Appendix 7C

DIVAST Modelling Studies

Department of the Marine and Natural Resources

Roinn na Mara agus Acmhainní Nádúrtha

Rossaveel Harbour Development

Final Design Report

Volume 3 – DIVAST Modelling Studies

March 2002

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Rossaveel Harbour Development

Final Design Report: Volume 3 - DIVAST Modelling Studies

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A	November 2001	S Nash	V P Crockett	G J Reilly	First Issue
B	March 2002	S Nash	V P Crockett	G J Reilly	Final Issue

List of Contents

Page

Chapters and Appendices

Figures

1 Introduction

1.1 Background

This document is Volume 3 of the Design Report for the Rossaveel Harbour Development and summarises the hydrographic fieldwork and DIVAST modelling studies carried out. Mott MacDonald commissioned Aqua-Fact as a sub-consultant to carry out this specialist work.

These investigations and model studies have been undertaken with the following aims: -

- to investigate the existing pattern of tidal stream flows in and out of Inner Cashla Bay to provide base data.
- to examine what effects the proposed development (dredging, access causeway and deep water quay) might have on the existing regime.
- to provide information on predicted tidal stream flows (after construction) which could be used as input into ship simulation modelling to confirm the details of the approach and turning basin and safety of berthing.
- to provide detailed information on tidal currents at the proposed berth for refinement of the design and detailing of mooring requirements, etc.
- to provide detailed information on existing and predicted future tidal streams and effluent flows as input into the environmental studies and to support the Environmental Impact Statement.

The primary focus of the study is the proposed deep water quay. This is because the proposed ferry development is remote from the main flows and would not be expected to have any effect on these.

The hydrographic field work was commenced on 11 October 2001 and completed by the end of November 2001. Current measurements are presented in graphical form in Appendix B to this volume.

1.2 Scope of Work

The Scope of Work was as follows :-

1. Drogue studies. Deploy 3 drogues (surface, midwater and off bottom) across the upper part of the bay at HW, HW+3 and at the seaward end of the bay at LW and LW+3 and plot their tracks with DGPS. Present results verbally and graphically.

2. Collect water samples at the proposed deep water quay location for E.coli and total coliform counts. Make suspended solids measurements at the proposed pierage location at HW, HW+3, LW and LW+3. Present and discuss results.

3. Make tidal measurements using Valeport DRC at the proposed deep water quay location and to the west of it at HW, HW+3, LW and LW+3 at surface, midwater and off-bottom. Present data graphically and comment.

4. Deploy a bottom mounted upward looking ADCP (RDI) at proposed deep water quay location and to the west of it for a two week period for each position. Analyse data and present report.

5. Develop a hydrodynamic model of the bay that will predict current speeds and velocities in the area where it is proposed to build the deep water quay.

1.3 Port Development Option Considered

The Deep Water Quay layout, which has been used in this study, is the "L" shaped configuration shown in Figure 13.1 of Volume 1 [(1.1)]. This layout provides an approach causeway at the southern end of the layout, which provides shelter to an inside berthing basin. For ease of reference, a copy of this figure is included in Appendix A to this volume.

1.4 References

(1.1) Mott MacDonald EPO, Rossaveel Harbour Development Design Report, Volume 1, November 2001.

2 Field Work

Details of the hydrographic field work carried out are as follows:-

- ADCP was deployed close to the proposed deep water quay location on 16 October 2001.
- Tidal gauge was deployed close to the proposed deep water quay location on 16 October 2001.
- Tidal gauge was deployed close to existing port on 16 October 2001.
- ADCP and two gauges were recovered on 11 November 2001.
- Data was downloaded from ADCP and the tidal gauges and ADCP were redeployed on 16 November 2001 at a location further west of proposed deep water quay.
- Surface, mid-water and off-bottom drogues were released on the flooding tide at the mouth of Cashla Bay and their movement was tracked with DGPS on 16 November 2001.
- Suspended solid measurements were made at the proposed deep water quay location at HW, HW+3.
- Current measurements were recorded at the proposed deep water quay location at HW, HW+3.
- ADCP was recovered after 30 November 2001 and further drogue and water measurements were carried out on the day of recovery.

3 DIVAST Model Study

3.1 Introduction

Aqua-Fact International Services Ltd., were commissioned by Mott MacDonald to develop a computer model to assess the hydrodynamics of Rossaveel Harbour and the possible effects of a proposed quay on the water circulation patterns of the estuary. The model was used to calculate current speeds and directions within the estuary. For this study two models were developed, one to examine the existing circulation patterns in the harbour, and the other to examine the circulation patterns in the harbour due to the presence of the proposed quay. The first model was calibrated against field measurements of water surface elevations and current magnitude and direction. The second model was then executed using these same parameters to determine the relative effects due to the proposed quay.

The extent of the model study area is presented in Figure 1. The bathymetry defining existing conditions in the harbour is presented in Figure 2 and three-dimensionally in Figure 4. The bathymetry defining the harbour with the inclusion of the proposed quay is presented in Figure 3.

This report details the development, calibration and application of the models developed and conclusions are presented.

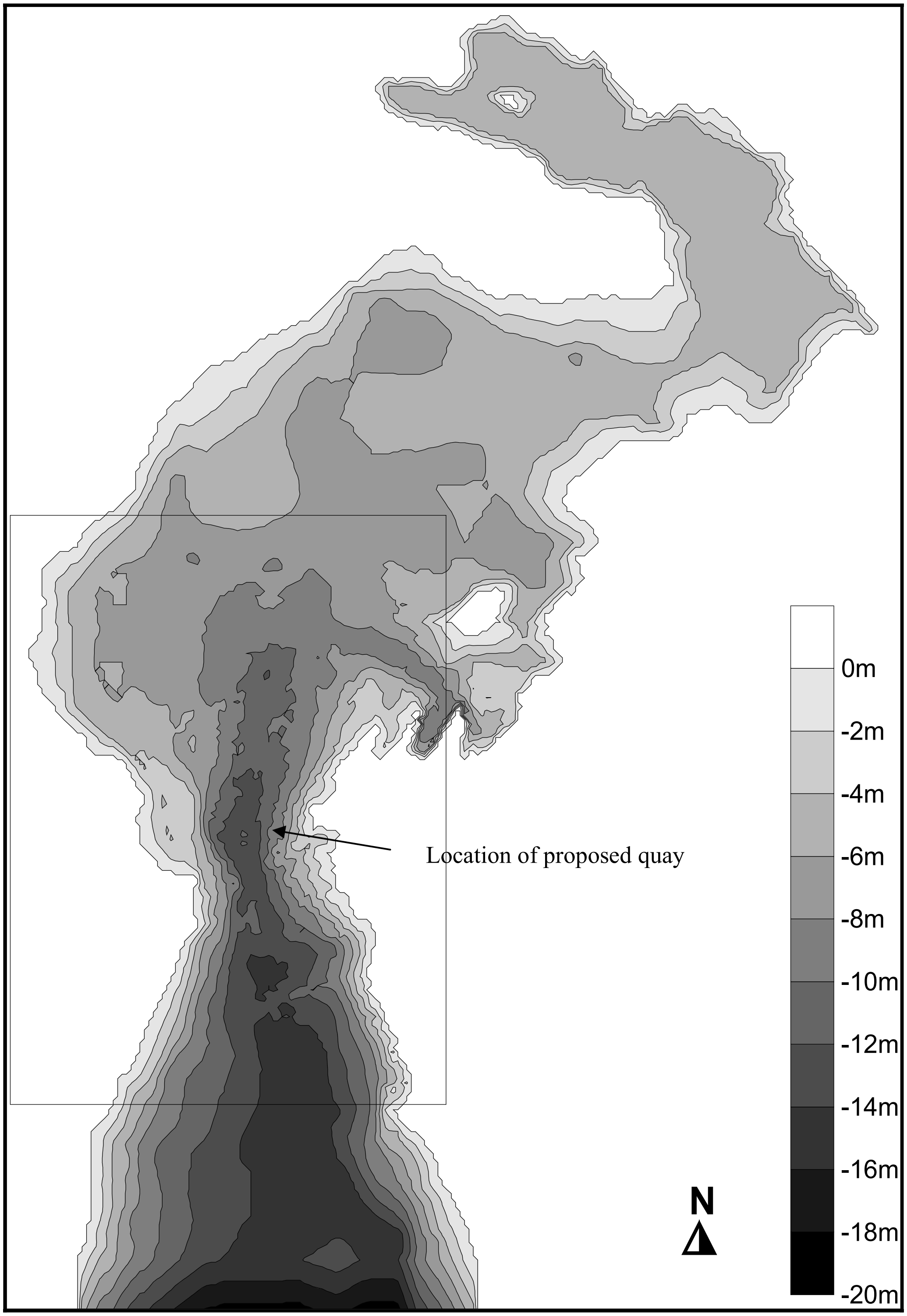


Figure 1: Extent of study area (depths in meters below spring high tide)

