# Suitability of a Mussel Production Site, Dunmanus Bay, County Cork
June 2021

Produced by

**AQUAFACT International Services Ltd**

On behalf of

**Bantry Bay Seafoods Ltd.**
**Final Report Issued June 2021**

**AQUAFACT INTERNATIONAL SERVICES Ltd.,**
**12 KILKERRIN PARK,**
**GALWAY.**
**www.aquafact.ie**
info@aquafact.ie
**tel +353 (0) 91 756812**

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# 1. Introduction

AQUAFACT International Services Ltd. was commissioned by Bantry Bay Seafoods to address the issues raised in an appeal against the decision of the Minister for Agriculture, Food and the Marine to grant an Aquaculture and Foreshore Licence to Dunmanus Bay Mussels Ltd., for the cultivation of Mussels using longlines and ropes at outer Dunmanus Bay, Co. Cork on Site T05/590A (Figure 1.1). There has been no mussel production on this site previously.

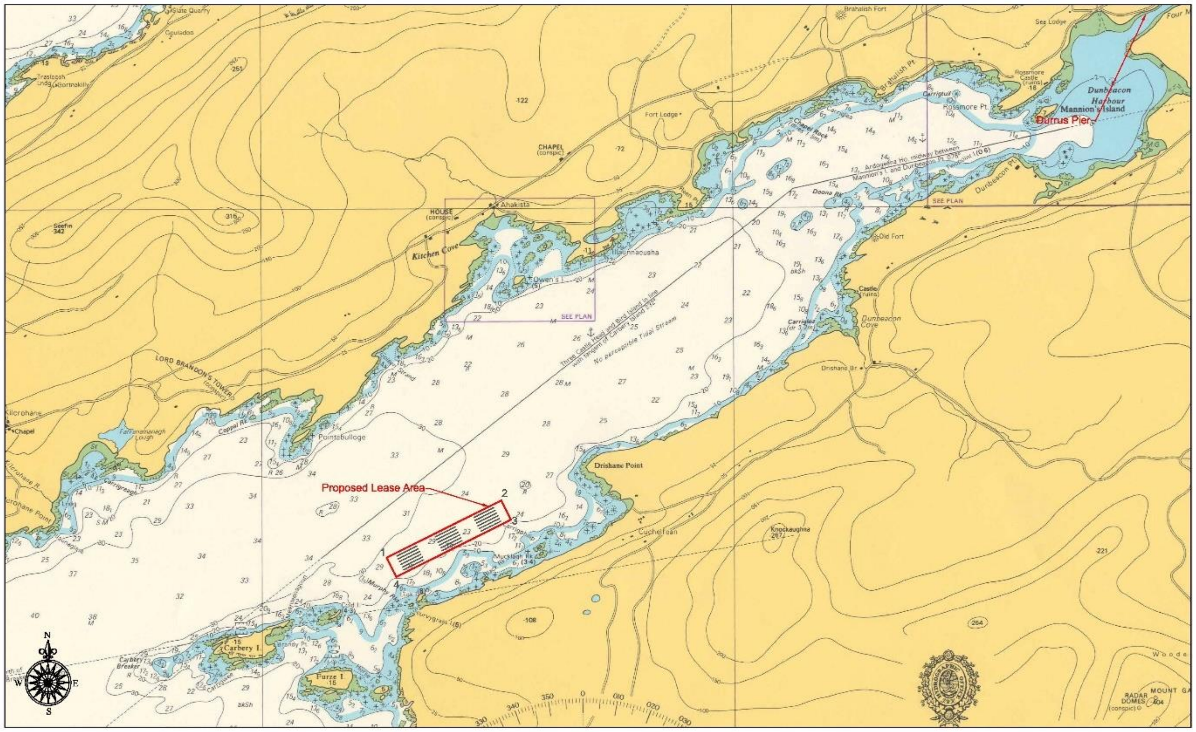

**Figure 1-1: Location of the mussel aquaculture site, Dunmanus Bay, Co. Cork.**

In line with Section 47(1)(a) of the Fisheries Amendment Act 1997, Dunmanus Mussels Ltd. were requested to provide additional site-specific evidence and/ or commentary regarding:

- the currents and flushing rates at the site reflective of the natural ranges expected;
- the rates of bio-deposit deposition across the site and surrounds;
- the calculations of the spatial extent of the deposition footprint;
- the potential benthic impacts associated with bio-deposit wastes; and
- clear descriptions of the rationale and assumptions made to predict the impacts.

In order to address these issues Aquafact proposed to:

a) Carry out a benthic survey of the area that is likely to be impacted by the mussel production.

b) Deploy an acoustic doppler current profiler (ADCP) at the site to record current speed and direction at various depths for a minimum of 14 days to cover both neap and spring tide conditions.

c) Develop a hydrodynamic model to predict potential impact on water quality and the benthic environment from the proposed mussel production.

Individual reports were produced for each of these elements and are included here as;

Appendix 1 - Dunmanus Benthic Survey 2021

Appendix 2 - Dunmanus Hydrography Report

Appendix 3 – Water Quality Modelling Dunmanus

# 2. Conclusions

The methods employed and rational behind each of the disciplines are described in the individual reports included as appendices. The conclusions below were made on the basis of the results from the benthic survey, current profile and model results.

## 2.1. Environmental Benthic Survey

The bottom survey in the vicinity of the proposed mussel aquaculture site located on the south shore of Dunmanus Bay, revealed a number of different bottom types, the distribution mainly determined by the depth profile they were located. The bottom directly under and in the immediate vicinity of the site consisted of muddy sand that had various levels of bioturbation activity from burrowing infauna. Few macrofauna species were imaged in the video transects across these areas with the starfish, *M. glacialis*, and the anemone, *Cerianthus lloydii*, imaged in low numbers to the east of the site. In the shallower locations to the east and west of the site closer to the shore, the bottom consisted of coarse to medium sand that had a cover of algal tufts and large stones and boulders with *Laminaria* sp. and red algae attached. Starfish *M. glacialis* and *A. rubens* were the main faunal species encountered. A localised area consisting predominantly of live maerl and its associated faunal community was located close to the shore, south east of the site boundary.

## 2.2. Current Profiles

The current profile that was recorded in Dunmanus Bay at the proposed mussel aquaculture site is representative of environmental conditions experienced between 29th April to 18th May 2021 and covers both a spring and neap tide. In general, current speeds are relatively low along a predominantly northeast-southwest axis with no significant difference between spring and neap tide conditions. However, meteorological conditions would appear to have a significant influence on the currents, particularly at the surface.

## 2.3. *Water Quality Model*

Results of the bespoke modelling programme found that there was no significant accumulation of settleable solids discharges arising from biowaste matter beyond the immediate vicinity of the proposed site. This was due to the low current speeds and sheltered location of the proposed site in Dunmanus Bay. Regarding sedimented biowaste, it was found that:

- The maximum and average daily deposition rates for total sedimented biowaste (pseudofaeces + faecal pellets) across the proposed lease area did not generally exceed 14 and 7g/m2 d-1 respectively.
- Beyond the perimeter of the proposed lease site, the maximum daily deposition rates of total sedimented biowaste were generally less than 1g/m2 d-1.
- The maximum and average total deposition rate decreased to 0 g/m2 d-1 approximately 600 metres beyond the perimeter of the proposed lease area.
- Sedimented biowaste produced from the proposed mussel farm aquaculture site in Dunmanus Bay will not have a significant detrimental impact on the benthos within Dunmanus Bay.

In respect of suspended total biowaste concentrations produced by the proposed mussel farm aquaculture site, modelling results found that:

- The maximum and average total suspended biowaste concentrations within the proposed lease area did not generally exceed 14g/m3 and 1.6g/m3 respectively.
- The maximum and average total suspended biowaste concentrations outside the proposed lease area did not generally exceed 1g/m3 and 0.2g/m3 respectively.

In summary, it can be concluded that based on the findings of the benthic survey, current profiling and extensive water quality assessment that utilised a calibrated and validated numerical model, the proposed mussel aquaculture site will not significantly impact the water quality or benthos within Dunmanus Bay.

# Appendix 1 - Dunmanus Benthic Survey 2021

# Environmental Survey at a Proposed Mussel Production Site, Dunmanus Bay, County Cork
## April 2021

Produced by

**AQUAFACT International Services Ltd**

On behalf of

**Bantry Bay Seafoods Ltd.**
**Final Report Issued May 2021**

**AQUAFACT INTERNATIONAL SERVICES Ltd.,**
**12 KILKERRIN PARK,**
**GALWAY.**
**www.aquafact.ie**
info@aquafact.ie
**tel +353 (0) 91 756812**

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# 1. Introduction

AQUAFACT International Services Ltd. was commissioned by Bantry Bay Seafoods to assess the current status of the benthic environment in the vicinity of a proposed mussel production site off the south shore of Dunmanus Bay, Co. Cork (Figure 1.1). There has been no mussel production on this site previously.

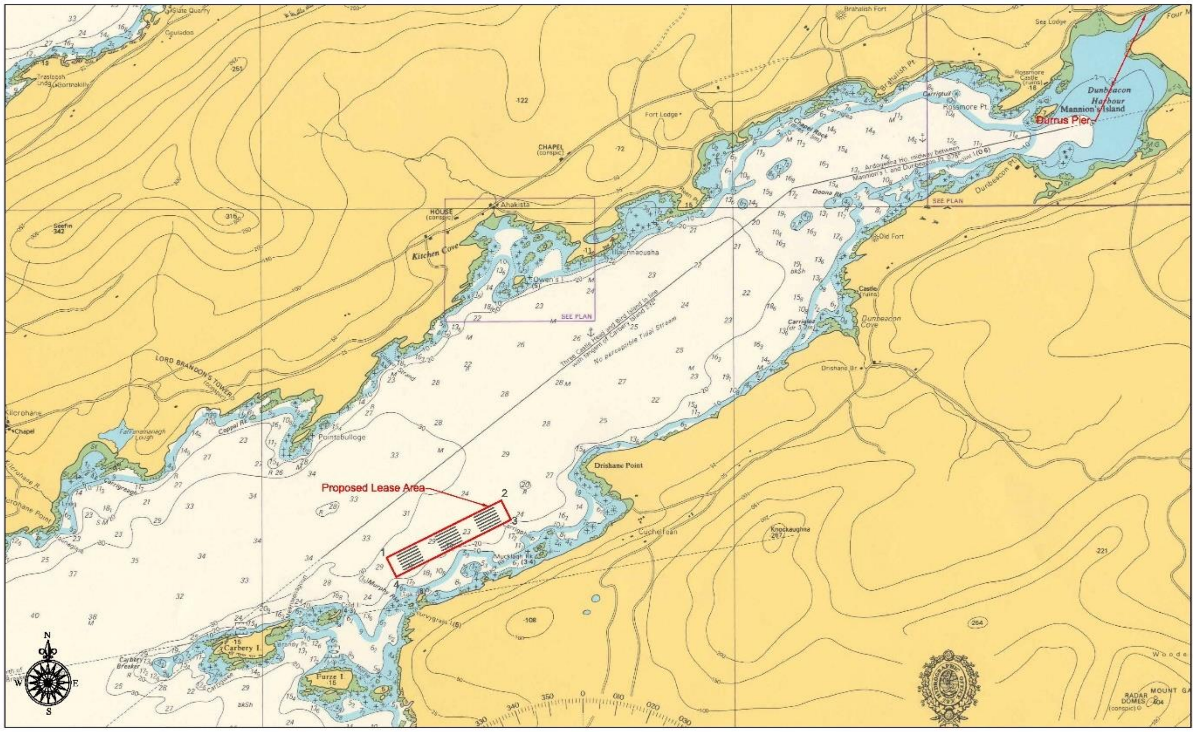

**Figure 1-1: Location of the mussel aquaculture site, Dunmanus Bay, Co. Cork.**

## 2. Sampling Procedure

All survey work took place on the 29th April 2021. Weather conditions were good with a clear sky and a light north easterly breeze. Seafloor conditions were assessed by drop down video with depths ranging from 5 - 30m.

### *2.1. Drop Down Video*

A video camera was lowered to the bottom and a recording made of the bottom type and flora and fauna encountered in several areas in the vicinity of the aquaculture site (Figure 2-1). Once the camera was recording, the boat was allowed to drift with the current during filming in order to get representative footage along each camera deployment. Filming occurred with a backing north easterly wind, each recording followed a south westerly track. The analogue video signal was digitised and recorded to hard drive for later analysis. Real time positions were recorded from the onboard DGPS and the start and end coordinates from each of the deployments presented in Table 2-1.

A small GoPro camera was also attached to the main video camera to record additional digital footage.

**Table 2-1 Coordinates of the video transects at Dunmanus Bay, 29th April 2021.**

| Transect | Start | | End | |
|---|---|---|---|---|
| | *Latitude* | *Longitude* | *Latitude* | *Longitude* |
| **V1** | 51.573947° | 9.619649° | 51.573852° | 9.619460° |
| **V2** | 51.575315° | 9.621820° | 51.575383° | 9.621693° |
| **V3** | 51.577232° | 9.625631° | 51.577348° | 9.625450° |
| **V4** | 51.571981° | 9.628341° | 51.572038° | 9.628120° |
| **V5** | 51.573117° | 9.63006° | 51.573250° | 9.629923° |
| **V6** | 51.574953° | 9.633723° | 51.575211° | 9.633693° |
| **V7** | 51.573265° | 9.632305° | 51.573537° | 9.632244° |
| **V8** | 51.569369° | 9.635418° | 51.569603° | 9.635418° |
| **V9** | 51.571492° | 9.638305° | 51.571724° | 9.638296° |
| **V10** | 51.573440° | 9.641531° | 51.573649° | 9.641583° |
| **V11** | 51.566712° | 9.645941° | 51.566904° | 9.645871° |
| **V12** | 51.567987° | 9.648031° | 51.568304° | 9.647851° |
| **V13** | 51.569662° | 9.649583° | 51.569920° | 9.649409° |
| **V14** | 51.561324° | 9.650560° | 51.561625° | 9.650675° |
| **V15** | 51.565223° | 9.654856° | 51.565593° | 9.654750° |
| **V16** | 51.567596° | 9.657003° | 51.567777° | 9.656762° |
| **V17** | 51.571335° | 9.624825° | 51.571540° | 9.624550° |

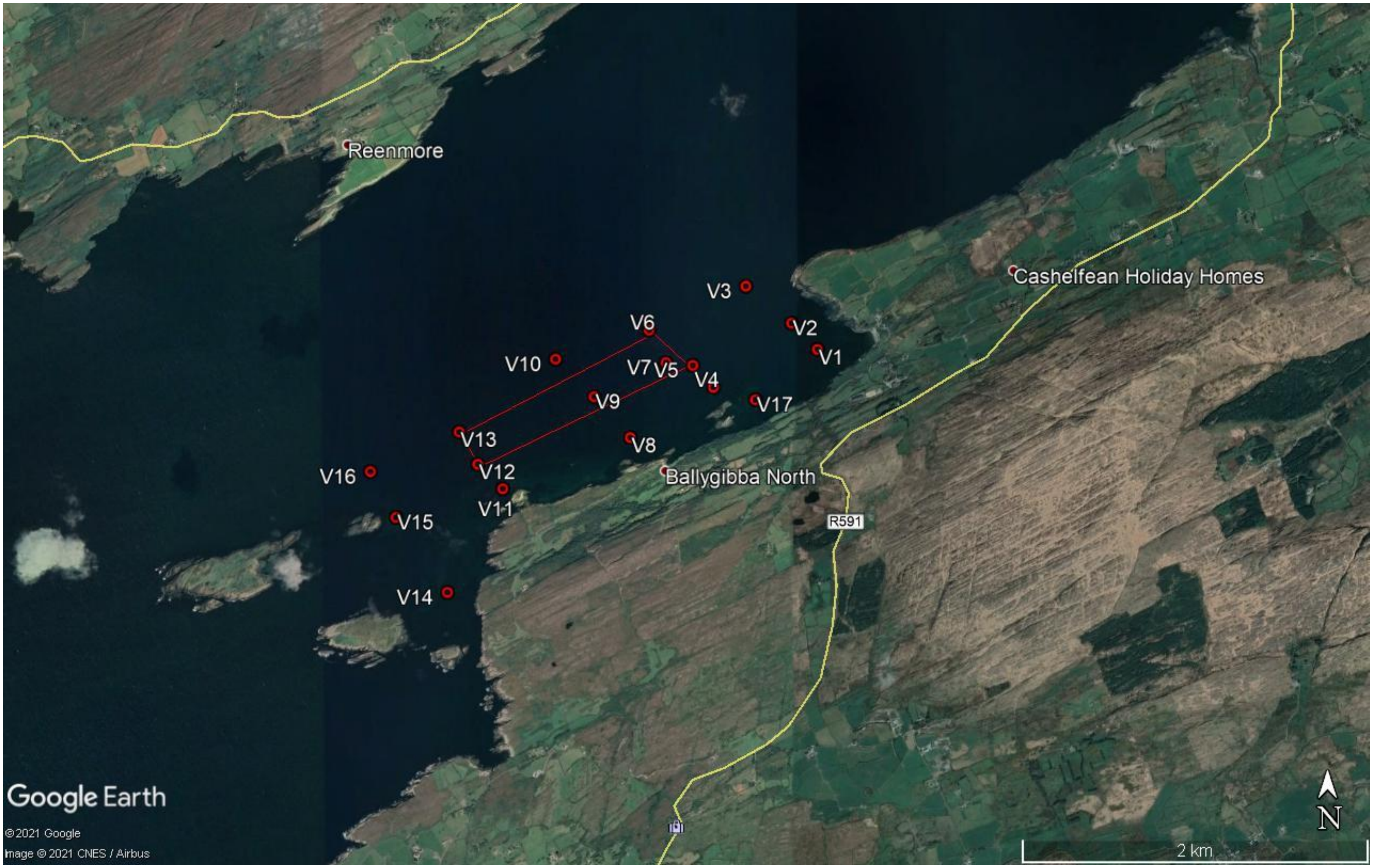

**Figure 2-1 Positions of the video transects in Dunmanus Bay, 29th April 2021**

# 3. Results

## *3.1. Video Transects.*

Images of the seafloor from each of the videos recorded at the various locations are presented below.

### 3.1.1. Transect V1

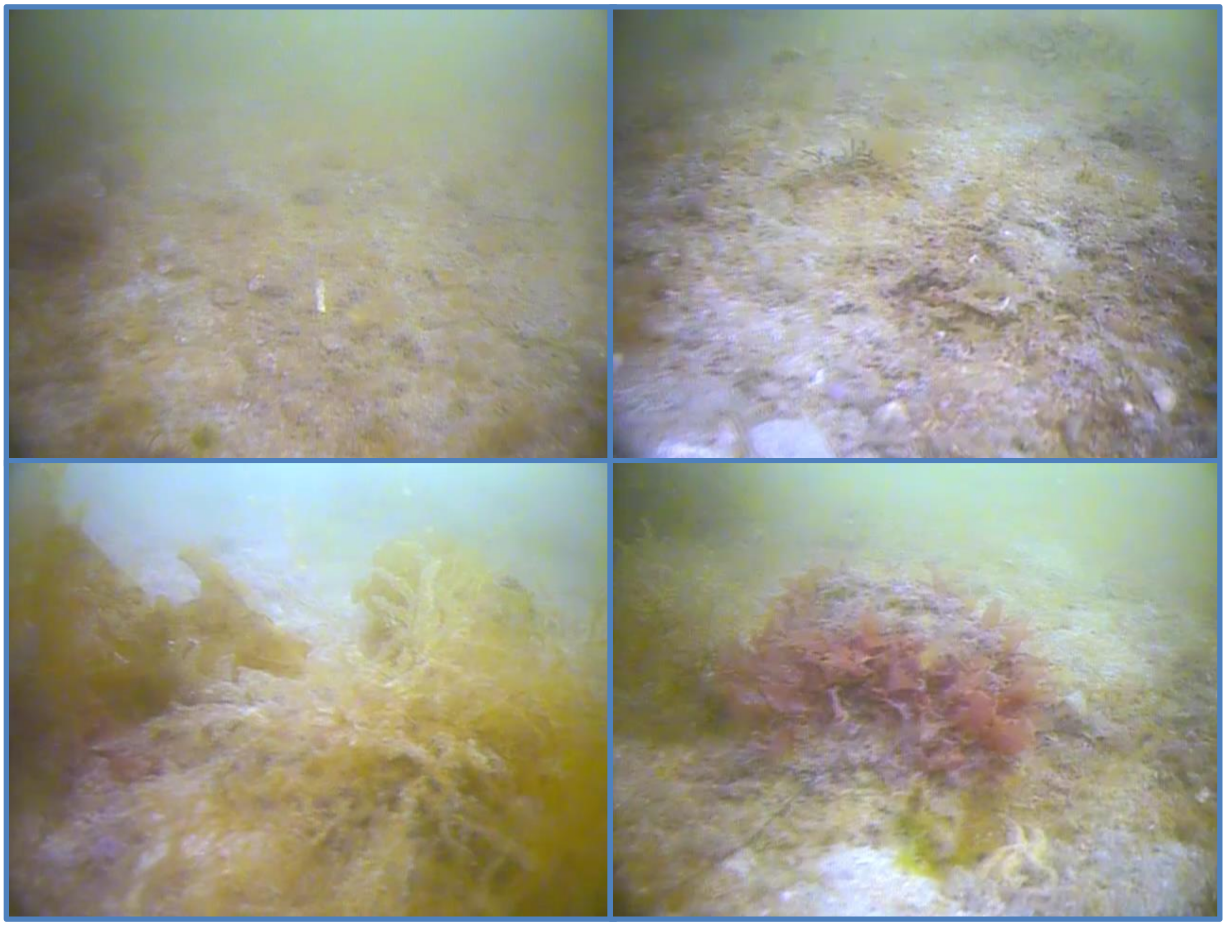

**Plate 3-1. Transect V1**

Transect V1 was located close to the shore east of the proposed site. (see Figure 2-1). The seafloor consisted of a mixture of coarse sand, cobble and shell debris and boulders. The rock and boulders provided attachment points for various red and brown algae. There was a scattering of dead and live maerl gravel. A starfish, *Marthasterias glacialis*, was noted.

### 3.1.2. Transect V2

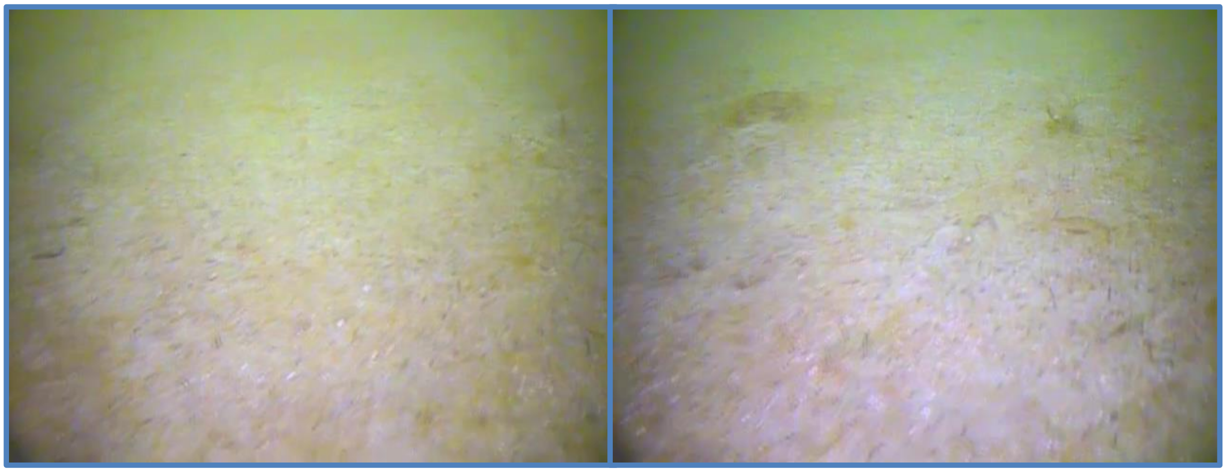

**Plate 3-2. Transect V2**

Transect V2 was located to the east of the site boundary. The seafloor consisted of muddy sand and was relatively flat. There were no notable features imaged on the video.

### 3.1.3. Transect V3

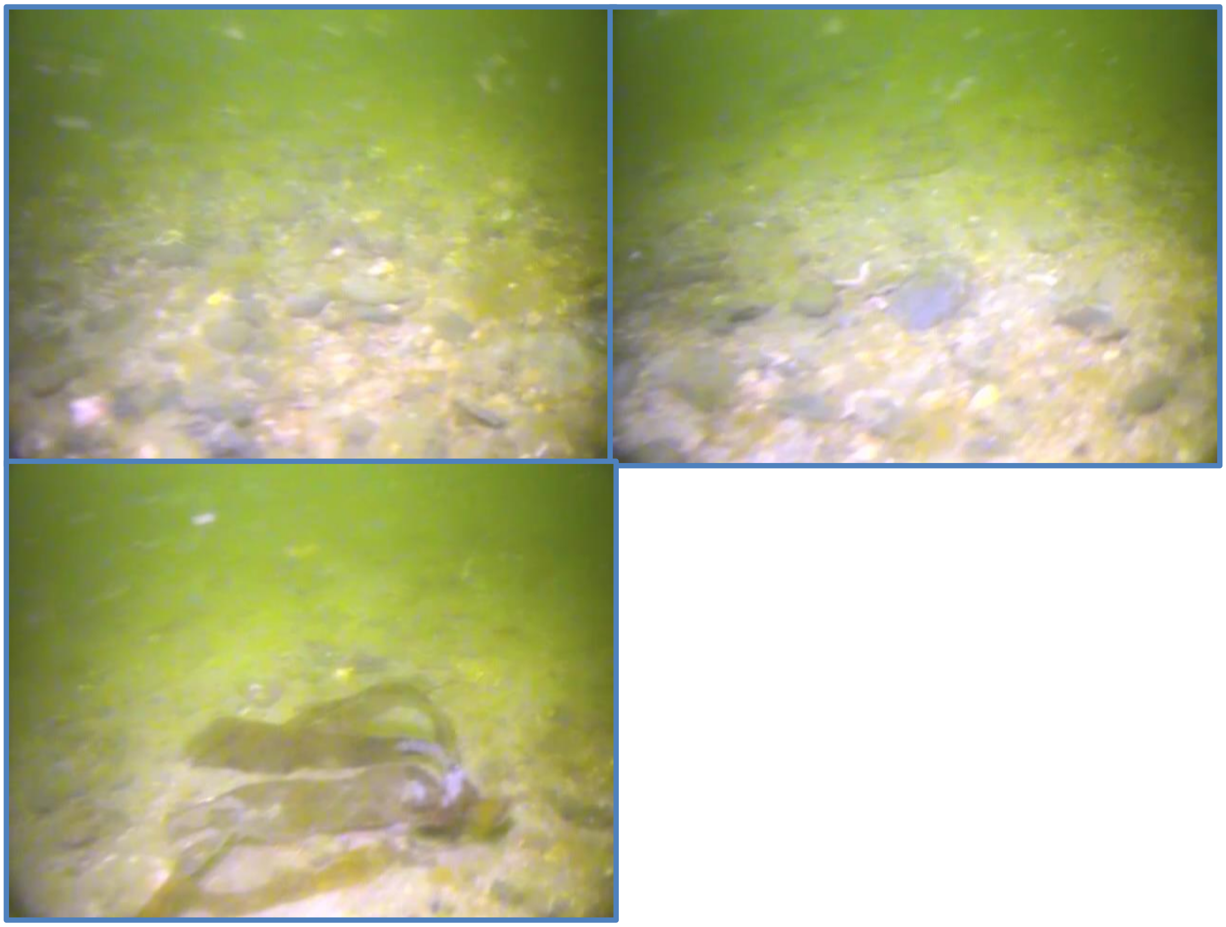

**Plate 3-3. Transect V3**

Transect V3 was located to the east of the site boundary (see Figure 2-1). The seafloor was relatively flat and consisted of cobble and sand. There was some algal debris scattered over the bottom and a starfish, *Asterias rubens*, was imaged..

### 3.1.4. Transect V4

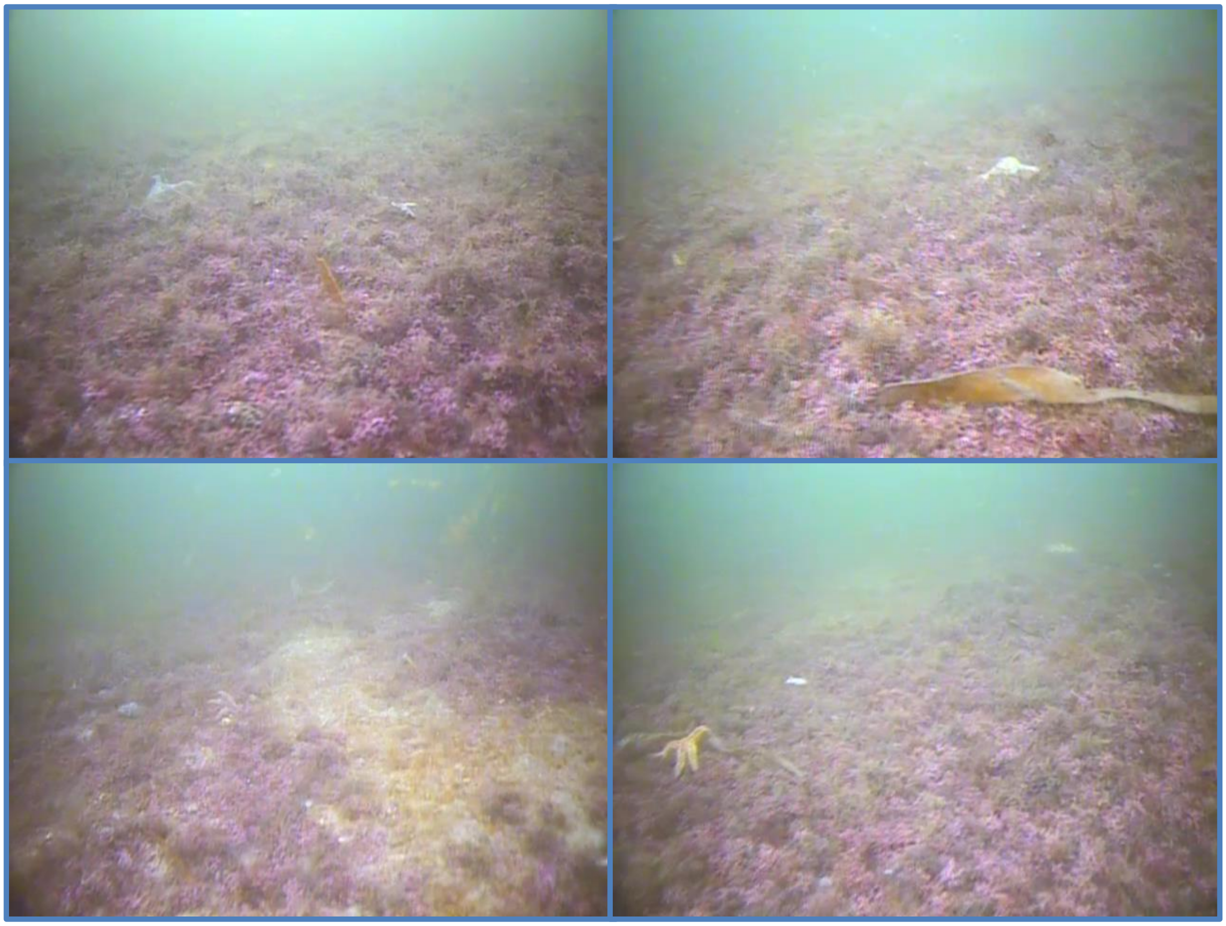

**Plate 3-4. Transect V4**

Transect V4 was located on the south east side of the site boundary. The seafloor consisted predominantly of live maerl with clumps of filamentous red and brown algae over its surface. Starfish, *A. rubens* and *M. glacialis*, were commonly encountered.

