



10th August 2025

Vementry NewDepomod Modelling Report

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Summary

Cooke Aquaculture Scotland Ltd. (CAS) has undertaken biomass and in-feed chemotherapeutant modelling for the proposed Vementry site. The pen layout uses 10, 120m circular pens, moored within 85m grids. The site was modelled using NewDepomod to determine the maximum biomass and in-feed chemical treatments. NewDepomod was ran using SEPA default values as a risk assessment tool to determine dispersion and depositional characteristics at the proposed site. A summary of the predicted footprints of the proposed site are given in Table 1.

Spatial contour plots and 2D transects quantifying the benthic footprints are presented for the default NewDepomod results. The majority of deposition occurs directly beneath the pens and north of the farm. In the default model, the predicted impact of the proposed Vementry site is comfortably within the benthic EQS thresholds for a site with a high wave exposure index.

In-feed chemical modelling complies with environmental standards when using 14g of Emamectin Benzoate. This simulates an impact area equivalent to 90.94% of the 100m mixing area. This permits a treatable biomass of 40 tonnes.

Table 1. Summary of the recommended consent limits for the proposed Vementry site.

Maximum biomass (T)	1,350	Stocking density	5.61
Biomass modelling		Default model	
100m mixing zone area (m ²)		172,500	
Impact area (m ²)		183,750	
Percentage of 100m mixing zone (%)		106.52	

Cage edge threshold (g m ² yr ⁻¹)	675.43
In-Feed Treatments	Default model
Chemical quantity (g)	14
Predicted impact area of proposed site (m ²)	156,880
Percentage of 100m mixing zone (%)	90.94
Predicted impact area of existing site (m ²)	156,880

1. Introduction

This report details the methodology and results for SEPA's default NewDepomod model for the proposed Vementry aquaculture site. Modelled footprint area and intensity are then used to determine the maximum biomass and in-feed chemical mass that complies with all SEPA's environmental quality standards (EQS).

1.1 Site Description

Vementry is considered a new potential site to be operated by Cooke Aquaculture Scotland. The site is located off the north coastline of Vementry island, in Shetland, on the north side of the West Mainland. The proposed site consists of a single group of 10 circular, 120m circumference pens with a net depth of 21m. These are arranged in a 2 x 5 layout with an 85 m separation, housing a maximum consented biomass of 1350T at a maximum stocking density of 5.61kg/m³. The site is aligned with a bearing of ~295.5° and has a wave exposure index of 3.52.

The proposed development adds a new site ~0.3 off the north coastline of Vementry with the site centre located at 430285.52 E, 1161466.97 N as shown in figure 1. Further information on the proposed site infrastructure and pen layout is presented in Table 2.