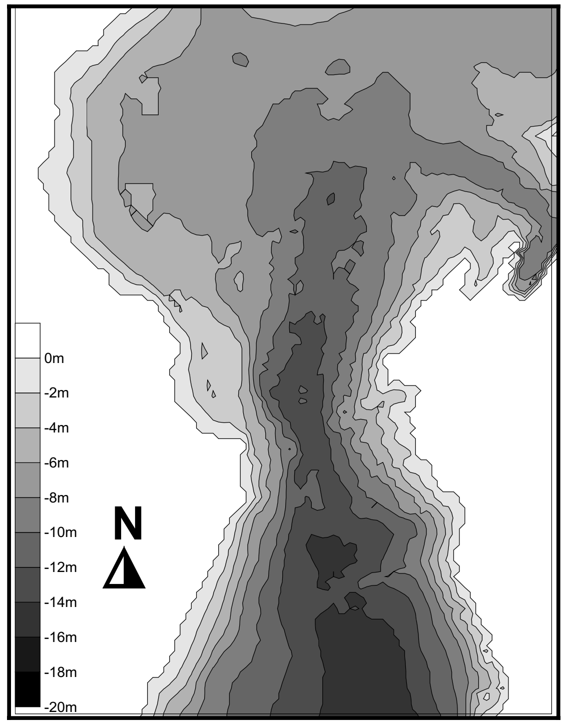


Figure 2: Existing bathymetry of Rossaveel Harbour

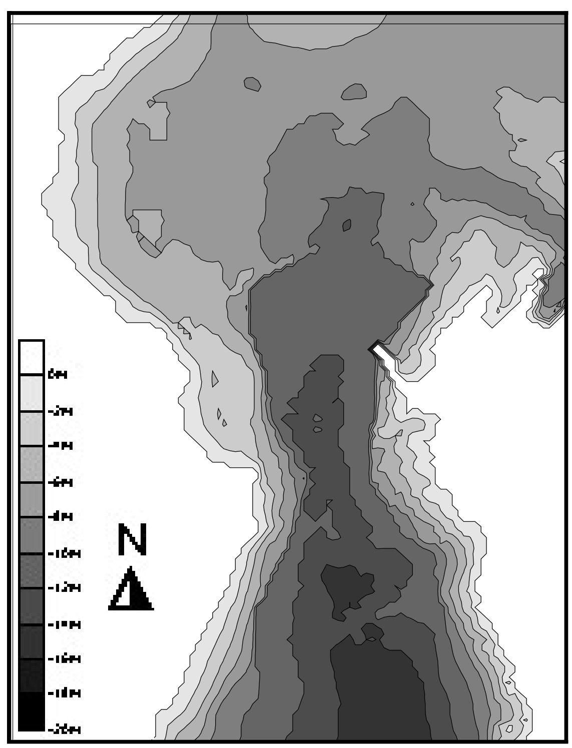


Figure 3: Bathymetry of Rossaveel Harbour

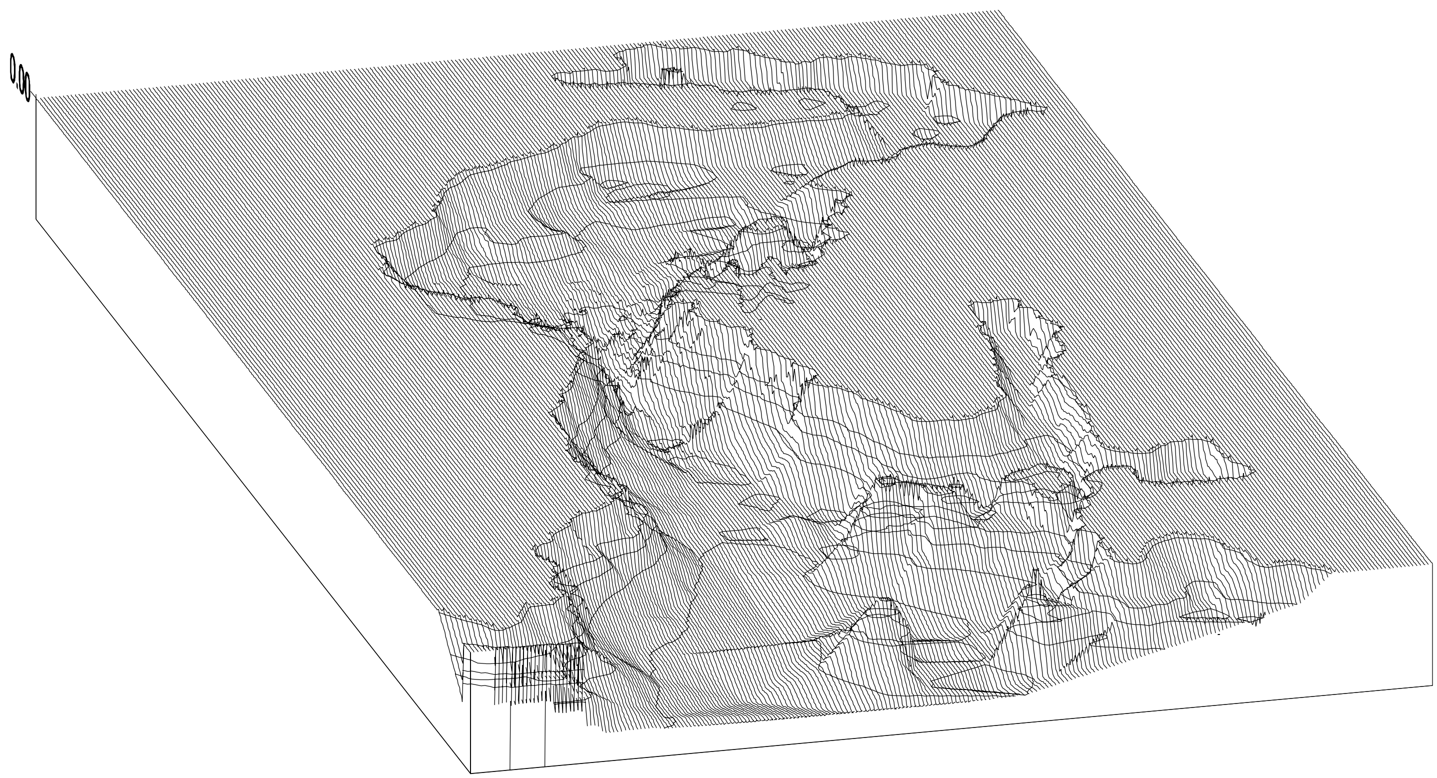


Figure 4: Three-dimensional bathymetric view of model study area

4 MODEL STUDY

4.1 Model Background

The type of model used in this study, DIVAST, is amongst the best tools available for the modelling of hydrodynamic conditions within a coastal environment. The mathematical formulation of the model is based on the Navier-Stokes equations that describe variations in current speeds and directions. DIVAST uses an implicit finite difference scheme to solve the Navier-Stokes equations for unsteady flow conditions. The finite difference technique is the most common method employed to solve these equations and is ideally suited for total water quality management of a water body as well as evaluating individual problems.

The computer model DIVAST was used to carry out a study of Rossaveel Harbour to examine the hydrodynamic patterns of the estuary and to assess the possibility of alterations in these patterns due to the construction of a quay. The model DIVAST was developed by Professor Roger Falconer at the University of Bradford about 17 years ago and is extended and upgraded on an ongoing basis. The model is widely used in Ireland and the U.K. for many different types of hydro-environmental studies in coastal waters such as sewage effluent discharges, oil spill modelling, aquaculture assessment and water quality management planning. The model has been used to date on more than 200 such studies throughout Ireland and the U.K. and has proven it to be a reliable tool for such analyses. DIVAST is an industry standard package for water quality model studies.

4.2 Model Development

The model study was carried out by developing a model capable of simulating the water circulation patterns within Rossaveel Harbour. This was performed in three stages:

The first stage consisted of developing a water circulation model of the estuary to compute the hydrodynamic patterns and tidal elevations within the estuary for prescribed environmental conditions.

The second stage in the study was the calibration of this hydrodynamic model against field data.

The third stage of the study consisted of the development and application of a second model to simulate the hydrodynamic regime throughout Rossaveel Harbour due to the proposed quay and dredging works.

The finite difference model of Rossaveel Harbour was developed by overlaying a grid on top of the relevant Admiralty Chart. The grid had equal spacing of 15m x 15m in two orthogonal directions. In total, 59,590 grid points were used to define the model. At each grid point the water depth at that location is identified to the model using the bathymetric data from the Admiralty Chart.

The topography of the area is defined by specifying land boundaries, which delineate the extent of the water body. At the southern limit of the model, a water elevation boundary is specified. This boundary condition is the main forcing function that induces circulation in the water body. The water currents that are observed in coastal waters are induced by many different forces. In the model employed for this study the following significant forcing functions were incorporated into all simulation runs of the hydrodynamic model:

- Tide elevations
- Coriolis effect

The Coriolis force induces water currents due to the fact that the water body is on the surface of a rotating globe. The force is a function of the latitude of the water body and the rotational velocity of the earth, in this case considered to be 53.3^{o} and 400 m/s respectively.

The calibration of the hydrodynamic model is presented in Section 5. The various model simulations and their results are presented in Section 6. Conclusions based on the model study are drawn and presented in Section 7.

5 MODEL CALIBRATION

5.1 Background

Calibration of computer models is an important aspect of any hydrodynamic study. Only when a model is calibrated will confidence be gained in model results and can decisions be made on them. Details of this calibration exercise are presented in this chapter.

5.1.1 Hydrodynamic Model Calibration

The hydrodynamic model was calibrated by comparing model predictions against field measurements of current speeds and directions for given environmental conditions.

When running the model tidal elevations were specified at the southern open sea boundary commensurate with measured tidal dynamics. For the calibration simulations the tidal elevations as measured on the day when the hydrographic survey was carried out were specified to the model.

Wind blowing over the surface of a large body of water will transmit some of its energy to the water, thereby, inducing currents. The induced water circulation is a function of the wind speed, direction and transfer coefficient. Again during the simulation the prevailing wind conditions were defined to the hydrodynamic model.

5.1.2 Hydrodynamic Model Calibration Results

The hydrodynamic model was calibrated by comparing current velocities and directions as calculated by the model against field measurements for the same parameters recorded by Aqua-Fact International Services Ltd.

The location of the current meters (CM) against which the model was validated is presented in Figure 5. Figure 6 presents the results of current measurements over a three day period, after a spring tide, as recorded by the CM deployed at location A. Figure 7 presents the recorded direction of the tide over the same period at this location. Figure 8 presents the results of current measurements over a three day period, after a spring tide, as recorded by the CM deployed at location B. Figure 9 presents the recorded direction of the tide over the same period at this location. Superimposed on these readings are the current velocities as calculated by the hydrodynamic model at the same location for the same environmental conditions.

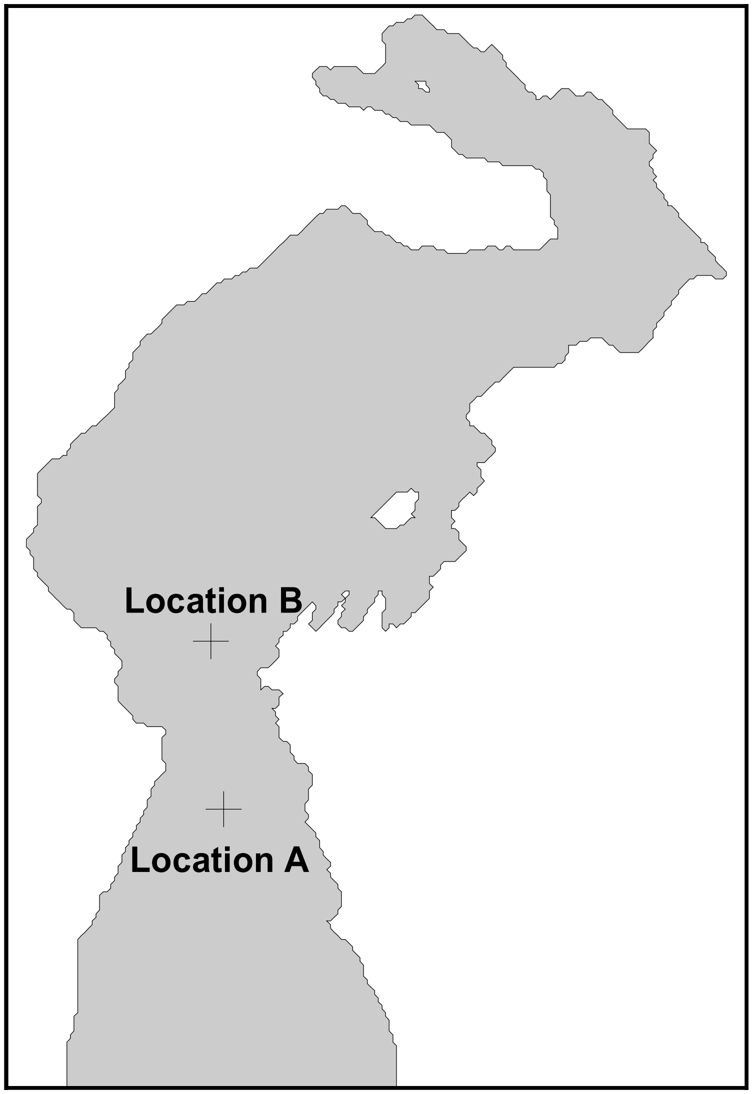


Figure 5: Locations of current meters used in model calibration.

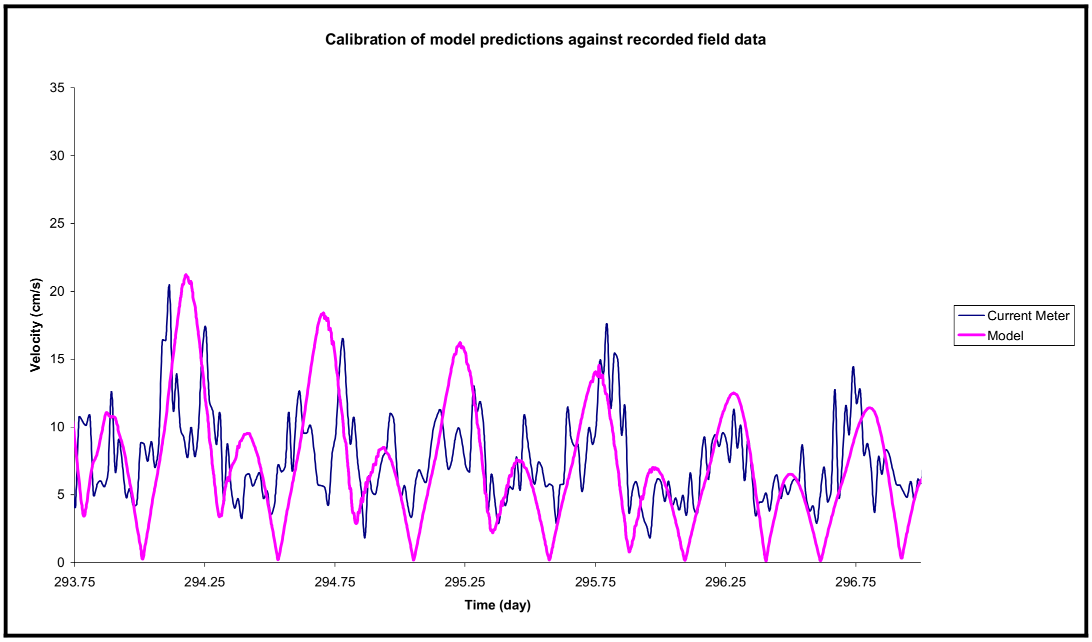


Figure 6: Comparison of velocities calculated by model against recorded velocities in the field at Location A.