### 3.1.5. Transect V5

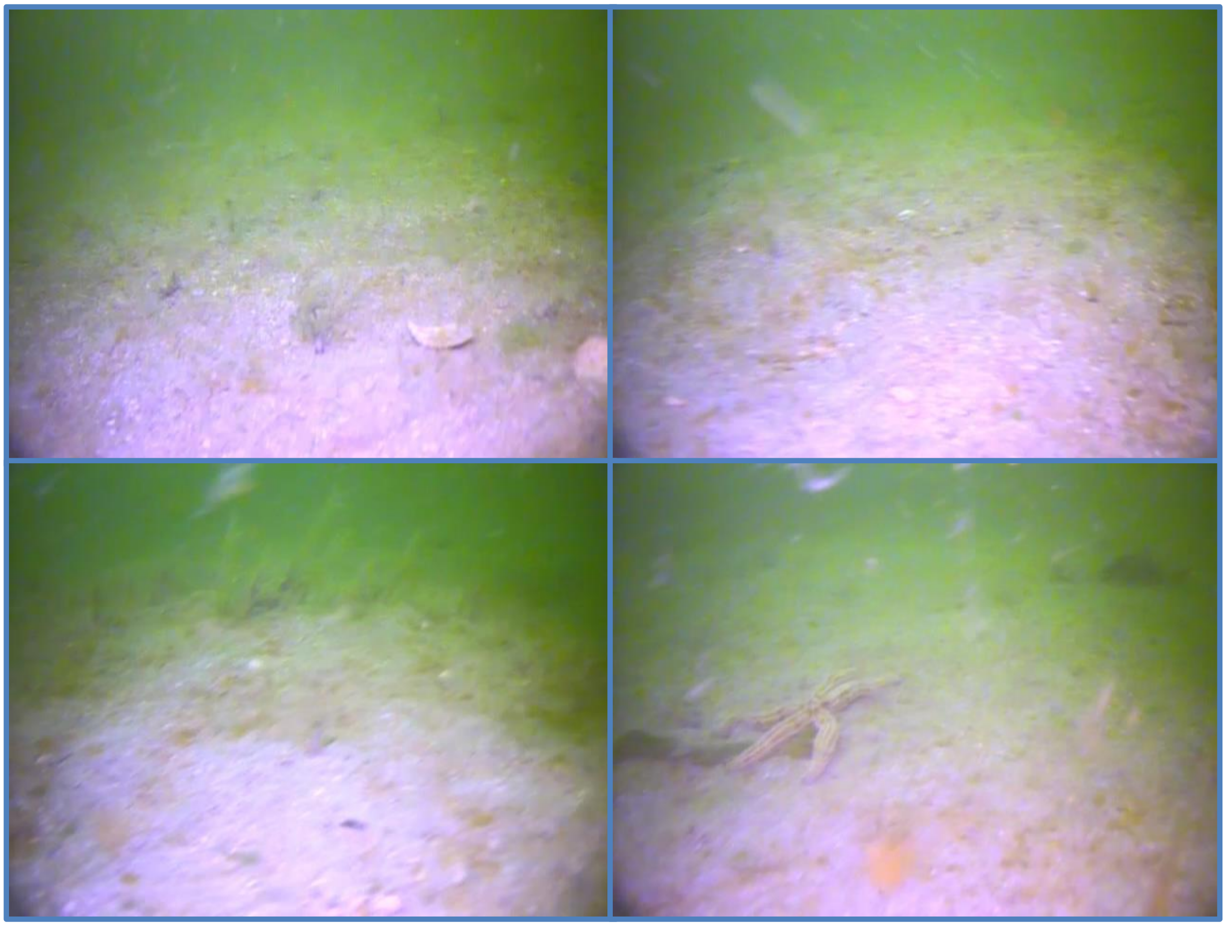

**Plate 3-5. Transect V5**

Transect V5 was located inside the eastern end of the site (see Figure 2-1). The seafloor was relatively flat and consisted predominantly of muddy sand with some shell fragments scattered over its surface. Starfish (*M. glacialis*) and the anemone, *Cerianthus lloydii*, were noted.

### 3.1.6. Transect V6

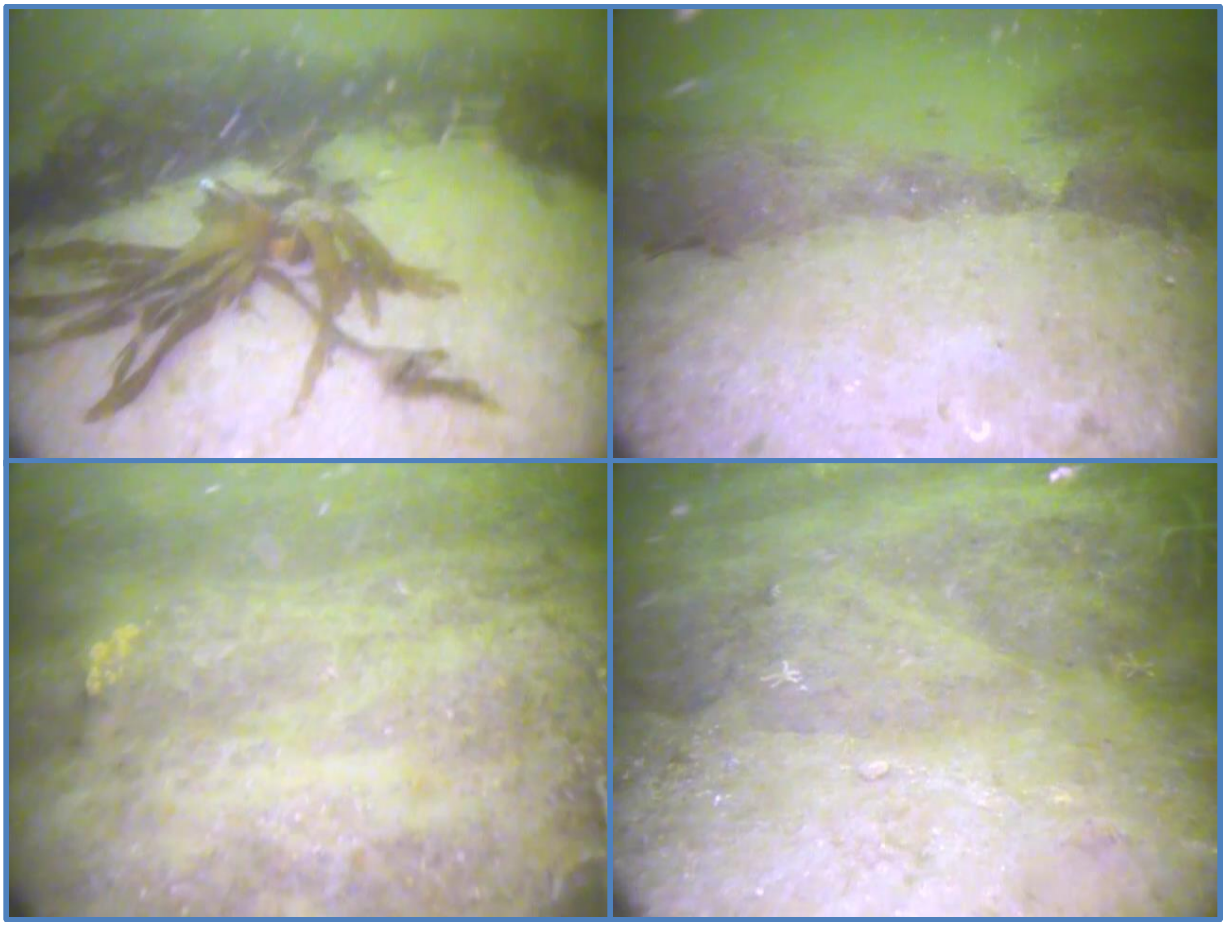

**Plate 3-6. Transect V6**

Transect V6 was located to the north east of the boundary. The seafloor consisted of a mixture of muddy sand , boulders and bedrock. Drift algae (*Laminaria* sp.) was scattered over the bottom. Starfish, (*A. rubens*) and sponge (*Cliona celata*) were noted on the rock.

### 3.1.7. Transect V7

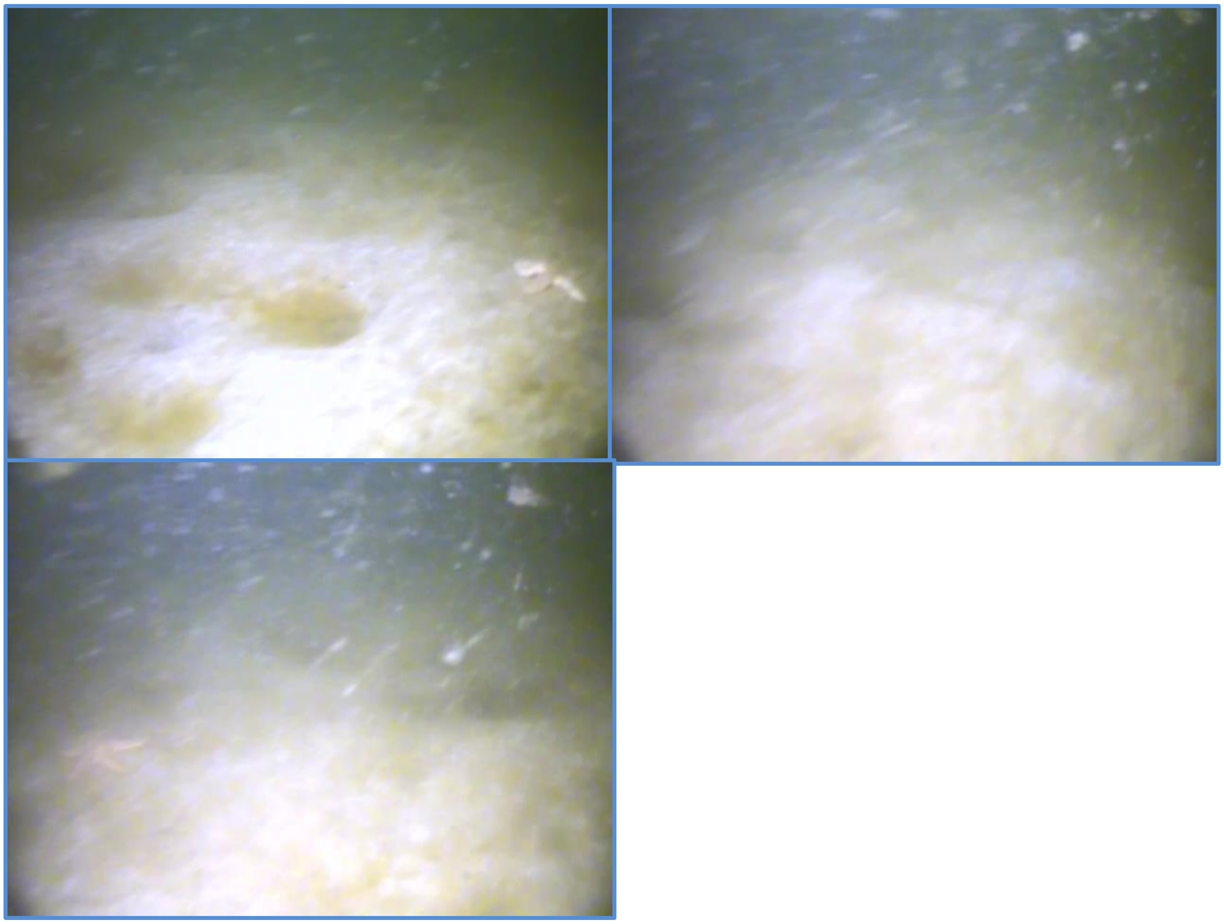

**Plate 3-7. Transect V7**

Transect V7 was located inside the boundary to the east of the site (see Figure 2-1). The seafloor consisted of muddy sand that had a bumpy appearance due to infaunal bioturbation. A starfish, *A. rubens,* was noted sitting on the bottom. Water clarity was bad due to particulate material present in the water column.

### 3.1.8. Transect V8

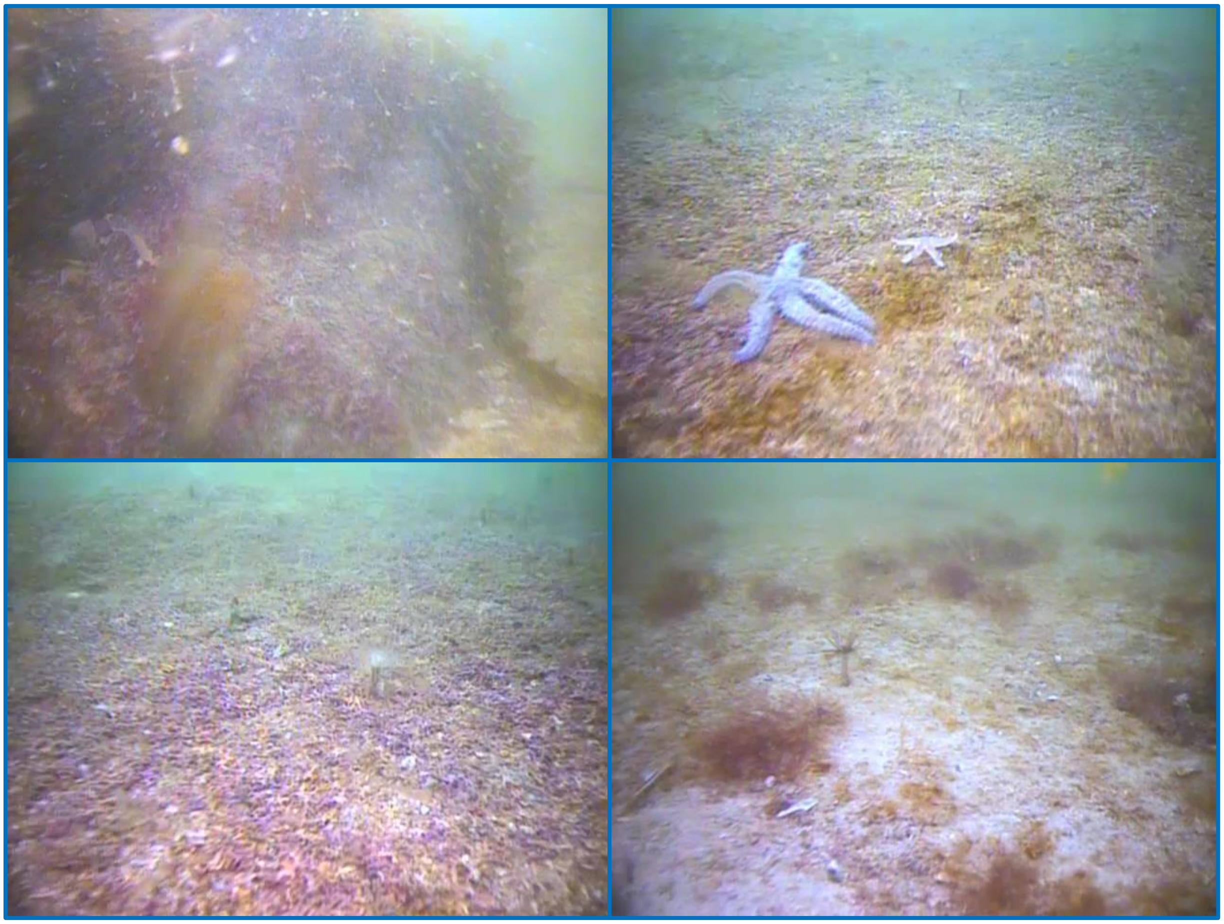

**Plate 3-8. Transect V8**

Transect V8 was located close to the shore outside the southern side of the site boundary (see Figure 2-1). At the start of the transect the seafloor consisted of muddy sand with large boulders that had a cover or red and brown algae. Numerous juvenile *A. rubens* were observed sitting on the boulders. Shortly in to the video the seafloor changed to a relatively flat bottom consisting of dead and live maerl which again changes to a coarse sand shell with interspersed algal tufts across the bottom. Starfish, *M. glacialis* and *A. rubens*, were imaged on the maerl surface while numerous anemone (*C. lloydii*) were noted protruding from the seafloor with their tentacles extended into the water column.

### 3.1.9. Transect V9

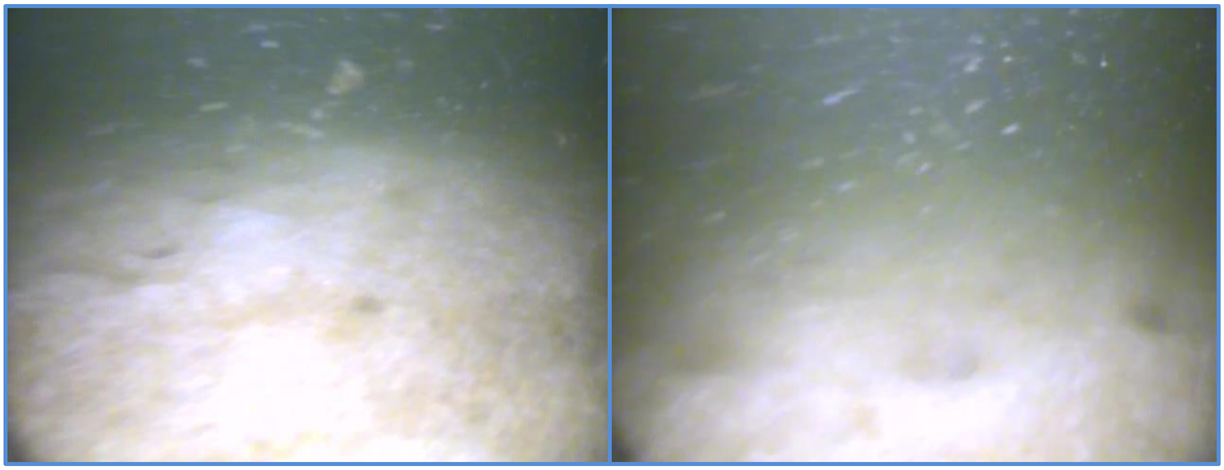

**Plate 3-9. Transect V9**

The seafloor along Transect V9, located inside the boundary in the middle of the site, consisted of muddy sand that had a bumpy appearance due to infaunal bioturbation. Water clarity was reduced and no notable macrofauna were recorded.

### 3.1.10. Transect V10

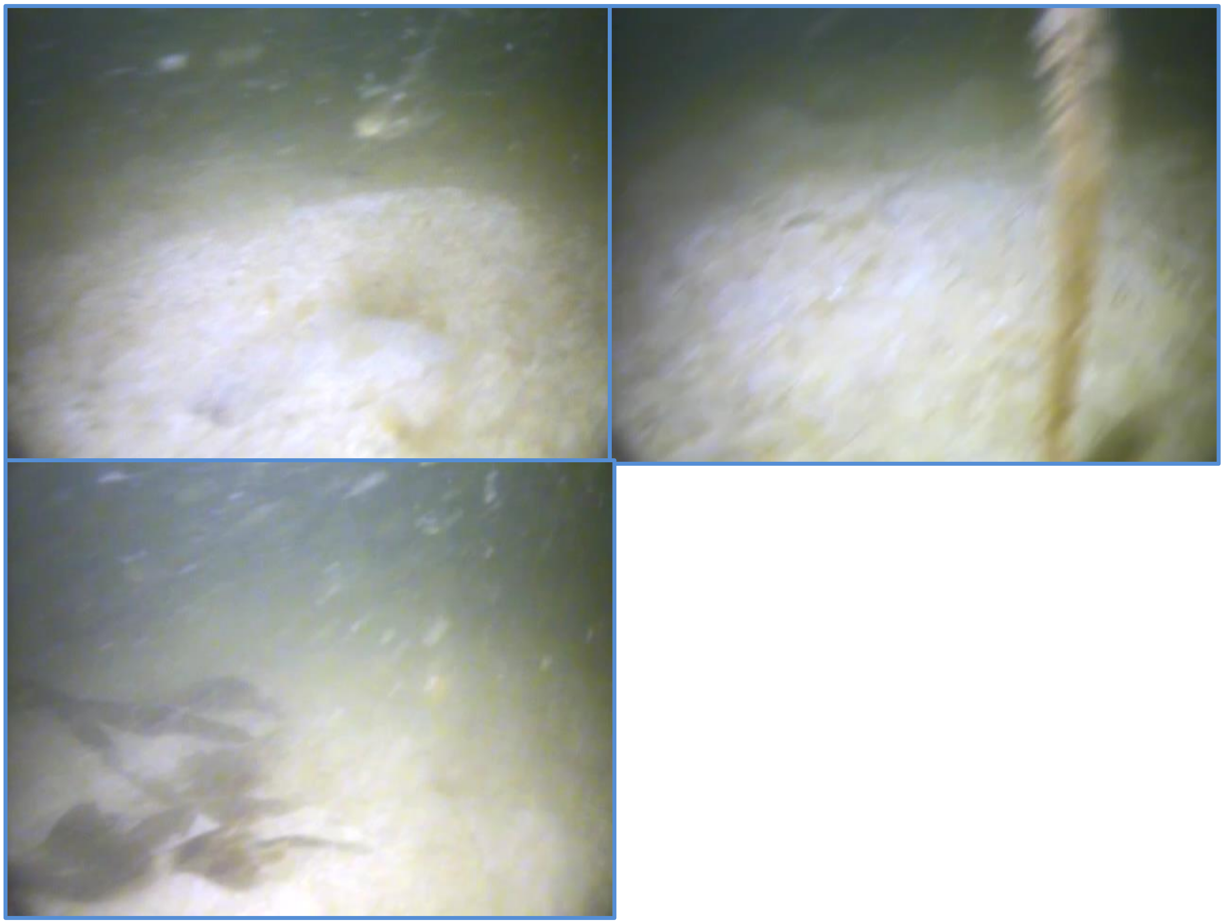

**Plate 3-10. Transect V10**

The seafloor along Transect V10, located outside the middle of the north side of the boundary consisted of muddy sand that had a bumpy appearance due to infaunal bioturbation. A sea pen, *Virgularia mirabilis*, was imaged standing erect out of the sediment and drift algae was scattered over the bottom.

### 3.1.11. Transect V11

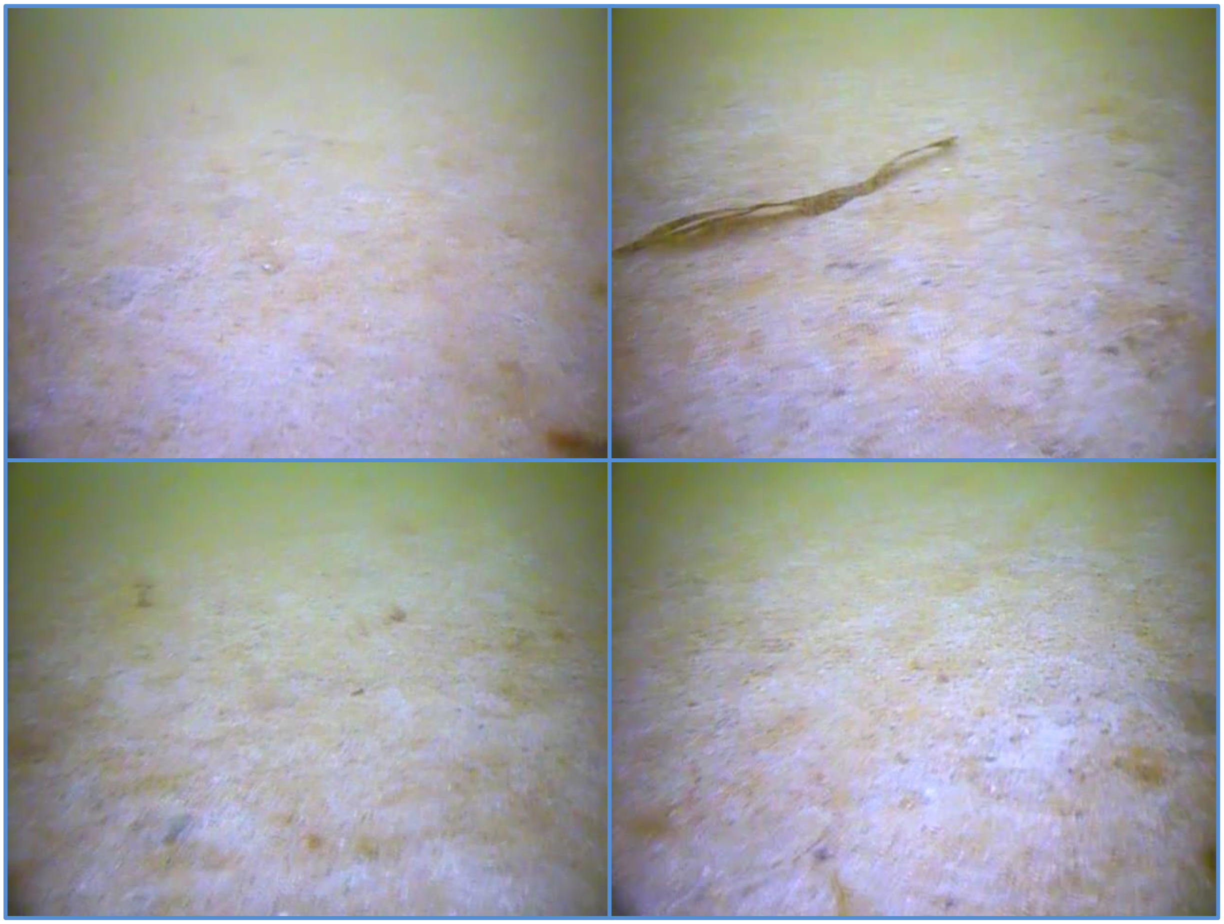

**Plate 3-11. Transect V11**

Transect V11, located outside the western end of the boundary on the shore side, consisted of a relatively flat muddy sand. No notable macrofauna were imaged.

### 3.1.12. Transect V12

**Plate 3-12. Transect V12**

The seafloor along Transect V12, located on the south western corner of the boundary, imaged a relatively flat seafloor consisting of muddy sand with drift algae scattered over its surface. No notable macrofauna were imaged.

### 3.1.13. Transect V13

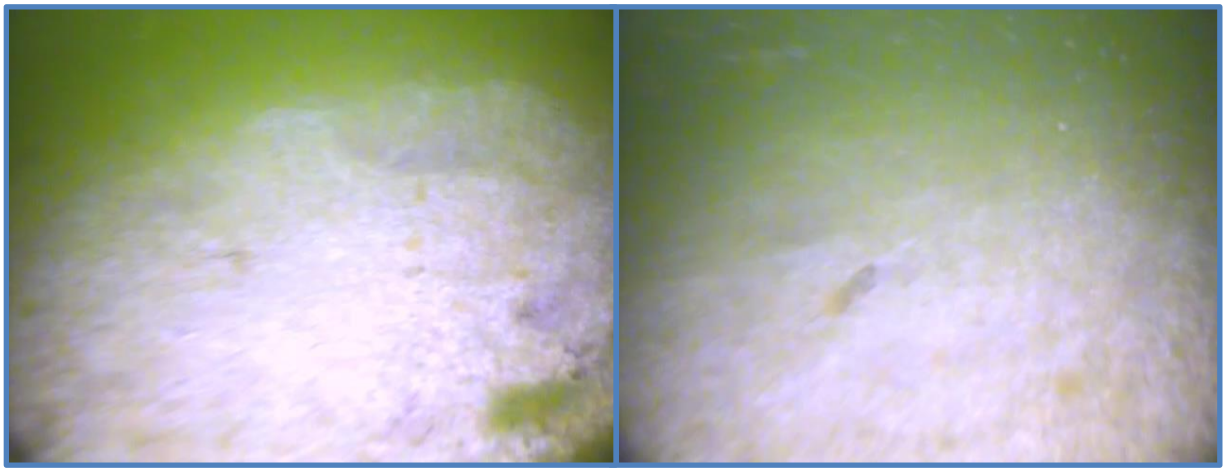

**Plate 3-13. Transect V13**

The seafloor along Transect V13, located on the north western corner of the boundary, consisted of muddy sand that had a bumpy appearance due to infaunal bioturbation. No notable macrofauna were imaged.

### 3.1.14. Transect V14

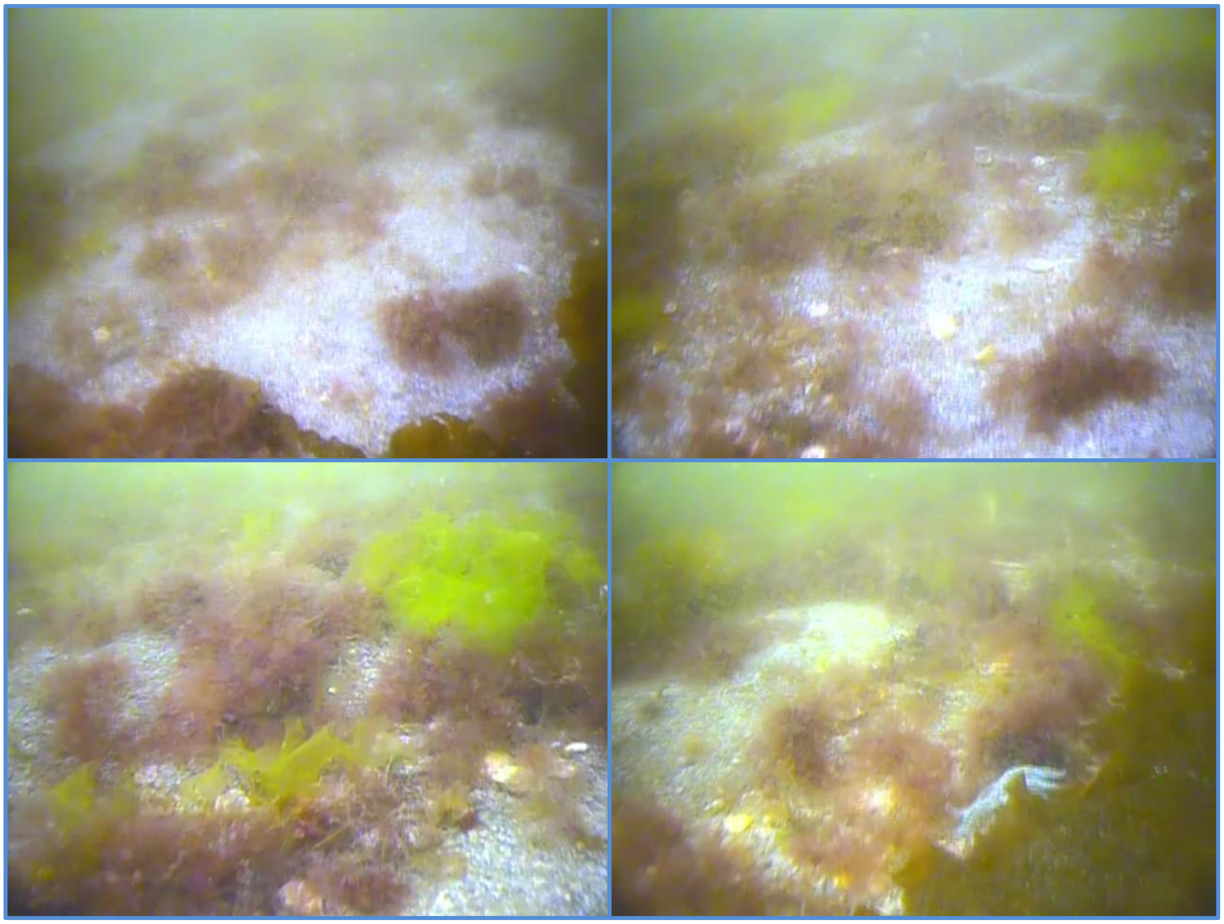

**Plate 3-14. Transect V14**

The seafloor along Transect V14, located to the south west of the site, consisted of medium to coarse sand with a cover of red algae tufts interspersed with the green algae, *Ulva lactuca*. A large starfish, *M. glacialis,* was imaged.

