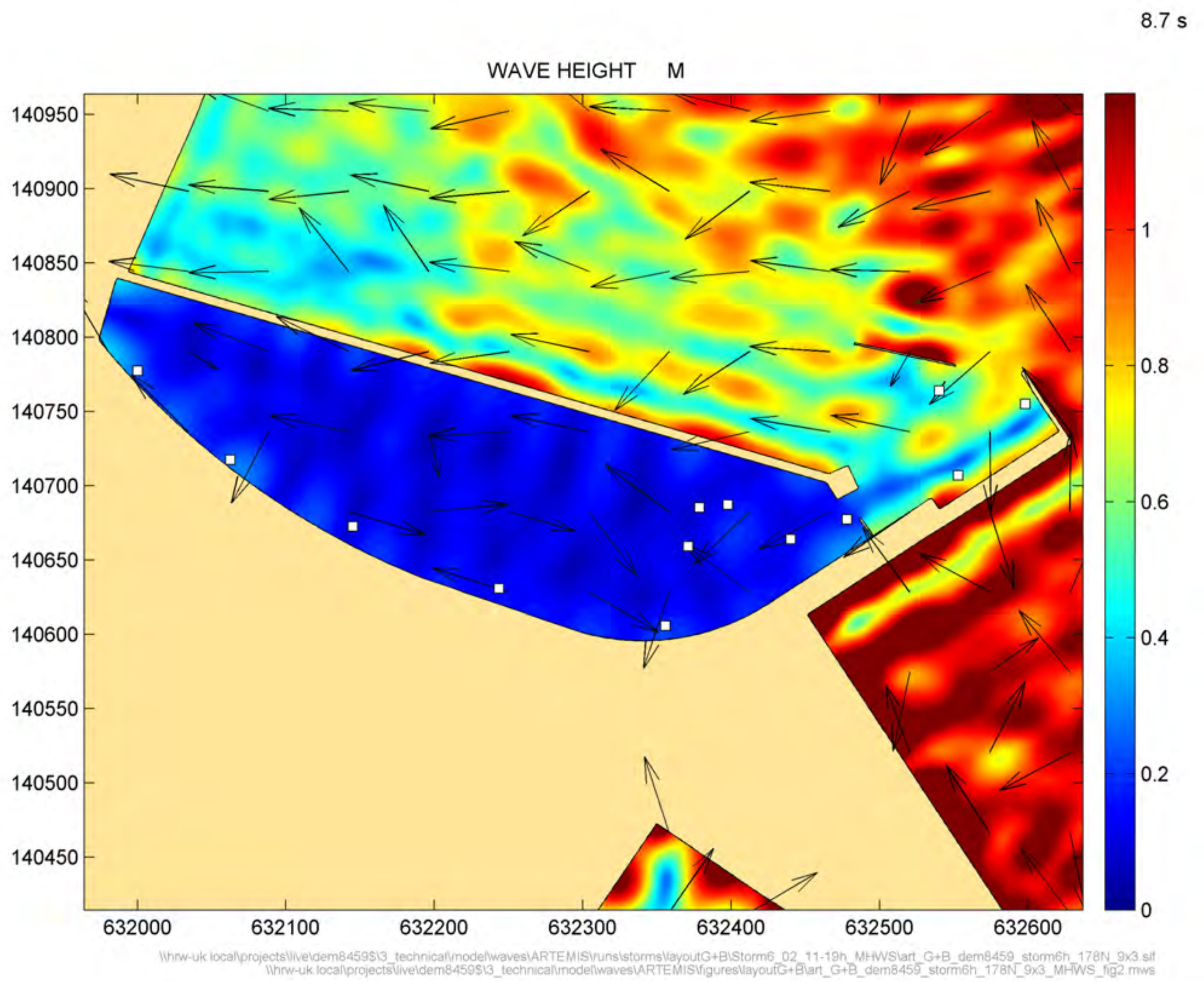

Figure 9.15: Wave conditions inside marina (Layout G+B: 1 Year 178°N + MHWS)

Source: HR Wallingford

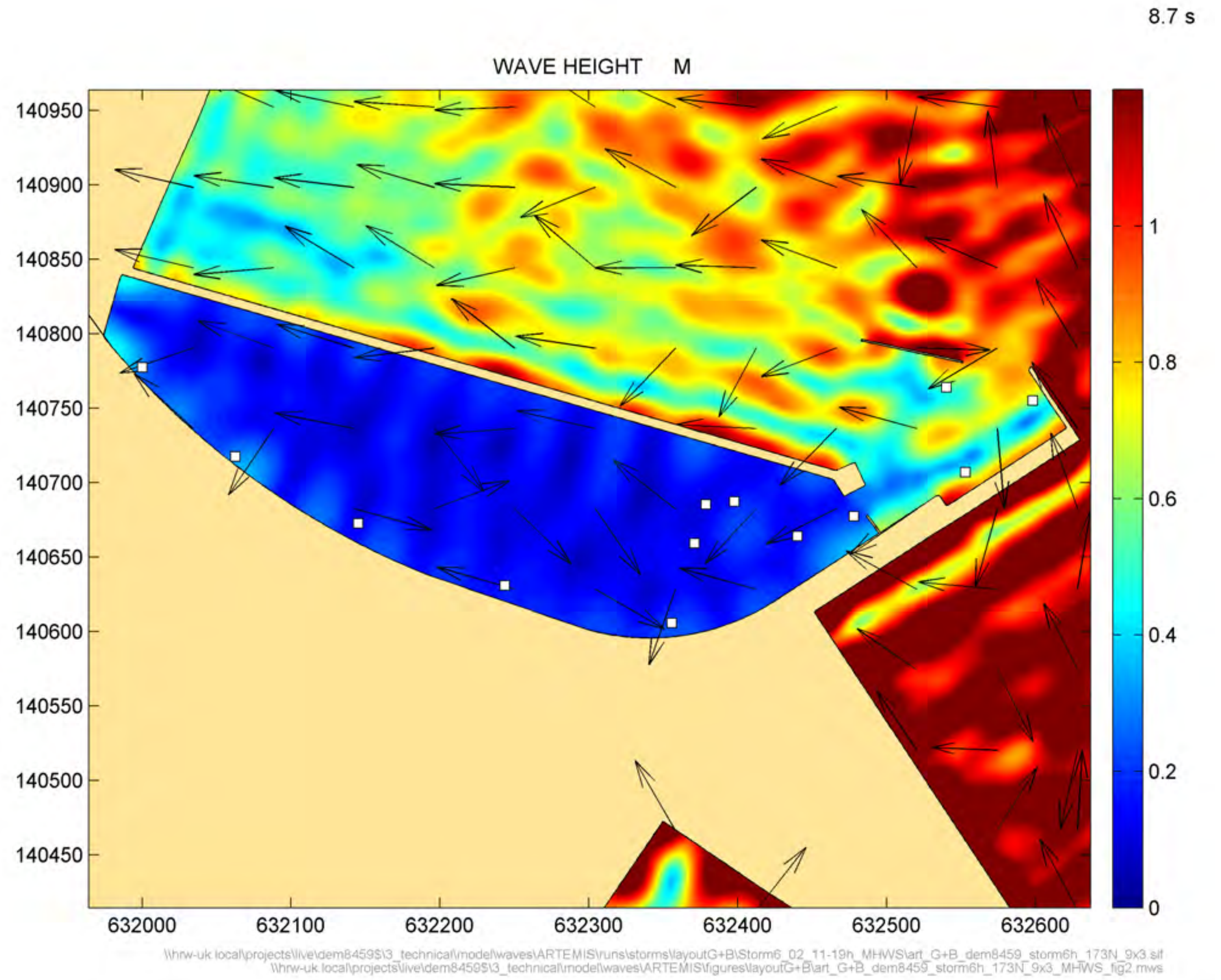

Figure 9.16: Wave conditions inside marina (Layout G+B: 1 Year 173°N + MHWS)

Source: HR Wallingford

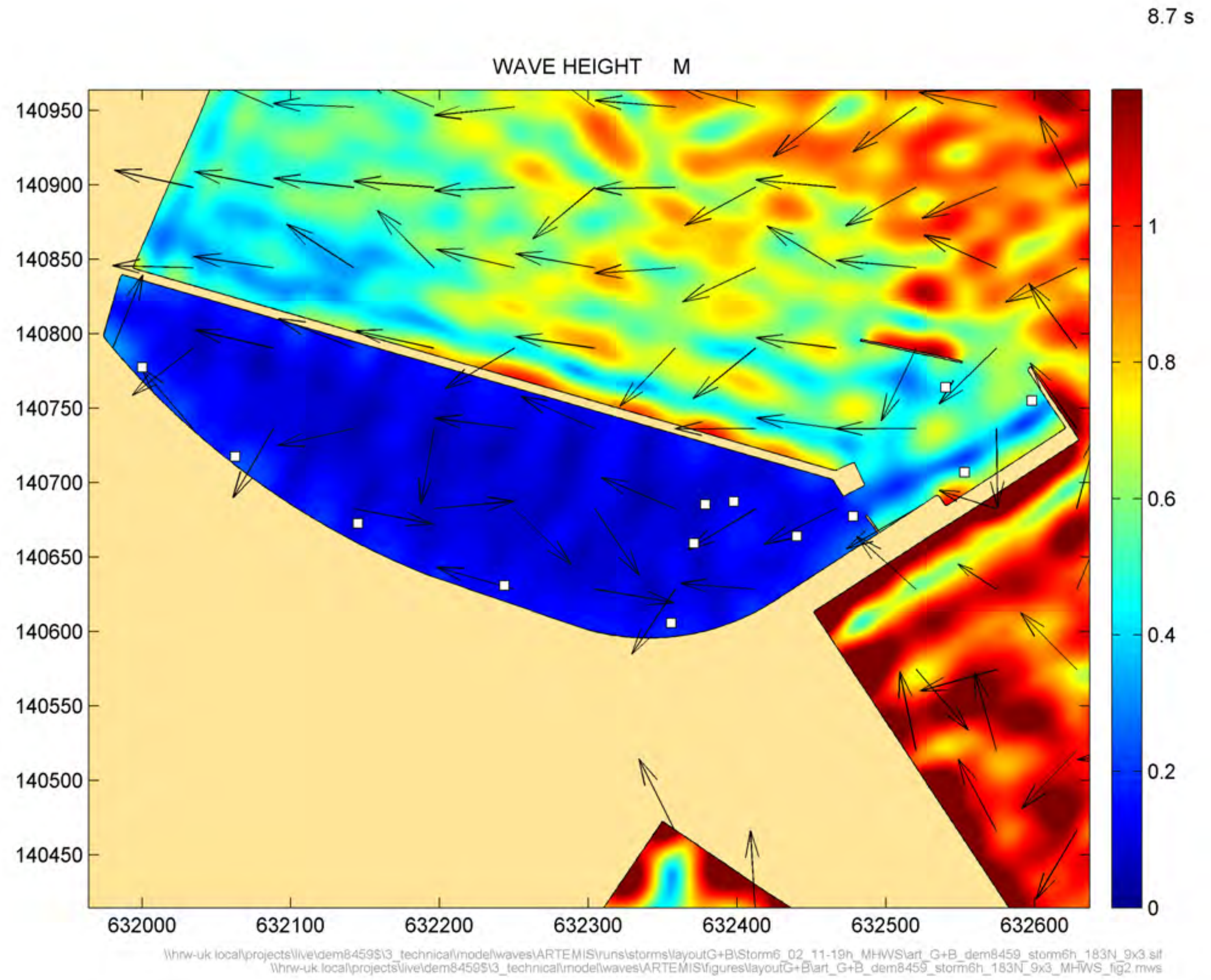

Figure 9.17: Wave conditions inside marina (Layout G+B: 1 Year 183°N + MHWS)

Source: HR Wallingford

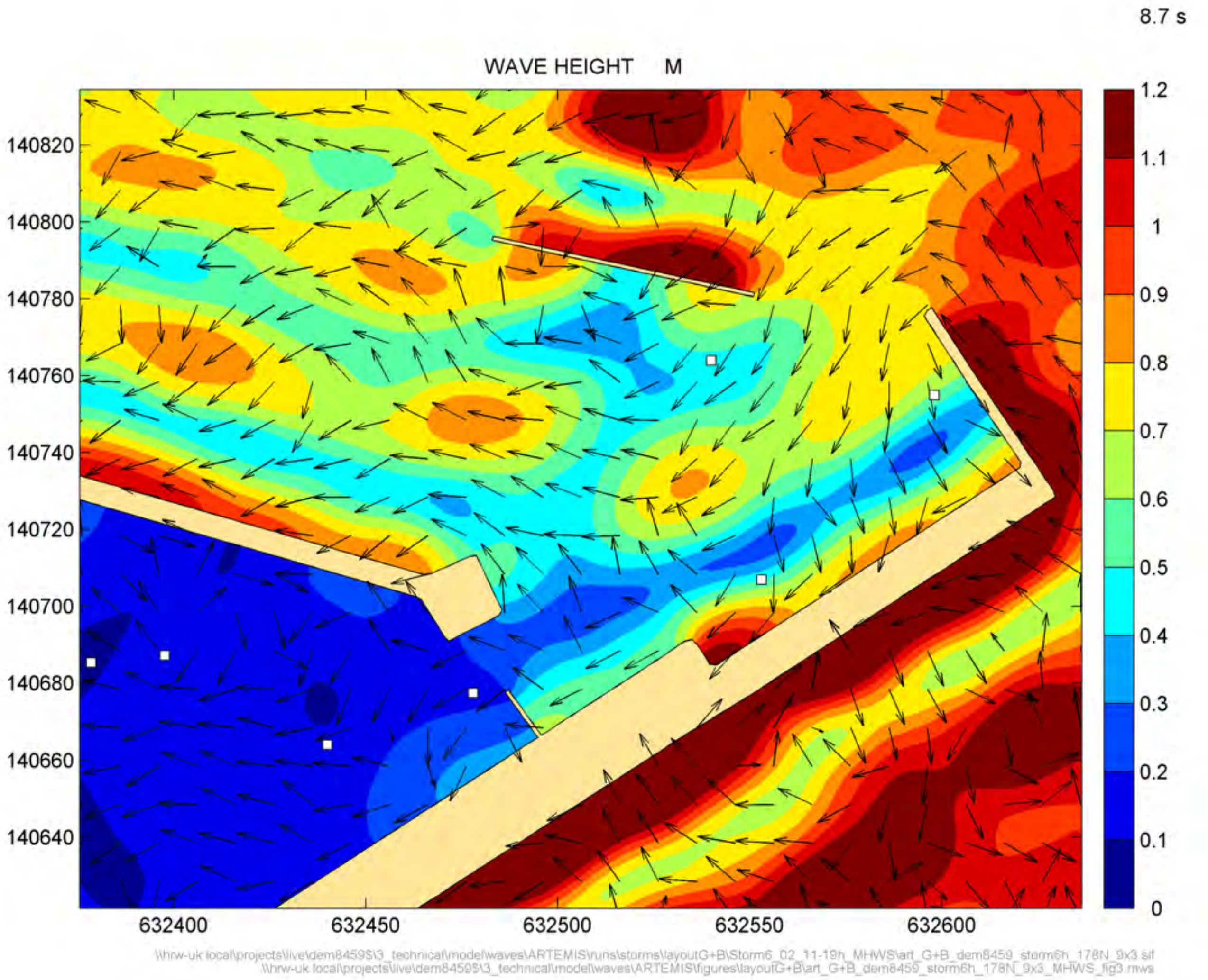

Figure 9.18: Wave conditions outside marina (Layout G+B: 1 Year 178°N + MHWS)

Source: HR Wallingford

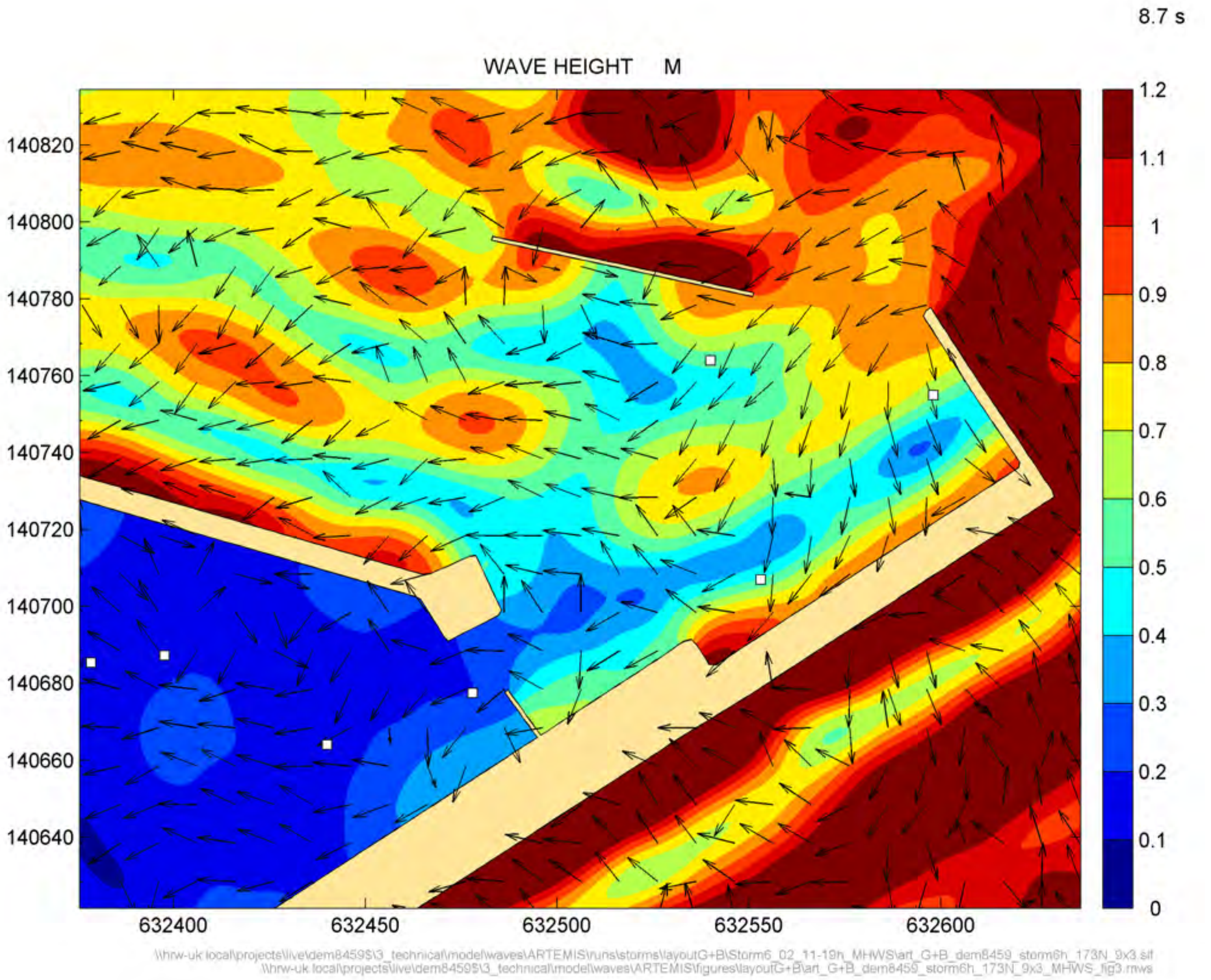

Figure 9.19: Wave conditions outside marina (Layout G+B: 1 Year 173°N + MHWS)

Source: HR Wallingford

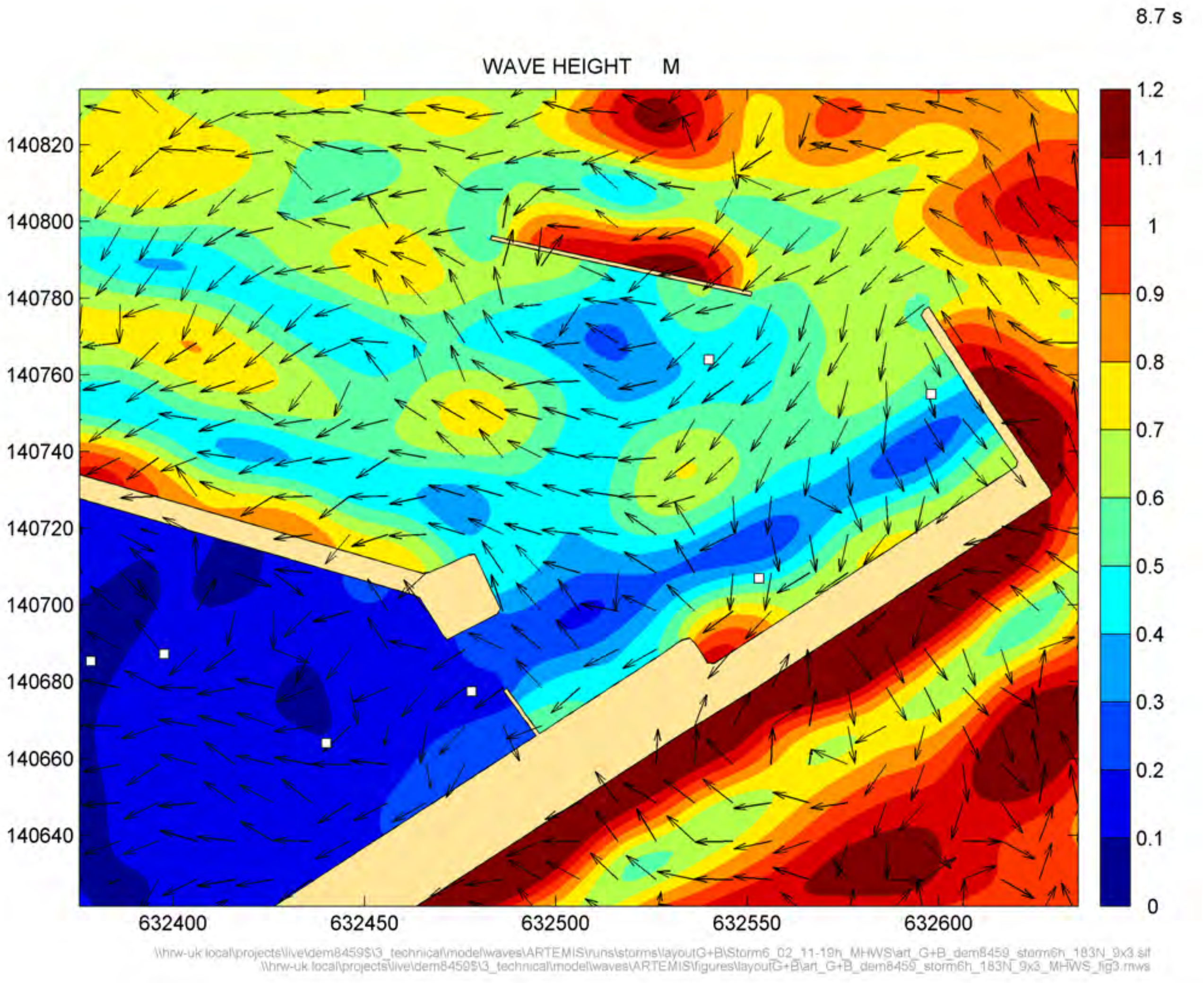

Figure 9.20: Wave conditions outside marina (Layout G+B: 1 Year 183°N + MHWS)

Source: HR Wallingford

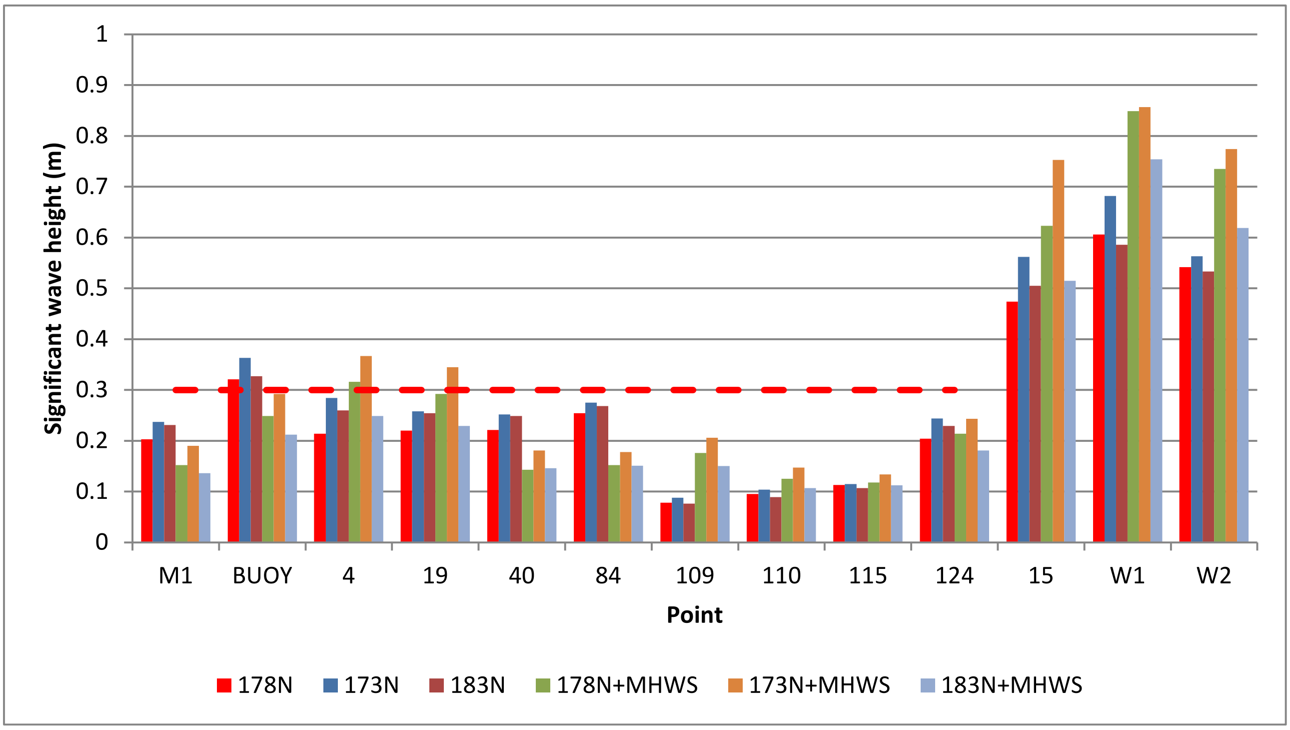

Figure 9.21: Summary of results: Representative 1 year storm condition + MHWS

Source: HR Wallingford

9.4. Sensitivity to boundary wave direction accounting for future Sea Level Rise (SLR) (1-year condition)

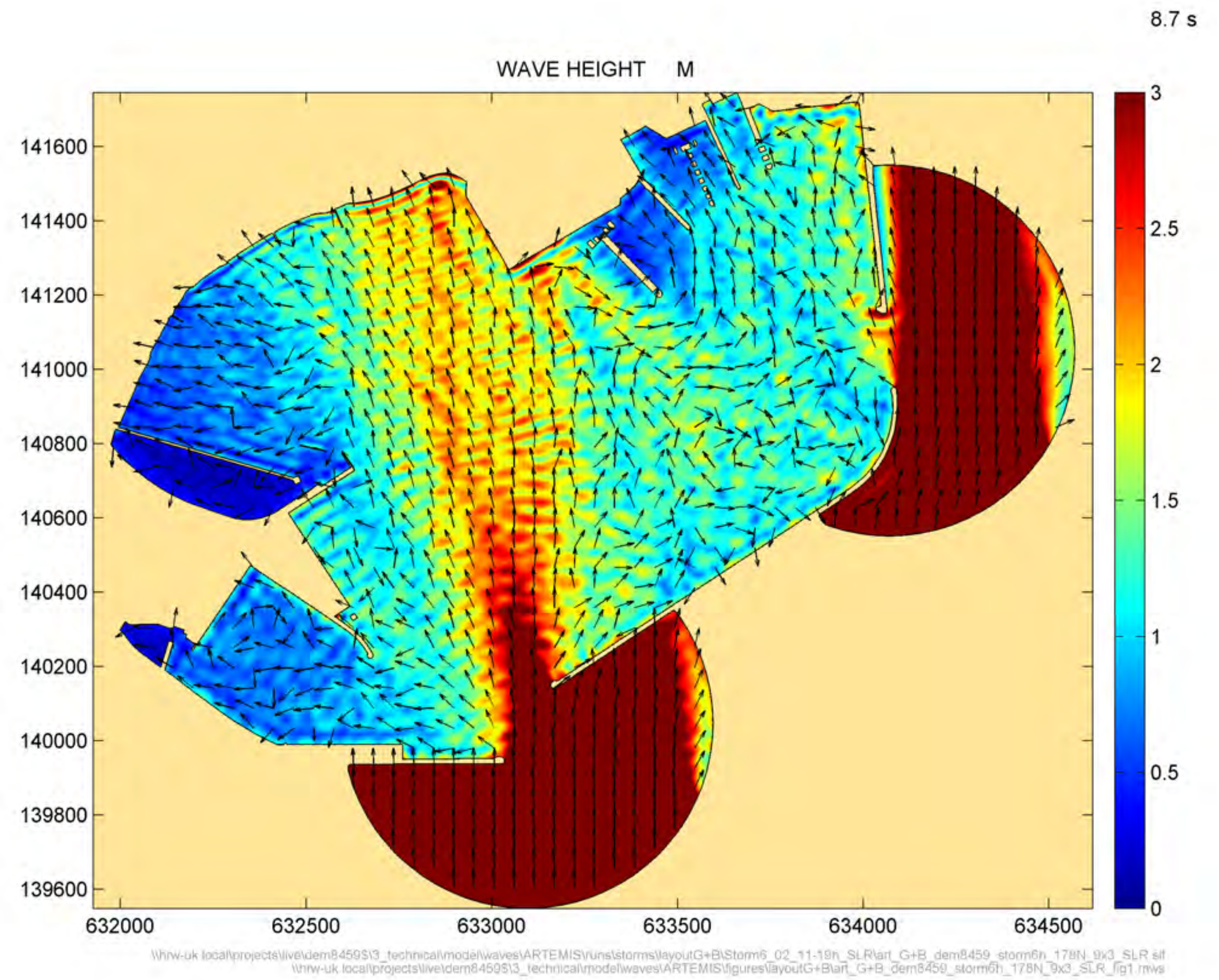

Figure 9.22: Wave conditions inside harbour (Layout G+B: 1 Year 178°N + SLR)

Source: *HR Wallingford*

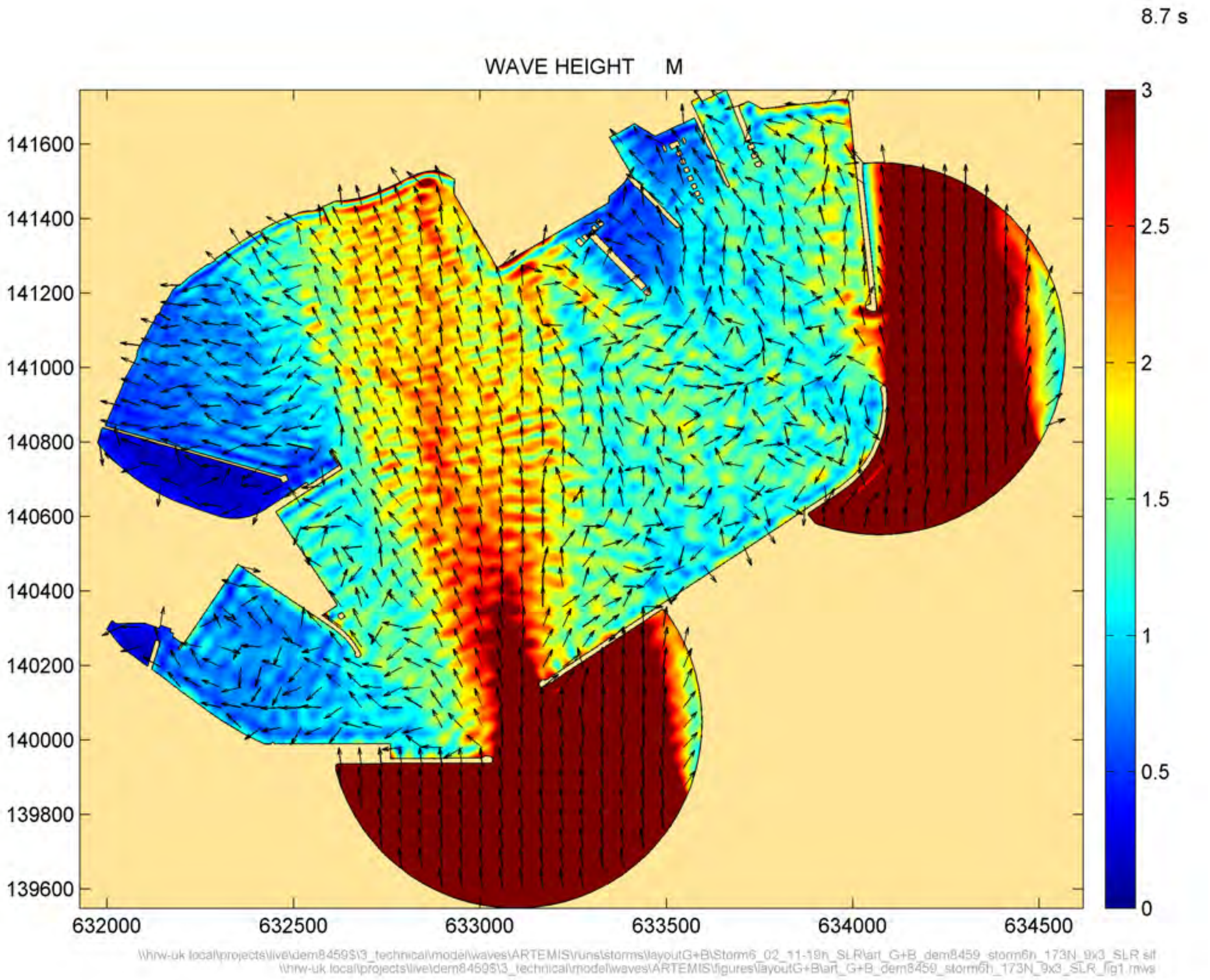

Figure 9.23: Wave conditions inside harbour (Layout G+B: 1 Year 173°N + SLR)

Source: HR Wallingford

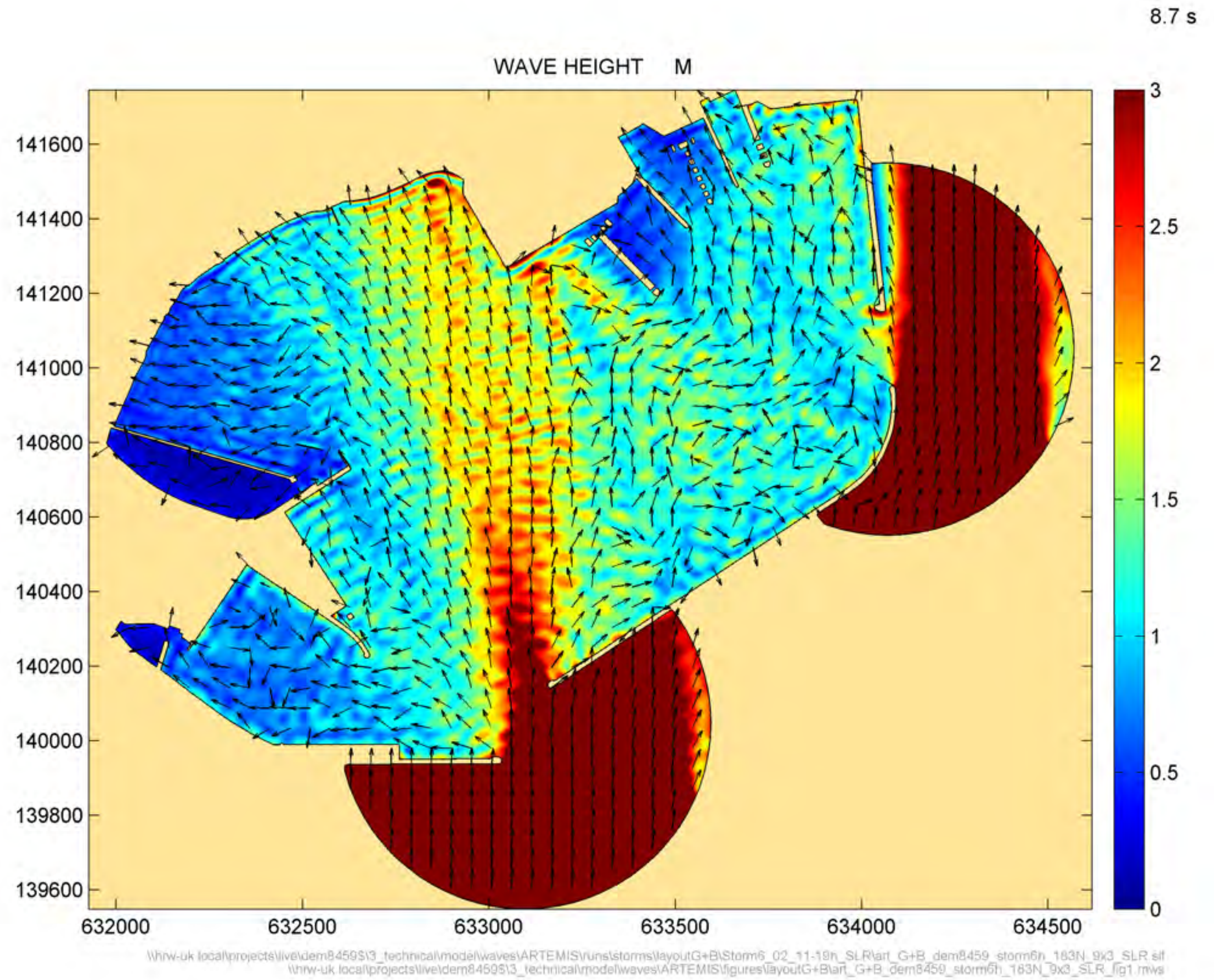

Figure 9.24: Wave conditions inside harbour (Layout G+B: 1 Year 183°N + SLR)