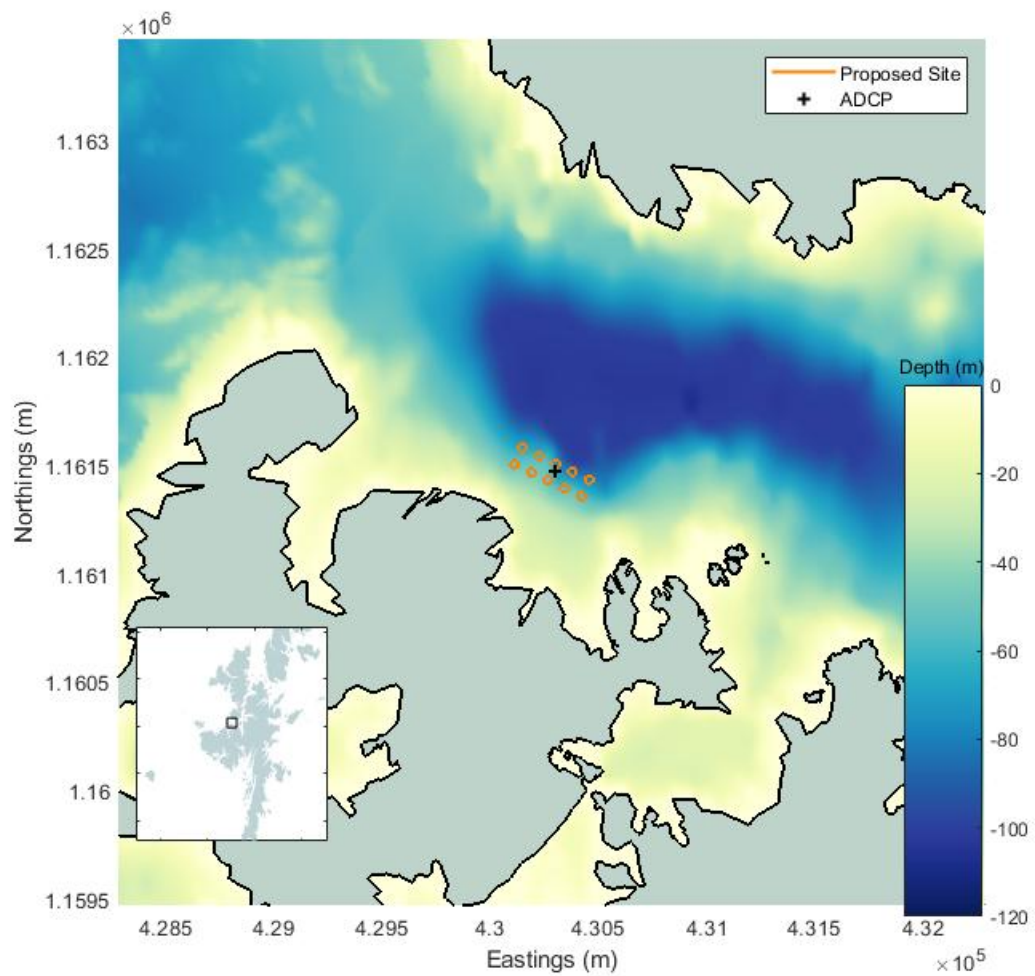


Figure 1. Proposed (orange) Vementry site infrastructure and bathymetry.

Table 2 – Proposed site infrastructure and pen layout.

	Vementry (Proposed)
Consent number	-
Company	Cooke Aquaculture Scotland
Receiving water	Swarbacks Minn
Site centre (OSGB36)	430285.52 E, 1161466.97 N

Current meter location (OSGB36)/year of deployment	430307E, 1161464N /2023
Distance to shore (km)	0.3
Average water depth (m)	58.2
Maximum biomass (t)	1350
Total number of pens	10
Number of pen groups	1
Formation	2 x 5
Pen group orientation (°)	295.5
Pen shape	Circular
Pen circumference (m)	120
Mooring grid (m)	85
Net depth	21
Wave exposure index	3.52

2. NewDepomod Modelling Methods

To determine maximum biomass and compliant in-feed chemotherapeutant quantities, a particle tracking model is applied. NewDepomod (version 1.5.0) simulates the release and deposition of waste feed and faecal material from farms to the seabed, from which the benthic impact is predicted. For in-feed treatments, specific chemical characteristics are accounted for to determine chemical concentration and accumulation.

For the SEPA default model, a specific model configuration was applied (SEPA, 2024).

2.1 Domain and Bathymetry

For the standard default model, the domain consists of a 2 km² area with grid cells at 25 m spacing. The coordinate system uses the cartesian Ordnance Survey of Great Britain 1936 system (OSGB 1936), with the site centred in the domain. Uniform bathymetry is applied, with the depth value set at the mean ADCP measured depth (58 m). Coastline data from Ordnance Survey (2022) is used to define the land boundary, which is set to 10 m above sea level.

2.2 Pen Configuration

Pen layouts described in table 2 are simulated in the centre of the model domain. All pens are classed as active and assigned an equal proportion of feed and faecal waste.

2.3 Flowmetry

An acoustic profiling current meter was deployed at the proposed site centre location for 97 days, from the 31st October 2023 and the 6th February 2024 at 430285.5E, 1161466.97N. From this, a 90-day subset was selected, spanning from 31/10/2023 13:20 to 29/01/2024 13:20 (GMT). Within this 90-day subset, no pitch and roll exceedances or water column errors were identified. A summary of the flow statistics over the 90-day deployment are given in Table 3.

Table 3. Hydrographic input information.