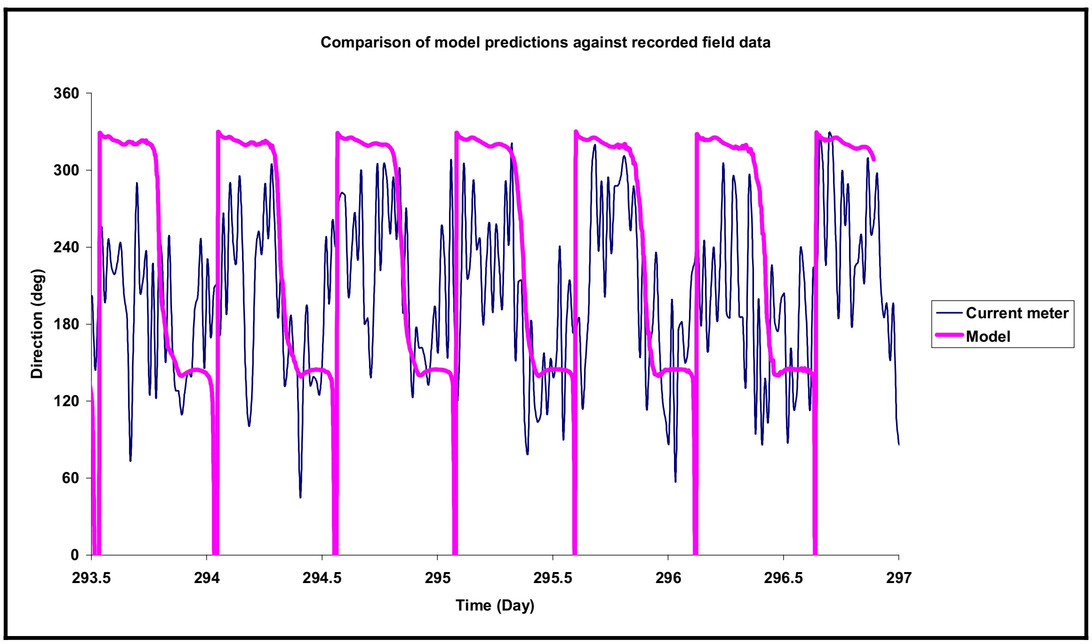


Figure 7: Comparison of current direction calculated by model against recorded current direction in the field at Location A.

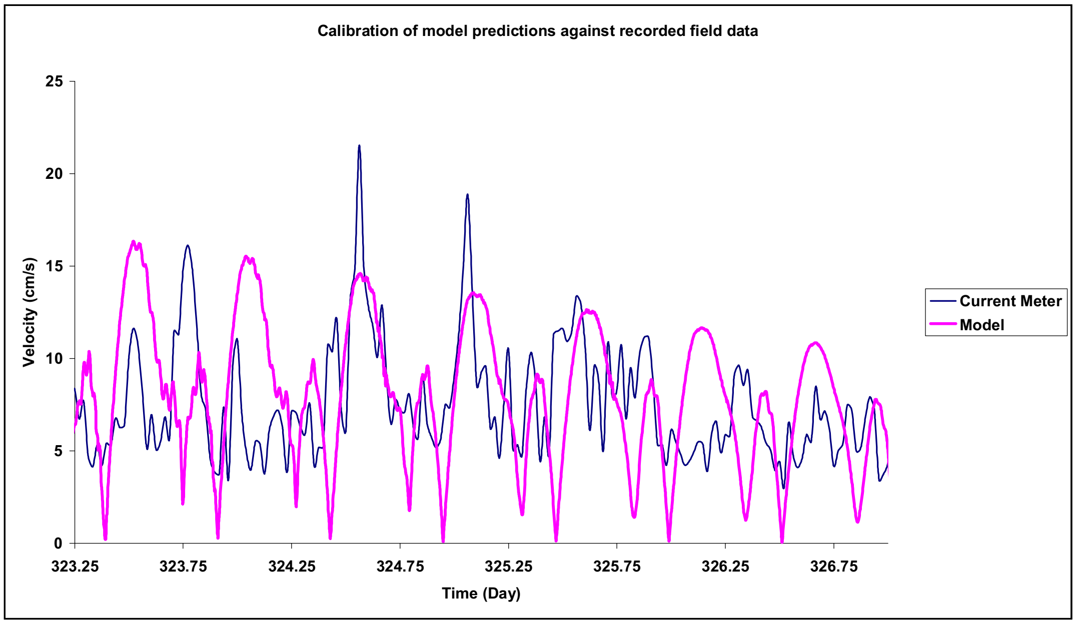


Figure 8: Comparison of velocities calculated by model against recorded velocities in the field at Location B.

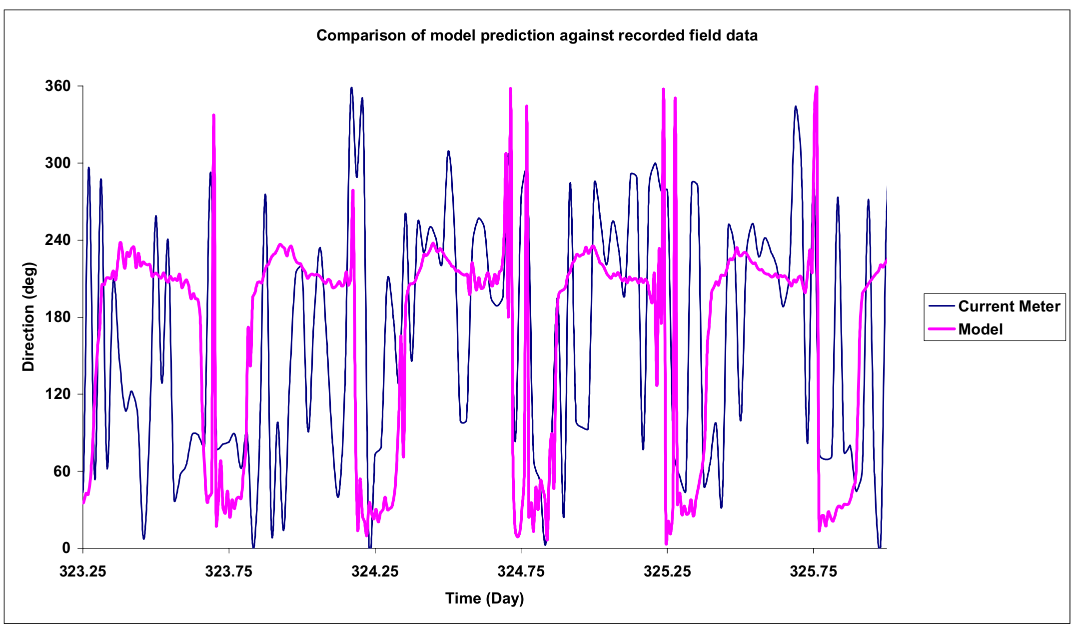


Figure 9: Comparison of current direction calculated by model against recorded current direction in the field at Location B.

The hydrodynamic model was validated against data recorded during the hydrographic survey. The model results agreed quite well with the field data. At Location A the model predicted values commensurate with the recorded data. The model accurately predicts the maximum velocities reached on both the ebb and flood tides and the differences between the ebb and flood velocities. The directions of the flooding and ebbing tides were also produced accurately. In general, at Location B, the current meter data shows that the current regime during this period is quite confused. This is most likely due to gusting of local winds. The record shows that during three occasions current speeds are about twice ambient magnitudes. This is due to the local wind effects. The model generally reproduced the measured data quite well during average conditions, but does not predict the above gust-induced wind peaks.

6 MODEL SIMULATIONS AND RESULTS

6.1 Introduction

The validated hydrodynamic model was used to predict water circulation patterns for the present situation in Rossaveel Harbour. These results are presented in Figure 11 to Figure 18. In accordance with the design specifications, the bathymetry of the model was altered to account for the proposed quay and associated dredging works. This model was then used to predict water circulation patterns with the proposed quay in place. The results from simulation one, (no quay), and simulation two, (quay), are then compared. The results in this chapter are presented in three different formats.

The current velocities from simulation one are presented as contoured snapshots in time taken at four stages of both a neap and spring tide. The stages of the tide at which the velocities are presented correspond to mid flood, high water, mid ebb and low water. These snapshots are presented in Figures 11 through Figure 18

The differences in current velocity between simulation one and simulation two over time are presented as time series plots at a number of locations throughout the domain. The locations at which these time series graphs are calculated are presented in Figure 10. The time series graphs are presented in Figure 19 through Figure 22.

The differences in current velocity between simulation one and simulation two over the entire study area are presented as snapshots in time at four stages of both a neap and spring tide. The stages of the tide at which the velocities are presented correspond to mid flood, high water, mid ebb and low water. These snapshots are presented in Figure 23 through 30.

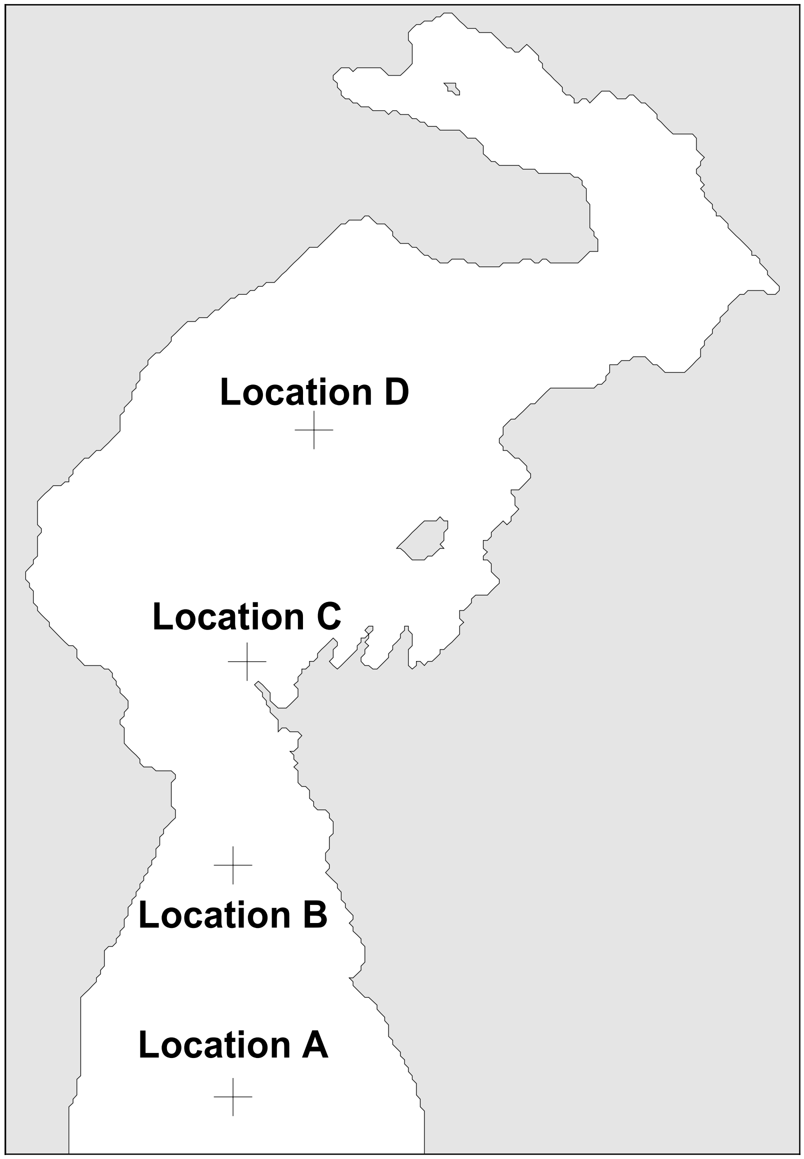


Figure 10: Location of time series graphs

6.2 Existing hydrodynamic regime

This section presents the simulation executed to determine the current hydrodynamic regime in Rossaveel Harbour. The results of this simulation are presented as vector plots of the current produced at four stages of a spring tide. These plots are presented in Figure 11 to Figure 14. The results are also presented in Figure 15 to Figure 22 as contour plots of the current velocities at the same four stages of the tide for both spring and neap conditions.

