# Technical Appendix 6.4

# Tidal Flow Modelling

# Falmouth Docks Development

## Tidal flow modelling

DER6962-RT005 R01-00
26 February 2025

Confidential

# Document information

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# Contents

Contents ..... 3
1 Introduction ..... 6
1.1 Background ..... 6
1.2 Proposed development ..... 6
1.3 Objectives ..... 8
2 Model establishment ..... 8
2.1 Choice of model ..... 8
2.2 Co-ordinate system and vertical datum ..... 8
2.3 Model bathymetry ..... 8
2.4 Model area and mesh resolution ..... 9
2.5 Boundary conditions ..... 11
2.6 Piled structures ..... 12
3 Model calibration and validation ..... 12
3.1 Spring tide results ..... 14
3.1.1 Water levels ..... 14
3.1.2 Currents ..... 15
3.2 Neap tide results ..... 18
3.2.1 Water levels ..... 18
3.2.2 Currents ..... 20
4 Model results ..... 22
5 Conclusions ..... 30
6 References ..... 30

## Figures

Figure 1.1: Project location ..... 6
Figure 1.2: Proposed development works of Falmouth Docks ..... 7
Figure 1.3: Proposed Dredging Plan ..... 7
Figure 2.1: Bathymetric data sources ..... 9
Figure 2.2: Flow model extent ..... 10
Figure 2.3: Baseline flow model bathymetry and mesh in the vicinity of the proposed development ..... 11
Figure 3.1: Locations of current observations ..... 13
Figure 3.2: Locations of tidal level measurements ..... 13
Figure 3.3: Locations of Admiralty tidal diamonds ..... 13
Figure 3.4: Comparison of observed and simulated spring tide water levels at St Antony's Head ..... 14
Figure 3.5: Comparison of observed and simulated spring tide water levels at Mylor ..... 14
Figure 3.6: Comparison of observed and simulated spring tide water levels at Flushing ..... 14
Figure 3.7: Comparison of observed and simulated spring tide water levels at Restronguet 14
Figure 3.8: Comparison of observed and simulated spring tide water levels at Penryn ..... 14
Figure 3.9: Comparison of observed and simulated spring tide water levels at Loe Beach ..... 14
Figure 3.10: Comparison of observed and simulated spring tide water levels at King Harry Ferry ..... 15
Figure 3.11: Comparison of observed and simulated spring tide water levels at Malpas ..... 15
Figure 3.12: Comparison of observed and simulated spring tide water levels at Truro ..... 15
Figure 3.13: Comparison of observed and simulated spring tide current speed and direction at Location A, 02/05/1985 ..... 15

Figure 3.14: Comparison of observed and simulated spring tide current speed and direction at Location B, 02/05/1985 ..... 15
Figure 3.15: Comparison of observed and simulated spring tide current speed and direction at Location C, 02/05/1985 ..... 16
Figure 3.16: Comparison of observed and simulated spring tide current speed and direction at Location D, 02/05/1985 ..... 16
Figure 3.17: Comparison of observed and simulated spring tide current speed and direction at Location E, 03/05/1985 ..... 16
Figure 3.18: Comparison of observed and simulated spring tide current speed and direction at Location F, 03/05/1985 ..... 16
Figure 3.19: Comparison of observed and simulated spring tide current speed and direction at Location G, 02/05/1985 ..... 16
Figure 3.20: Comparison of observed and simulated spring tide current speed and direction at Location H, 03/05/1985 ..... 16
Figure 3.21: Comparison of observed and simulated spring tide current speed and direction at Location I, 03/05/1985 ..... 17
Figure 3.22: Comparison of observed and simulated spring tide current speed and direction at Location J, 03/05/1985 ..... 17
Figure 3.23: Comparison of observed and simulated spring tide current speed and direction at Diamond A, Chart 154 ..... 17
Figure 3.24: Comparison of observed and simulated spring tide current speed and direction at Diamond B, Chart 154 ..... 17
Figure 3.25: Comparison of observed and simulated spring tide current speed and direction at Diamond C, Chart 154 ..... 17
Figure 3.26: Comparison of observed and simulated spring tide current speed and direction at Diamond D, Chart 154 ..... 17
Figure 3.27: Comparison of observed and simulated spring tide current speed and direction at Diamond B, Chart 32 ..... 18
Figure 3.28: Comparison of observed and simulated spring tide current speed and direction at Diamond C, Chart 32 ..... 18
Figure 3.29: Comparison of observed and simulated spring tide current speed and direction at Diamond D, Chart 32 ..... 18
Figure 3.30: Comparison of observed and simulated spring tide current speed and direction at Diamond E, Chart 32 ..... 18
Figure 3.31: Comparison of observed and simulated neap tide water levels at St Antony's Head ..... 18
Figure 3.32: Comparison of observed and simulated neap tide water levels at Mylor ..... 18
Figure 3.33: Comparison of observed and simulated neap tide water levels at Flushing ..... 19
Figure 3.34: Comparison of observed and simulated neap tide water levels at Restronguet 19
Figure 3.35: Comparison of observed and simulated neap tide water levels at Penryn ..... 19
Figure 3.36: Comparison of observed and simulated neap tide water levels at Loe Beach ..... 19
Figure 3.37: Comparison of observed and simulated neap tide water levels at King Harry Ferry ..... 19
Figure 3.38: Comparison of observed and simulated neap tide water levels at Malpas ..... 19
Figure 3.39: Comparison of observed and simulated neap tide water levels at Truro ..... 20
Figure 3.40: Comparison of observed and simulated neap tide current speed and direction at Diamond A, Chart 154 ..... 20
Figure 3.41: Comparison of observed and simulated neap tide current speed and direction at Diamond B, Chart 154 ..... 20
Figure 3.42: Comparison of observed and simulated neap tide current speed and direction at Diamond C, Chart 154 ..... 20
Figure 3.43: Comparison of observed and simulated neap tide current speed and direction at Diamond D, Chart 154 ..... 20
Figure 3.44: Comparison of observed and simulated neap tide current speed and direction at Diamond B, Chart 32 ..... 21
Figure 3.45: Comparison of observed and simulated neap tide current speed and direction at Diamond C, Chart 32 ..... 21

Figure 3.46: Comparison of observed and simulated neap tide current speed and direction at Diamond D, Chart 32 .... 21
Figure 3.47: Comparison of observed and simulated neap tide current speed and direction at Diamond E, Chart 32 .... 21
Figure 4.1: Predicted current speed and direction at peak ebb tide – baseline conditions .... 23
Figure 4.2: Predicted current speed and direction at peak flood tide – baseline conditions .... 23
Figure 4.3: Predicted current speed and direction at peak ebb tide – development conditions .... 24
Figure 4.4: Predicted effect of development on current speed at peak ebb tide .... 25
Figure 4.5: Predicted current speed and direction at peak flood tide – development conditions .... 25
Figure 4.6: Predicted effect of development on current speed at peak flood tide .... 26
Figure 4.7: Predicted effect of development on maximum current speed .... 27
Figure 4.8: Predicted effect of development on maximum water level .... 28
Figure 4.9: Predicted effect of development on minimum water level .... 29

# 1 Introduction

## 1.1 Background

The Falmouth Docks is located in the Docks Basin in the Inner Harbour at Falmouth, Cornwall (see Figure 1.1). The proposed works are sited in Falmouth Inner Harbour. This is located at the confluence of the lower Fal Estuary with the Penryn River.

The main channel into Falmouth (Carrick Roads) is 20-30 mCD deep. This deep channel extends further into the Fal Estuary but bypasses the location of the Inner Harbour. The Inner Harbour and approaches have water depths which are around 6 mCD deep. Immediately outside of the Inner Harbour the water depths shallow to a few metres.

Tidal ranges at Falmouth are 4.6 m on spring tides and 2.3 m on neap tides (Admiralty Chart Tables).

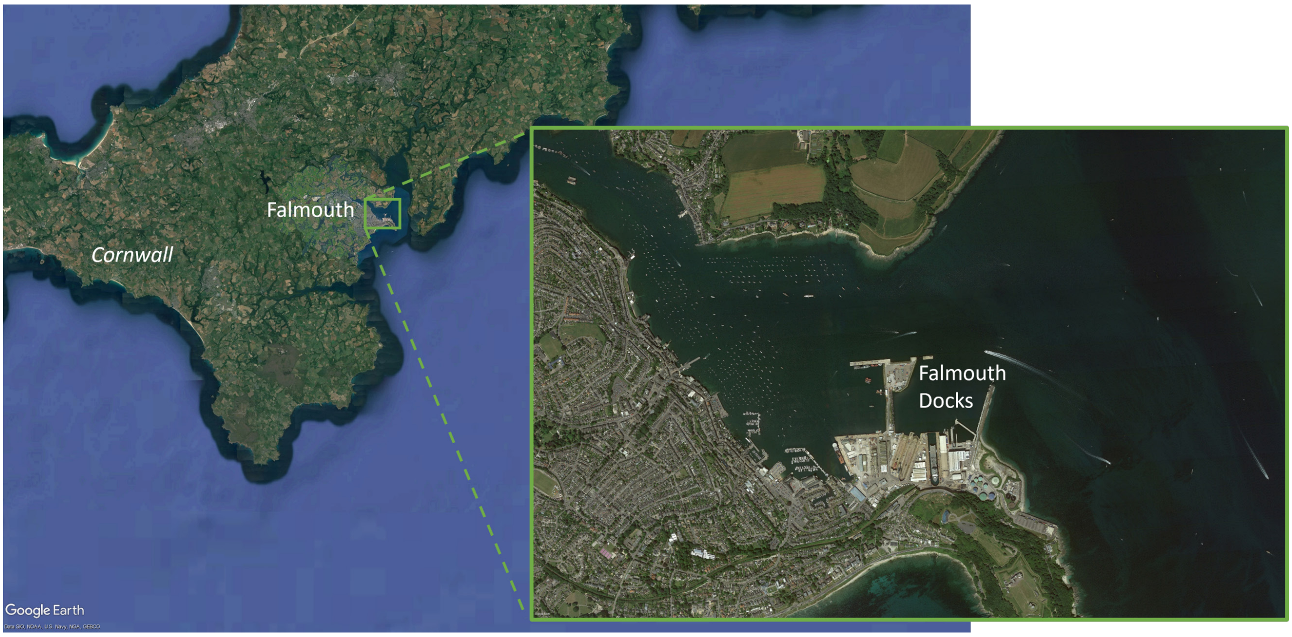
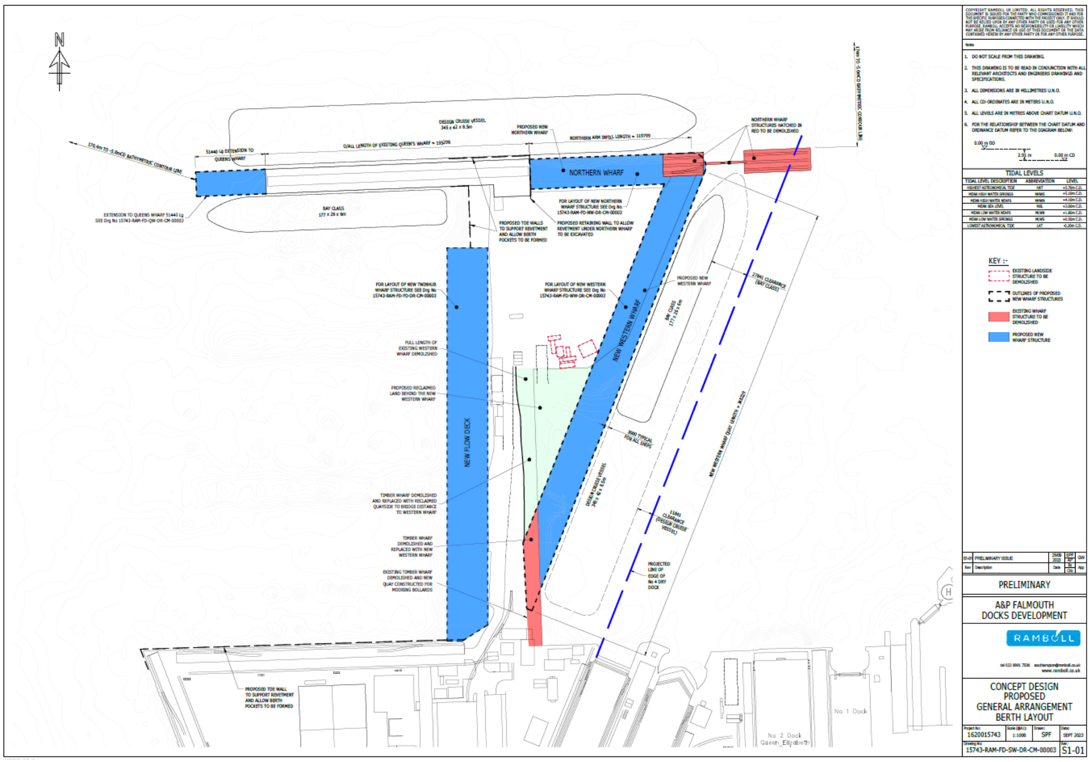



