Hellisay, CAR/L/1095612/V5

Waste Solids & In-feed Medicine Deposition Modelling Report

Mowi Scotland Ltd.

December 2022

› Mowi Scotland

[redacted]

CONTENTS

List of Figures

List of Tables

EXECUTIVE SUMMARY

Model simulations have been performed to assess the likely deposition of waste solids and in-feed medicine at a salmon farm site at Hellisay, in the Sound of Hellisay, following a proposed change from the existing 12 x 120m pens to 5 x 200m pens. Simulations have also been performed for a proposed interim trial deployment comprising of 3 x 200m pens. This report explains the application of the NewDepomod model to describe the deposition of waste solids and in-feed medicine beneath the pens and in the surrounding environment. The modelling procedure followed as far as possible guidance presented by the Scottish Environment Protection Agency (SEPA) in July 2019 (SEPA, 2019) and January 2022 (SEPA, 2022a, b). Modelling of the dispersion of the in-feed medicine emamectin benzoate is also described.

Results indicated that deposition at Hellisay will be low, with a maximum deposition of 2,332 g m^{-2} (Table 1). The footprint area, where the deposition exceeded the critical deposition rate of 250 g m^{-2}, was 0.08375 km^2. The intensity of deposition, 536.3 g m^{-2} was less than the critical value of 4,000 g m^{-2} for this exposed site. The results also confirm that the current consented amount (TAQ) of Emamectin Benzoate (EMBZ) of 2187.5 g can be used with the proposed layout.

These results indicate that the proposed new layout at Hellisay will comfortably meet pertinent Environmental Quality Standards for salmon farm waste solids and in-feed medicine dispersion.

Table 1. Site details & summary of results

Site Details	
Site Name:	Hellisay
Site Location:	Sound of Hellisay
Peak Biomass (T):	2,150
Feed Load (T/year):	5,493
Pen Details	
Number of Pens:	5
Pen Dimensions:	200m Circumference
Working Depth (m):	10
Configuration:	1x5, 120m matrix
NewDepomod Results	
Allowable Mixing Zone (m^2):	176,646
Maximum Deposition (g m^{-2}):	2,332
Modelled Footprint Area (m^2):	83,750
Mean Footprint Deposition (g m^{-2}):	536.3
In-feed Medicine	
Emamectin Benzoate TAQ (g)	2187.5

1 INTRODUCTION

This report has been prepared by Mowi Scotland Ltd. to describe the deposition of waste solids from a marine salmon farm at Hellisay in the Sound of Hellisay (Figure 1 and Figure 2), following a proposed change from the existing 12 x 120m pens to 5 x 200m pens, including an interim trial using 3 x 200m pens. It explains the application of the NewDepomod model to describe the deposition of waste solids and in-feed medicine beneath the pens and in the surrounding environment. The modelling procedure followed as far as possible guidance presented by the Scottish Environment Protection Agency (SEPA) in January 2022 (SEPA, 2022a, b).

Figure 1. Location of the Hellisay site

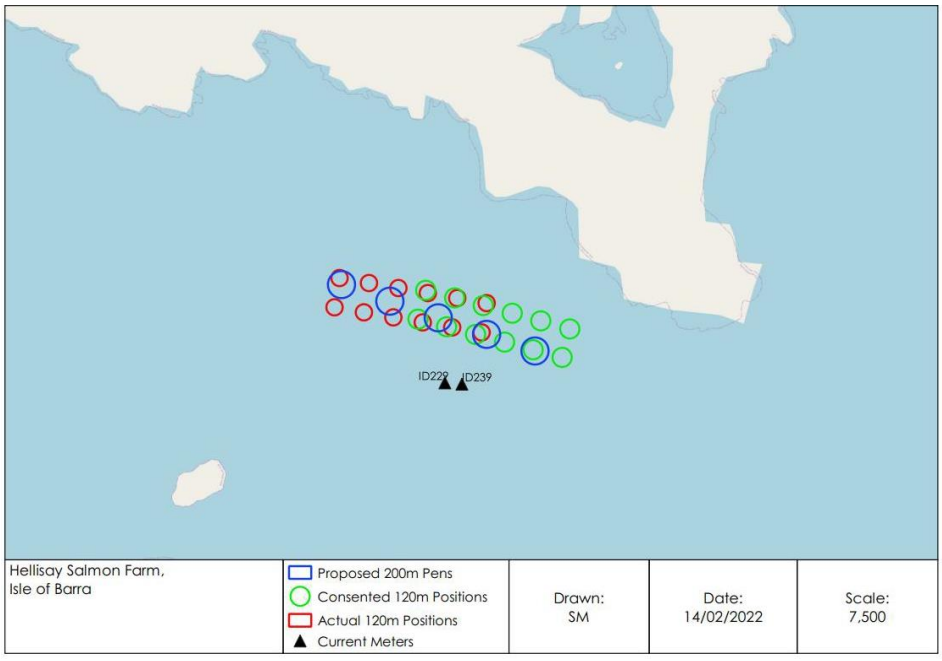

Figure 2. Existing (red) and proposed (blue) pen layouts at the Hellisay salmon farm. Current meter deployment locations ID229 and ID239 are marked (▲).