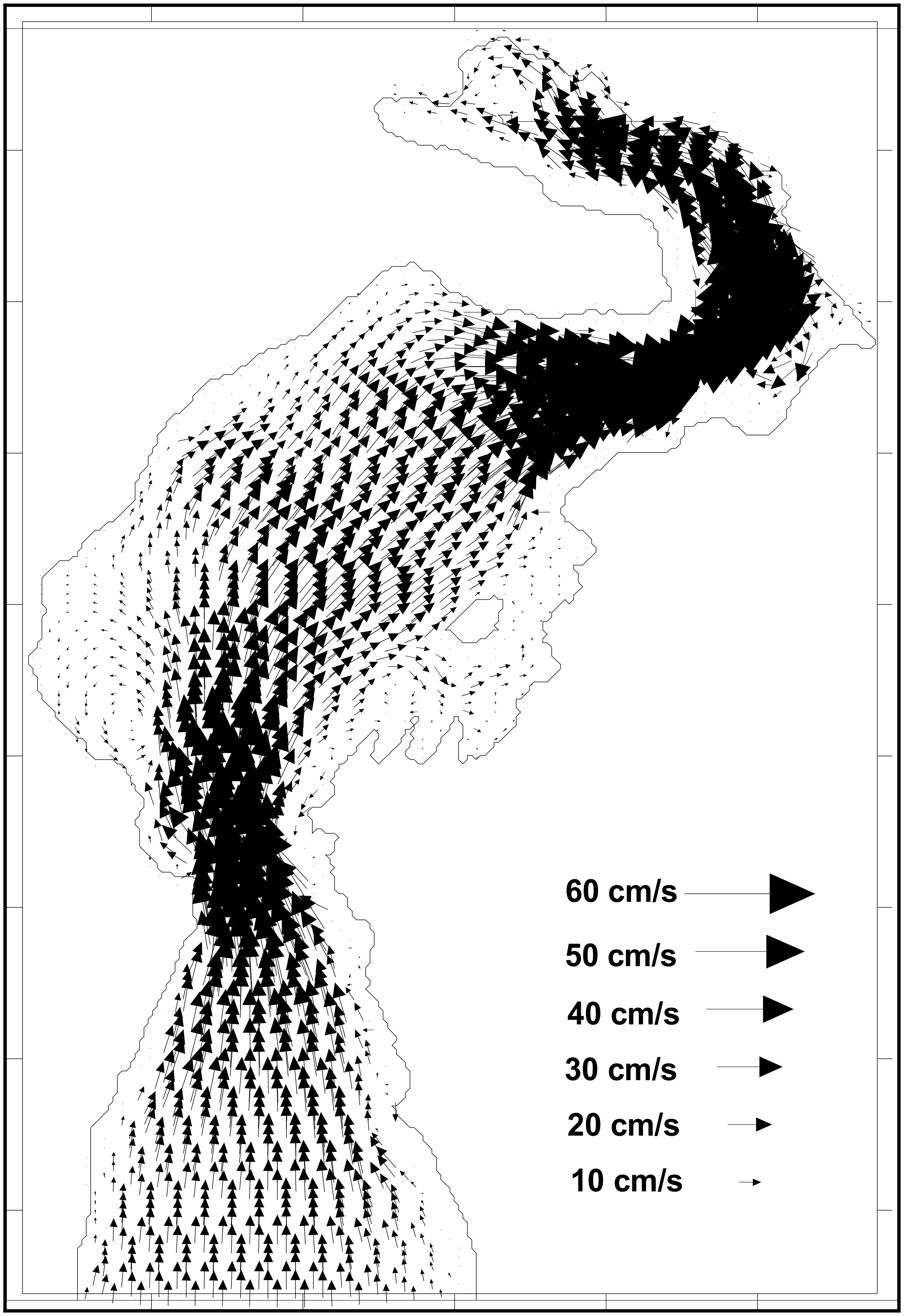


Figure 11: Hydrodynamic regime at mid flood on spring tide.

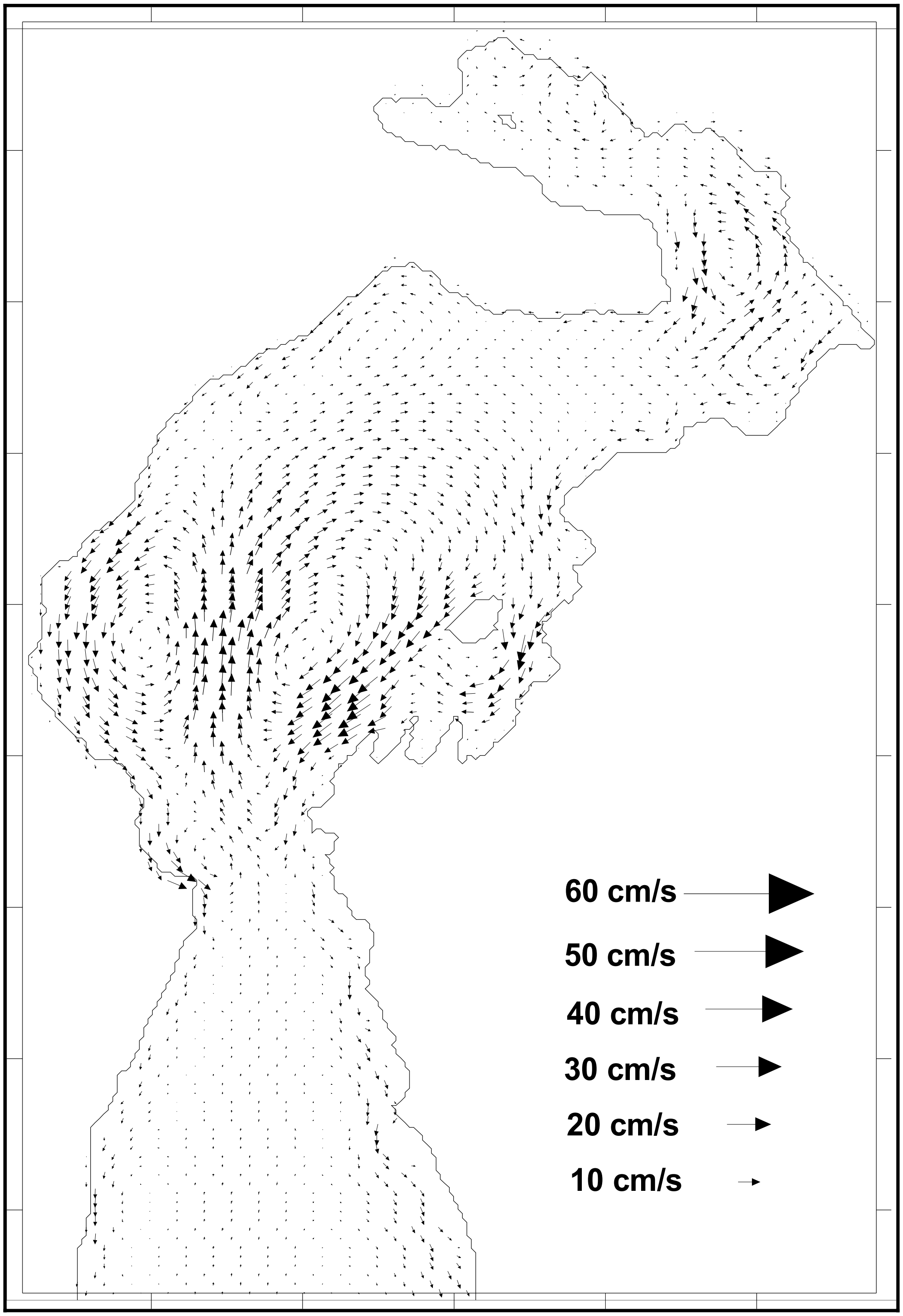


Figure 12: Hydrodynamic regime at high water on spring tide.

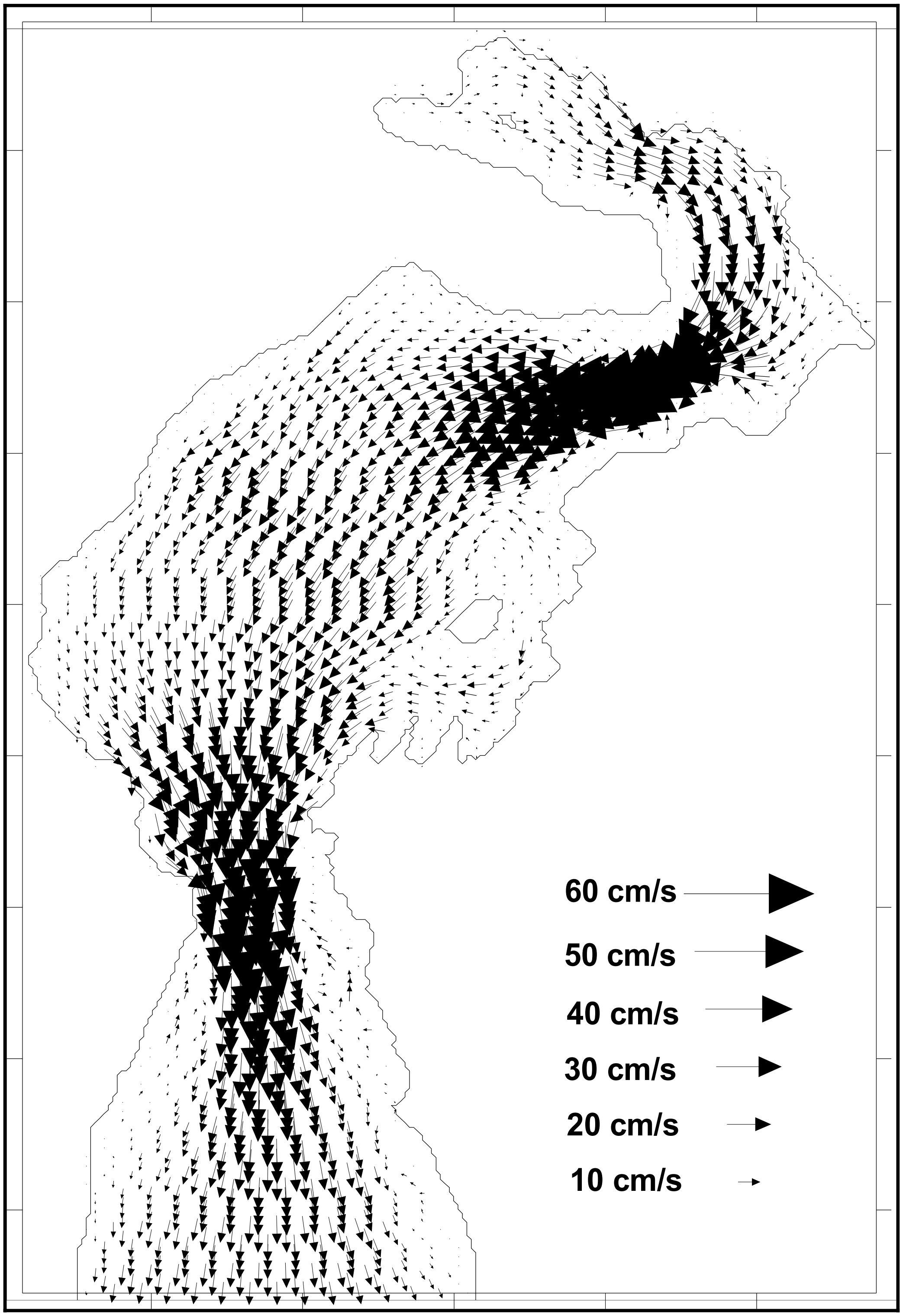


Figure 13: Hydrodynamic regime at mid ebb on spring tide.