Figure 1.1: Project location

## 1.2 Proposed development

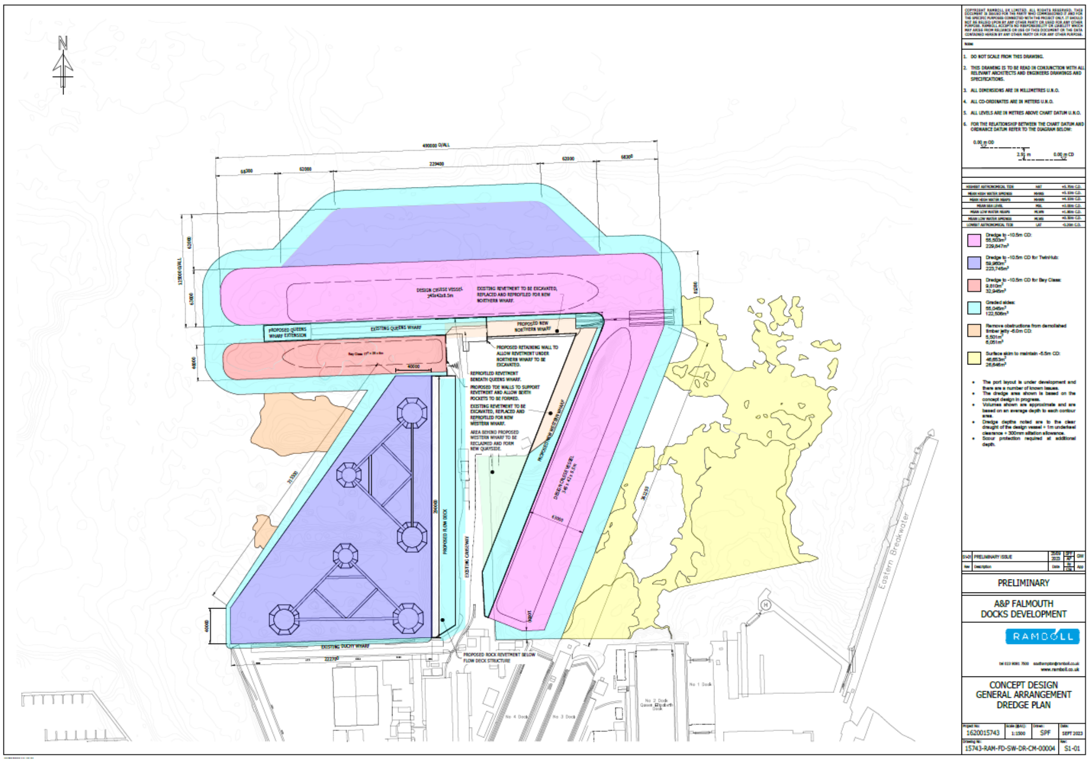
The proposed development aims to restore and upgrade the existing facilities at Falmouth Docks, in order to reinstate and provide new alongside berth capacity, to facilitate the floating offshore wind (FLOW) renewable energy industry and accommodate cruise ships up to Excellence Class at the Docks (see Figure 1.2).

The works will include construction of new suspended deck structures (Western Wharf, Northern Wharf and FLOW Deck) with a rock revetment under the suspended decks, an area of reclamation behind the Western Wharf, an extension of Queen's Wharf and demolition of the eastern and western parts of the existing Northern Arm. Dredging of the berths will also be carried out to accommodate cruise ships up to Excellence Class and FLOW devices, as detailed in the Dredging Plan shown in Figure 1.3.




## Figure 1.2: Proposed development works of Falmouth Docks

*Source: Ramboll*




## Figure 1.3: Proposed Dredging Plan

*Source: Ramboll*

## 1.3 Objectives

This study is part of modelling studies including waves (ES Technical Appendix 6.1, sediment dynamics (ES Technical Appendix 6.2), sediment dispersion during dredging (ES Technical Appendix 6.3, and underwater noise (ES Technical Appendix 7.1) undertaken by HR Wallingford to support the Environmental Impact Assessment (EIA) for the proposed development.

This report presents the tidal flow modelling study, carried out to model the effect of the proposed dredging and disposal operations on water levels and currents. The tidal flow modelling also provides input to the sediment regime and sediment plume modelling studies.

# 2 Model establishment

## 2.1 Choice of model

Tidal flow modelling was undertaken using TELEMAC, an industry-accepted finite element modelling system currently being used by more than 200 professional and research organisations worldwide. TELEMAC uses an unstructured, triangular grid to finely resolve waters with complex coastlines and accurately represent dredged extents. For this study, considering the well mixed nature of the flow at the study site, TELEMAC-2D, which simulated depth averaged currents was used.

## 2.2 Co-ordinate system and vertical datum

The model was set up in metres using horizontal positions relative to the Universal Transverse Mercator (UTM) co-ordinate system. The development site is in UTM Zone 30N. The vertical datum used was mean sea level (MSL) which is taken as a flat datum for the study area.

## 2.3 Model bathymetry

The model bathymetry was defined using bathymetric data from the United Kingdom Hydrographic Office (UKHO), supplemented with data obtained from International Hydrographic Charts from C-Map (https://www.c-map.com/en-gb/home/), and recent local surveys covering the approaches to and within the harbour carried out in 2020 and 2022, supplied by the client for the study, (Figure 2.1). The data sets were set to the same vertical datum of MSL and merged to provide the bathymetry used in the model.

The proposed changes to the quay lines and dredged areas as shown by the Dredging Plan (Figure 1.3) was included in the developed layout. A 1:3 side slope was used for the dredged areas.

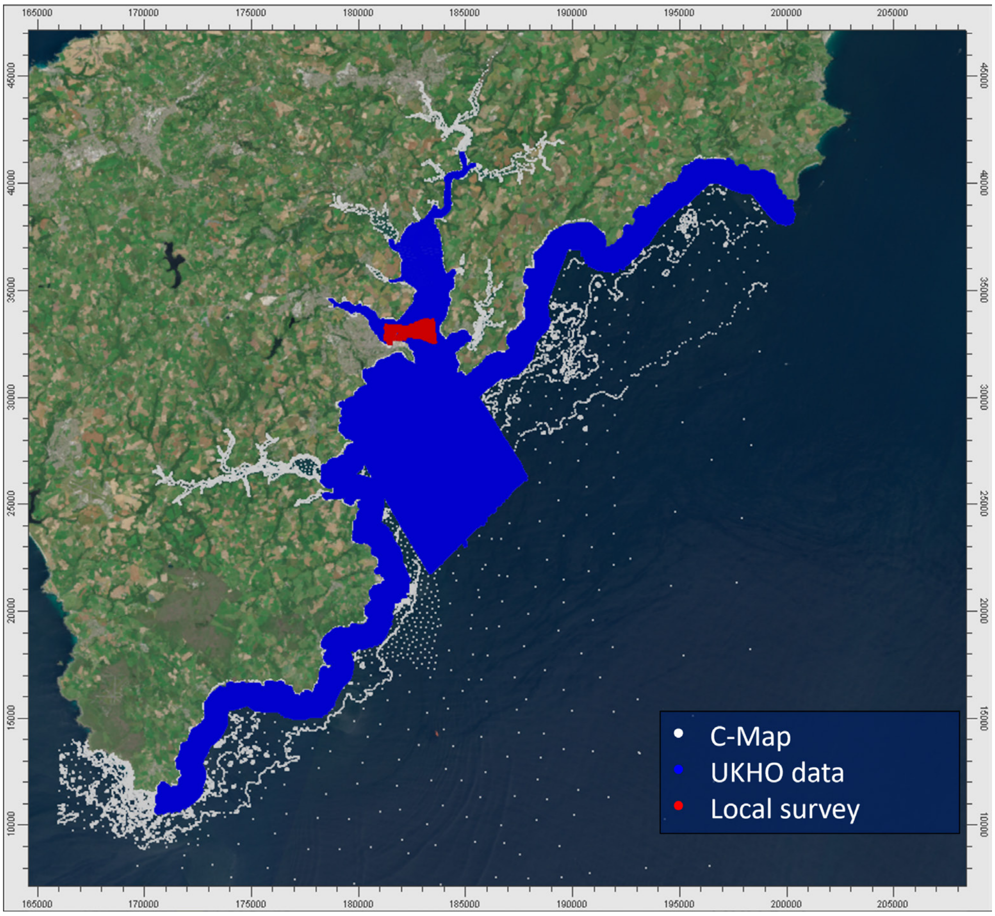



Figure 2.1: Bathymetric data sources

*Source: Background image Copernicus Sentinel data 2023*

## 2.4 Model area and mesh resolution

The flow model covers the area as shown in Figure 2.2, extending from The Lizard in the south west towards Portholland in the north east and extending between 15 km and 20 km offshore. The bathymetry and mesh resolution used in the model local to the proposed works is shown in Figure 2.3. The resolution is less than 10 m in the vicinity of the works, and around 40 m within the Fal Estuary, but much larger (around 1000 m) near the model boundary. The tidal flow and wave models used the same mesh to allow both to be input to the sediment transport modelling without the errors associated with interpolating between model grids.

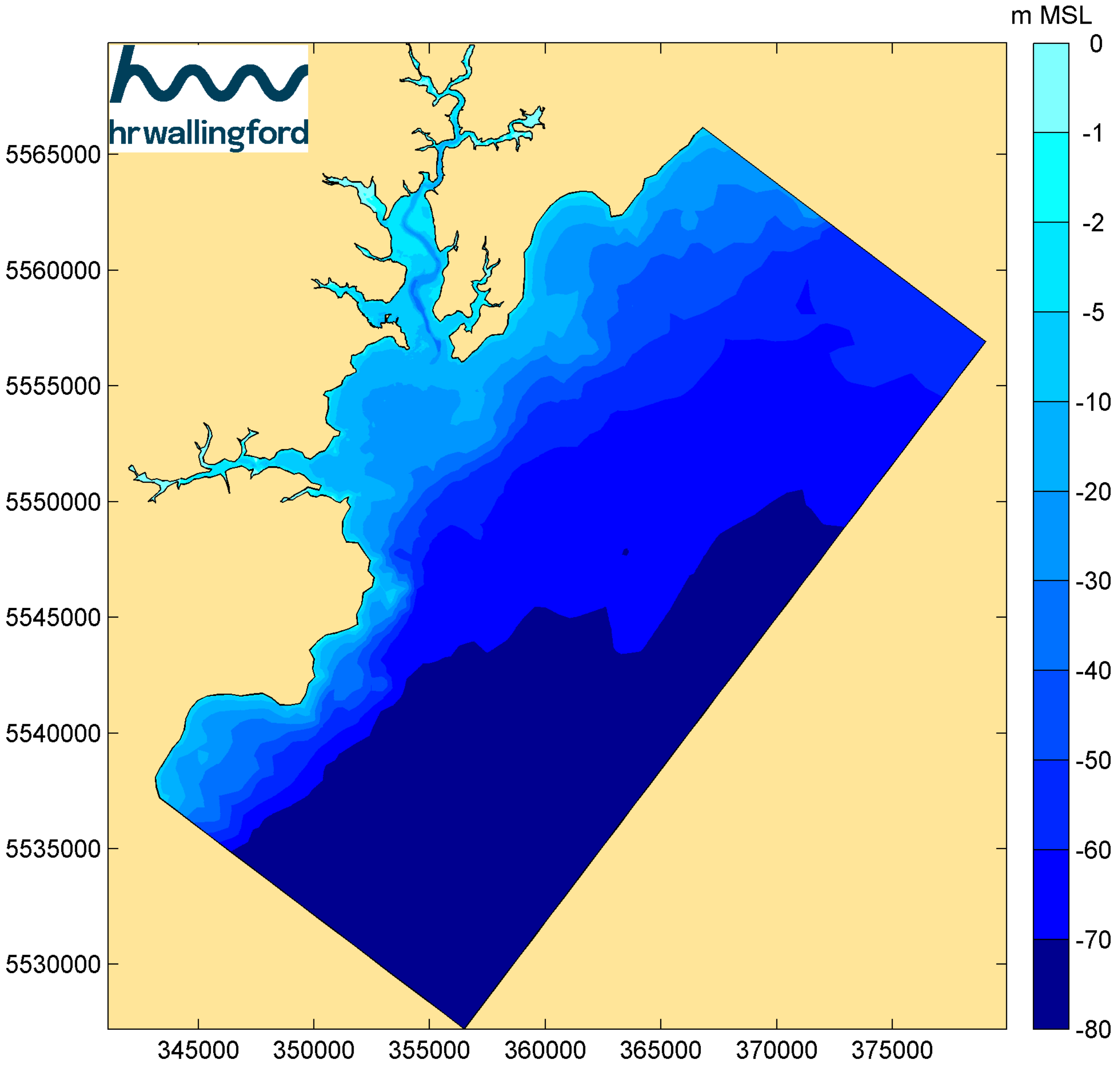
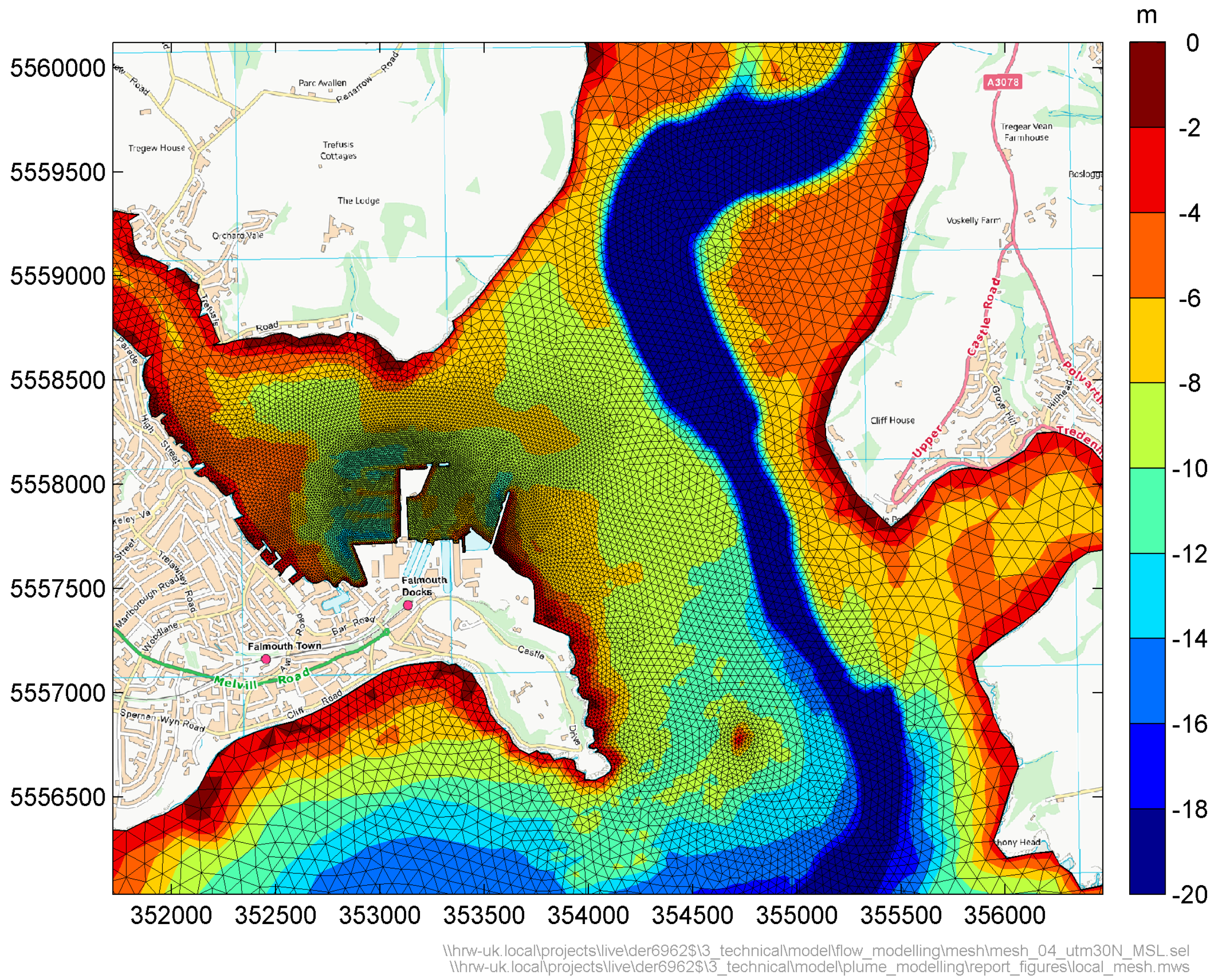