	Near Surface	Cage Bottom	Near Bed
Height from seabed (m)	40.62	38.62	2.62
Depth cell	40	38	2
Mean speed (m/s)	0.036	0.035	0.045
Ranked percentage at 0.03m/s (%)	48.27	49.70	35.34
Ranked percentage at 0.045m/s (%)	72.22	73.23	58.48
Ranked percentage at 0.095m/s (%)	97.53	97.88	93.30
Maximum speed (m/s)	0.250	0.238	0.309

Residual speed (m/s)	0.008	0.007	0.025
Residual direction (°)	221.19	211.52	79.24

Typically, the site experiences mean velocities ~0.04m/s. Residual currents at the site centre are shown to be strong at the near bed depth layer, contributing ~54.2% to the overall mean velocity. As residual currents exceed 35% of the mean bed speed, they are excluded from the flowmetry data for use within the SEPA default NewDepomod model.

The vertical (z) resuspension dispersion coefficient used in the SEPA default model is calculated based on the mean bed velocity ($\bar{u}_z$). For Vementry the mean bed velocity is 0.00347 m/s.

2.4 Inputs

2.4.1 Default Model

Peak biomass is simulated for the entire model duration, this is equal to 365.25 days for the benthic model. Maximum biomass is then used to calculate the feed waste and faecal matter using the values in table 4.

Table 4. Input feed parameters

Parameter	Value
Feed requirement	7kg per 1000kg biomass per day
Feed water (%)	9%
Feed waste (%)	3%
Feed absorbed (%)	85%
Feed carbon (%)	49%
Faeces carbon (%)	30%

2.4.2 In-feed Treatment

In-feed chemical compliance determines the maximum quantity of Emamectin Benzoate (EmBz) to be used on site. In-feed model settings are identical to the benthic

model with the exception of a few variables that control particle consolidation and decay (table 5). Input feed parameters are defined by table 3 and the equations in section 2.1.1. Settling, erosion and dispersion parameters are defined in table 4.

For the treatment of EmBz, simulation duration is reduced to 223 days, where the EQS is recorded at 118 days. This is based on the average chemical concentration from the 48 hours leading up to the 118th day, sampled at 3-hour intervals. The model domain is 2km².

Table 5. Infeed parameter specific to chemical modelling.

Parameter	Benthic (solids input)	In-feed (EmBZ input)
Consolidation time of faeces	0	345600
Consolidation time of feed	0	345600
Degrade T50 chemical (s)	Infinity	21600000

2.5 Environmental Quality Standards

The Environmental Quality Standards (EQS) values and descriptions that are used to define a maximum acceptable impact are provided in table 6. To determine potential risk to the seabed, the Infaunal Quality Index (IQI) provides a numerical value that corresponds to the health of the seabed. As NewDepomod does not model IQI directly, a relationship between sediment flux and IQI is used as a proxy for environmental impact. For the SEPA default model, this states that a solid flux of 250g/m² is equivalent to an IQI of 0.64. Therefore, any deposition above the 250g/m² is defined as having a significant impact on the seabed. The 100m composite mixing zone is defined as the pen area plus an additional 100m buffer zone. An additional intensity standard is applied that restricts the mean concentration of the impacted area, where the permitted average is based on the sites wave exposure. The existing and proposed Vementry sites have wave exposure values greater than 2.8.

Table 6. Default benthic EQS parameters

Pen-edge	Intensity	Mean deposited mass within the 250 g/m ² impact area should not exceed 2000 g/m ² where wave exposure is less than 2.8, and 4000 g/m ² where wave exposure is more than 2.8.
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Mixing zone	Area	Total area (m ²) with a mean deposited mass in excess of 250 g/m ² should not exceed the 100 m composite mixing zone area (m ²). If wave exposure is 2.8 or above, the mixing area may occupy 120% of the 100m mixing zone.
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These values and descriptions are given in table 7. This uses the 100m mixing zone principle, on the 763 ng/kg wet weight standard. For existing farms, the previous consented chemical quantity can be used providing very limited impact to new seabed areas. If the new area of impact exceeds 15%, then the chemical quantity should be reduced until this area is below the maximum new area percentage.