1.1 Site Details

The existing site is situated in the Sound of Hellisay on the southern shore of the island of Hellisay (Figure 1 and Figure 2). The consented, actual and proposed pen centre locations are given in Table 2 and Table 3. These locations were used in the computer modelling (Section 2). Details of the site and hydrographic summary are provided in Table 1 and Table 4. Hydrographic data were collected over two deployments in 2018 (ID229 and ID239, Figure 2). The receiving water is defined as open water.

Hellisay is located in a high wave exposure location (wave exposure index = 3.7); as such, the criteria for mean deposition within the footprint will be set at 4,000 g m^2.

Table 2. Details of the current consented and actual 120m pen centre locations and net depths used in the modelling for Hellisay.

	Consented		Actual		Net
Cage	Easting	Northing	Easting	Northing	Depth (m)
1	75829	803255	75626	803290	12
2	75897	803237	75609	803217	12
3	75964	803219	75699	803273	12
4	76032	803201	75682	803200	12
5	76099	803183	75772	803256	12
6	76167	803164	75755	803183	12
7	75811	803187	75845	803239	12
8	75878	803169	75828	803166	12
9	75946	803151	75918	803223	12
10	76014	803133	75901	803149	12
11	76081	803115	75991	803206	12
12	76149	803097	75975	803133	12

Table 3. Details of the proposed 200m pen centre locations and net depths used in the modelling for Hellisay.

Cage	Easting	Northing	Net Depth (m)
1	75649	803268	10
2	75762	803227	10
3	75875	803186	10
4	75987	803145	10
5	76100	803104	10

2 MODEL DETAILS

Three sets of solid waste simulations were performed. The first and second set focussed on localised deposition of waste solids from the consented and actual pen locations and utilised the NewDepomod model, configured with the standard default parameter values specified by SEPA and using measured flow data to force the model. The third set predicted the local deposition from the proposed pen locations. Simulations were also performed to assess the change in potential change in concentrations of the consented in-feed medicine, emamectin benzoate, with the proposed change in pens.

Table 4. Summary of the near-bed hydrographic data at Hellisay.

Hydrographic Summary	**ID229**	**ID239**
Deployment Date	Jun - Aug 2018	Aug - Oct 2018
Easting	75874	75914
Northing	803037	803034
Mean Speed (m/s)	0.057	0.082
Residual Speed (m/s)	0.015	0.038
Residual Direction (°G)	296	308
Tidal Amplitude Parallel (m/s)	0.100	0.123
Tidal Amplitude Normal (m/s)	0.031	0.044
Major Axis (°G)	290	305

2.1 Local Deposition: NewDepomod

NewDepomod is a bespoke modelling software designed to simulate the dispersion of particulate wastes from salmon farms. The model (SAMS, 2021) has been developed by the Scottish Association for Marine Science (SAMS) and is supplied under licence. The version used for the modelling described here was:

library version:
numerics version: Final 1.20220131164706.1643647287
datatypes version: Final 1.20220131164658.1643647287
util version: v1.4.0-final-(SEPA)

A regular model grid was prepared. The grid for simulating solids deposition covered a 3 km x 2 km area, with a 25m grid spacing in both directions. The grid size was 120 x 80 cells. The water depth was 21.66 m, the weighted average of the depths at the two current meter deployments (ID229 and ID239). The flowmetry file combined the data from ID229 and ID239; after merging the length of the combined record was exactly 90 days in total.

A larger grid (6km x 5km) was prepared for the Emamectin Benzoate modelling. The same grid spacing and water depth was used.

2.1.1 Localised Waste Feed and Faeces Deposition

The model was configured exactly as specified by SEPA in the modelling guidance published in January 2022 (SEPA, 2022a, b). The site was modelled for a maximum biomass of 2150

tonnes with a feed load of 7 kg/tonne/day. This configuration of the model produces a conservative estimate of the benthic footprint, with a deposition rate of 250 g m^{-2} equating approximately to an Infaunal Quality Index (IQI) of 0.64 (the boundary between moderate and good status). Work by SEPA has shown that footprints predicted by this "standard default" configuration broadly match the footprint area derived from seabed samples, although there is a great deal of variability from site to site.