Figure 2.2: Flow model extent




*Contains Ordnance Survey data © Crown Copyright*

Figure 2.3: Baseline flow model bathymetry and mesh in the vicinity of the proposed development

## 2.5 Boundary conditions

Tidal boundary conditions for the flow model were obtained from version 9.1 of the TPXO global tidal model (Egbert and Erofeeva, 2002).

The Fal River, together with the various creeks that flow into the Fal Estuary, provides very little freshwater input to the estuary system (National River Flow Archive). For this reason, the TELEMAC model was run without freshwater input.

For the present study, hydrodynamic conditions were chosen that will be representative of those that occur at the site. A typical spring-neap cycle was simulated in which spring and neap tidal ranges are close to the mean spring and mean neap ranges, therefore ensuring that the simulations are suitably representative of the range of tidal variation. For the purposes of the plumes study the flow model was used to generate a 17 day period of flow starting on 3rd March 2021.

## 2.6 Piled structures

The existing and proposed development both include piled structures. The influence of piles on the flow is included in the model by adding extra turbulent drag within each model cell within the piled region using the following equation:

$$F_{u,v} = -0.5 * N * D * C_D * U_{norm} \qquad \text{(Eq. 1)}$$

Where:

$F_{u,v}$ = drag in the X and Y direction

N = total number of piles in the jetty

D = diameter of the piles (m)

$C_D$ = a drag coefficient related to the shape of the pile; for square piles $C_D$ = 2.0 (Mutlu Sumer and Fredsøe, 2006)

$U_{norm}$ = depth averaged current flow speed (m/s).

$F_u$ and $F_v$ are then included implicitly within the hydrodynamic momentum equations used by the model.

The numbers, size and shape of the piles were provided for the development case by the client. For the baseline case, publicly available data was reviewed to estimate the nature of the piled structures.

# 3 Model calibration and validation

The model calibration used the same dataset as that for a previous study of Falmouth Harbour (HR Wallingford, 2008). The generally low amounts of sediment movement as demonstrated by the sediment regime modelling (Technical Appendix 6.2) indicates very low rates of morphological change and hence the continued applicability of the observed data collected in 1985.

The available dataset included current metering at 9 locations around Falmouth Harbour (Figure 3.1) and simultaneous tidal level measurements at 9 locations (Figure 3.2). The current data was added to by reference to tidal diamond data at the relevant charts (Figure 3.3). The diamonds are derived from data of unknown age, targeted to be representative of mean spring and mean neap tides and therefore the primary dataset for calibration and validation are the site specific measurements made in 1985 with the diamonds providing additional evidence of the model performance.

The dates of the surveys were:

- Spring tide water levels – 5th May 1985
- Spring tide currents – 2nd and 3rd May 1986, tidal diamonds
- Neap tide water levels – 11th May 1985
- Neap tide currents – tidal diamonds.

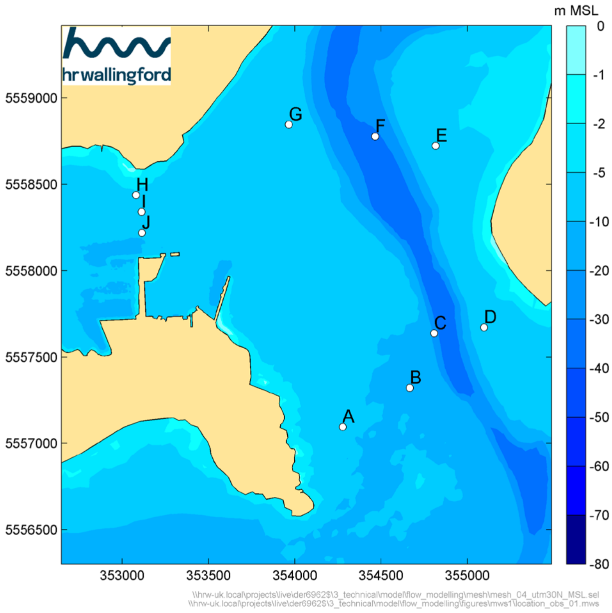



Figure 3.1: Locations of current observations

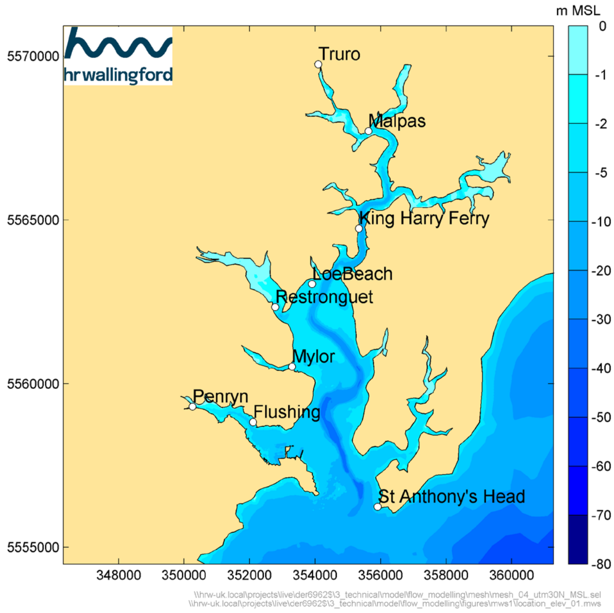



Figure 3.2: Locations of tidal level measurements

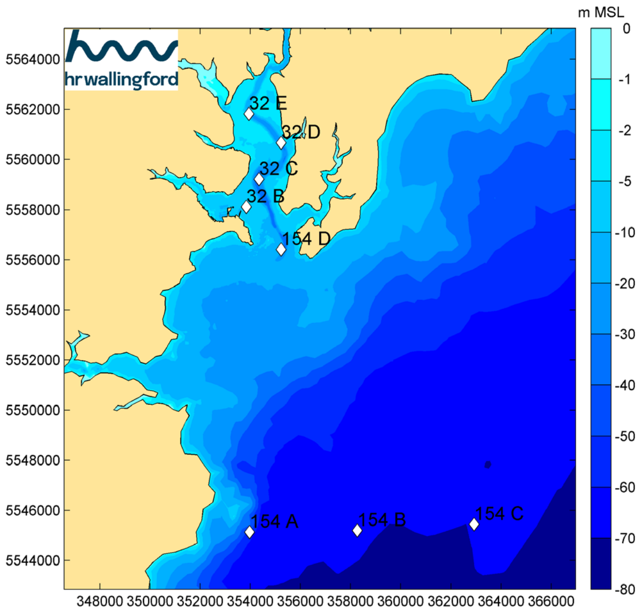



Figure 3.3: Locations of Admiralty tidal diamonds

*Source: Admiralty charts 154 and 32*

## 3.1 Spring tide results

### 3.1.1 Water levels

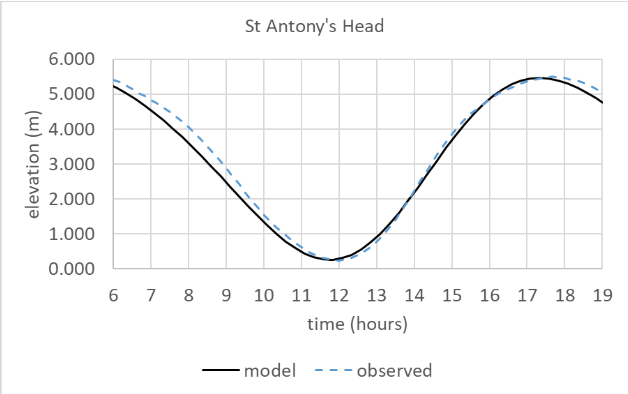



Figure 3.4: Comparison of observed and simulated spring tide water levels at St Antony's Head

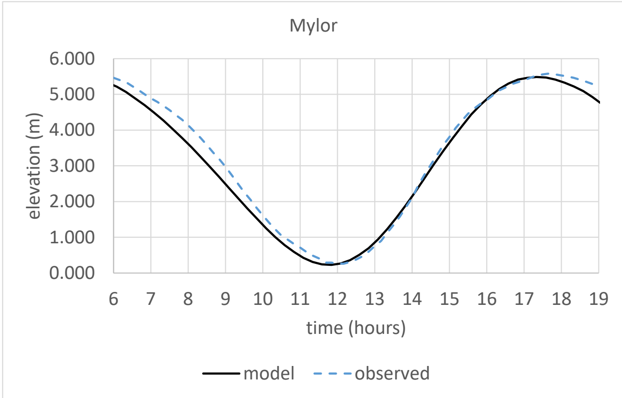



Figure 3.5: Comparison of observed and simulated spring tide water levels at Mylor

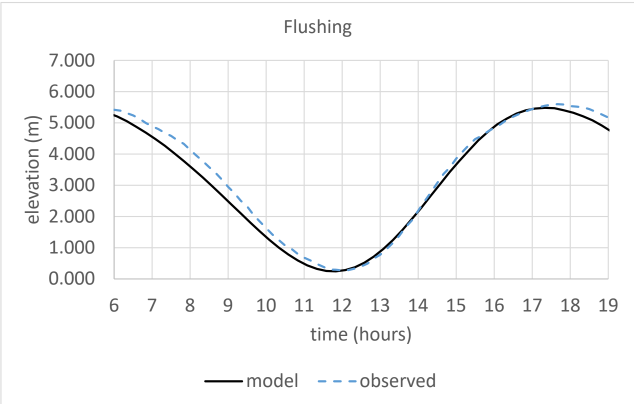



Figure 3.6: Comparison of observed and simulated spring tide water levels at Flushing

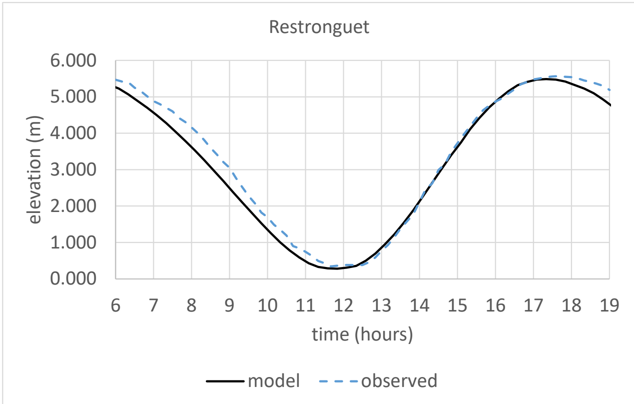



Figure 3.7: Comparison of observed and simulated spring tide water levels at Restronguet

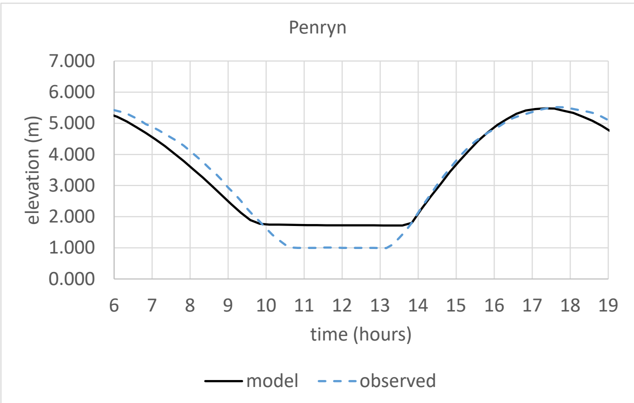



Figure 3.8: Comparison of observed and simulated spring tide water levels at Penryn