Source: HR Wallingford

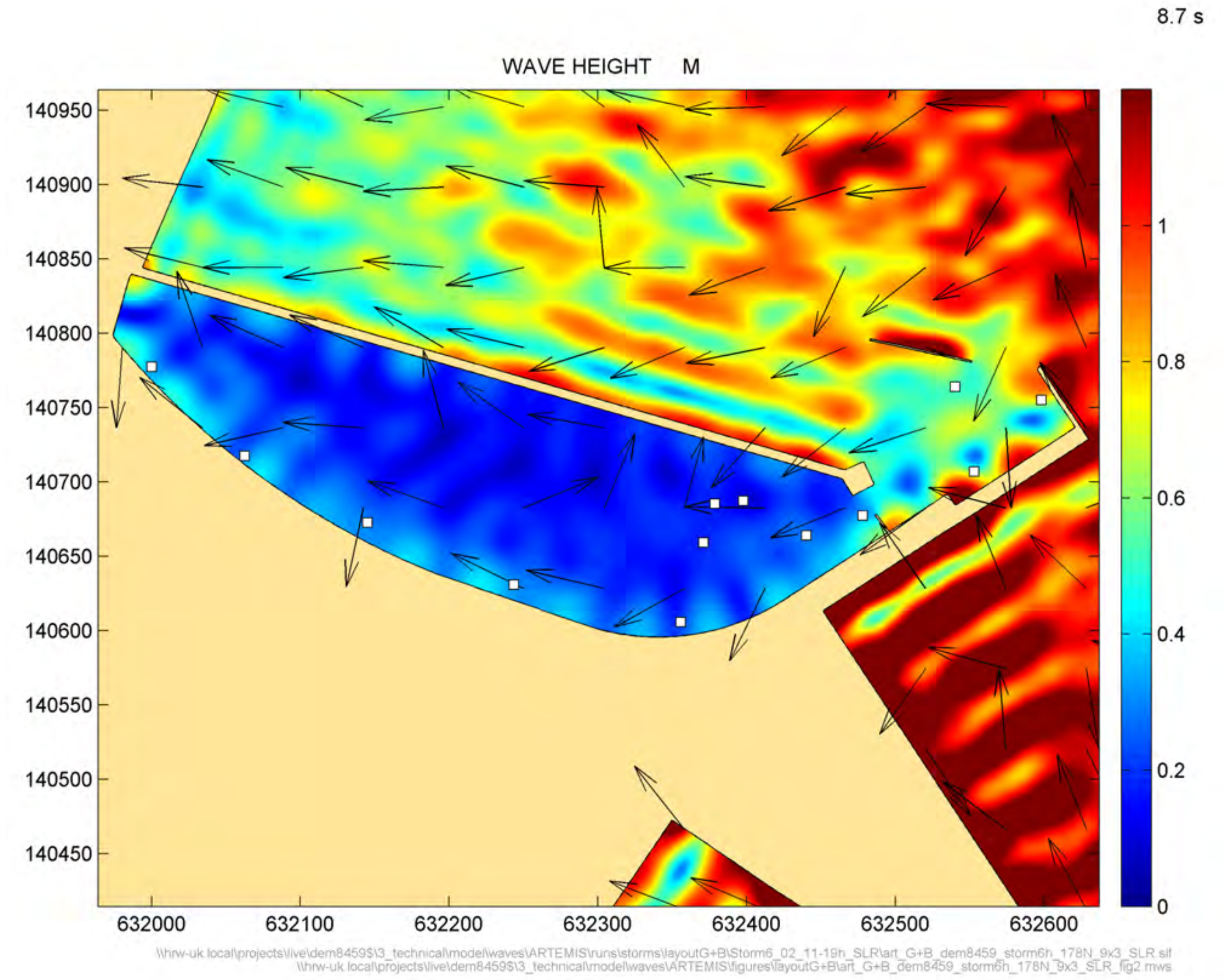

Figure 9.25: Wave conditions inside marina (Layout G+B: 1 Year 178°N + SLR)

Source: HR Wallingford

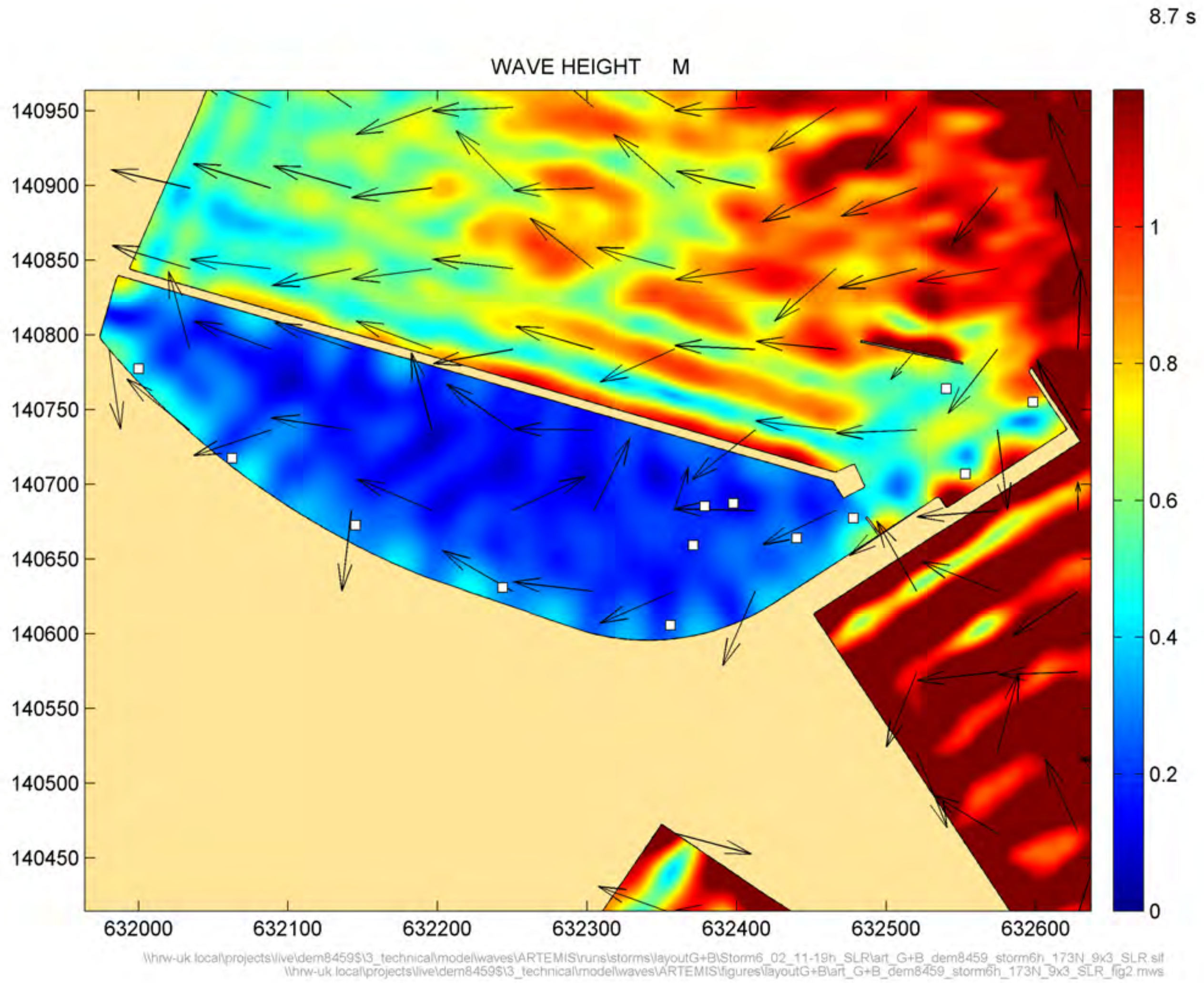

Figure 9.26: Wave conditions inside marina (Layout G+B: 1 Year 173°N + SLR)

Source: HR Wallingford

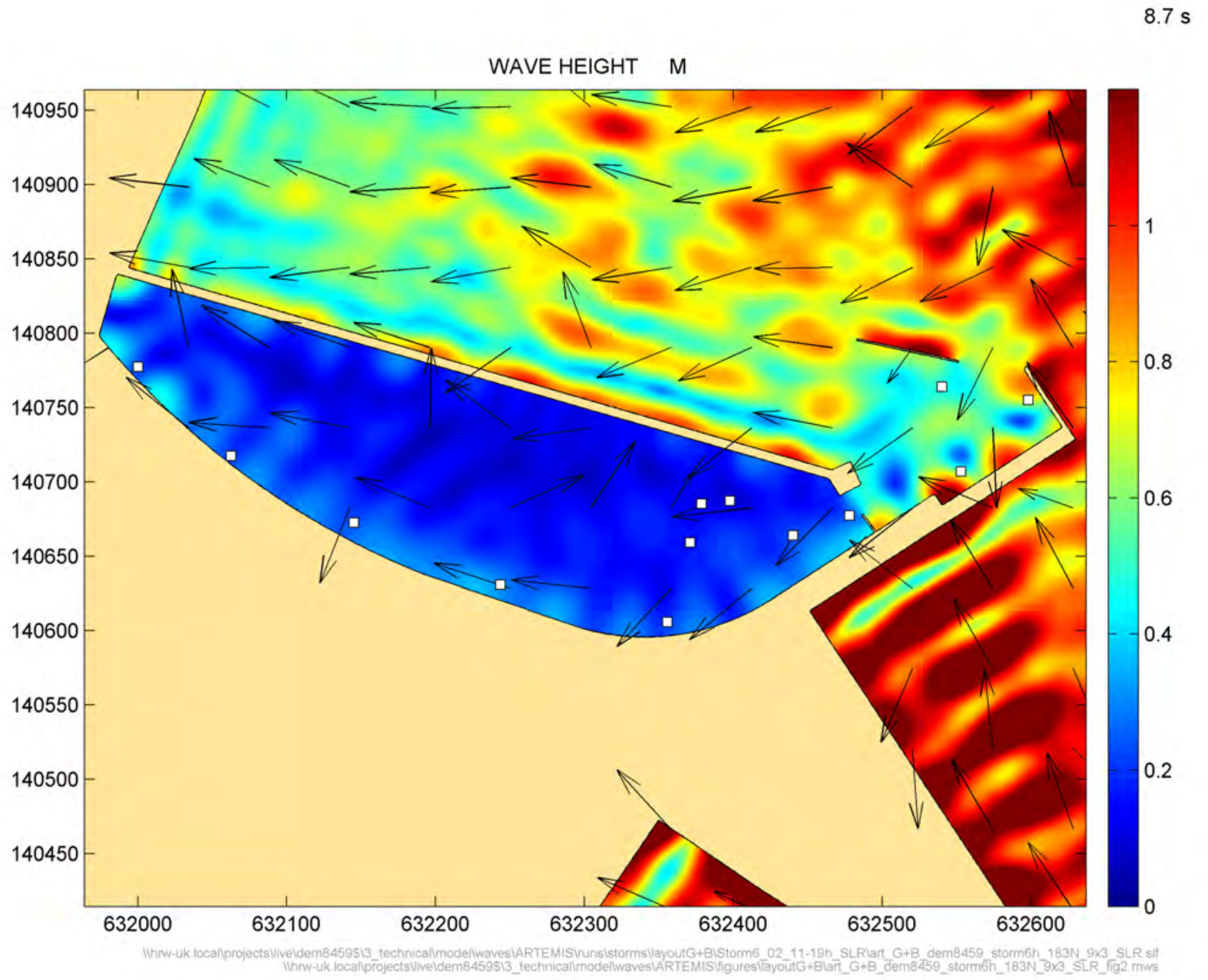

Figure 9.27: Wave conditions inside marina (Layout G+B: 1 Year 183°N + SLR)

Source: HR Wallingford

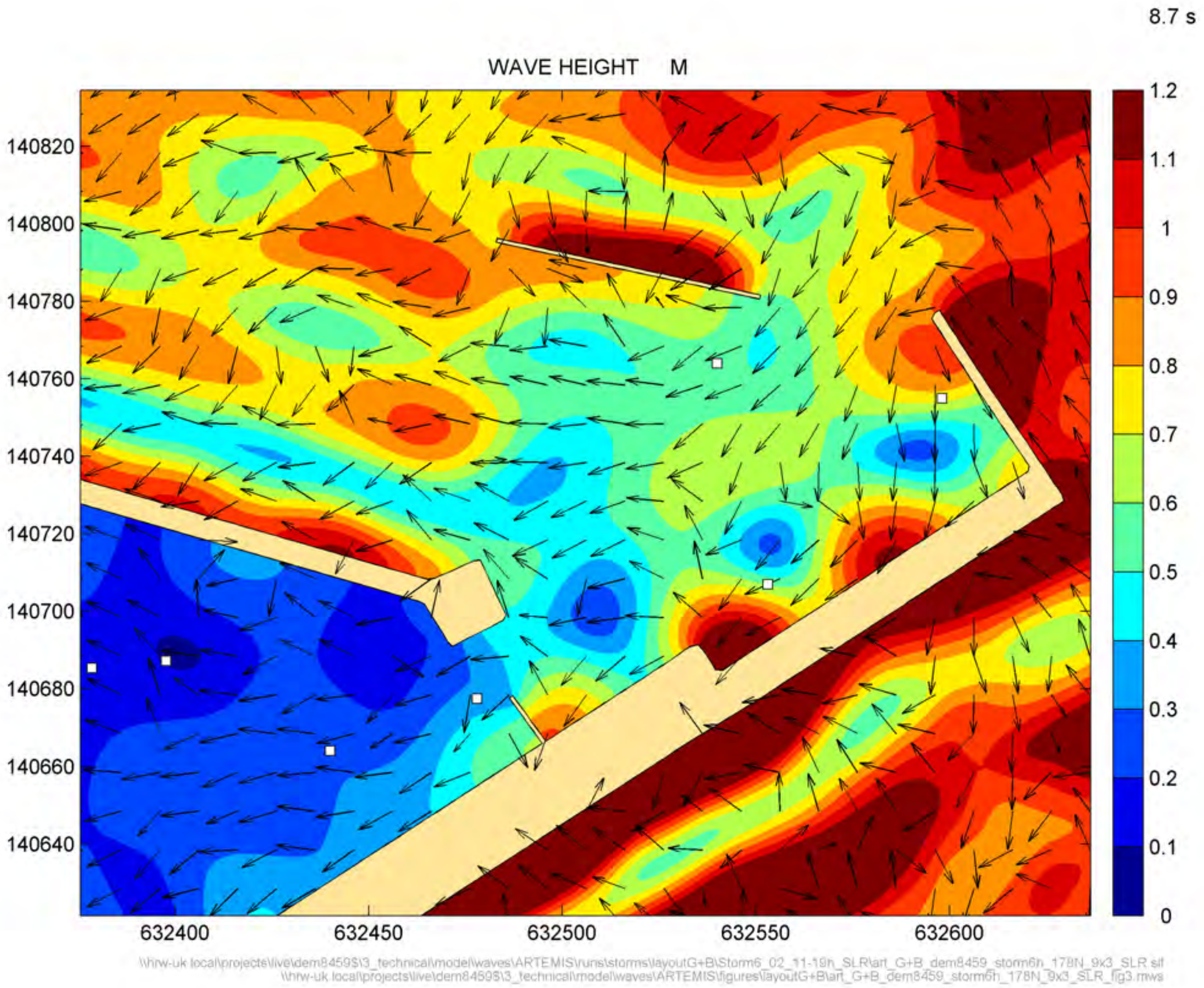

Figure 9.28: Wave conditions outside marina (Layout G+B: 1 Year 178°N + SLR)

Source: HR Wallingford

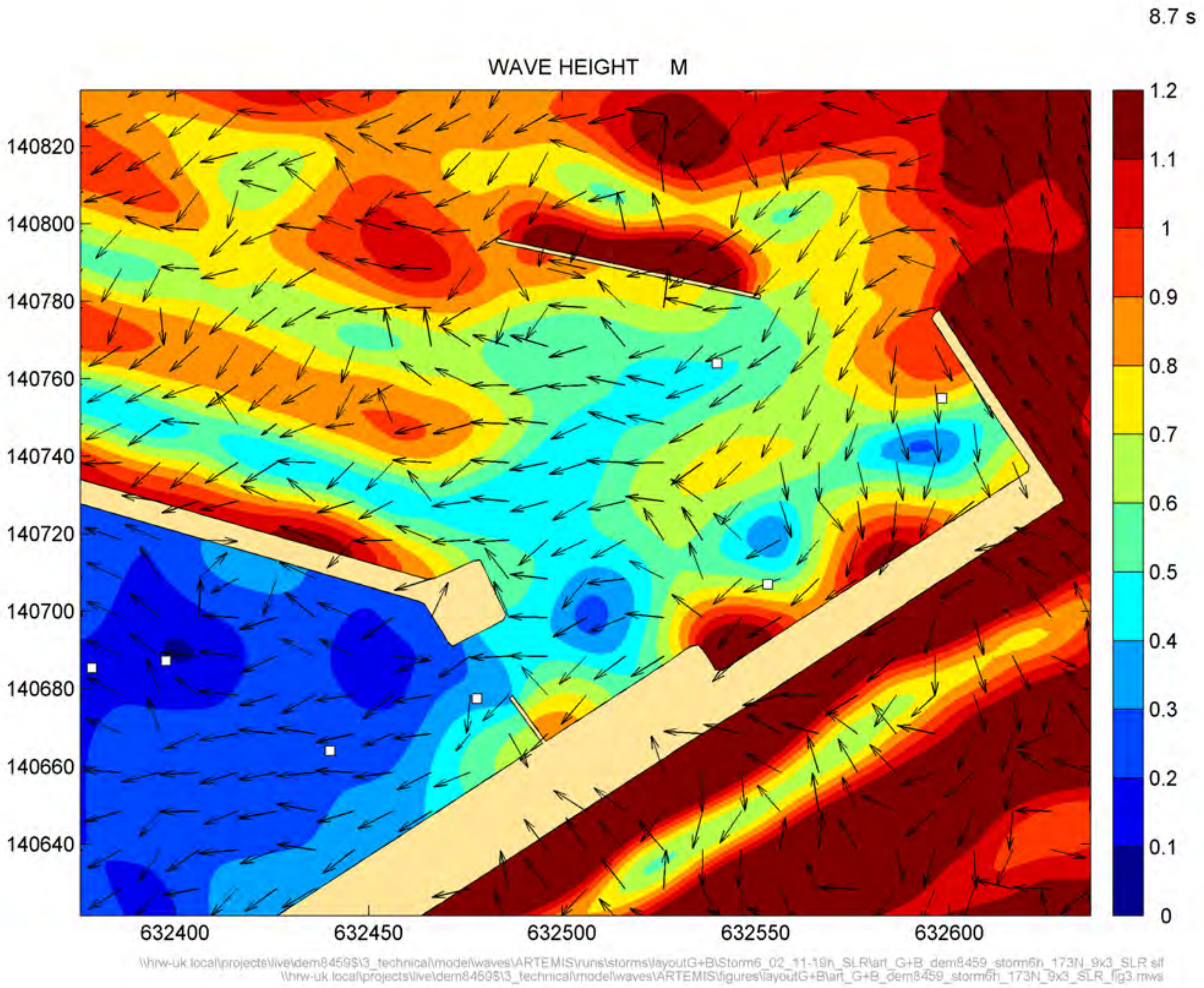

Figure 9.29: Wave conditions outside marina (Layout G+B: 1 Year 173°N + SLR)

Source: HR Wallingford

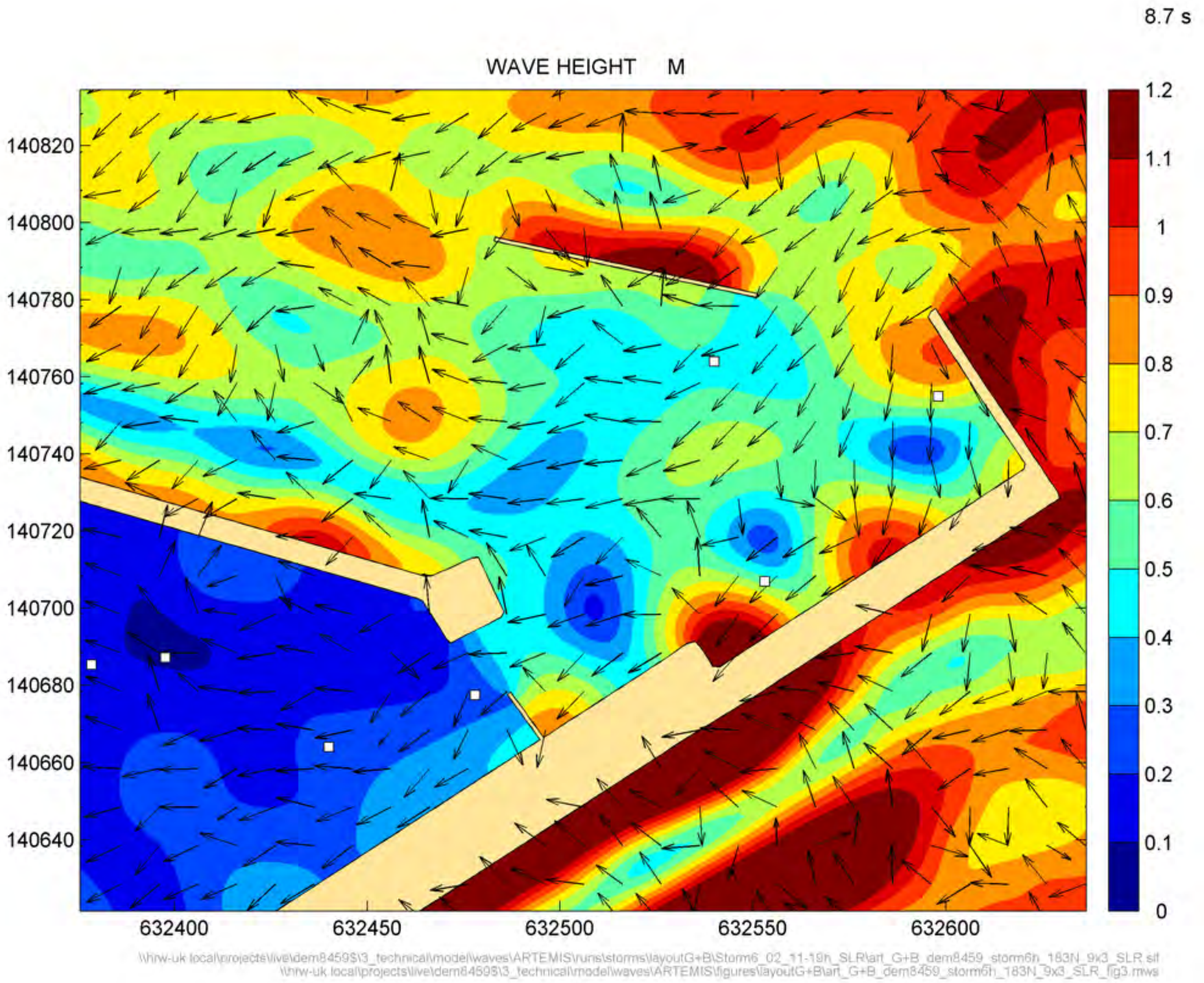

Figure 9.30: Wave conditions outside marina (Layout G+B: 1 Year 183°N + SLR)

Source: HR Wallingford

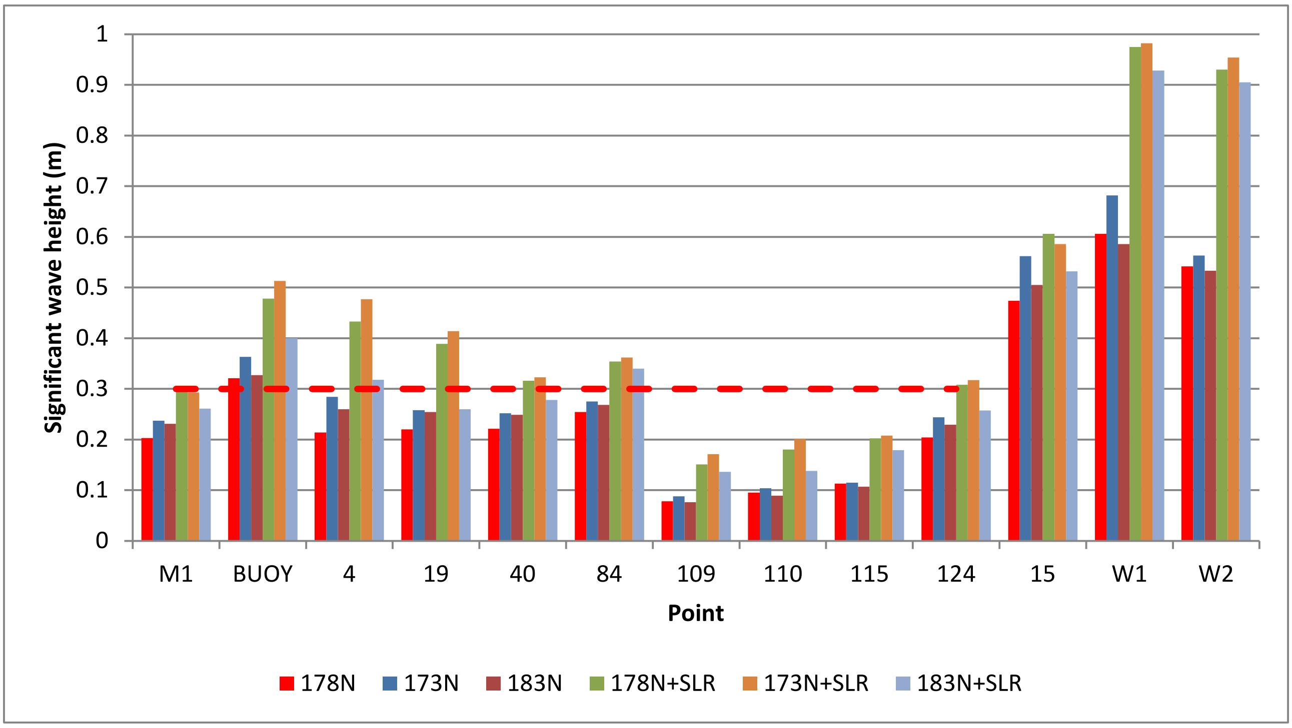

Figure 9.31: Summary of results: Representative 1 year storm condition + SLR

Source: HR Wallingford

9.5. Sensitivity to boundary wave direction (50-year condition)

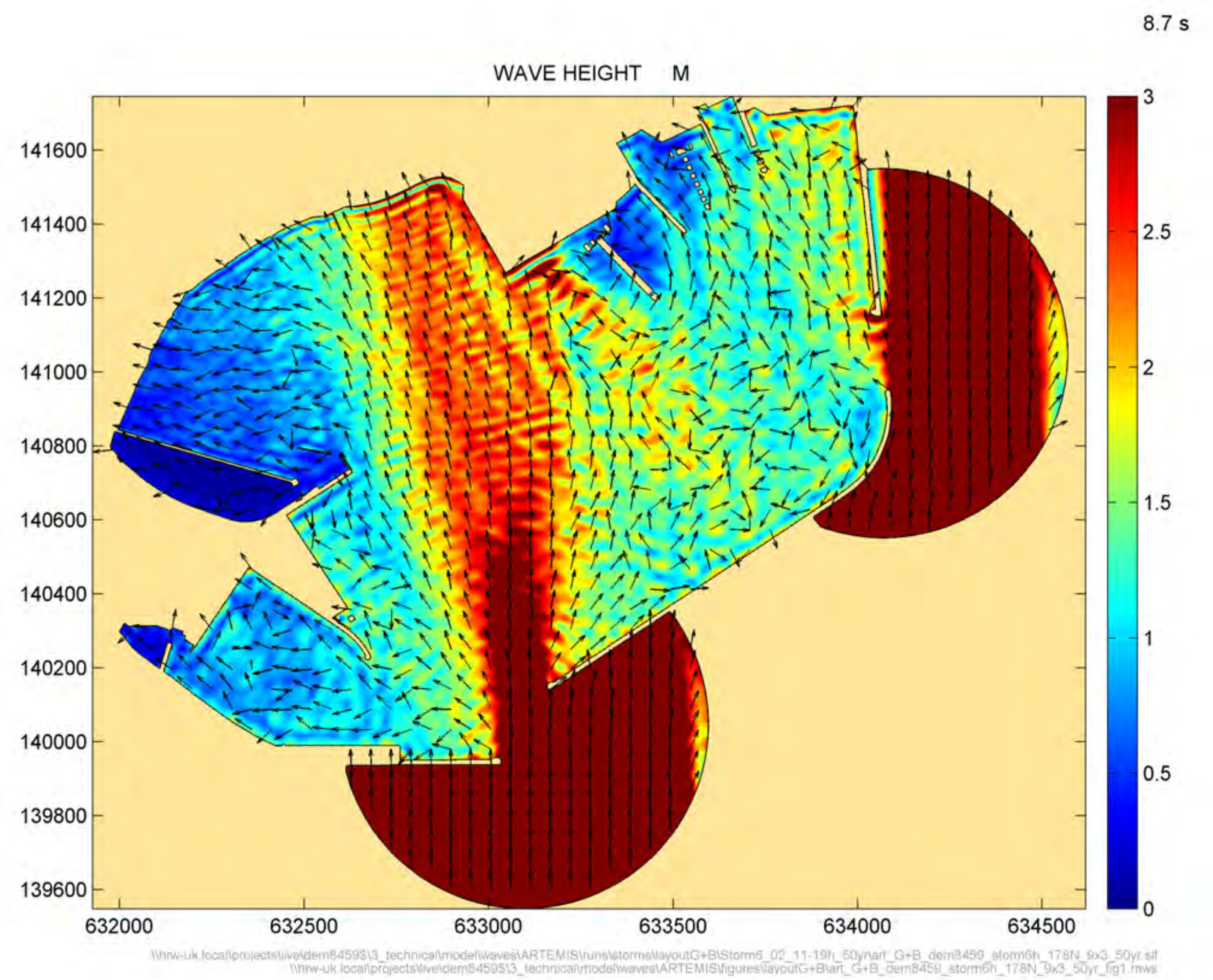

Figure 9.32: Wave conditions inside harbour (Layout G+B: 50 Year 178°N)

Source: HR Wallingford

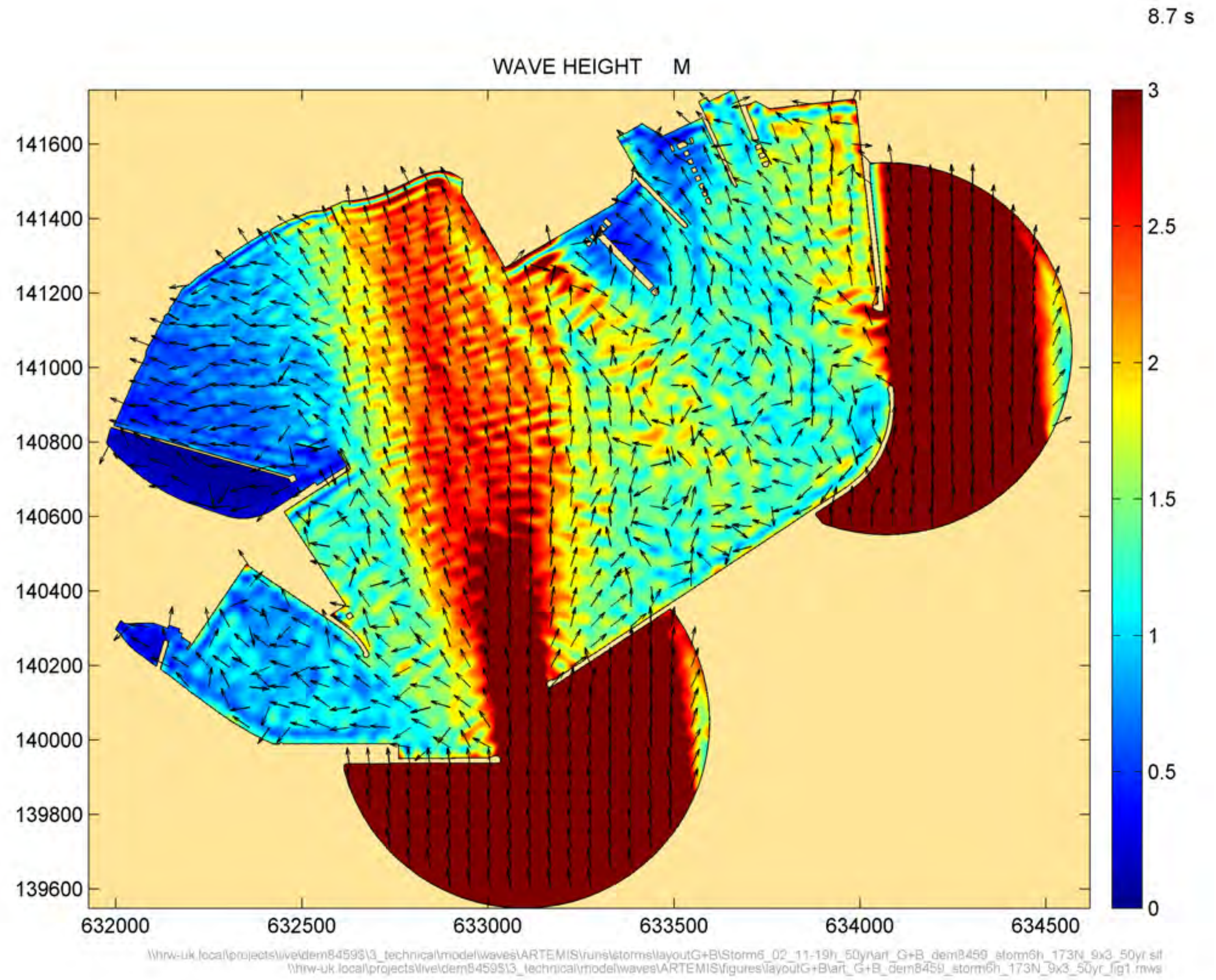

Figure 9.33: Wave conditions inside harbour (Layout G+B: 50 Year 173°N)

Source: HR Wallingford

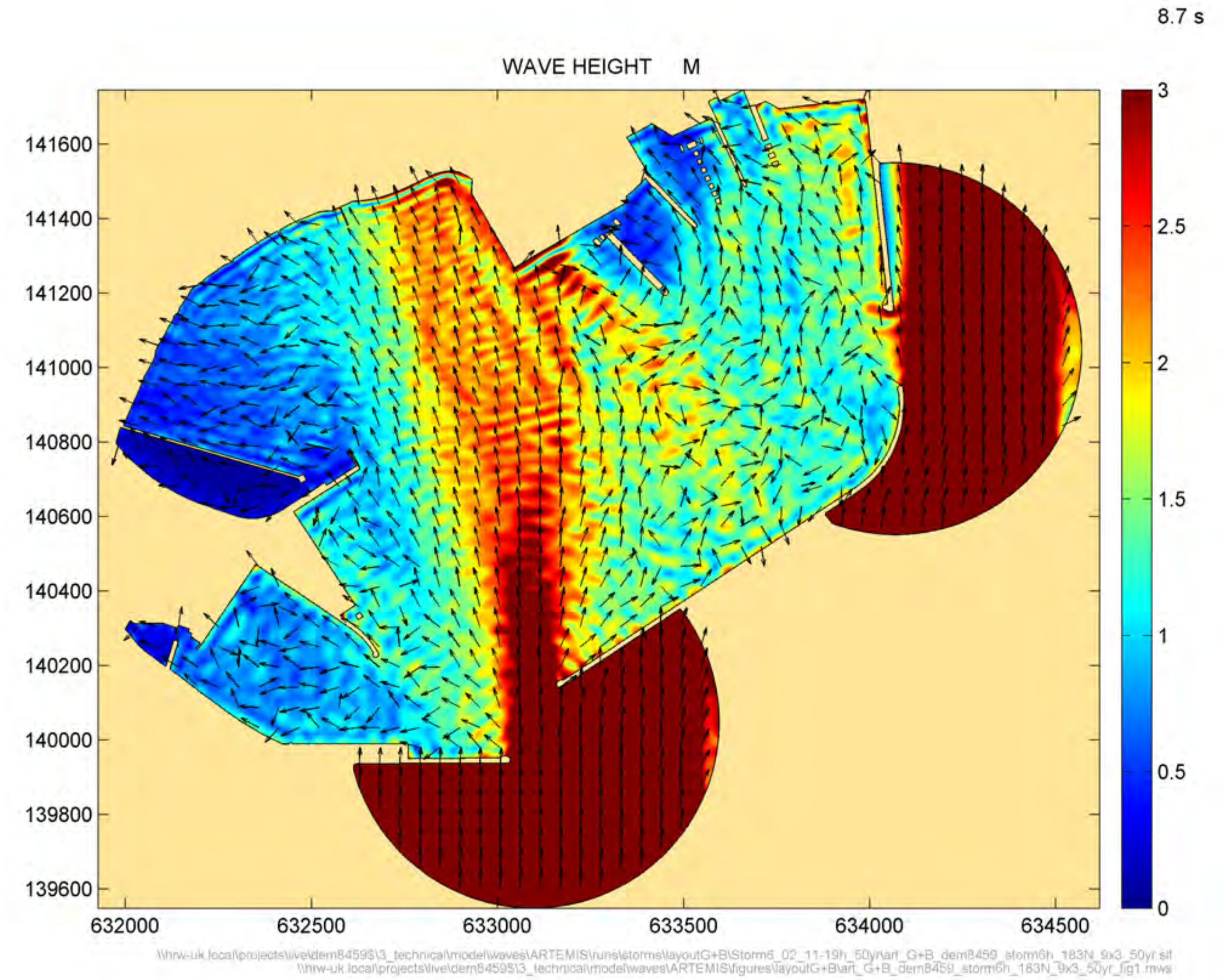

Figure 9.34: Wave conditions inside harbour (Layout G+B: 1 Year 183°N)

Source: HR Wallingford

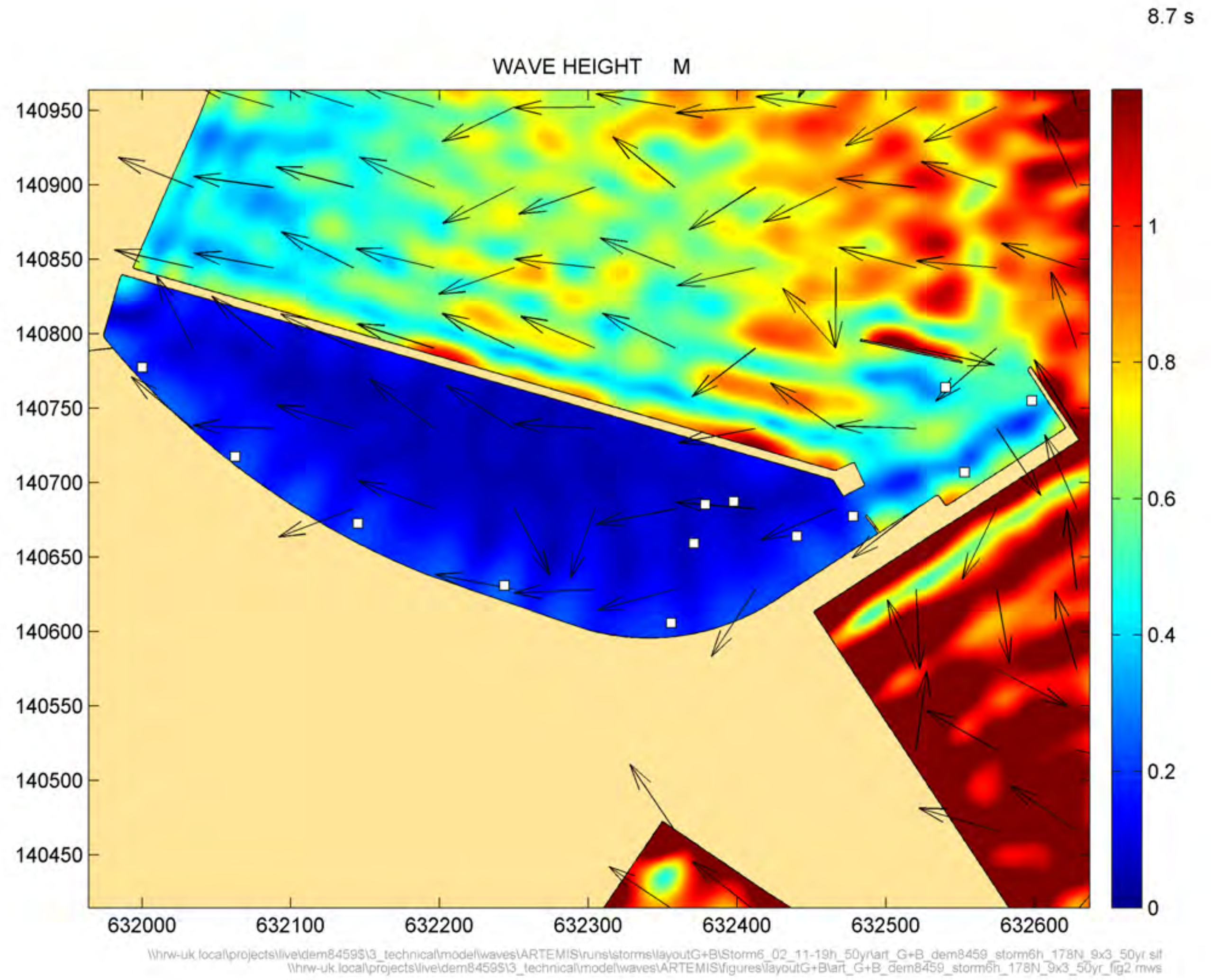

Figure 9.35: Wave conditions inside marina (Layout G+B: 50 Year 178°N)