### 3.1.15. Transect V15

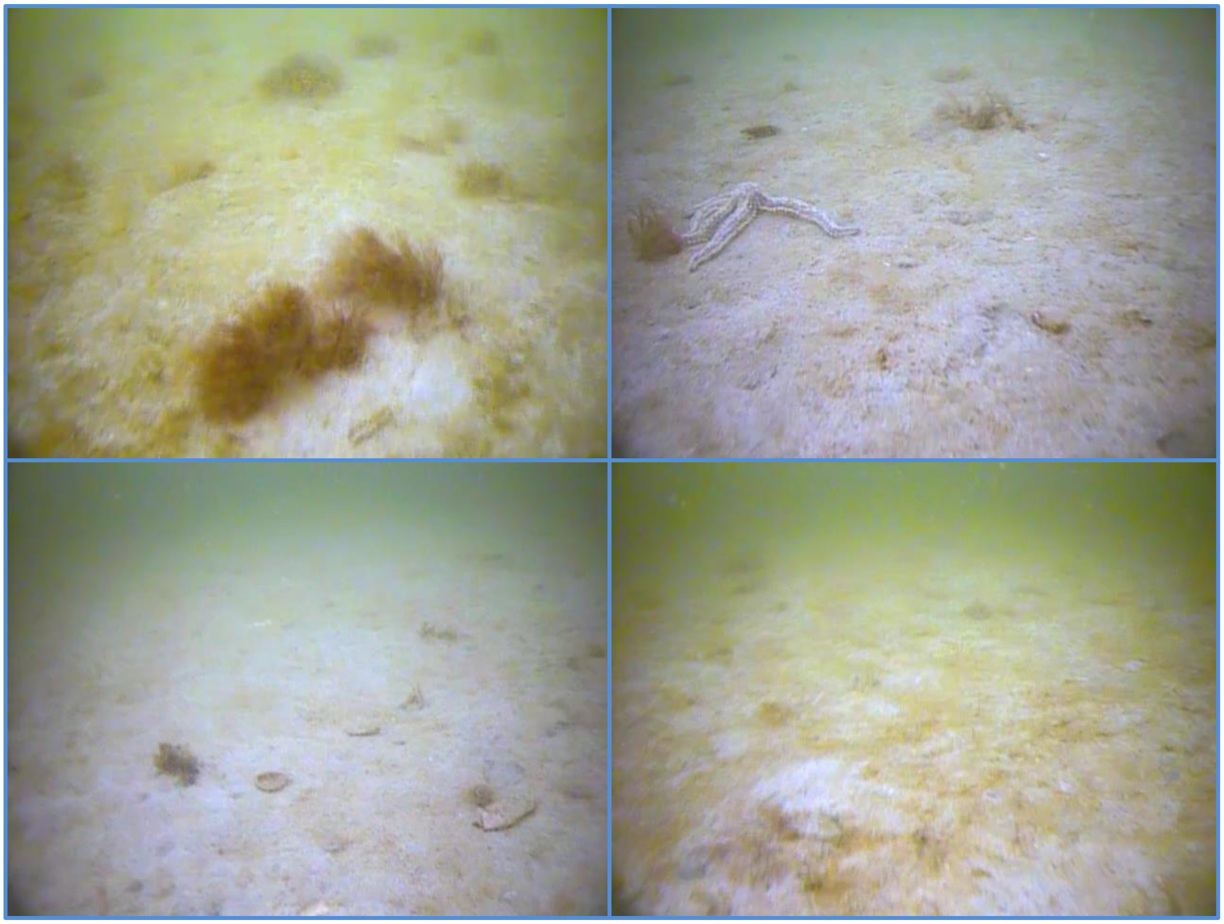

**Plate 3-15. Transect V15**

The seafloor along Transect V15, located to the west of the site, was relatively flat consisting of muddy sand with sparce algae tufts and shell debris. A large starfish, *M. glacialis,* was imaged.

### 3.1.16. Transect V16

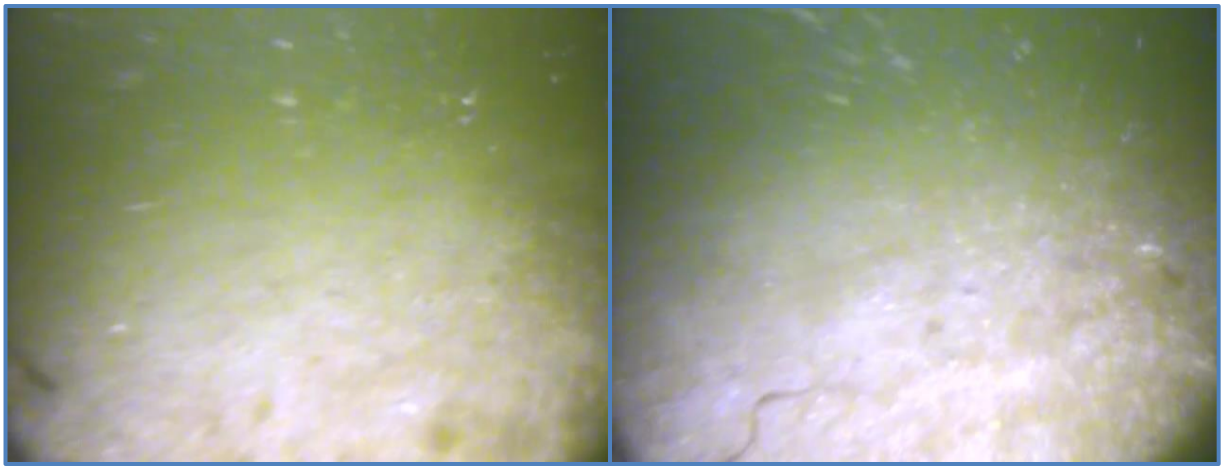

**Plate 3-16. Transect V16**

The seafloor along Transect V16, located to the north west of the site, consisted of a relatively flat muddy sand. No notable macrofauna were imaged.

### 3.1.17. Transect V17

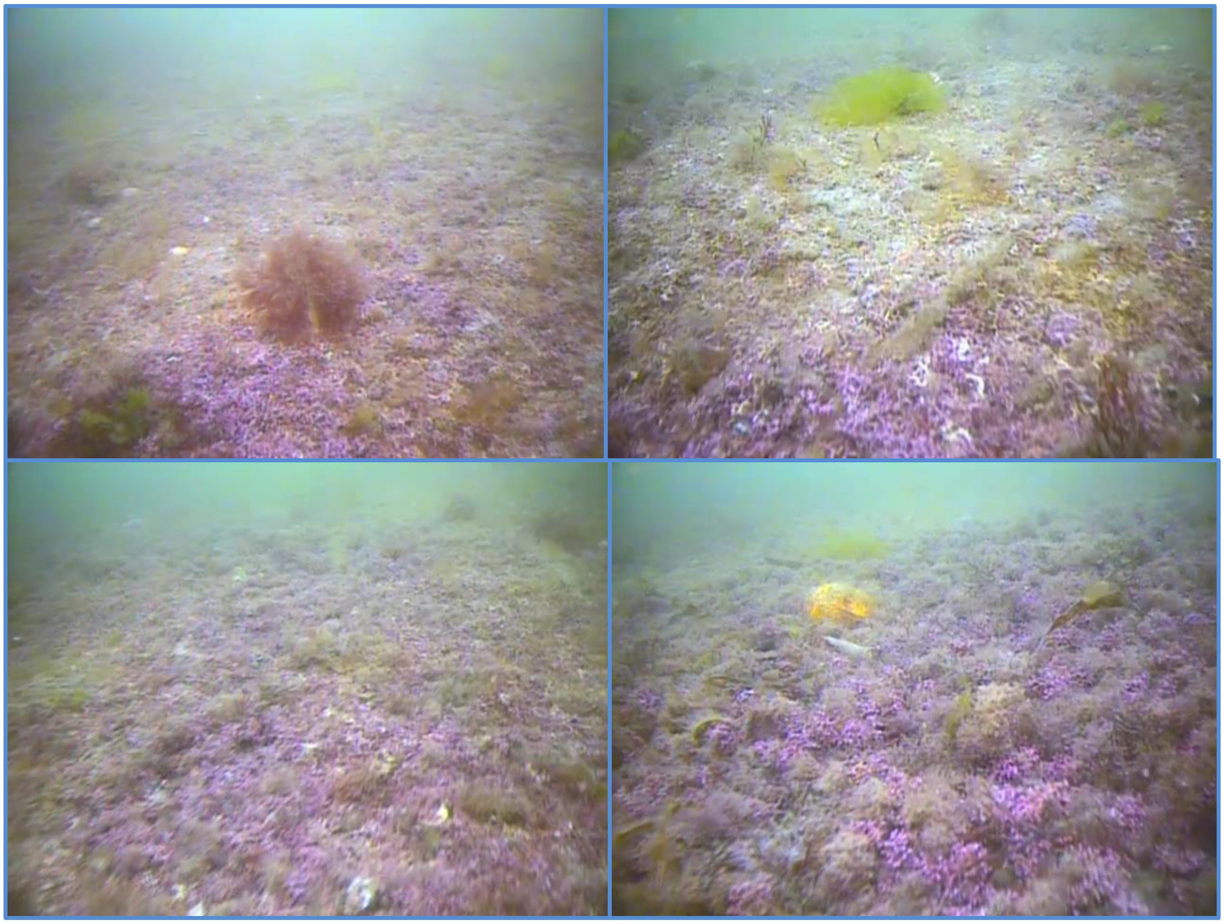

**Plate 3-17.Transect V17**

The seafloor along Transect V17, located south of the site close to the shore, consisted predominantly of live maerl interspersed with patches of dead maerl over a muddy sand. Starfish, *M. glacialis* and *A. rubens*, were imaged on the maerl surface while numerous anemone (*C. lloydii*) were noted protruding from the seafloor with their tentacles extended into the water column.

# 4. Conclusions

The bottom survey in the vicinity of the proposed mussel aquaculture site located on the south shore of Dunmanus Bay, revealed a number of different bottom types, the distribution mainly determined by the depth profile they were located. The bottom directly under and in the immediate vicinity of the site consisted of muddy sand that had various levels of bioturbation activity from burrowing infauna. Few macrofauna species were imaged in the video transects across these areas with the starfish, *M. glacialis*, and the anemone, *Cerianthus lloydii*, imaged in low numbers to the east of the site. In the shallower locations to the east and west of the site closer to the shore, the bottom consisted of coarse to medium sand that had a cover of algal tufts and large stones and boulders with *Laminaria* sp. and red algae attached. Starfish *M. glacialis* and *A. rubens* were the main faunal species encountered. A localised area consisting predominantly of live maerl and its associated faunal community was located close to the shore, south east of the site boundary.

# Appendix 2 - Dunmanus Hydrography Report

# MARINE HYDROGRAPHIC SURVEY,
# DUNMANUS BAY, CO. CORK

**MAY 2021**

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Produced by

## AQUAFACT International Services Ltd

**AQUAFACT International Services Ltd.**
**12 Kilkerrin Park**
**Tuam Road**
**Galway City**
**www.aquafact.ie**

info@aquafact.ie

**tel +353 (0) 91 756812**
**fax +353 (0) 91 756888**

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# 1. Introduction

This document reports on the deployment of a current profiler for the measurement of water currents and tidal elevations in Dunmanus Bay, Co. Cork over a spring and neap tide period. The requirement for this hydrographic data is part of an aquaculture application for the deployment of mussel longlines at a site located in the Bay as shown in Figure 1-1. The data collected by the current profiler was used to calibrate a computer model developed to predict the settlement of biowaste from the proposed mussel lines.

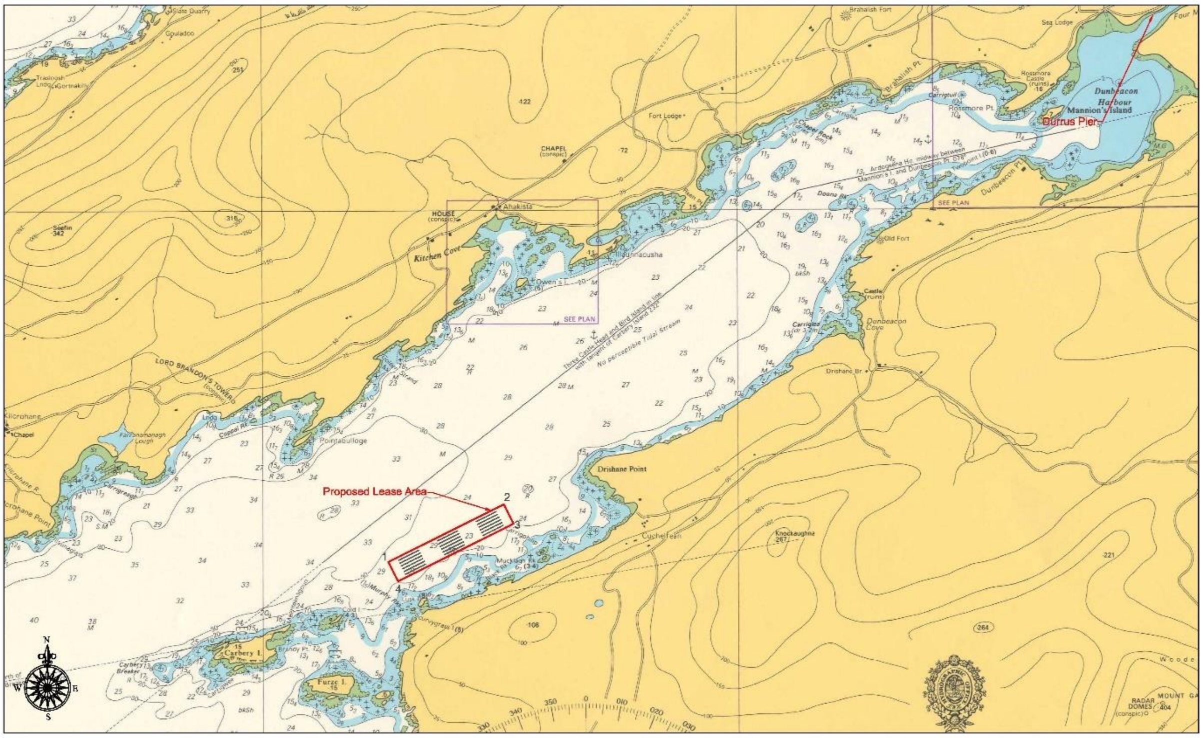


**Figure 1-1 Site in Dunmanus Bay, Co. Cork**

# 2. Methodology

## 2.1. Introduction

A Nortek Aquadopp Z-Cell 1MHz Acoustic Doppler Current Profiler was deployed at the potential aquaculture site in Dunmanus Bay on 29th April 2021 at 51.57342°N, 9.63230°W in approximately 27 m water depth. The location of the deployment site is presented in Figure 2-1. The meter was retrieved three weeks after deployment on 18th May 2021.

**Figure 2-1 Location of the ADCP in Dunmanus Bay, Co. Cork**

The Z-Cell (Zero Cell) Aquadopp allows current measurement to start right at the instrument's level through an innovative approach: it has side-looking beams fully integrated into the instrument's head, effectively removing the blanking distance normally applicable to ADCPs. The system averages the full current profile over the prescribed averaging interval. The whole sequence will start over again each measurement interval.

The Aquadopp sits on its own mooring on the seafloor looking up into the water column and records current speed and direction at set distances above the transducer head. Prior to deployment the profiler was calibrated and set up to record currents in one-meter bins above the transducer head every ten minutes. The Aquadopp was deployed along with a series of moorings to anchor the meter and the upright stable condition of the profiler was checked by diver following deployment. An automatic release mechanism was also deployed to aid retrieval and negate the need for a surface buoy to mark the location and avoid navigational hazards for boat traffic.

Tidal variations and temperature were recorded by means of the internal pressure and temperature sensors that are inbuilt in the unit.

On retrieval of the Aquadopp, all data was downloaded and quality checks run to ensure the reliability of the output. This program read in the data file and output the results from each burst measurement as ASCII files.

Data output include;

- Current and water level output in time series format with date and time on the first column and various current speed and direction for each bin as well as water levels on the remaining columns.
- Water temperature recorded at the transducer head for the same time intervals as current recordings.

# 3. Results

## 3.1. *Introduction*

All data recorded by the meter during the hydrographic survey in Dunmanus Bay are included as Excel files and accompany this report.

On retrieval, all data was downloaded and processed as part of a quality control check for accuracy. In general, the data was good and recorded all parameters for the duration of the deployment.

## 3.2. *Tidal Variation*

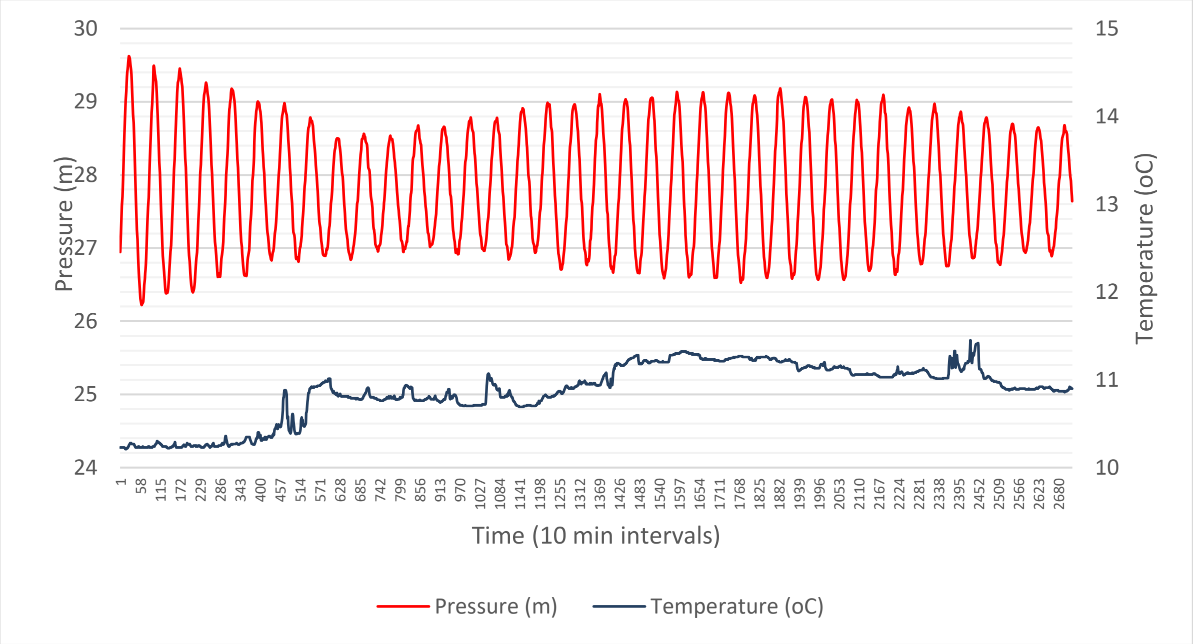


**Figure 3-1 Tidal variation recorded by the ADCP, 29th April to 18th May 2021.**

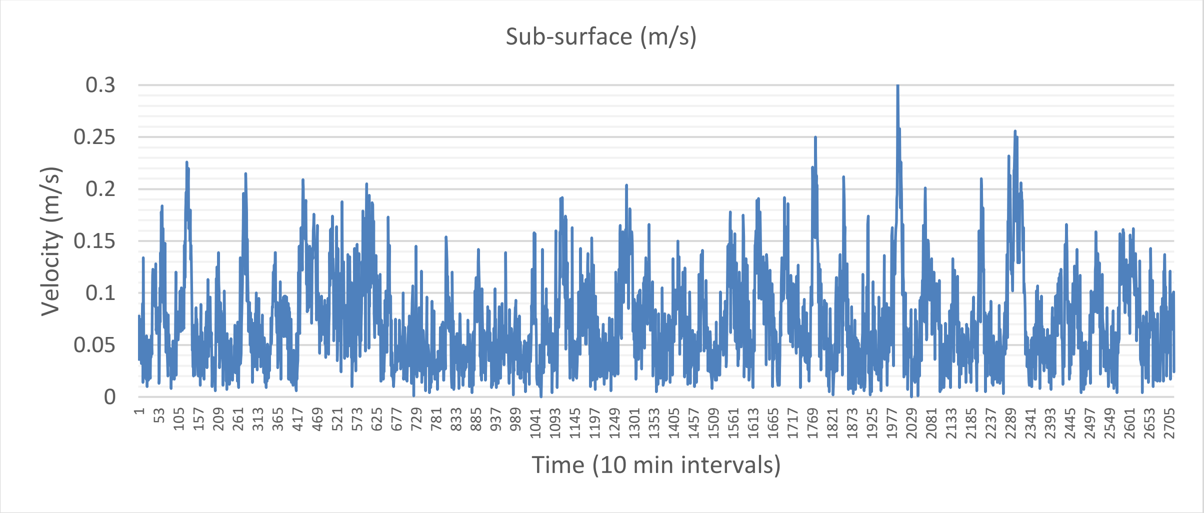
The ADCP was located in approximately 27 m water depth and the tidal range recorded over the deployment period is presented in Figure 3-2. Maximum range during a spring tide was just over 3.2 m while the range during neaps was just under 1.6 m. Water temperature at the transducer head was initially 10.2°C, which gradually increased, with some variability, over the deployment period and a water temperature of 10.7°C was recorded when the meter was retrieved.

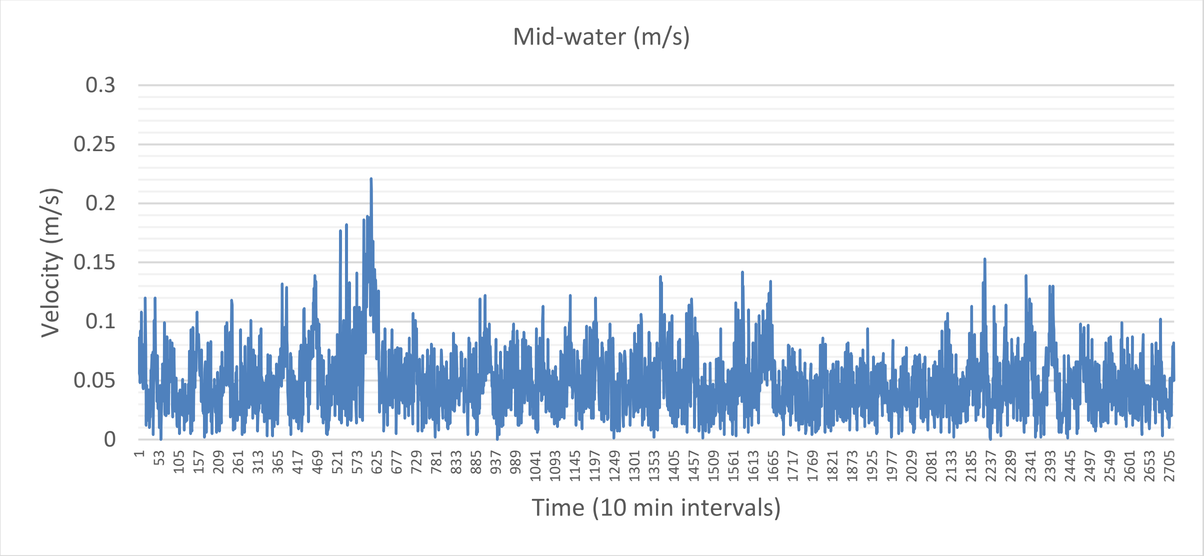
## *3.3. Currents*

Current speed recorded at three depths from 29th April to 18th May 2021 are presented in Figure 3-3. Maximum current speeds recorded sub-surface, mid-water and off bottom were 0.32 $ms^{-1}$ (0.62 knots), 0.214 $ms^{-1}$(0.42 knots) and 0.184 $ms^{-1}$(0.36 knots), respectively.

Horizontal current vector scatter plots from sub-surface, mid-water and off bottom (Figures 3-4) show west-southwest to east-northeast directional trend at all depths.

Cumulative vector plots from sub-surface, mid-water and off bottom (Figures 3-5) indicate a residual flow to the northeast at all depths although this is limited at the bottom station.





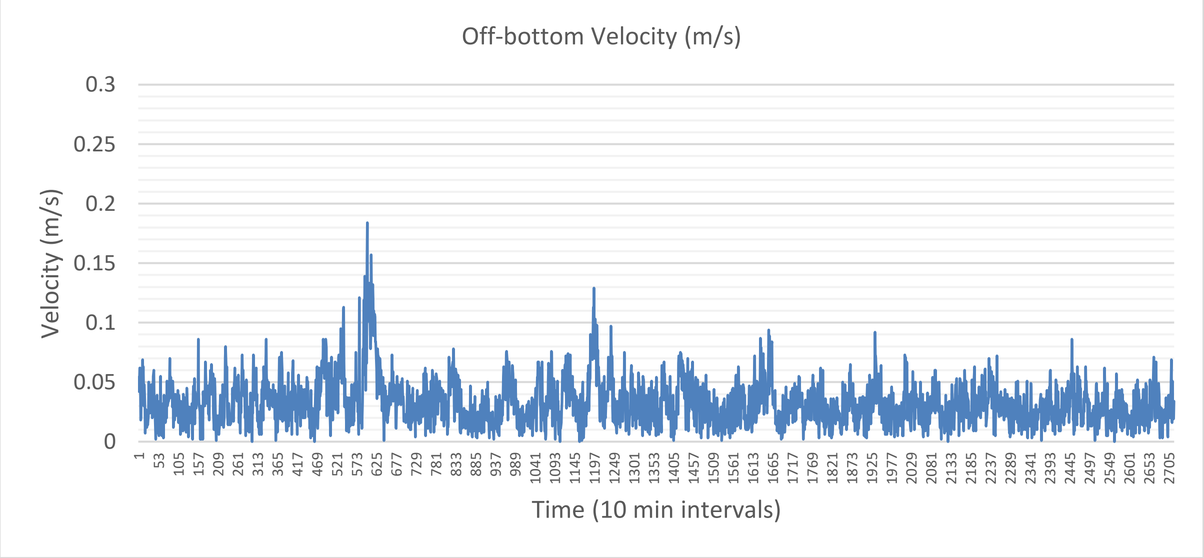


**Figure 3-2 Current speed recorded at three depths, 29th April to 18th May 2021.**

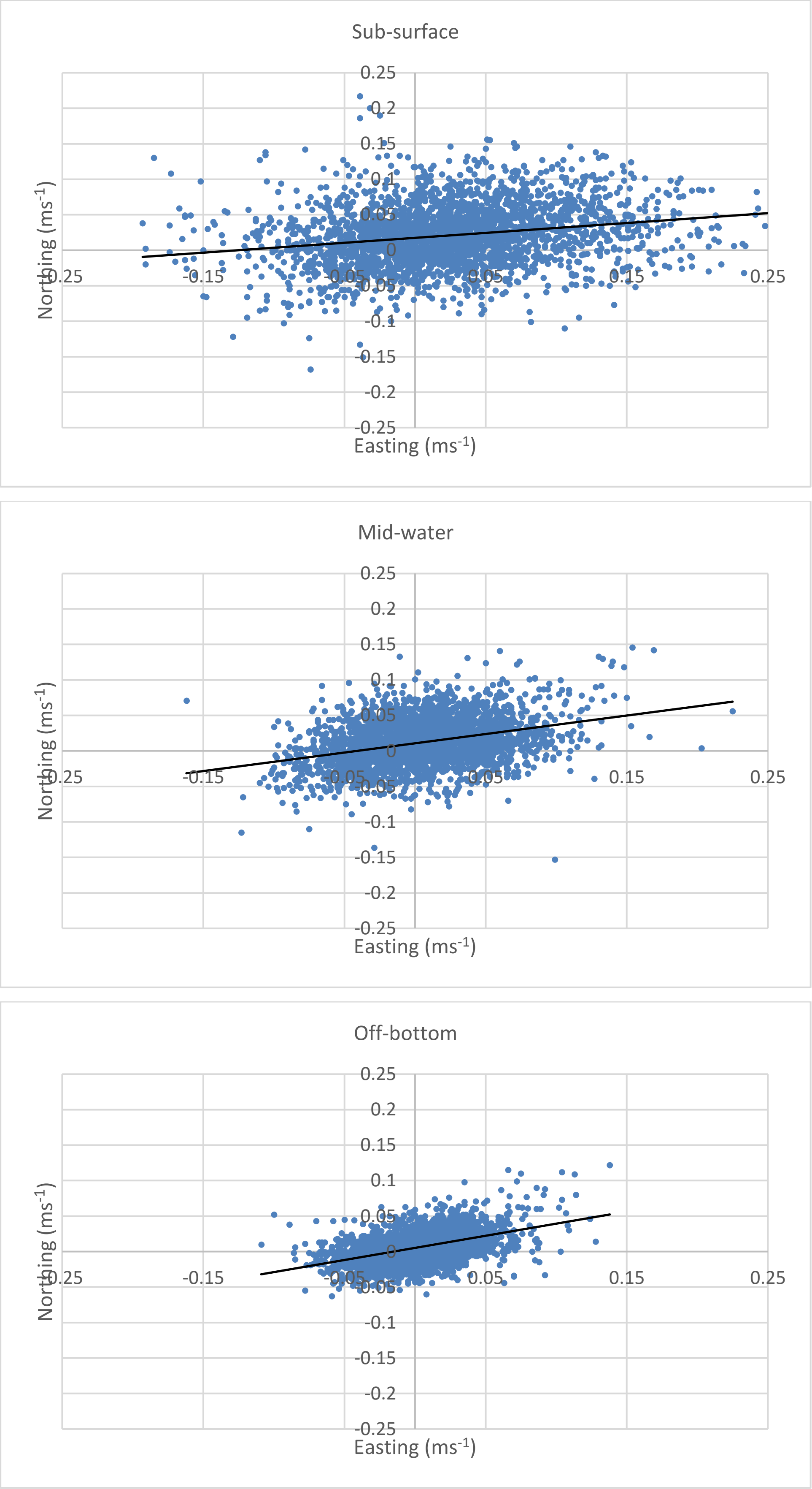


**Figure 3-3 Water current vector scatter plot, 29th April to 18th May 2021.**

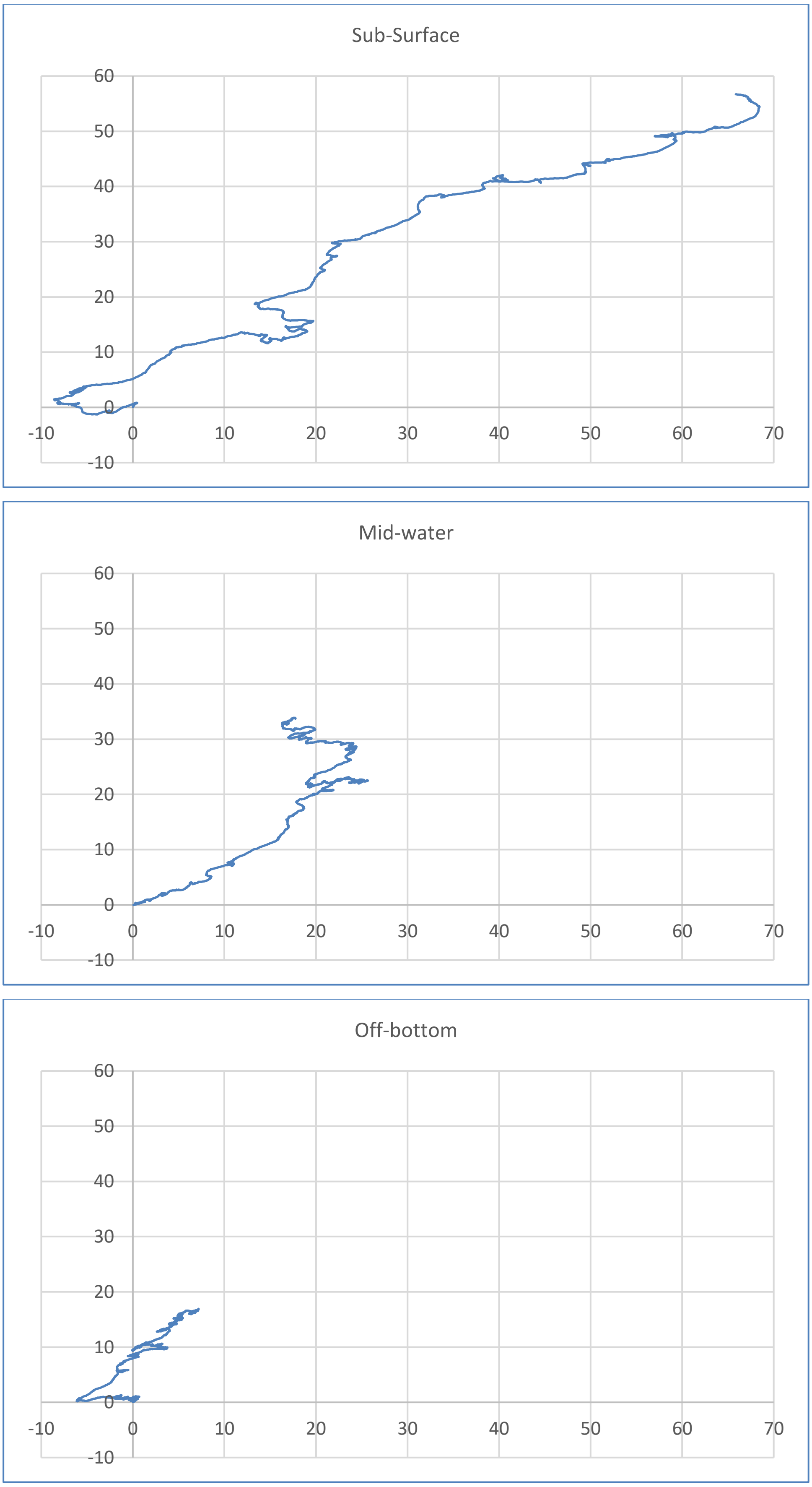


**Figure 3-4 Current cumulative vector plot for three depths, 29th April to 18th May 2021.**

A summary of current velocity and direction from sub-surface, mid-water and off-bottom are presented in the following water velocity and direction roses (Figures 3-6 to 3-8). Current direction is **to** the direction shown. Although currents are experienced in all directions, the predominant current is to the north east, particularly at the subsurface.