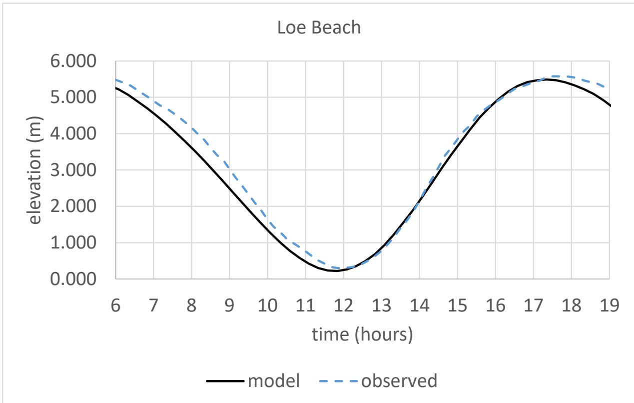



Figure 3.9: Comparison of observed and simulated spring tide water levels at Loe Beach

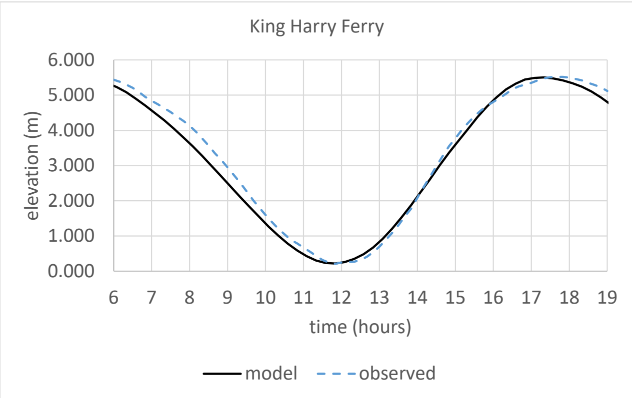



Figure 3.10: Comparison of observed and simulated spring tide water levels at King Harry Ferry

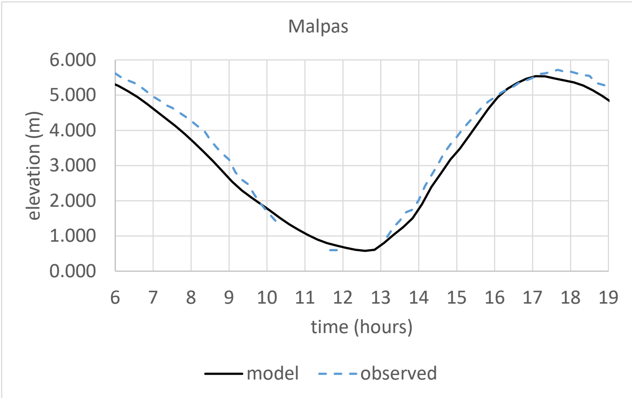



Figure 3.11: Comparison of observed and simulated spring tide water levels at Malpas

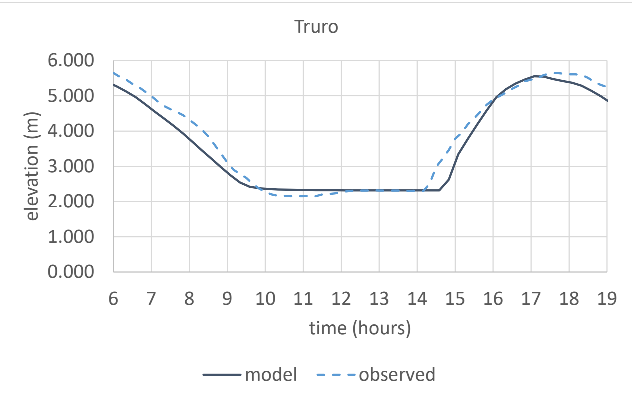



Figure 3.12: Comparison of observed and simulated spring tide water levels at Truro

## 3.1.2 Currents

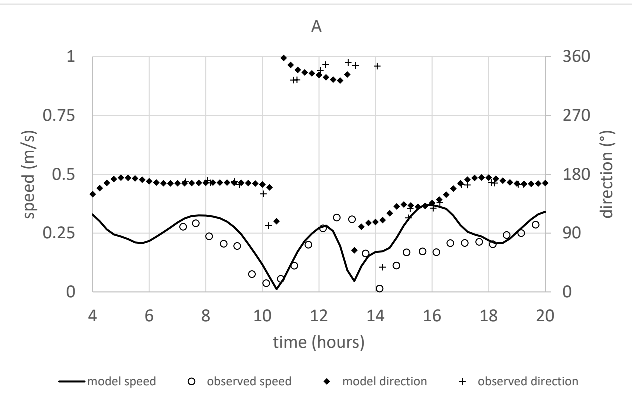



Figure 3.13: Comparison of observed and simulated spring tide current speed and direction at Location A, 02/05/1985

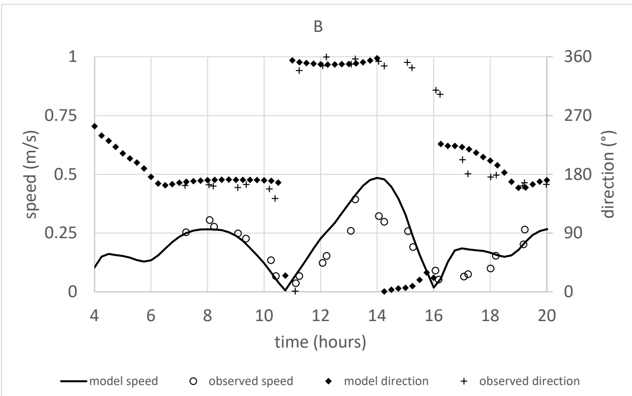



Figure 3.14: Comparison of observed and simulated spring tide current speed and direction at Location B, 02/05/1985

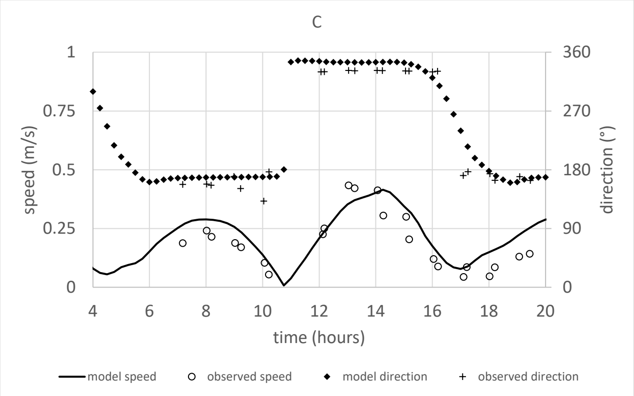



Figure 3.15: Comparison of observed and simulated spring tide current speed and direction at Location C, 02/05/1985

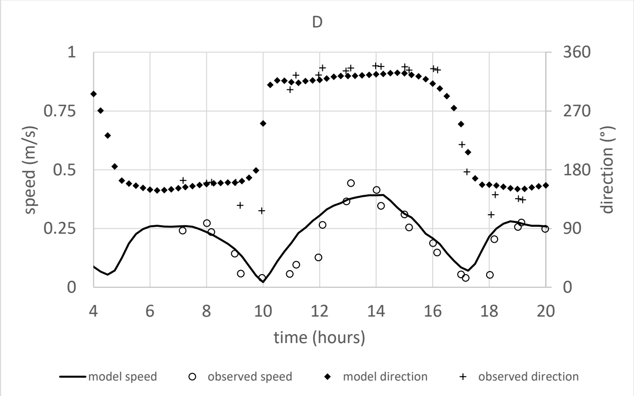



Figure 3.16: Comparison of observed and simulated spring tide current speed and direction at Location D, 02/05/1985

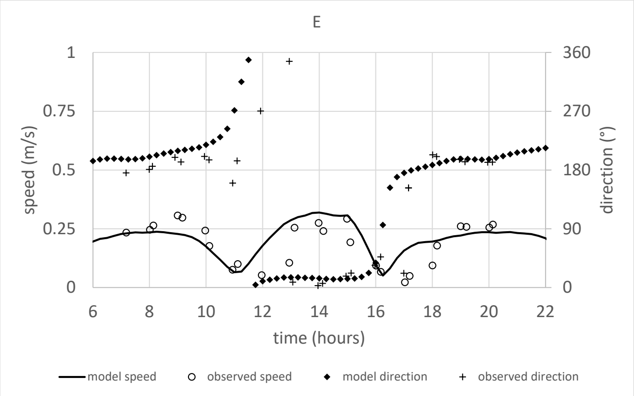



Figure 3.17: Comparison of observed and simulated spring tide current speed and direction at Location E, 03/05/1985

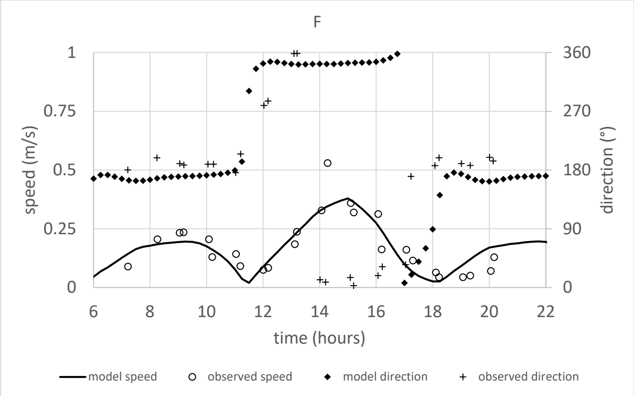



Figure 3.18: Comparison of observed and simulated spring tide current speed and direction at Location F, 03/05/1985

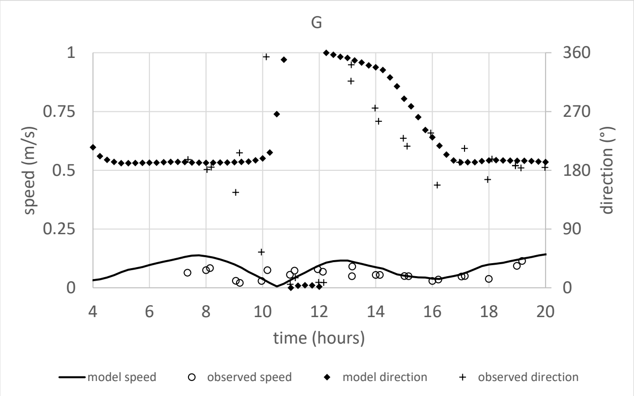



Figure 3.19: Comparison of observed and simulated spring tide current speed and direction at Location G, 02/05/1985

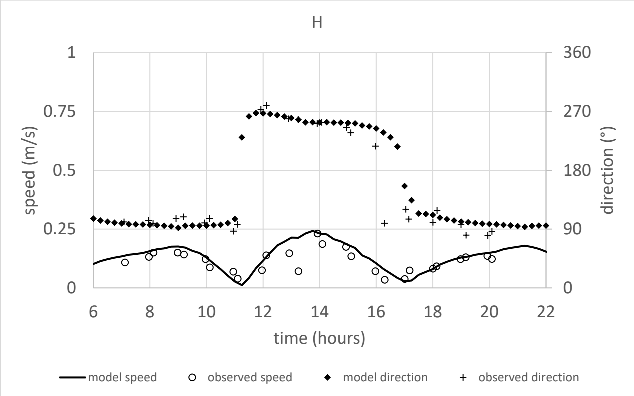



Figure 3.20: Comparison of observed and simulated spring tide current speed and direction at Location H, 03/05/1985

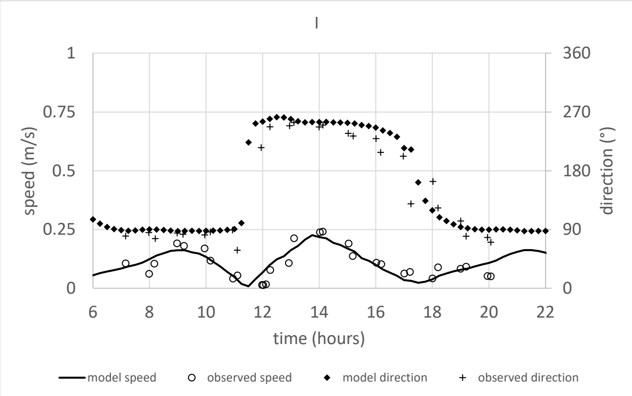



Figure 3.21: Comparison of observed and simulated spring tide current speed and direction at Location I, 03/05/1985

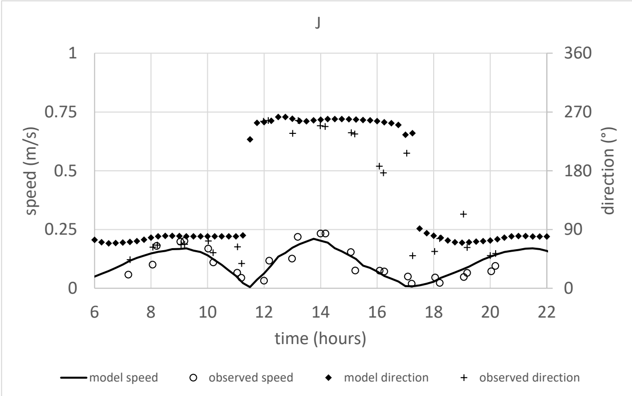



Figure 3.22: Comparison of observed and simulated spring tide current speed and direction at Location J, 03/05/1985