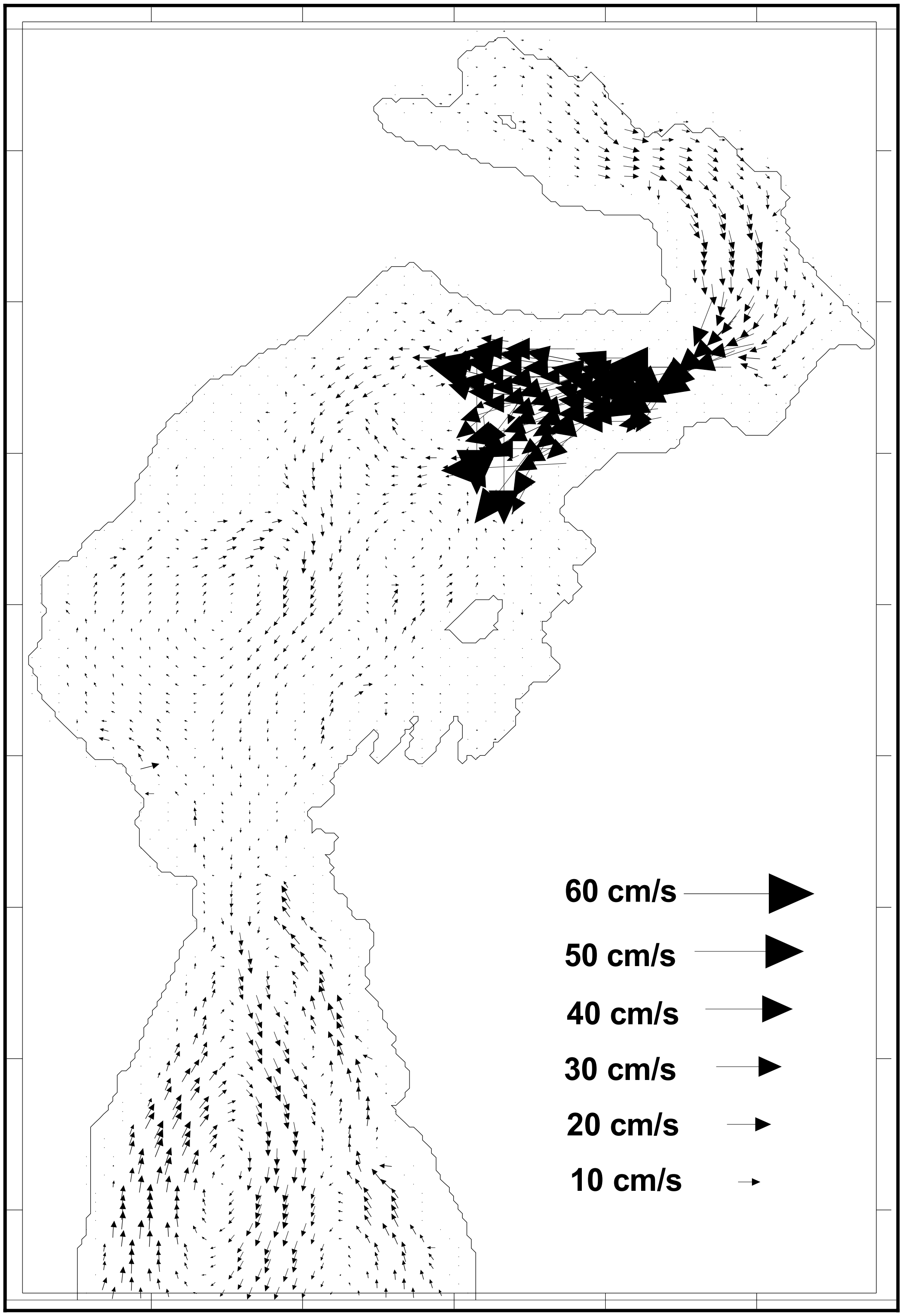
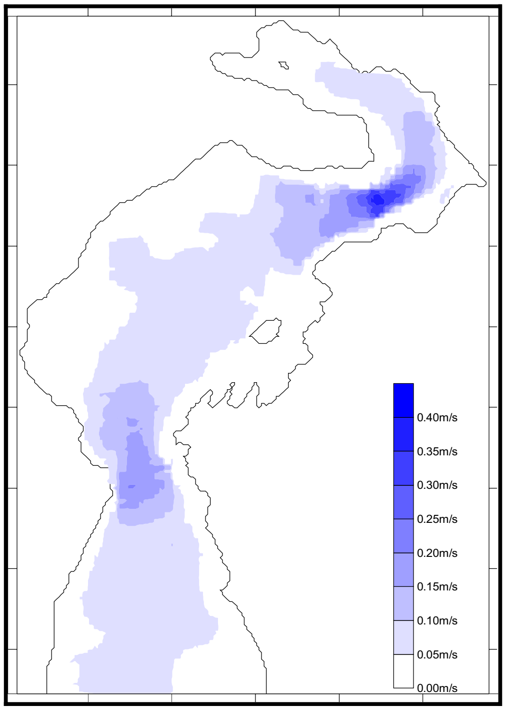


Figure 14: Hydrodynamic regime at low water on spring tide.

Figure 15 to Figure 18 present contour plots of current velocities at four stages of the tide as calculated by the model for a neap tide for existing conditions as modelled for simulation one.



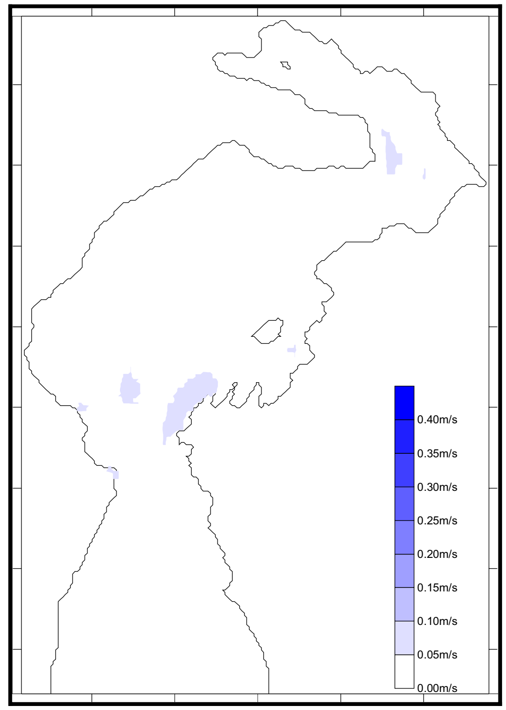
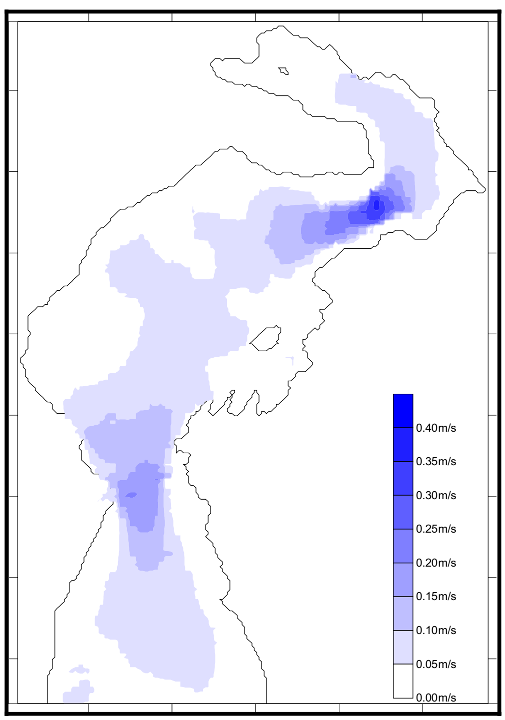


Figure 15: Neap Tide Mid Flood

Figure 16: Neap Tide High Water



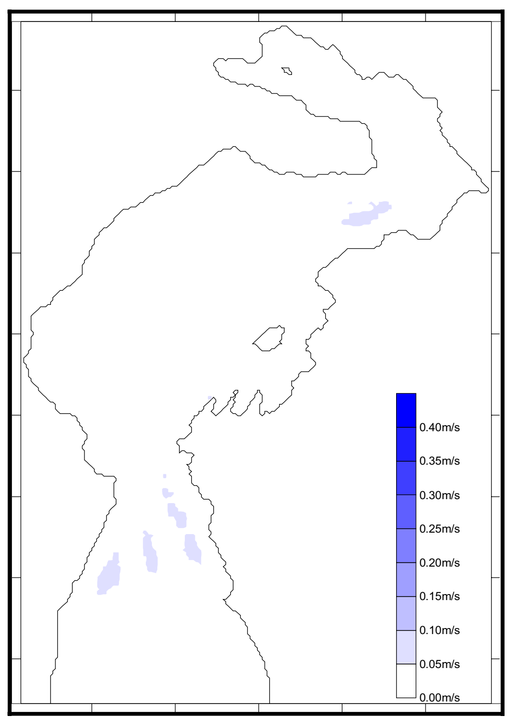


Figure 17: Neap Tide Mid Ebb

Figure 18: Neap Tide Low Water

Figure 19 to Figure 22 present the current velocities at four stages of the tide as calculated by the model for a spring tide for existing conditions as modelled for simulation one.

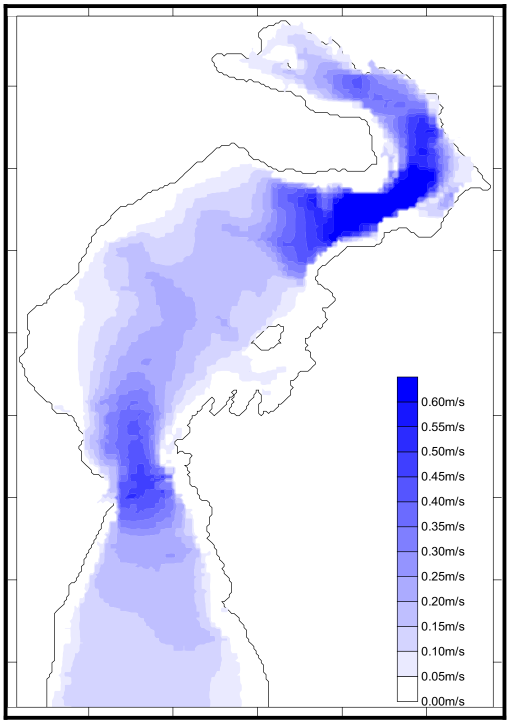


Figure 19: Spring Tide Mid Flood

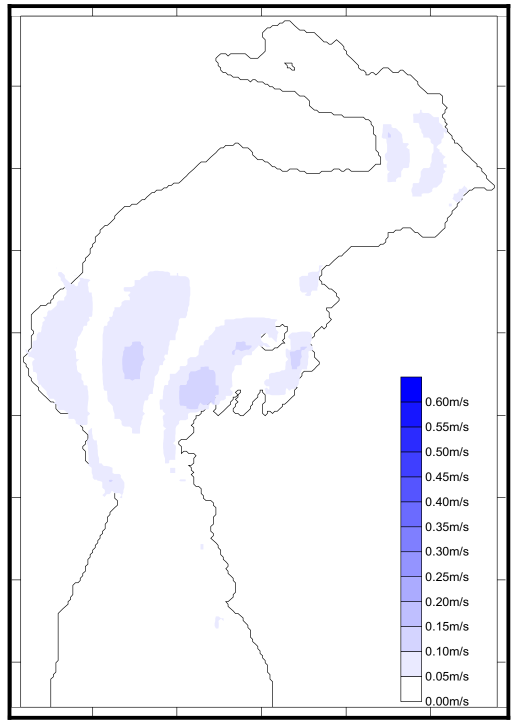


Figure 20: Spring Tide HighWater

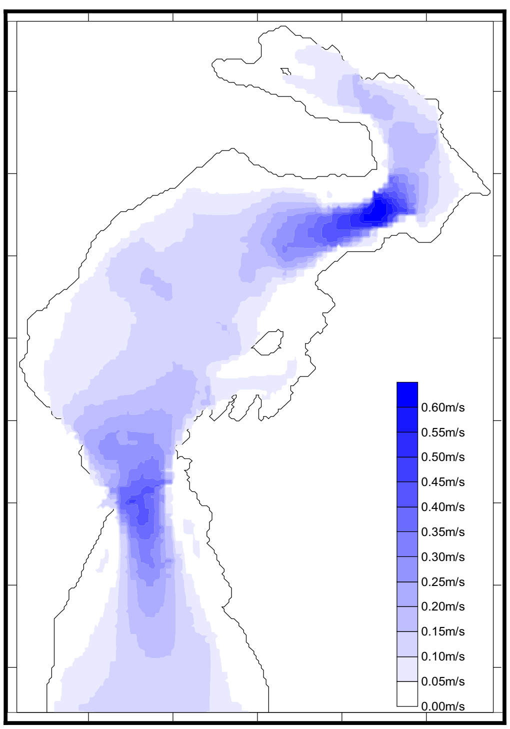


Figure 21: Spring Tide Mid Ebb

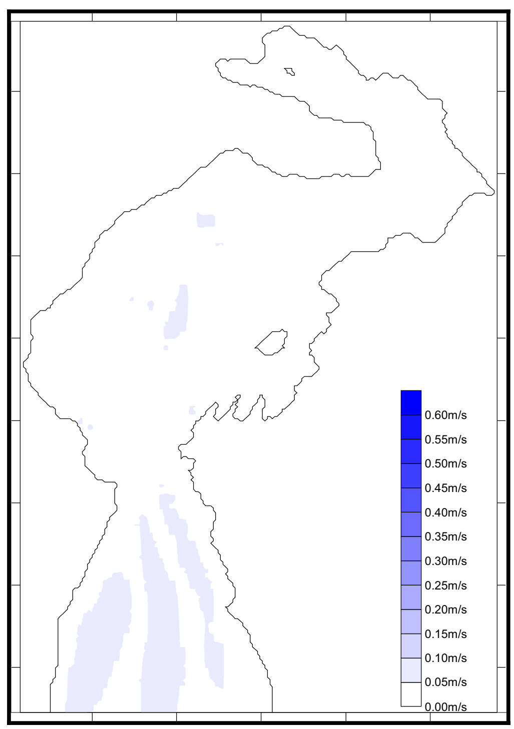


Figure 22: Spring Tide Low Water

Figure 15 to Figure 18 show that the maximum current velocity in simulation one over the study area for a neap tide occurs at both the mid flood and mid ebb stages of the tide, reaching a maximum of 0.4m/s at the head of the harbour. At both high and low water the maximum current velocity is in the range 0.05 – 0.1 m/s (5-10 cm/s).