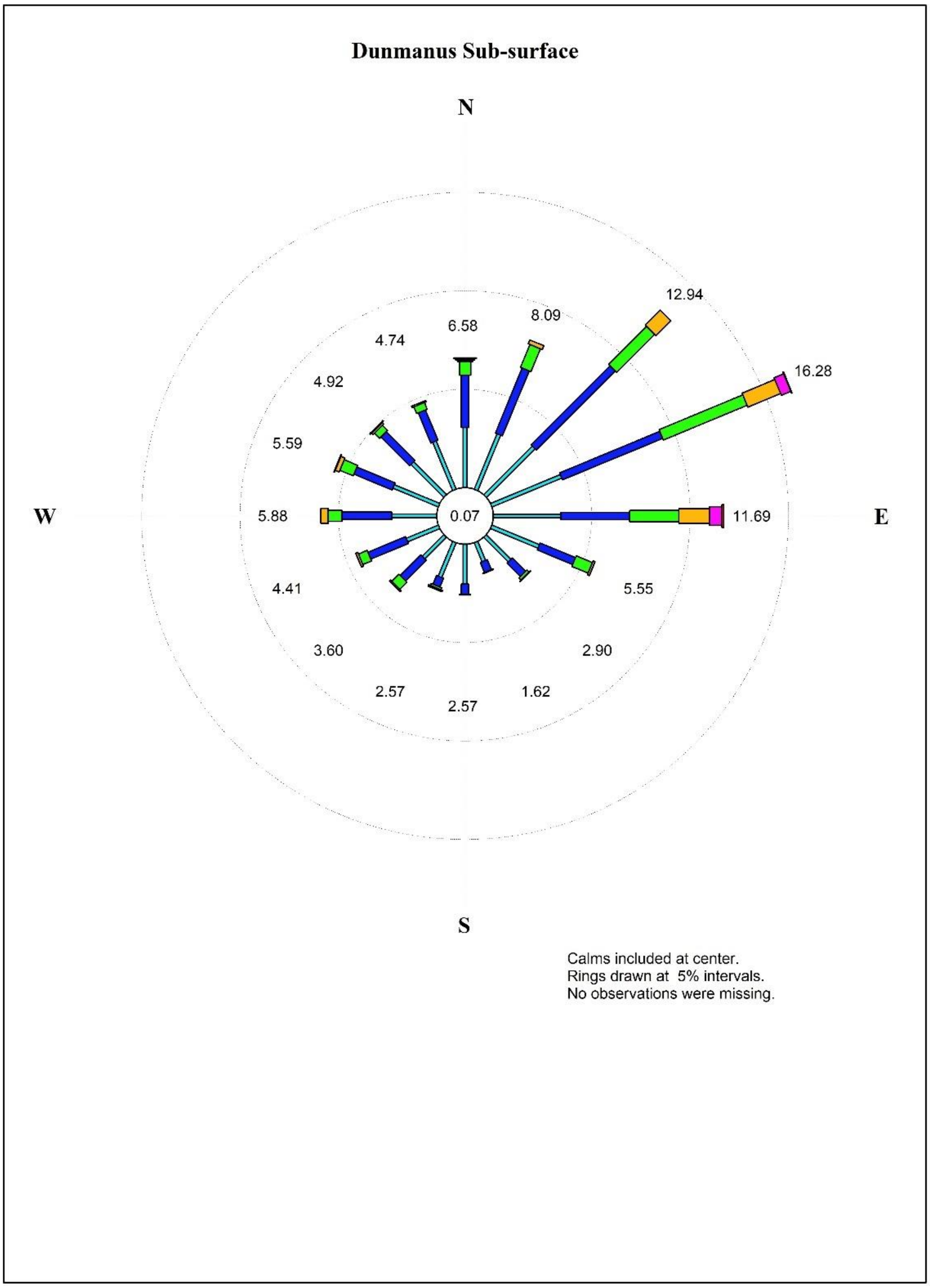


**Figure 3-5 Dunmanus sub-surface current velocity and direction, 29th April to 18th May 2021.**

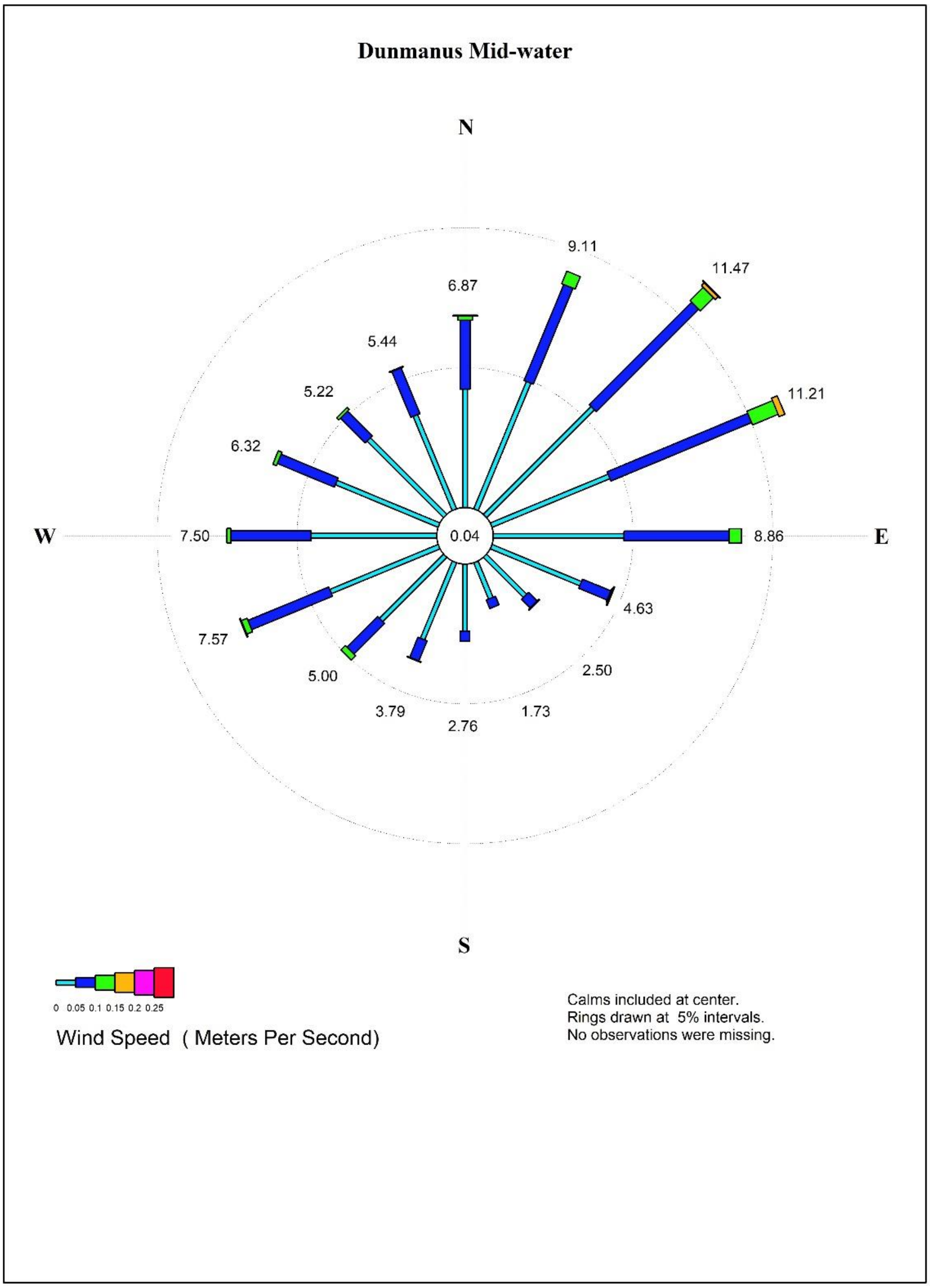


**Figure 3-6 Dunmanus mid-water current velocity and direction, 29th April to 18th May 2021.**

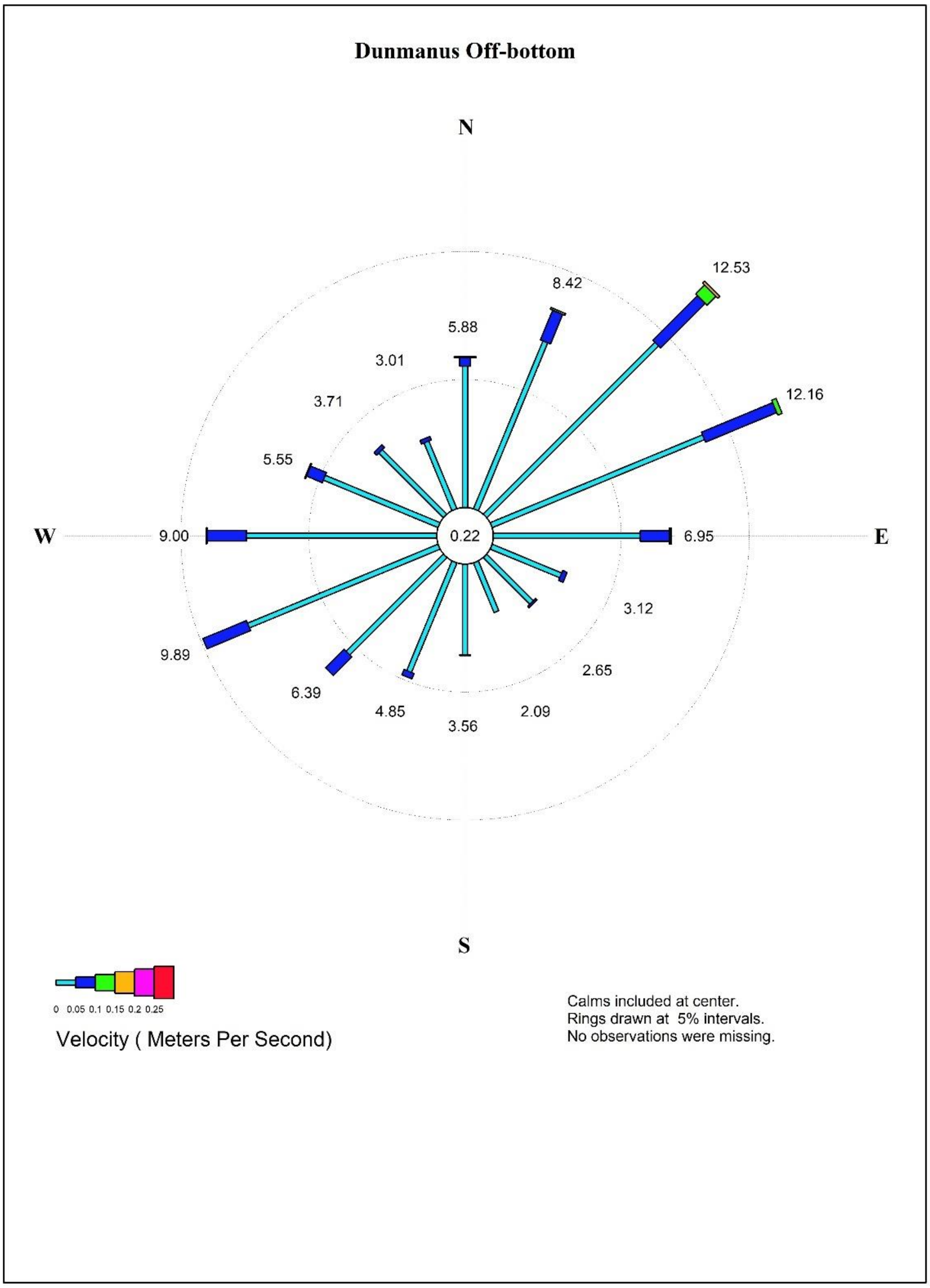


Figure 3-7 **Dunmanus Off-bottom current velocity and direction, 29th April to 18th May 2021.**

# 4. Conclusions

The current profile that was recorded in Dunmanus Bay at the proposed mussel aquaculture site is representative of environmental conditions experienced between 29th April to 18th May 2021 and covers both a spring and neap tide. In general, current speeds are relatively low along a predominantly northeast-southwest axis with no significant difference between spring and neap tide conditions. However, meteorological conditions would appear to have a significant influence on the currents. Wind data recorded from 29th April to 18th May 2021 at the M3 buoy located off the south west coast of Ireland is presented in Figure 4-1. Wind speeds increased from a southwest-west direction on the 2nd and 3rd May reaching speeds of over 30 knots and an increase in water currents was experienced at all depths at this time (see Figure 3-3). Similarly, surface currents increased around the 15th May when wind speeds were also seen to pick up with speeds of just under 30 knots from the south-southwest direction prevalent at the site.

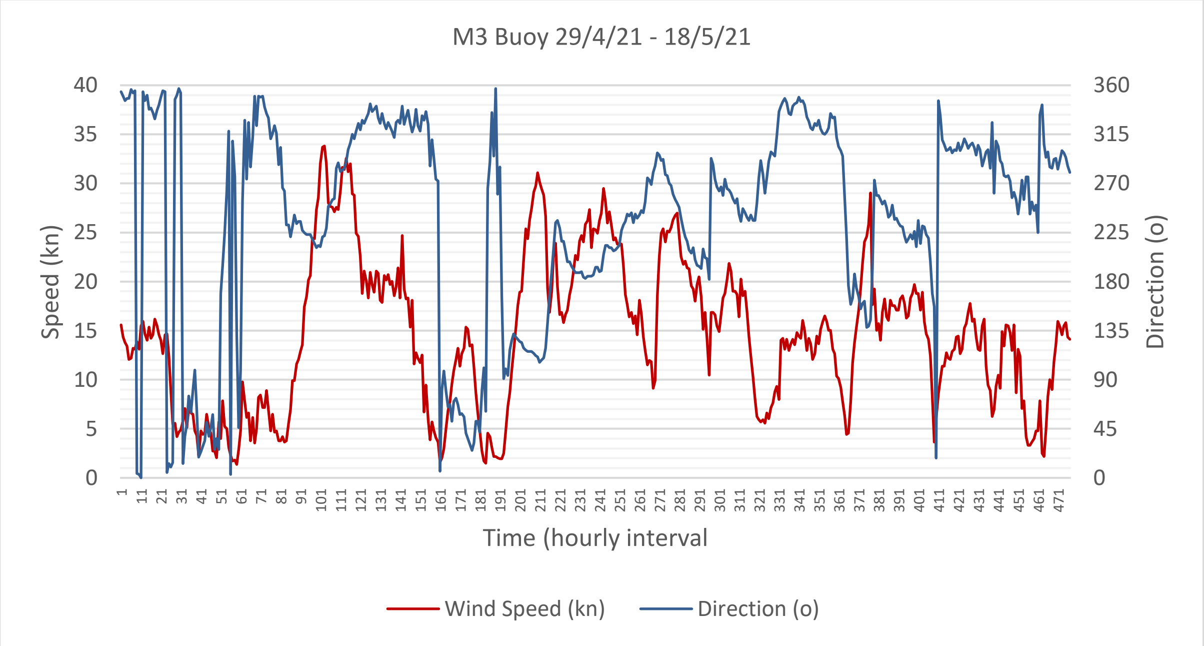


Figure 4-1 Mean wind data recorded from the M3 Buoy, 29th April to 18th May 2021.

# Appendix 3 – Water Quality Modelling Dunmanus

# WATER QUALITY MODELLING, DUNMANUS BAY

## Aquafact Ltd

IBE1888 WQ Modelling,
Dunmanus Bay
Rev 02
24 June 2021

rpsgroup.com

## Document status

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| Rev01 | Draft | KC | | | 22/06/2021 |
| Rev02 | Final | KC | R.M | N.S | 24/06/2021 |

## Approval for issue

| | | |
|---|---|---|
| K. Calder | K. Calder | 24 June 2021 |

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Prepared by:

**RPS**

Kristopher Calder
Associate - Water Environment and Flood Risk Management

Elmwood House
74 Boucher Road, Belfast
Co. Antrim BT12 6RZ

**T** +44 2890 667 914
**E** Kristopher.calder@rpsgroup.com

Prepared for:

**Aquafact Ltd.**

Mark Costello
Technical Manager

Aquafact Ltd.,
AQUAFACT International Services Ltd. 12 Kilkerrin Pk.,
Liosbaun, Galway, Ireland

**T** 353-91-756812
**E** info@aquafact.ie

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# 1 INTRODUCTION

Aquafact Ltd. commissioned RPS to investigate the potential effects on water quality and the benthos of coastal mussel *Mytilus edulis* aquaculture in Dunmanus Bay, County Cork. Dunmanus Bay Mussels Ltd. is seeking a license for one lease area at Kilcomane, on the southern side of the bay, northeast of Lusk Island. The proposed licensing site is shown in Figure 1.1.

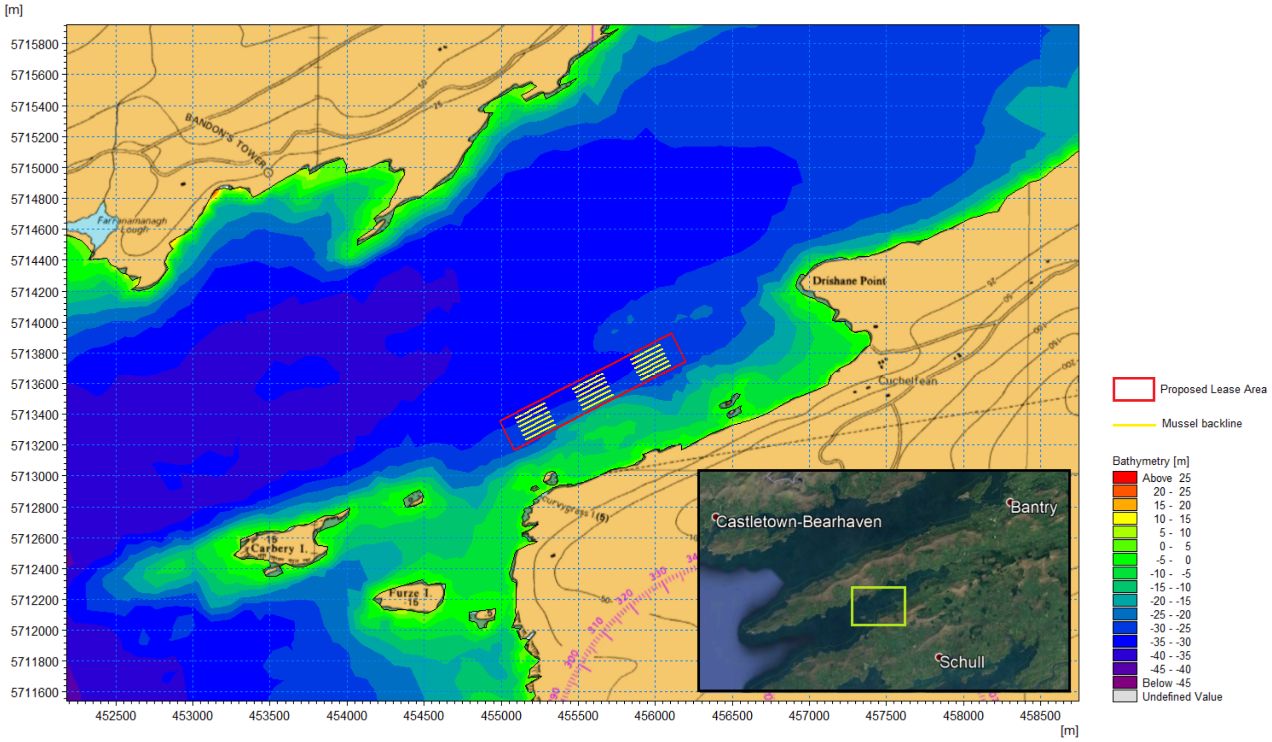

**Figure 1.1: Location of proposed mussel farm aquaculture site in Dunmanus Bay.**

The brief for this study included the following:-

1. Updating and calibration of the RPS tidal model of Dunmanus Bay, developed with the MIKE21 HD software, validated using all available current data for the region.
2. Simulation of the dispersion and fate of biowaste produced from the mussel farm site in order to quantify their likely impacts on the bay and its environment.

This report outlines the processes used to develop the calibrated model of Dunmanus Bay and documents the model validation. The results of the water quality assessment are presented in the following Sections of this document.

# 2 DUNMANUS BAY: MODELLING SYSTEM

## 2.1 MIKE 21 Couple Model FM

The MIKE 21 Coupled Model FM modelling suite developed by DHI was implemented for this study. It is a dynamic modelling system for application within coastal and estuarine environments. It can be used for investigating the morphological evolution of the nearshore bathymetry, due to the impact of engineering works (coastal structures, dredging works etc.). The engineering works may include breakwaters (surface-piercing and submerged), groynes, shore-face nourishment, harbours etc. MIKE 21 Coupled Model FM can also be used to study the morphological evolution of tidal inlets.

MIKE 21 Coupled Model FM is composed of following modules:

- Hydrodynamic Module
- Transport Module
- ECO Lab Module
- ABM Module
- Mud Transport Module
- Sand Transport Module
- Particle Tracking Module
- Spectral Wave Module

The Hydrodynamic Module is the basic computational component of the modelling system. Using MIKE 21 Coupled Model FM it is possible to simulate the mutual interaction between waves and currents using a dynamic coupling between the Hydrodynamic Module and the Spectral Wave Module. The MIKE 21 Coupled Model FM also includes a dynamic coupling between the Mud Transport, Particle Tracking and Sand Transport models and the Hydrodynamic Module and the Spectral Wave Module. Hence, a full feedback of the bed level changes on the waves and flow calculations can be included.

The main features of the MIKE 21 Coupled Model FM are as follows:

- Dynamic coupling of flow and wave calculations
- Full feedback of bed level changes on flow and wave calculations
- Easy switch between 2D and 3D calculations (hydrodynamic module and process modules)
- Optimal degree of flexibility in describing bathymetry and ambient flow and wave conditions using depth-adaptive and boundary-fitted unstructured mesh

## 2.2 The Hydrodynamic Model

The tidal flow simulations, which form the basis for the dispersion simulations conducted, were undertaken using DHI's MIKE21 FMHD hydrodynamic flow model. This provides the hydrodynamic basis for the computations performed in the modules for Environmental Hydraulics, i.e. the transport and particle tracking modules.

The Hydrodynamic Module simulates water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The effects and facilities include:

- Flooding and drying
- Momentum dispersion
- Bottom shear stress
- Coriolis force
- Wind shear stress
- Barometric pressure gradients
- Tidal potential
- Precipitation/evaporation
- Wave radiation stresses
- Sources and sinks

The Hydrodynamic Module can be used to solve both three-dimensional (3D) and two-dimensional (2D) problems. In 2D, the model is based on the shallow water equations; the depth-integrated incompressible Reynolds averaged Navier-Stokes equations.

## 2.3 Irish Sea Model

Tidal flow in Dunmanus Bay was simulated by a model driven by the RPS Irish Seas Surge model, which was used to derive boundary data. The Irish Sea model itself stretches from the north-western end of France, including the English Channel to Dover, to 16° West into the Atlantic, including the Porcupine Bank and Rockall. To the South, it stretches from the Northern part of the Bay of Biscay to just south of the Faeroes Banks in the North. Overall, the model covers the Northern Atlantic Ocean to a distance of 600km from the Irish Coast, as illustrated in Figure 2.1.

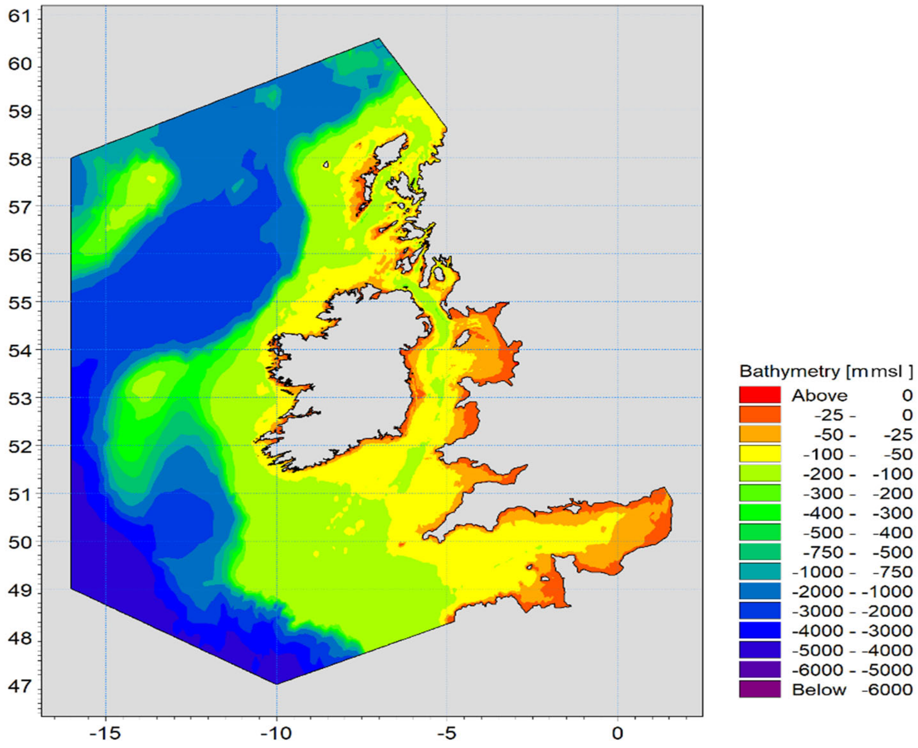

**Figure 2.1: Extent of Irish Sea Tidal Surge Model**

The Irish Sea model was constructed using a flexible mesh which allows the size of the computational cells to vary, depending on user requirements. The Irish Atlantic coast has been discretised, using cells of an average size of 3km. In the Irish Sea the maximum cell size is limited to 3.5 km, decreasing to less than 200m along most of the Irish coastline.

The bathymetry of the model was generated from several different sources. The model was constructed using the most up-to-date and highest resolution data available, including the entire INFOMAR database, which incorporates the OSI LiDAR datasets. An example of the coverage in the southwest is shown in Figure 2.2 which includes detailed LiDAR data in Dunmanus Bay (Figure 2.3), in addition to individual site surveys, carried out for numerous projects. Several local hydrographic surveys carried out by Geological Survey Ireland (GSI) were also incorporated into the model, along with data from surveys carried out by GSI to the South West of Ireland as part of the Irish National Seabed Survey (INSS).