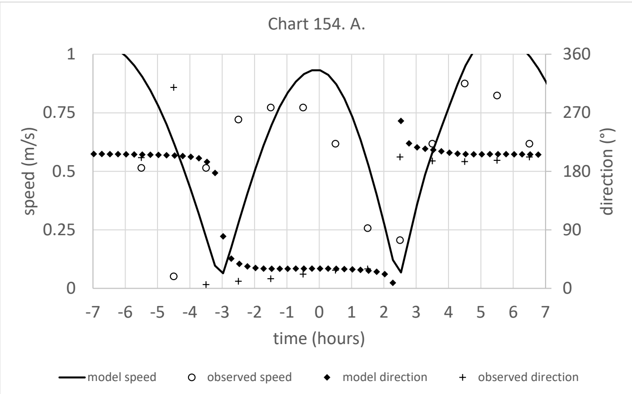



Figure 3.23: Comparison of observed and simulated spring tide current speed and direction at Diamond A, Chart 154

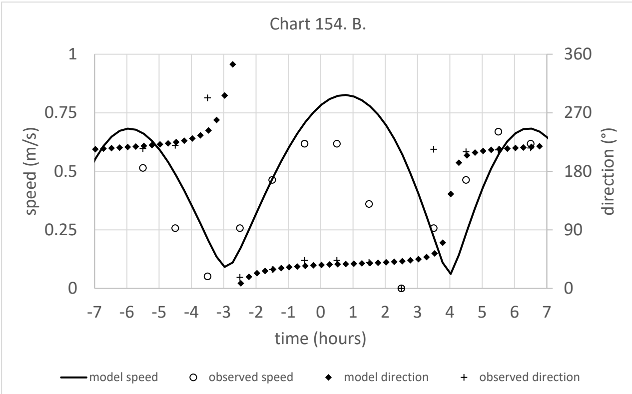



Figure 3.24: Comparison of observed and simulated spring tide current speed and direction at Diamond B, Chart 154

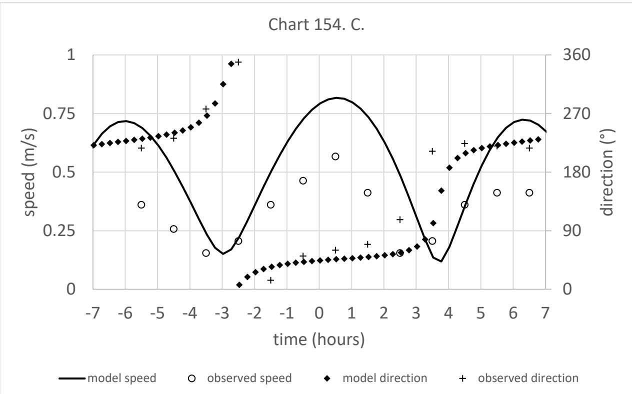



Figure 3.25: Comparison of observed and simulated spring tide current speed and direction at Diamond C, Chart 154

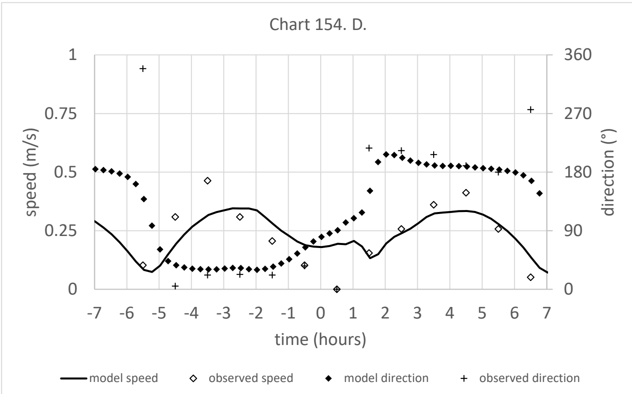



Figure 3.26: Comparison of observed and simulated spring tide current speed and direction at Diamond D, Chart 154

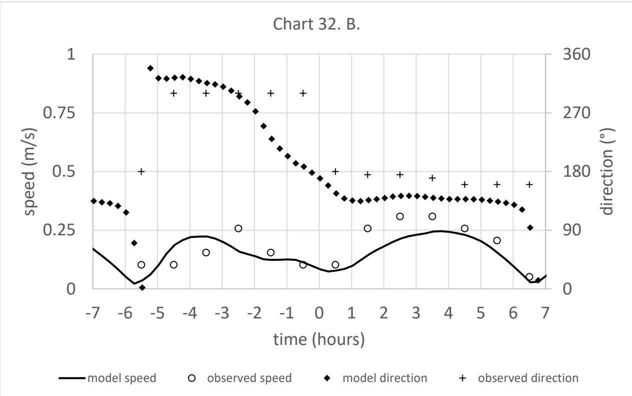



Figure 3.27: Comparison of observed and simulated spring tide current speed and direction at Diamond B, Chart 32

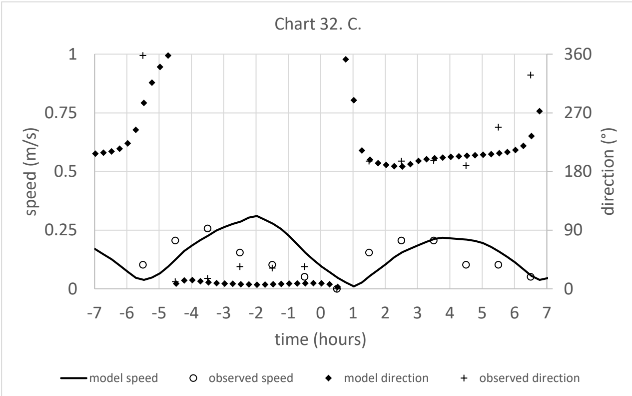



Figure 3.28: Comparison of observed and simulated spring tide current speed and direction at Diamond C, Chart 32

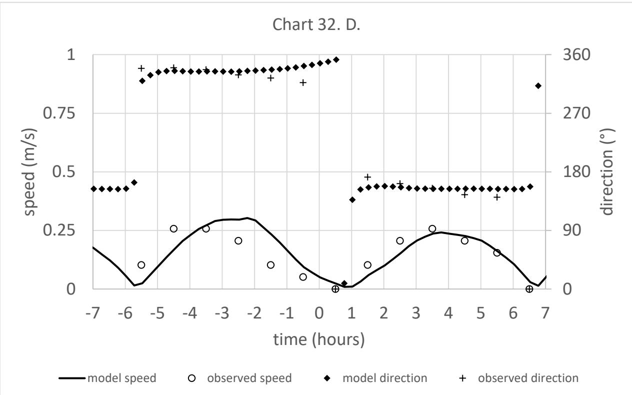



Figure 3.29: Comparison of observed and simulated spring tide current speed and direction at Diamond D, Chart 32

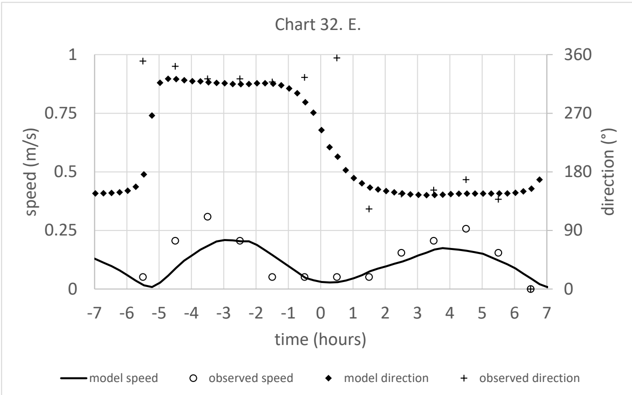



Figure 3.30: Comparison of observed and simulated spring tide current speed and direction at Diamond E, Chart 32

## 3.2 Neap tide results

### 3.2.1 Water levels

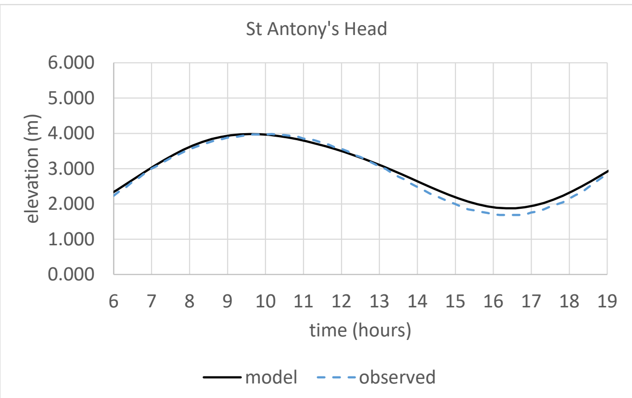



Figure 3.31: Comparison of observed and simulated neap tide water levels at St Antony's Head

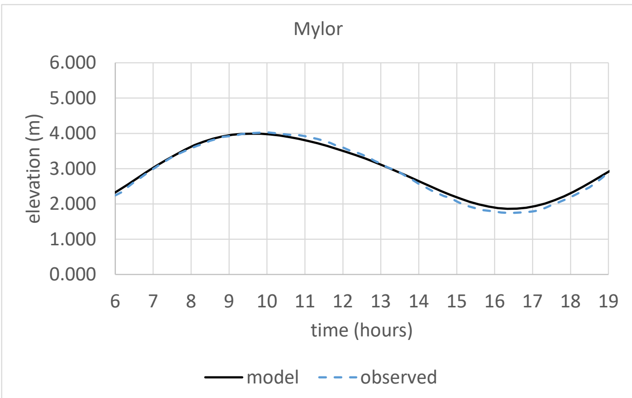



Figure 3.32: Comparison of observed and simulated neap tide water levels at Mylor

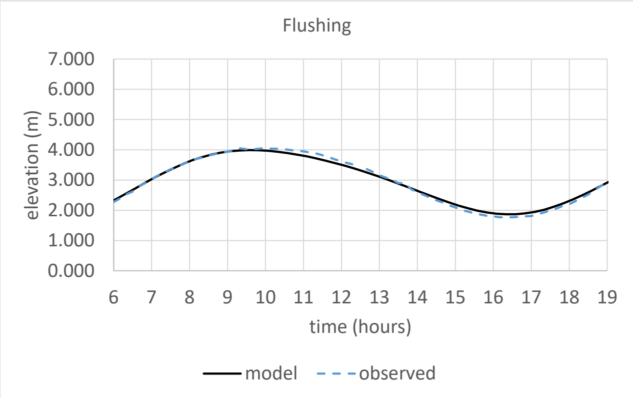



Figure 3.33: Comparison of observed and simulated neap tide water levels at Flushing


Figure 3.34: Comparison of observed and simulated neap tide water levels at Restronguet

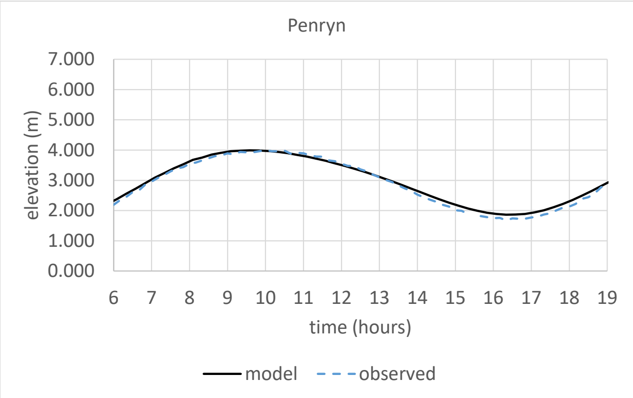



Figure 3.35: Comparison of observed and simulated neap tide water levels at Penryn

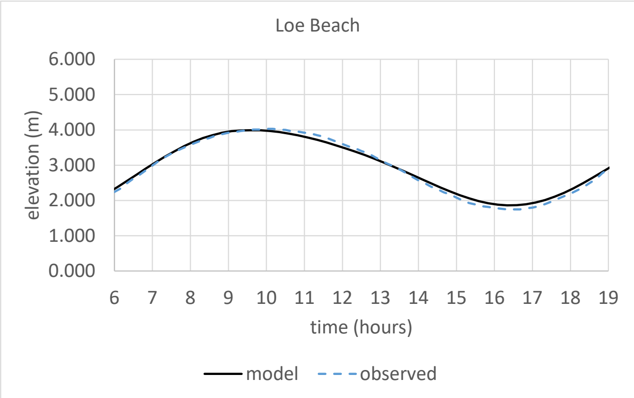



Figure 3.36: Comparison of observed and simulated neap tide water levels at Loe Beach

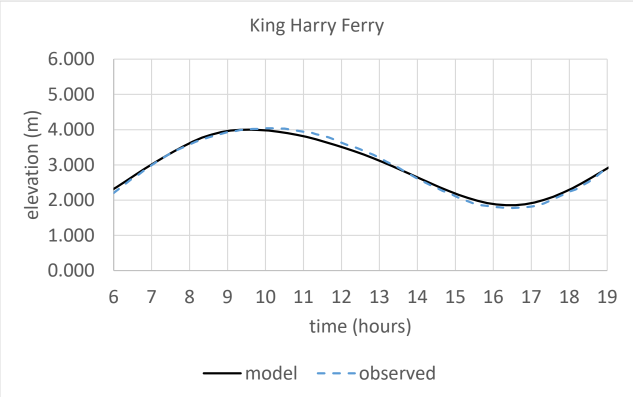



Figure 3.37: Comparison of observed and simulated neap tide water levels at King Harry Ferry

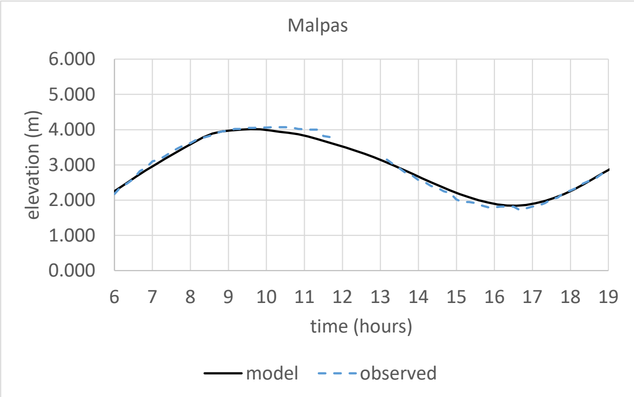



Figure 3.38: Comparison of observed and simulated neap tide water levels at Malpas