Following the standard default approach, NewDepomod was used to simulate one year of deposition at the maximum farm biomass. Results were analysed over the final 90 days of the simulation, with the mean deposition rate across the model domain being calculated and the footprint area being delimited by the 250 g m^{-2} contour (SEPA, 2022a, b). The results are presented in Section 3.1.

An additional run was also performed with the biomass of 2150 tonnes held in 3 x 200m pens (Pens 3 – 5, Table 3).

2.1.2 In-feed Medicine Modelling

Hellisay salmon farm has a current EMBZ Maximum Treatment Quantity (MTQ) consent of 752.5g. To check that the proposed 5 x 200m pens do not negatively impact the deposition, the in-feed medicine model of New-Depomod was used. It was run for 118 days, with hourly results over the final two days (Days 116 – 118) saved to file. This approach followed that of the standard default modelling approach outlined in the SEPA Regulatory Modelling Guidance (SEPA, 2022a, b). The mean concentrations of Emamectin Benzoate were calculated from this output for comparison with the EQS value of 65.5 ng/kg (wet weight, equivalent to 131 ng/kg dry weight), which is the current position standard (SEPA, 2022c).

The in-feed medicine model of NewDepomod was also run using the consented Total Allowable Quantity (TAQ) amount of EMBZ of 2187.5 g, for both the existing and proposed layout. This follows guidance received from SEPA on 31st August 2022.

2.2 Regional Particulate Waste Deposition Modelling

The particulate deposition modelling, performed using the UnPTRACK model (Gillibrand 2021), simulated the settling of waste solids (waste feed and faeces) discharged from pens during a production cycle. The same pen positions were used in these simulations as the model runs used in NewDepomod (Table 3). Particles were discharged continuously, with each numerical particle representing 5 kg of particulate waste. Feed and faecal particles were assigned settling velocities within the range of 0.095 m s^{-1} ±10% and 0.032 m s^{-1} ± 10% respectively, the same as the values used by NewDepomod. The particle tracking model used the simulation from August – October 2018 (ID239) and this was repeated through to make 365 days.

When a particle reaches the seabed due to its settling velocities, it may be resuspended into the water column and be subject again to advection and diffusion. Resuspension is modelled using a stochastic approach, whereby a probability of resuspension is specified for each settled particle every time step. In the present simulations, the probability of resuspension, P, was calculated by:

$$P = c_r(\tau_b - \tau_{bc})^{\beta}$$

where $\tau_b = \rho u_*^2$ is the bed shear stress derived from the local modelled current speed, τ_{bc} is the minimum critical shear stress required to erode particles off the seabed, c_r is a resuspension constant, and β is a constant. With this approach, the probability of particle erosion increases with the excess shear stress. The parameters c_r, τ_{bc} and β are tunable coefficients that can be used to calibrate the deposition model. For the simulations presented in §3.2, values of c_r = 1.0, τ_{bc} = 0.02 Pa and β = 1.0 were used. A bed roughness scale of z_0 = 0.01 m was used to calculate the bed shear stress from the local current speed.

The regional particulate waste modelling used flow fields from a hydrodynamic model of the Sound of Barra area, described in Mowi (2022b). The flow fields from the simulation of ID239 (August – October 2018) were used in the modelling described below.

3. RESULTS

3.1 Local Waste Solids Deposition

The modelled footprints for the Hellisay farm using the SEPA standard default method are shown in Figure 3 for the various pen configurations. The areas of the modelled footprint, defined as the area where the deposition rate exceeds 250 g m^{-2}, are given in Table 5. For the proposed pens, the footprint area of 83,750 m2 was well within (47% of) the allowable mixing zone. The maximum 90-day-mean deposition was 2,332 g m^{-2}, with the mean intensity of deposition within the footprint was 536.3 g m^{-2}, well below the critical value of 4,000 g m^{-2} for this highly exposed site (wave exposure index greater than 2.8).

Table 5. The modelled footprint areas and mean footprint deposition rates for Hellisay for the consented biomass, using the SEPA standard default method, for the three pen configurations.