Source: HR Wallingford

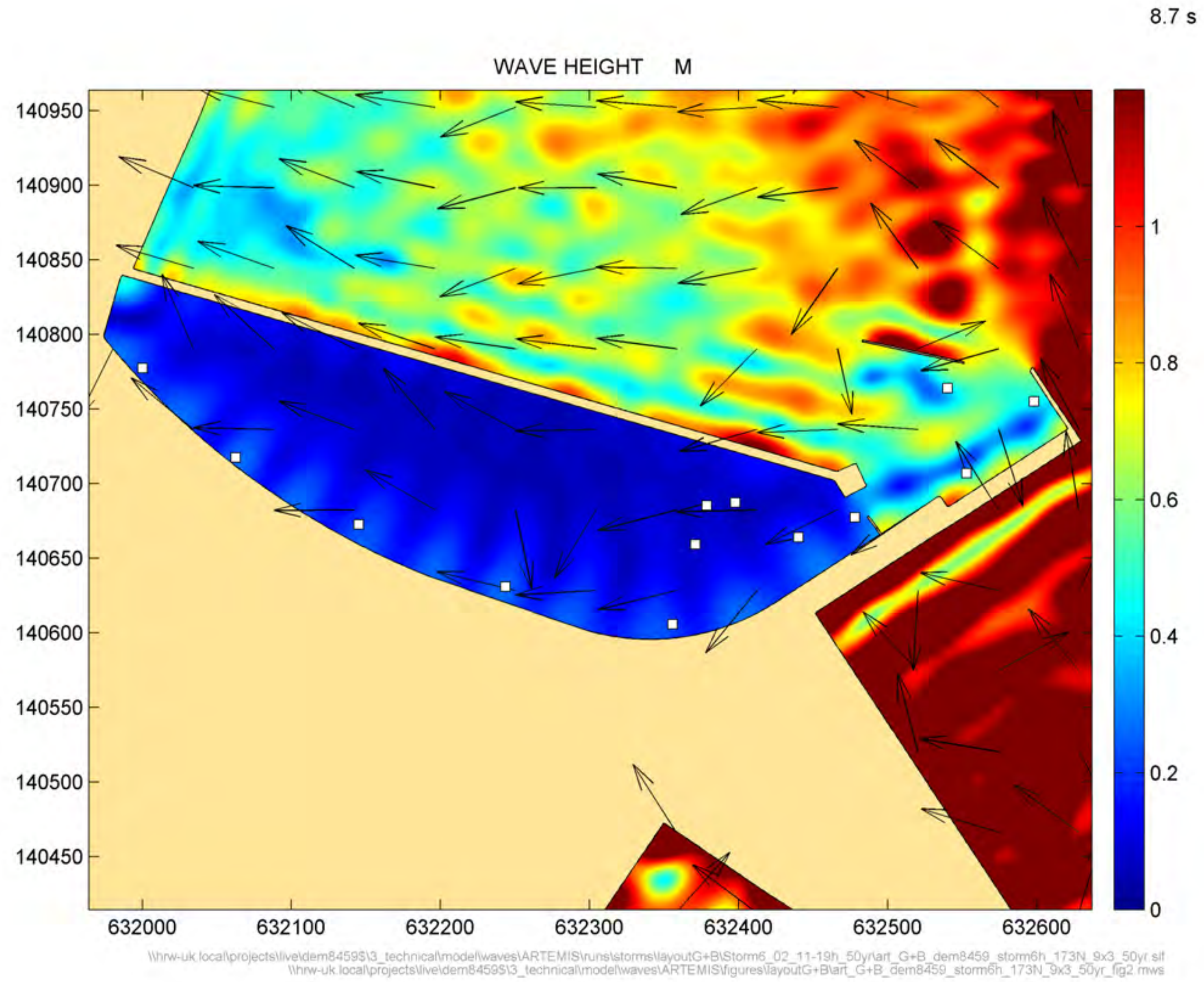

Figure 9.36: Wave conditions inside marina (Layout G+B: 50 Year 173°N)

Source: HR Wallingford

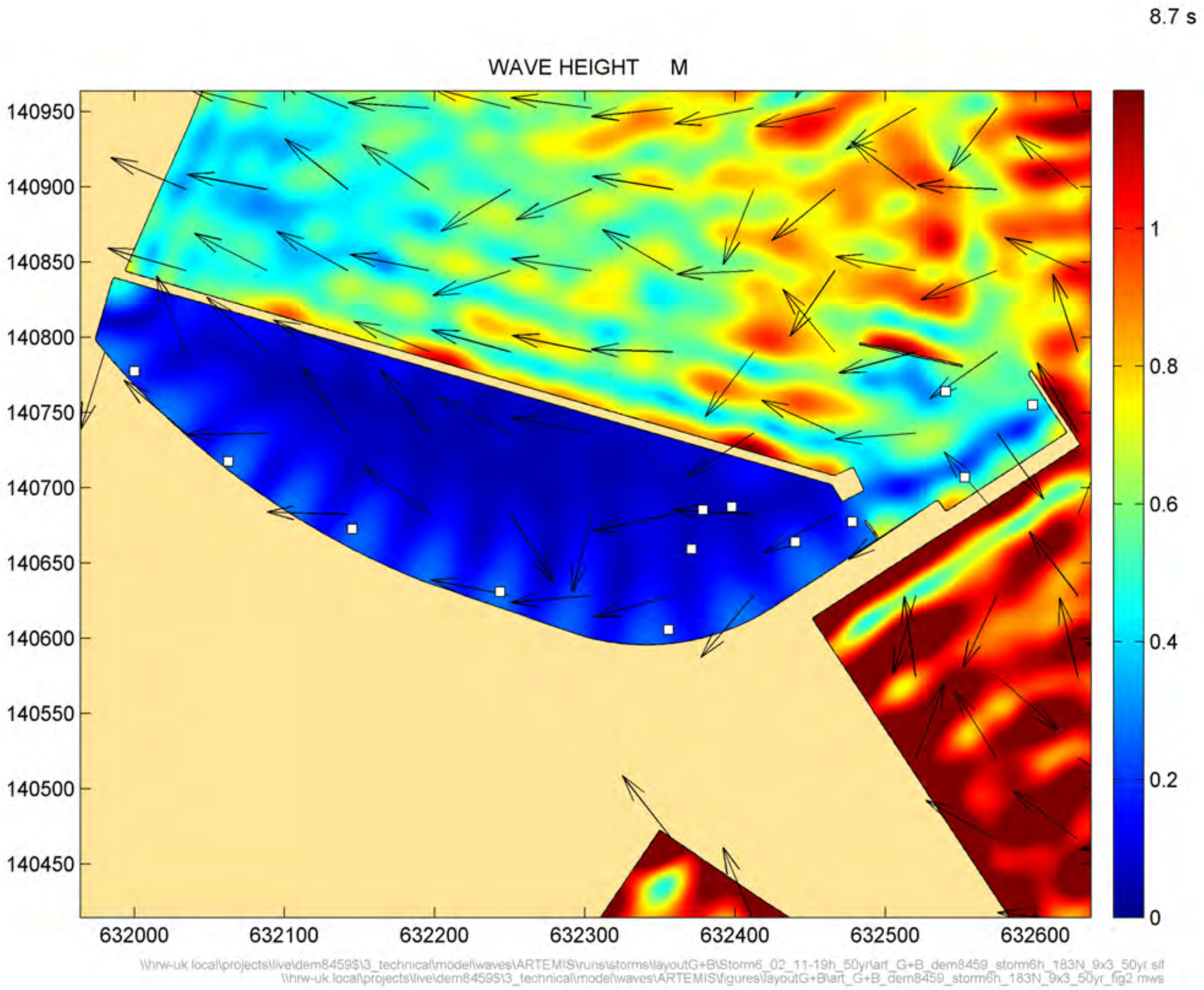

Figure 9.37: Wave conditions inside marina (Layout G+B: 50 Year 183°N)

Source: HR Wallingford

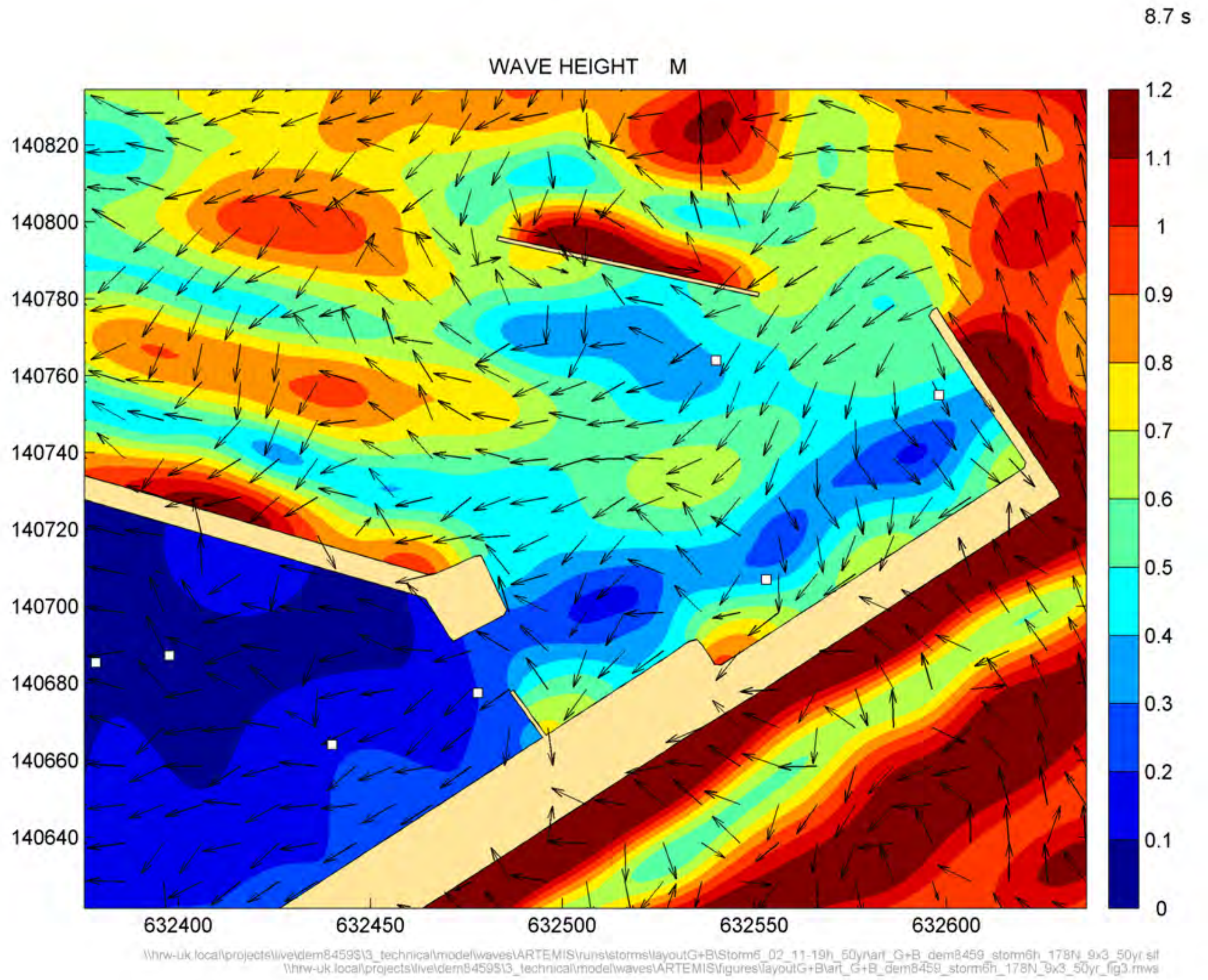

Figure 9.38: Wave conditions outside marina (Layout G+B: 50 Year 178°N)

Source: HR Wallingford

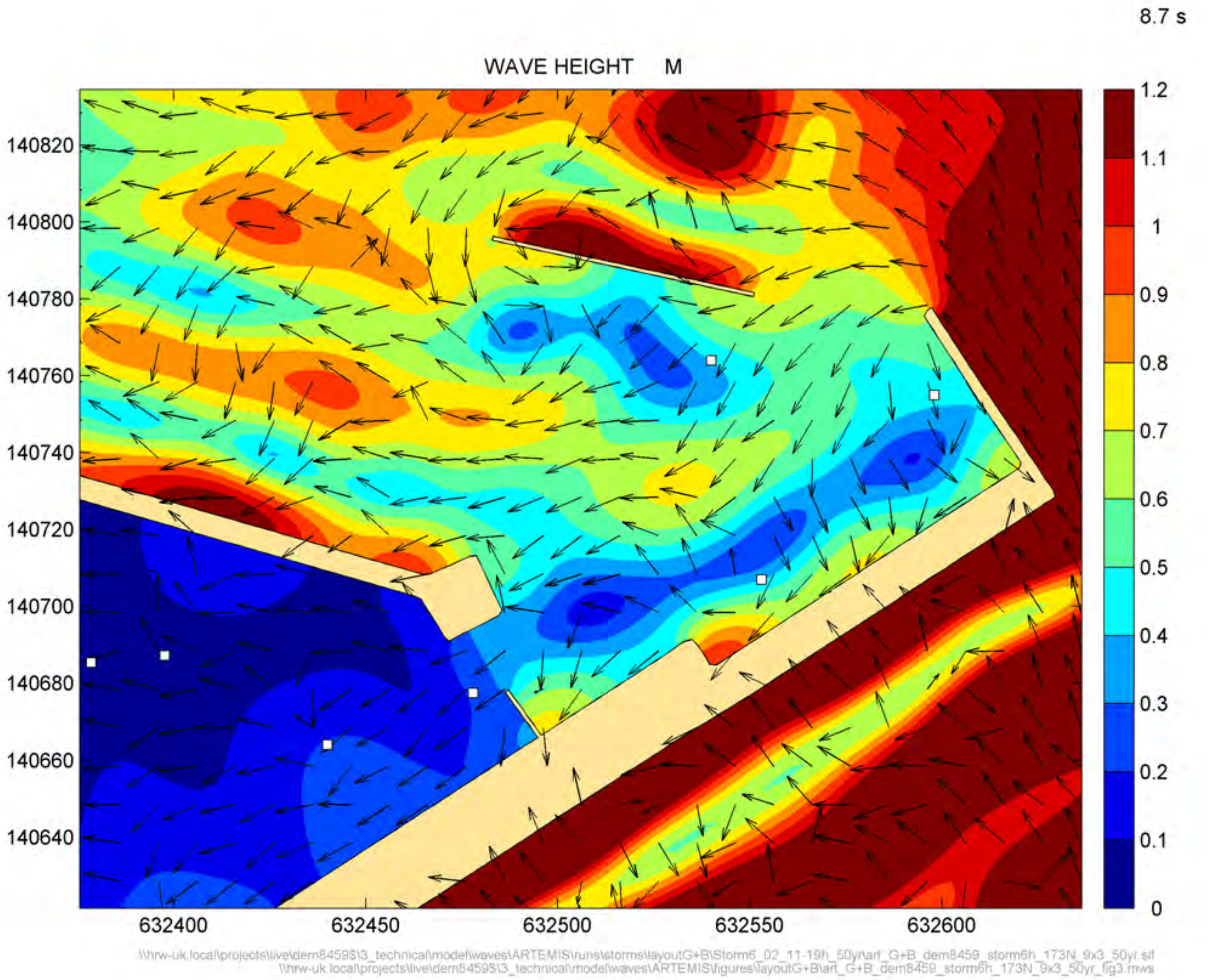

Figure 9.39: Wave conditions outside marina (Layout G+B: 50 Year 173°N)

Source: HR Wallingford

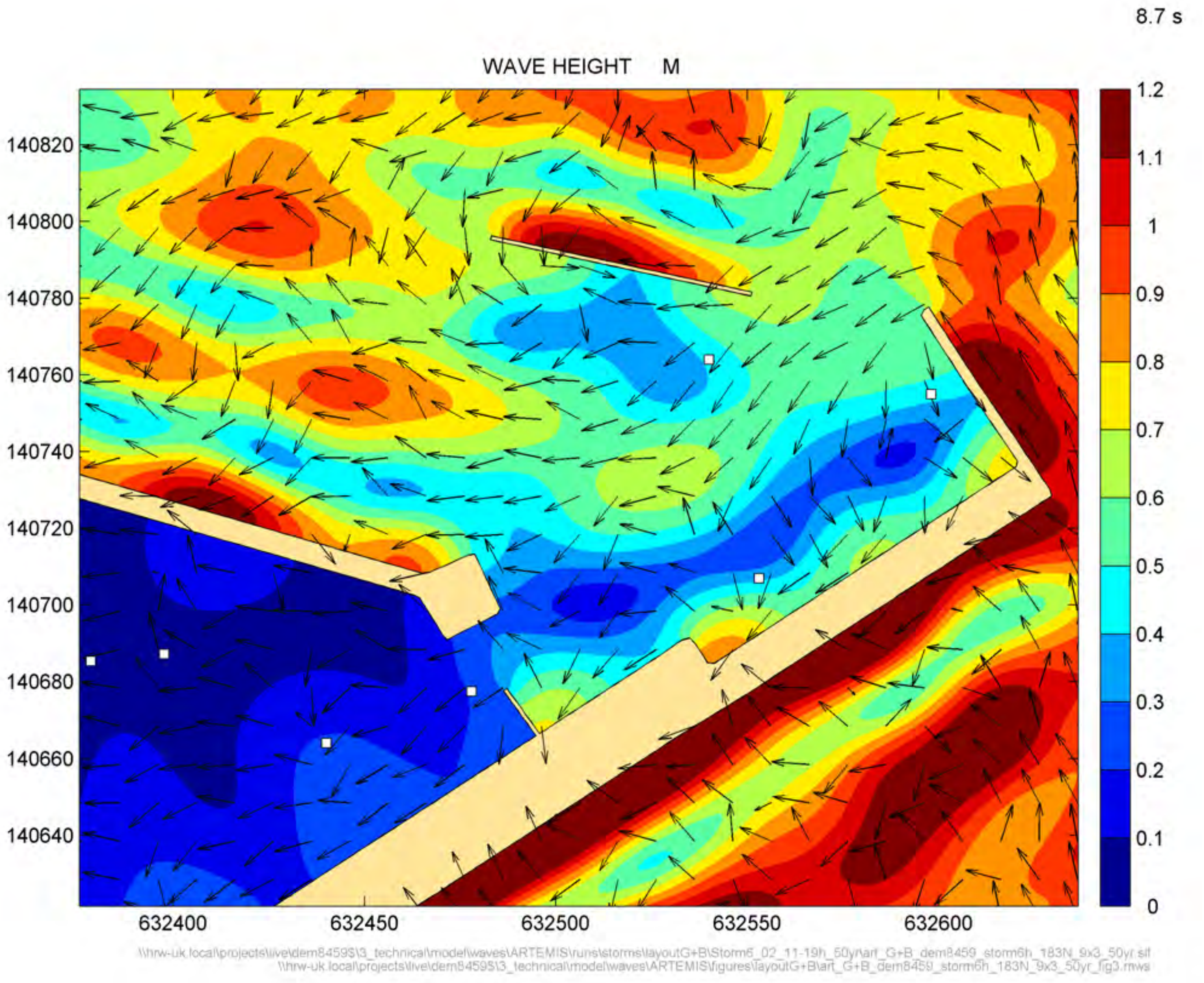

Figure 9.40: Wave conditions outside marina (Layout G+B: 50 Year 183°N)

Source: HR Wallingford

9.6. Sensitivity to boundary wave direction MHWS (50-year)

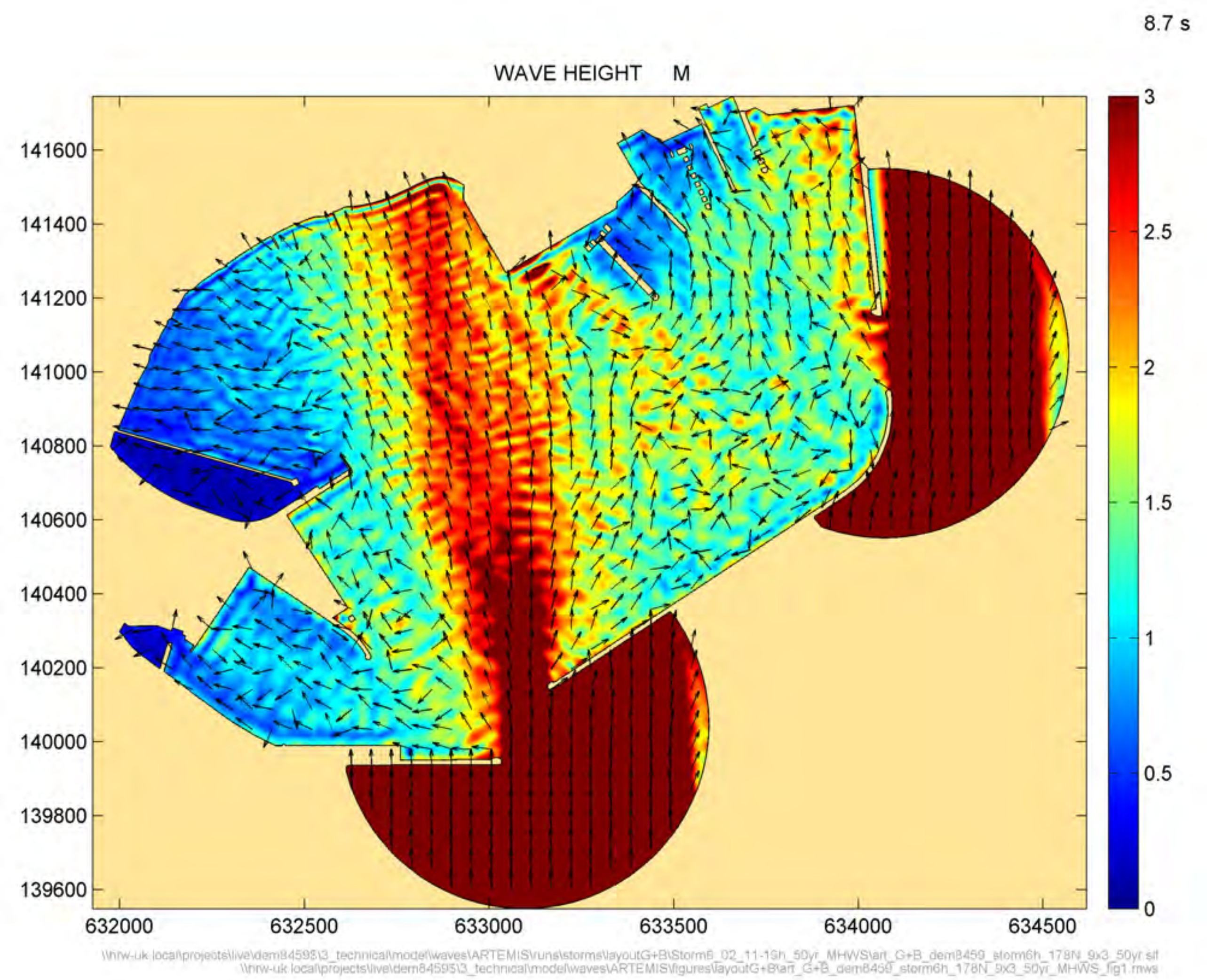

Figure 9.41: Wave conditions inside harbour (Layout G+B: 50 Year 178°N + MHWS)

Source: HR Wallingford

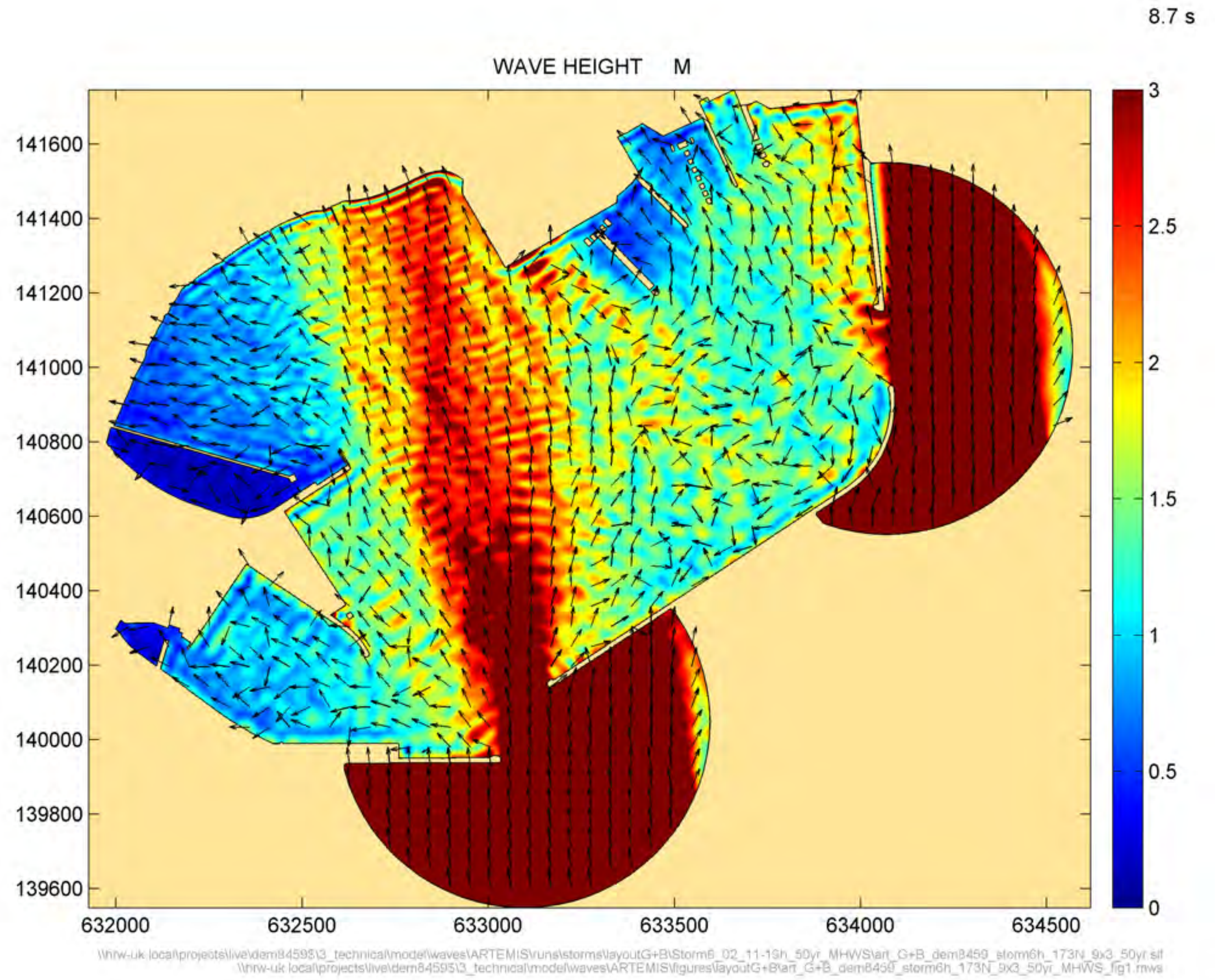

Figure 9.42: Wave conditions inside harbour (Layout G+B: 50 Year 173°N + MHWS)

Source: HR Wallingford

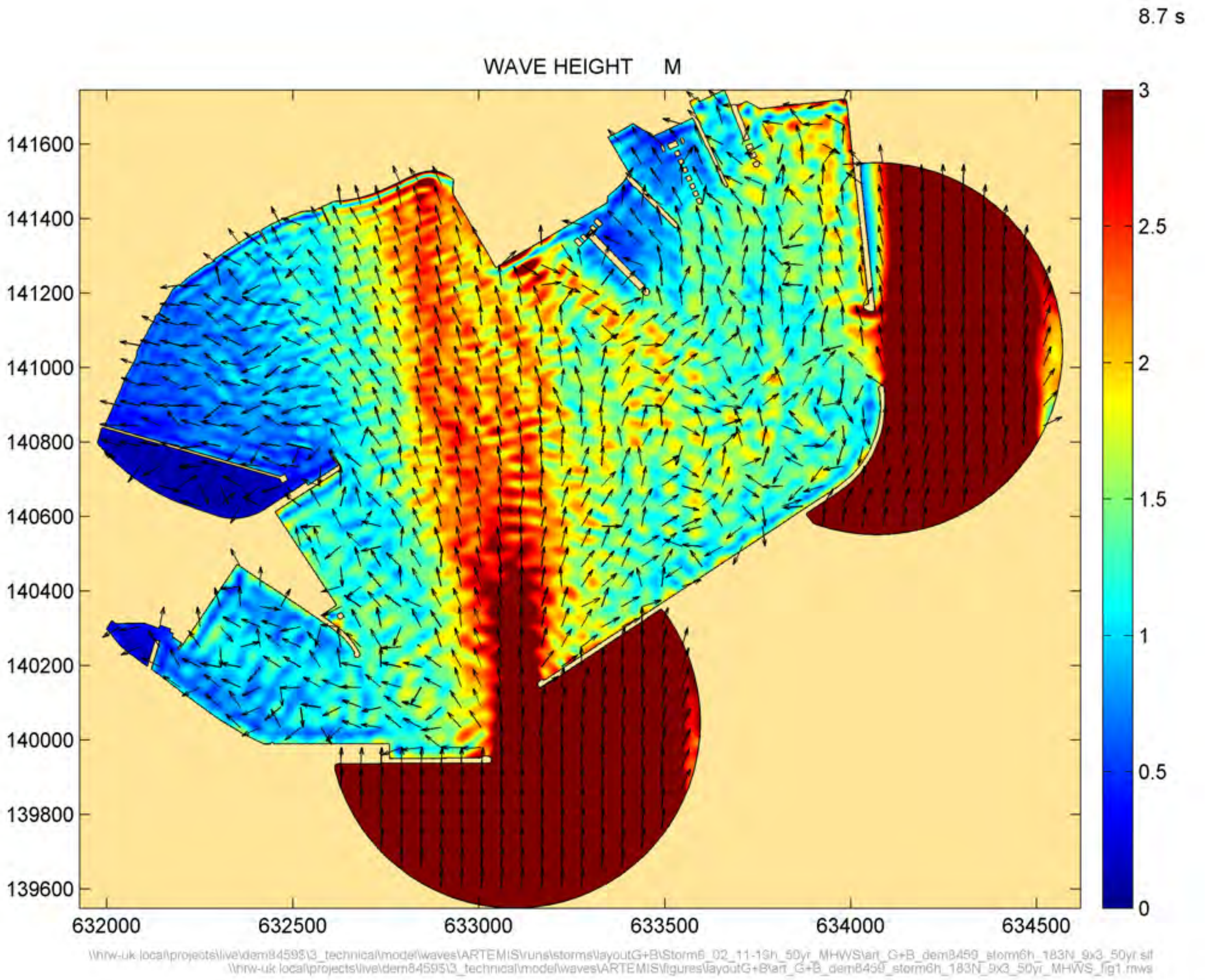

Figure 9.43: Wave conditions inside harbour (Layout G+B: 50 Year 183°N + MHWS)

Source: HR Wallingford

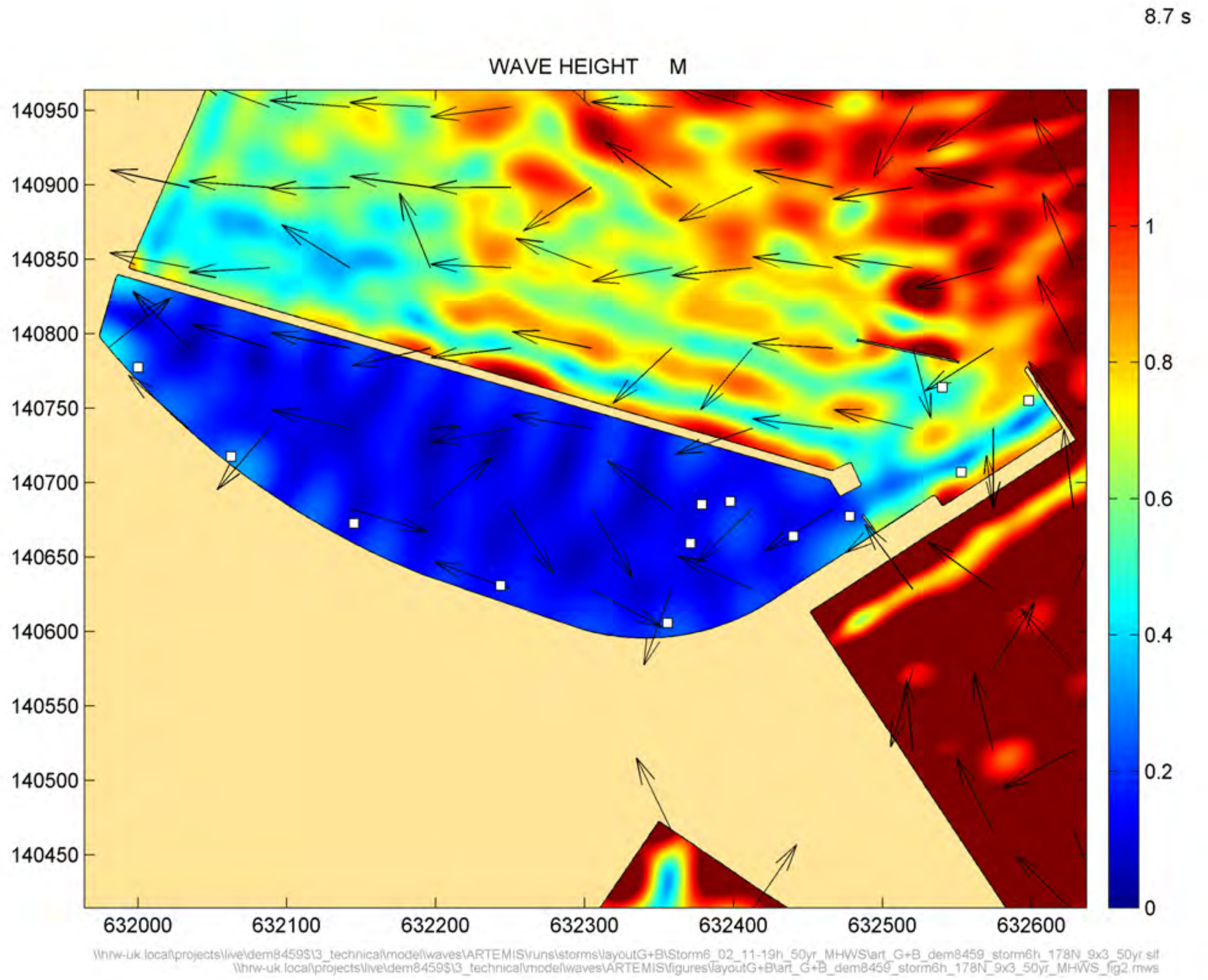

Figure 9.44: Wave conditions inside marina (Layout G+B: 50 Year 178°N + MHWS)

Source: HR Wallingford

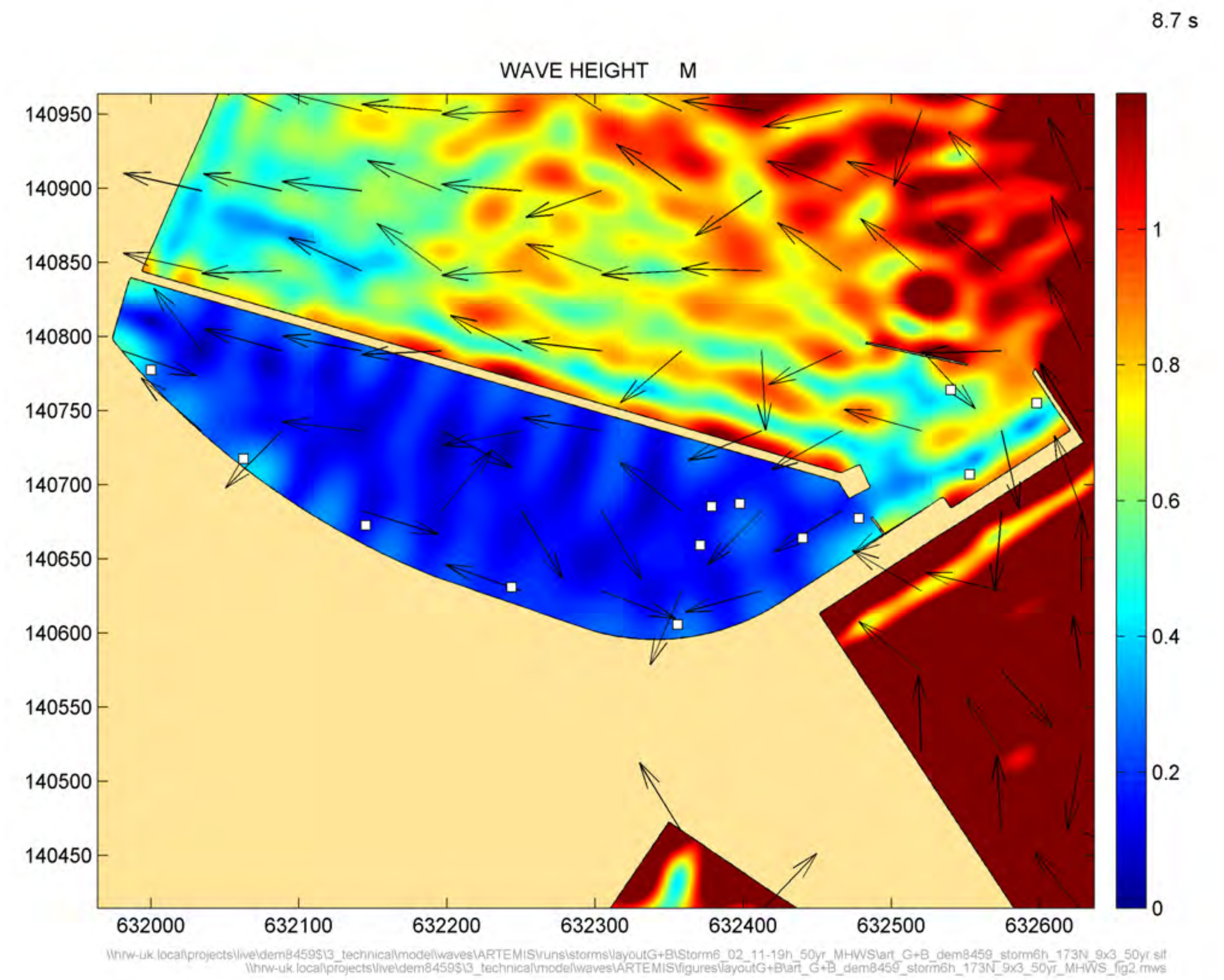

Figure 9.45: Wave conditions inside marina (Layout G+B: 50 Year 173°N + MHWS)