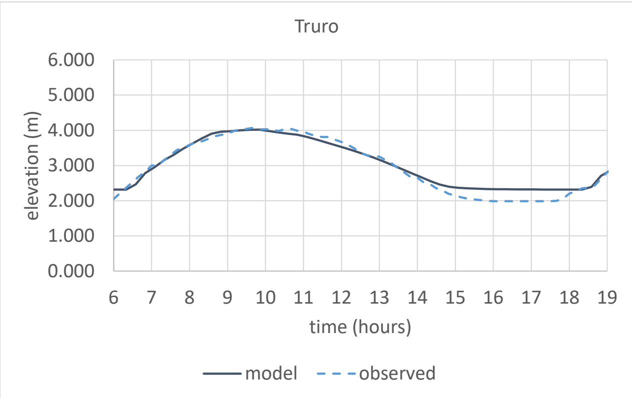



Figure 3.39: Comparison of observed and simulated neap tide water levels at Truro

## 3.2.2 Currents

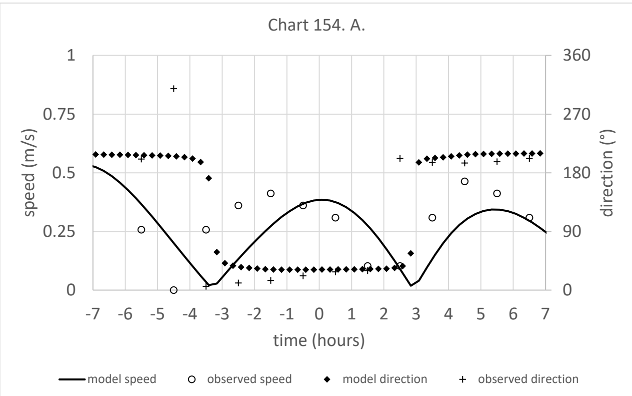



Figure 3.40: Comparison of observed and simulated neap tide current speed and direction at Diamond A, Chart 154

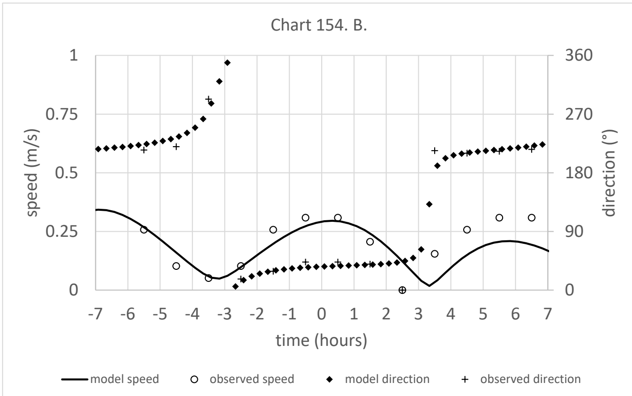



Figure 3.41: Comparison of observed and simulated neap tide current speed and direction at Diamond B, Chart 154

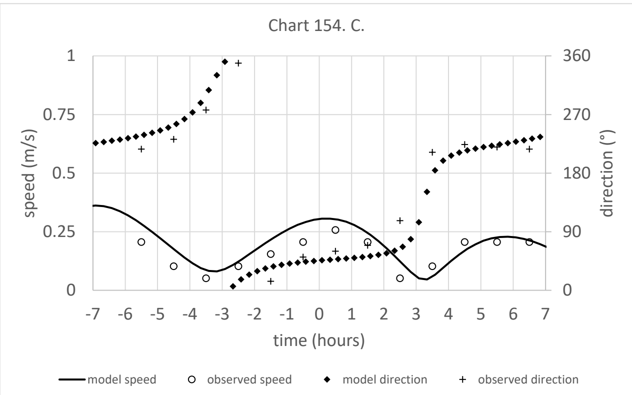



Figure 3.42: Comparison of observed and simulated neap tide current speed and direction at Diamond C, Chart 154

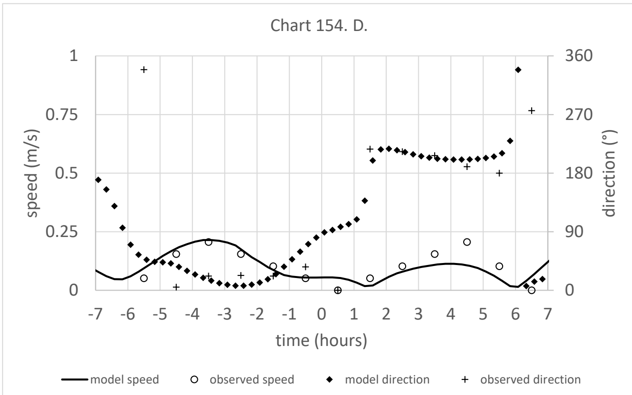



Figure 3.43: Comparison of observed and simulated neap tide current speed and direction at Diamond D, Chart 154

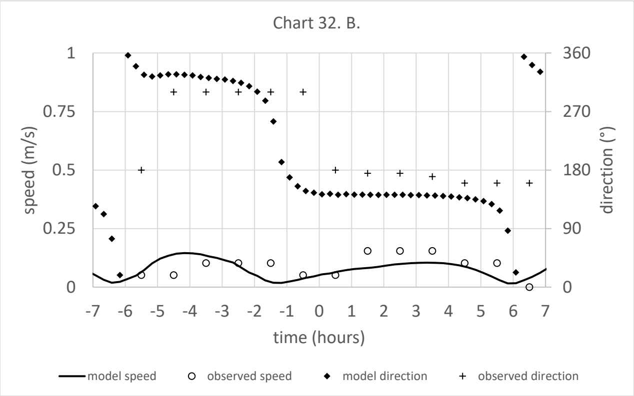



Figure 3.44: Comparison of observed and simulated neap tide current speed and direction at Diamond B, Chart 32

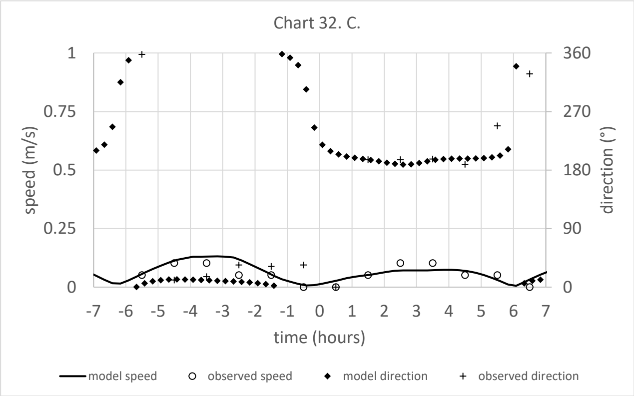



Figure 3.45: Comparison of observed and simulated neap tide current speed and direction at Diamond C, Chart 32

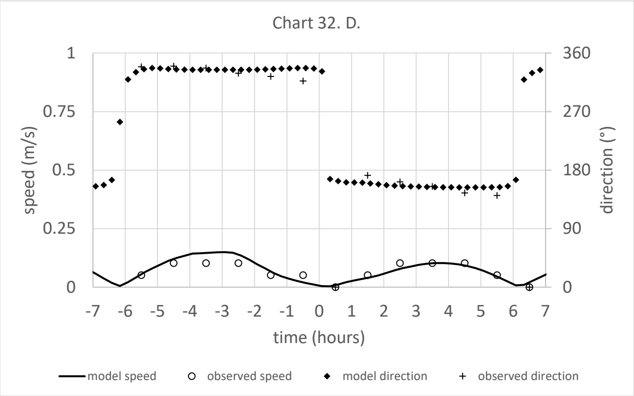



Figure 3.46: Comparison of observed and simulated neap tide current speed and direction at Diamond D, Chart 32

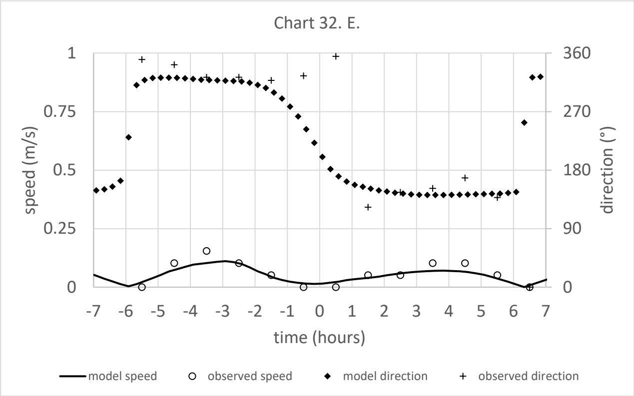



Figure 3.47: Comparison of observed and simulated neap tide current speed and direction at Diamond E, Chart 32

# 4 Model results

Four types of figures are presented to summarise the predicted changes in tidal regime resulting from the proposed works. These are as follows:

- Peak current speed and pattern at times of peak ebb and flood tide.
- Difference in peak current speed and pattern at times of peak ebb and flood tide.
- Difference in maximum current speed. These confirm the plots at the times of peak ebb and flood tide capture the magnitude and footprint impact of the works.
- Difference in maximum and minimum water level. This plot shows any effect on tidal propagation, hence impacts on flood risk or intertidal exposure.

Figure 4.4 and Figure 4.6 show the effect of the development on current speeds at the times of peak ebb and flood tides. A minimum threshold for plotting any change of 0.02 m/s has been used. This value is much lower than that typically used for similar assessments however it does allow the full footprint of any effect to be seen. The main changes seen are an area of small reduction in current speed associated with the increased cross sectional area with the dredging to the north of the development included. The change to the shape and dredged depths in the western wharf area alter the slow moving circulation within the wharf area. This effect results in some speed increases for the flow passing the western wharf on both the ebb and flood tide, however these changes are small and transient. The implications of the changed hydrodynamics on sediment regime are described in Technical Appendix 6.2.

Figure 4.8 and Figure 4.9 show the effect of the development on maximum or minimum water levels (plotted in mm). Only very small patches of effect, less than 1 mm are seen.

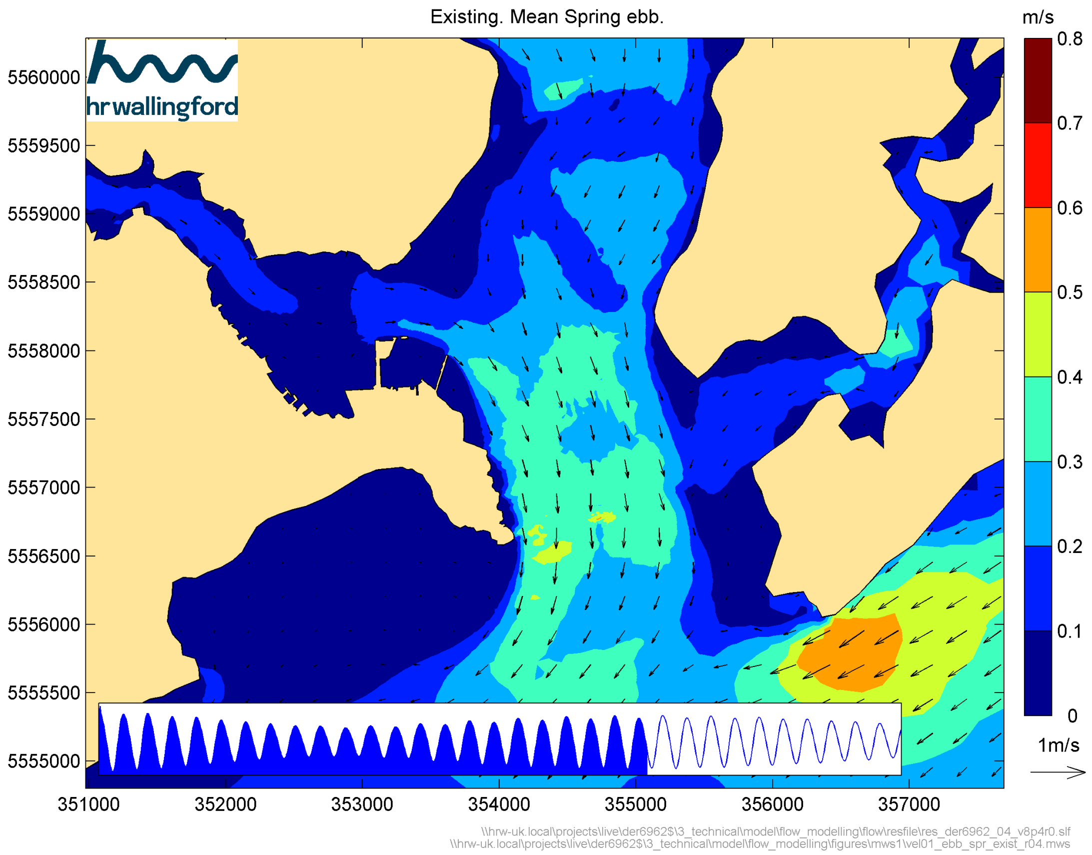



Figure 4.1: Predicted current speed and direction at peak ebb tide – baseline conditions