NewDepomod Results Summary	**Licenced**	**Actual**	**Proposed**
Maximum Biomass (T)	2,150	2,150	2,150
Feed Load (T/year)	5,493	5,493	5,493
Solid Waste Release Rate (kg/day)	2,403	2,403	2,403
Allowable Mixing Zone (m^2)	167,690	178,078	176,646
Maximum Deposition (g m^{-2})	1,674	1,010	2,332
Modelled Footprint (m^2)	85,000	80,625	83,750
Mean Footprint Deposition (g m^{-2})	504.4	478.9	536.3

These results indicate that the proposed equipment change and biomass increase will comfortably meet pertinent Environmental Quality Standards for salmon farm waste solids.

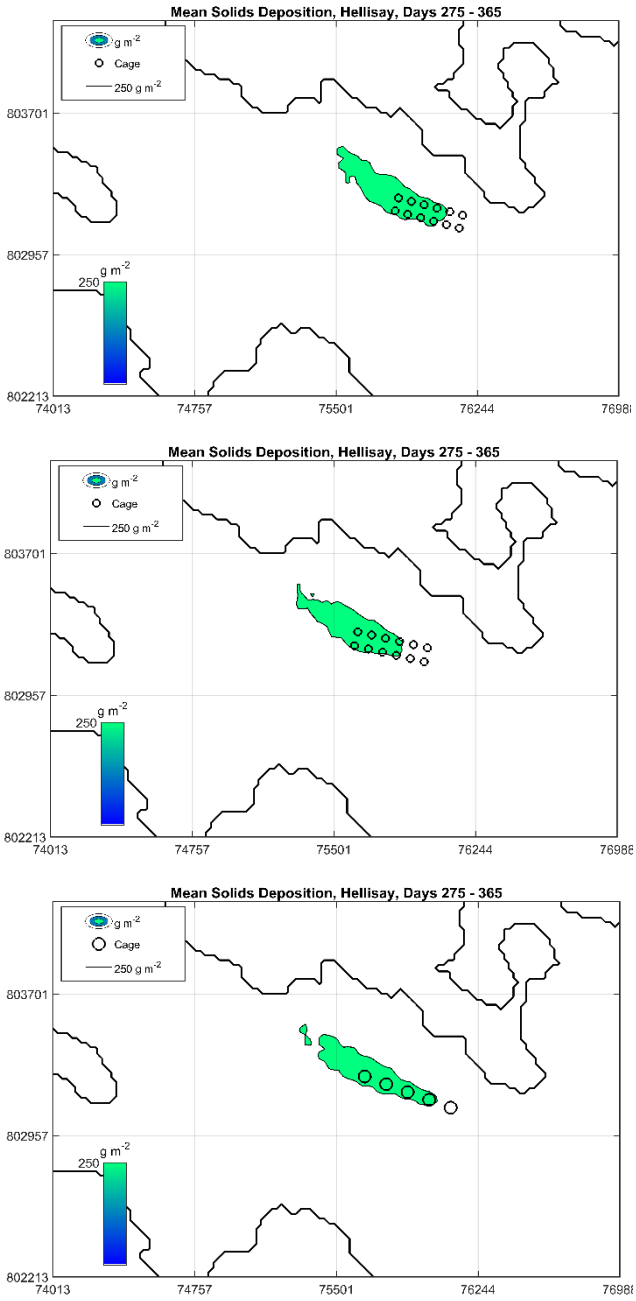

Figure 3. The modelled footprint for Hellisay for the consented biomass of 2150 tonnes with pens located at the consented (top), actual (middle) and proposed (bottom) locations.

3.1.1 Local Waste Solids for 3 x 200m pens

Results from the additional run, with 2150 tonnes of fish held in 3 x 200m pens are shown in Figure 4. The modelled footprint was well within the allowable mixing zone and the intensity limit of 4000 g m^{-2} (Table 6).

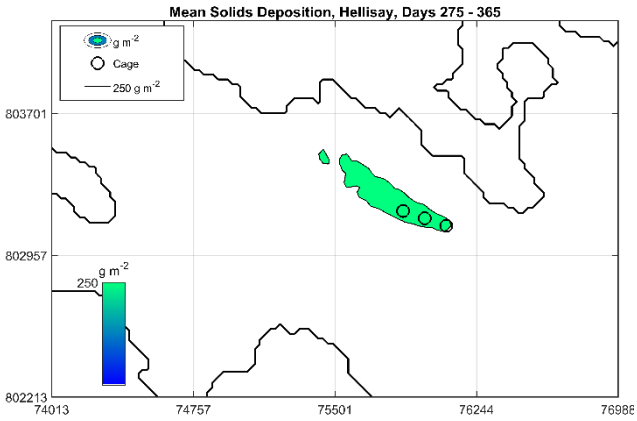

Figure 4. The modelled footprint for Hellisay for the consented biomass of 2150 tonnes with 3 x 200m pens.