Figure 19 to Figure 22 show that the maximum current velocity in simulation one over the study area for a spring tide occurs at both the mid flood and mid ebb stages of the tide, reaching a maximum of 0.6m/s at the head of the harbour. At high water the maximum current velocity is in the range 0.10 – 0.15 m/s (10-15 cm/s). At low water the maximum current velocity is in the range 0.05 – 0.10 m/s (5-10 cm/s).

6.3 Comparison between hydrodynamic regimes for existing and proposed scenarios

This section compares the magnitude of the currents as calculated in simulation two against the current magnitudes calculated in simulation one, as presented in the previous section.

Figure 23 to Figure 26 present time series plots of the current velocities over a 140 hour period covering the range from neap tides to spring tides. These figures present the difference as calculated by model between simulation one and simulation two.

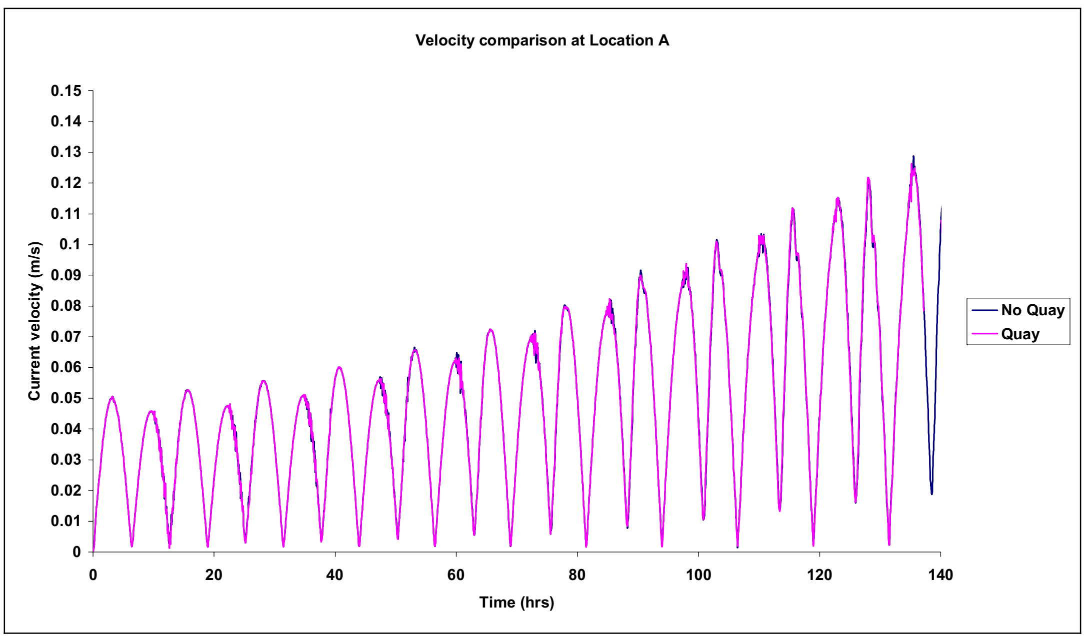


Figure 23: Comparison of current velocities at Location A.

At location A, as presented in Figure 23, it can be sent that there is virtually no difference between both simulations.

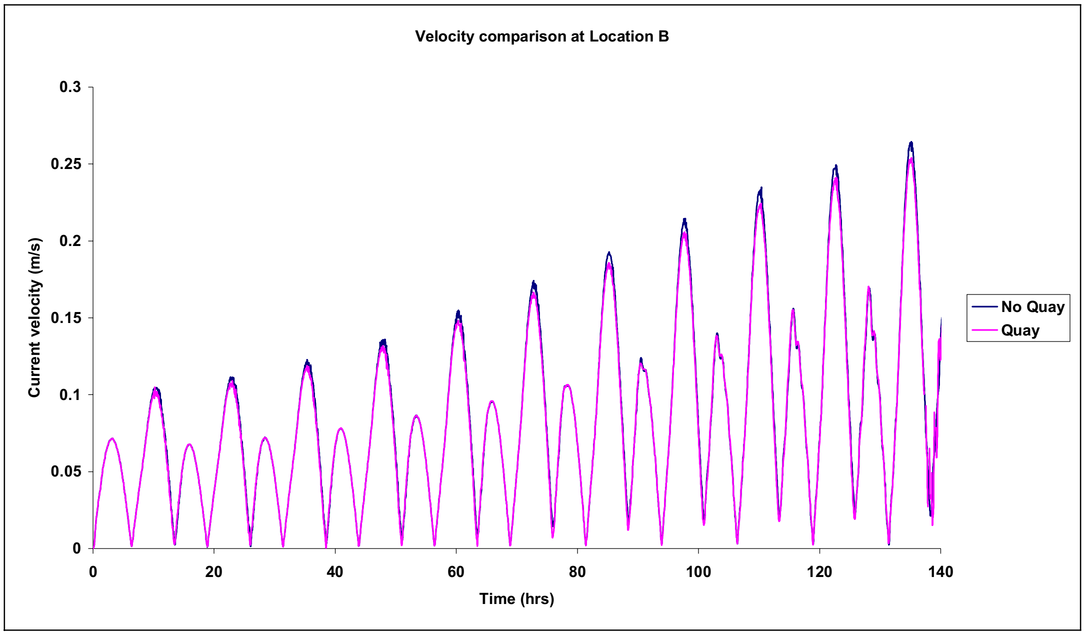


Figure 24: Comparison of current velocities at Location B.

At location B, as presented in Figure 24, it can be sent that whilst there is a difference between both simulations approaching spring tides (80hr-140hr) it is very small.

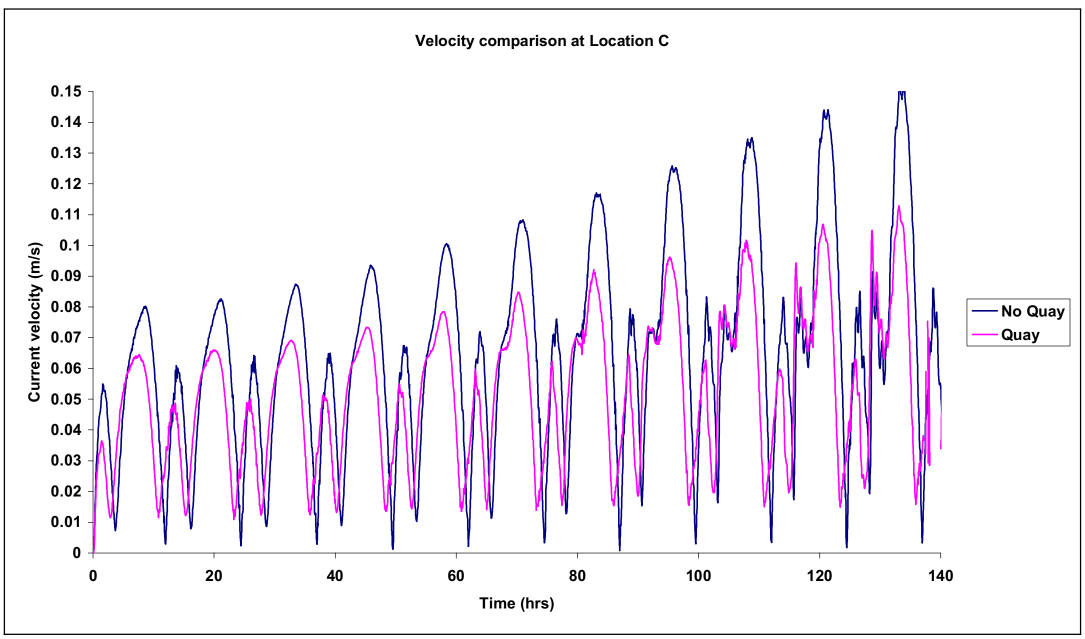


Figure 25: Comparison of current velocities at Location C.

At location C, as presented in Figure 25, it can be sent that there is a noticeable difference between both simulations. Location C is situated just offshore at the location of the proposed quay and therefore it is to be expected that this location will show the greatest difference between both simulations. The maximum difference between both simulations occurs over a spring tide, (135hr), and is approximately 0.05m/s, (5cm/s).

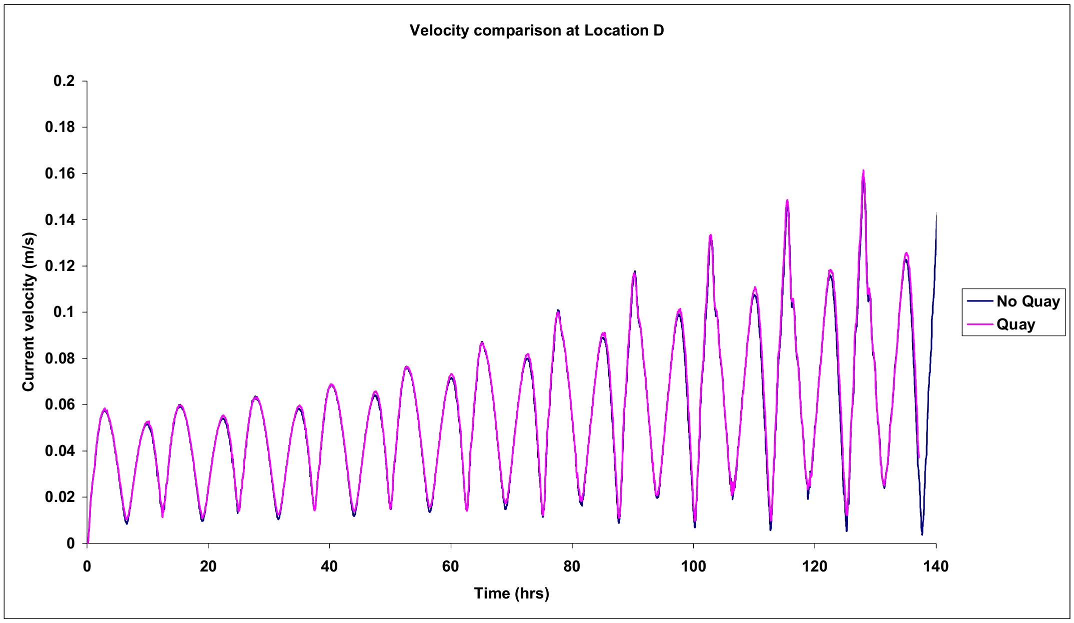


Figure 26: Comparison of current velocities at Location D.

At location D, as presented in Figure 26, it can be seen that there is no difference between both simulations.

Figure 27 to Figure 30 present the differences in current magnitude at four stages of a neap tide. These figures show that the greatest difference in current velocities in the study area over a neap tide occurs at both the mid flood and mid ebb stages of the tide in the vicinity of the proposed quay

A positive difference indicates the current velocity with no quay is greater, whereas, a negative difference indicates the current velocity with the quay present is greater.