Table 7. In-feed chemical EQS parameters

Mixing zone	Area	For the 763ng/kg wet weight standard – existing footprint area is calculated using the 136 ng/kg (wet wt) contour. The proposed changes must not result in more than 15% of new seabed impacted or an increase in chemical quantities.
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4. Results – Benthic

4.2 Proposed Site

4.2.1 Default Model

The impacted seabed, where concentrations exceed 250g/m², is predicted to cover an area of 183,750m² – this is equivalent to 106.52% of the 100m mixing zone area. The pen edge EQS experiences a mean deposited flux value of 675.43g/m². This is within the compliant cage edge threshold for a site with a high wave exposure (< 4000 g/m²). Using the SEPA default model parameters and EQS values, the proposed site passes all benthic standards.

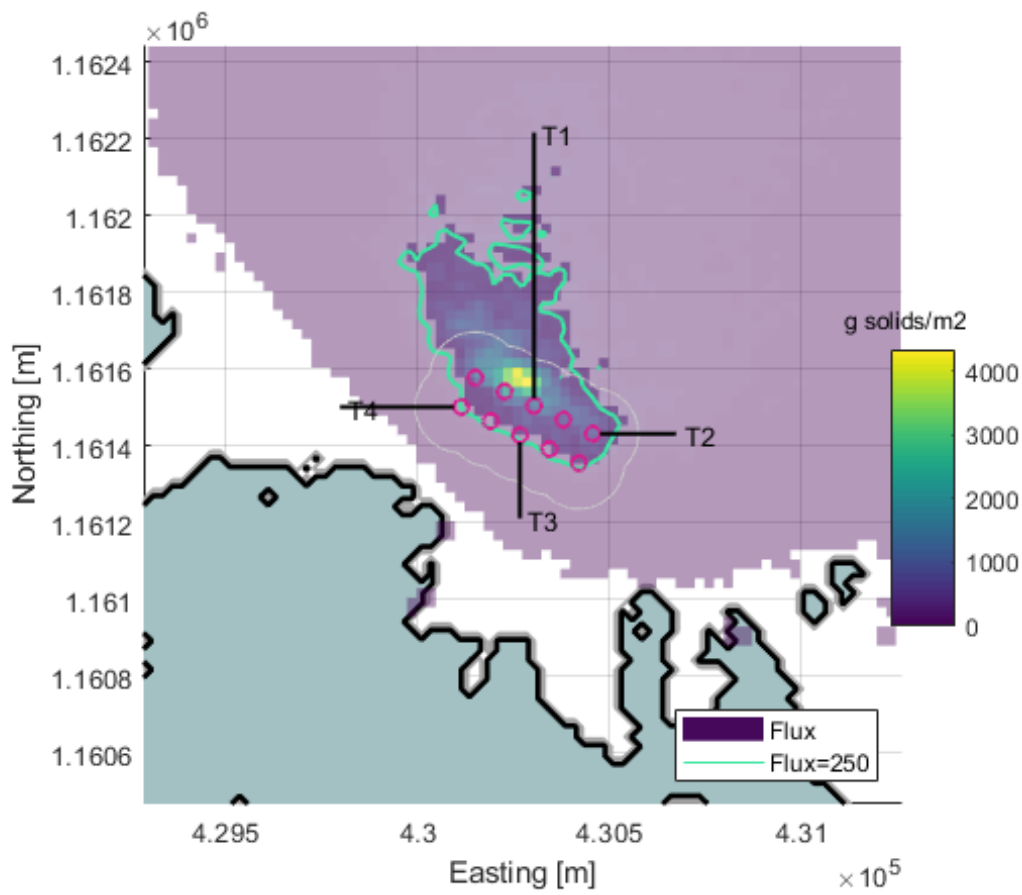


Figure 2. Modelled benthic footprint for the proposed Vementry site (1350T) using the default model (residual currents removed). Transects locations 1-4 are also shown.

To further illustrate the variability in sediment flux with distance from the farm, four transects are extended radially outwards from the pen edges. The locations of these are shown in figure 2. Figure 3 shows the changing deposition along these transects. As distance from the cage edge increases, flux values are shown to reduce. For T2, T3 and T4 sediment flux values reach 0g/m² within 300m of the pen edge, indicating a tightly constrained footprint in the south, west and east directions. T1 shows material extending 700m towards the north direction.