Table 6. The modelled footprint area and mean footprint deposition for Hellisay for the consented biomass, using the SEPA standard default method, for 3 x 200m pens.

NewDepomod Results Summary	**3 x 200m**
Maximum Biomass (T)	2,150
Feed Load (T/year)	5,493
Solid Waste Release Rate (kg/day)	2,403
Allowable Mixing Zone (m^2)	115,624
Maximum Deposition (g m^{-2})	5,123
Modelled Footprint (m^2)	81,250
Mean Footprint Deposition (g m^{-2})	766.0

3.2 Regional Solids Deposition and Sensitive Features

Reefs and Subtidal Sandbanks (inc. Maerl Beds) sensitive features have been identified (SEPA, 2021) to be potentially at risk from sediment influence due to their proximity to the Hellisay site. Maerl surveys were conducted at the Hellisay site in 2010, 2016, 2017, 2020 and 2021. Comparisons between these surveys were undertaken to look for changes over time and it was shown that overall there was an increase in maerl coverage across all densities of 205% (Table 7). See Mowi Scotland (2022) for more details on these comparisons. Figure 5 and Figure 6 show the location of the special features in relation to the Hellisay site and the solids footprint from both the existing and proposed configuration, respectively.

Table 7. Summary of maerl density distribution by year. Coloured entries reflect highest (green) values and lowest (red) values recorded in each survey.

Survey Year	Total Area of Maerl (over 50%) 'High' Density	Total Area of Maerl (25-50%) 'Moderate to High' Density	Total Area of Maerl (5-25%) 'Moderate to Low' Density	Total Area of Maerl (0-5%) 'Low' Density	Total Coverage
2010	838 m²	1,761 m²	6,240 m²	176,093 m²	184,932 m²
2016	314 m²	4,010 m²	60,442 m²	223,266 m²	**288,032 m²**
2017	139 m²	5,784 m²	73,692 m²	315,559 m²	395,174 m²
2020/2021	603 m²	11,703 m²	76,880 m²	291,209 m²	**380,395 m²**
Percentage Change Since 2010	**- 28%**	**+ 664%**	**+ 1,232%**	**+ 165%**	**+ 205%**

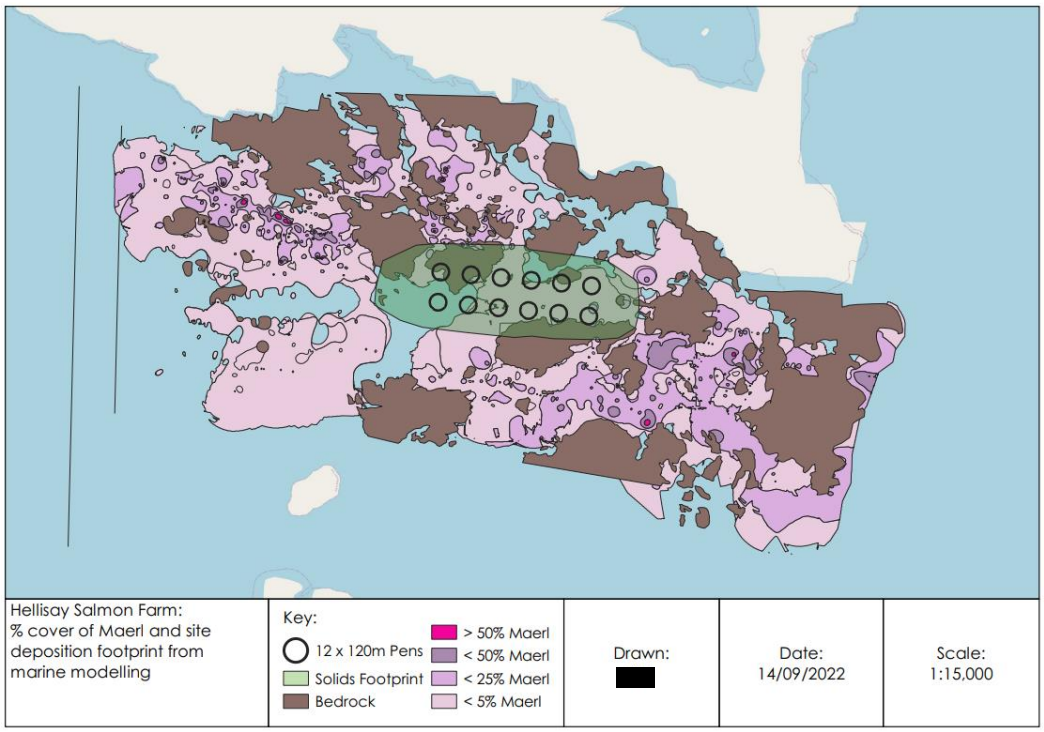

Figure 5. Solids footprint of existing layout at Hellisay salmon farm and % cover of Maerl.