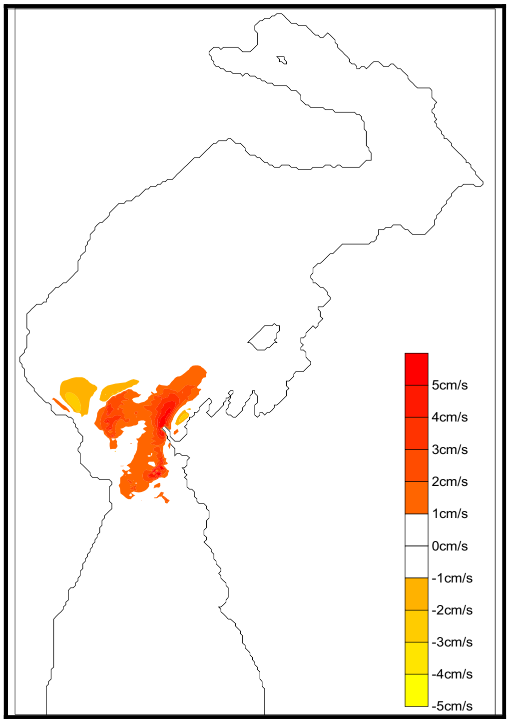


Figure 27: Neap Tide Mid Flood

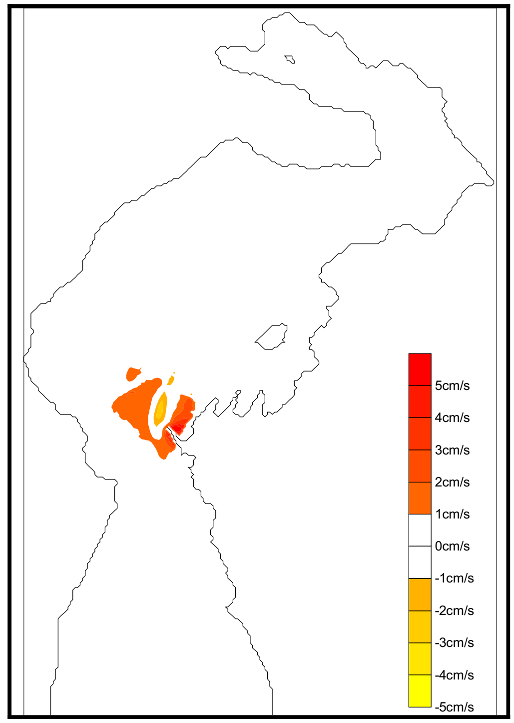


Figure 28: Neap Tide High Water

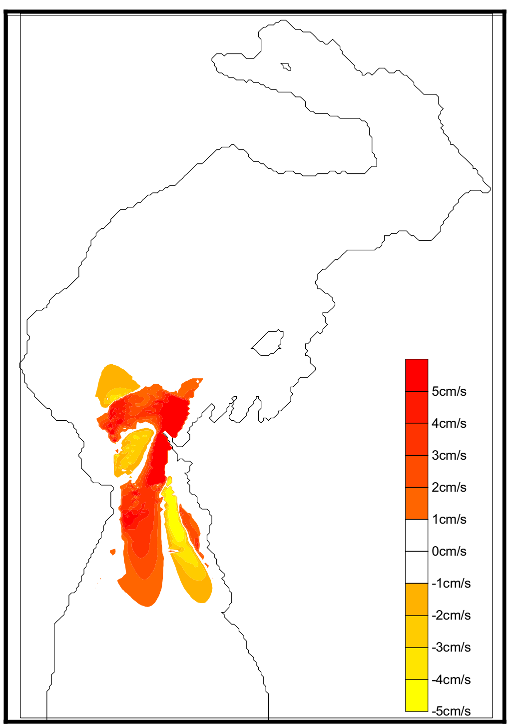


Figure 29: Neap Tide Mid Ebb

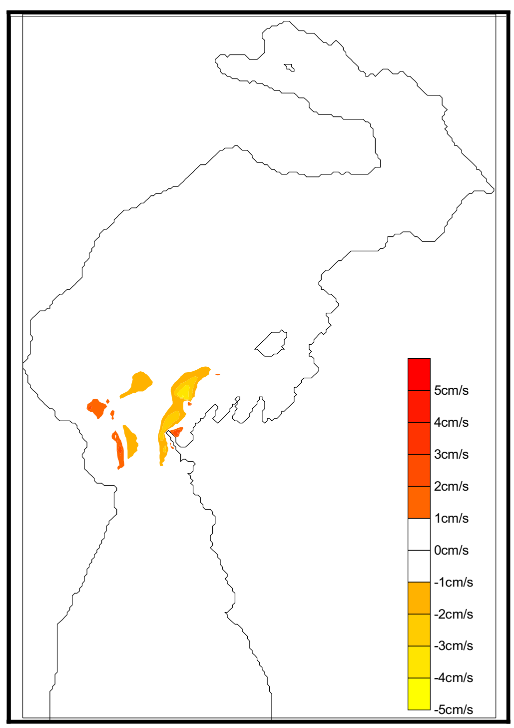
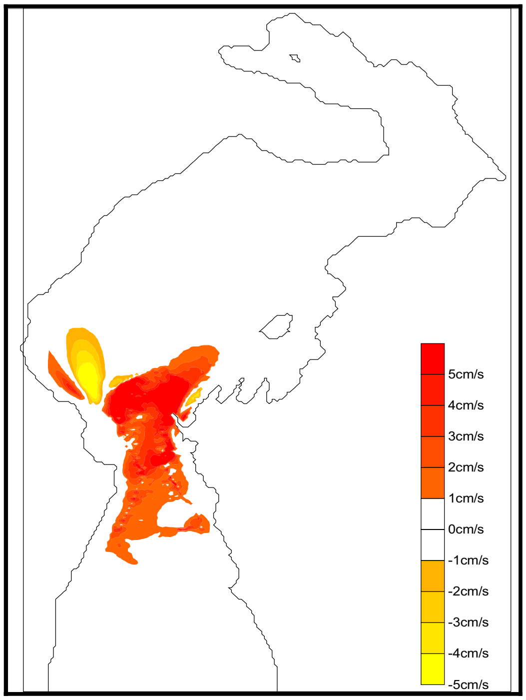


Figure 30: Neap Tide Low Water

The maximum difference between simulation one and simulation two over a neap tide is between 4-5 cm/s and occurs on an ebbing tide.

Figure 31 to Figure 34 present the current velocities at four stages of a spring tide.



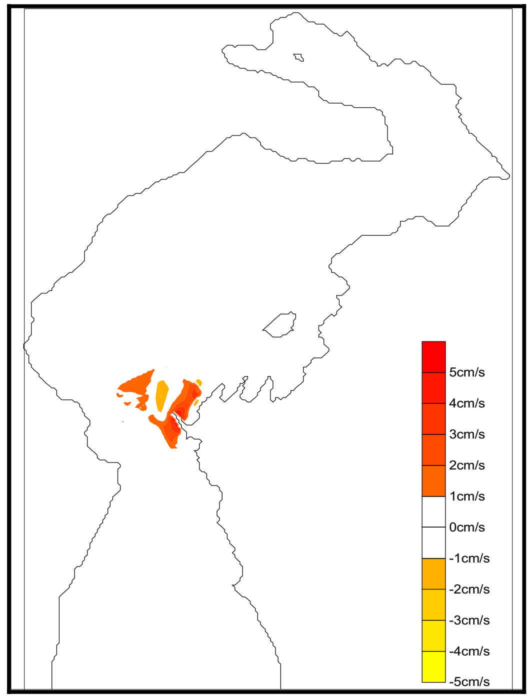
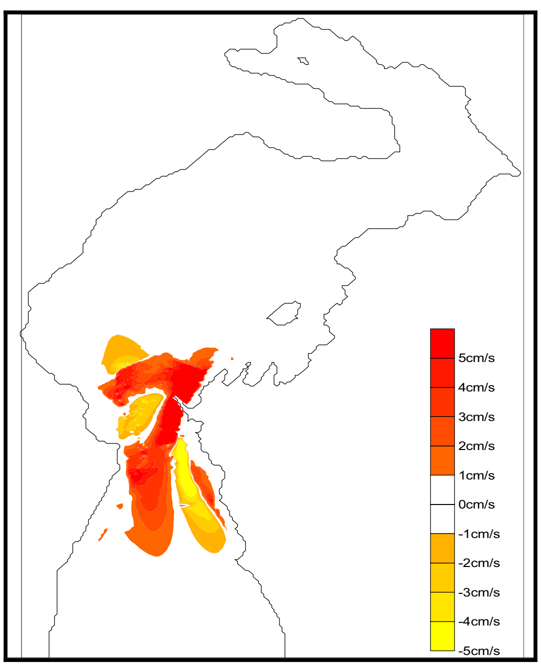


Figure 31: Spring Tide Mid Flood **Figure 32: Spring Tide High Water**



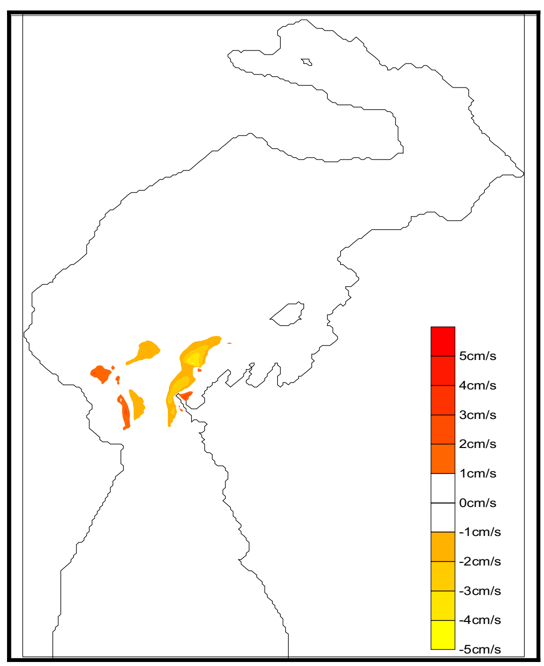


Figure 33: Spring Tide Mid Ebb **Figure 34: Spring Tide Low Water**

Figure 27 to Figure 29, previous, show that the maximum difference in current velocity in the study area over a spring tide occurs at both the mid flood and mid ebb stages of the tide in the vicinity of the proposed quay. The maximum difference between simulation one and simulation two over a spring tide is between 4-5 cm/s and occurs on both an ebbing and flooding tide.

7 SUMMARY AND CONCLUSIONS

In this chapter the results presented previously are summarised and commented upon. Conclusions are then drawn based on these results.

As shown in Section 5, the numerical model used in this study was calibrated against available field data, showing that the model can simulate the existing hydrodynamic regime in the harbour. The model was then used to simulate the impacts of the proposed quay and associated dredging in the harbour.

The time series plots presented in Figures 23 to 26 show that there is virtually no difference in the magnitude of the calculated currents at three locations, (A,B,D), but there is a reasonable significant difference in the vicinity of the proposed quay.

The time series plots show that at Location C, the velocities calculated in simulation two will be approximately 5cm/s less than the velocities calculated in simulation one on a spring tide.

The snapshots in time showing the difference in velocity magnitude as presented in Figures 27 to 30 show that, as with the time series plots, there is no difference in the magnitude of the calculated currents except in the vicinity of the proposed quay development.

The snapshots show that over a spring tide, at high and low water there is very little difference between both simulations. On the ebbing and flooding tide generally, the difference in current magnitude is positive, showing that the velocities calculated in simulation one are greater than those calculated in simulation two.

The snapshots show that over a neap tide, at high and low water there is very little difference between both simulations. On the ebbing and flooding tide generally, the difference in current magnitude is positive, showing that the velocities calculated in simulation one are greater than those calculated in simulation two.

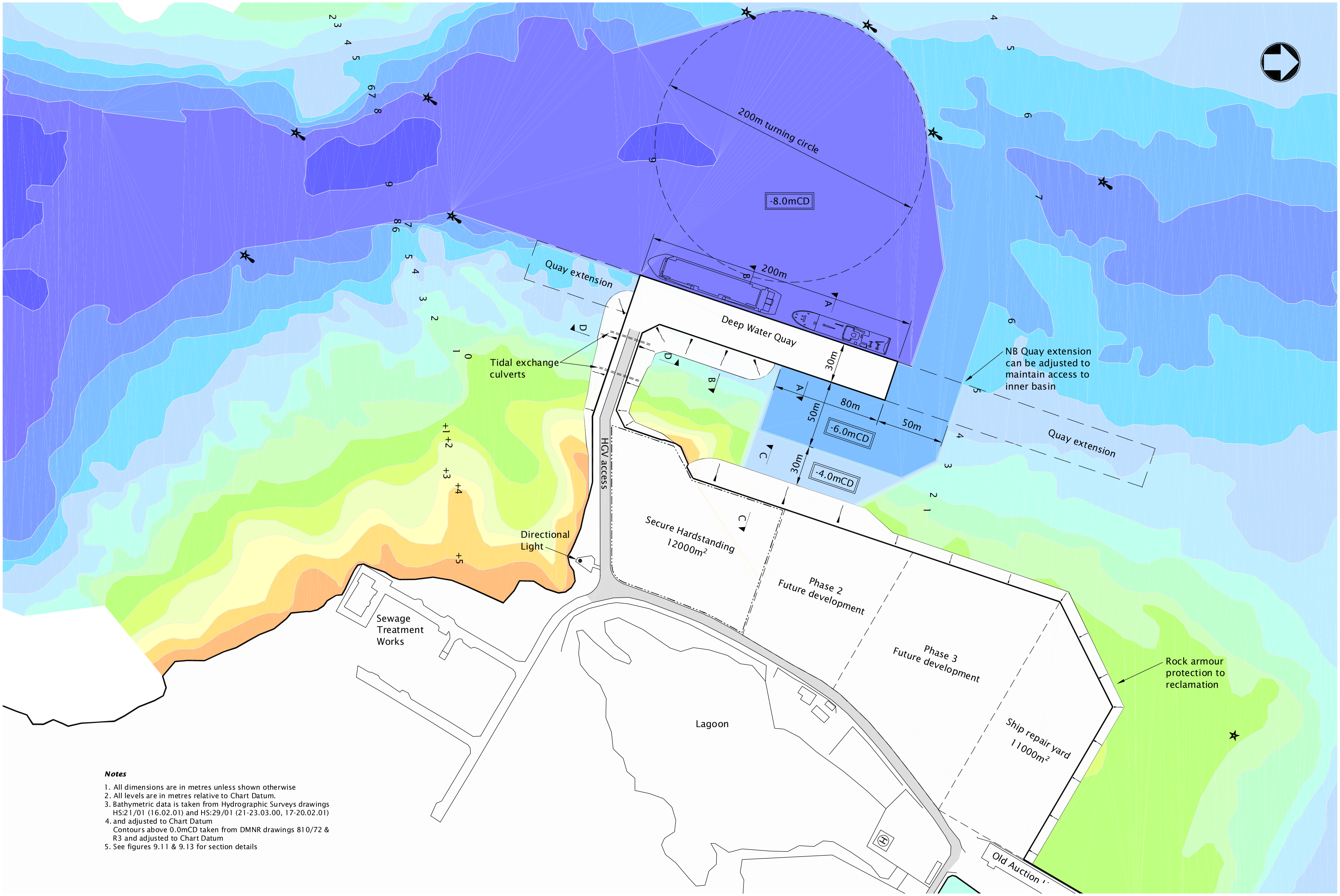
The velocities calculated in simulation two in the region of the proposed quay are generally less than those calculated in simulation one as it proposed to dredge this area to a depth of –8m below ordnance datum. This allows a larger volume of water to travel through this region, giving rise to lower velocities when compared to the simulation one.