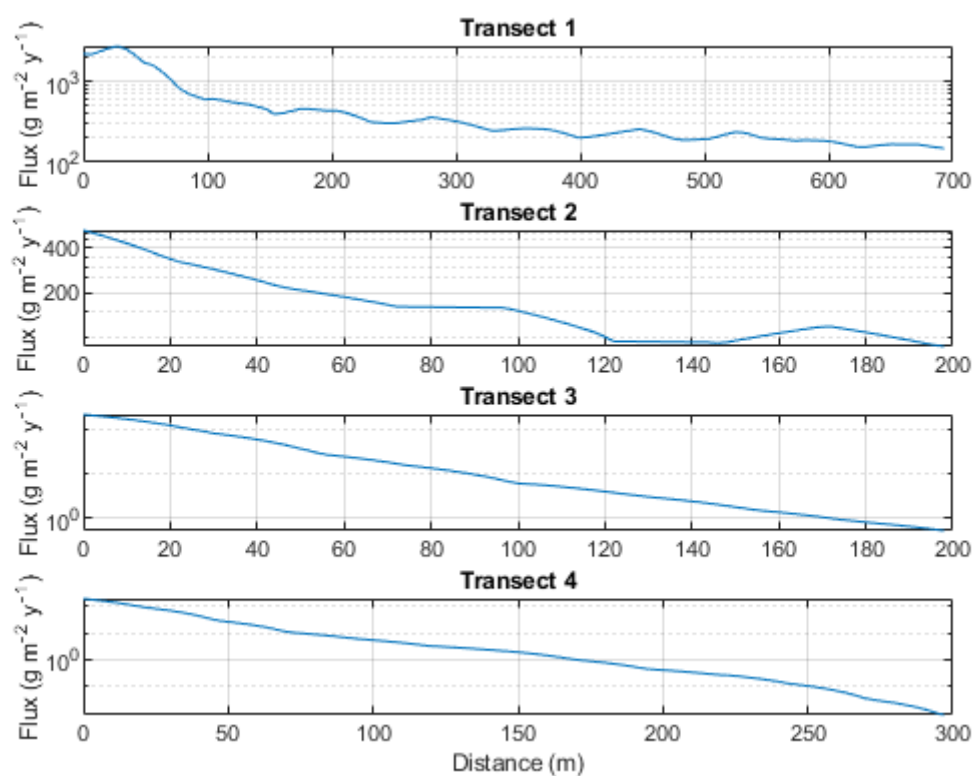


Figure 3. Transects (T1-T4) of organic solids deposition with distance from cage edge for the proposed Vementry site using the default model.

Table 13. EQS results from benthic NewDepomod model runs – proposed site.

Model type	SEPA default (residual currents removed)
Residual currents	Removed
Feed input	Maximum biomass
Sediment flux equivalent to IQI=0.64 (g/m ²)	250
Biomass (tonnes)	1,350
Stocking density (kg/m ³)	5.61
100m mixing zone (m ²)	172,500
Predicted impact area (m ²)	183,750

Area of 100m mixing (%)	106.52
Mean deposited mass ($\text{g m}^{-2} \text{yr}^{-1}$)	675.43

5. Results – In-feed Treatment

In-feed treatments are used to control sea lice numbers in salmon farms. Slice™, active ingredient Emamectin Benzoate (EmBZ), is applied as a coating to the daily feed quota. To better understand the environmental effects of chemotherapeutants, the in-feed chemical default model was applied.

5.1 Default Model

The predicted chemical footprints for the proposed Vementry site are shown in figures 4 and 5. Applying a mixing zone EQS of $0.136 \mu\text{g/kg}$, a maximum consented treatment quantity of 14g results in a $158,120\text{m}^2$ impact area (91.66% of the 100m mixing zone). These values are presented in table 10.