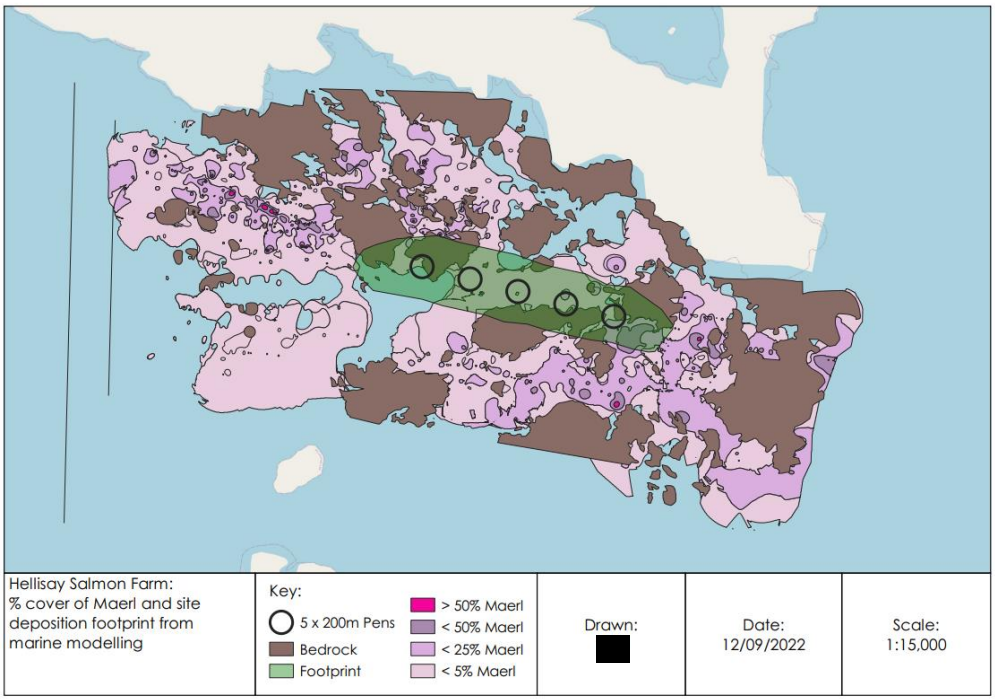

Figure 6. Solids footprint of proposed layout at Hellisay salmon farm and % cover of Maerl.

These results show that the modelled footprint from both the existing and proposed layouts will have minimal impact on the special features, and that an over-lap is only seen in areas of no maerl, bedrock, less than 5% maerl and less than 25% maerl. Because of the exposed location of the Hellisay site, most particulate waste will be removed leaving a relatively small solids footprint.

Deposition modelling was also undertaken for the wider domain around the Sound of Barra. Figure 7 shows low levels of predicted mean deposition (generally less than 100 g m^{-2}) in the larger domain for existing and proposed pen layouts. This, however, is only one possible outcome of many and is intended as a worst-case scenario: parameter values have been selected so that there is no consolidation of waste on the seabed beneath the pens and, when the critical shear stress threshold is exceeded, more resuspension occurs creating larger footprints with lower values. The plot shows that the mean deposition levels in the sound of Barra were low, and did not exceed the 250 g m^{-2} threshold (Figure 8), except for an artefact at a single grid point in a bay on the south coast of the island of Fuday in central Sound of Barra. However, it must be emphasized that some consolidation of waste material beneath the pens is likely and that export to the Sound of Barra is likely to be less than shown in Figure 7. When consolidation was included in the simulations, no waste solids material was exported into the Sound of Barra (Figure 9).

Time series of the maximum predicted deposition in the Sound of Barra (north of 804000N) over the final 90 days of the simulations are shown in Figure 10 (deposition at the single grid cell location adjacent to the island of Fuday was neglected for this time series). The model results indicate a gradual accumulation of sediment in the Sound of Barra (but recall that NewDepomod does not simulate the breakdown of particulate organic carbon). The maximum value of deposition at each time step does not occur at the same location, otherwise the mean concentration would be higher. **And we reiterate that this simulation represents a worst**

possible case scenario, since no waste is consolidated beneath the farm pens and is all available for export. In the simulation with consolidation of waste beneath the pens, no export to the Sound of Barra was simulated (Figure 8).