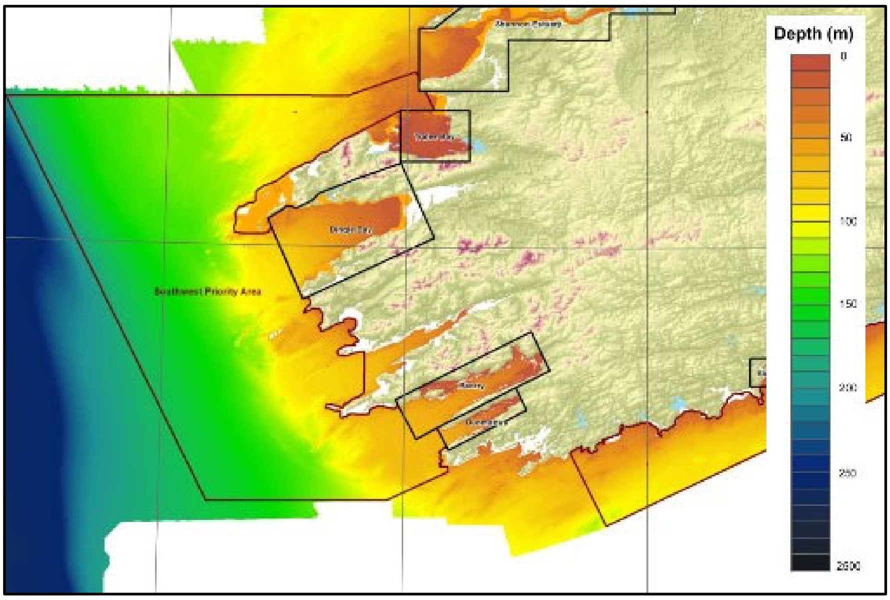

Figure 2.2: INFOMAR datasets used for Dunmanus tidal model – wider domain

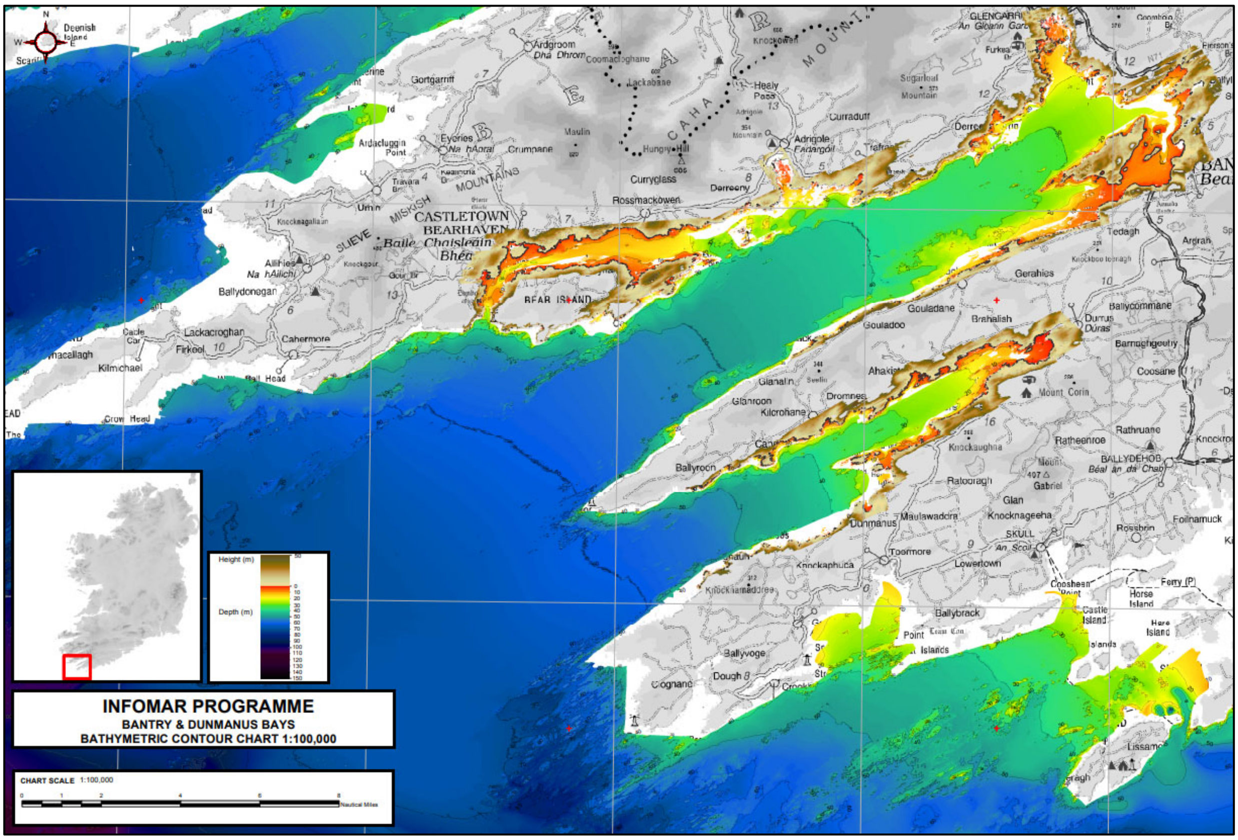

Figure 2.3: INFOMAR datasets used for the Dunmanus tidal model

The simulation of the astronomic tides in the model area is mainly driven by the oscillation of water levels along the open boundaries. The Irish Sea Tidal Surge Model has six open boundaries, five in the Atlantic and one in the English Channel. The time series of tidal elevations along these boundaries are generated using a global tidal model designed by a team at the National Space Institute, Demark (DTU10). The DTU10 global tidal model is based on the prediction of tidal elevations using 10 semi-diurnal and diurnal tidal harmonic constants (as opposed to the United Kingdom Hydrographic Office approach which uses 4-6 harmonic constants). These constants were derived through the simulation of the effect of astronomic forces due to the sun and moon on the water surfaces. Figure 2.4 shows the amplitude of the M2 semi-diurnal (12.25hour) tidal harmonic constituent over the global model domain.

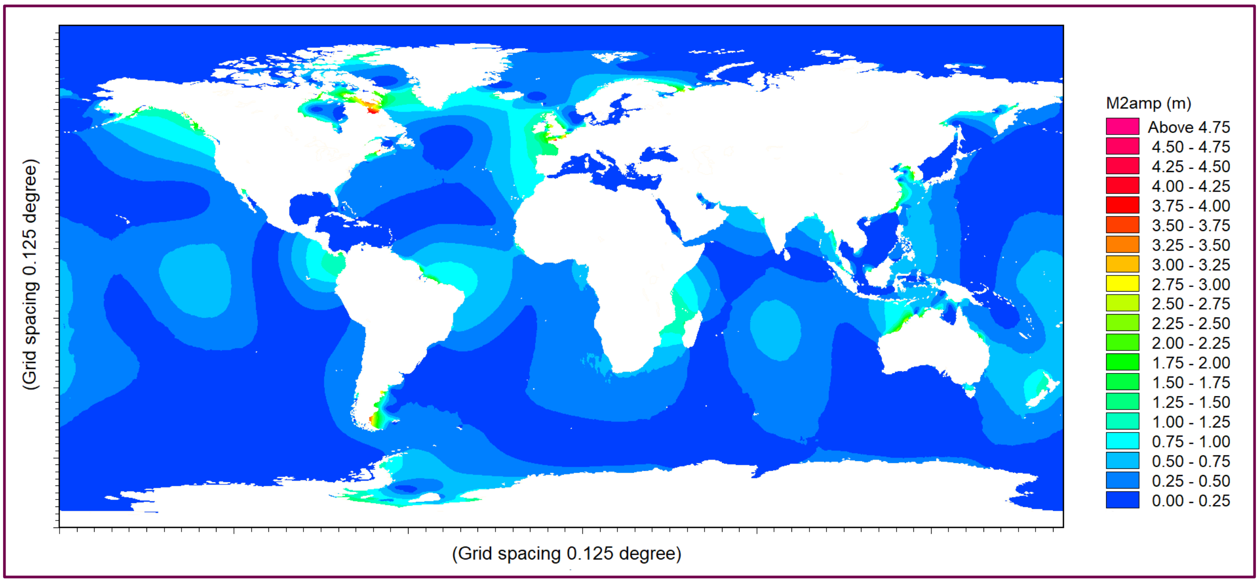

**Figure 2.4: Tidal harmonic for M2 amplitude for the DTU10 global model**

## 2.4 Dunmanus Bay model

The hydrodynamic model for the Bantry Bay study extended from just south of Great Skellig on the west coast and as far east as Toehead Bay westerly of The Stags on the south coast, as illustrated in Figure 2.5. A relatively large domain was required to simulate the complex convergence of tides that occurs offshore of the southwest coast of Ireland. The bathymetry was derived from the same datasets as used for the Irish Sea model and discussed in the previous section, Section 2.3, although these were updated for the local model development.

The mesh size for the model region varied greatly across the domain to both delineate the large scale tidal gyres and also to be suited to the small scale dispersion characteristics whilst maintaining computational efficiency. Offshore cells were in the order of kilometres squared whilst at each of the farm sites cells were circa 20m$^2$ so that the biowaste from mussel farm backlines could be discerned. Figure 2.6 shows the location of the farm site included in the model bathymetry, with the bathymetry level being given relative to mean sea level.

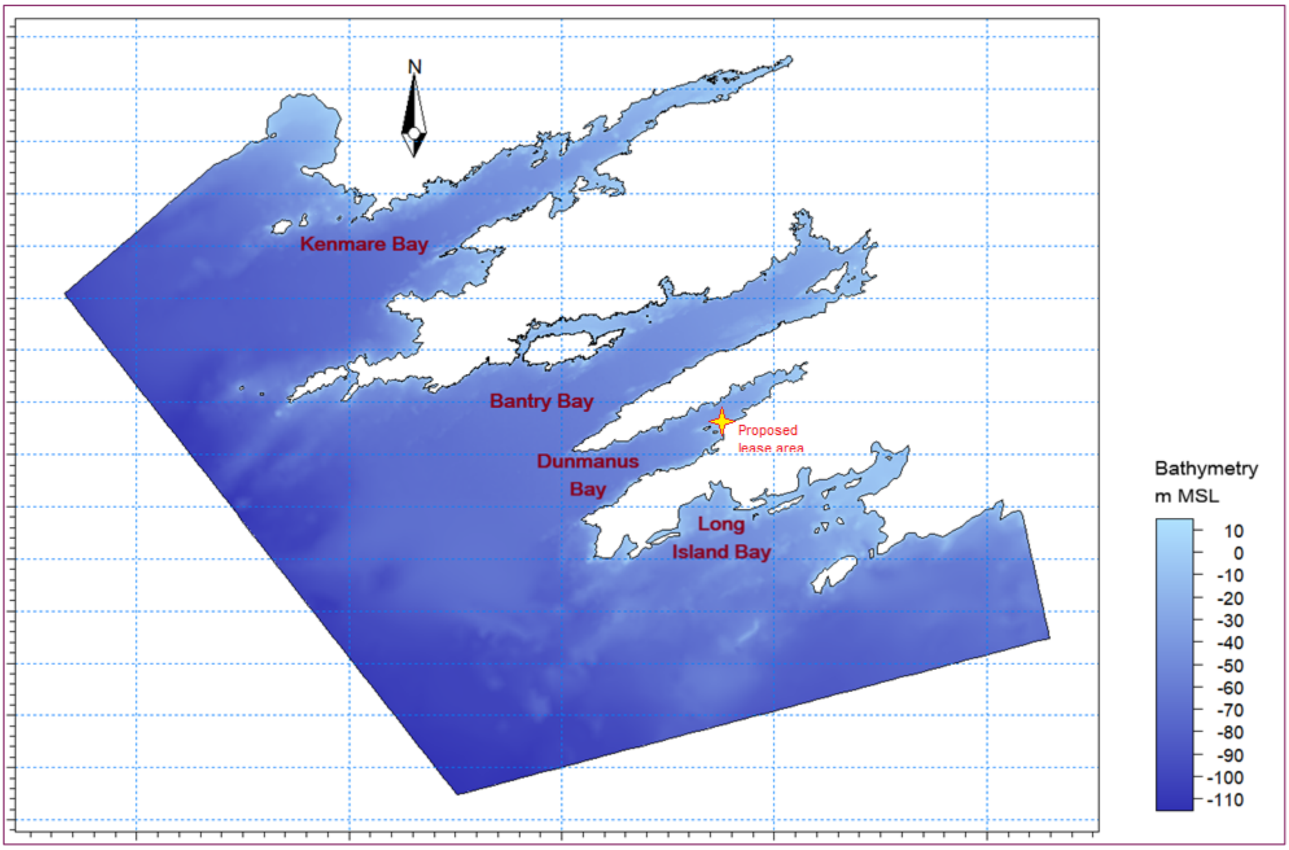

Figure 2.5: Extent of tidal model bathymetry (MSL)

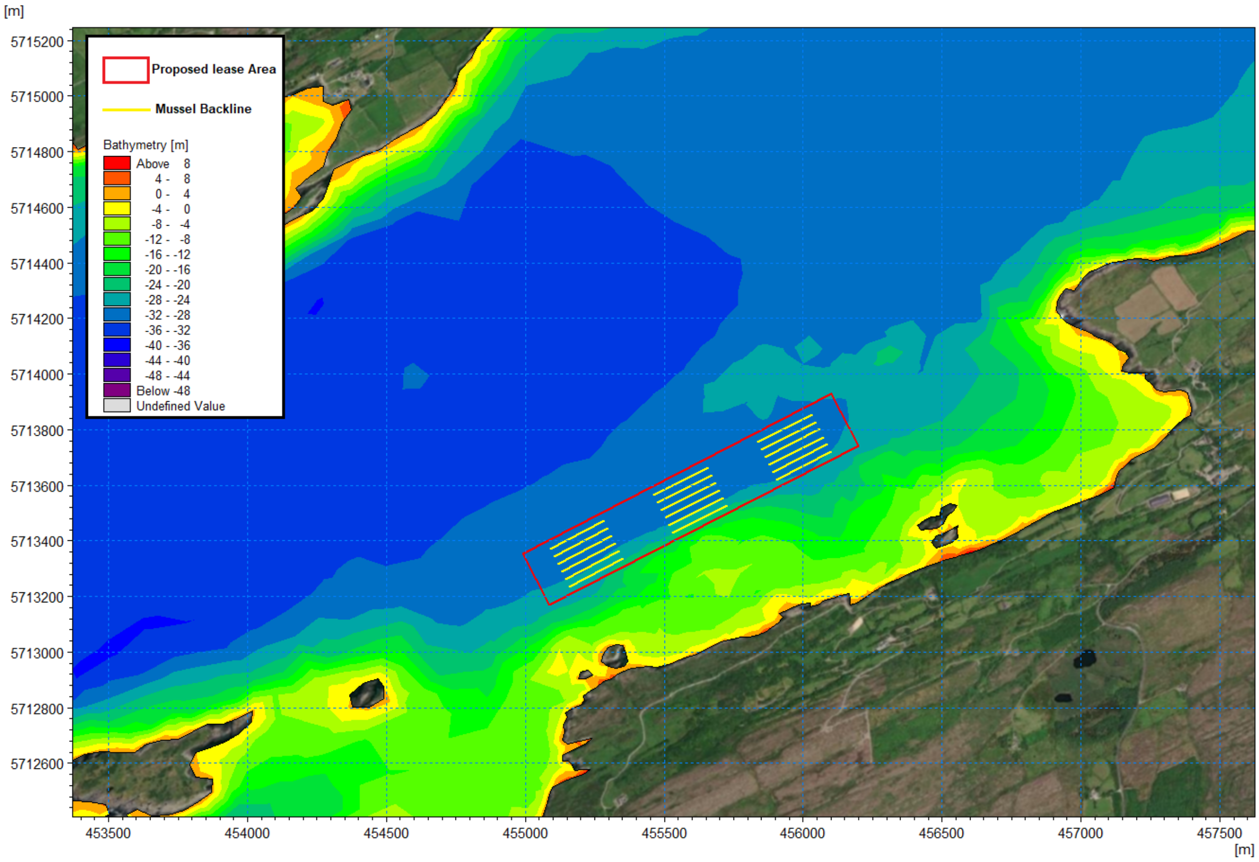

Figure 2.6: Location of proposed mussel farm aquaculture site in Dunmanus Bay.

The model was used to simulate tidal flow patterns for a period of 31 days, to include both neap and spring tidal cycles in the simulation. Typical tide patterns for mean spring tides are presented in Figure 2.7 to Figure 2.10. Figure 2.7 shows the flood tide pattern for Dunmanus Bay as a whole whilst Figure 2.8 shows mean spring flood tide flow at the proposed lease site. Figure 2.9 and Figure 2.10 show the corresponding ebb tide pattern plots for mean spring ebb tide.

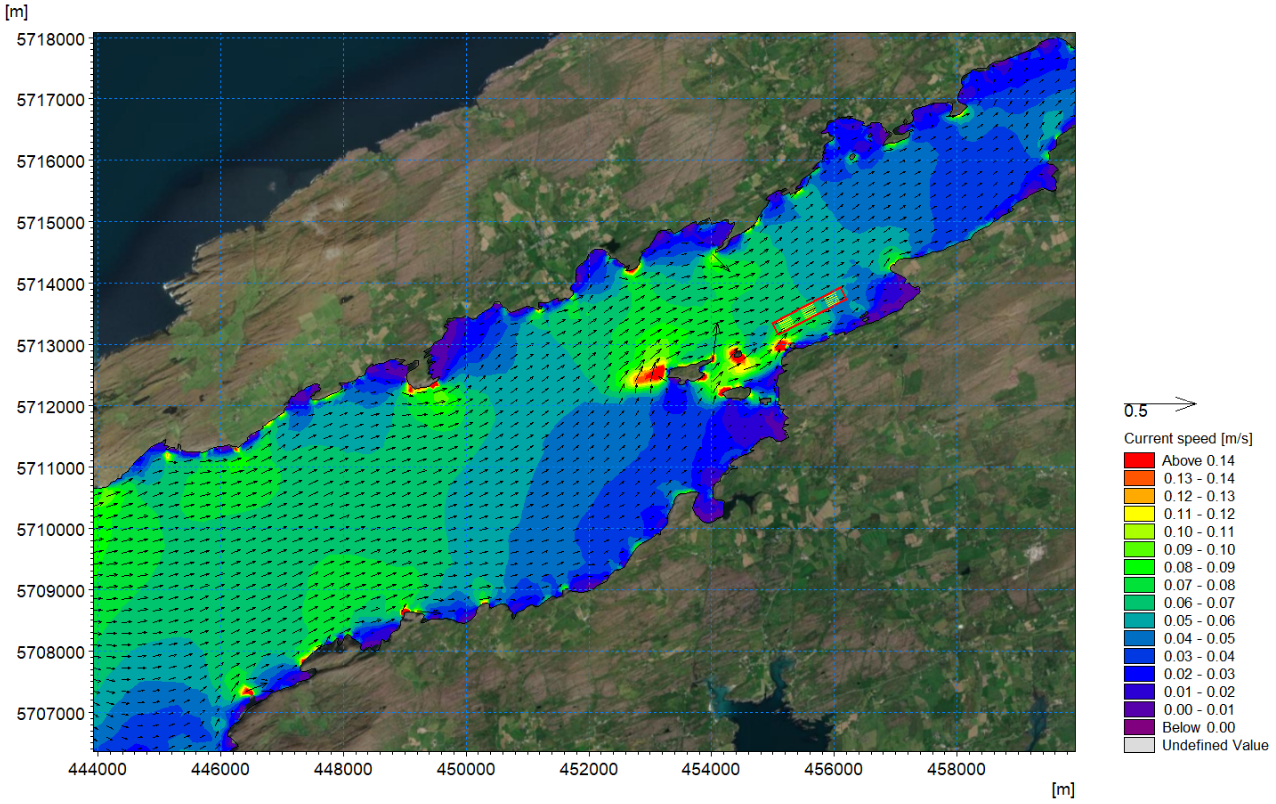

Figure 2.7: Flood tide pattern for Dunmanus Bay – Mean Spring Tide

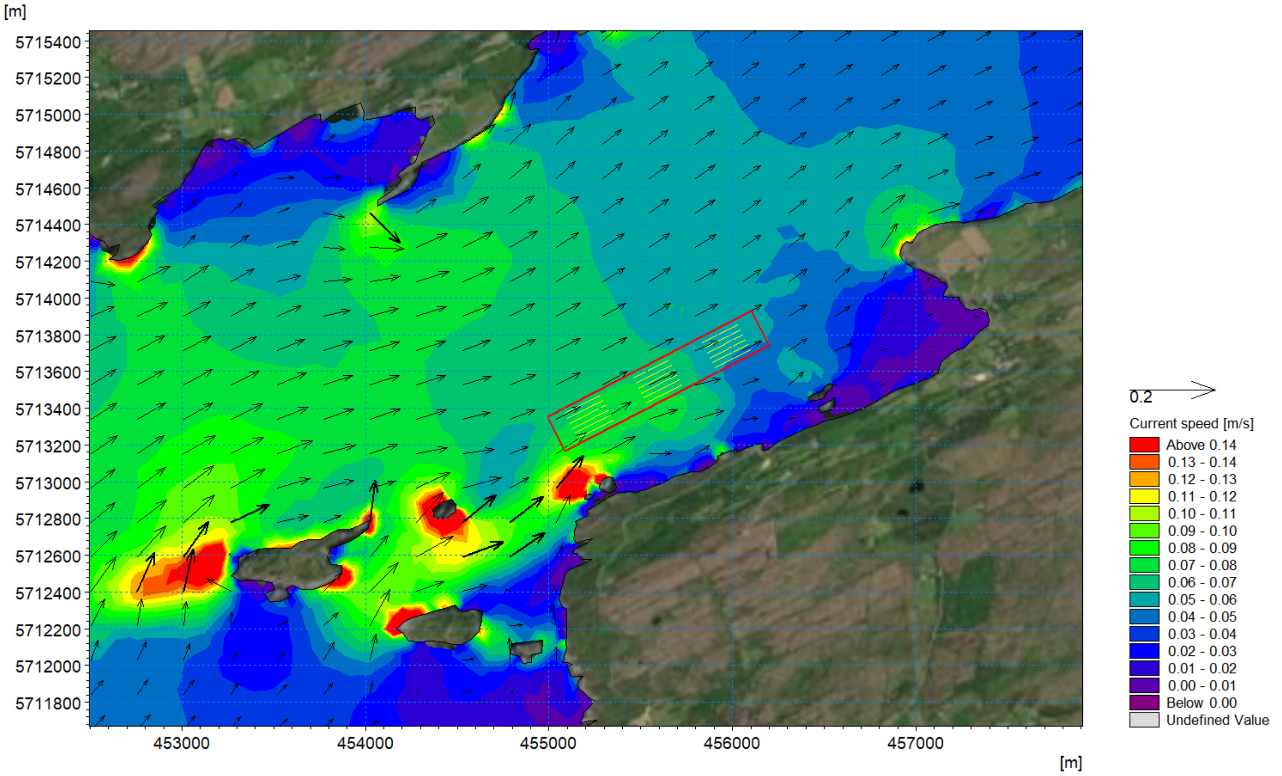

Figure 2.8: Flood tide pattern at the proposed lease area – Mean Spring Tide

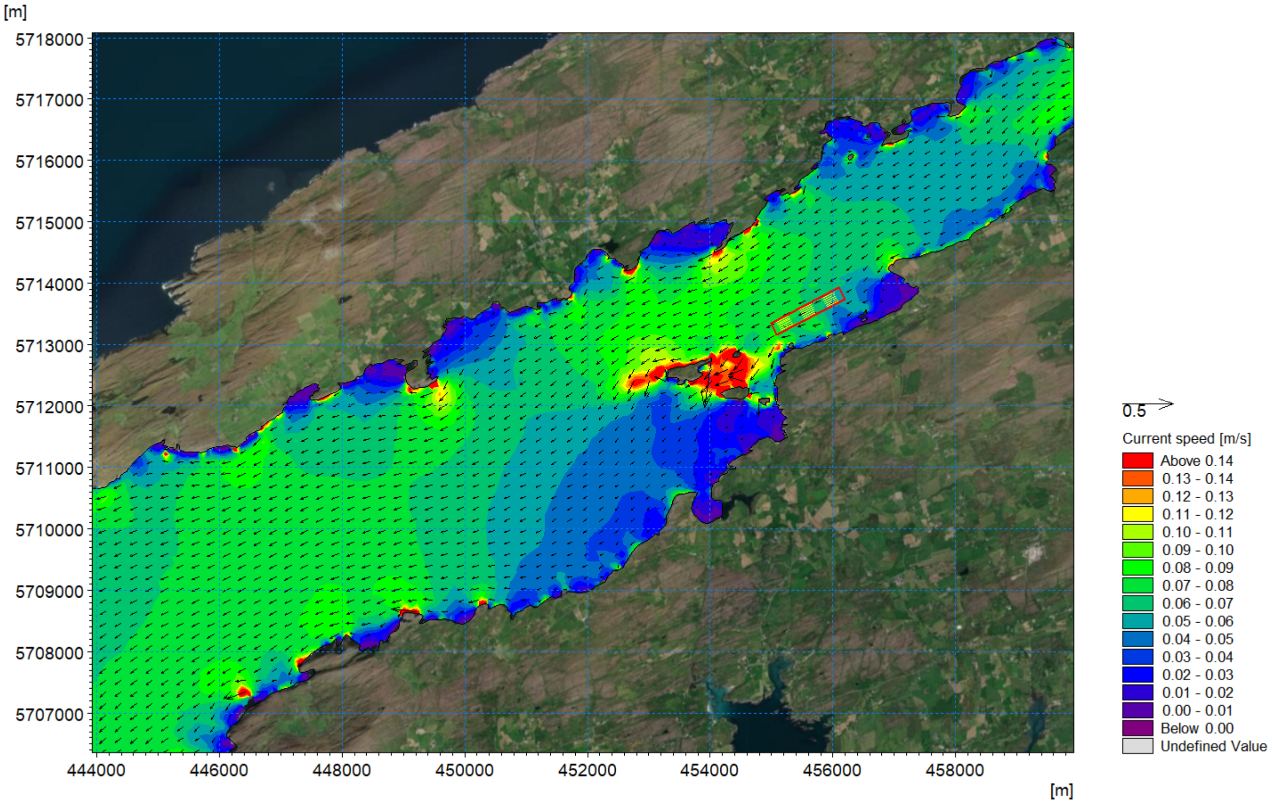

**Figure 2.9: Ebb tide pattern for Dunmanus Bay – Mean Spring Tide**

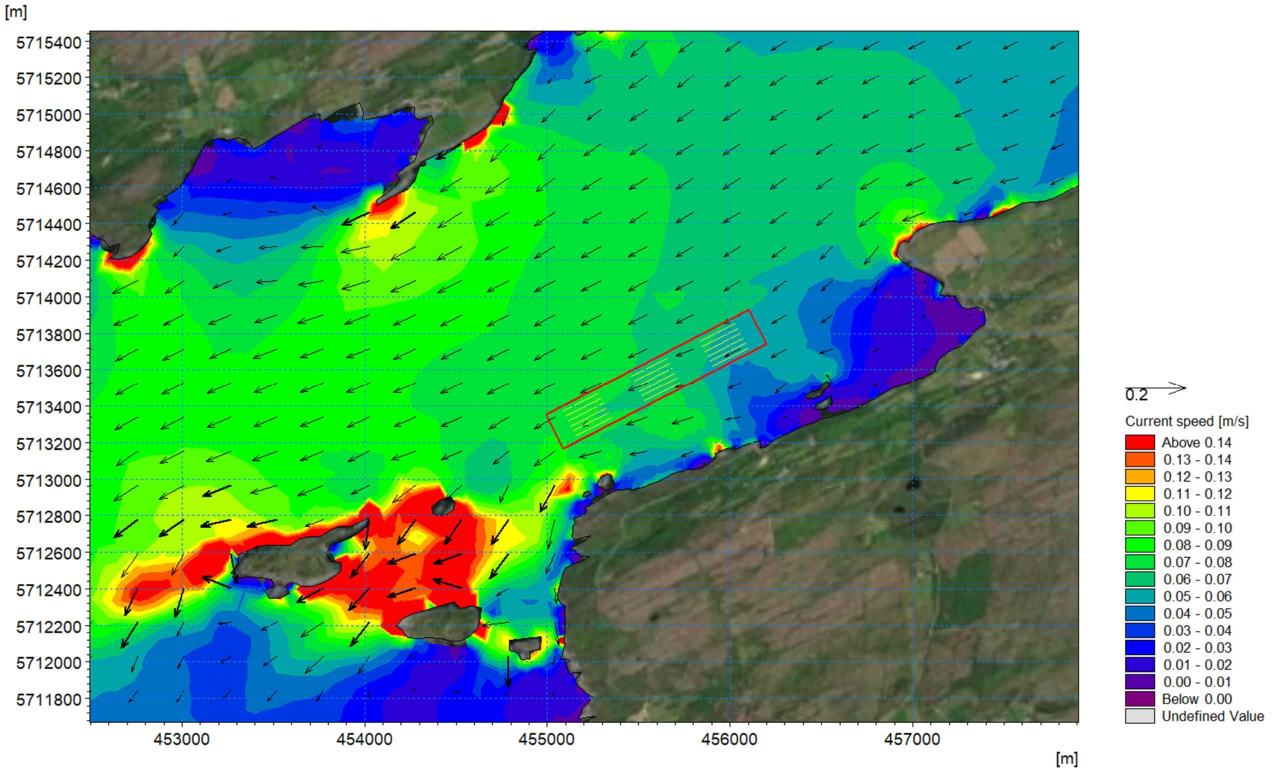

**Figure 2.10: Ebb tide pattern at the proposed lease area – Mean Spring Tide**

These plots demonstrate the complex nature of flow within the bay. Whilst the hydrodynamics in Dunmanus Bay are not well reported or described in any academic research or Journals, however, the Irish Cruising Club do note that "*tidal flows in Dunmanus Bay are almost imperceptible*". Given the wedge shape nature of the Bay, these results are unsurprising and are reflective of hydrodynamic conditions in neighbouring bays such as Bantry. The New British Channel Pilot by J W Norie, Eleventh Edition, published in 1839, states of Bantry Bay that *"The stream of the tide is scarcely sensible in any part of it."*

The overall magnitude of ebb end current speeds in Dunmanus Bay is generally less than 0.1m/s as the convergence of tides in the outer domain limit the prevailing currents. It will be seen from Figure 2.8 and Figure 2.10 that the presence of Carbery and Furze Islands produce marginally higher current speeds near the proposed lease area. Despite this, current flows in this area are generally less than 0.15m/s.

Flow characteristics and particularly dispersion potential in an area may be assessed by the examination of residual currents. Residual currents can be calculated by considering the vector components of tidal currents over the course of complete tide cycles. As a general rule, areas showing little or no residual current are characterised by tidal flows which ebb and flood along the same axis and at a similar magnitude. In such a situation, any material or biowaste released may be carried back on the returning tide. In contrast, greater residual currents through an area are observed when the differential between the ebb and flood currents increases.

Figure 2.11 shows that residual currents are relatively low in the main body of Dunmanus Bay. However, higher residual currents can be observed around the few promontories and islands within the Bay, including the nearby Carbery and Furze Islands. As shown in Figure 2.12, residual currents are generally very low at the proposed lease area, however, a very weak eddy structure that occupies the width of the bay may assist in flushing biowaste material out of the bay.