Source: HR Wallingford

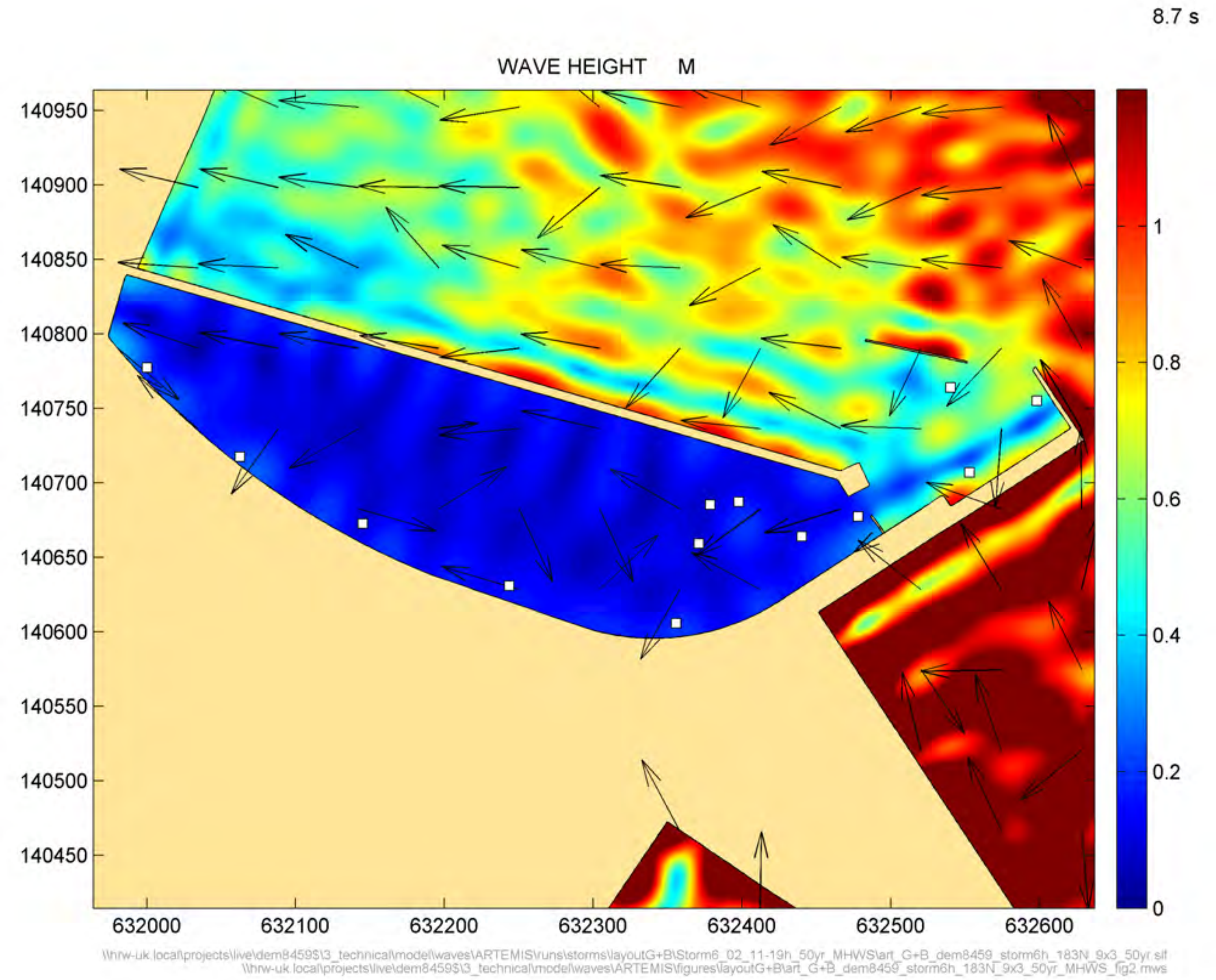

Figure 9.46: Wave conditions inside marina (Layout G+B: 50 Year 183°N + MHWS)

Source: HR Wallingford

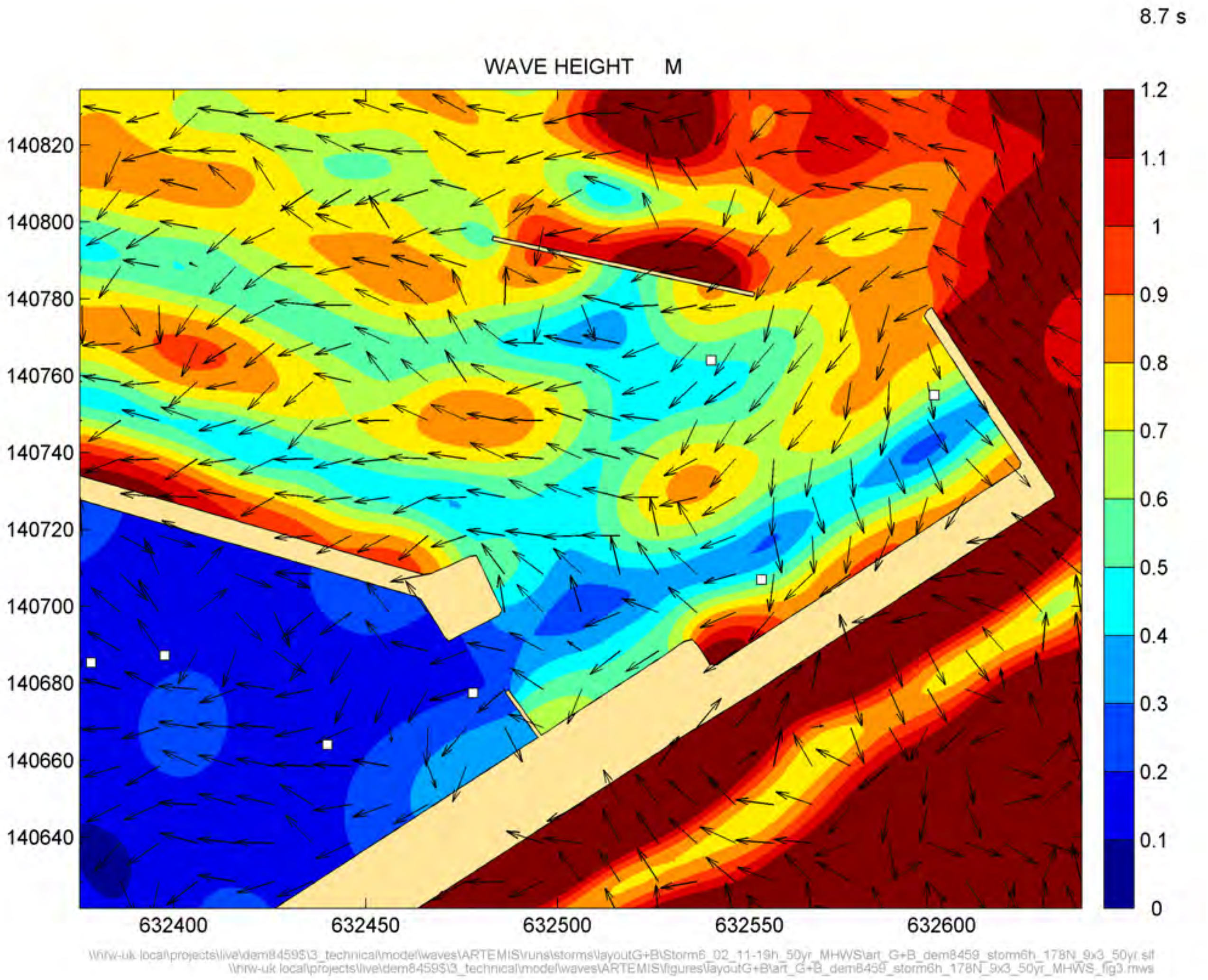

Figure 9.47: Wave conditions outside marina (Layout G+B: 50 Year 178°N + MHWS)

Source: HR Wallingford

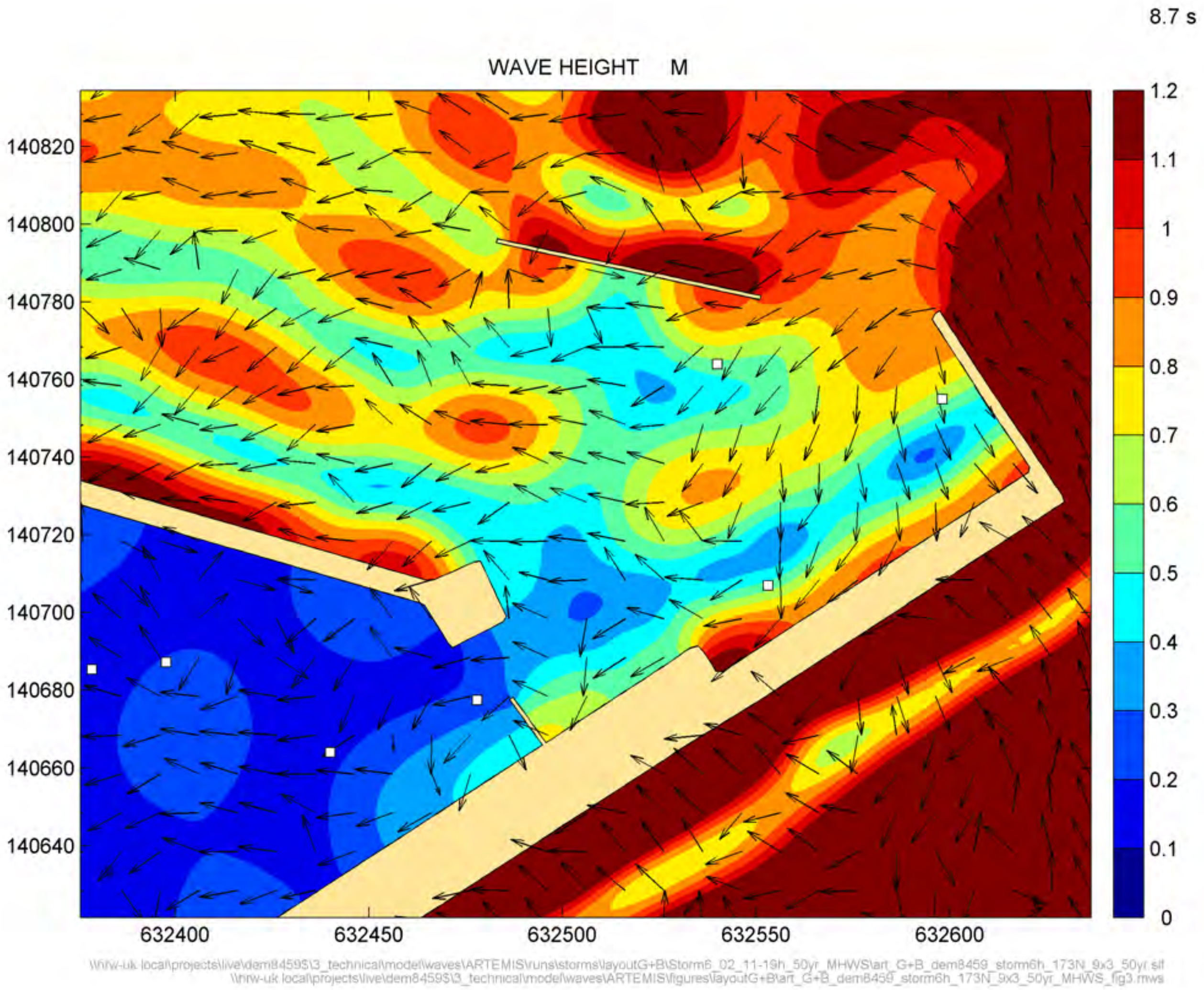

Figure 9.48: Wave conditions outside marina (Layout G+B: 50 Year 173°N + MHWS)

Source: HR Wallingford

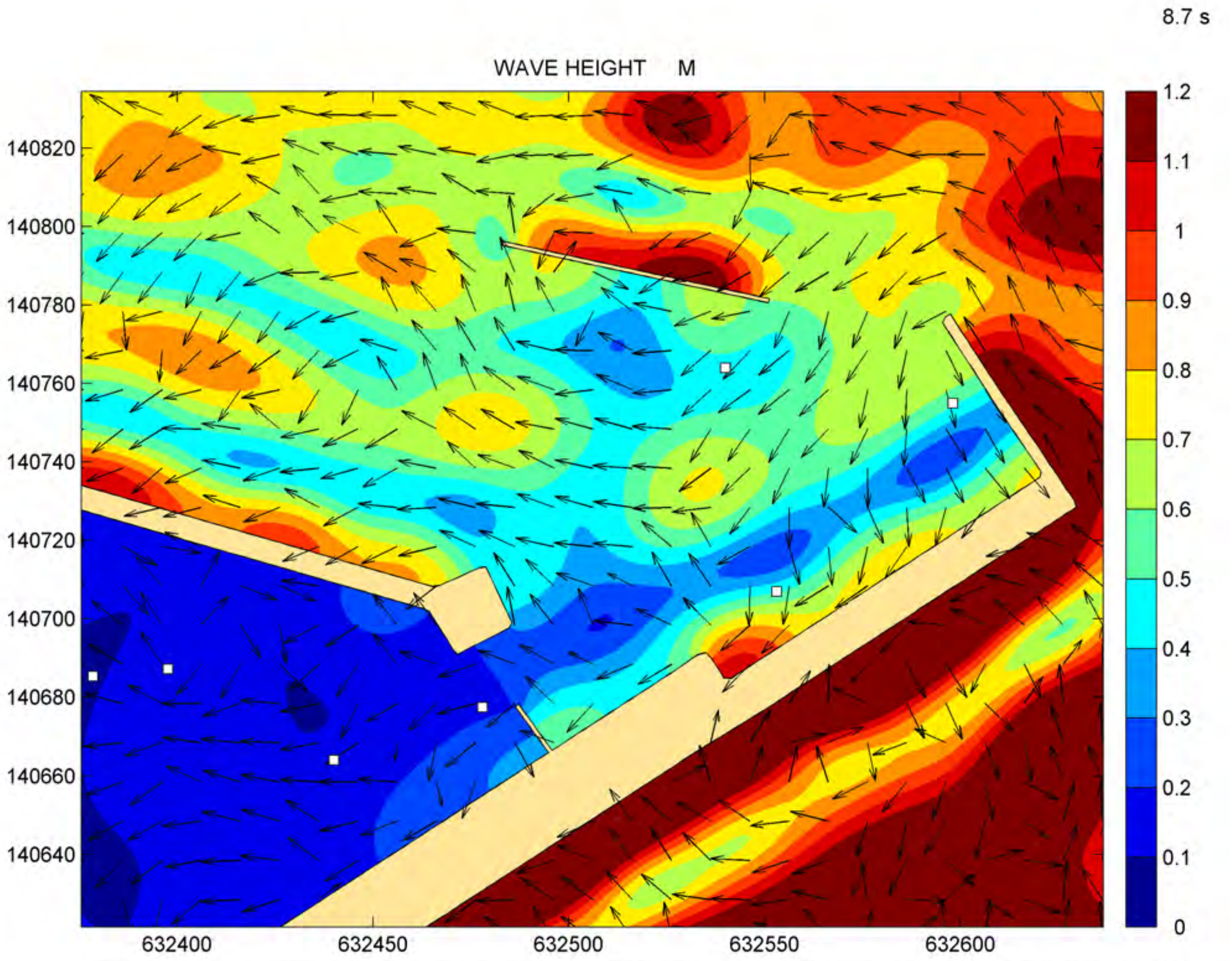

Figure 9.49: Wave conditions outside marina (Layout G+B: 50 Year 183°N + MHWS)

Source: HR Wallingford

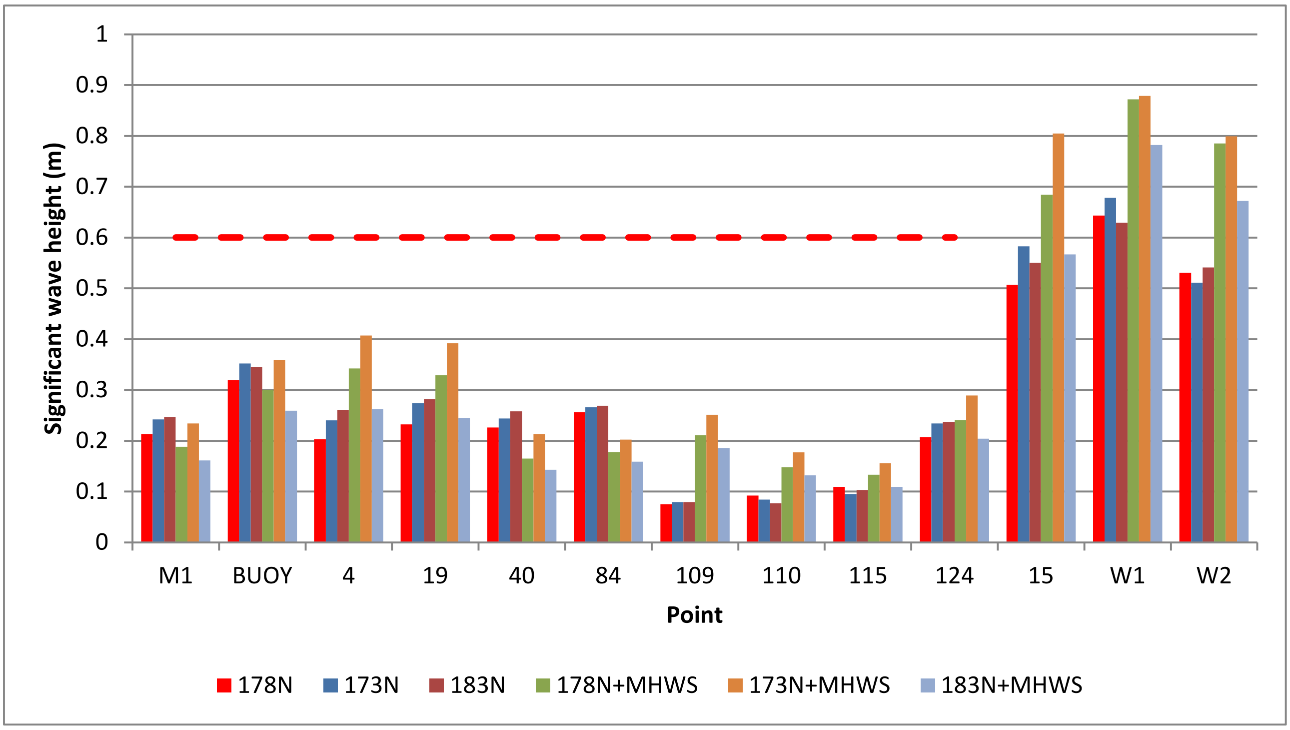

Figure 9.50: Summary of results: 50 year storm condition + MHWS

Source: HR Wallingford

9.7. Sensitivity to boundary wave direction accounting for future Sea Level Rise (SLR) (50-year condition)

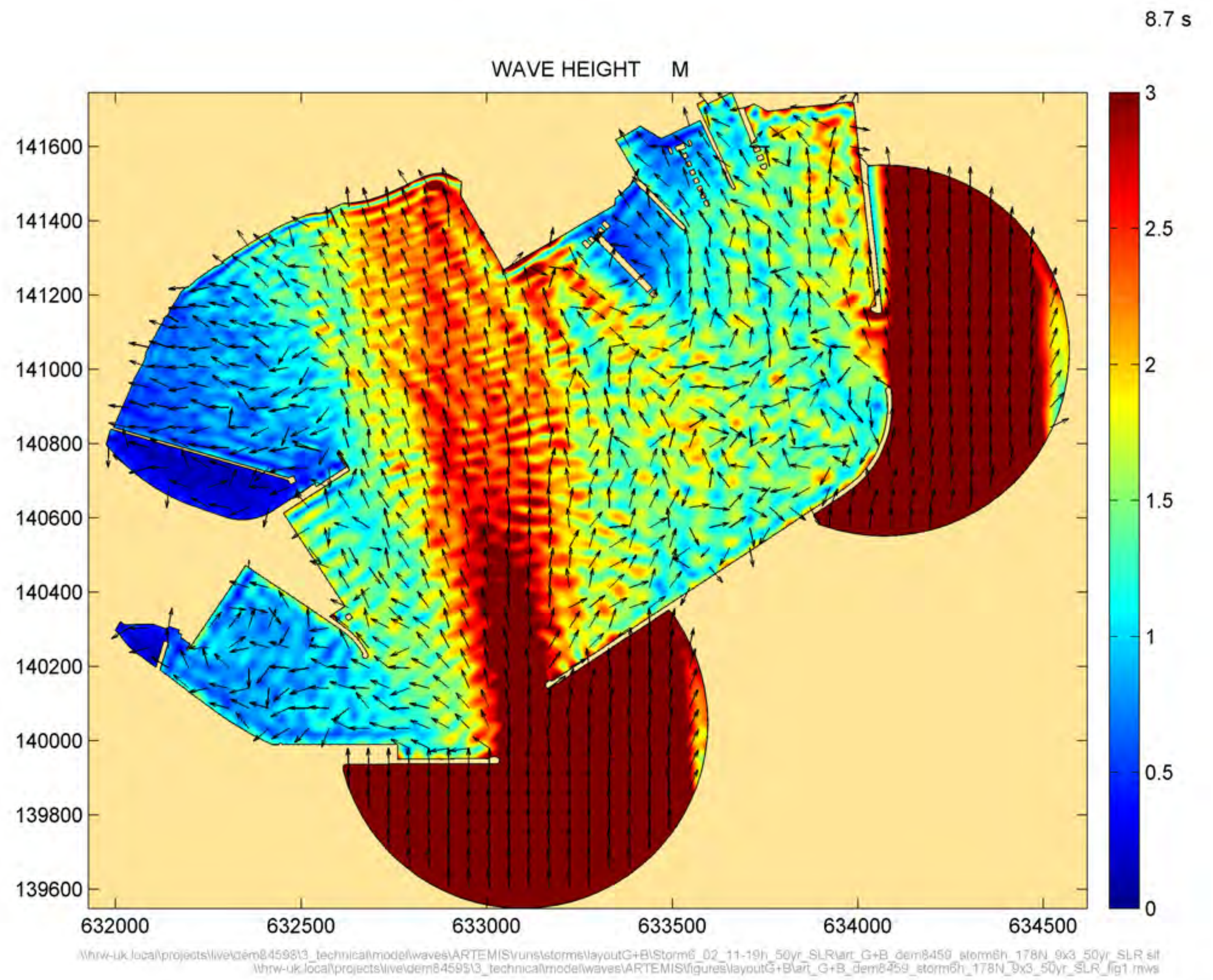

Figure 9.51: Wave conditions inside harbour (Layout G+B: 50 Year 178°N + SLR)

Source: HR Wallingford

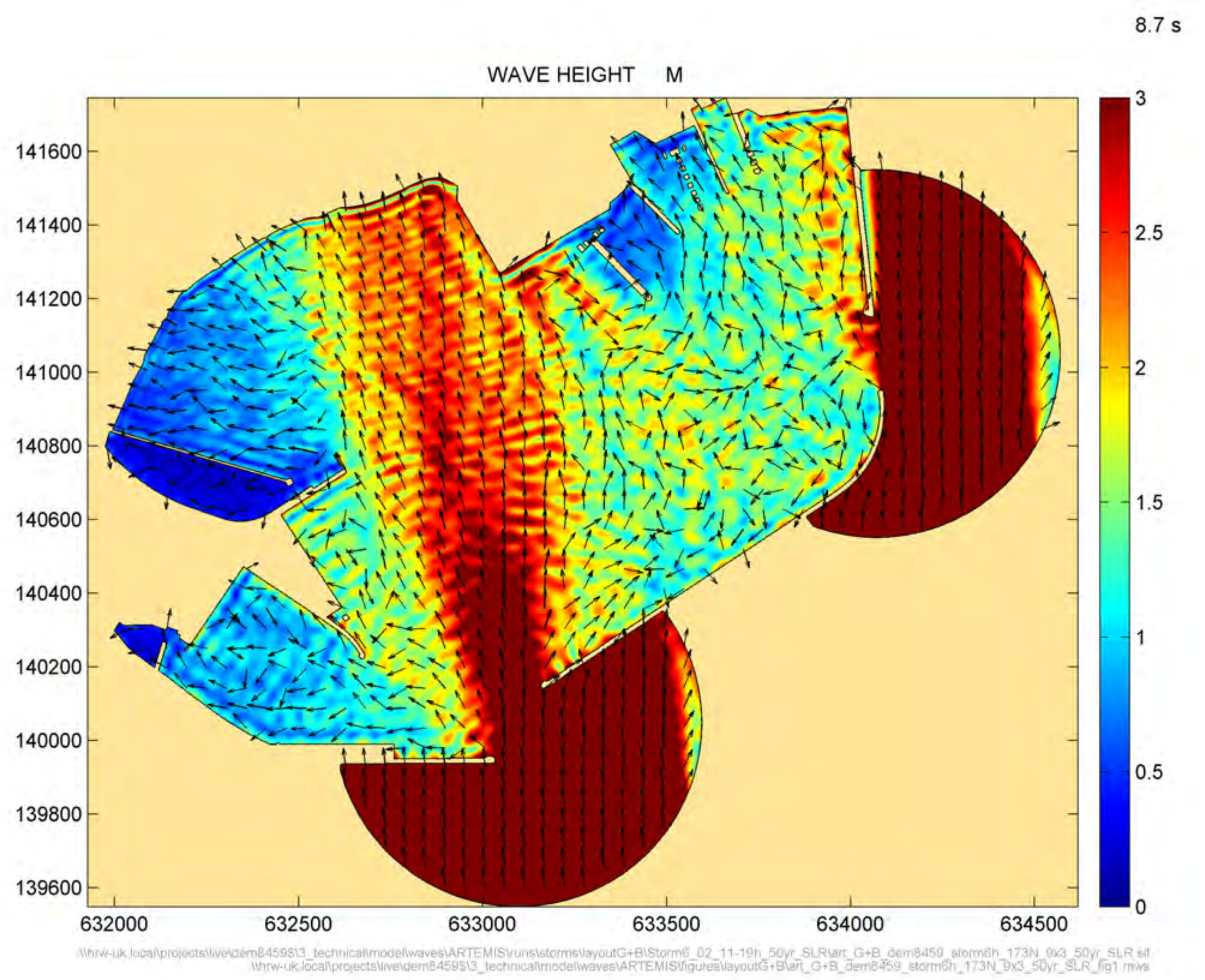

Figure 9.52: Wave conditions inside harbour (Layout G+B: 50 Year 173°N + SLR)

Source: HR Wallingford

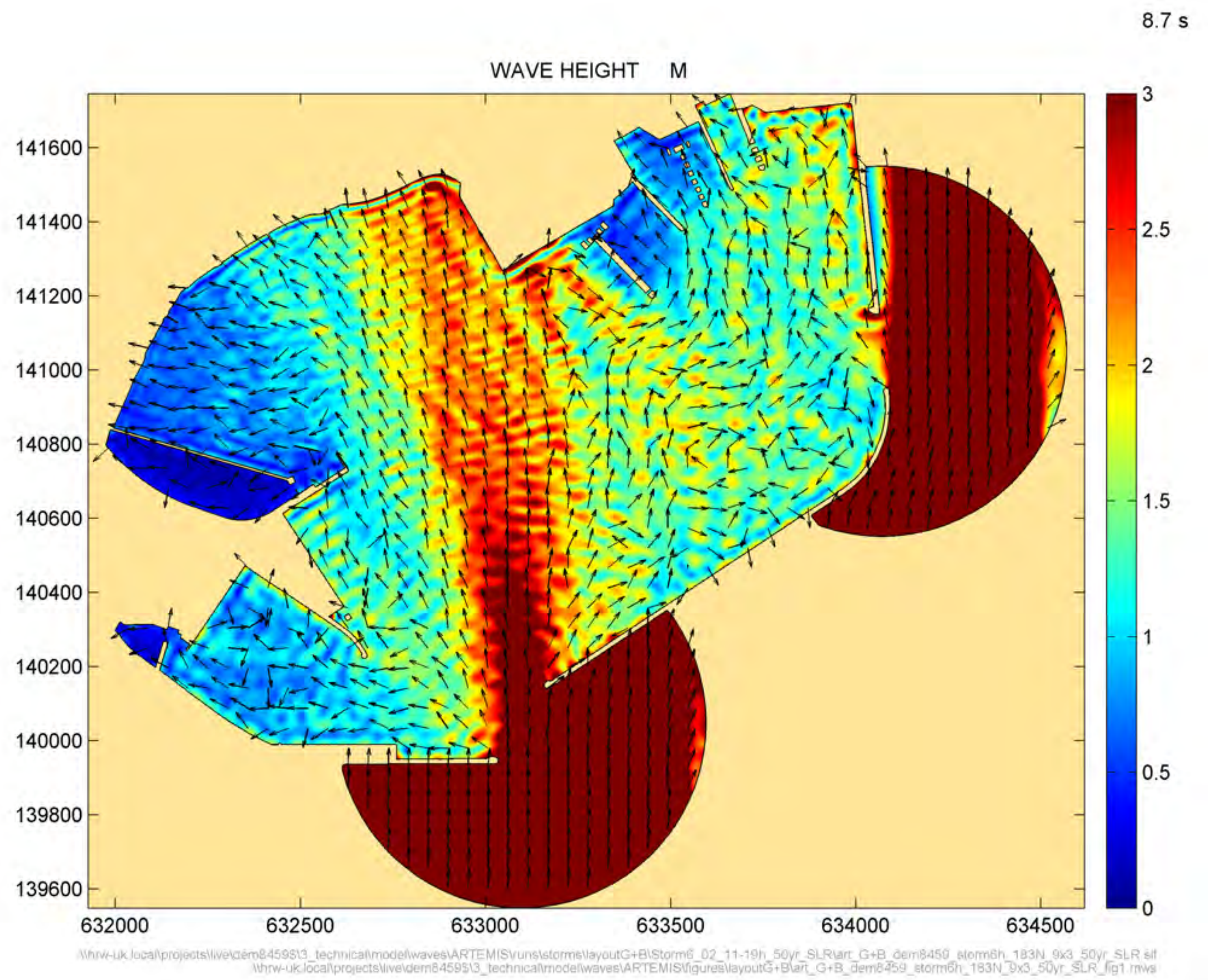

Figure 9.53: Wave conditions inside harbour (Layout G+B: 50 Year 183°N + SLR)

Source: HR Wallingford

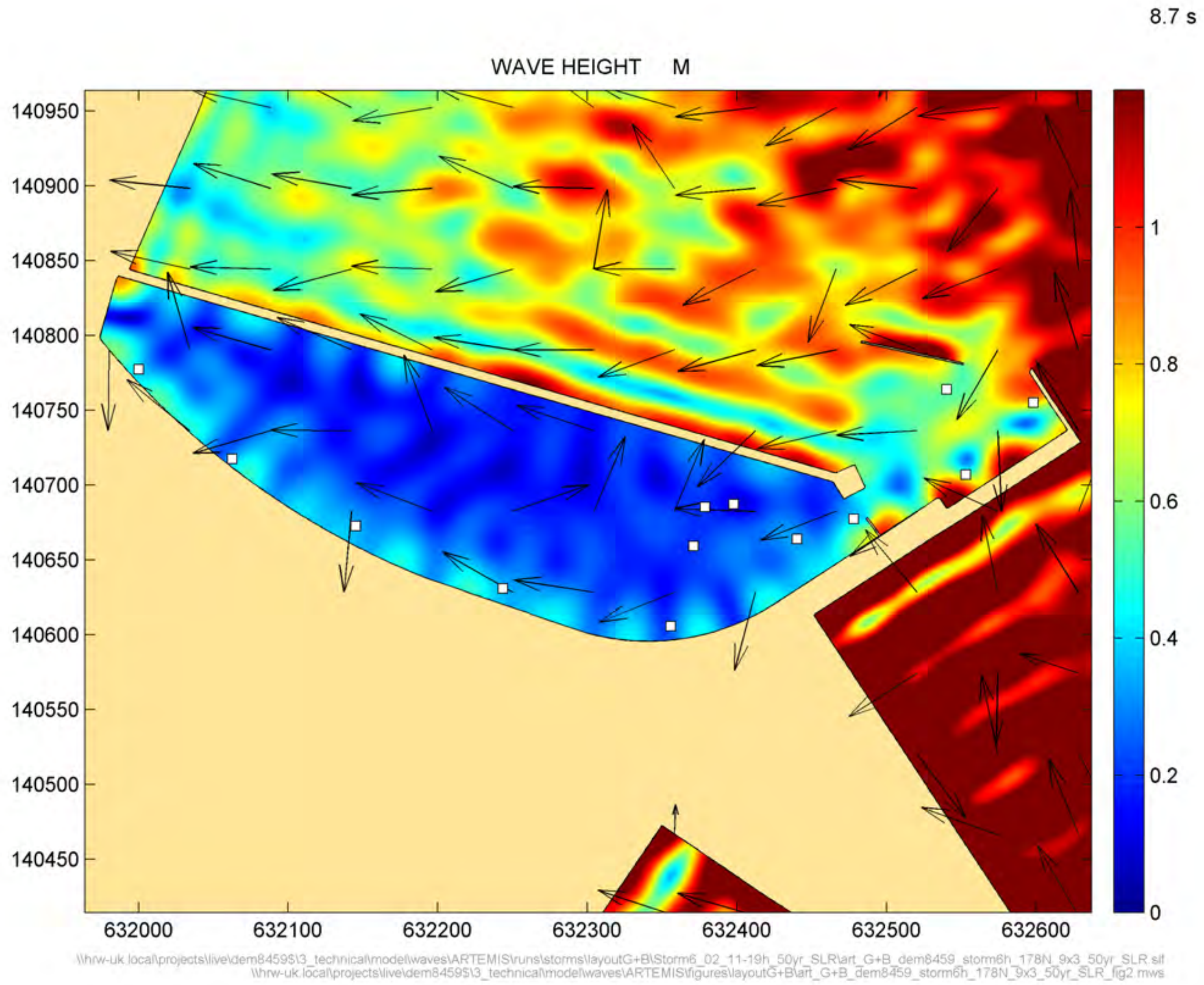

Figure 9.54: Wave conditions inside marina (Layout G+B: 50 Year 178°N + SLR)

Source: HR Wallingford

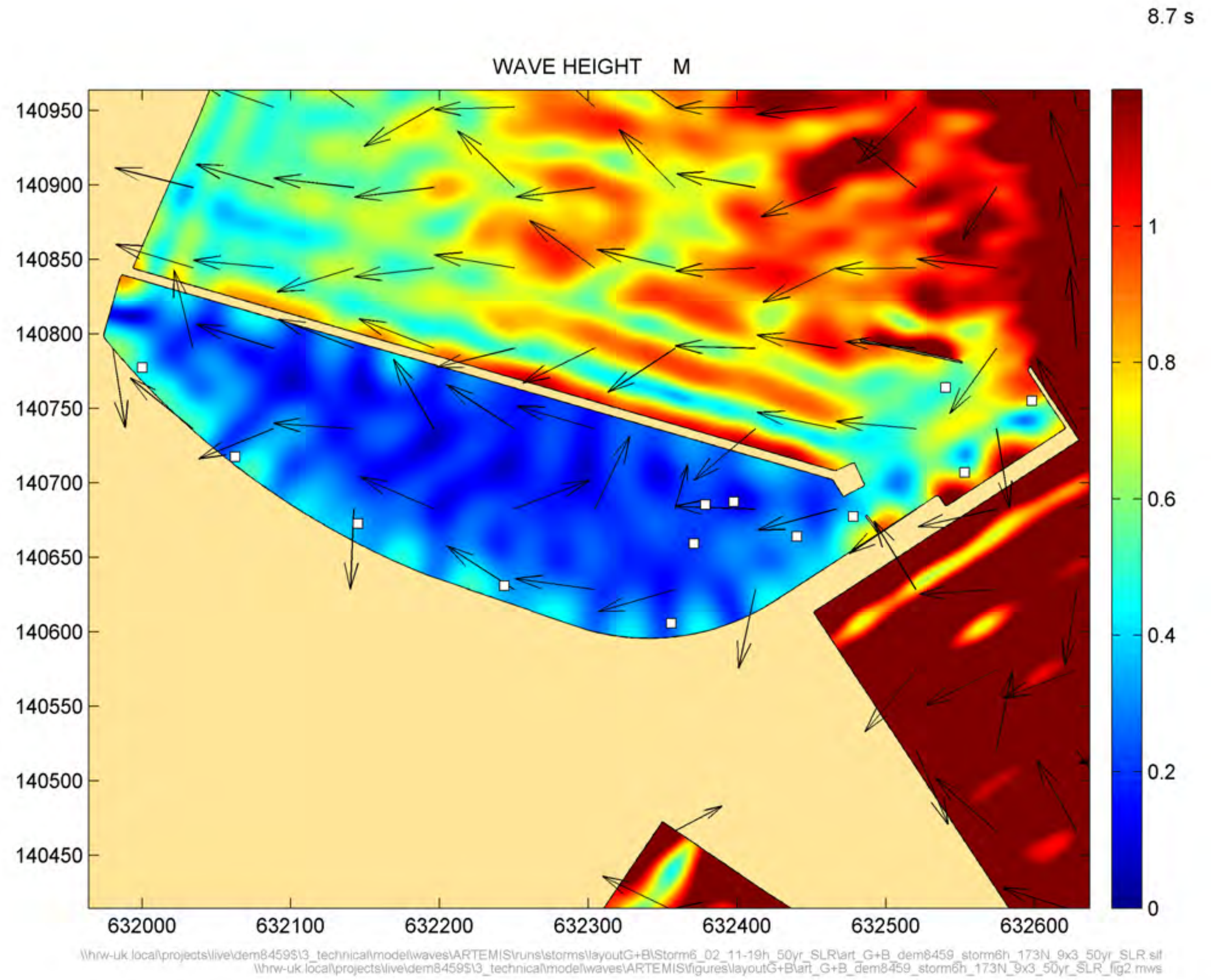

Figure 9.55: Wave conditions inside marina (Layout G+B: 50 Year 173°N + SLR)