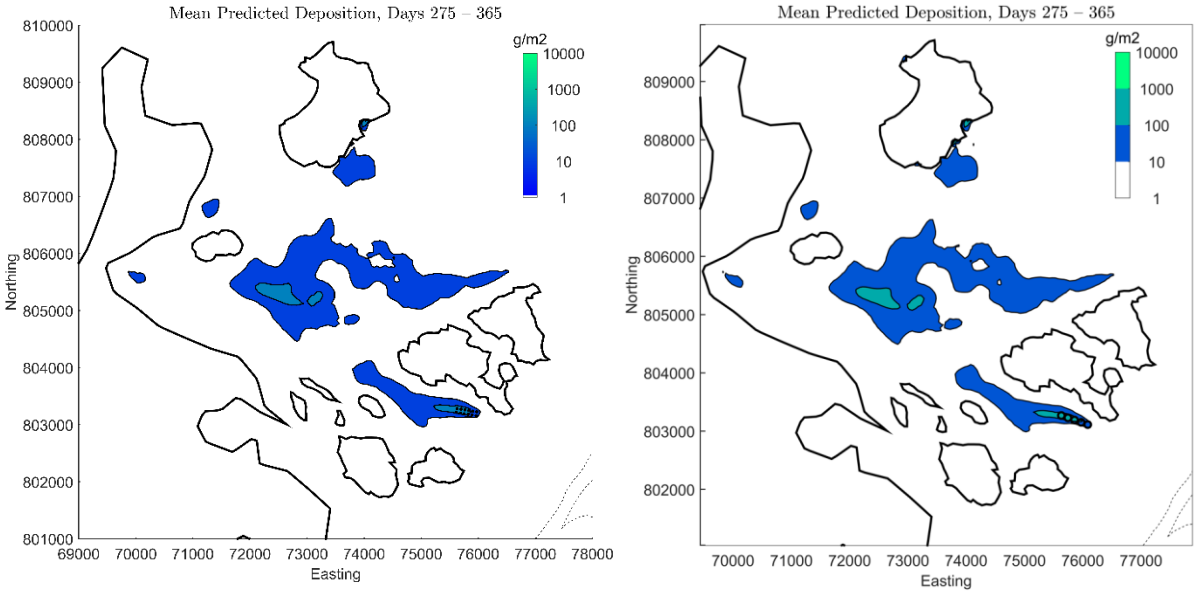

Figure 7. Modelled mean deposition in the Sound of Barra from 2150 tonnes in 12 x 120 m pens (left) and 5 x 200m pens (right). The model was configured to allow maximum resuspension of deposited material from beneath the farm pens; the levels of deposition in the Sound of Barra shown therefore represent worst case scenarios.

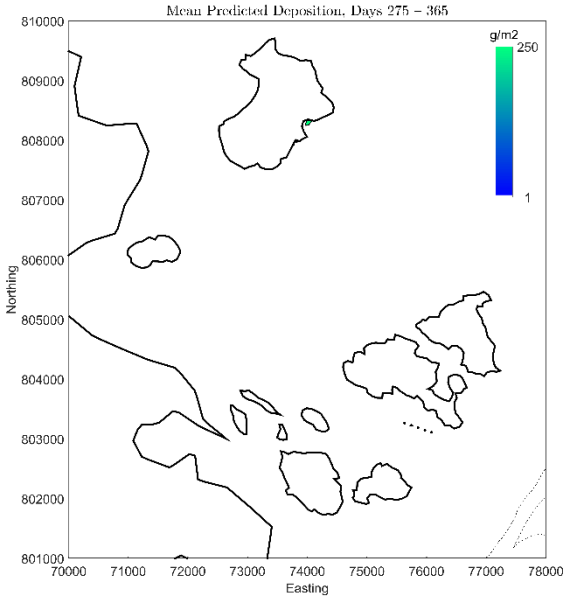

Figure 8. Modelled mean deposition in the Sound of Barra from 2150 tonnes in 5 x 200m pens, shown using the 250 g m^{-2} contour. The model was configured to allow maximum resuspension of deposited material from beneath the farm pens. No material was exported to the Sound of Barra above this mean threshold concentration (except for an artefact at a single grid point in a bay on the south coast of the island of Fuday).