The maximum current velocity difference between both simulations is approximately 5cm/s and occurs in the immediate area around the proposed quay development. Both simulations also show current direction in the vicinity of the key to be flowing in a NNE direction at mid flood and SSW direction at mid ebb approximately parallel to the existing shoreline.

Based on the results of this study it is found that the construction of the proposed quay will not significantly affect the current hydrodynamic regime in Rossaveel Harbour away from the immediate vicinity of the proposed development.

Appendix A: Deep Water Quay Layout

(Figure 13.1 from Volume 1)



Notes

1. All dimensions are in metres unless shown otherwise
2. All levels are in metres relative to Chart Datum.
3. Bathymetric data is taken from Hydrographic Surveys drawings HS:21/01 (16.02.01) and HS:29/01 (21-23.03.00, 17-20.02.01)
4. and adjusted to Chart Datum
   Contours above 0.0mCD taken from DMNR drawings 810/72 & R3 and adjusted to Chart Datum
5. See figures 9.11 & 9.13 for section details

Mott MacDonald
063107\drawings\volume 4\fig 13-1
Project: 200046

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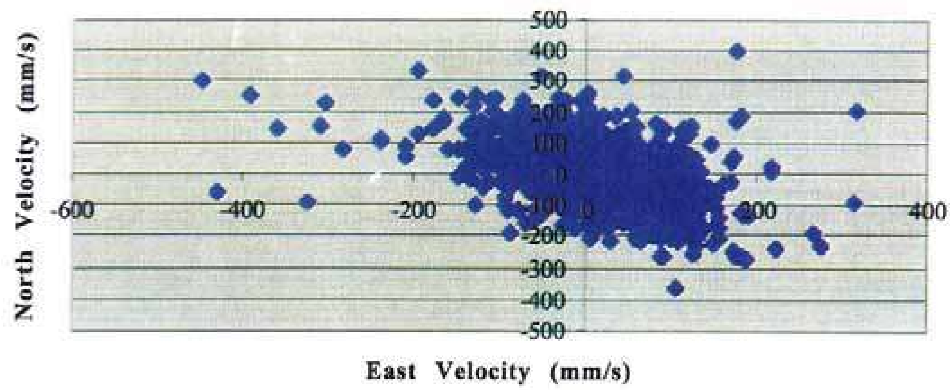
1:2500 @ A3 — 0, 50, 100, 150, 200, 250m

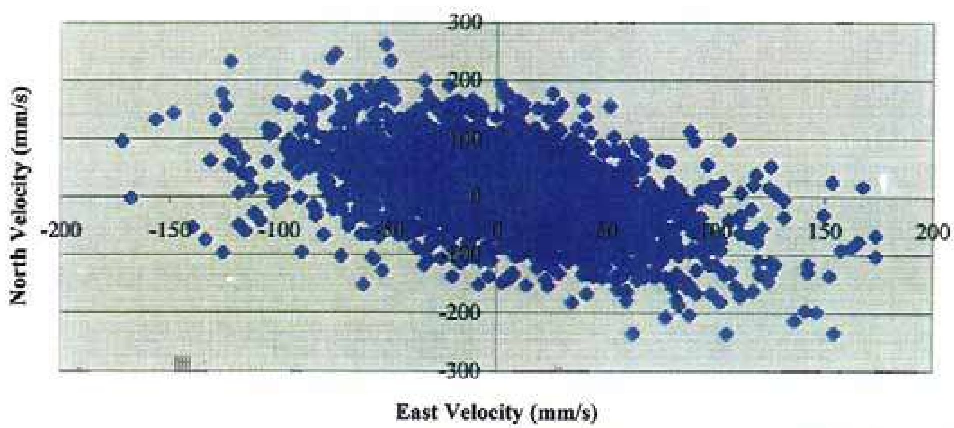
Deep Water Quay - Preferred Option
Figure 13.1

Appendix B: Current Velocity - Field measurements

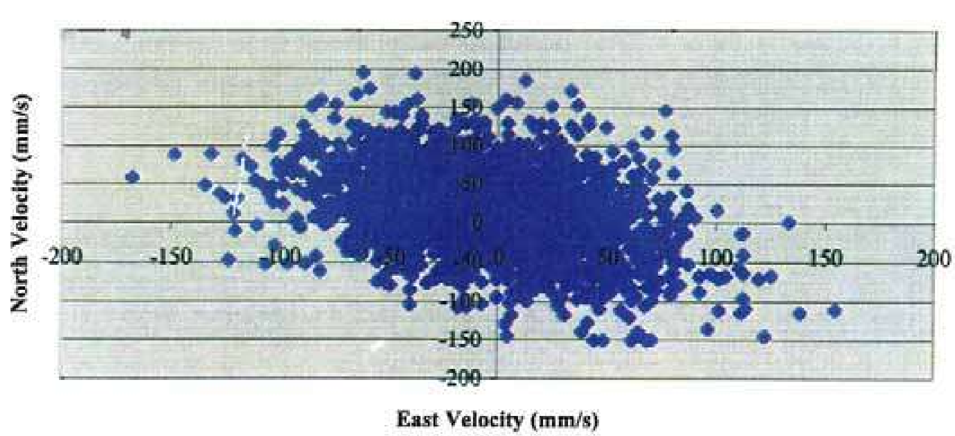
Sub-surface Current Direction 16/10-11/11/01

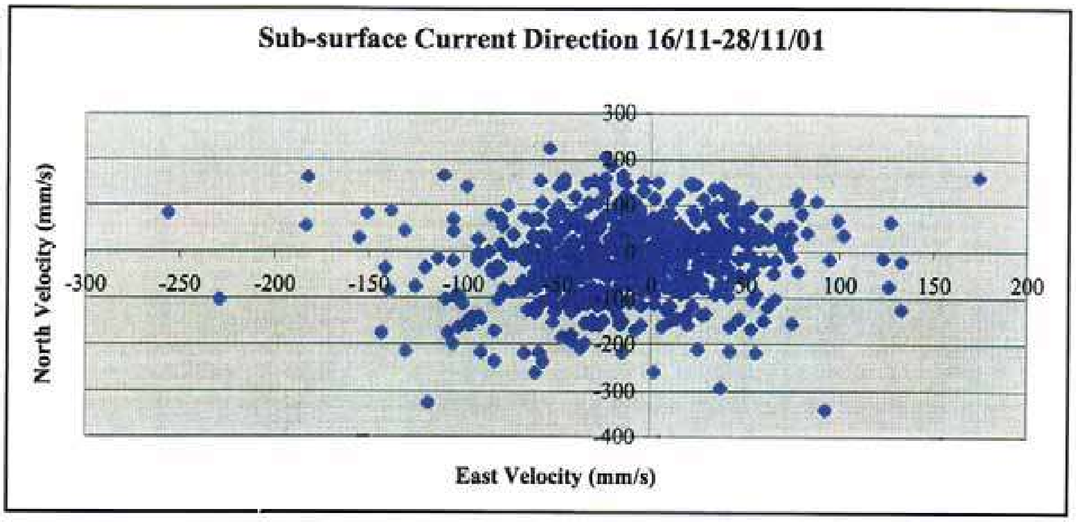


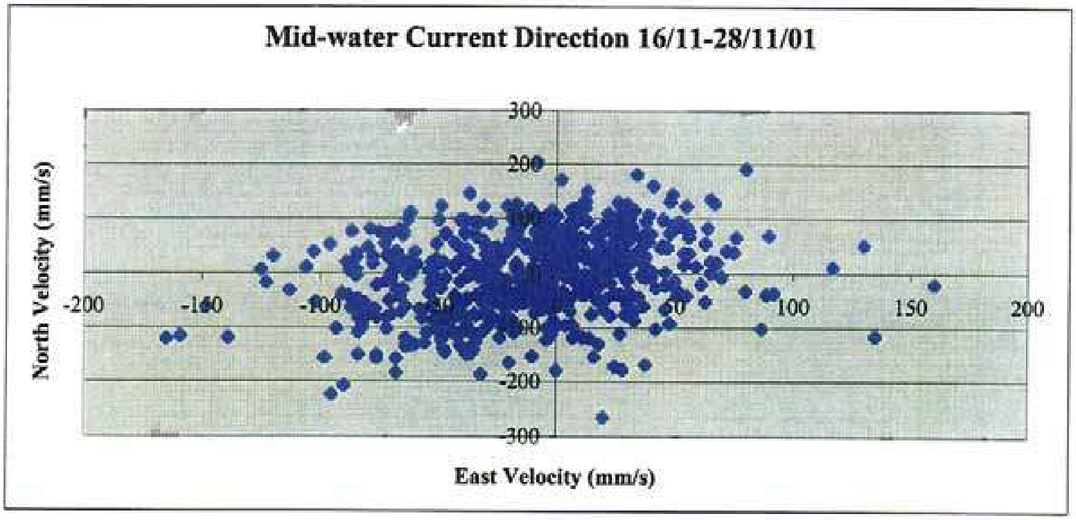
Mid-water Current Direction 16/10-11/11/01

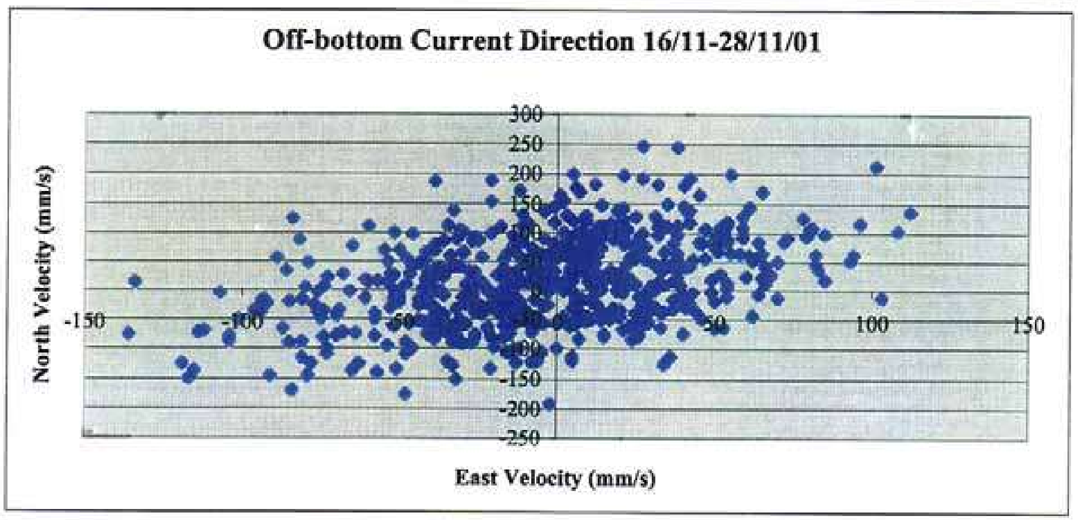


Off-bottom Current Direction 16/10-11/11/01




Sub-surface Current Direction 16/11-28/11/01
North Velocity (mm/s)
300
200
100
0
-100
-200
-300
-400
-300
-250
-200
-150
-100
50
100
150
200
East Velocity (mm/s)


Mid-water Current Direction 16/11-28/11/01
North Velocity (mm/s)
300
200
100
-200
-300
-200
-150
-100
50
100
150
200
East Velocity (mm/s)


Off-bottom Current Direction 16/11-28/11/01
North Velocity (mm/s)
300
250
200
150
0
-150
-200
-250
-150
-100
50
100
150
East Velocity (mm/s)