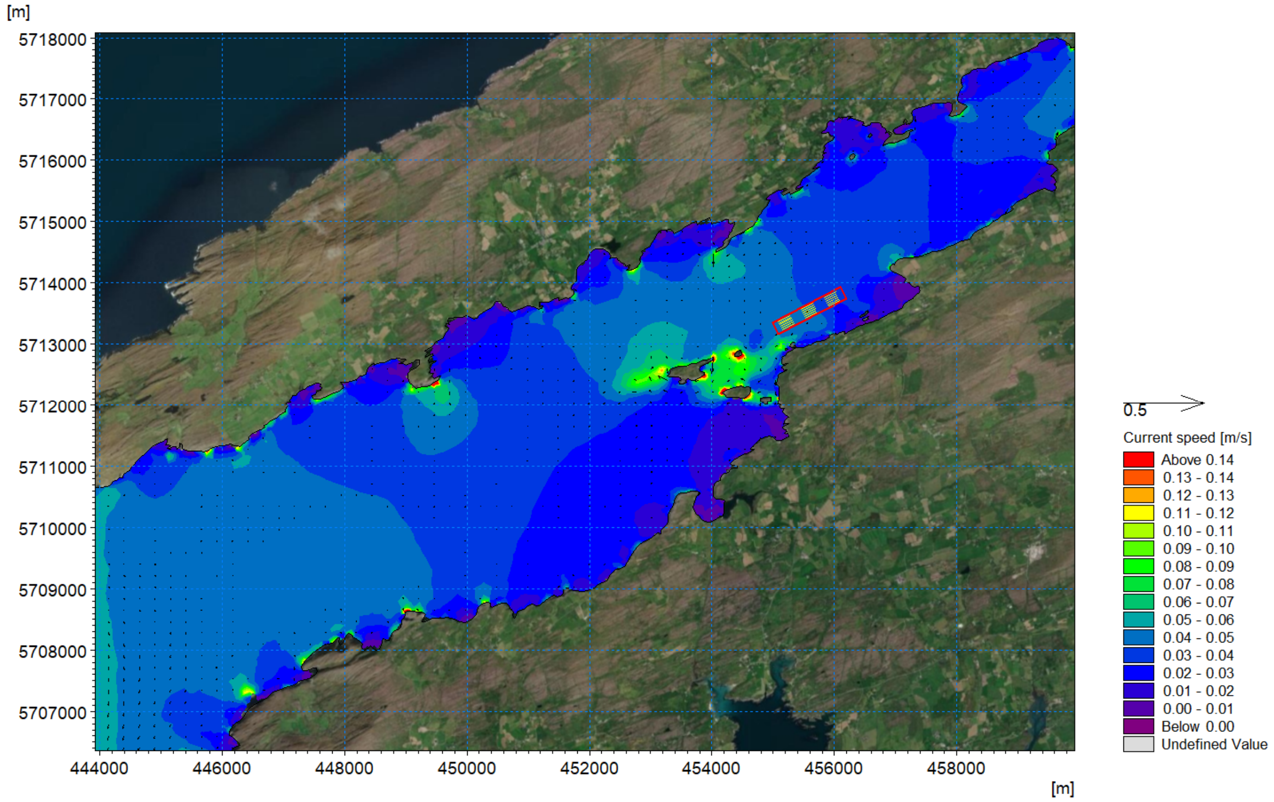

**Figure 2.11: Residual current for Bantry Bay – Mean Spring Tide**

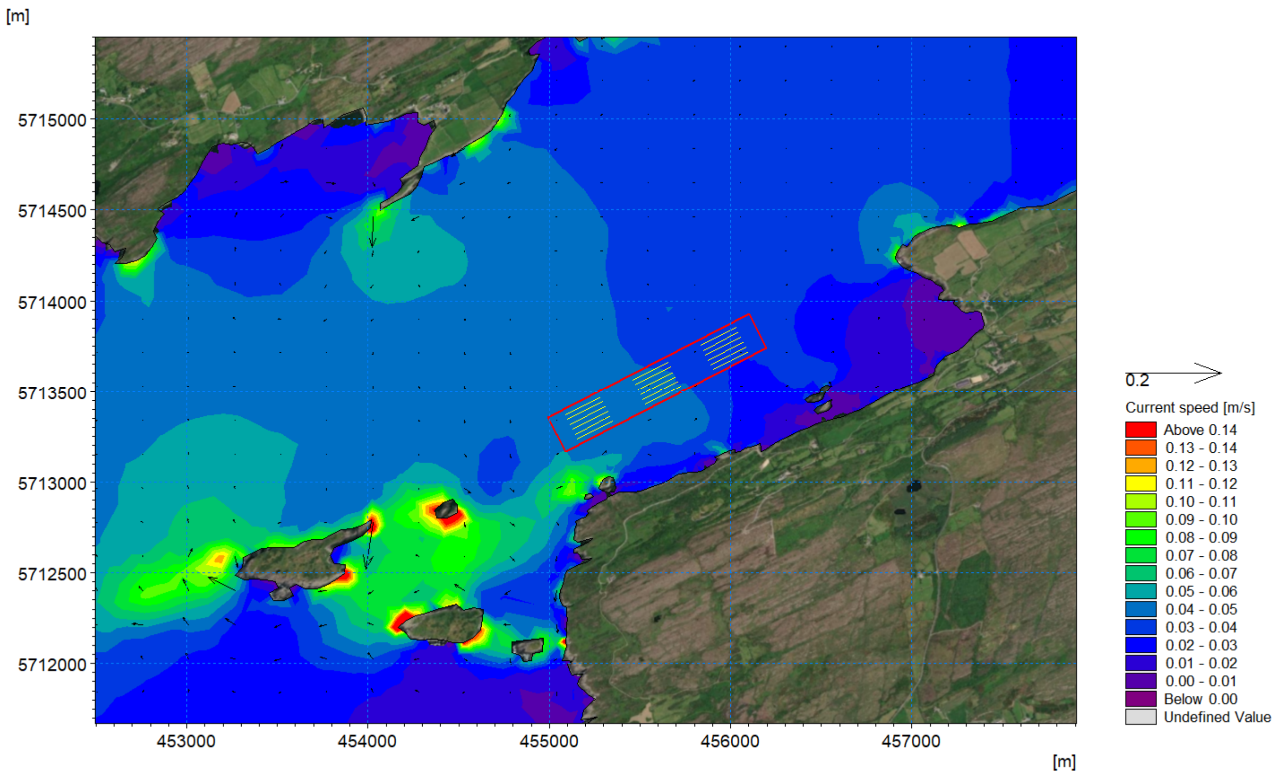

**Figure 2.12: Residual current at the proposed lease area – Mean Spring Tide**

## 2.5 Dunmanus Bay model verification

Although the south-west of Ireland model had been extensively calibrated previously, the refined Dunmanus Bay for this study was verified to ensure the hydrodynamic model characteristics were maintained.

As discussed in previous Sections of this report, the hydrodynamics in Dunmanus Bay are not well reported or described in any academic research or Journals. As such, good quality data against which to validate the Dunmanus model is lacking. In recognition of this, Aquafact Ltd. deployed an Acoustic Doppler Current Profiler (ADCP) within the immediate vicinity of the proposed lease area as shown in Figure 2.13. This device was deployed for >14 days to capture a full range of spring and neap tidal conditions.

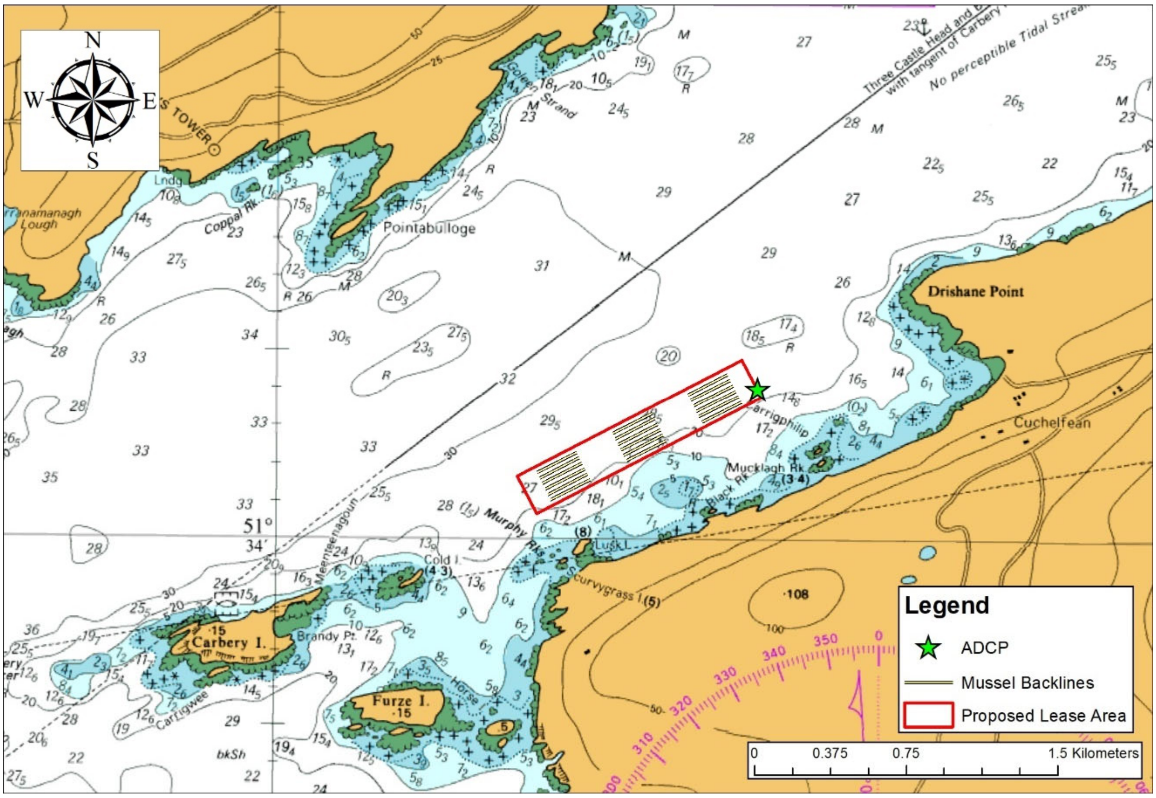

**Figure 2.13: Location of current survey data**

As it was important to simulate the full range of velocities experienced within Dunmanus bay for the assessment of water quality, the model validation period was chosen for spring and neap tides, which encompassed the range of flow conditions experienced at the sites. This also aided the verification process as the comparison period was chosen based on the tidal excursion.

The ADCP device deployed by Aquafact Ltd. recorded current speeds and directions throughout the water column. This data was processed to produce representative data for the near bed, mid-depth and near-surface layers. As the model is depth-averaged, only a single trace is provided. Figure 2.14 and Figure 2.15 presents a comparison of recorded and simulated current speeds and directions respectfully during a typical spring tide. Figure 2.16 and Figure 2.17 presents similar data but for a typical neap tidal regime.

It will be seen from Figure 2.14 to Figure 2.17 that measured velocities and directions are quite erratic. This is because the current speeds throughout most of Dunmanus Bay are below that which an ACDP can effectively operate. A model-driven from harmonic data will not provide such an erratic response without fluctuating forcings being applied, such as meteorological variations. However, the modelled trace does correspond with the trends in both current direction and speed giving confidence that subsequent water quality simulations will provide a good representation of the dispersion of material released from the proposed lease site into Dunmanus Bay.

Whilst there is no Admiralty tidal elevation data for anywhere within Dunmanus Bay, the range of tidal elevations occurring nearby at Castletownbere and Bantry are shown in Figure 2.18 and Figure 2.19 for respectively. These Figures demonstrate that the tidal excursion throughout the model is well represented.

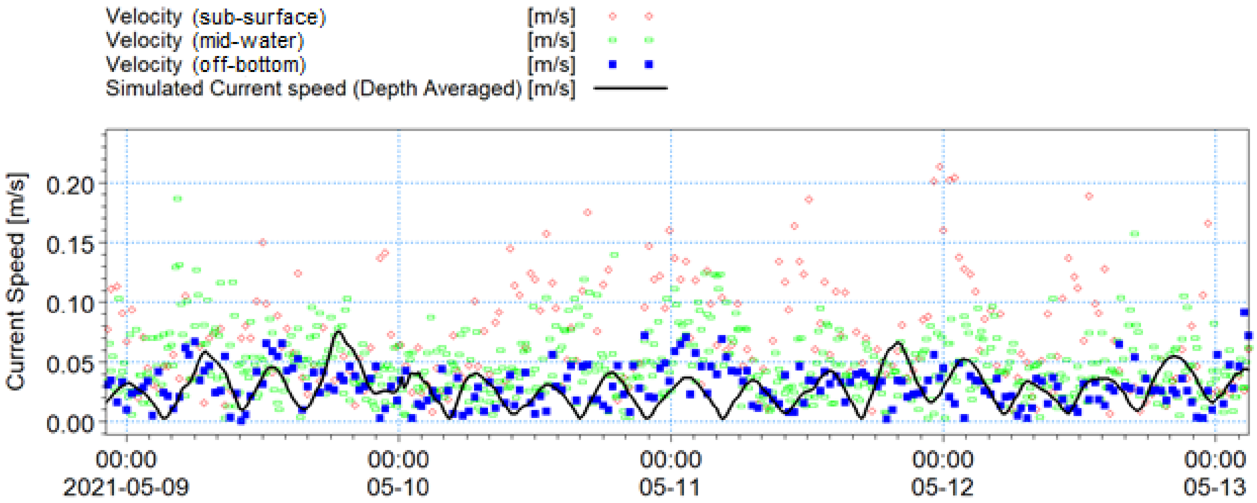

Figure 2.14: Recorded and simulated current speeds at the proposed lease site during a typical spring tidal regime

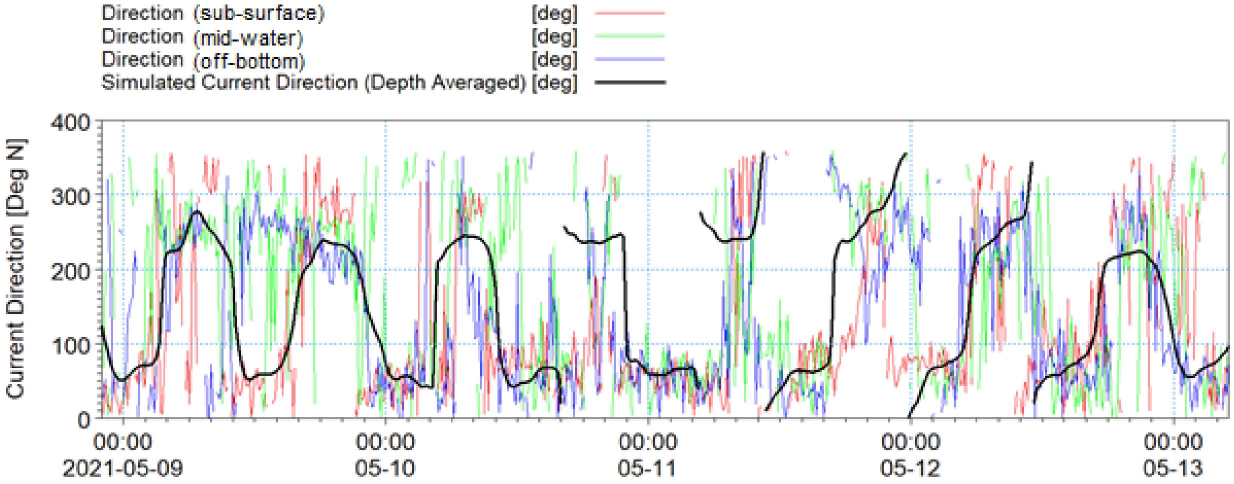

Figure 2.15: Recorded and simulated current directions at the proposed lease site during a typical spring tidal regime

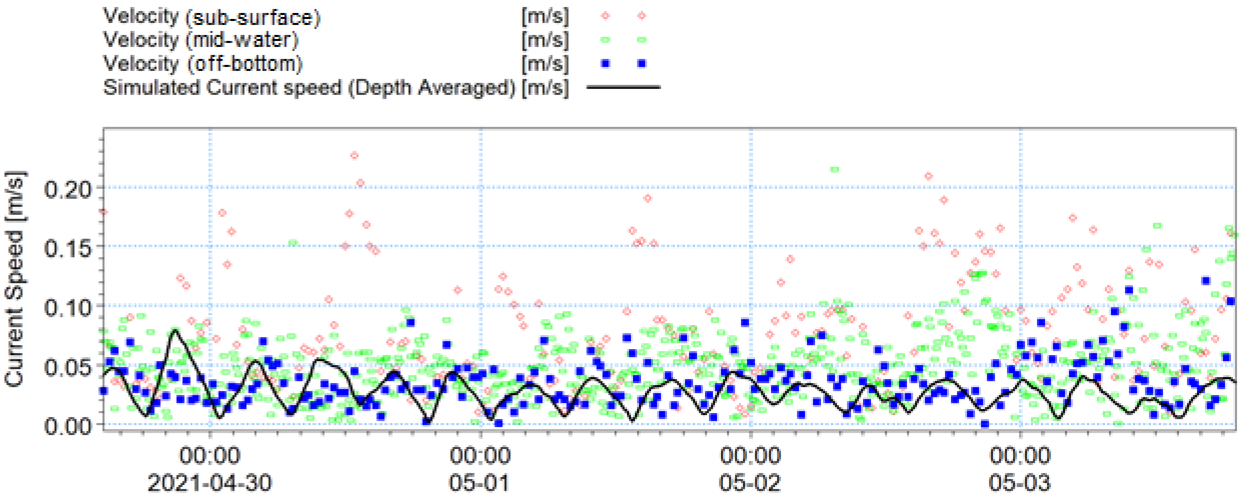

Figure 2.16: Recorded and simulated current speeds at the proposed lease site during a typical neap tidal regime

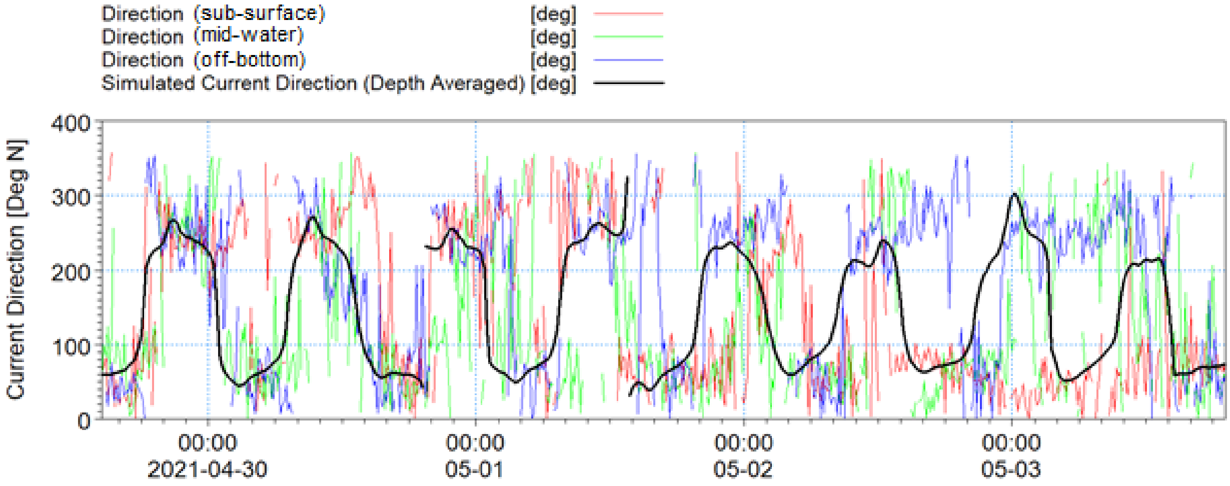

Figure 2.17: Recorded and simulated current directions at the proposed lease site during a typical neap tidal regime

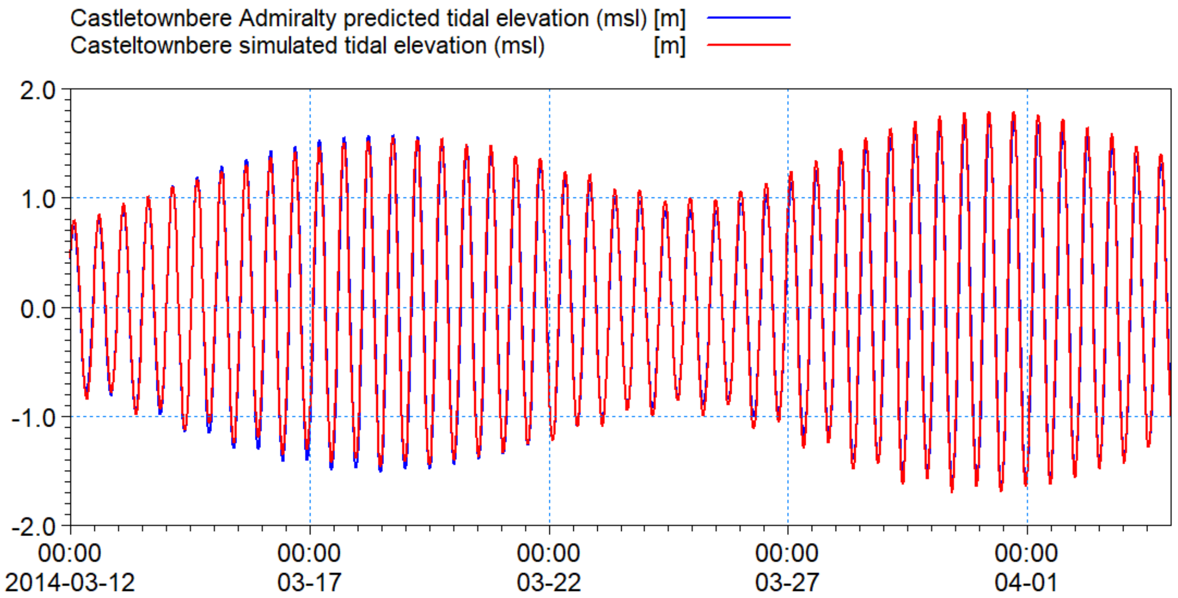

Figure 2.18: Admiralty and simulated tidal elevation Castletownbere

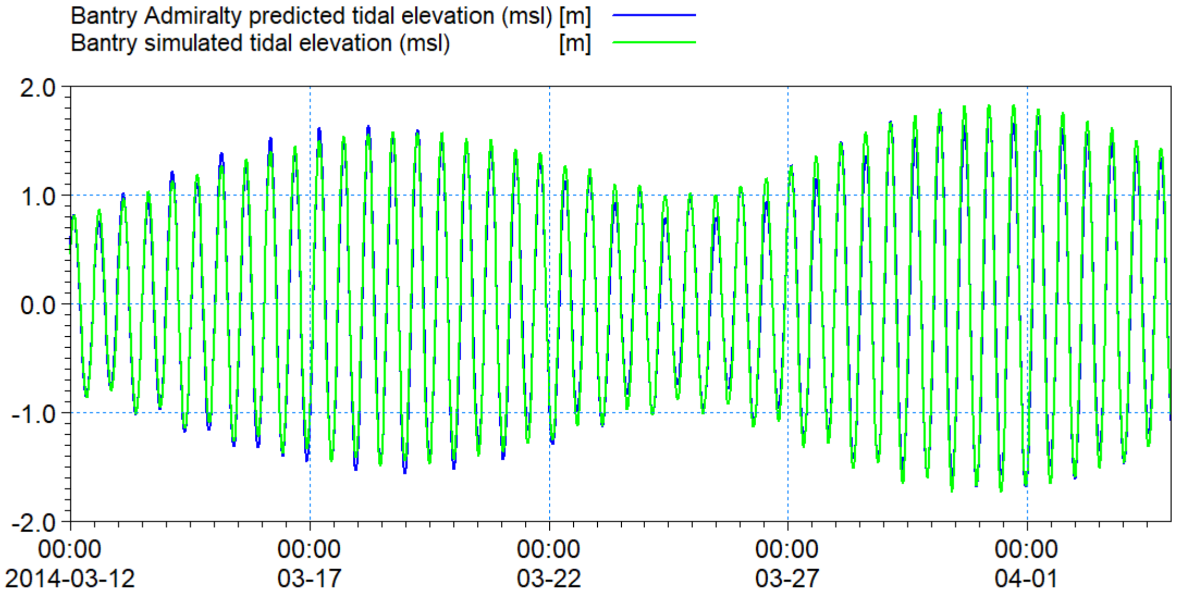

Figure 2.19: Admiralty and simulated tidal elevation Bantry

# 3 WATER QUALITY MODELLING

## 3.1 Particle Tracking Module

Water quality modelling based on a particle tracking approach was used to establish the dispersal and fate of biowaste associated with mussel production at the Dunmanus Bay site.

The DHI MIKE 321 Particle Tracking model, which describes the transport and fate of solutes or suspended matter uses data from the hydrodynamic model to provide information on the general movement of the water body.

Within MIKE 321 PT, the transported substance is considered as a mass of particles, being advected within the surrounding water body and dispersed as a result of random processes in a 2-Dimensional (or 3-Dimensional regime if applicable), using the Lagrangian approach. Hence, the resolution of the plume is not restricted by the cell size of the current field. In this case, the model can be used to determine the fate of suspended biowaste that is discharged into the Bay or is transported to the open sea. The model may simulate the effects of wind-driven currents and includes a mechanism to deal with overturning currents (waves) along the shoreline. The loss of active material from the water column through either settlement or decay can also be included within the model simulations if applicable.

Although the model uses data from the 2-Dimensional depth-averaged hydrodynamic flow model, the MIKE321 PT model generated for Dunmanus Bay applies bed shear to represent the vertical velocity profile to provide a more accurate assessment of the displacement of particles located at different depths in the water column. Employing this facility in the dispersion simulations provides a more realistic representation of the dispersion at full scale.

## 3.2 Site characteristics

The proposed mussel farm aquaculture site in Dunmanus Bay is comprised of three individual blocks, with each block comprising 6 x 220m mussel backlines. Each backline will support 7m long ropes that hosts a mix cohort of mussels. Each of the six mussel backlines was represented by on average nine individual nodes within the Dunmanus Bay model as illustrated in Figure 3.1.

A schematic plan view and section view of one mussel block is presented in Figure 3.2 overleaf.

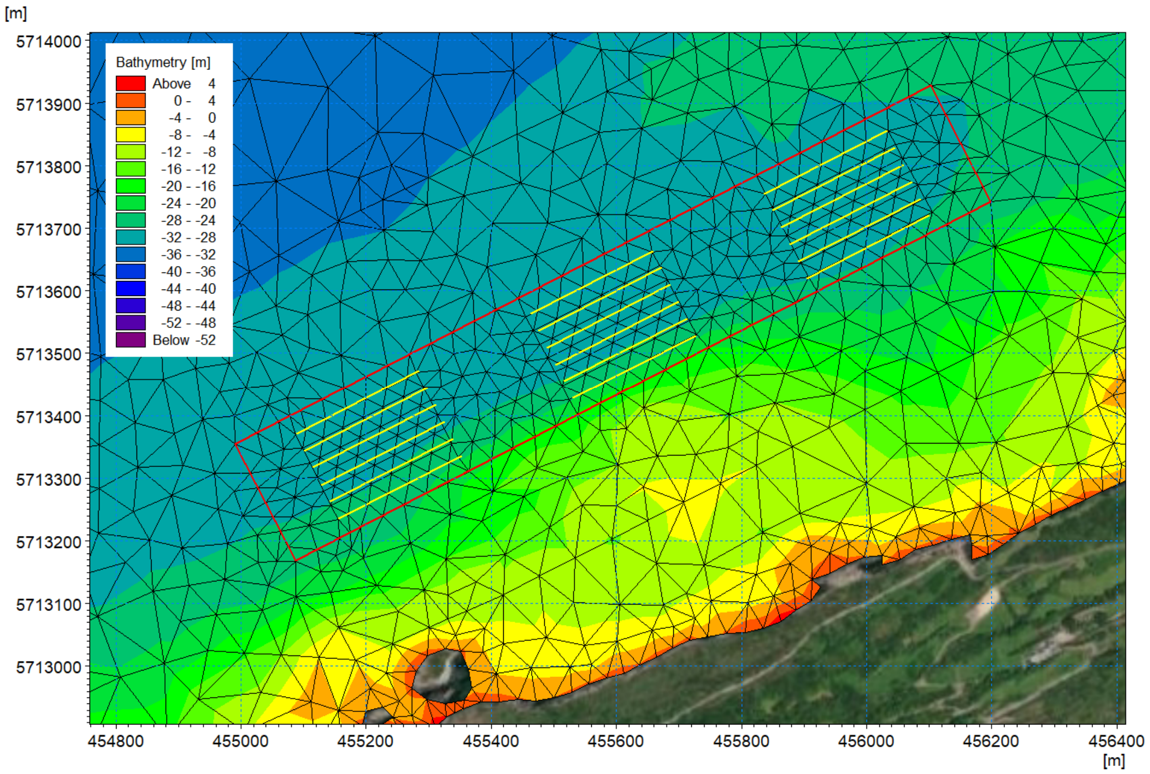

**Figure 3.1: Layout plan of the mussel lines within the proposed lease site in Dunmanus Bay**

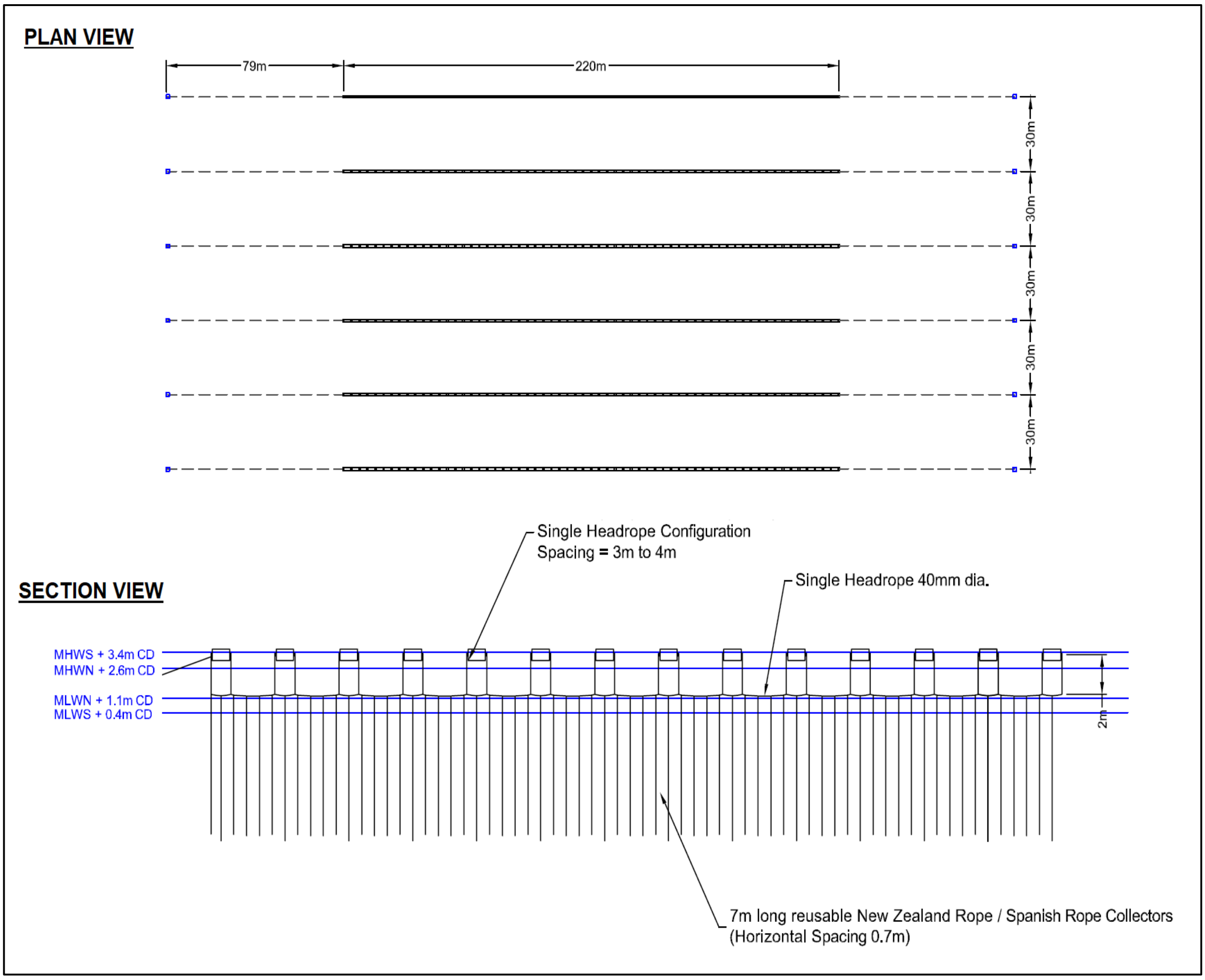

**Figure 3.2: Schematic plan and section view of one mussel farm block proposed for Dunmanus Bay**

## 3.3 Water Quality Parameters

Following a similar approach successfully utilised by (Weise, 2013), the DHI MIKE 321 PT module was used to simulate biowaste production from the proposed mussel farm in Dunmanus Bay. This approach involved defining the “feed input” with zero digestibility which resulted in all particles representing biodeposits. (Weise, 2013) notes that biodeposits can generally be categorised as either **pseudofaeces** (i.e. rejected particles that are expelled without having passed through the digestive tract) or as **faecal pellets**. Both types of biowaste were therefore represented in the Dunmanus Bay PT model.

It is recognised that biowaste production generally increases as mussel farms mature throughout their three-year grow-out cycle. Whilst there are relatively few studies that describe biowaste production for different mussel farm cohorts, the study undertaken by (Weise, 2013) presents results from benthic surveys undertaken at sites in House-Harbour Lagoon (HH), Great Entry Lagoon (GE) and Cascapedia Bay (CAS) that quantifies production rates. This information, as summarised in Table 3.1, was used to derive the inputs for the Dunmanus Bay PT modelling.