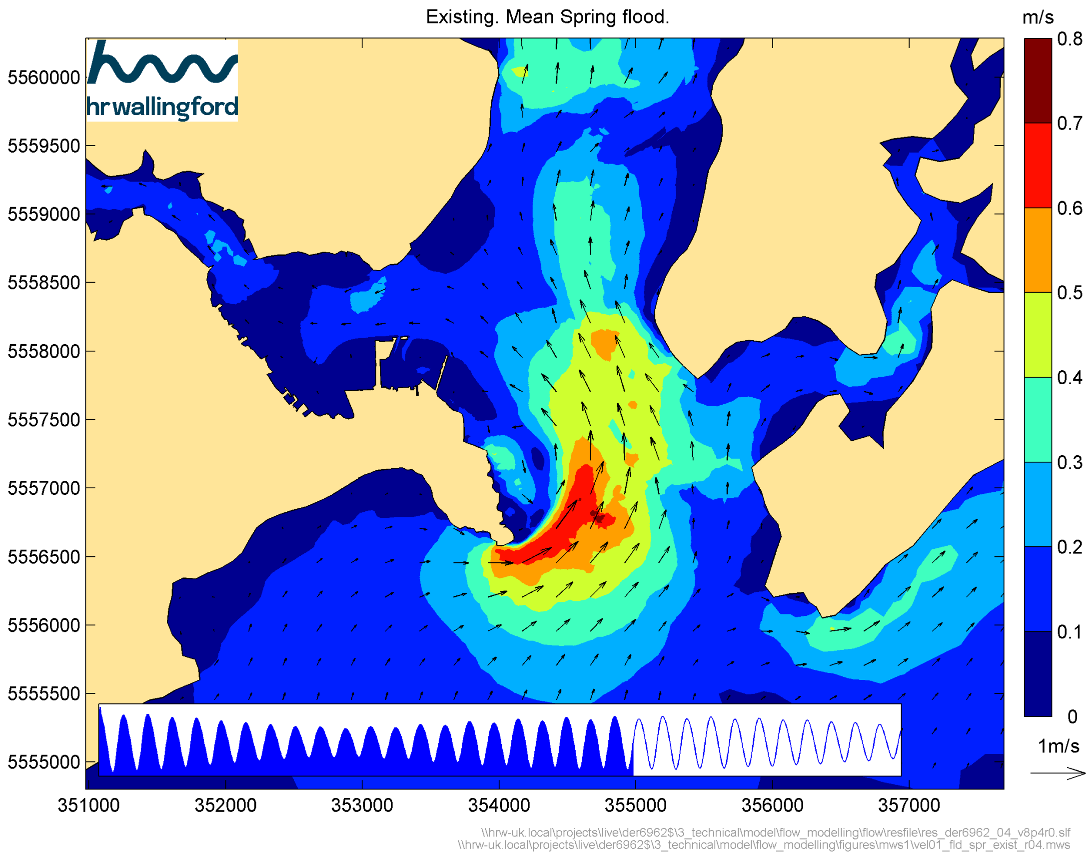



Figure 4.2: Predicted current speed and direction at peak flood tide – baseline conditions

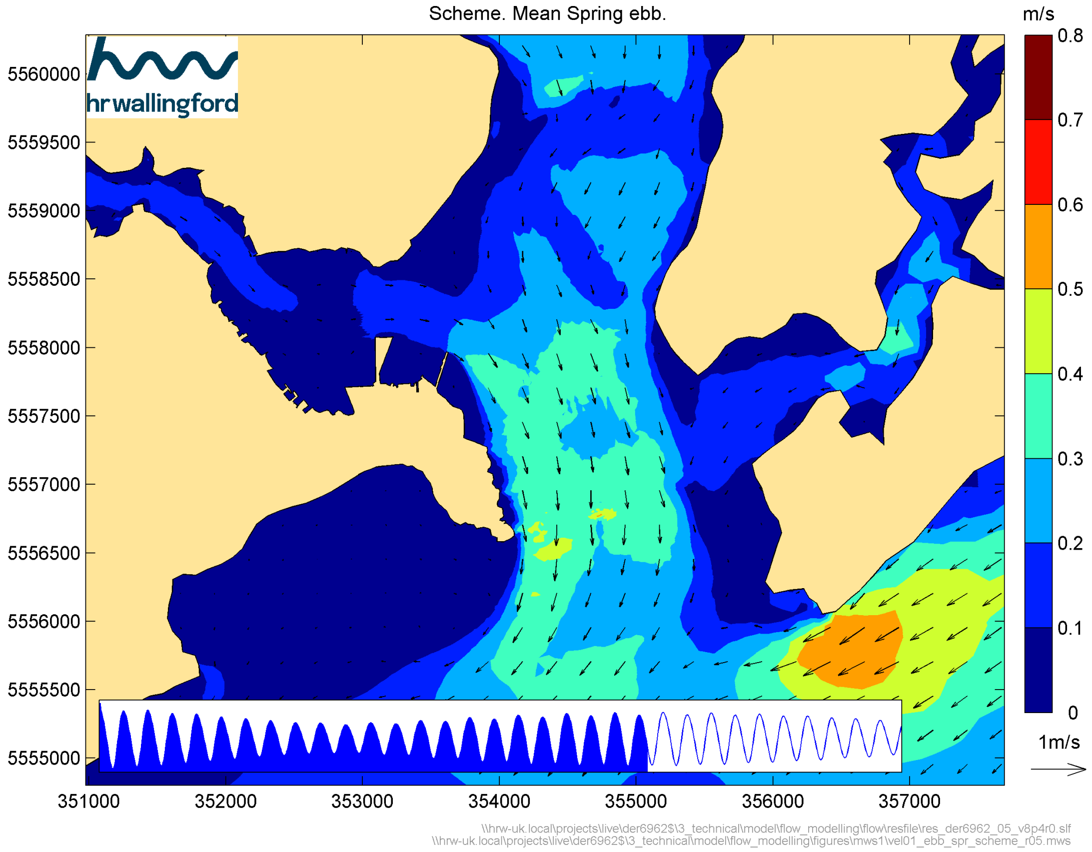



Figure 4.3: Predicted current speed and direction at peak ebb tide – development conditions

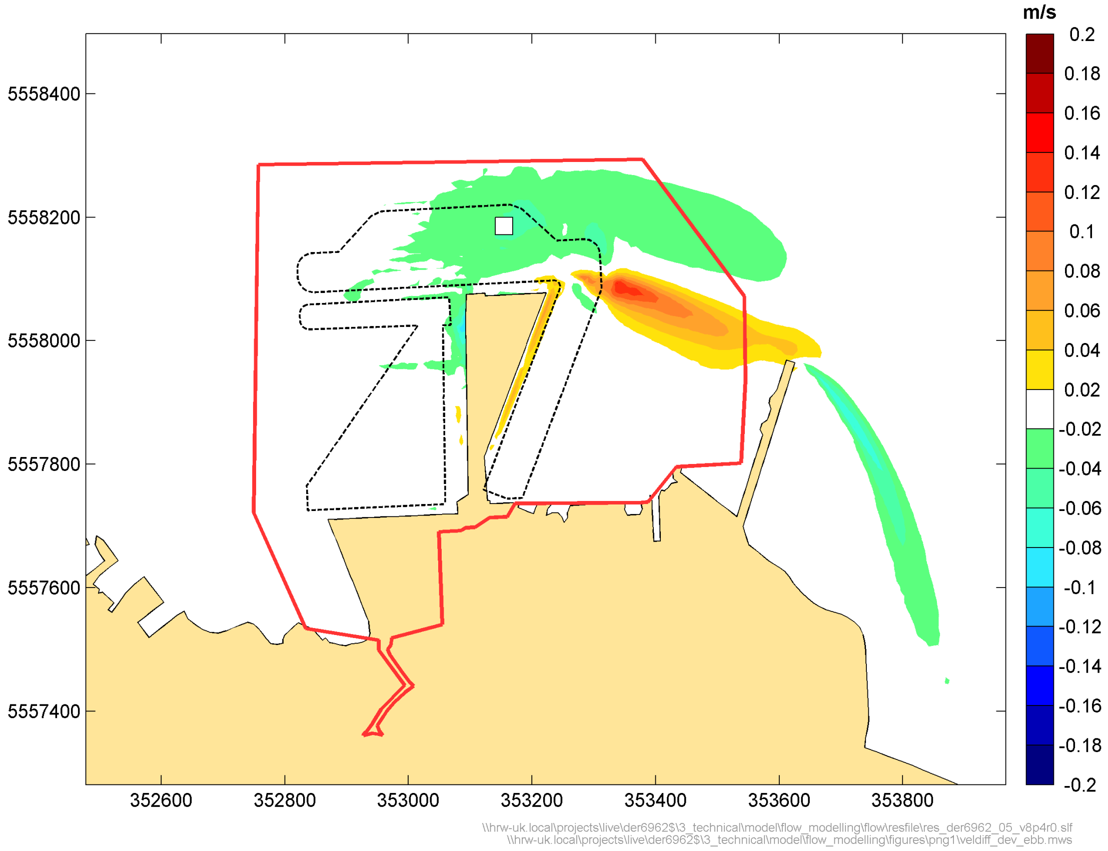



Figure 4.4: Predicted effect of development on current speed at peak ebb tide

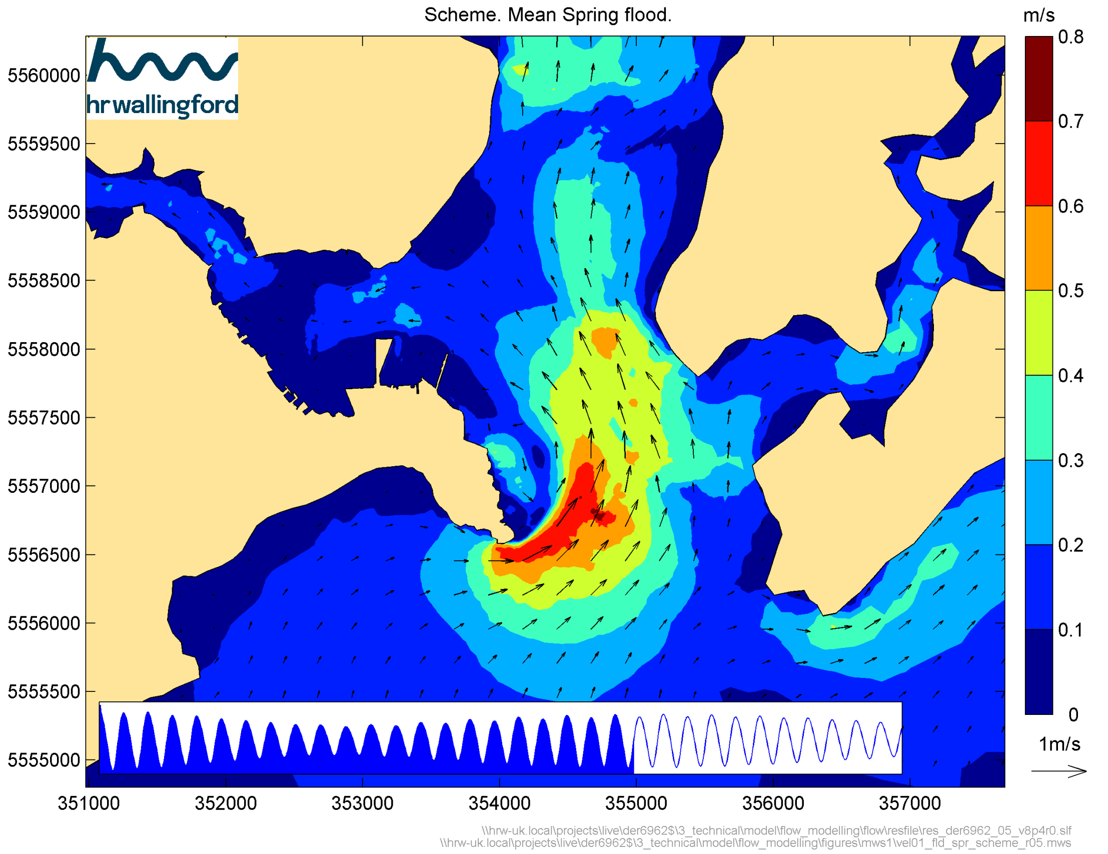



Figure 4.5: Predicted current speed and direction at peak flood tide – development conditions