Source: HR Wallingford

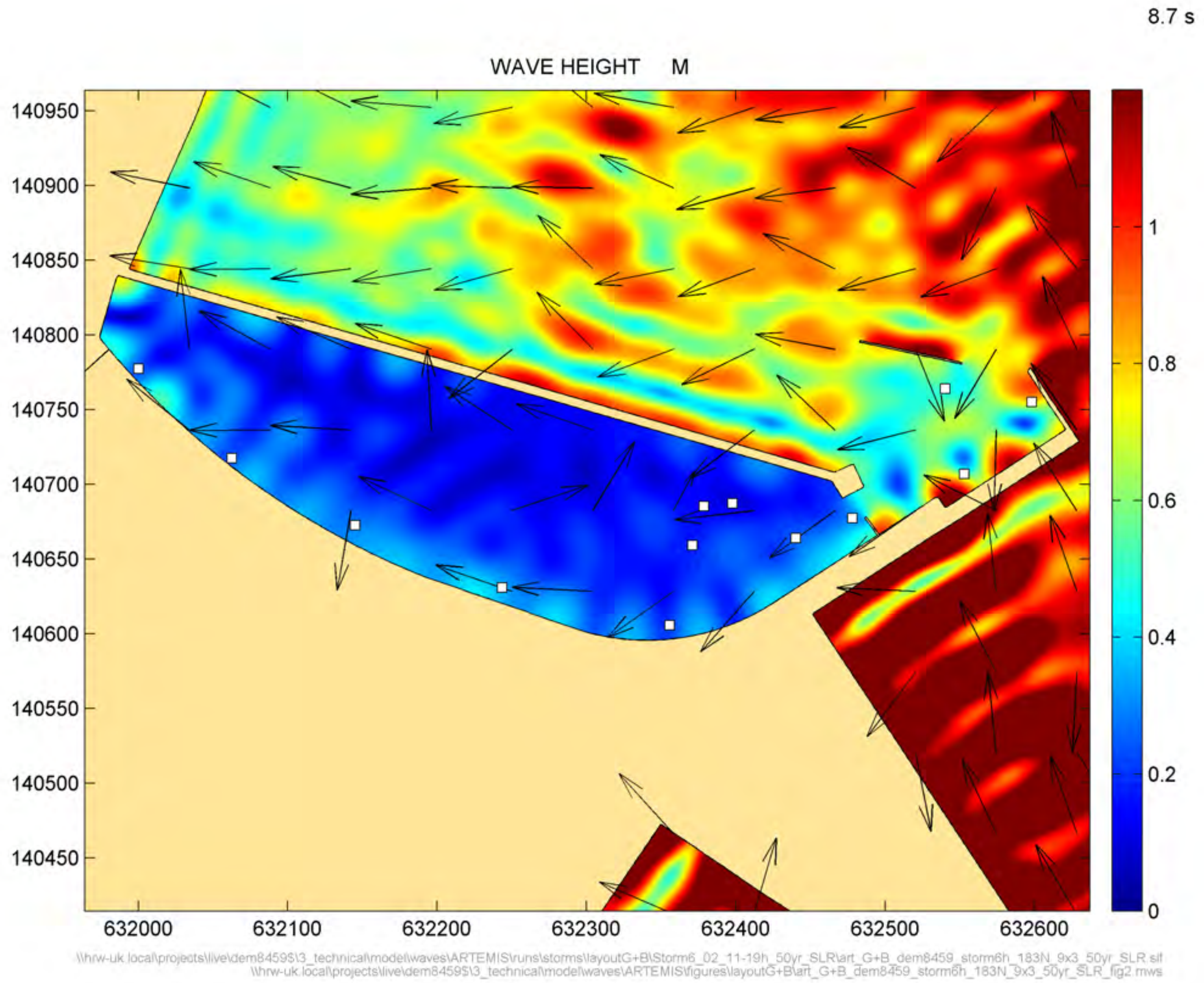

Figure 9.56: Wave conditions inside marina (Layout G+B: 50 Year 183°N + SLR)

Source: HR Wallingford

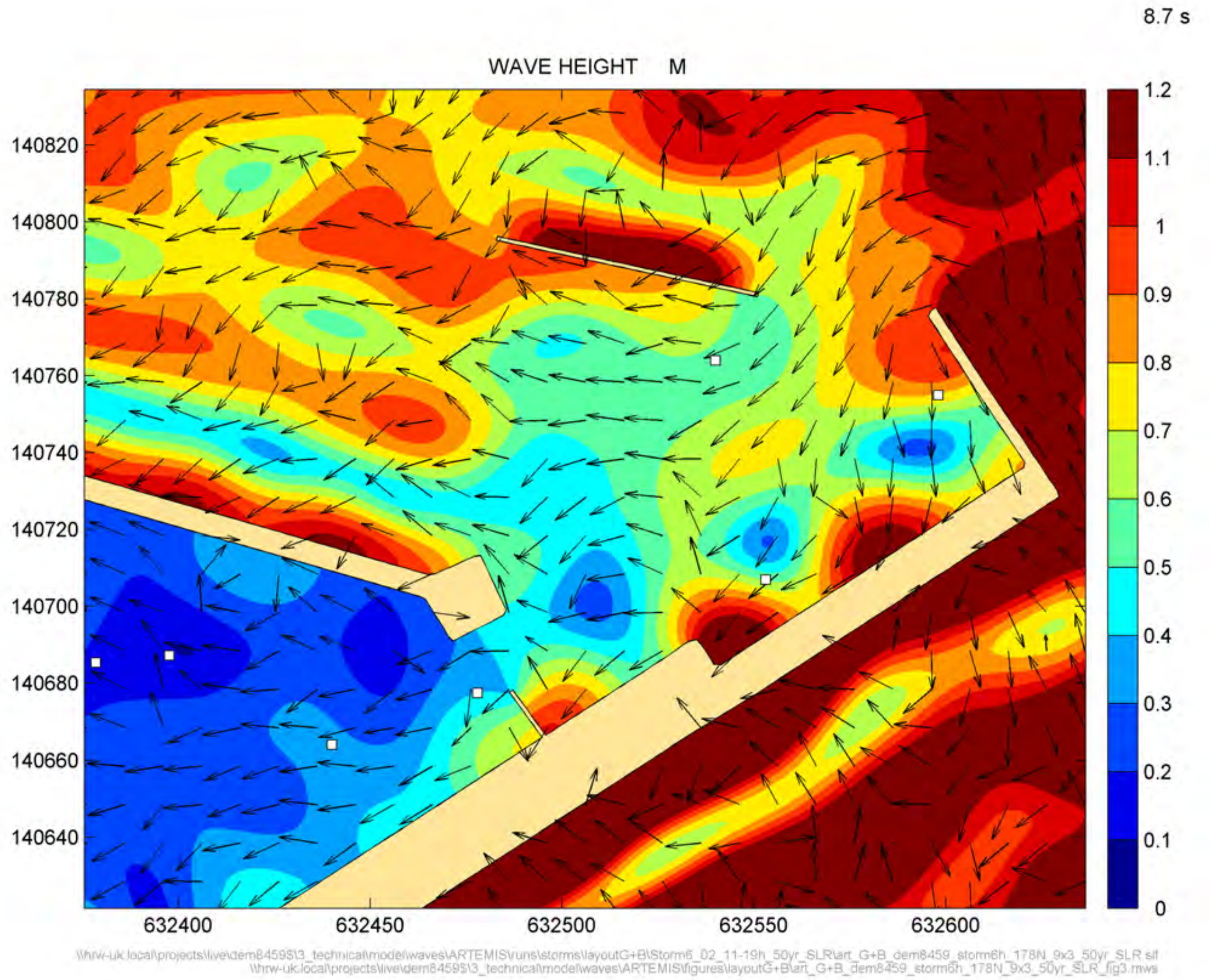

Figure 9.57: Wave conditions outside marina (Layout G+B: 50 Year 178°N + SLR)

Source: HR Wallingford

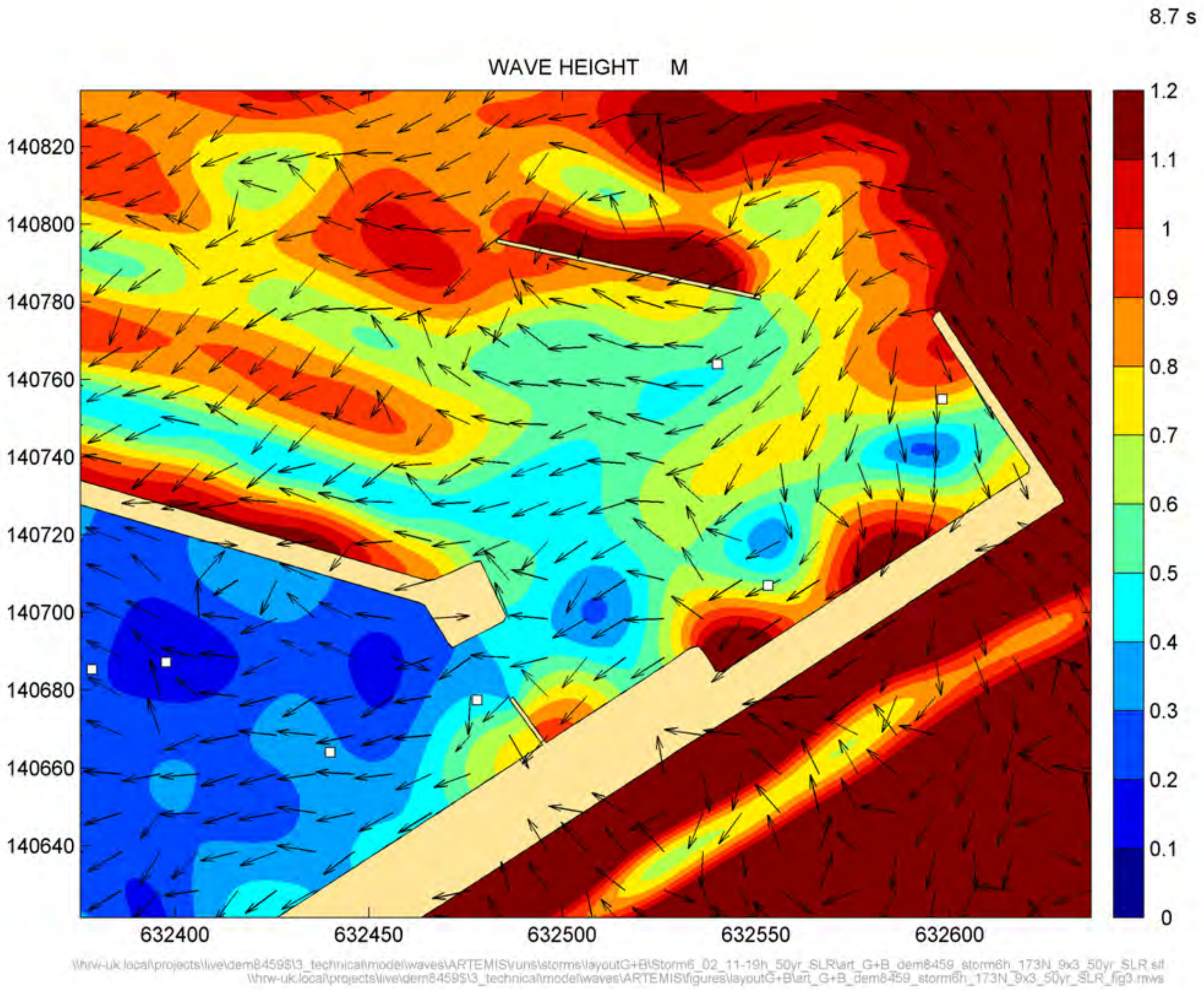

Figure 9.58: Wave conditions outside marina (Layout G+B: 50 Year 173°N + SLR)

Source: HR Wallingford

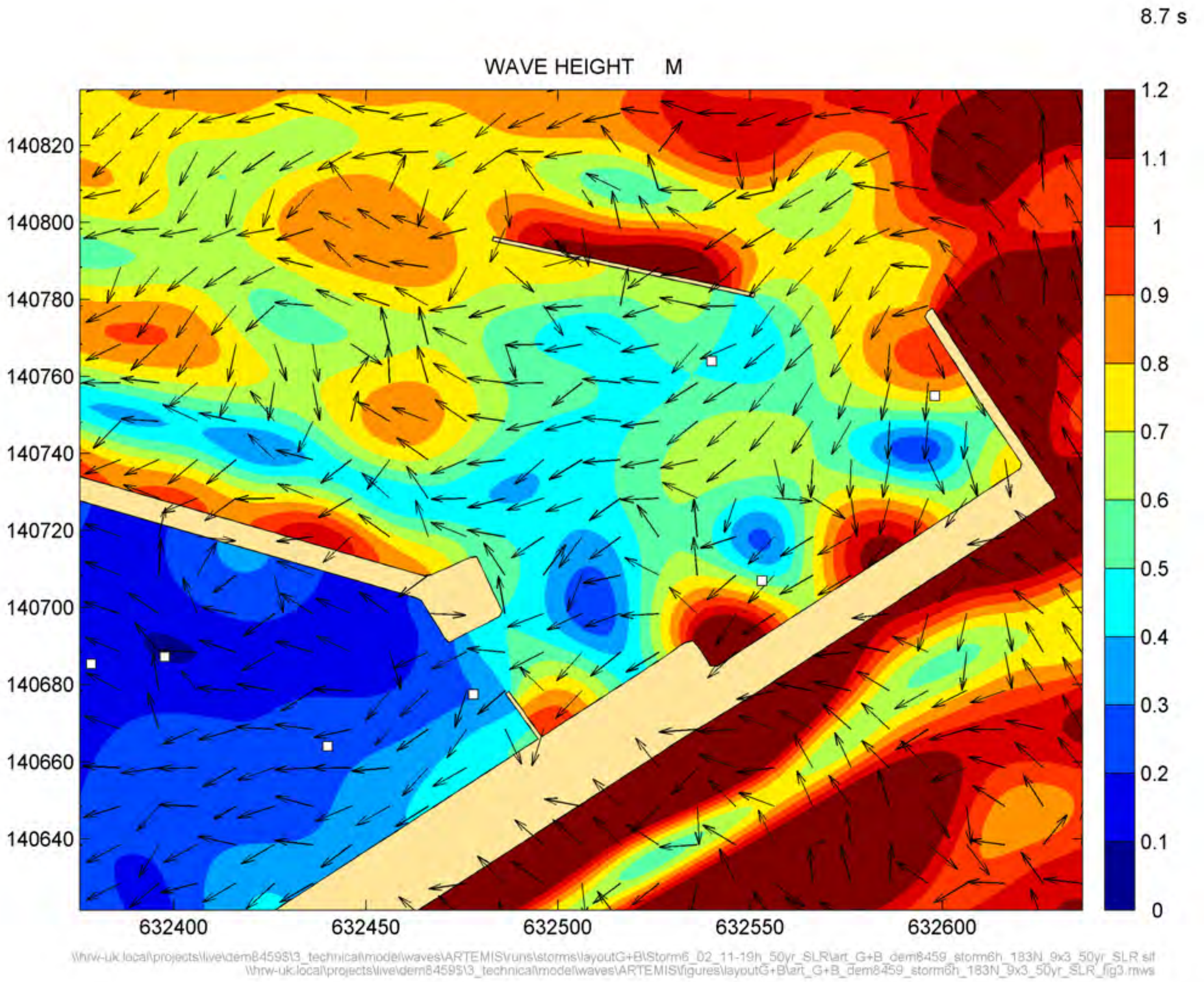

Figure 9.59: Wave conditions outside marina (Layout G+B: 50 Year 183°N + SLR)

Source: HR Wallingford

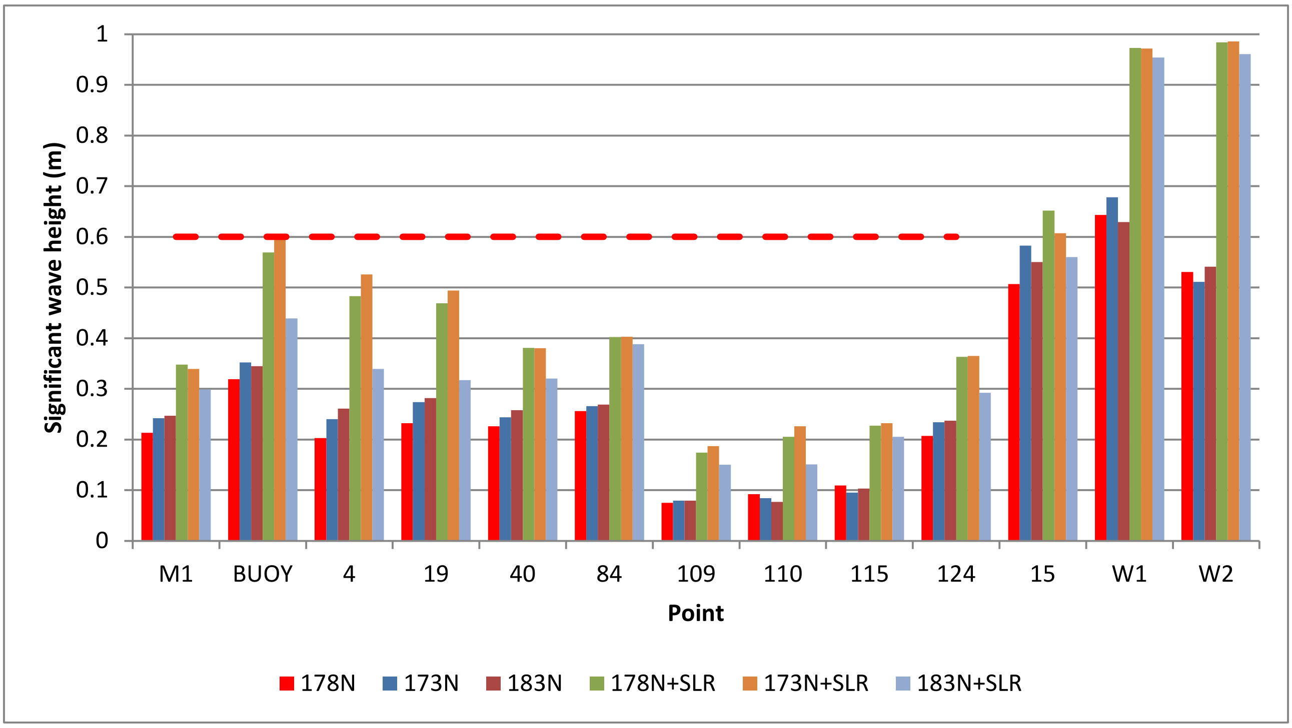

Figure 9.60: Summary of results: 50 year storm condition + SLR

Source: HR Wallingford

9.7.1. 50 Year incident only wave conditions at Breakwater B.

For the design of Breakwater B, incident only wave conditions are required. The ARTEMIS model incorporating breakwaters G and B was therefore re-run for the important 50 year condition from 173°N (including the allowance for sea level rise, as reported in Section 9.7, above), with the reflection coefficient along Breakwater B set to zero. The corresponding results outside the marina are presented in Figure 9.61 and Figure 9.62, with and without reflections from Breakwater B, respectively. Model results were also extracted within the polygon shown in Figure 9.62. The maximum significant wave heights within the polygon and associated wave periods are presented in Table 9.1.

The vectors in Figure 9.62 show predicted mean wave directions. However, it should be noted that wave directions at Breakwater B are expected to be bi-directional due to waves diffracting around the Marine Curve extension (with wave crests perpendicular to B) and reflected waves from Marine Parade (with wave crests parallel to B).

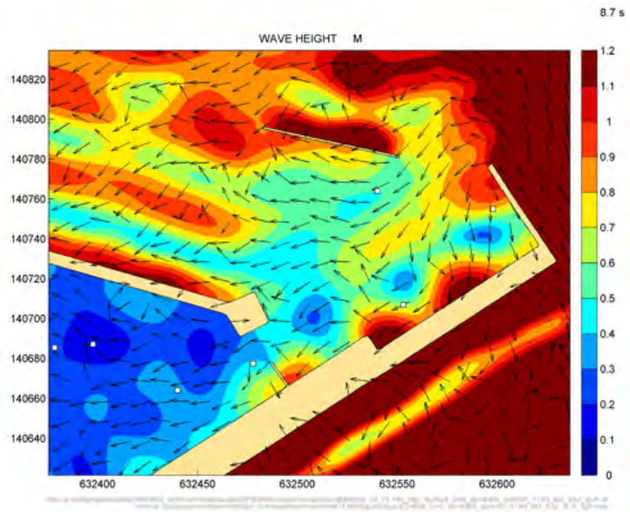

Figure 9.61: Wave conditions outside marina (Layout G+B: 50 Year 173°N + SLR + reflections)

Source: HR Wallingford

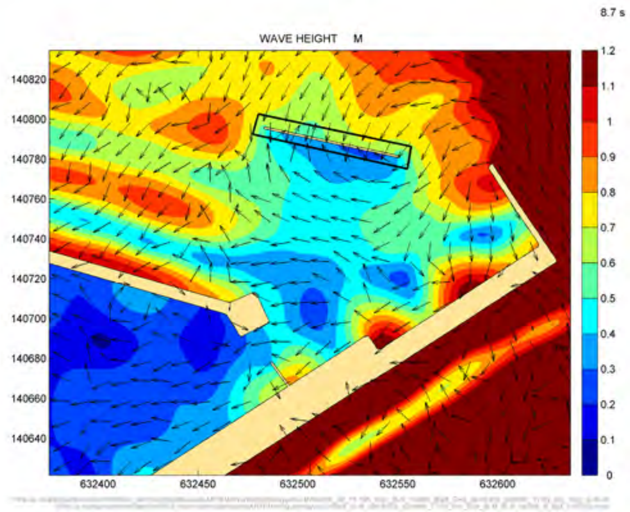

Figure 9.62: Wave conditions outside marina (Layout G+B: 50 Year 173°N + SLR + no reflections from Breakwater B.

Source: HR Wallingford

Table 9.1: 50 Year incident only wave conditions at Breakwater B

Return Period (years)	Water level (mCD)	Significant wave height Hs (m)	Peak Period Tp (s)	Mean Period Tm-10 (s)	Mean Period Tm01 (s)	Mean Period Tm02 (s)
50	7.21	0.7	8.7	8.7	8.4	8.3

Source: HR Wallingford

9.7.2. 1, 50 and 100 Year incident only wave conditions at Breakwater G

For the design of Breakwater G, incident only wave conditions are required. The ARTEMIS model incorporating breakwaters G and B was therefore re-run for the 1 and 50 year condition from 173°N, as previously considered (including the allowance for sea level rise, as reported in Section 9.7, above), with the reflection coefficient along the outer face of Breakwater G set to zero. The corresponding results outside the marina are presented in Figure 9.63 and Figure 9.64, and Figure 9.65 and Figure 9.66, with and without reflections from Breakwater G, for the 1 and 50 year conditions, respectively. Model results were also extracted in the corner between Breakwater G and the Marina Curve seawall. The maximum significant wave heights and associated wave periods are presented in Table 9.2. This table also gives an estimate of the 100 year incident wave conditions based on extrapolation of the 1 and 50 year conditions.

It should be noted that the wave conditions presented are based on the model including reflections from Marine Parade which are based on existing beach levels. Should beach levels change, with associated changes to the amount of wave reflections, then wave conditions would be expected to change within the marina and incident along both Breakwaters B and G, respectively.

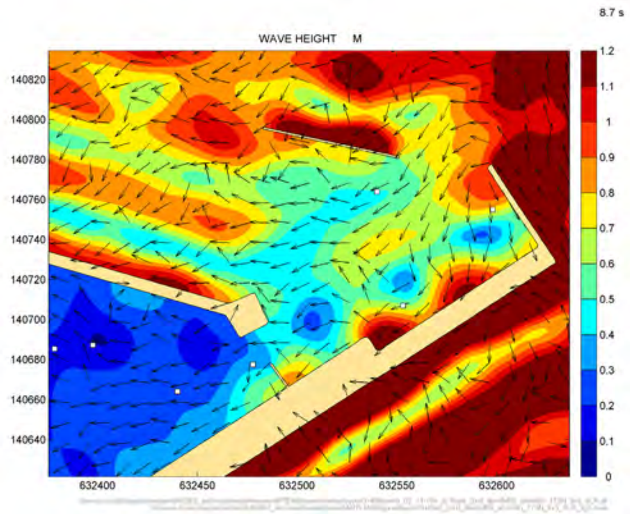

Figure 9.63: Wave conditions outside marina (Layout G+B: 1 Year 173°N + SLR + reflections)

Source: HR Wallingford

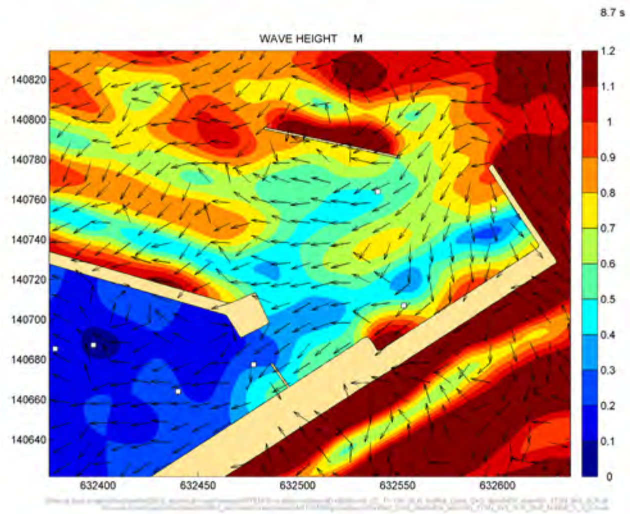

Figure 9.64: Wave conditions outside marina (Layout G+B: 1 Year 173°N + SLR + no reflections from Breakwater G.

Source: HR Wallingford

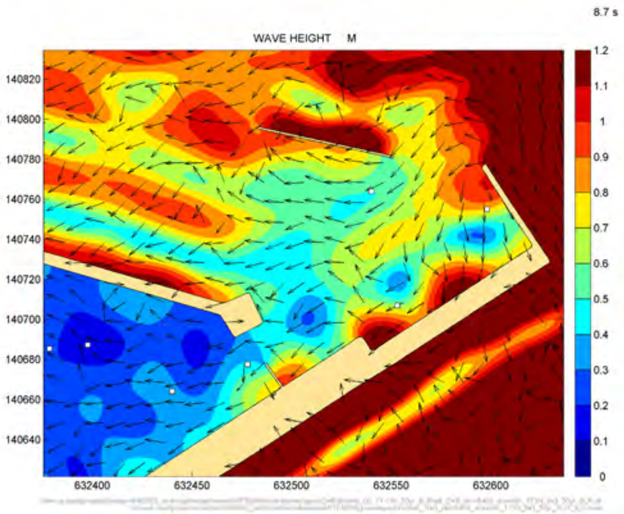

Figure 9.65: Wave conditions outside marina (Layout G+B: 50 Year 173°N + SLR + reflections)

Source: HR Wallingford

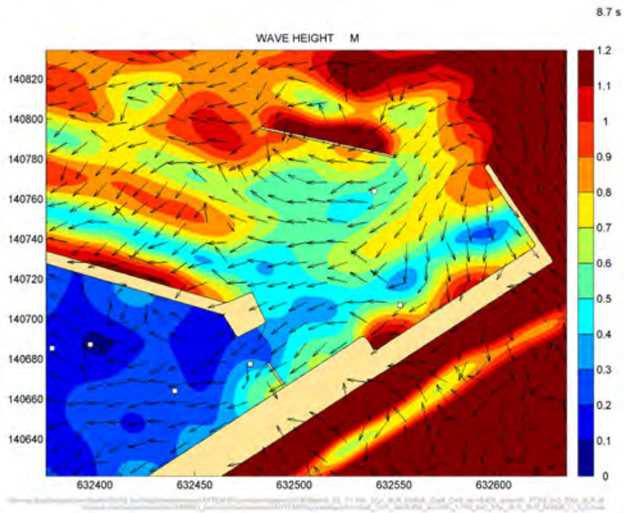

Figure 9.66: Wave conditions outside marina (Layout G+B: 50 Year 173°N + SLR + no reflections from Breakwater G.

Source: HR Wallingford

Table 9.2: Extreme incident only wave conditions at Breakwater G

Return Period (years)	Water level (mCD)	Significant wave height Hs (m)	Peak Period Tp (s)	Mean Period Tm-10 (s)	Mean Period Tm01 (s)	Mean Period Tm02 (s)
1	7.21	0.48	8.7	8.1	7.9	7.7
50	7.21	0.51	8.7	8.2	8.0	7.9
100	7.21	0.52	8.7	8.2	8.0	7.9

Source: HR Wallingford

9.8. Period Scanning results (Layout G+B)

The period scanning run carried out for the as-built layout as reported in HR Wallingford (2020) was repeated for Layout G+B, which also includes Pier F, although this was previously shown not to affect conditions much within the marina for waves from the south-west. The period scanning runs were carried out at a still water level of +6.8m (MHWS) and +7.21m (MHWS plus an allowance for future sea level rise).

The model results were extracted at the point locations inside the marina as shown in Figure 9.67 and presented as plots of wave height coefficient against wave period in Figure 9.68 to Figure 9.77. For reference the results for the as-built layout as originally quoted, labelled Baseline are also reproduced in these figures.

In general the model results show similar predictions for both layouts and water levels. For the important period range between 5 and 10 seconds the model results appear to show lower wave height coefficient in general for layout G+B, compared with the as-built layout, with wave height coefficients generally below 0.2m for Layout G+B. This will be a result of the additional shelter provided by Breakwaters G and B.

For wave periods above about 15 seconds the two additional breakwaters in Layout G+B result in similar wave height coefficients, but at slightly different periods, indicating that these breakwaters are less effective at reducing such long period waves.

At M1, the Buoy and point 4, and to a lesser extent at other points within the marina, the relatively high wave height coefficients for periods between 30 and 35 seconds are similar for each layout and water level, with the differences expected to be due partly to changes in the wavelength as well as the general layout which will affect the resonant response of the marina. And as previously noted in HR Wallingford (2020) for periods above 20 seconds there is expected to be little associated incident wave energy at the harbour entrance. Therefore for these longer periods, the magnitude of corresponding waves at these periods are expected to be small within the marina.