Given that the proposed mussel farms at Dunmanus will comprise a mix of cohorts, RPS calculated an average rate of biowaste produced per metre length of back using the information in Table 3.1. The average biowaste production, therefore, equated to 29.13kg per backline per day. Adjusting this production value to account for a 220m backline at Dunmanus, the total biowaste production per backline equated to 60.1 kg per backline per day. Whilst these production rates were less than the maximum rates observed at Cascapedia bay, they were still greater than the median production rates of all five sites described in Table 3.1 and were therefore still considered relatively conservative.

Based on the work of (Weise, 2013), 67% of the biowaste production was represented as filtered material rejected as faecal pellets, whilst the remaining 33% of the biowaste production was represented as pseudofaeces. The faecal pellet waste material was assigned a settling velocity of 0.8cm/s and a critical re-suspension value of 9.5cm $s^{-1}$. The pseudofaeces material was assigned a settling velocity of 0.2cm/s and a critical re-suspension value of 9.5cm $s^{-1}$. These model input parameters are summarised in Table 3.2.

**Table 3.1: Key biowaste production values for several sites as reported by (Weise, 2013)**

| Parameter | GE 1+ (2003) | GE 0+ (2003) | GE 0+ (2004) | HH 0+ (2004) | CAS 1+ (2005) |
|---|---|---|---|---|---|
| **Backline dimensions (1 x w x d)(m)** | 91 x 0.2 x 1 | 91 x 0.2 x 2 | 91 x 0.2 x 2 | 76 x 0.2 x 1 | 142 x 0.2 x 5.5 |
| **Biowaste production (kg backline$^{-1}$ d$^{-1}$)** | 26.4 | 15.8 | 15.8 | 18.0 | 52.8 (1+)<br>86.5(2+) |
| **Faeces settling velocity (cm s$^{-1}$)** | 1.0 ± 0.3 | 0.8 ± 0.3 | 0.8 ± 0.3 | 0.8 ± 0.3 | 0.8 ± 0.3 |
| **Pseudofaeces settling velocity (cm s$^{-1}$)** | 0.2 ± 0.02 | 0.2 ± 0.02 | 0.2 ± 0.05 | 0.2 ± 0.02 | N/A |

**Table 3.2: Input parameters used for the Dunmanus Bay water quality model**

| Parameter | Dunmanus Bay Mussel Farm |
|---|---|
| **Backline length (m)** | 220 |
| **Average Biowaste production (kg backline$^{-1}$ d$^{-1}$)** | 60.1 |
| **Faeces production (kg backline$^{-1}$ d$^{-1}$)** | 40.23 |
| *Faeces settling velocity (cm s$^{-1}$)* | 0.80 |
| *Faeces resuspension threshold (cm s$^{-1}$)* | 9.5 |
| **Pseudofaeces production (kg backline$^{-1}$ d$^{-1}$)** | 19.78 |
| *Faeces settling velocity (cm s$^{-1}$)* | 0.20 |
| *Faeces resuspension threshold (cm s$^{-1}$)* | 9.5 |

## 3.4 Definition of Terms

The simulations for each of the parameters considered were carried out using a model mesh for the extent of Dunmanus Bay, with a variable time-step of typically less than 120 seconds and simulations lasting for a period of 31 days. Models of this resolution generate huge amounts of data. To condense the results for analysis and presentation, four types of graphical output have been generated:

- Maximum Concentration Plume Envelope
- Average Concentration Plume Envelope
- Typical Ebb Concentration Plume Envelope
- Typical Flood Concentration Plume Envelope

### Maximum Concentration Plume Envelope

The purpose of the Maximum Concentration Plume Envelope is to show the maximum concentration of the given parameter reaches at each nominal cell location in any time step during the entire course of each simulation. All the maximum values recorded are then plotted as concentration contours in the graphical output. It is most important for the observer to appreciate that, whilst the resulting diagram is of use in showing the maximum values that can be reached at any point throughout the area covered and throughout the simulation, it does not represent a real situation in space or time because there is little likelihood of any of the maximum values recorded occurring simultaneously. In fact, in most cases, this is very unlikely as each plume passes through the domain over the time period concerned, with the maximum concentration at its centre, undergoing dispersion and dilution as it moves in the prevailing currents.

Additionally, whilst the time for which the maximum value persists in any given mesh cell will vary and, overall, the percentage frequency of occurrence will be low due to tidal oscillation.

### Average Concentration Plume Envelope

The purpose of the Average Concentration Plume Envelope is to show the average concentration of the given parameter reached in each cell during the entire course of each simulation. This was generated by averaging all the values recorded in all time steps in each cell over the course of the simulation. Once again, the resulting diagram is not related to a given point in time but it is useful when used in conjunction with the maximum plume envelope for gauging the ‘typical’ values in any area and to indicate how often the maximum values occur.

For example, a high concentration may be recorded at one location and presented on the maximum envelope, but when the average plot is interrogated the value is much lower at this location. This indicates that the maximum value obtained was only experienced for a short period of time.

### Typical Ebb and Flood Concentration Plume Envelopes

To give an indication of the actual dispersion pattern within the Bay for each parameter, the typical flood and ebb contour plots have also been included. These are ‘snapshots’ from the model for a typical mid-flood or mid-ebb tide situation. Unlike the previous plots, these values can be related to real moments in time.

# 4 MODEL OUTPUTS

As illustrated in Figure 4.1, solids discharges were simulated using nine separate point discharge sources located along each backline for the pseudofaeces and faecal pellets, using the appropriate release rates and settlement characteristics as described in Table 3.2.

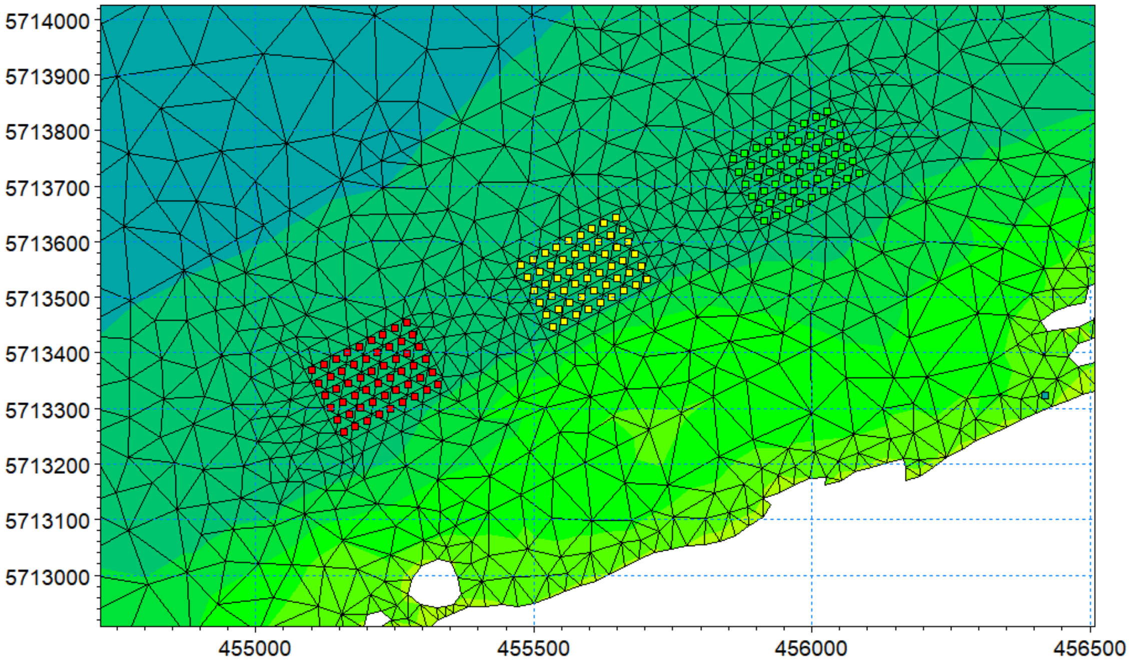

**Figure 4.1: Location of particle tracking discharge points across the three mussel farm blocks**

The modelling approach used was by particle tracking as outlined in Section 3. A period of 31 days was simulated to cover all tidal conditions. A worst-case scenario was adopted in that the discharged solids are treated as conservative throughout the simulation and no allowances are made for their biological decomposition or assimilation by the local epifauna and infauna, whilst both take place naturally in such circumstances.

As described previously, the hydrodynamic model forms the basis of the particle tracking model. However, a bed shear velocity profile has been adopted to improve the simulation of conditions within Dunmanus Bay, as near-bed velocities are clearly important in sediment deposition. The re-suspension of sediment was controlled using the critical shear stress associated with the material properties.

It should be noted that the values for sedimentation and deposition described by (Weise, 2013) should be compared with those values measured on-site. The critical re-suspension speed for pseudofaeces and faecal pellets is 0.095m/sec. From the results presented previously in the model verification section, (Section 2.5), it can be seen that both the modelled and measured current speeds across the site and for much of the main body of Dunmanus Bay are of low magnitude. As a result, current speeds remain below those required to maintain the suspension of solids for much of the tidal cycle. Equally, this also indicates that significant re-suspension of settled material would be unlikely to occur. The results from the sedimented solids are presented overleaf.

## 4.1 Sedimented Biowaste

Table 4.1 below provides a summary description of the various modelling outputs produced to describe the sedimentation generated from the proposed mussel farm aquaculture site in Dunmanus Bay. It should be noted that the colour palette used to represent biowaste deposition changes across the Figures, thus caution should be applied when interpreting results.

It will be seen by comparing Figure 4.2 and Figure 4.4 that a greater magnitude of faecal pellets become sedimented within the proposed lease area relative to pseudofaeces. The reason for this is twofold, firstly a greater volume of faecal pellets released (i.e. a ratio of 67:33) across the site and secondly, the settling velocity associated with the pseudofaeces is significantly lower. As such, the pseudofaeces remains suspended in the water column for longer and can therefore be dispersed further from the site. The average daily deposition rates across the proposed lease areas do not generally exceed 5 and 2.5g/m$^2$ d$^{-1}$ for faecal pellets and pseudofaeces as shown in Figure 4.2 in Figure 4.4 respectively.

As indicated in Figure 4.3 and Figure 4.5, the maximum daily deposition rates across the proposed lease areas do not generally exceed 10 and 5.5g/m$^2$ d$^{-1}$ for faecal pellets and pseudofaeces respectively.

The maximum and average daily deposition rates for total sedimented biowaste (pseudofaeces + faecal pellets) across the proposed lease area do not generally exceed 14 and 7g/m$^2$ d$^{-1}$ respectively. The statistical maximum and average daily deposition rates of total sedimented biowaste are illustrated in Figure 4.7 and Figure 4.6.

Beyond the perimeter of the proposed lease site, the maximum daily deposition rates of total sedimented biowaste do not generally exceed 1g/m$^2$ d$^{-1}$ as illustrated in Figure 4.7. The majority of this material is comprised of pseudofaeces owing to the lower settling velocities and greater potential for dispersion.

The maximum and average total deposition rate decreases to 0 g/m$^2$ d$^{-1}$ approximately 600 metres beyond the perimeter of the proposed lease area. As such, it can be concluded that sedimented biowaste produced from the proposed mussel farm aquaculture site in Dunmanus Bay will not have a significant detrimental impact on the benthos within Dunmanus Bay.

**Table 4.1: Summary description of particle tracking modelling results for Dunmanus Bay (sedimented material)**

| Figure Description | Figure Number |
|---|---|
| Average sedimented faecal pellets per day (g/m$^2$) | Figure 4.2 |
| Maximum sedimented faecal pellets per day (g/m$^2$) | Figure 4.3 |
| Average sedimented pseudofaeces per day (g/m$^2$) | Figure 4.4 |
| Maximum sedimented pseudofaeces per day (g/m$^2$) | Figure 4.5 |
| Average total sedimented biowaste (pseudofaeces + faecal pellets) per day (g/m$^2$) | Figure 4.6 |
| Maximum total sedimented biowaste (pseudofaeces + faecal pellets) per day (g/m$^2$) | Figure 4.7 |

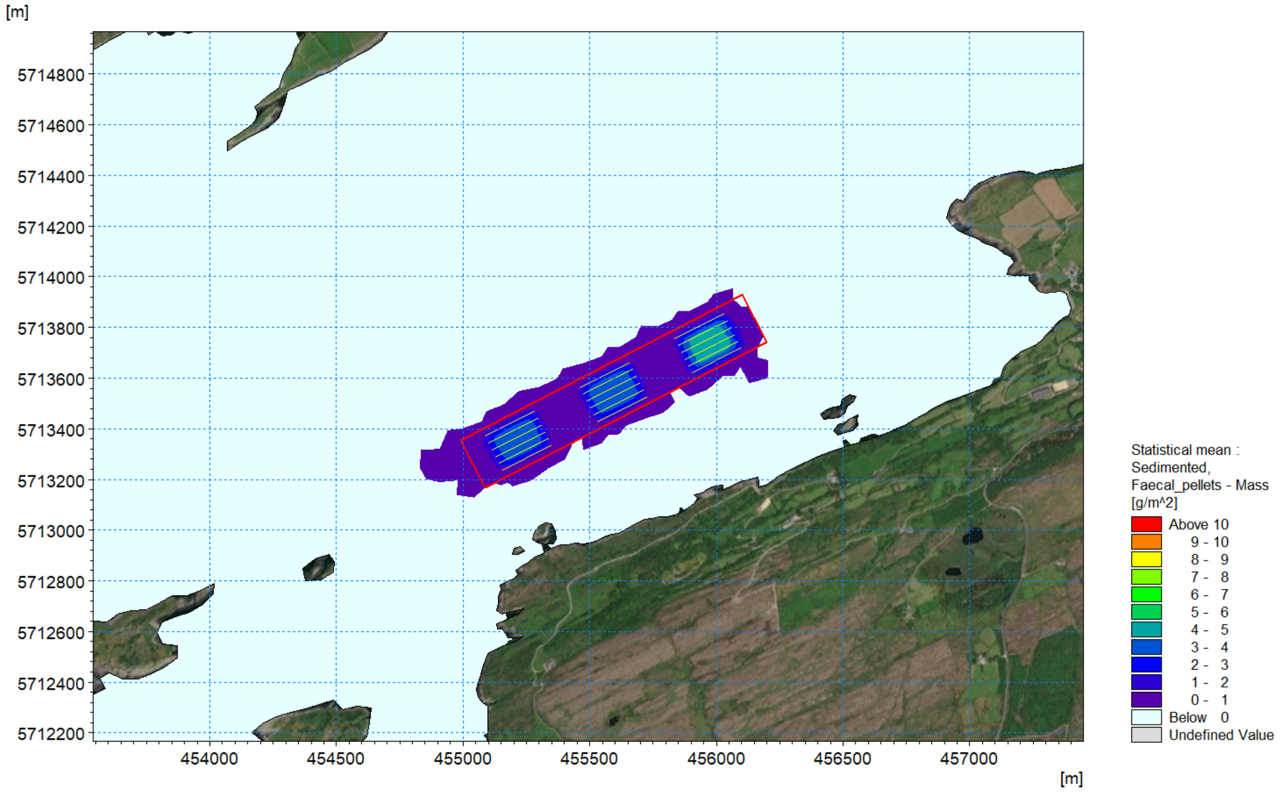

**Figure 4.2: Average sedimented faecal pellets per day (g/m$^2$)**

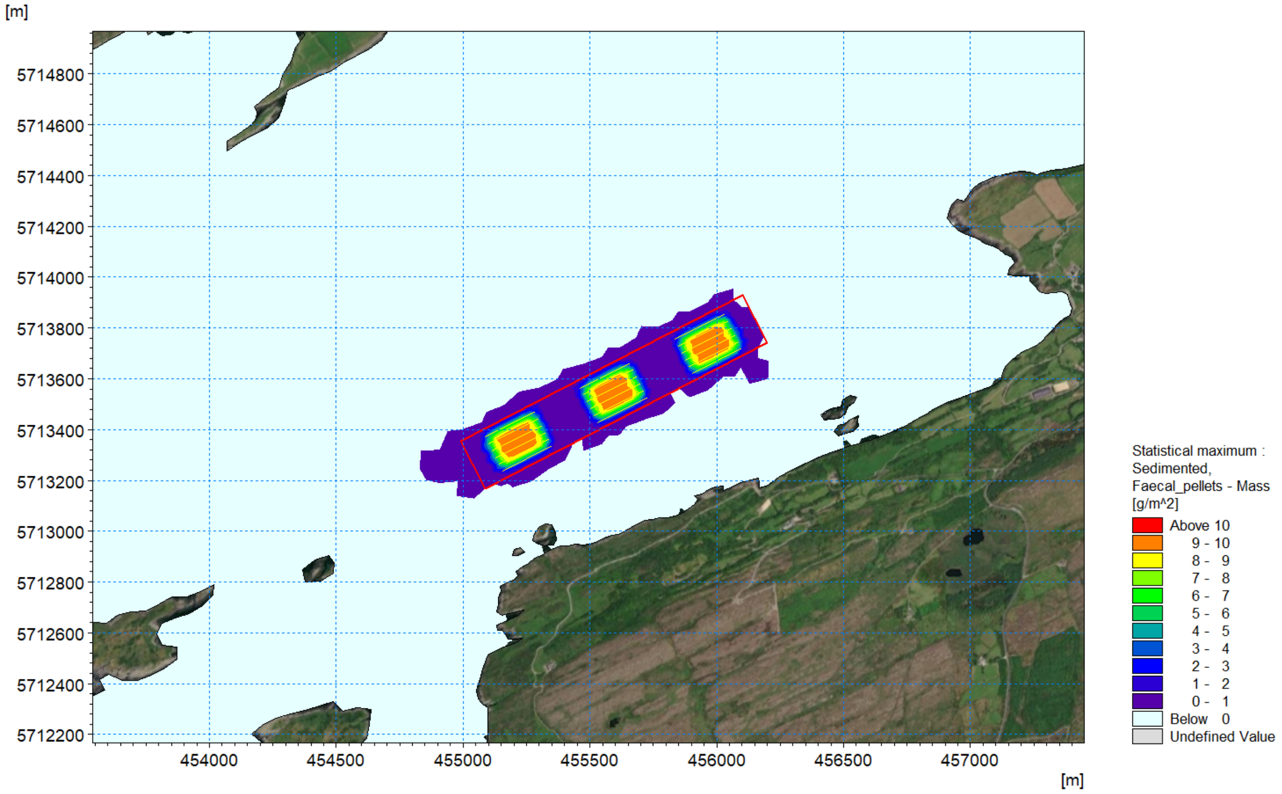

**Figure 4.3: Maximum sedimented faecal pellets per day (g/m$^2$)**

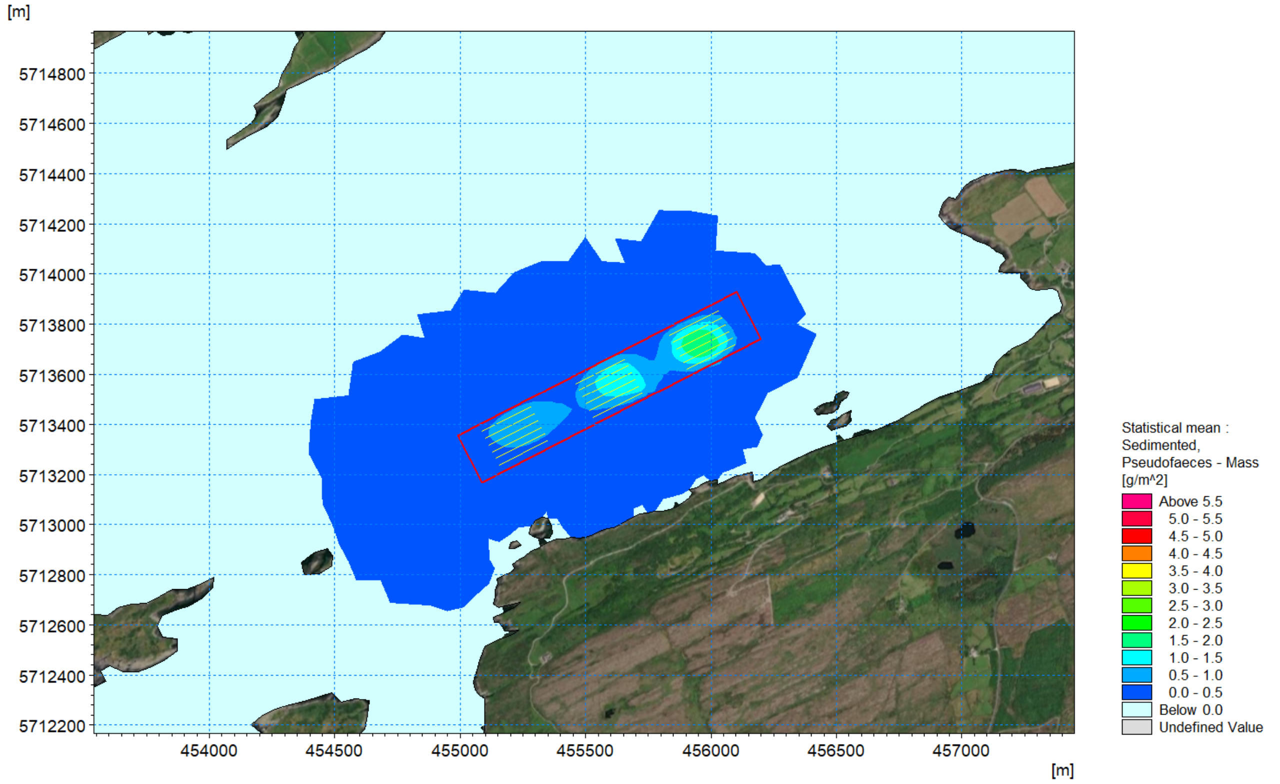

Figure 4.4: Average sedimented pseudofaeces per day (g/m$^2$)

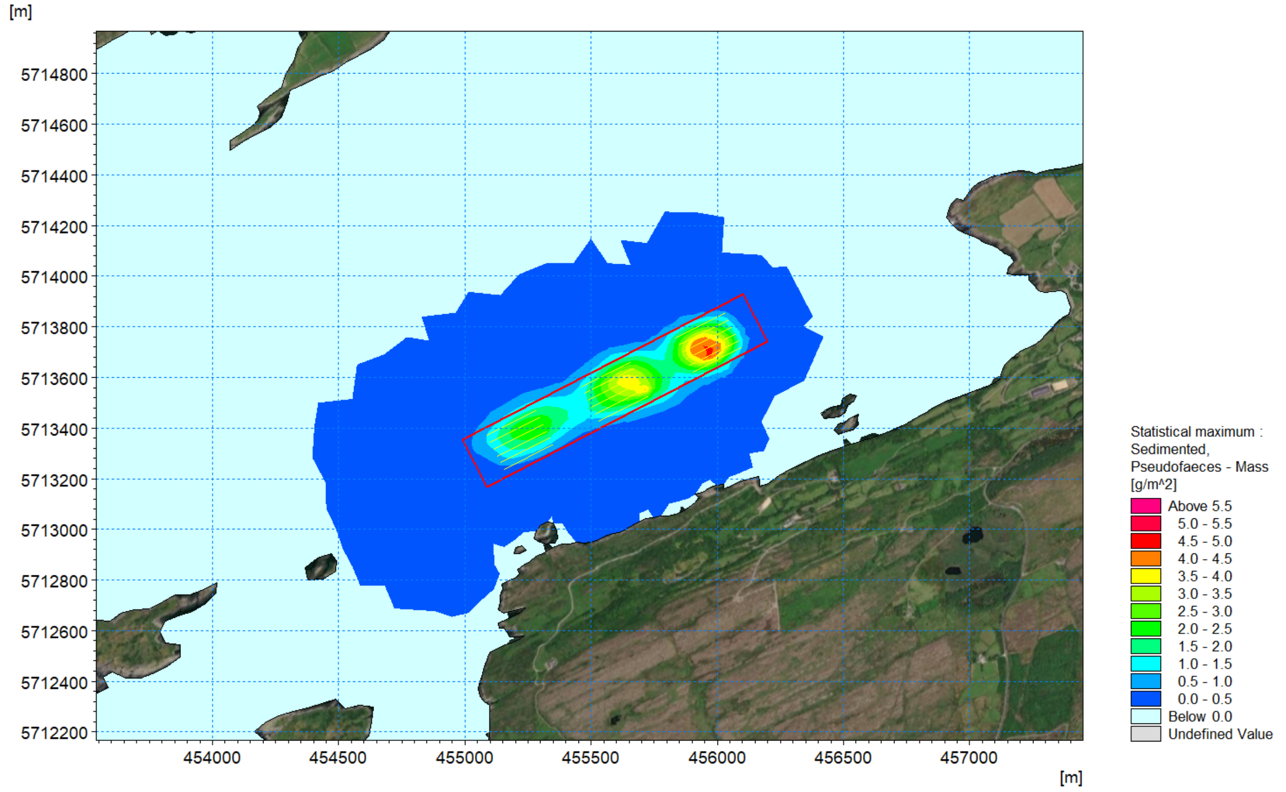

Figure 4.5: Maximum sedimented pseudofaeces per day (g/m$^2$)

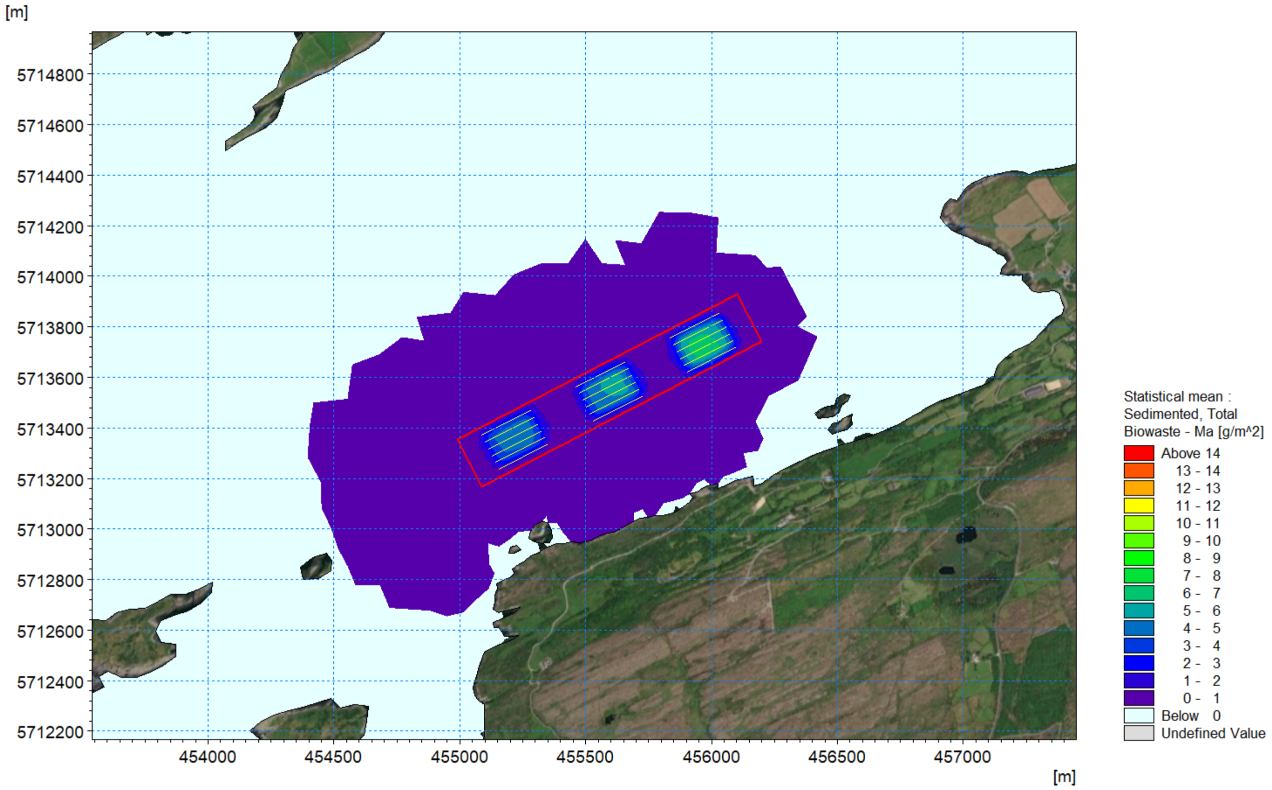

Figure 4.6: Average total sedimented biowaste (pseudofaeces + faecal pellets) per day (g/m$^2$)

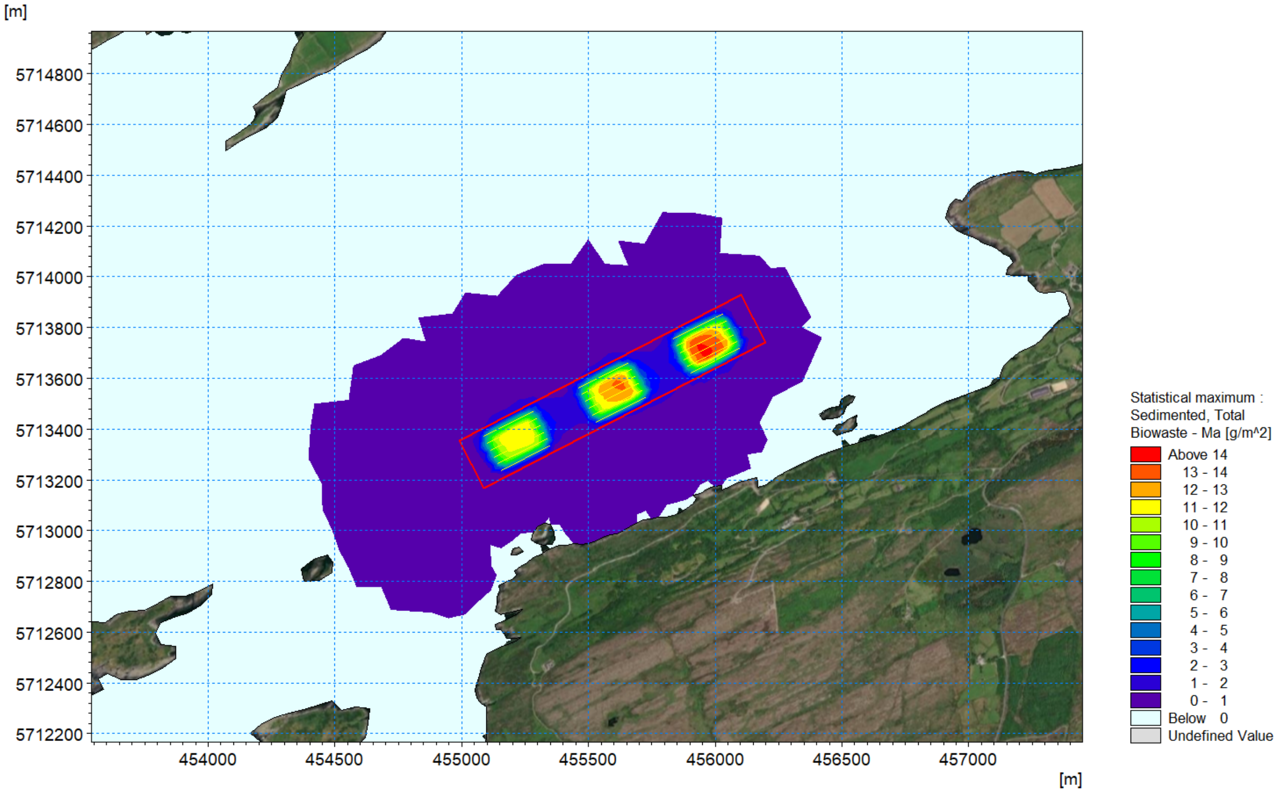

Figure 4.7: Maximum total sedimented biowaste (pseudofaeces + faecal pellets) per day (g/m$^2$)

## 4.2 Suspended Biowaste

Table 4.1 below provides a summary description of the various modelling outputs produced to describe the suspended biowaste plumes generated from the proposed mussel farm aquaculture site in Dunmanus Bay.