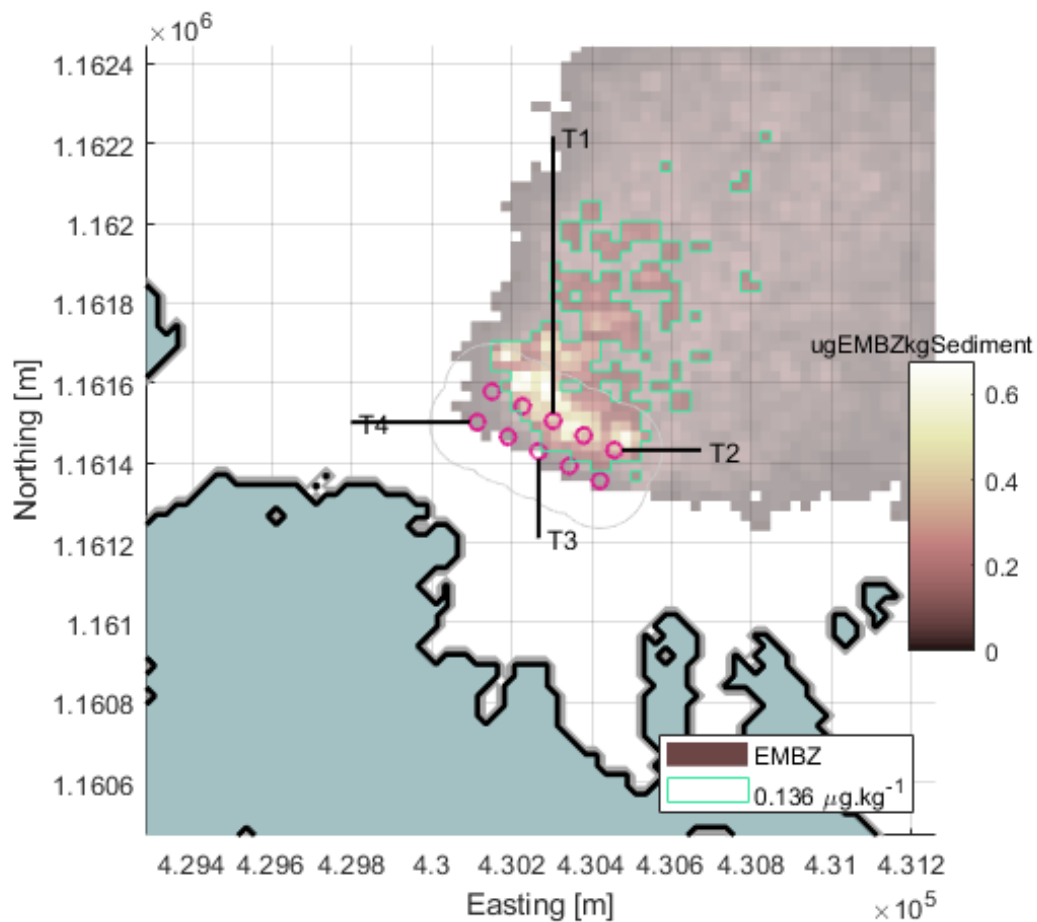


Figure 4. EmBz impact area for the proposed Vementry site using the default NewDepomod model where residual currents are removed and an EQS of 0.136 $\mu\text{g/kg}$. Transects locations 1-4 are also shown.

The in-feed chemical footprint shows a patchy distribution of the impacted area towards the northeast of the farm. Chemical concentrations are plotted along the transects presented in figure 5. All transects show small quantities of EmBz present at the pen edge. Concentrations in all transects (T1, T2, T3 and T4) quickly reduce as the distances increase from the site.