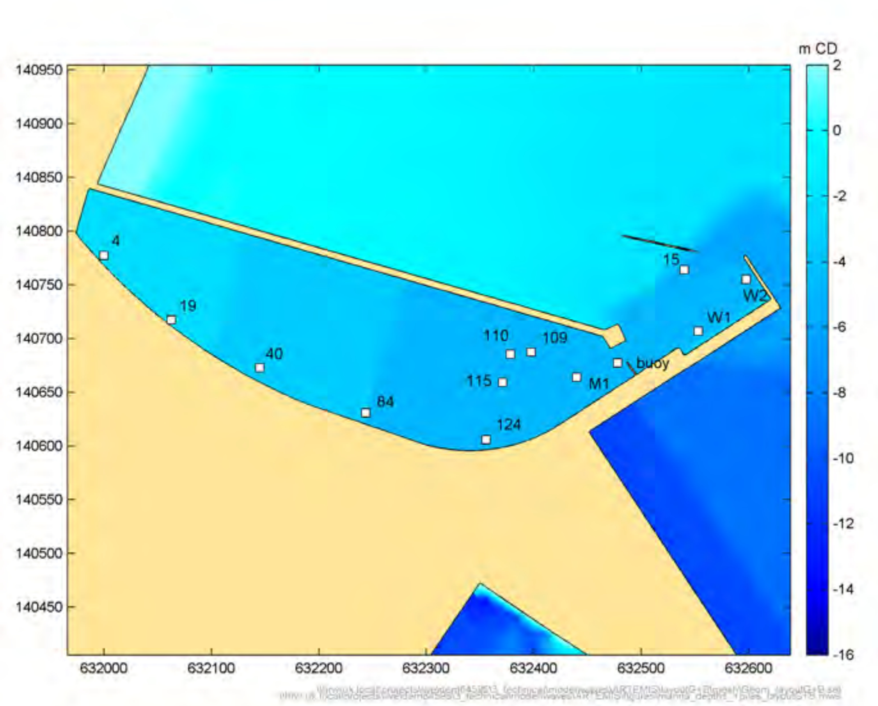

Figure 9.67: Layout G+B: Period Scanning output locations inside marina

Source: HR Wallingford

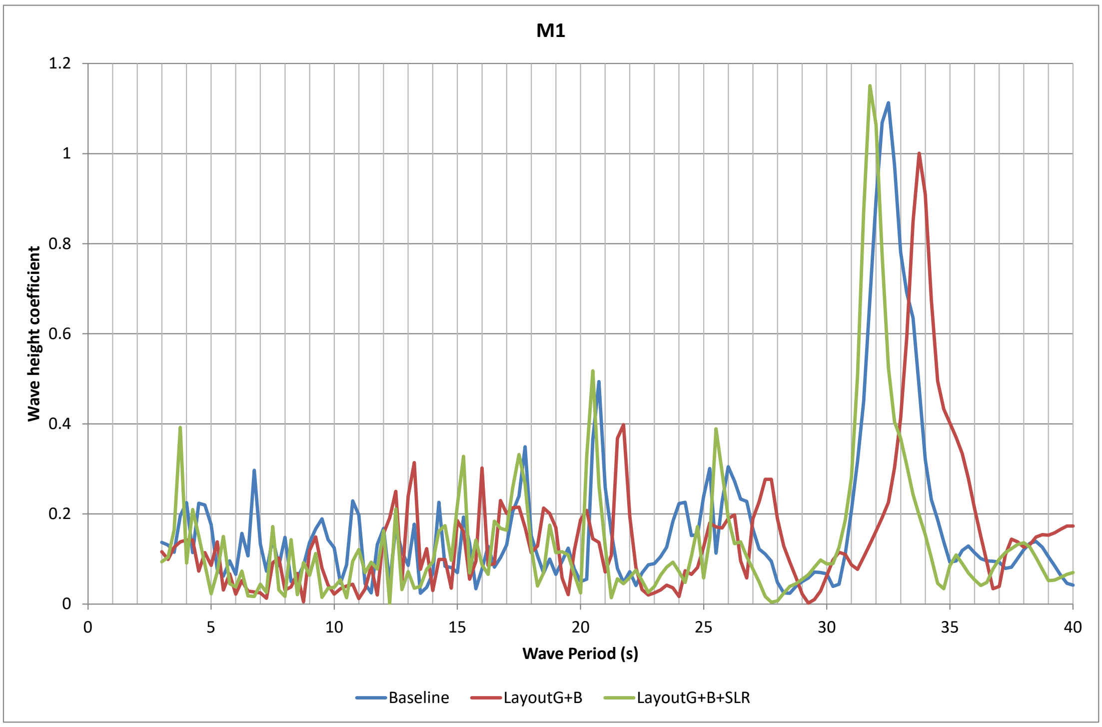

Figure 9.68: Period scanning results at M1

Source: HR Wallingford

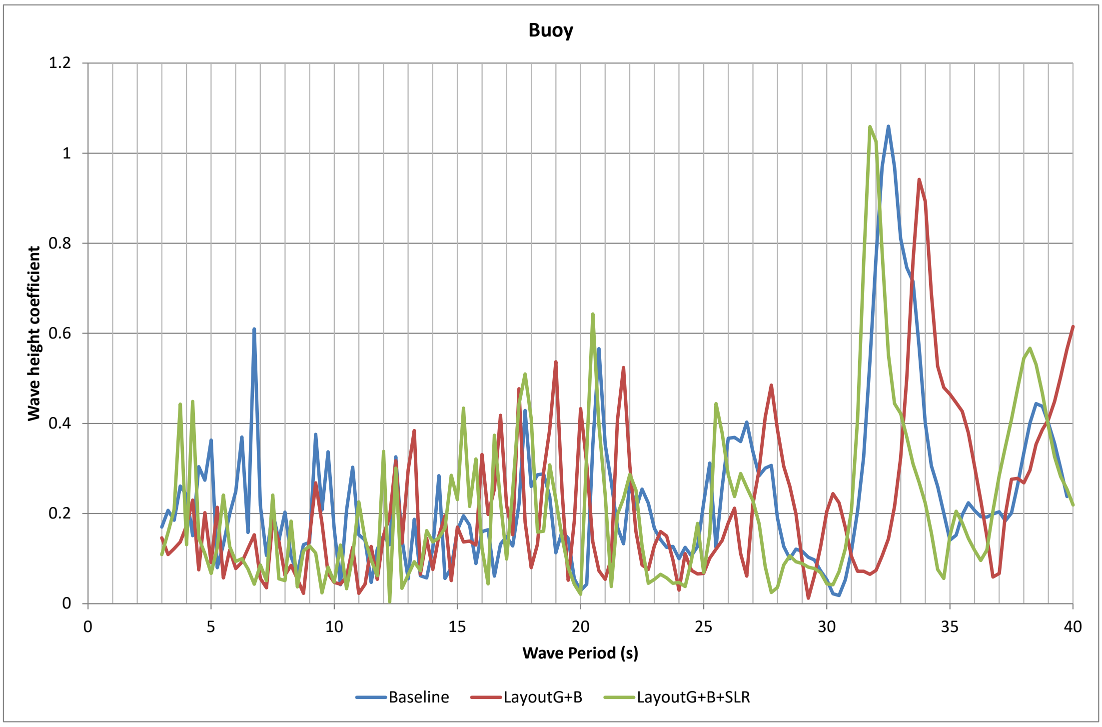

Figure 9.69: Period scanning results at the Buoy

Source: HR Wallingford

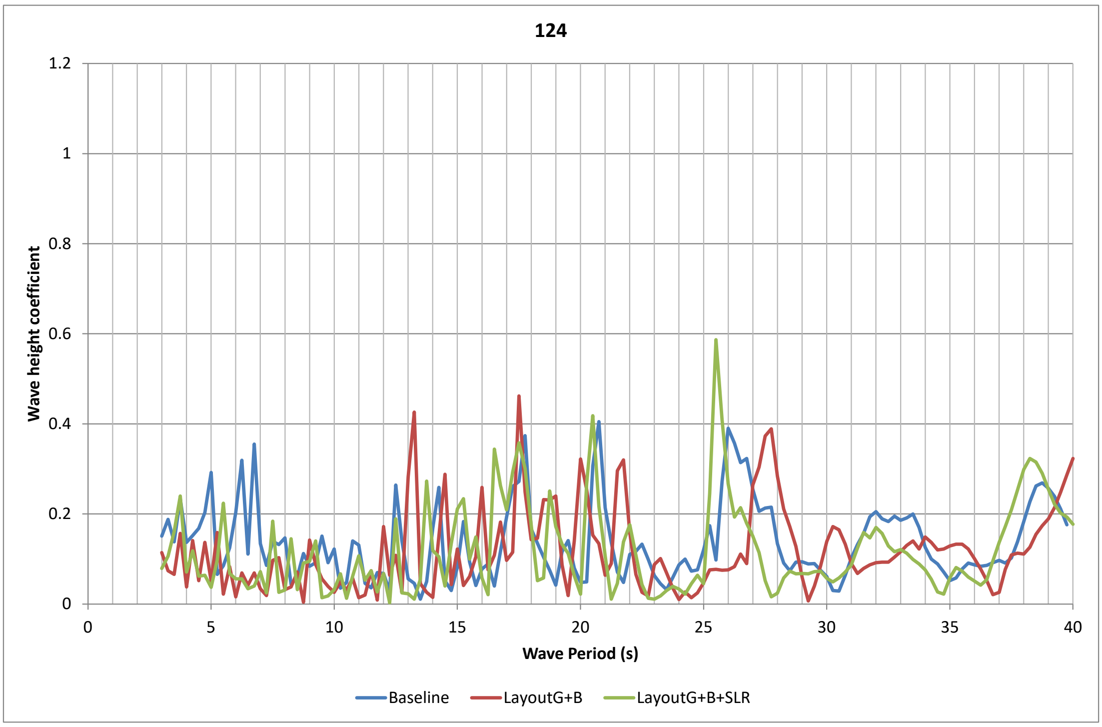

Figure 9.70: Period scanning results at 124

Source: HR Wallingford

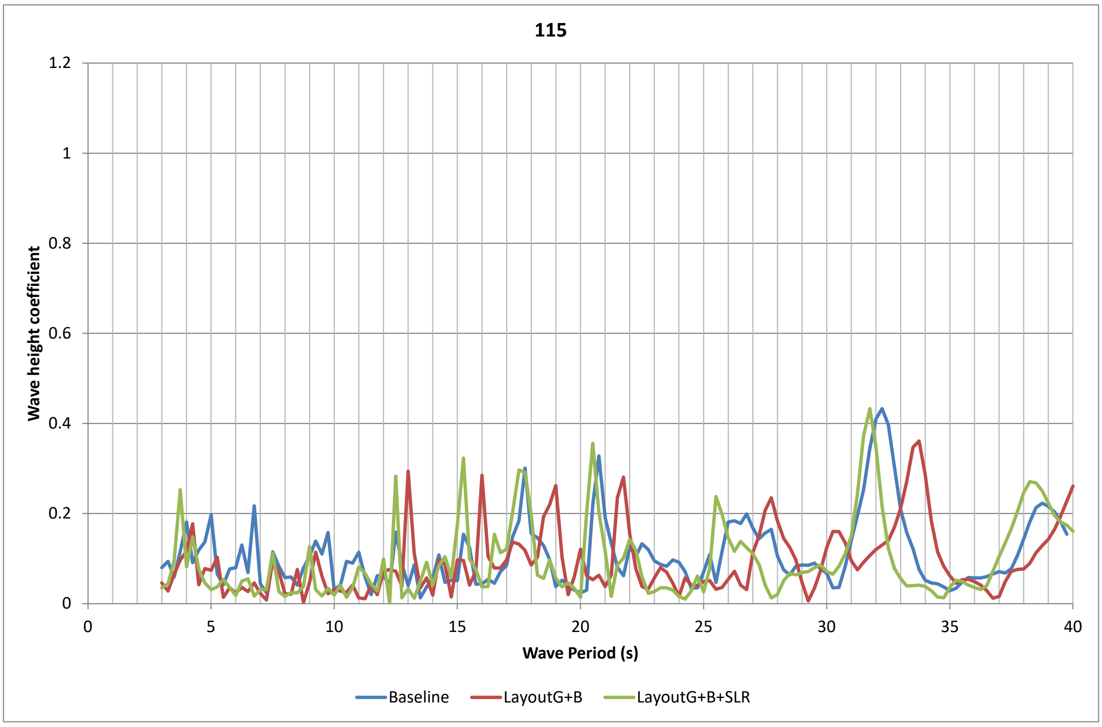

Figure 9.71: Period scanning results at 115

Source: HR Wallingford

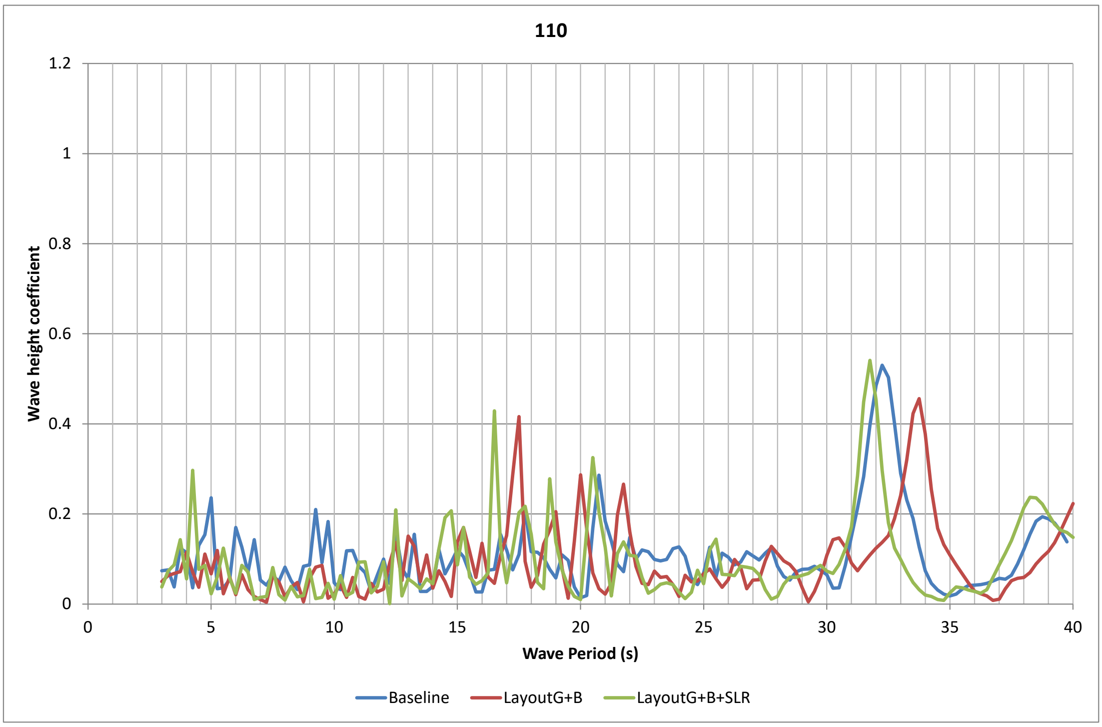

Figure 9.72: Period scanning results at 110

Source: HR Wallingford

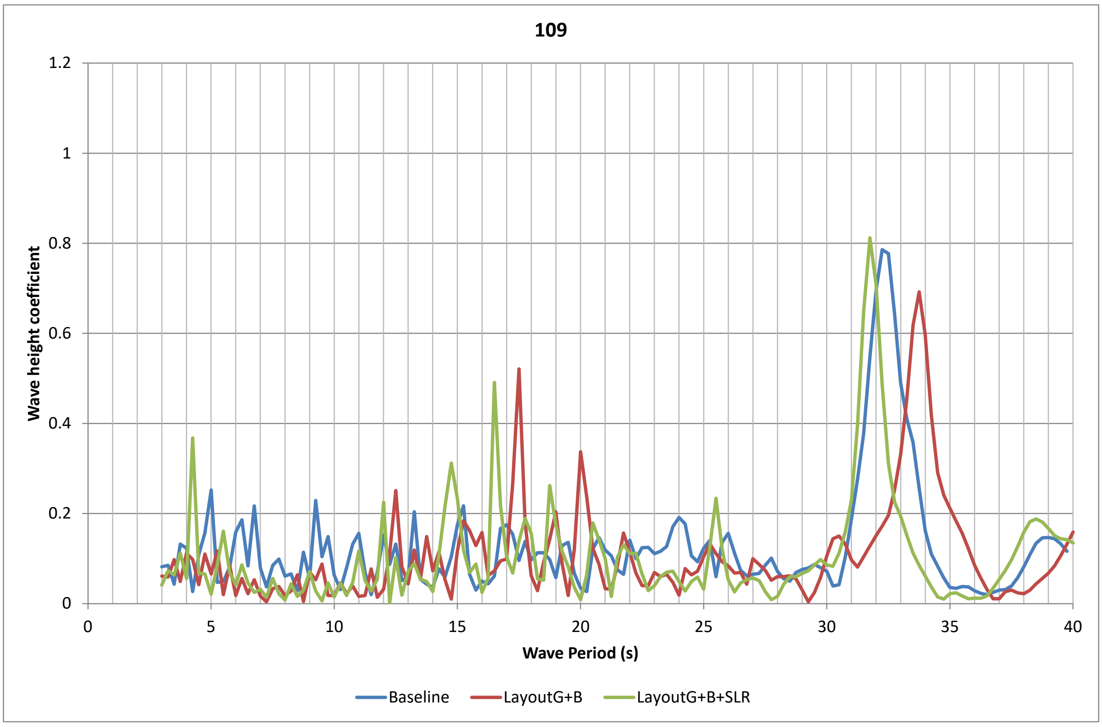

Figure 9.73: Period scanning results at 109

Source: HR Wallingford

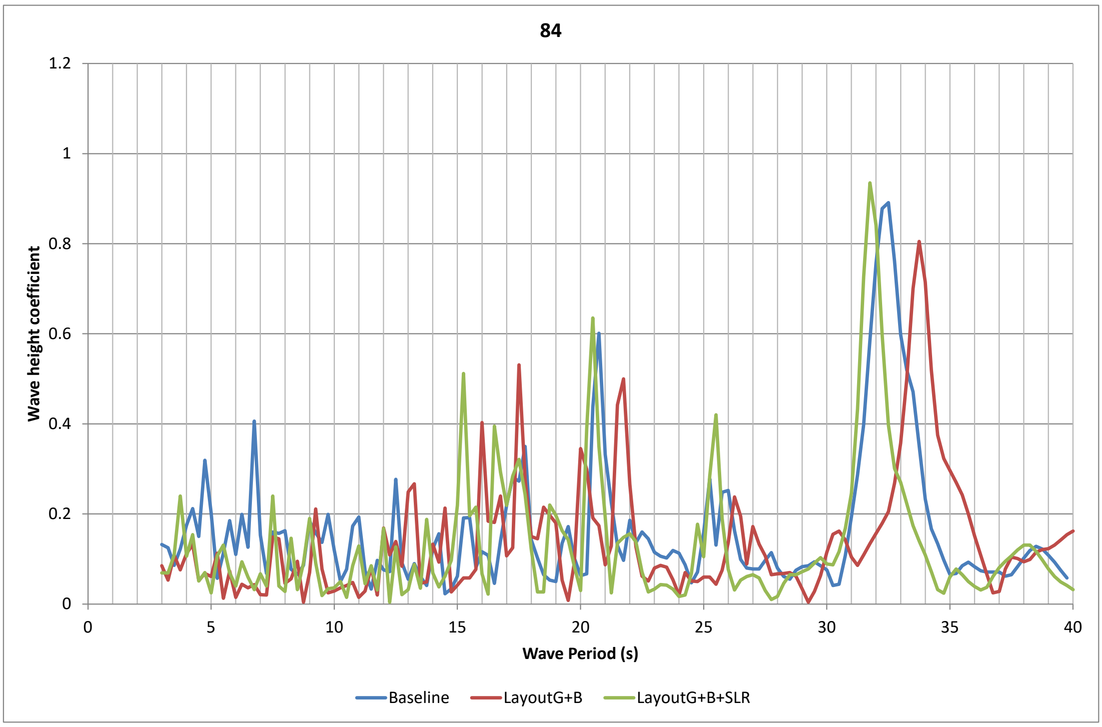

Figure 9.74: Period scanning results at 84

Source: HR Wallingford

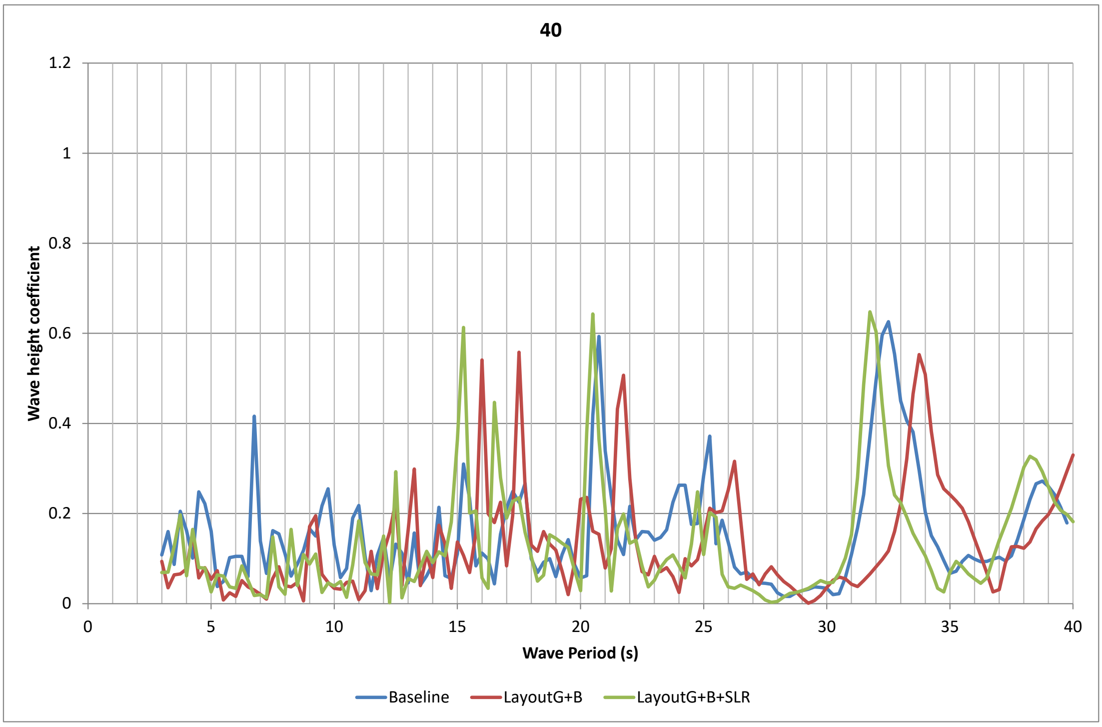

Figure 9.75: Period scanning results at 40

Source: HR Wallingford

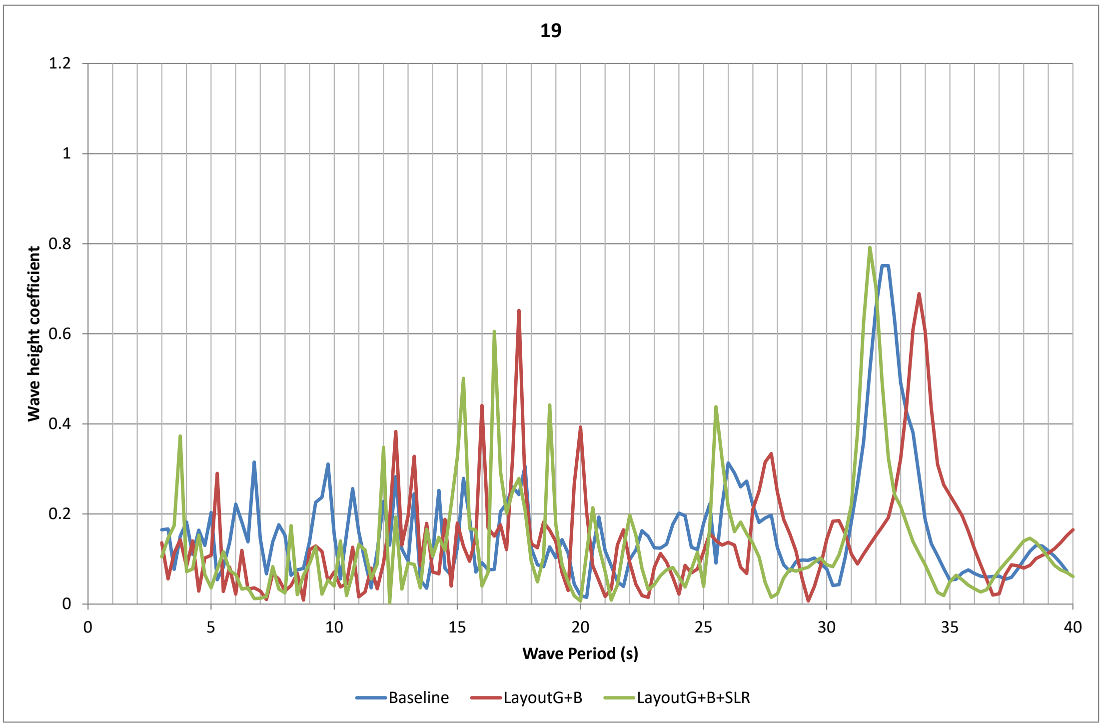

Figure 9.76: Period scanning results at 19

Source: HR Wallingford

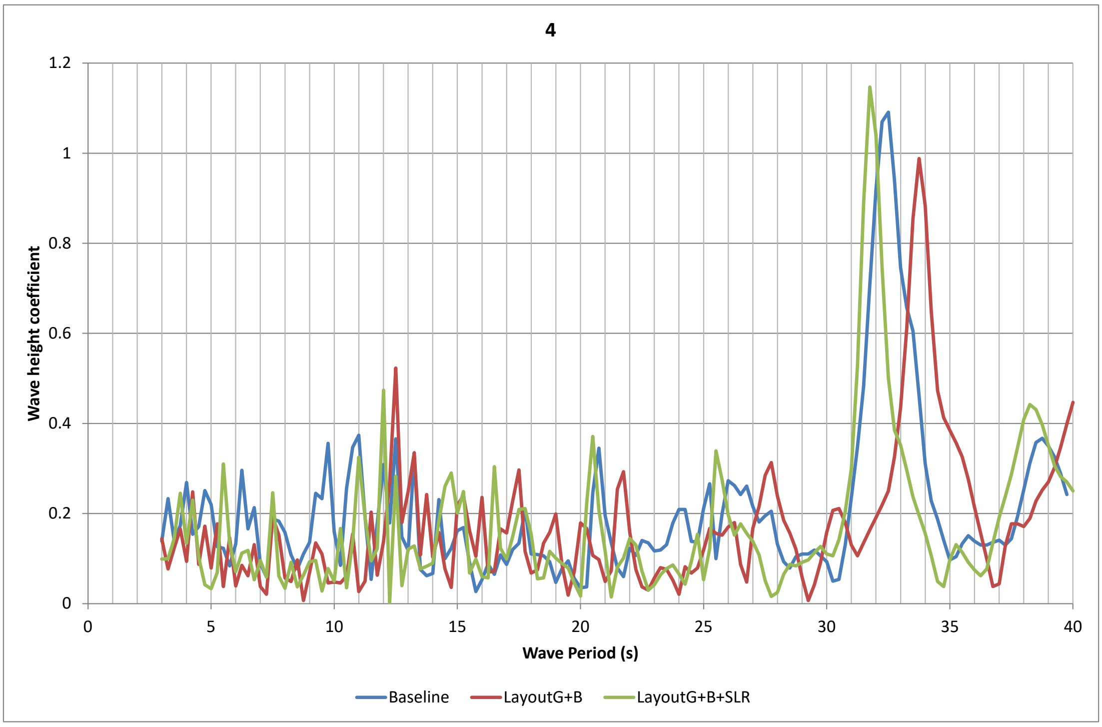

Figure 9.77: Period scanning results at 4

Source: HR Wallingford

10. Recent events following construction of Breakwater G

Following construction of Breakwater G, visual observations of wave heights were collected by DHB during periods of high waves and noticeable pontoon movement. Table 10.1 summarises the observations on 11/10/2019 and 21/12/2020, before and after the construction of Breakwater G.

Table 10.1: Visual observations of waves within the marina

	11/10/2019 (Before construction of Breakwater G)		21/12/2020 (After construction of Breakwater G)	
Pile Reference	**Time**	**Crest to Trough Height (m)**	**Time**	**Crest to Trough Height (m)**
PP110	11:28	0.1 - 0.2	13:59	0.1
PP115	11:32	0.1 - 0.2	13:59	0.1
PP124	11:38	0.3 - 0.4	13:59	0.1 - 0.2
PP109	11:45	0.2 - 0.3	13:59	0.1 - 0.2
PP084	11:53	0.2 - 0.3	13:59	0.1
PP040	11:58	0.2 - 0.3	13:59	0.1
PP019	12:04	0.2 - 0.25	13:59	0.1 - 0.2
PP004	12:12	0.3 - 0.4	13:59	0.1 - 0.2

Source: DHB

As shown in Figure 10.1 and Figure 10.2 which show the measured water levels at the Prince of Wales Pier and the wave conditions within the marina and harbour, respectively, at the time of the measurements quoted in Table 10.1, the water levels were very similar, at around +5mCD. Referring to the Wavenet measurements of waves at Hastings, shows that the maximum significant wave height at Hastings on the 21/12/2020 was approximately 3.4m and on the 11/10/2019 (Storm 5) it was approximately 2.78m, i.e. wave heights were higher on the 21/12/2020 than Storm 5. Nevertheless, Table 10.1 indicates that waves inside the marina were significantly calmer for the 21/12/2020 storm after the construction of the Breakwater G indicating that this is likely to have had a significant benefit.

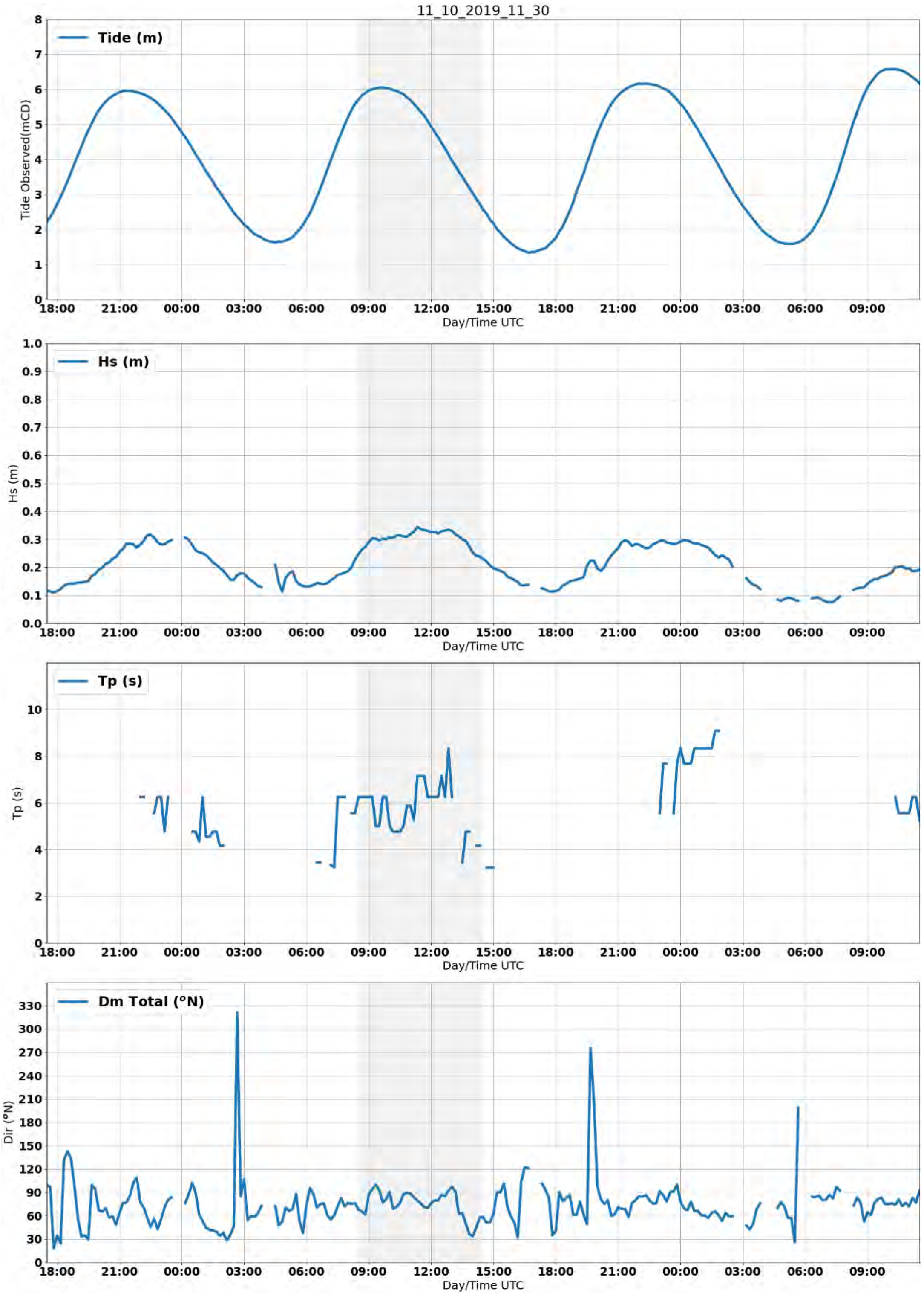

Figure 10.1: Wave conditions within the marina and water levels (Storm 5: 11/10/2019)

Source: https://dover.port-log.net

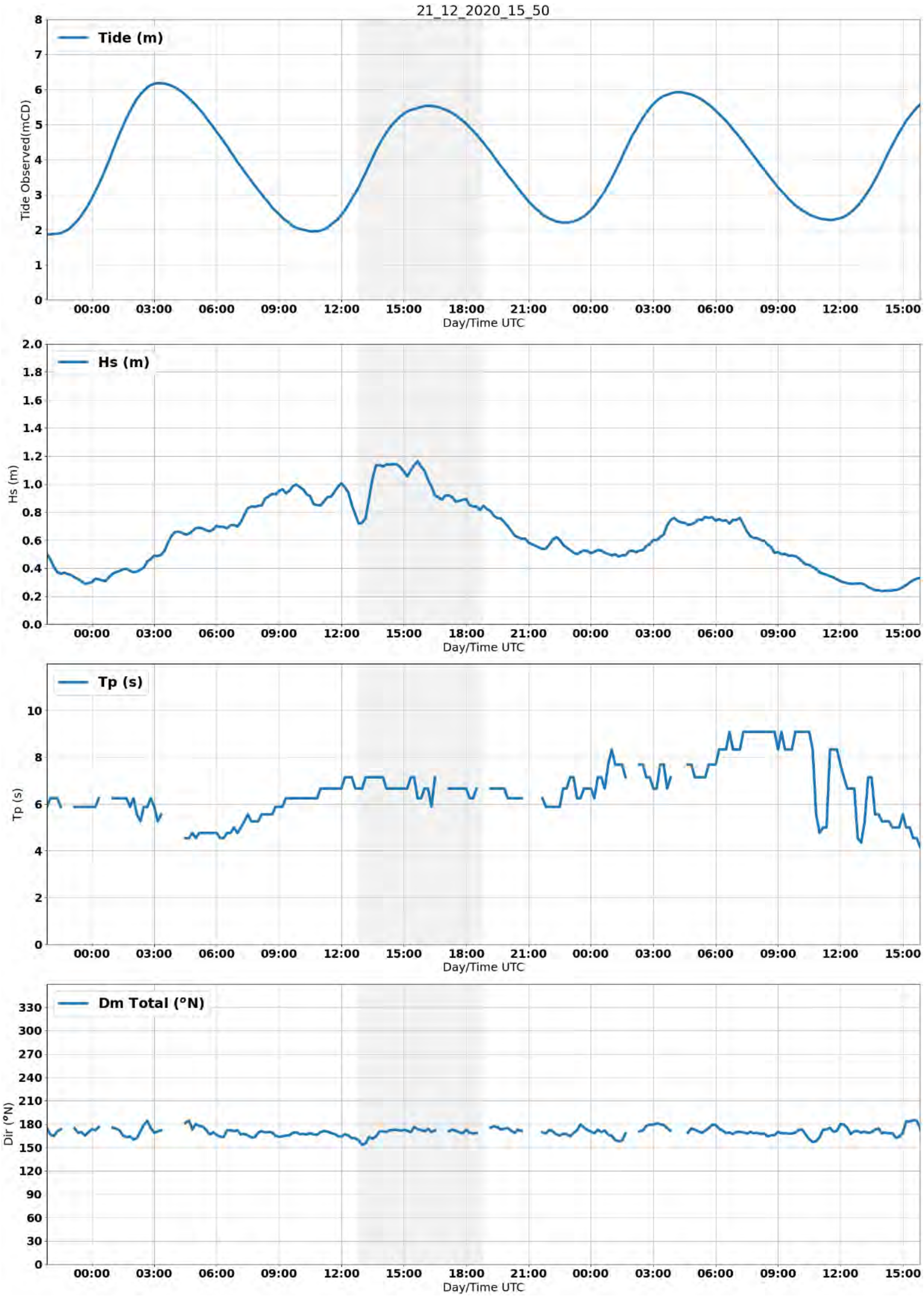

Figure 10.2: Wave conditions within the harbour and water levels (21/12/2020)

Source: https://dover.port-log.net

For Storm 6 (2/11/2019) the Wavenet measurements at Hastings give a maximum significant wave height of approximately 4.5m, which was estimated to have a return period of approximately 1 year. Therefore, the event of 21/12/2020 was predicted to be more frequent than a 1 year return period, so corresponding wave heights within the marina would be expected to be lower than presented in e.g. Figure 4.9.

Significant wave heights measured at Hastings during the more recent Storm Bella (27/12/2020) were approximately 5.0m, and were estimated to have a return period of approximately 3 years. Therefore, corresponding conditions with the marina are expected to be higher than shown for Layout G in Figure 4.9. In addition, Figure C.1 in Appendix C shows that the water level measured during Storm Bella was approximately +5mCD. Therefore, for higher water levels and the same incident wave conditions, the corresponding wave heights within the marina would be expected to be higher than those observed during that event.

11. Conclusions and Recommendations

The results of modelling a partial renourishment of the beaches adjacent to Marine Parade, back to pre-2015 levels, are predicted to result in lower wave heights within the marina. However the predicted wave heights remain slightly above the recommended height for good conditions for a 1 year condition at some locations. More importantly, such a partial renourishment of the beach is likely to move along the coast and experience natural fluctuations in beach levels. Management to maintain the partial renourishment may prove difficult to achieve during winter periods when most change to the beach levels would be expected. Therefore if the renourished beach is to be relied upon to keep the waves in the marina sufficiently low, additional renourishment will be required in order to provide a buffer to allow for the natural variations in the beach.

To reduce wave conditions within the marina will therefore require further renourishment of the beaches or in combination with a breakwater solution.

Model tests incorporating a 14m vertical breakwater at the marina entrance (without beach renourishment) is close to reducing wave heights within the marina to a target wave height of 0.3m. Breakwater G gives a marina entrance width or aperture of only approximately 18m, which compared to international standards is rather narrow but HR Wallingford has not assessed the navigational aspects of the layout. To reduce wave conditions within the marina will therefore require combining with renourishment of the beaches as modelled or in combination with a secondary breakwater. If a solution which includes Breakwater G is adopted it may be prudent to recheck whether the navigational width provided is sufficient for present and future uses.

Model results for a 36m extension to the marine curve breakwater (Breakwater A1) show little further sheltering to waves within the marina, but this extension provides some shelter to the outer berths. If the wave heights at all points with the marina are to meet the criteria for good conditions under 1 year conditions further measures will be required, e.g. lengthening Breakwater A1, or consideration of a detached breakwater e.g. Breakwater B instead.

Results for the combination of Breakwater G and detached Breakwater B indicate that wave conditions inside the marina will now meet the criteria for good conditions. At the proposed berths outside the marina entrance, wave conditions are substantially higher with a standing wave giving significant wave heights up to 0.9m for the 50 year conditions. This will need to be considered in the selection of pontoons to be installed at this location and the planned use of the outer berths.

Model results for Layout G2+B+J1 show that significant wave heights for the 1 and 50 year conditions are predicted to meet the criteria for good conditions inside the marina. For the 50 year condition, significant wave heights are predicted to be just below the threshold of the proposed pontoons at the outer berths (0.78m) so this layout can be considered a minimum length option for this type of scheme. Ideally the pontoons would not be placed directly in the corners or along the wall but it would be better if they were further out so they were not at an antinode of the standing wave pattern. Further, but probably small reductions in wave energy in the outer berths may be possible through refinement of the position and length of Breakwaters B and J1, but the alignment and lengths of Breakwaters, G, B and J1 are considered to be near optimal for this concept of layout. Any further reduction of waves at the outer berths would require reduction in the amount of wave energy reflected from beach Section A, either by renourishment of the beach or provision of an additional length of sheltering structure.

Breakwater J is considered to be relatively expensive for the shelter it provides at the outer berth. Therefore a lower cost option for reducing wave heights at the outer berths, in particular between the Marina Curve and the Protrusion was considered by incorporating a breakwater fillet (H1) into Layout G+B. The results for Layout G+B+H1 show very similar wave heights within the marina as predicted for Layout G+B, with only a very localised reduction in wave heights at the outer berths, with wave heights slightly above the target significant wave heights of 0.78m in a 50 year event. If this option is adopted it is recommended to reconsider the layout of the pontoons in the area outside the marina entrance as described in the paragraph above to, as far as possible, keep them away from the corner and other areas of high wave activity.

Layout G+B was subsequently taken forward as the preferred option. A series of sensitivity tests to incident wave conditions and water level were carried out. These tests showed that the wave heights within the marina or entrance were not very sensitive to a +/- 5 degree change to the incident wave direction. More noticeable differences were predicted to occur with increases to water level, with the increases in predicted wave heights most notably at the outer berths. Period scanning model runs for Layout G+B were carried out. The results showed that the amplitude of the waves in the primary period range 5-10 seconds were generally reduced compared with the as-built layout. At longer periods between 15s to 20s the proposed breakwater Layout G+B was shown to lead to slightly higher wave amplitudes at some locations and periods, most likely due to the change in general shape of the marina and entrance area with increased trapping of waves of these longer period and longer wave lengths.

The model results also showed a relatively low wave height region outside the marina, approximately parallel to the proposed outer berths. This information will be important in the positioning and design of the outer berth mooring arrangements. This area of lower wave height is at a node of the partial standing wave formed by interference between incident and reflected waves. Although the wave height is lowest at this location, giving less vertical motion of any pontoon, the oscillating currents due to the wave will be at a maximum at the nodal point giving greater horizontal motion that will need to be considered in the design of any mooring pontoons.

Following construction of Breakwater G, videos and visual observations of wave conditions were taken for the days 3/12/2020, 16/12/2020, 18/12/2020, 21/12/2020 and 27/12/2020. Based on wave measurements at Hastings, the first four dates were more frequent than a 1 year condition, whereas the event of 27/12/2020 (Storm Bella) was estimated to have a return period of approximately 3 years. Therefore wave heights are predicted to be lower than those presented in the Breakwater G results in Figure 4.9 for the first 4 events, but higher during Storm Bella.

It is highly recommended that continuously recording, accurate measurements of waves are reinstated within the marina to properly quantify wave conditions following construction of Breakwater G and any further construction works.

12.References

1. HR Wallingford (2020). Dover Harbour. Wave Disturbance Modelling. HR Wallingford Report DEM8459-RT002-R03-00. August 2020.
2. Environment Agency (2020). https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#sea-level (accessed 3 Nov 2020).
3. Met Office (2020) https://ukclimateprojections-ui.metoffice.gov.uk/ui/home (accessed 3 Nov 2020).

Appendices

A. Wave Overtopping of Breakwater G

A.1. Wave overtopping

In order to help determine an appropriate crest level of Breakwater G, the following table summarises incident wave conditions and estimates of mean overtopping rates.

Table A.1: Wave Overtopping at Breakwater G

Crest Level (mCD)	Wave Return period (s)	Sig. wave height Hm0 (m)	Peak Period Tp (s)	Mean Period Tm-10 (s)	Water level (mCD)	Front water depth (m)	Free board (m)	Mean Over-topping rate Q (l/s/m)
9.5	1	1.09	8.7	8.1	7	12	2.5	0.1
	1	1.09	8.7	8.1	7.5	12.5	2	0.6
	1	1.09	8.7	8.1	8	13	1.5	3.4
	1	1.09	8.7	8.1	8.24	13.24	1.26	7.8
8.5	1	1.09	8.7	8.1	7	12	1.5	3.4
	1	1.09	8.7	8.1	7.5	12.5	1	17.9
	1	1.09	8.7	8.1	8	13	0.5	73.4
	1	1.09	8.7	8.1	8.24	13.24	0.26	127.5
9.5	100	1.13	8.7	8.3	7	12	2.5	0.1
	100	1.13	8.7	8.3	7.5	12.5	2	0.8
	100	1.13	8.7	8.3	8	13	1.5	4.4
	100	1.13	8.7	8.3	8.24	13.24	1.26	9.5
8.5	100	1.13	8.7	8.3	7	12	1.5	4.4
	100	1.13	8.7	8.3	7.5	12.5	1	21.1
	100	1.13	8.7	8.3	8	13	0.5	80.9
	100	1.13	8.7	8.3	8.24	13.24	0.26	137.1

Source: HR Wallingford

In Table A.1:

- The 100 year wave height and period were extrapolated from the 1 and 50 year conditions run in the ARTEMIS model of the as–built layout, so are representative of incident only wave heights, as opposed to the total wave heights including the reflected component.
- Chart Datum, (CD) is approximately 3.67m below OD.
- Mean high water Spring (MHWS) is approximately +6.8mCD.
- Highest Astronomical Tide (HAT) is approximatively +7.4mCD.
- The 1 year water level is approx. +7.5mCD.
- The 100 year water level is approx. +8.24mCD (as quoted in HR Wallingford report DKR5770-RT001-R01-00_Dover_Beach_Management_Plan.pdf).
- The bed level at Breakwater G is -5mCD.

The mean overtopping rates (Q) quoted in Table A.1 use Equation 7.2 of the EurOtop Manual (http://www.overtopping-manual.com/assets/downloads/EurOtop_II_2018_Final_version.pdf):

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot exp[-(2.12\frac{R_c}{H_{m0}})^{1.3}] \qquad 7.2$$

The joint return periods of extreme wave heights and water levels have not been determined, but a relatively high degree of correlation between high waves and high water levels is expected for the south-westerly conditions of interest. For present day operational conditions at Breakwater G it would not be unreasonable to test for overtopping of the 1 year wave at 7.5m (1 year water level).

The results show that lowering the breakwater crest from 9.5m to 8.5m would lead to about 1 order of magnitude higher wave overtopping.

The incident wave heights and associated overtopping rate estimates quoted are based on the as-built layout, so will be lower with the construction of Breakwater B.

A.2. Wave transmission due to wave overtopping

Wave transmission due to wave overtopping is also addressed by the EurOtop manual (http://www.overtopping-manual.com/assets/downloads/EurOtop_II_2018_Final_version.pdf).

Figure 4.11 in the EurOtop manual was derived for incident significant heights of 3m and also for higher overtopping so is not so relevant at Breakwater G, where the incident significant wave height is approximately 1m.