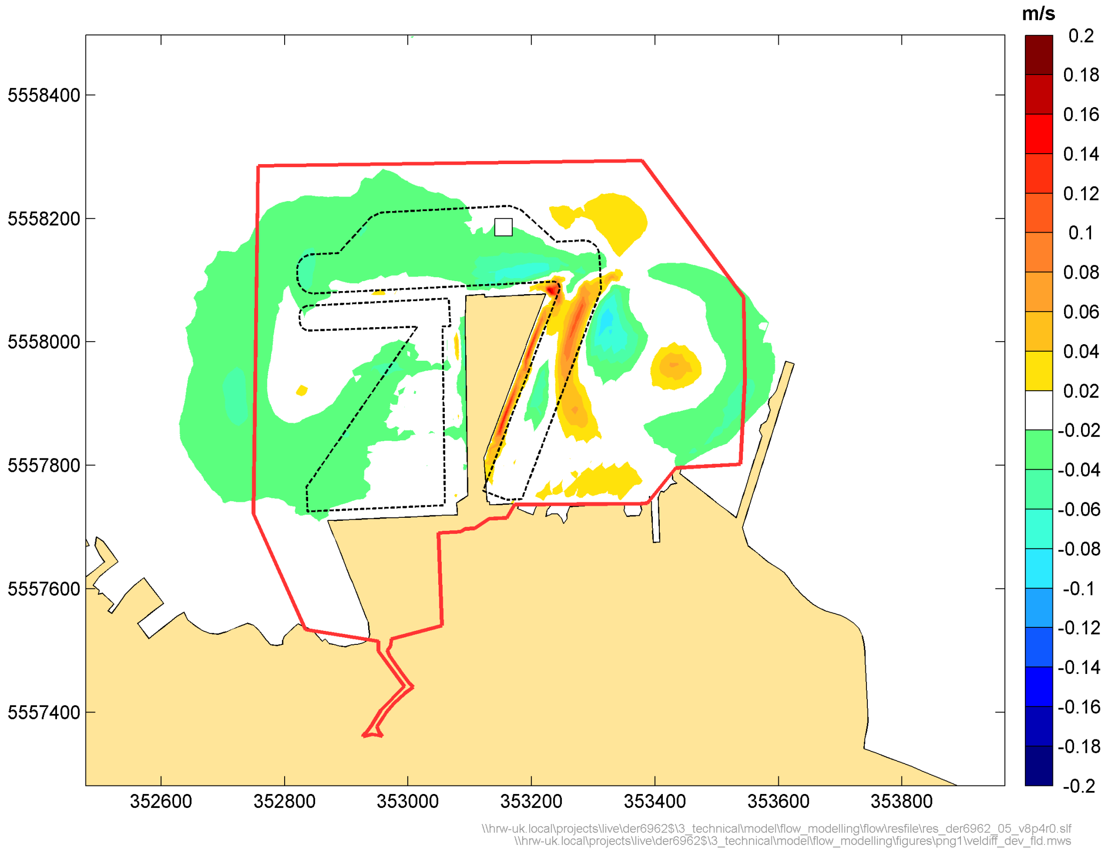



Figure 4.6: Predicted effect of development on current speed at peak flood tide

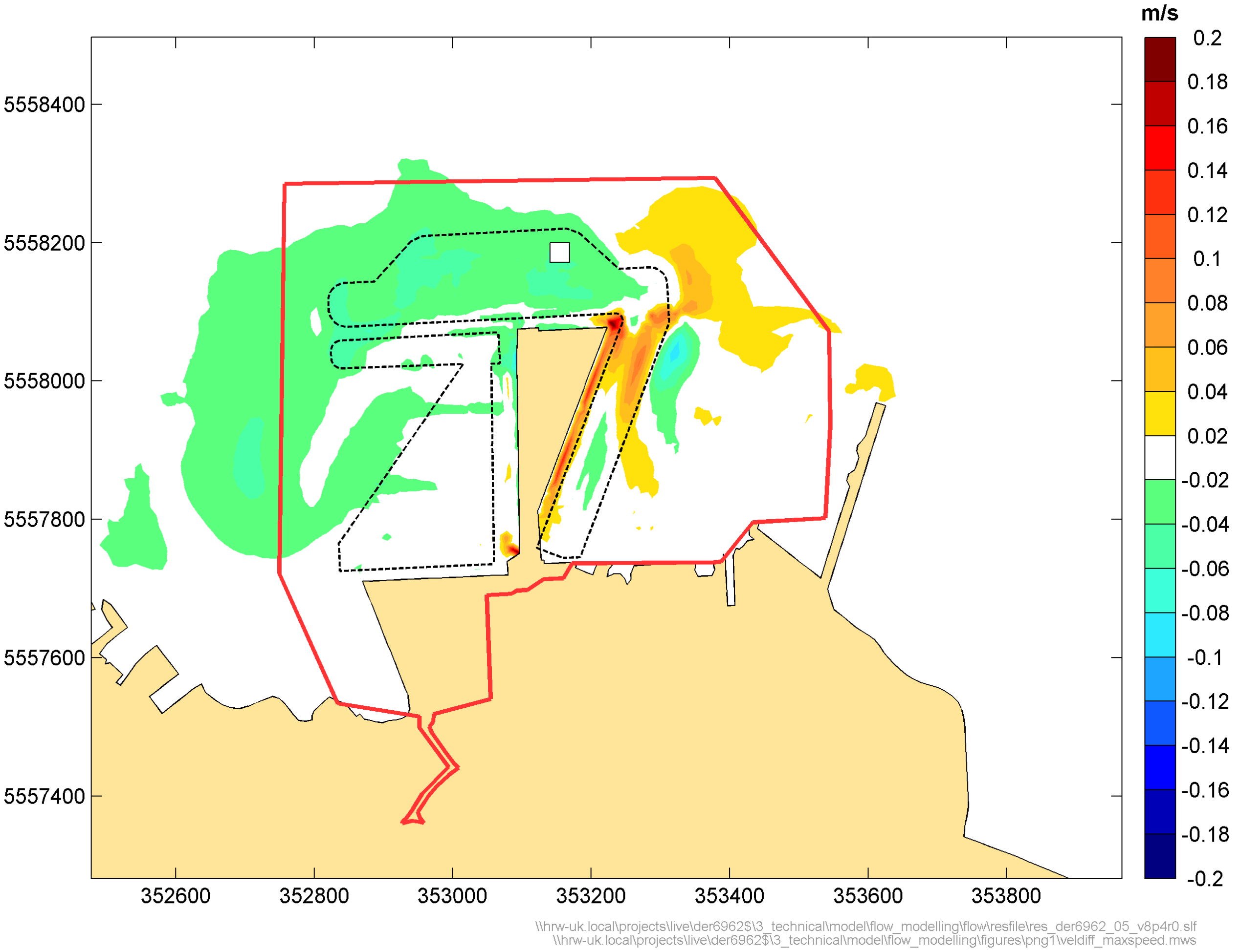



Figure 4.7: Predicted effect of development on maximum current speed

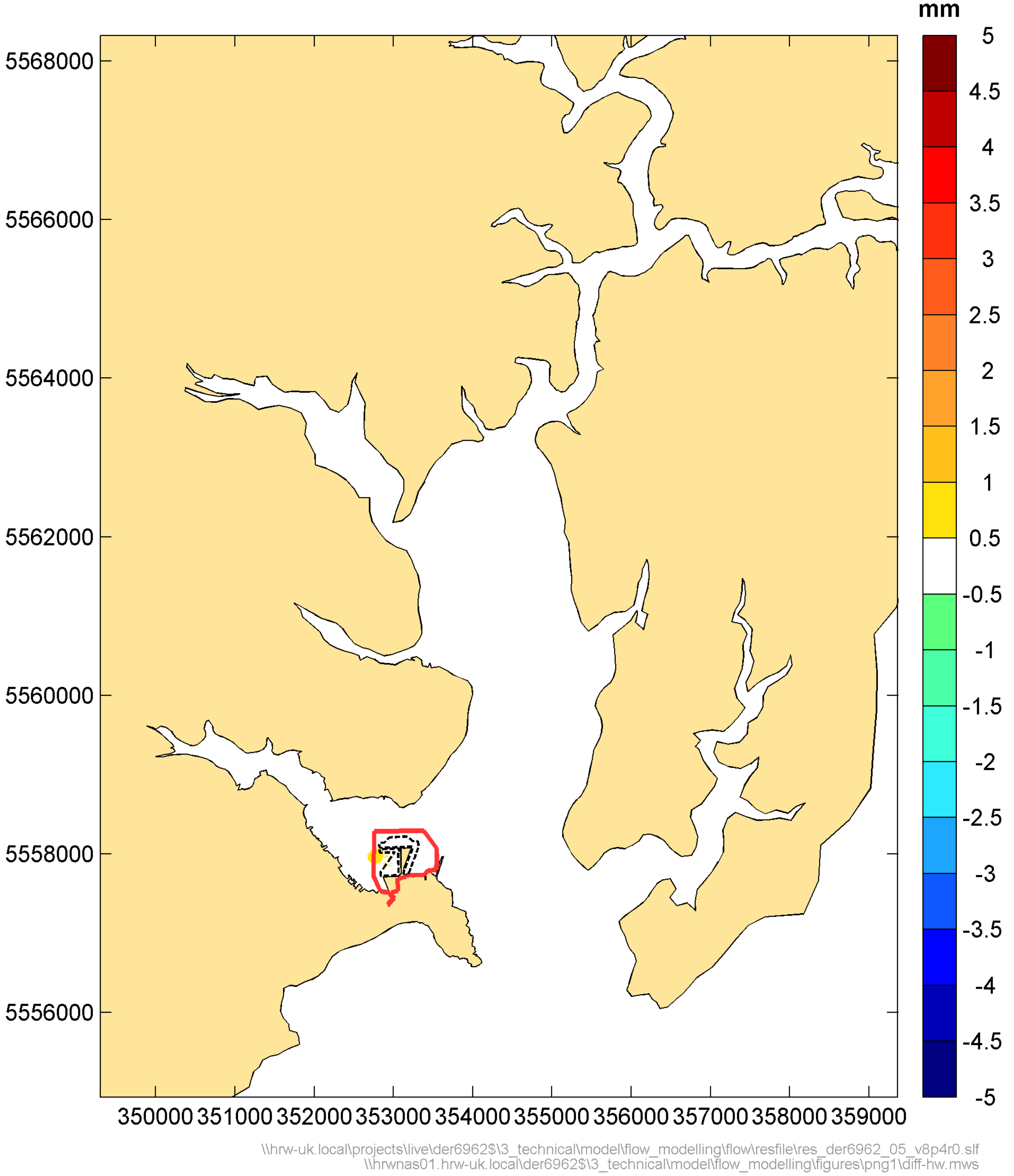



Figure 4.8: Predicted effect of development on maximum water level

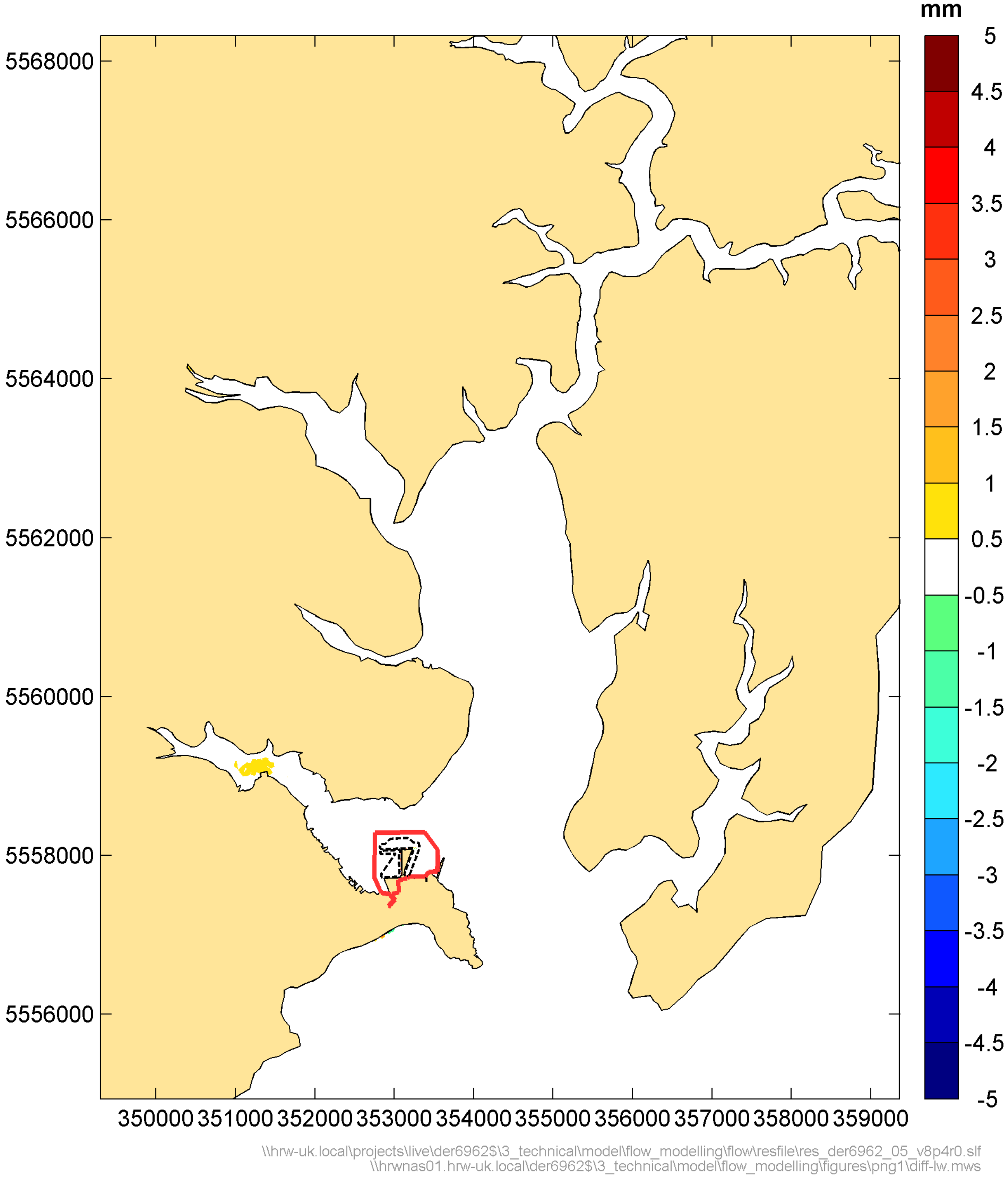



Figure 4.9: Predicted effect of development on minimum water level

# 5 Conclusions

A tidal flow model of Falmouth Harbour has been built to assess the impact of the proposed development on water levels and tidal current speeds. The outputs from the tidal modelling study will be used within the sediment regime and sediment plume modelling studies.

The predicted effects of development are as follows:

- No effect on maximum or minimum water level greater than 1 mm.
- Localised areas of reduction in current speed of up to 0.1 m/s, associated with the increased cross sectional area with the dredging to the north of the development included.
- The change to the shape and dredged depths in the western wharf area alter the slow moving circulation within the wharf area.
- Areas of speed increases of up to 0.16 m/s, for the flow passing the western wharf on both the ebb and flood tide due to the change to the recirculation pattern.
- All changes are of small extent, within 300-400 m of the development site and are transient during the tidal cycle.

# 6 References

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Mutlu Sumer, B. and Fredsøe, J. (2006). Hydrodynamics Around Cylindrical Structures (New edition). World Scientific Publishing Co Pte Ltd, Singapore. ISBN 13: 978-9-81-270039-1.

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