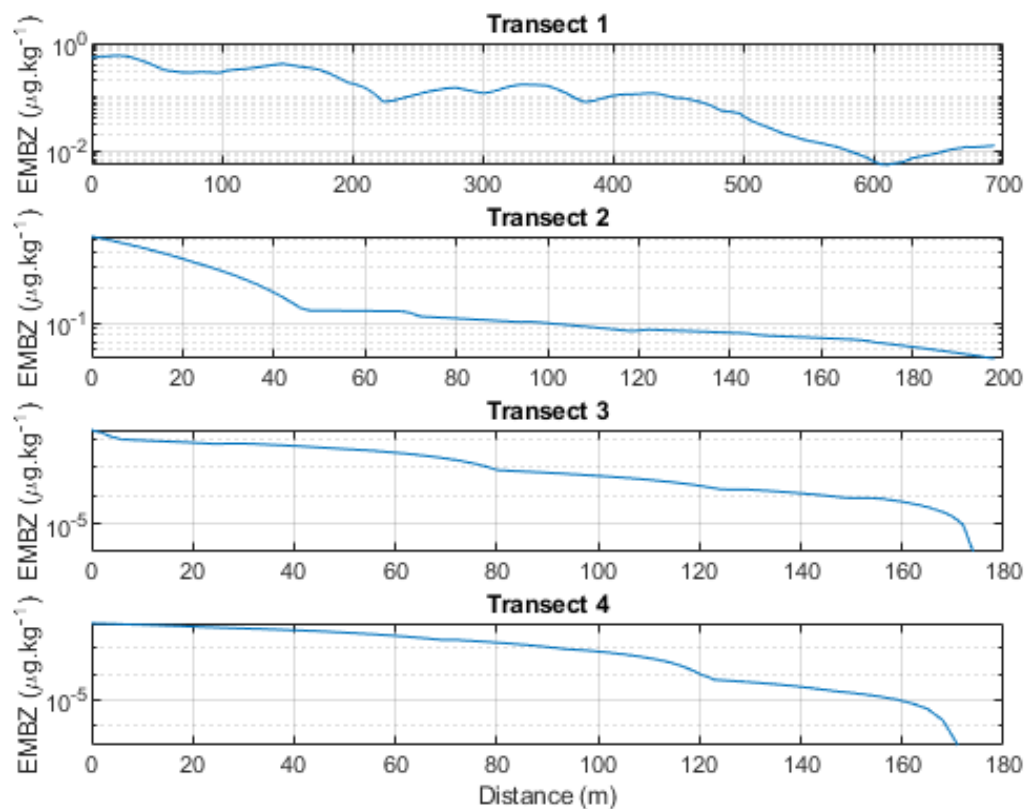


Figure 5. Transects (T1-T4) of EmBz deposition with distance from cage edge for the proposed Vementry site using the default model.

The compliant treatable chemical mass is used to determine the maximum treatable biomass. The total amount of Slice required is calculated using the chemical quantity multiplied by 0.5. Treatable biomass is calculated by dividing the chemical quantity by 0.35. This provides a treatable biomass of 40 T, requiring 7 Kg of SLICE.

Table 14. EQS results from the EmBz SEPA default model.

	Proposed
Model type	Default
Biomass (tonnes)	1,350
Stocking density (kg/m³)	5.61
Chemical quantity (g)	14
Domain size (km²)	2
100m mixing zone (m²)	172,500
Predicted impact area (m²)	158,120
Area of 100m mixing zone (%)	91.66

6. Conclusion

The risk-assessment (default) benthic modelling approach shows a maximum biomass of 1,350 tonnes at the proposed site complies with mixing zone EQS thresholds. A predicted impact area equivalent to 106.52% of the 100m mixing area was predicted in the default model. The mean deposited concentration for the default model run was 675.43 g/m².

In-feed chemical compliance was determined by the proportion of impacted seabed compared to the 100m mixing zone. Results from the default model determined a compliant EmBz quantity of 14g. This permits a treatable biomass of 40 tonnes using 7 kg of SLICE.

7. References

Ordnance Survey (2022) “Boundary-Line” Available at <https://osdatahub.os.uk/downloads/open> (Accessed 03/02/2022)

Scottish Environment Protection Agency (SEPA) (2019a) “Regulatory Modelling Guidance for the Aquaculture Sector” Version 1.1. Available at <https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-the-aquaculture-sector.pdf>. (Accessed on 01/08/22).

Scottish Environment Protection Agency (SEPA) (2019b) “Regulatory Modelling Process and Reporting Guidance for the Aquaculture Sector”. Version 1.1. Available at <https://www.sepa.org.uk/media/450278/regulatory-modelling-process-and-reporting-guidance-for-the-aquaculture-sector.pdf>. (Accessed on 01/08/22).

Scottish Environment Protection Agency (SEPA) (2022b) “Ellipse fitting toolbox” Available at: [aquaMetrics/kraken](https://github.com/aquaMetrics/kraken): $\odot$ Assess Size of the Mixing Zone Ellipse $\odot$ (github.com)