For a crest height of e.g. +9.3mCD (which is a level suggested by DHB's engineers) this means that even at the 100 year water level of +8.24mCD the relative freeboard to Hm0 ratio is approximately 1m. Equation 4.9 in the EurOtop Manual gives a transmission coefficient of about 0.15. This would give a significant wave height Hm0 of about 0.15m immediately behind Breakwater G due to overtopping. However, this overtopping wave is occurring only over a short length of breakwater and would decay fairly rapidly as it spreads out into the marina by diffraction so is not expected to add a significant amount to the wave disturbance due to waves propagating through the marina entrance. Also the actual overtopping volumes leading to transmitted wave energy are expected to be very intermittent – perhaps one every 20-30 waves, so this wave energy is not expected to build up as much within the marina. Care should be taken, however not to place pontoons of moored craft directly behind Breakwater G where they could be affected by the overtopping.

B. Measured water levels and waves inside the marina

The following figures show a sample of the measured wave heights within the marina and water levels measured at the Prince of Wales Pier. The plots are shown in descending order of magnitude of maximum significant wave height.

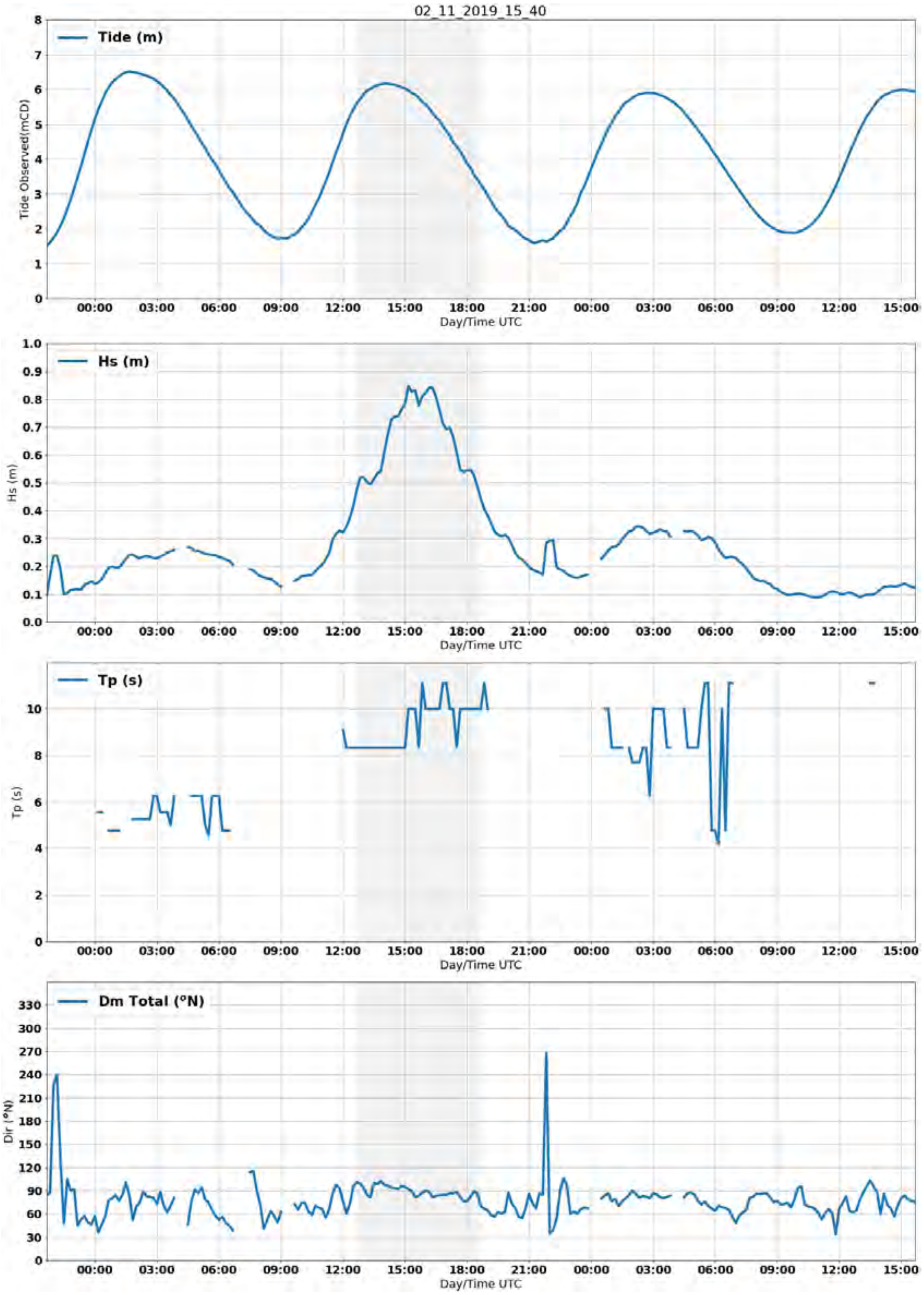

Figure B.1: Water levels and wave heights within the Marina (Storm 6)

Source: DHB

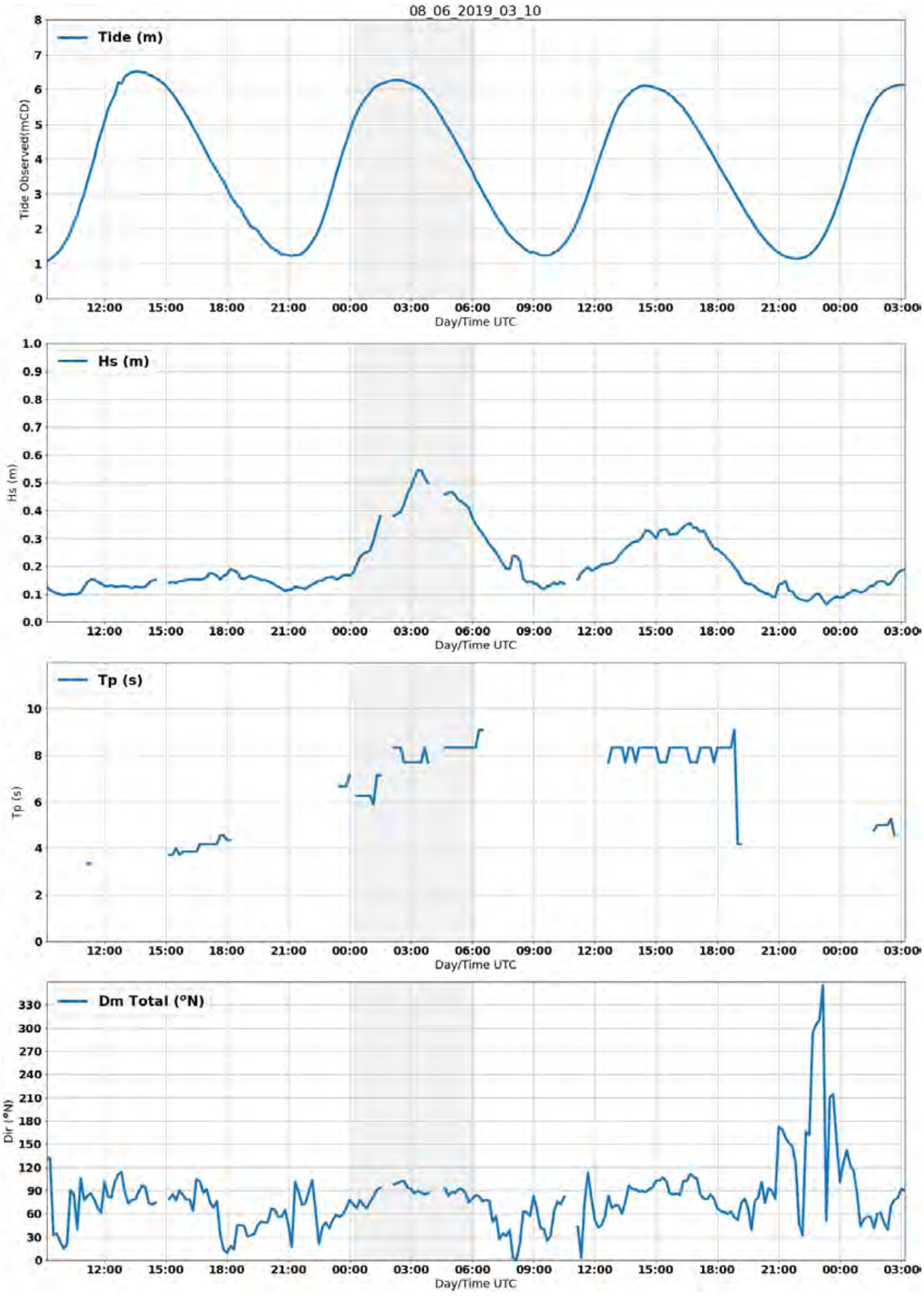

Figure B.2: Water levels and wave heights within the Marina (8 June 2019)

Source: DHB

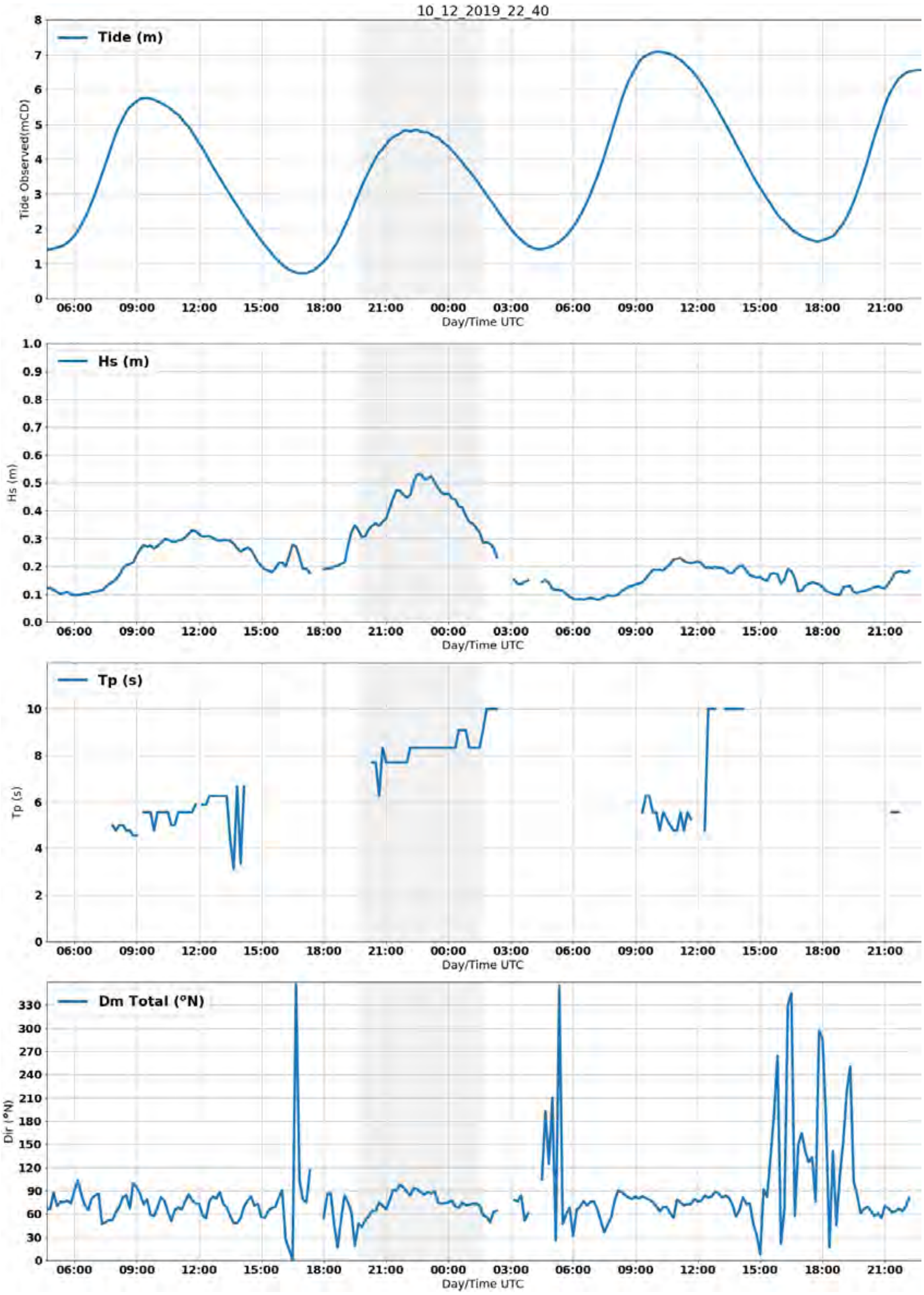

Figure B.3: Water levels and wave heights within the Marina (10 Dec 2019)

Source: DHB

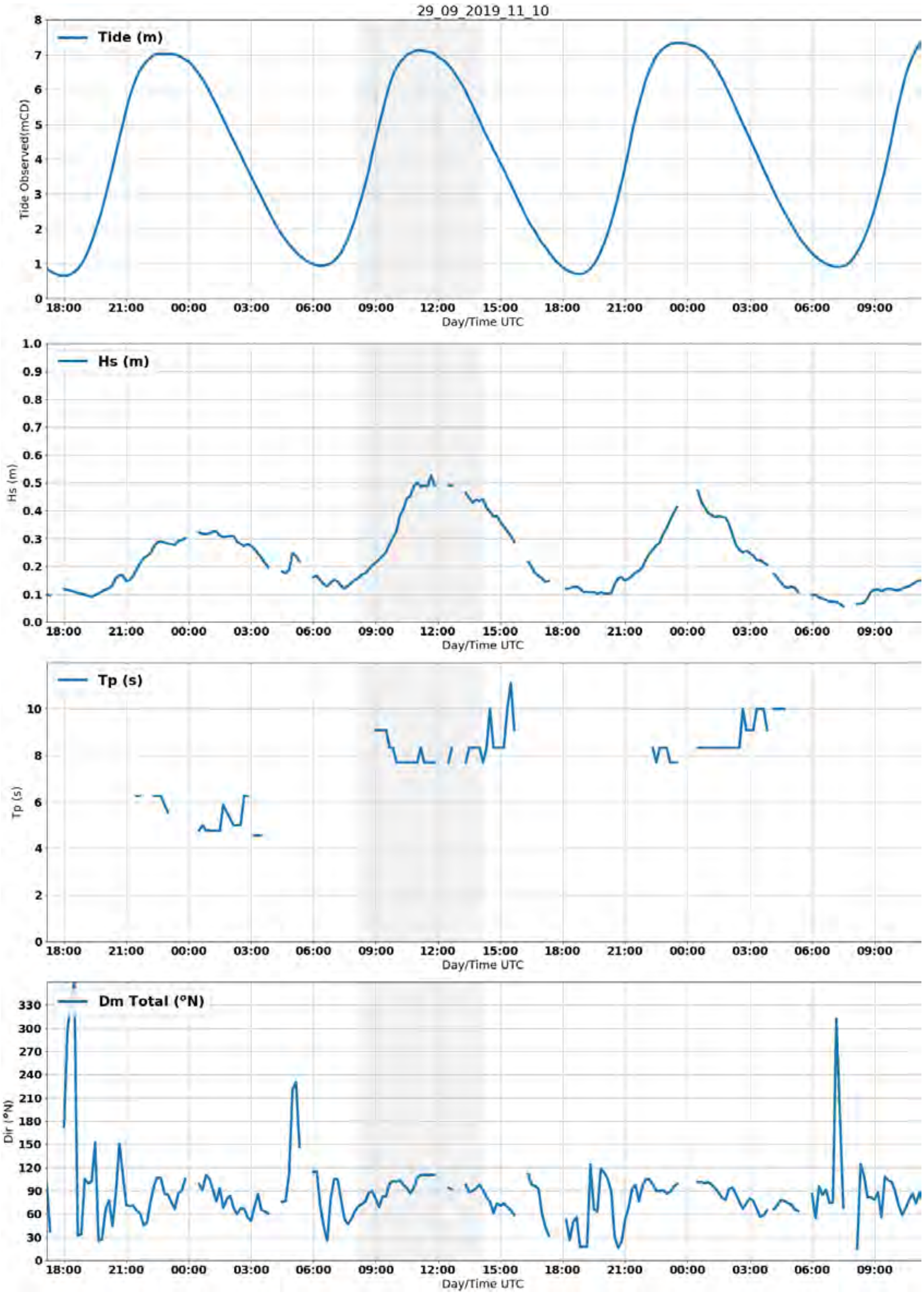

Figure B.4: Water levels and wave heights within the Marina (29 Sep 2019)

Source: DHB

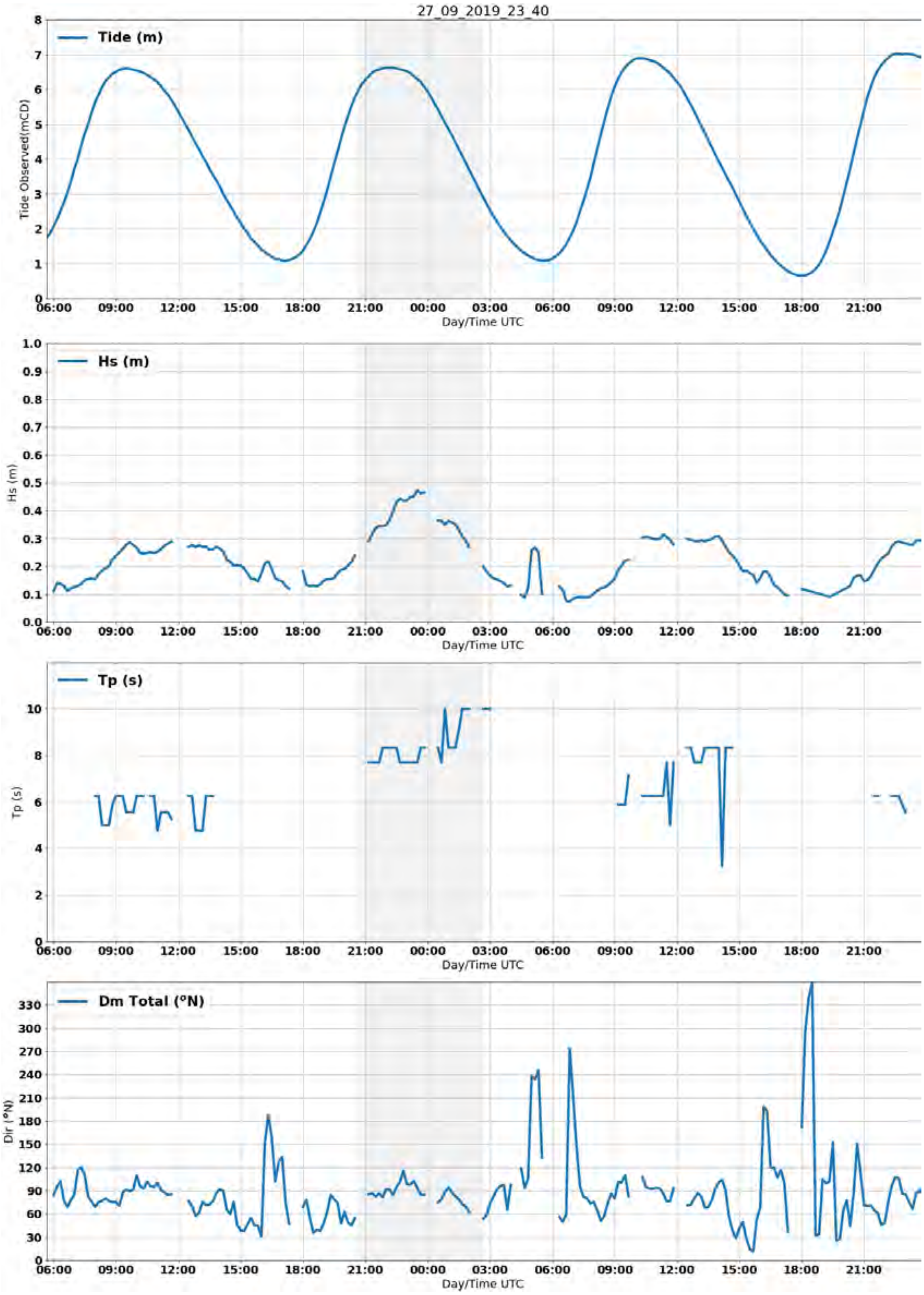

Figure B.5: Water levels and wave heights within the Marina (27 Sep 2019)

Source: DHB

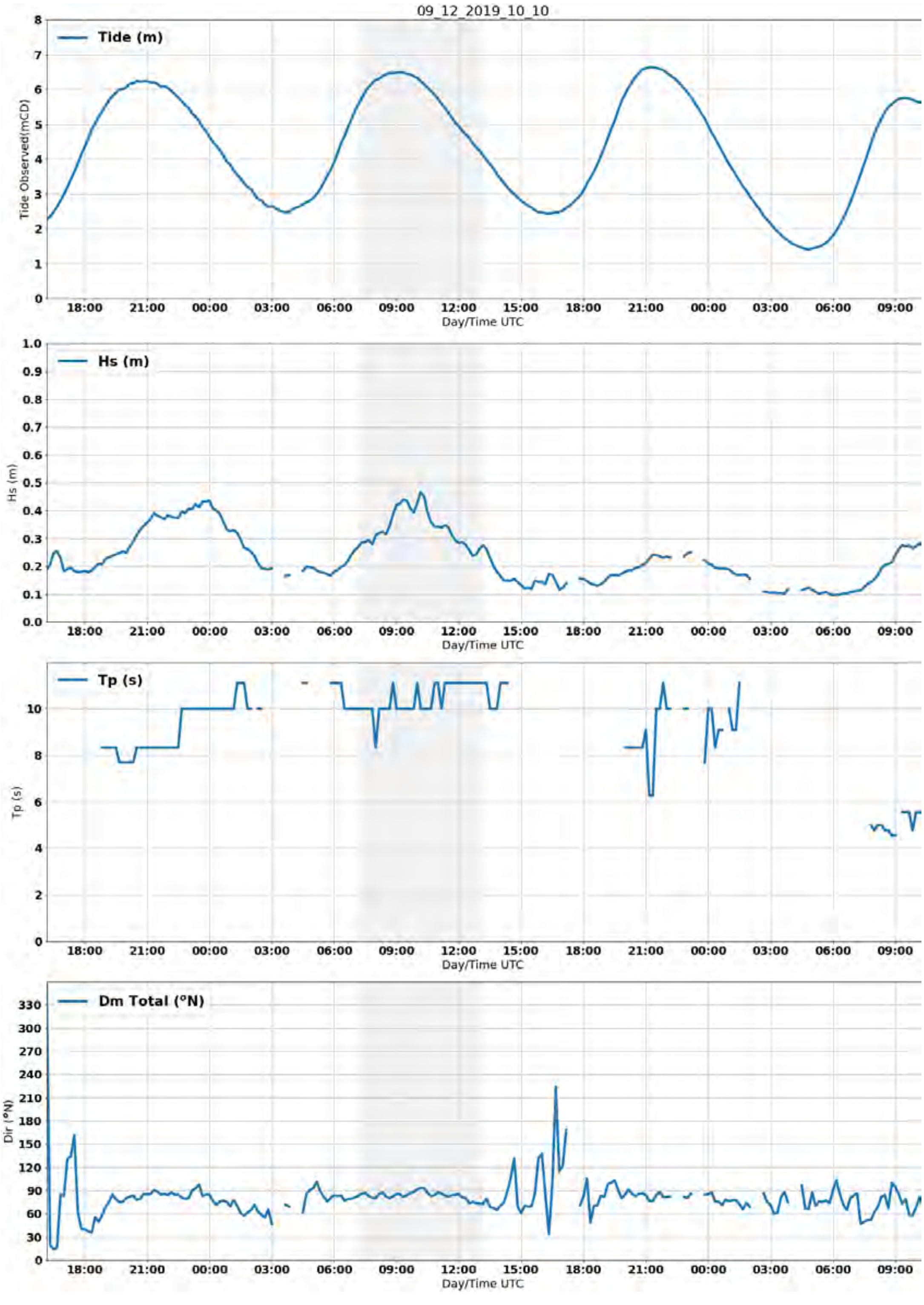

Figure B.6: Water levels and wave heights within the Marina (9 Dec 2019)

Source: DHB

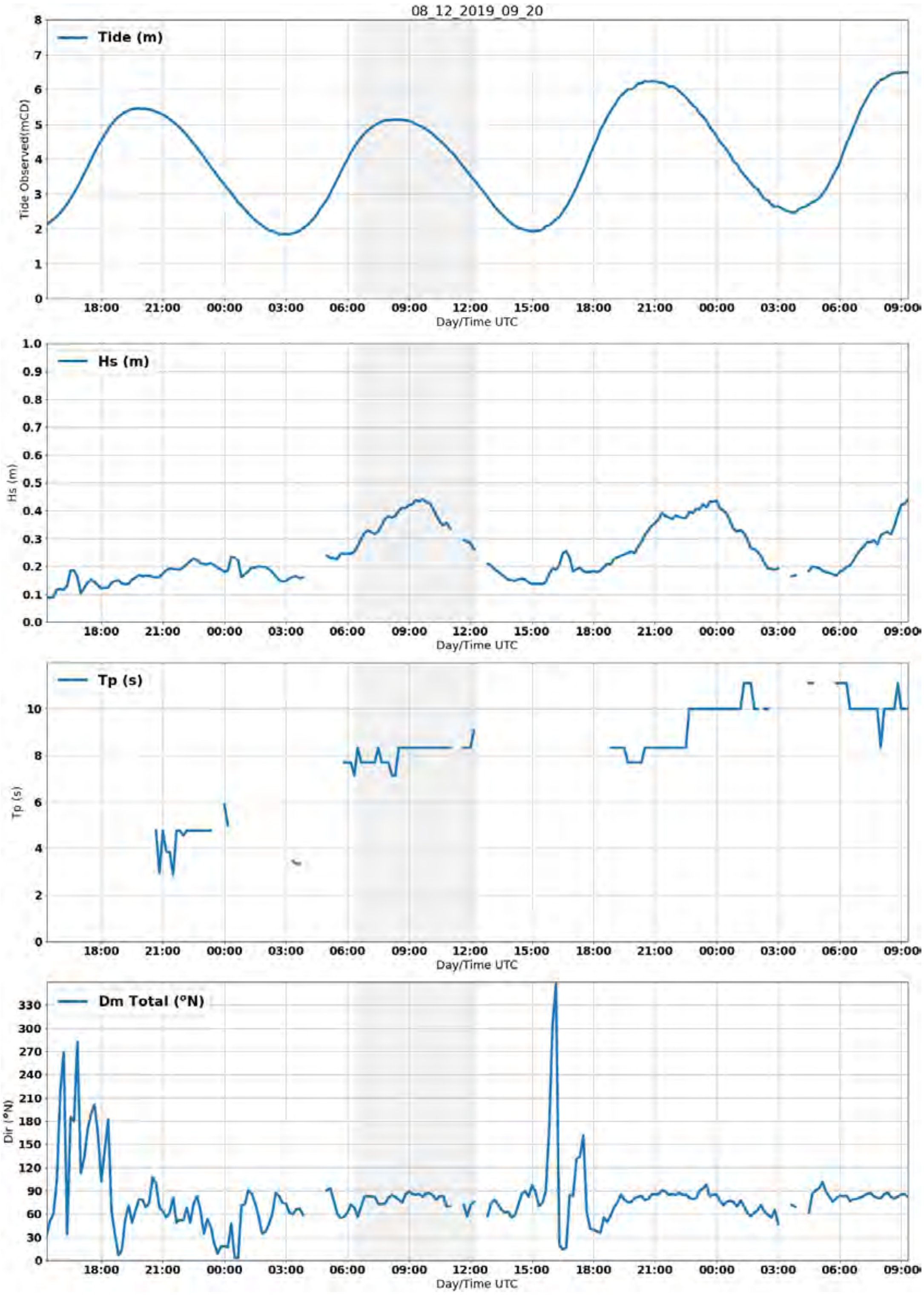

Figure B.7: Water levels and wave heights within the Marina (8 Dec 2019)

Source: DHB

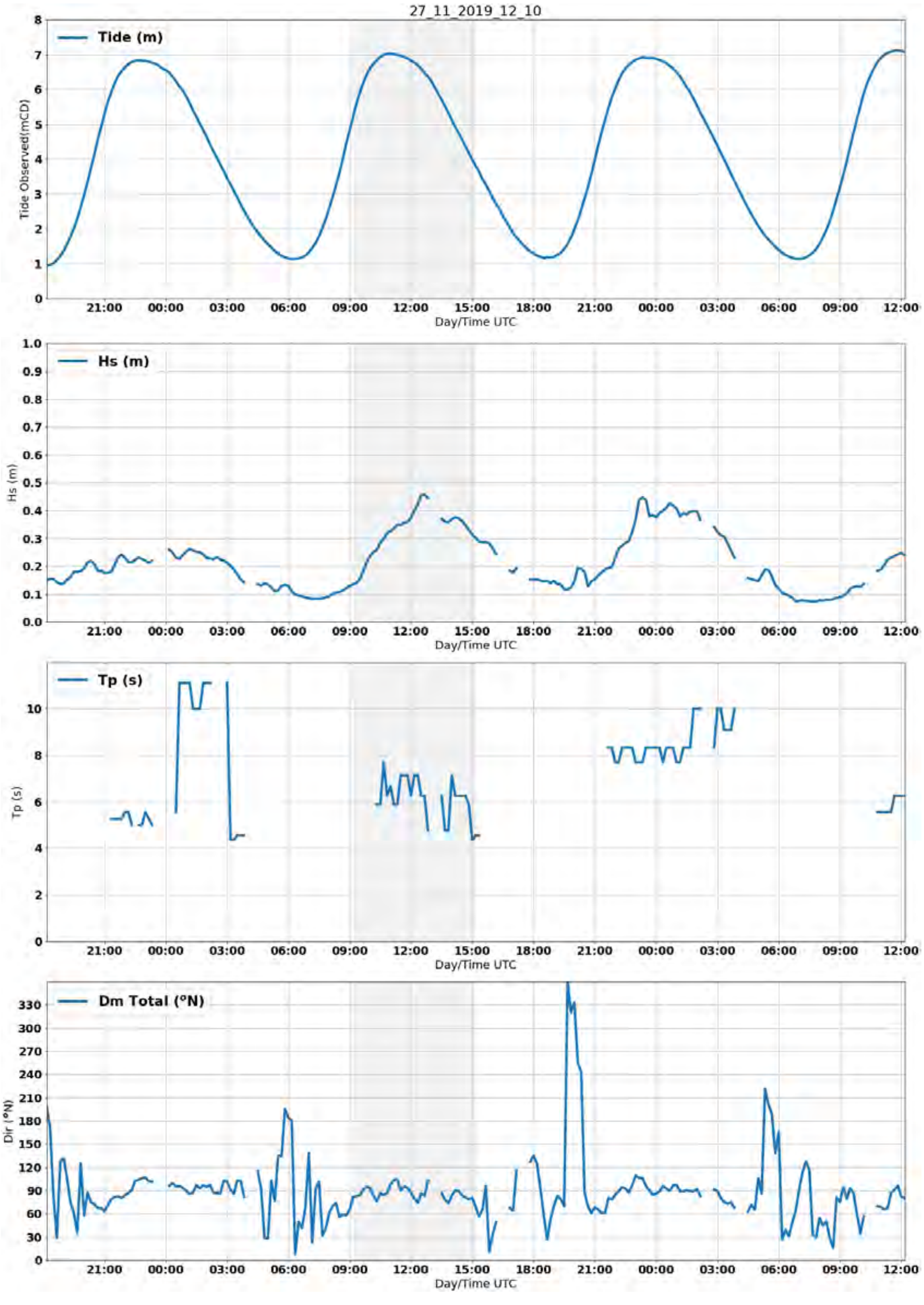

Figure B.8: Water levels and wave heights within the Marina (27 Nov 2019)

Source: DHB

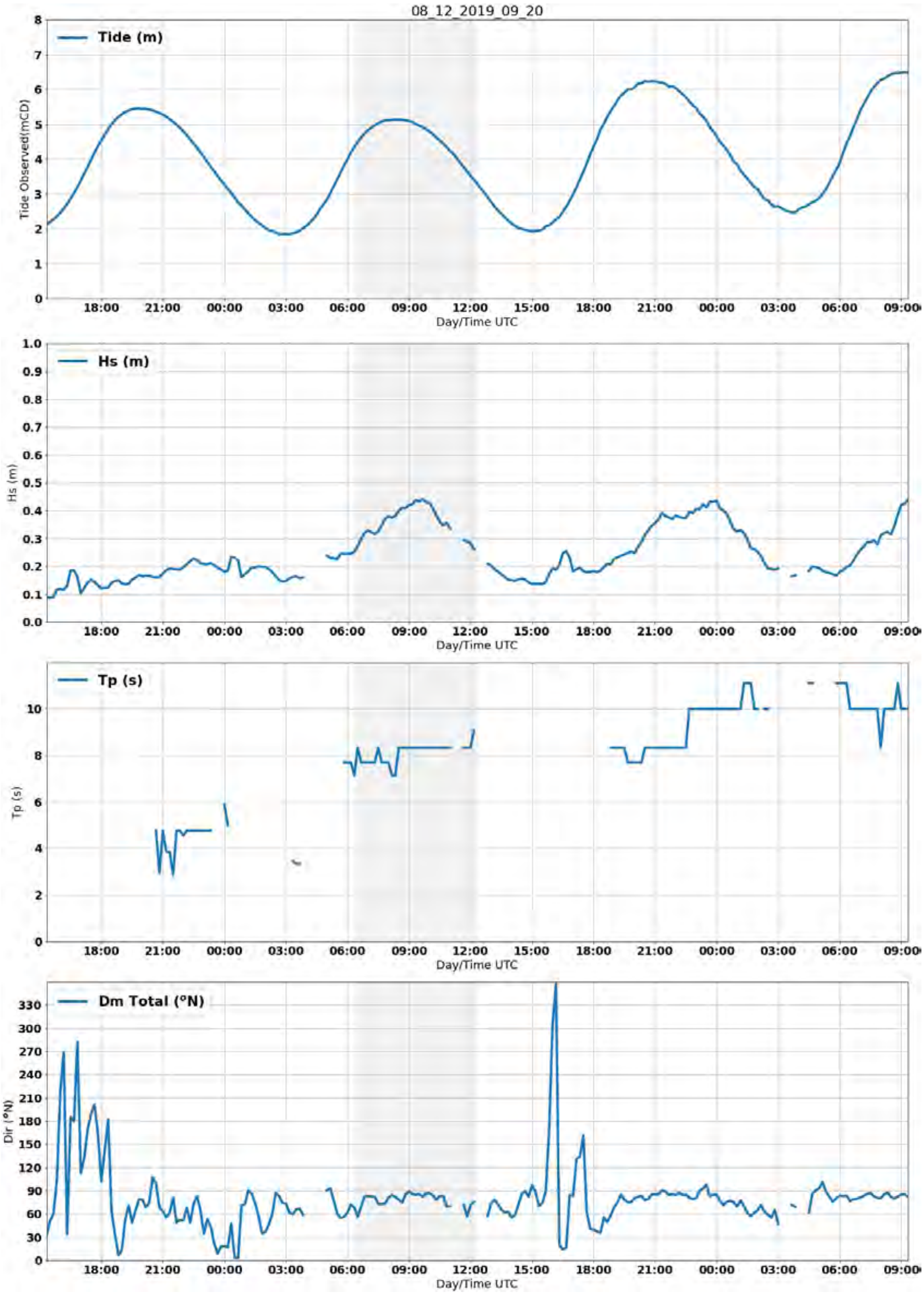

Figure B.9: Water levels and wave heights within the Marina (8 Dec 2019)

Source: DHB

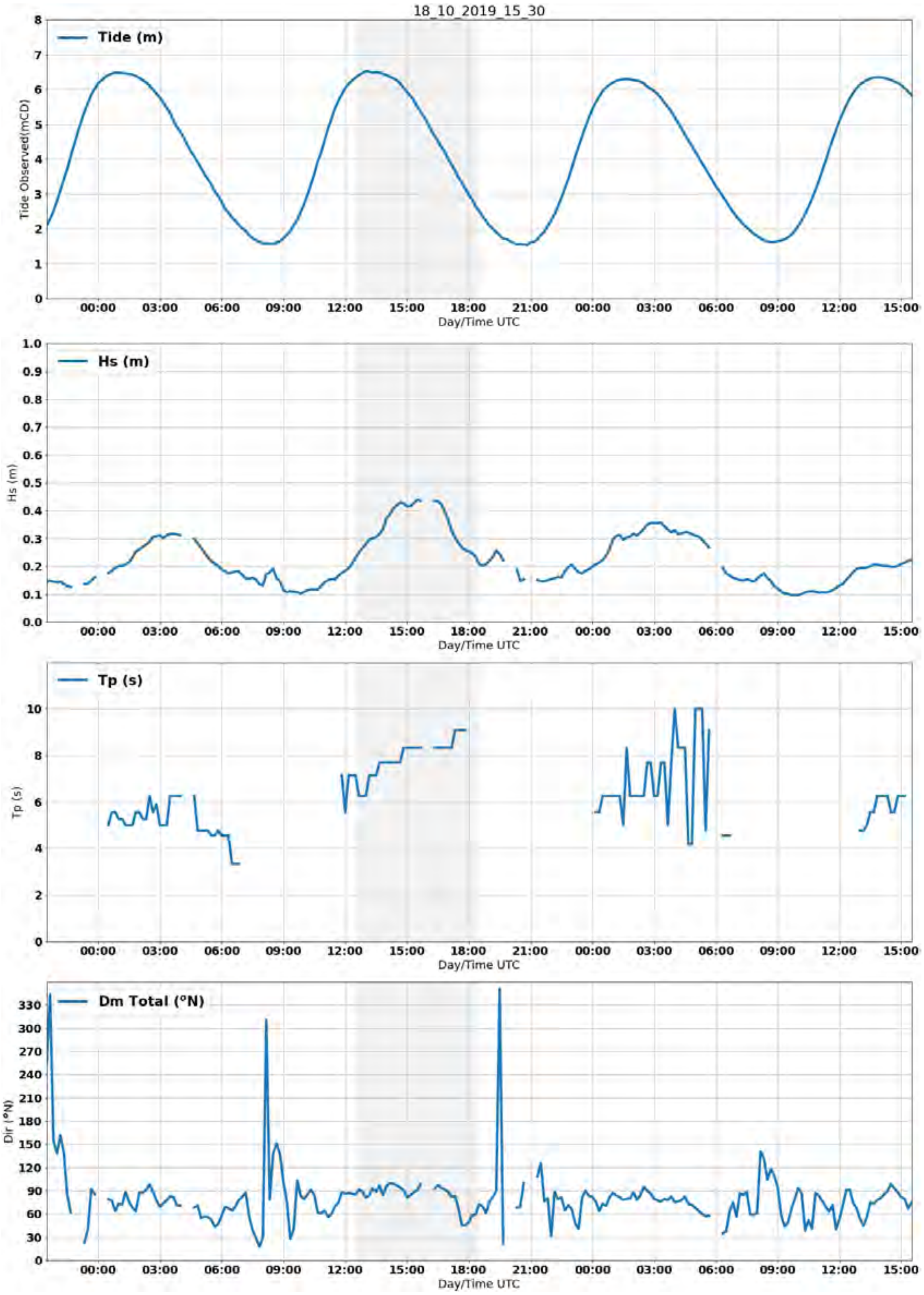

Figure B.10: Water levels and wave heights within the Marina (18 Oct 2019)

Source: DHB

C. Measured water levels and waves inside the harbour

The following figures show a sample of the measured wave heights within the harbour and water levels measured at the Prince of Wales Pier. The plots are shown in descending order of magnitude of maximum significant wave height.