In order to give an indication of the actual dispersion pattern within the Bay for each parameter, plots representing the suspended faecal pellet concentrations during a typical mid-flood and mid-ebb phase of a spring tidal regime have been presented in Figure 4.8 and Figure 4.9 respectively. It will be seen from these Figures that the concentration of suspended faecal pellets does not generally exceed 1.7g/m$^3$. The concentration of suspended pseudofaeces during the same tidal phases is significantly lower at *c.* 0.7g/m3 owing to the lower settling velocities.

The total suspended biowaste (pseudofaeces + faecal pellets) concentrations during a typical spring mid-flood and mid-ebb tide are illustrated in Figure 4.12 and Figure 4.13. As demonstrated by these plots, the suspended sediment concentrations are greatest within the proposed lease area owing to the low current prevailing current speeds. Even within the site boundaries, the total suspended biowaste concentrations do not generally exceed 2.6g/m$^3$. Beyond the perimeter of the site boundary, total suspended biowaste concentrations are significantly less, reducing to *c.*0.2g/m$^3$ during typical spring mid-flood and mid-ebb conditions.

The statistical maximum and average total suspended biowaste concentrations across the proposed lease area are illustrated in Figure 4.14 and Figure 4.15 respectively. The statistical maximum and average daily deposition rates of total sedimented biowaste are illustrated in Figure 4.7 and Figure 4.6. Owing to similar current conditions observed during spring and neap tidal conditions, the maximum and average total suspended biowaste concentrations are similar to those described above. These can be summarised as follows:

- The maximum and average total suspended biowaste concentrations within the proposed lease area does not generally exceed 14g/m$^3$ and 1.6g/m$^3$ respectively.
- The maximum and average total suspended biowaste concentrations outside the proposed lease area does not generally exceed 1g/m$^3$ and 0.2g/m$^3$ respectively.

Based on the results described above, it can be concluded that suspended biowaste produced from the proposed mussel farm aquaculture site in Dunmanus Bay will not have a significant detrimental impact on the water quality within Dunmanus Bay.

**Table 4.2: Summary description of particle tracking modelling results for Dunmanus Bay (suspended material)**

| Figure Description | Figure Number |
|---|---|
| Suspended faecal pellet concentration during a typical spring mid-flood tide (g/m3) | Figure 4.8 |
| Suspended faecal pellet concentration during a typical spring mid-ebb tide (g/m3) | Figure 4.9 |
| Suspended pseudofaeces concentration during a typical spring mid-flood tide (g/m3) | Figure 4.10 |
| Suspended pseudofaeces concentration during a typical spring mid-ebb tide (g/m3) | Figure 4.11 |
| Total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m3) | Figure 4.12 |
| Total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-ebbtide (g/m3) | Figure 4.13 |
| Maximum total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m3) | Figure 4.14 |
| Average total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m3) | Figure 4.15 |

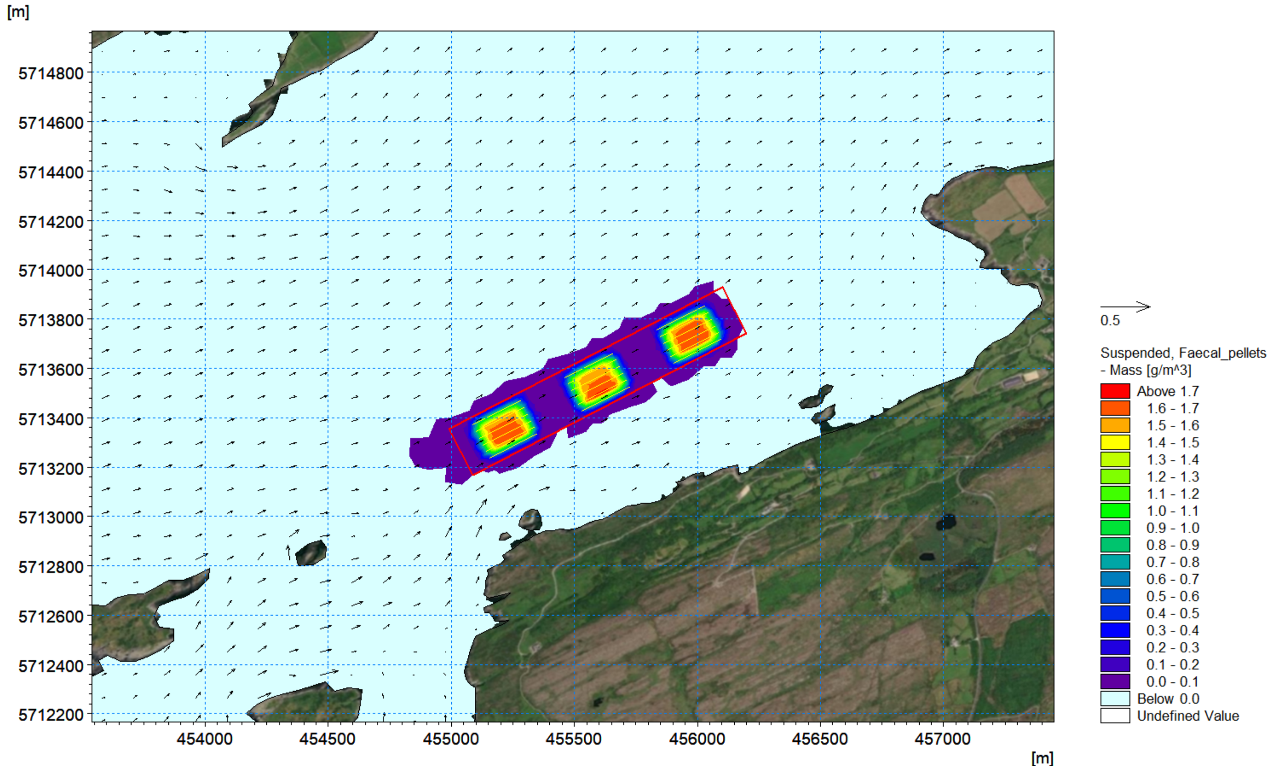

**Figure 4.8: Suspended faecal pellet concentration during a typical spring mid-flood tide (g/m$^3$)**

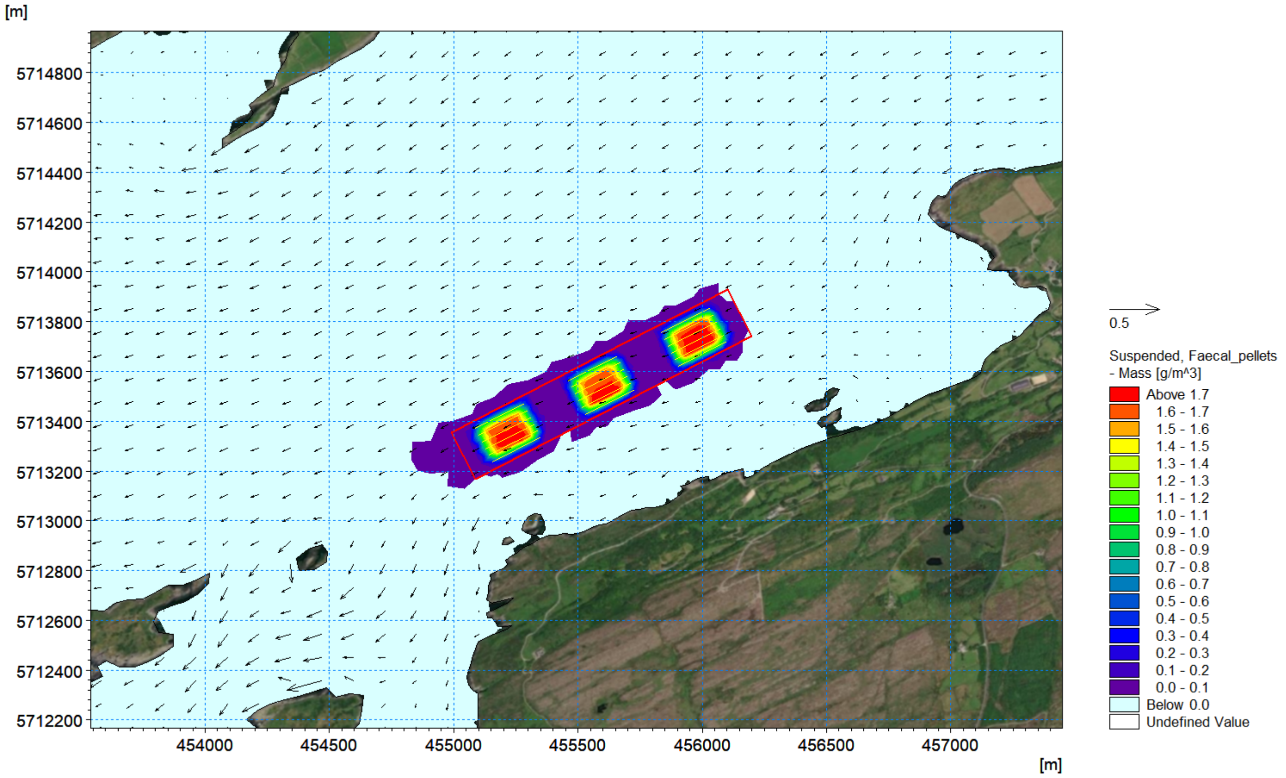

**Figure 4.9: Suspended faecal pellet concentration during a typical spring mid-ebb tide (g/m$^3$)**

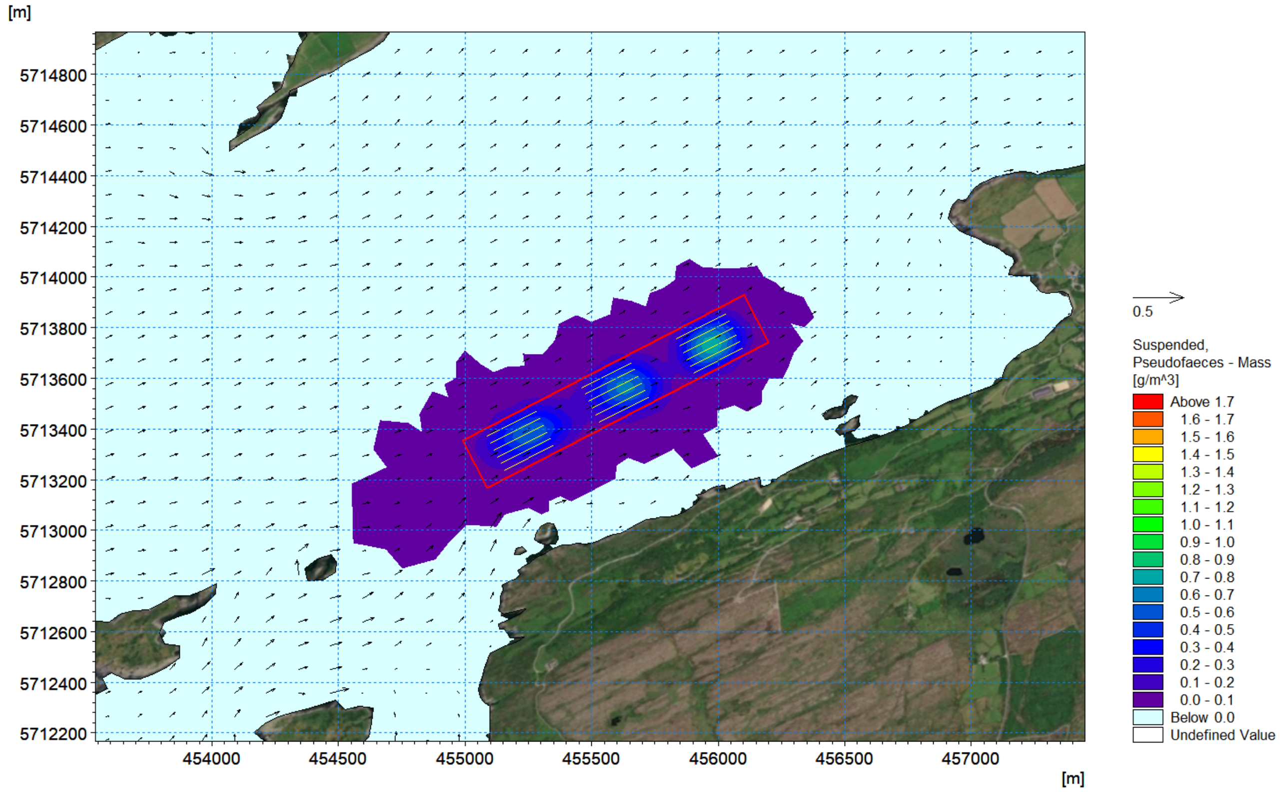

Figure 4.10: Suspended pseudofaeces concentration during a typical spring mid-flood tide (g/m$^3$)

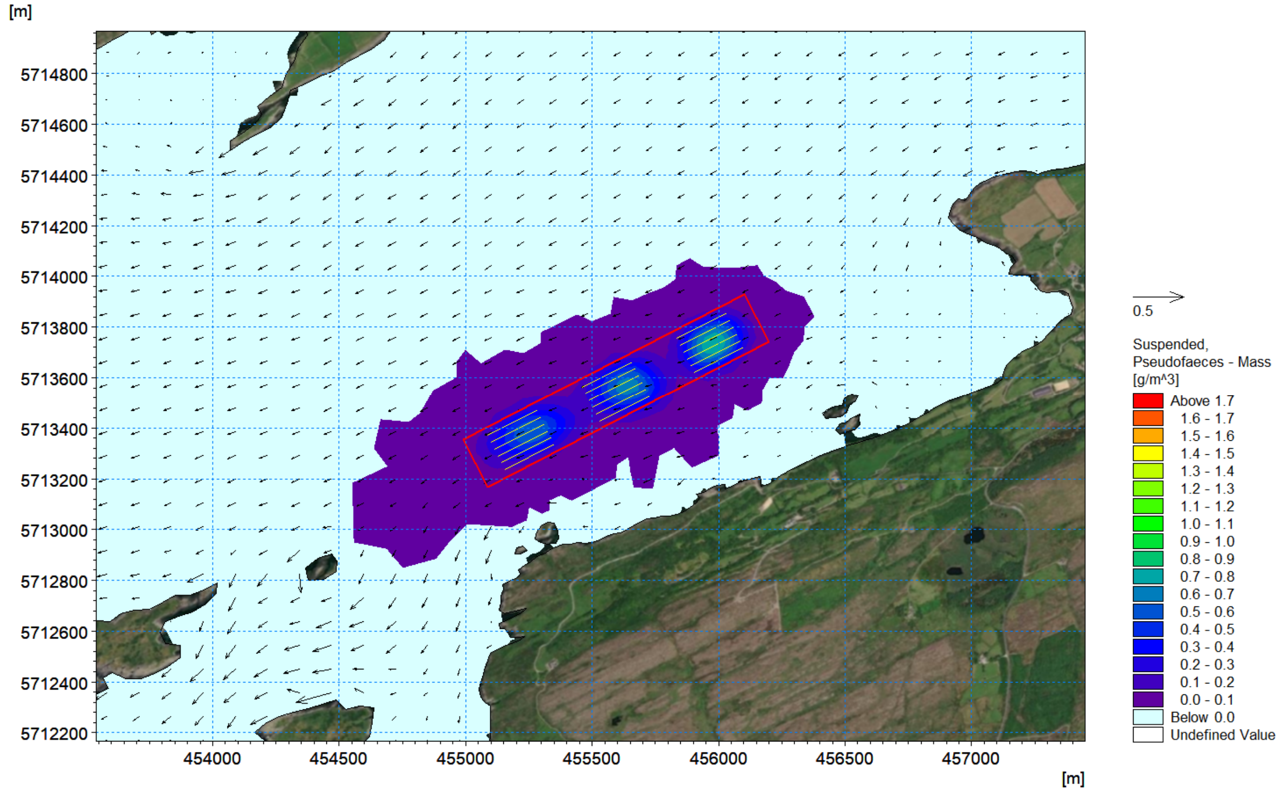

Figure 4.11: Suspended pseudofaeces concentration during a typical spring mid-ebb tide (g/m$^3$)

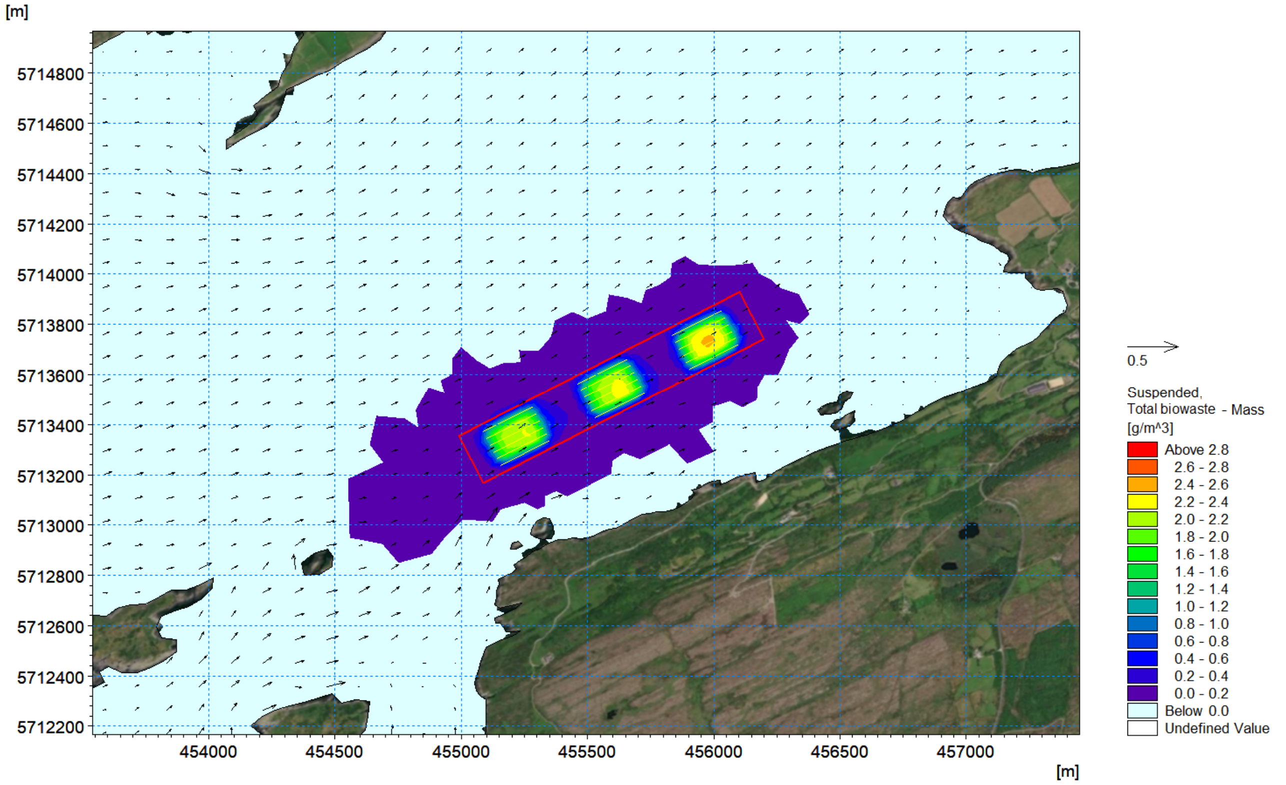

**Figure 4.12: Total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m$^3$)**

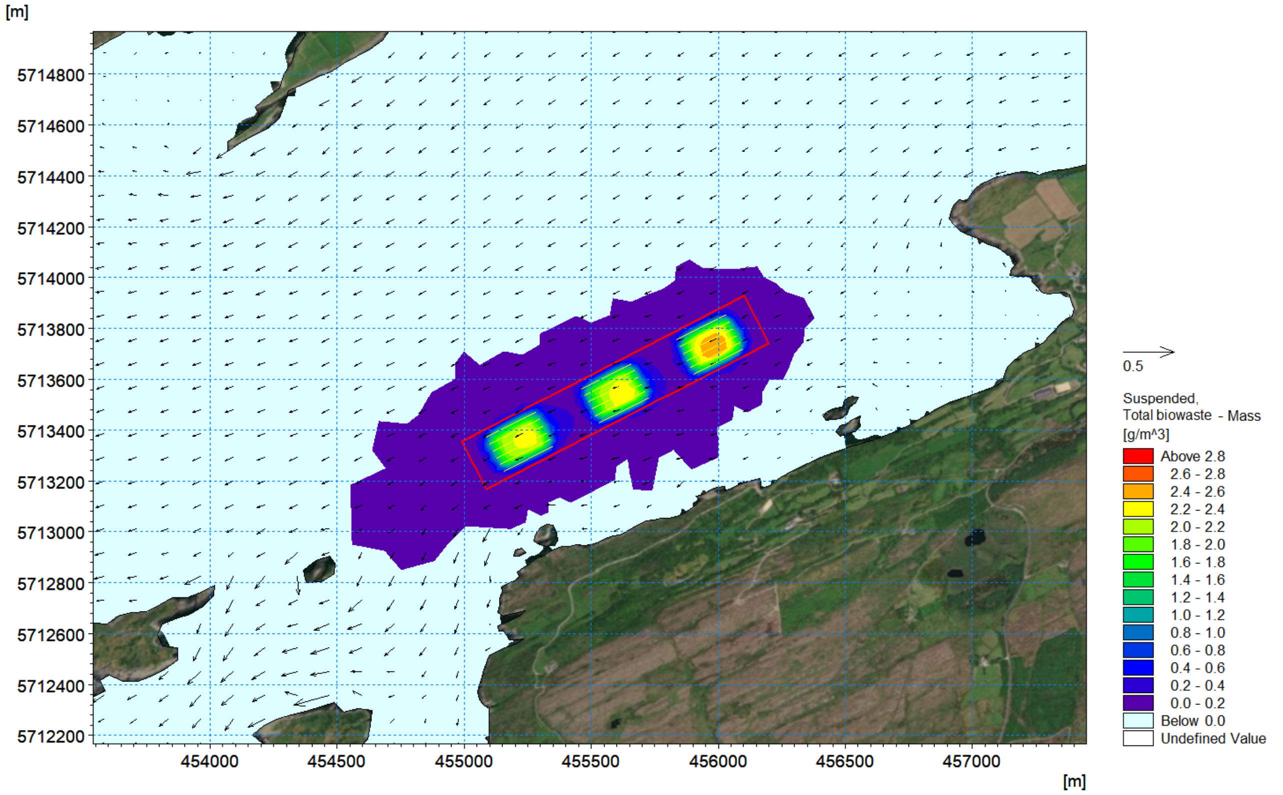

**Figure 4.13: Total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-ebbtide (g/m$^3$)**

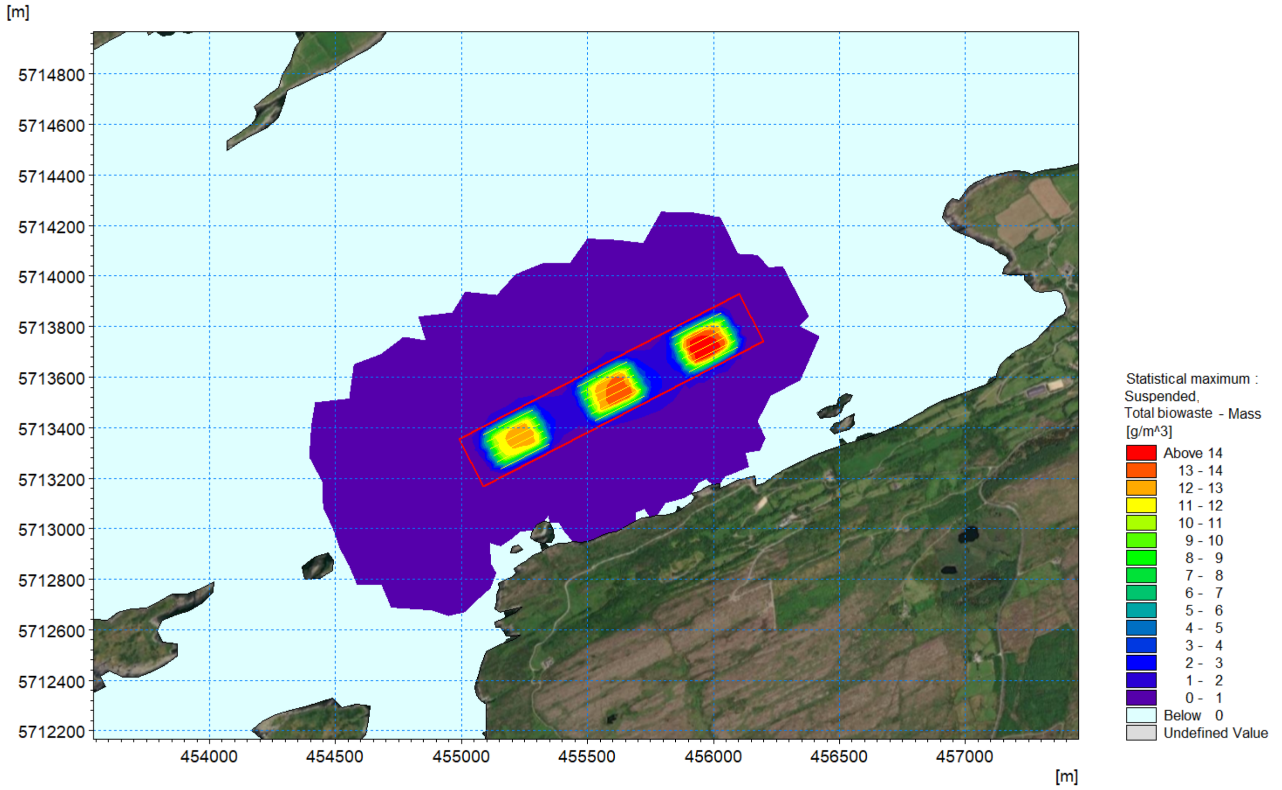

Figure 4.14: Maximum total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m$^3$)

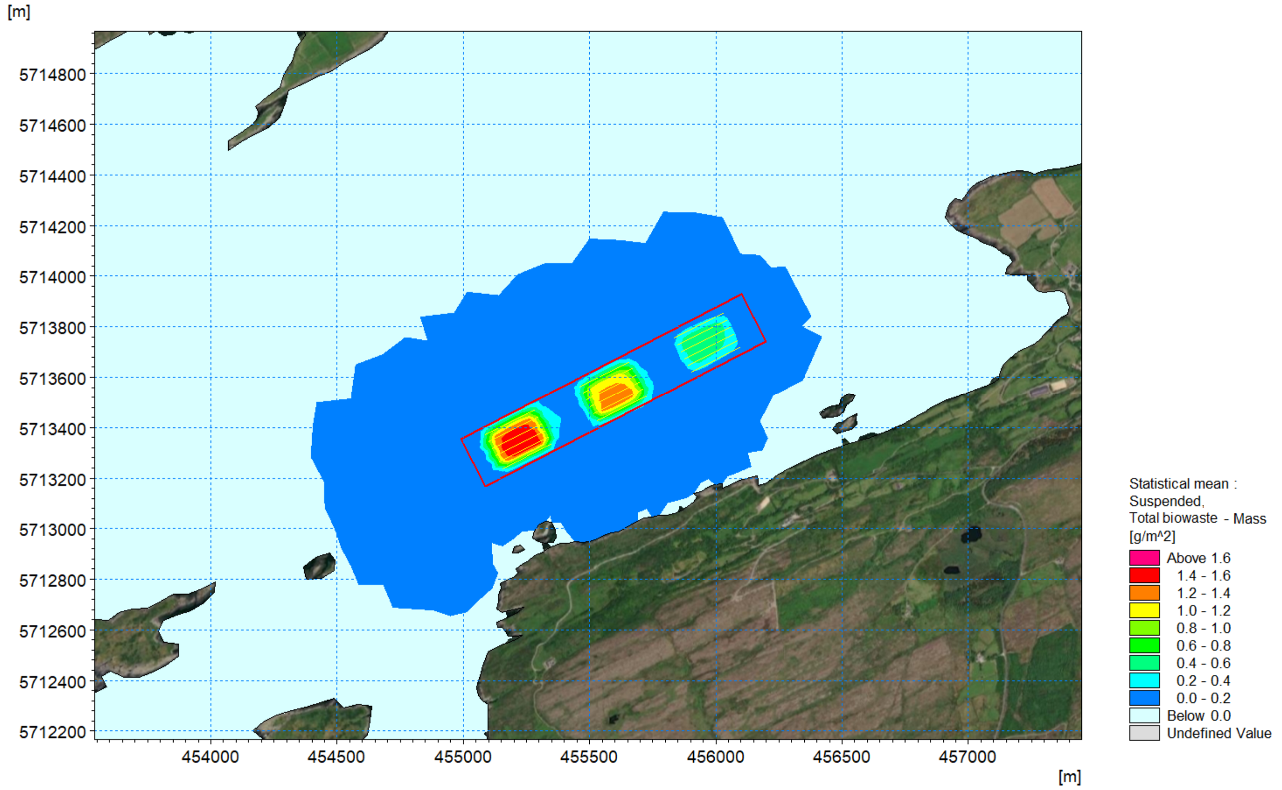

Figure 4.15: Average total suspended biowaste (pseudofaeces + faecal pellets) concentration during a typical spring mid-flood tide (g/m$^3$)

# 5 CONCLUSION

A commission was undertaken by RPS, on behalf of Aquafact Ltd, to investigate the effects on water quality of mussel farm aquaculture site at Dunmanus Bay, County Cork. To this end, a comprehensive numerical modelling study was undertaken. During the first phase of the modelling study, an existing hydrodynamic model of Dunmanus Bay was updated and validated using hydrodynamic field data, which was collected and collated for this purpose.

The model output showed a good level of correlation with the measured data and the model is therefore deemed suitable for water quality modelling. The calibrated hydrodynamic model was then used in the second phase to assess the effects of all potential discharges into the Bay as a result of the mussel farming activities in line with methods described by (Weise, 2013). This approach involved modelling **pseudofaeces** (i.e. rejected particles that are expelled without having passed through the digestive tract) and **faecal pellets** biodeposits using a particle tracking numerical model over 31 days.

Results of the bespoke modelling programme found that there was no significant accumulation of settleable solids discharges arising from biowaste matter beyond the immediate vicinity of the proposed site. This was due to the low current speeds and sheltered location of the proposed site in Dunmanus Bay. Regarding sedimented biowaste, it was found that:

- The maximum and average daily deposition rates for total sedimented biowaste (pseudofaeces + faecal pellets) across the proposed lease area did not generally exceed 14 and 7g/m$^2$ d$^{-1}$ respectively.
- Beyond the perimeter of the proposed lease site, the maximum daily deposition rates of total sedimented biowaste were generally less than 1g/m$^2$ d$^{-1}$.
- The maximum and average total deposition rate decreased to 0 g/m$^2$ d$^{-1}$ approximately 600 metres beyond the perimeter of the proposed lease area.
- Sedimented biowaste produced from the proposed mussel farm aquaculture site in Dunmanus Bay will not have a significant detrimental impact on the benthos within Dunmanus Bay.

In respect of suspended total biowaste concentrations produced by the proposed mussel farm aquaculture site, modelling results found that:

- The maximum and average total suspended biowaste concentrations within the proposed lease area did not generally exceed 14g/m$^3$ and 1.6g/m$^3$ respectively.
- The maximum and average total suspended biowaste concentrations outside the proposed lease area did not generally exceed 1g/m$^3$ and 0.2g/m$^3$ respectively.

In summary, it can be concluded that based on the findings of an extensive water quality assessment that utilised a calibrated and validated numerical model, the proposed mussel farm aquaculture site will not significantly impact the water quality or benthos within Dunmanus Bay.