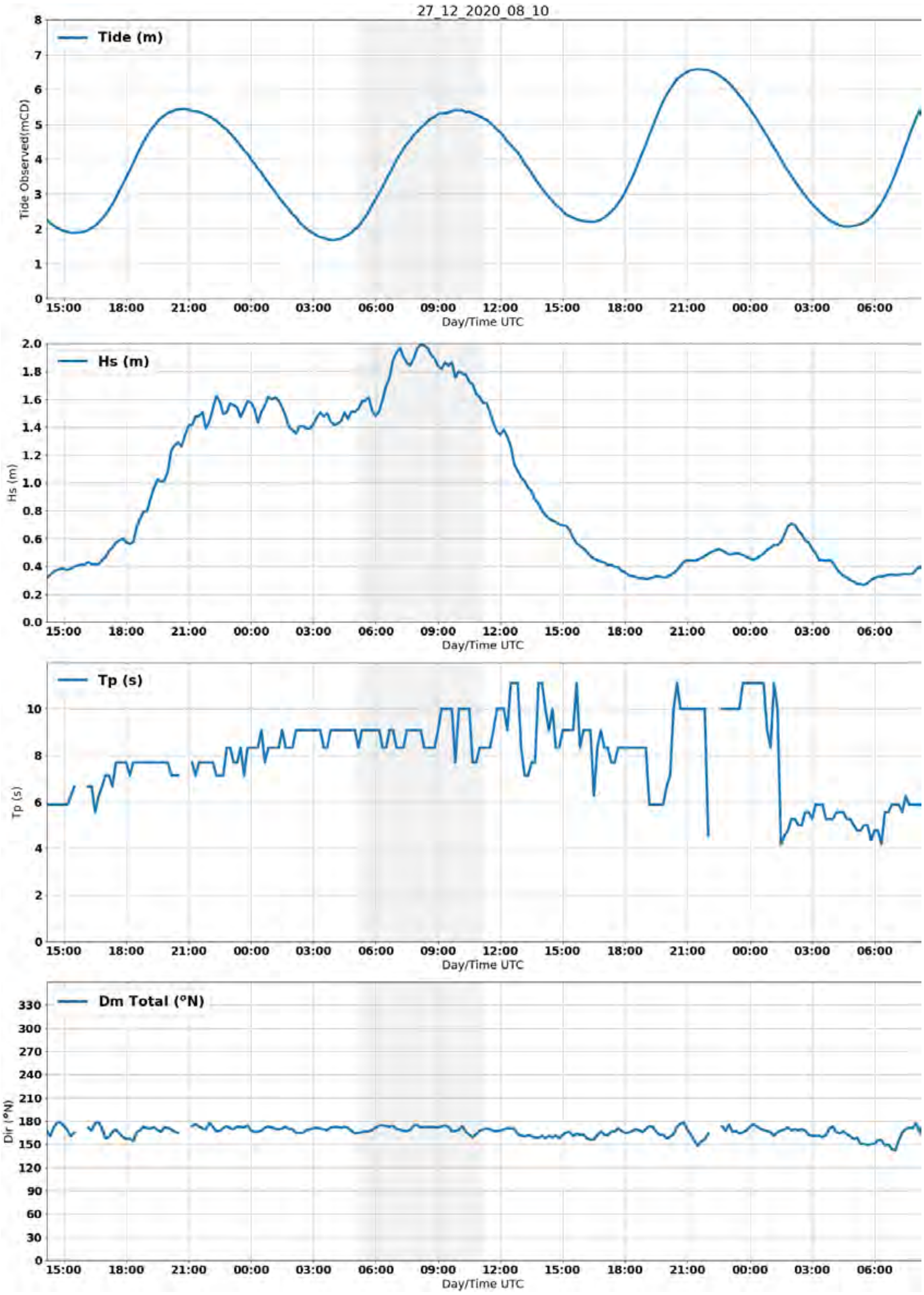

Figure C.1: Water levels and wave heights within the Harbour (27 Dec 2020: Storm Bella)

Source: DHB

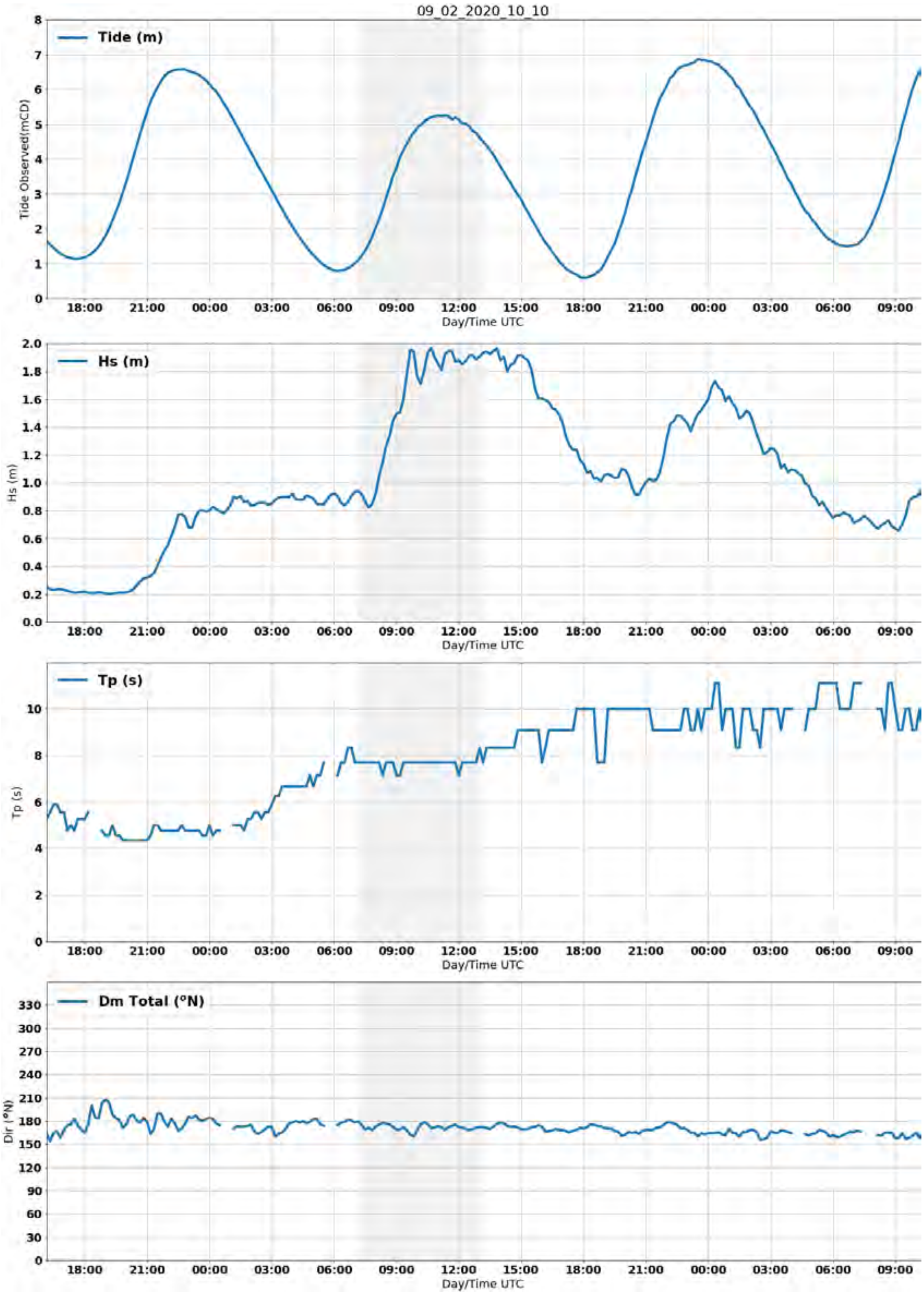

Figure C.2: Water levels and wave heights within the Harbour (9 Feb 2020)

Source: DHB

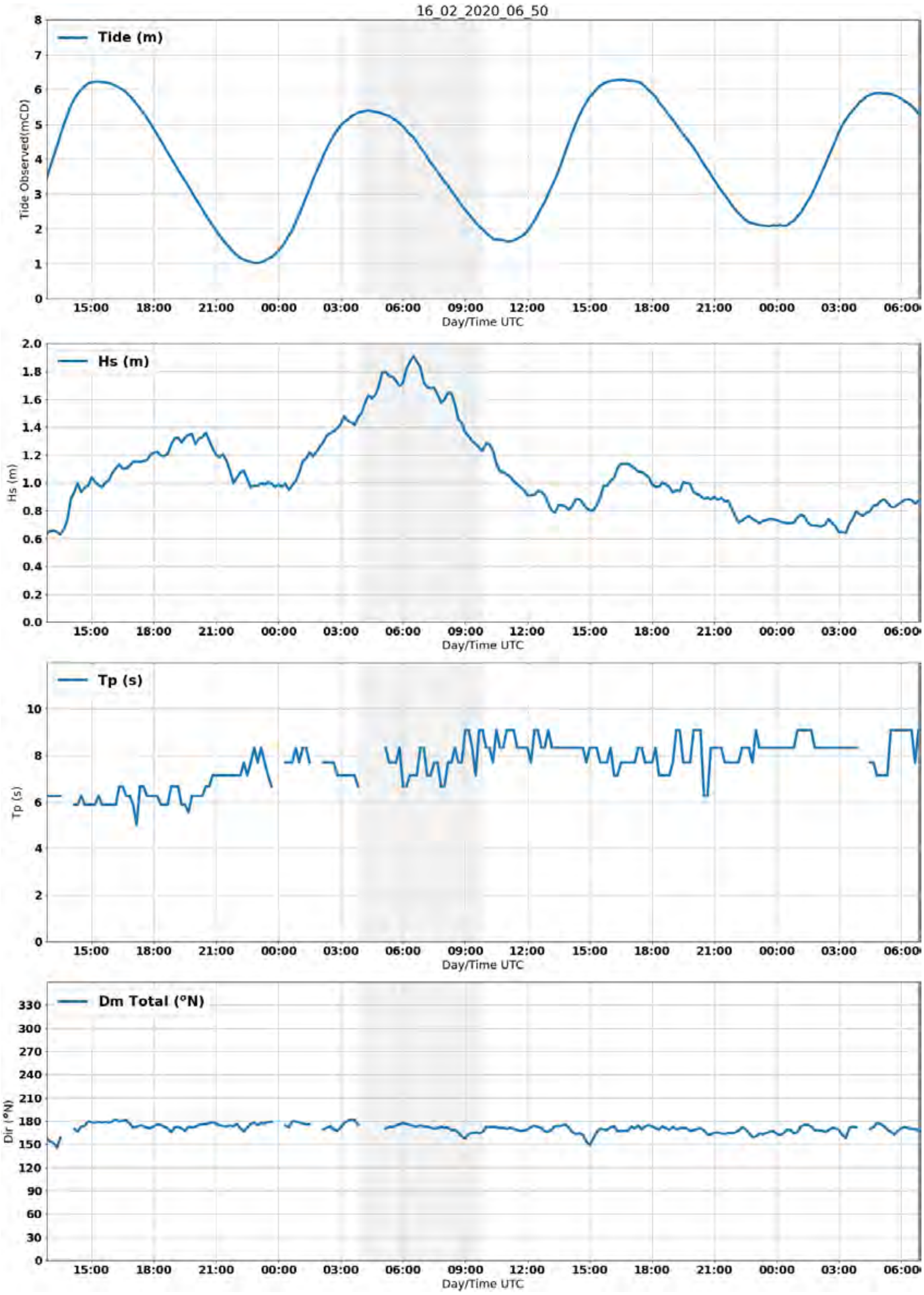

Figure C.3: Water levels and wave heights within the Harbour (16 Feb 2020)

Source: DHB

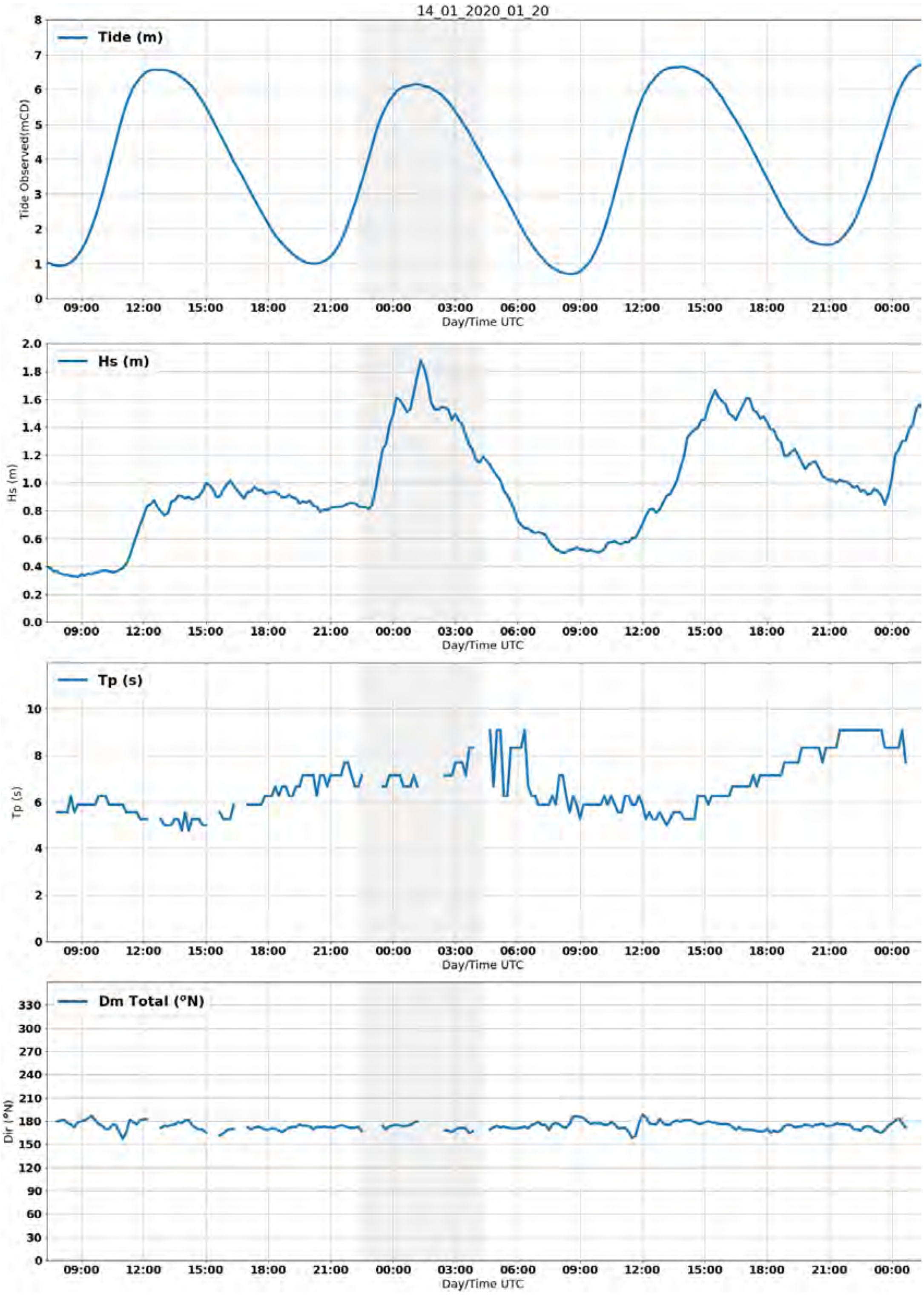

Figure C.4: Water levels and wave heights within the Harbour (14 Jan 2020)

Source: DHB

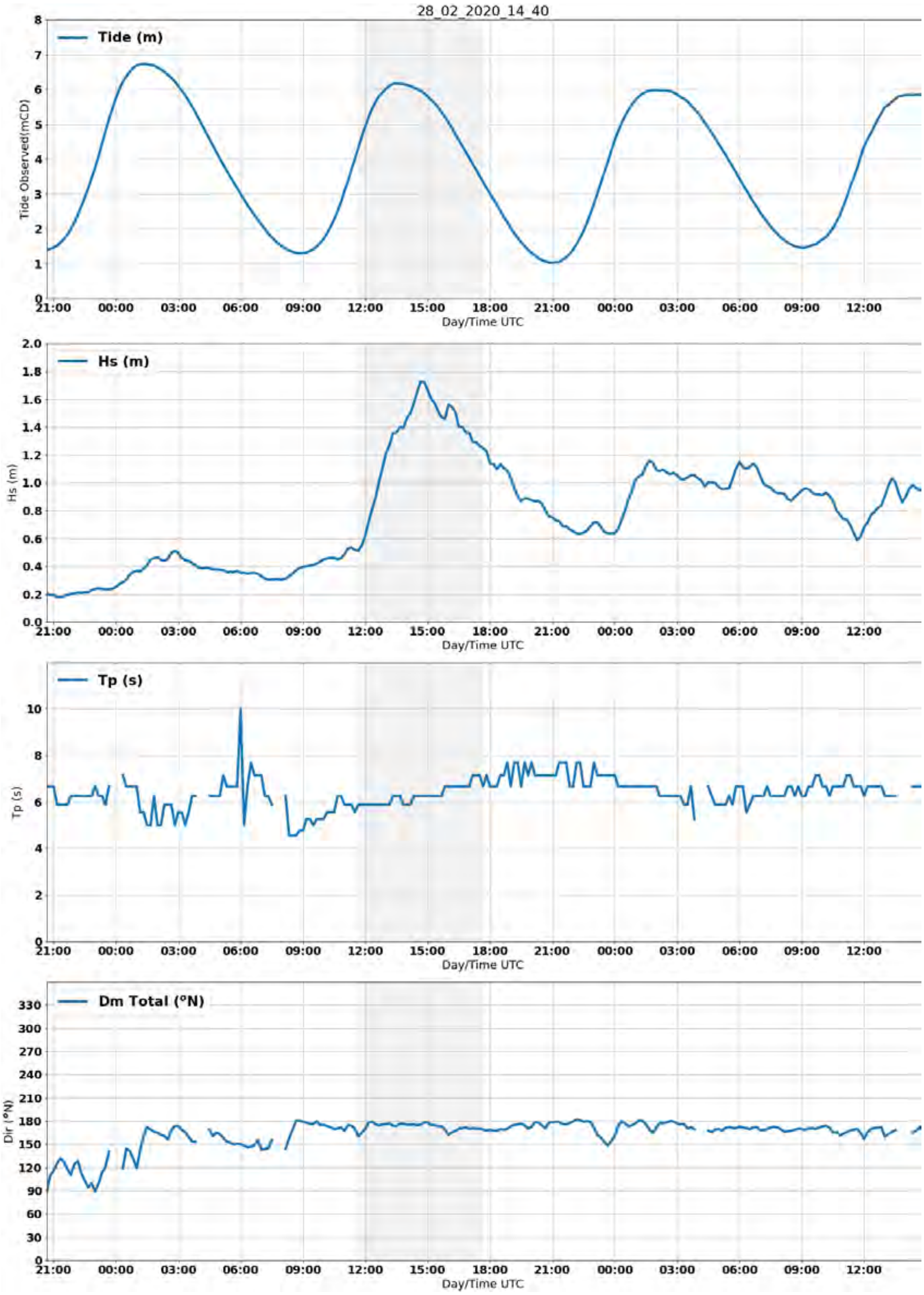

Figure C.5: Water levels and wave heights within the Harbour (28 Feb 2020)

Source: DHB

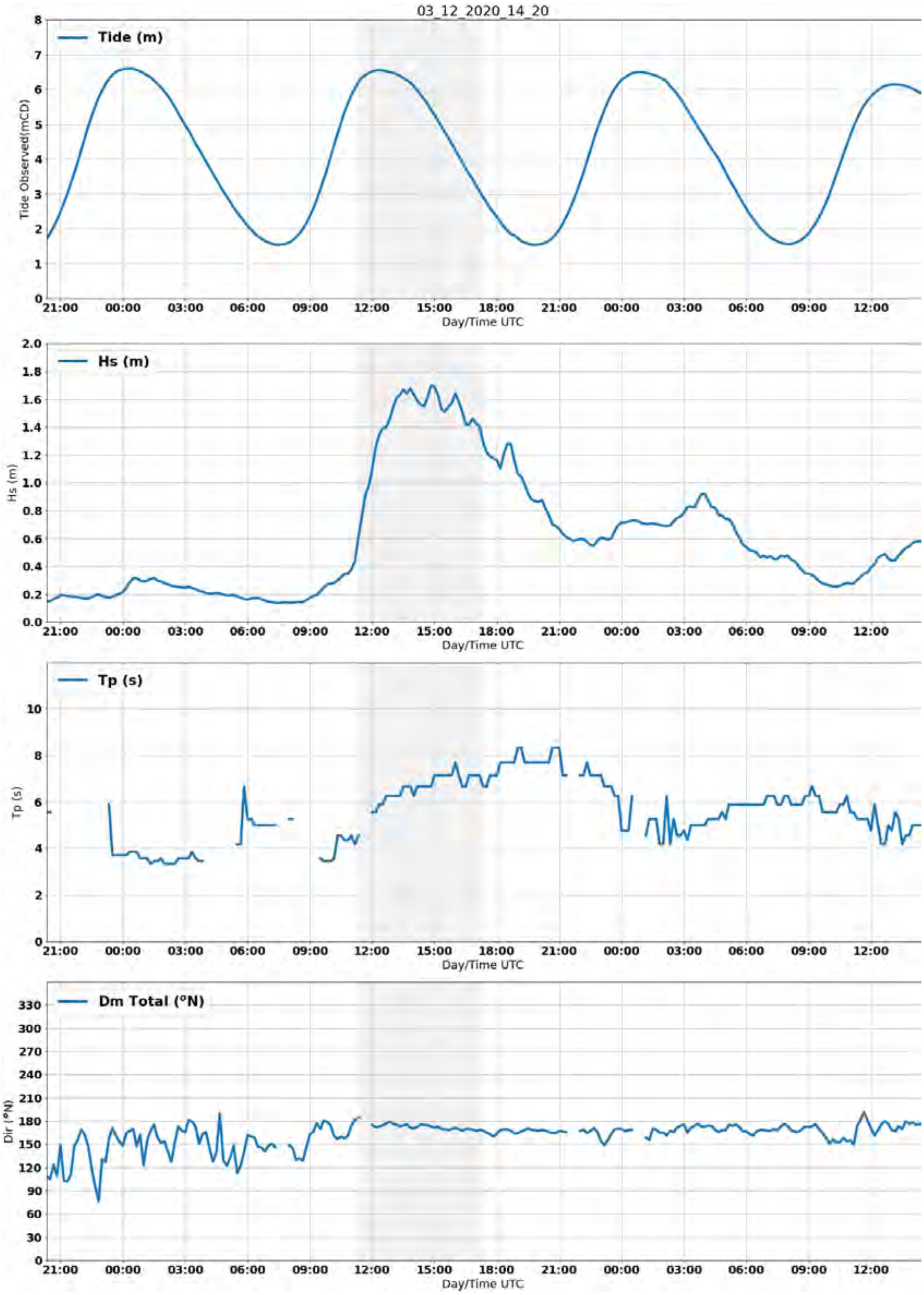

Figure C.6: Water levels and wave heights within the Harbour (3 Dec 2020)

Source: DHB

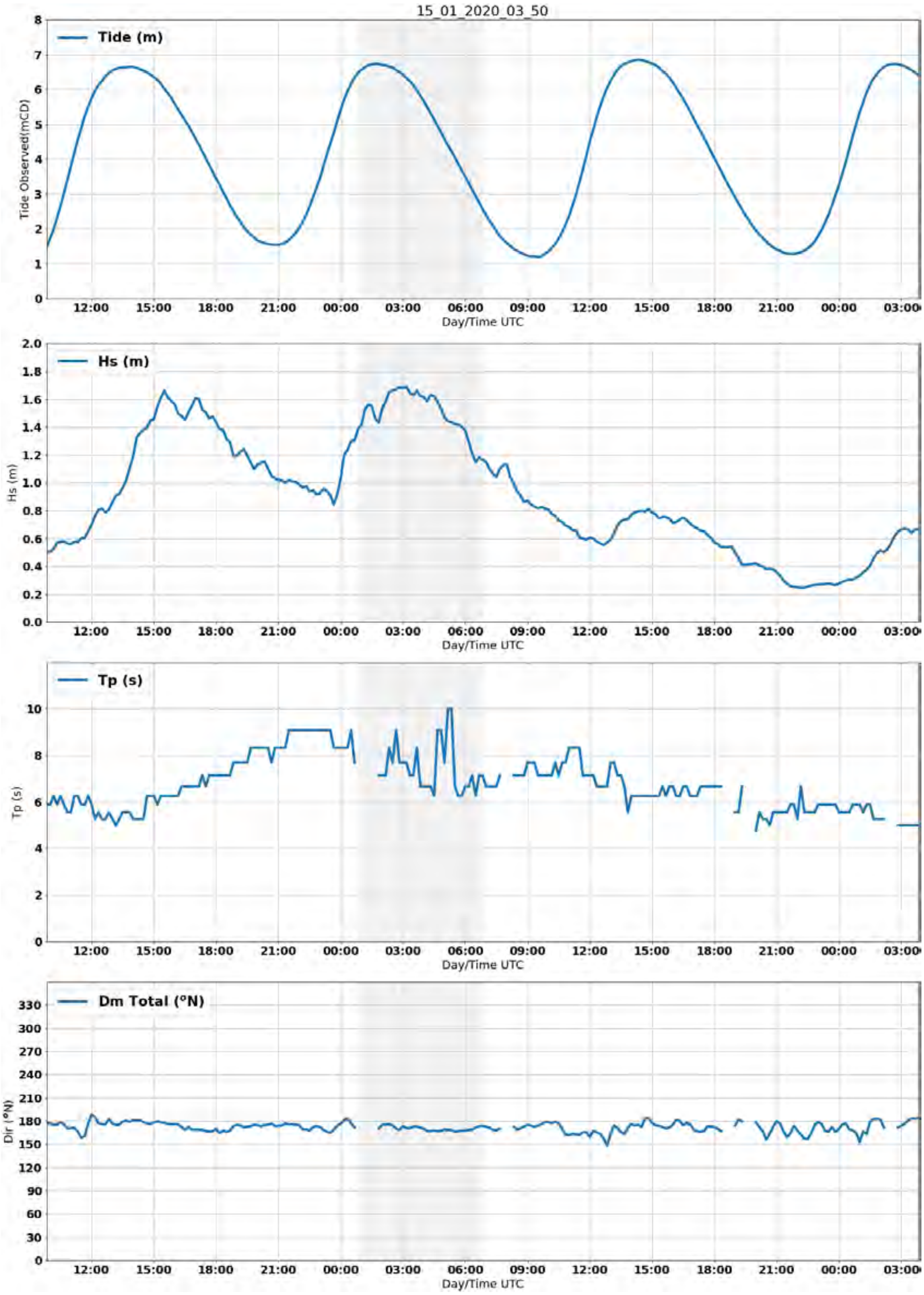

Figure C.7: Water levels and wave heights within the Harbour (15 Jan 2020)

Source: DHB

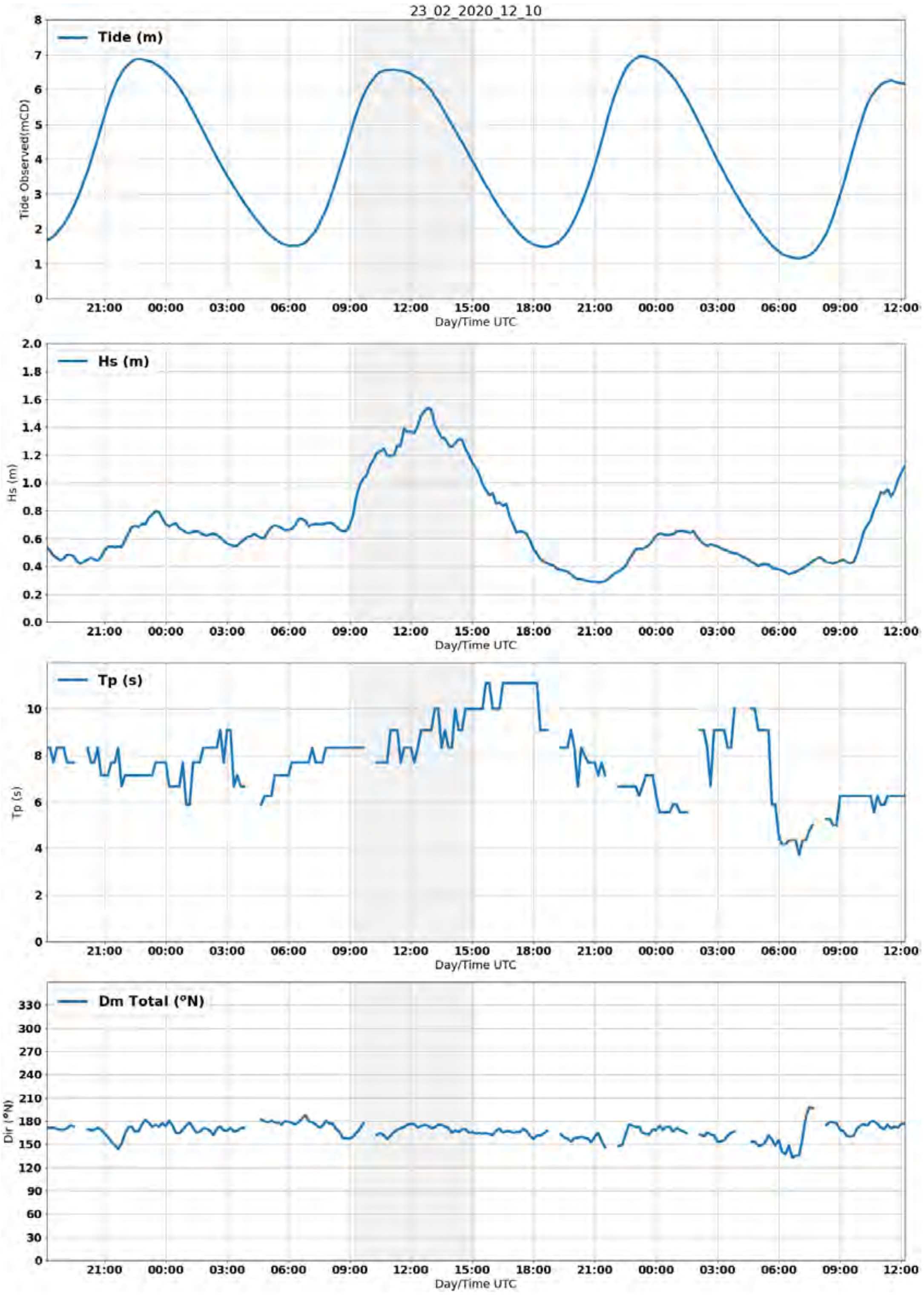

Figure C.8: Water levels and wave heights within the Harbour (23 Feb 2020)

Source: DHB

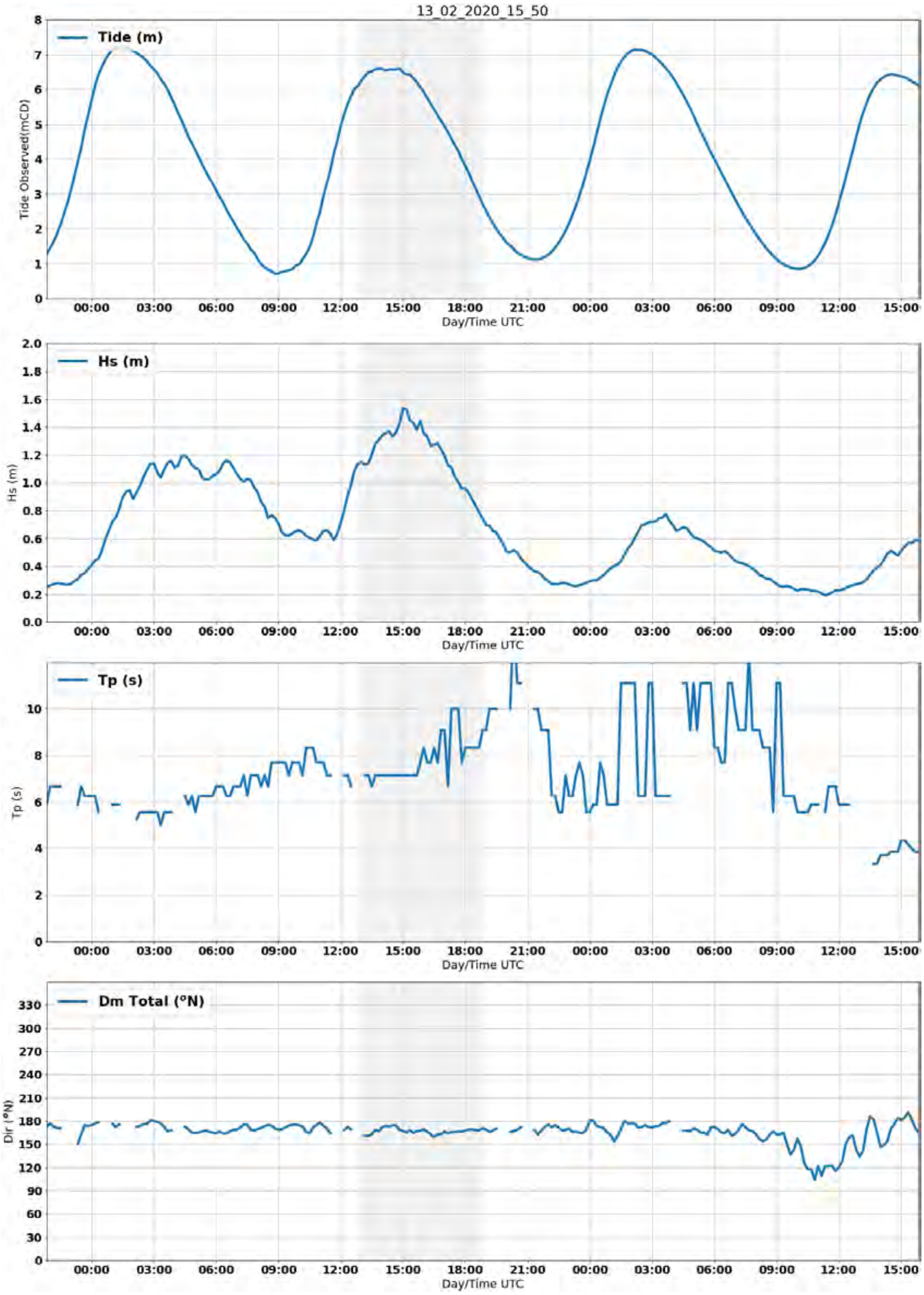

Figure C.9: Water levels and wave heights within the Harbour (13 Feb 2020)

Source: DHB

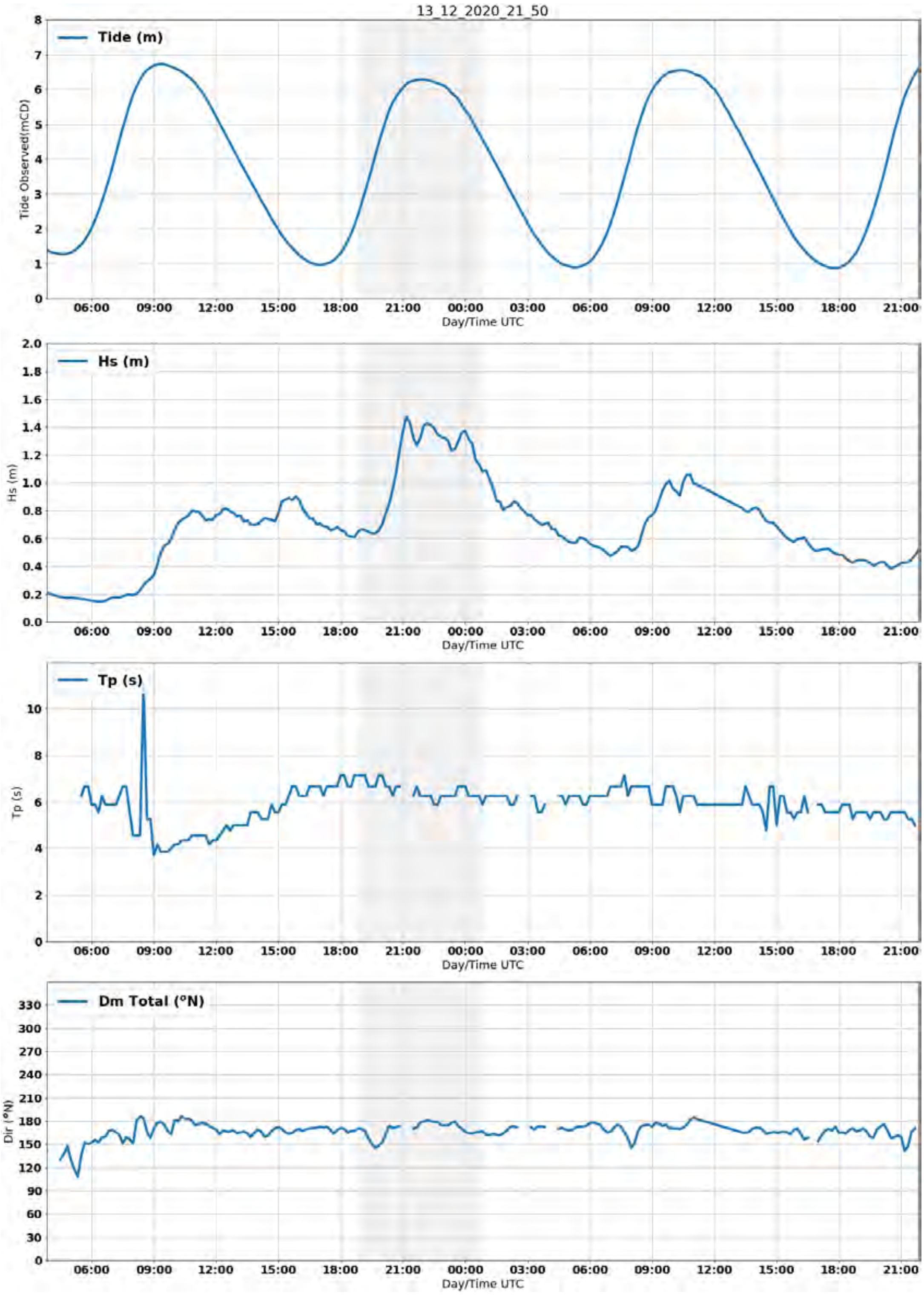

Figure C.10: Water levels and wave heights within the Harbour (13 Dec 2020)

Source: DHB

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