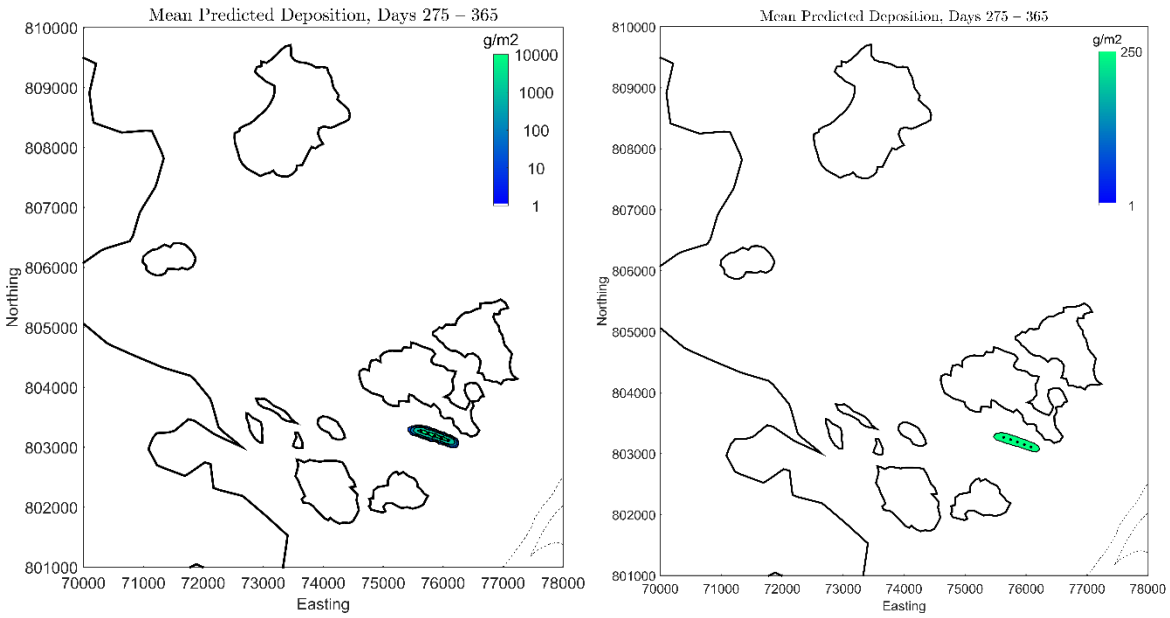

Figure 9. *Modelled mean deposition in the Sound of Barra from 2150 tonnes in 5 x 200m pens with the model configured to allow consolidation of deposited material beneath the farm pens. No material was exported to the Sound of Barra. The results are shown using a range of contours (left) and the 250 g m^{-2} contour (right).*

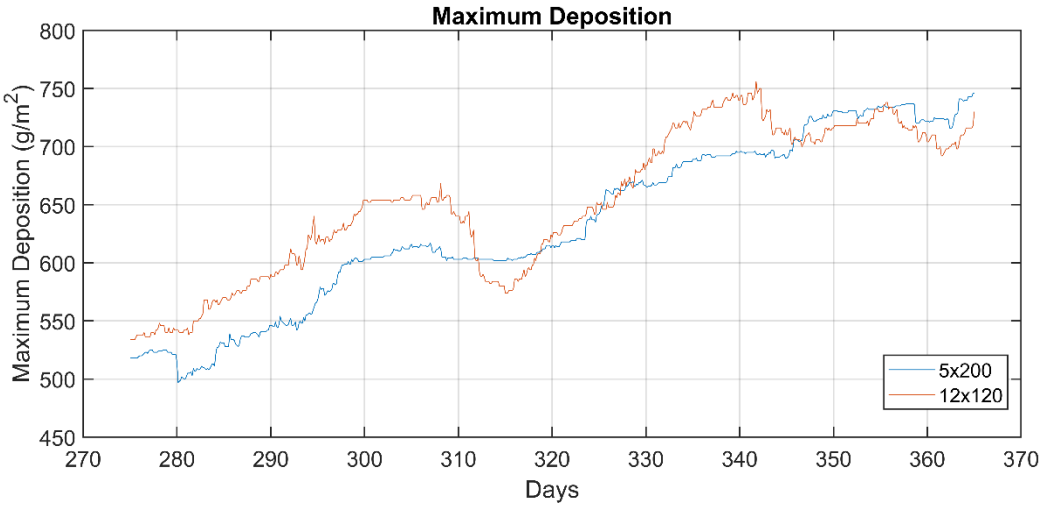

Figure 10. Time series of maximum solids deposition in the Sound of Barra (north of 804000N) from Days 275 - 365 for both the existing 12x120m and the proposed 5x200m pens from the marine modelling results. The model was configured to allow maximum resuspension of deposited material from beneath the farm pens; the levels of deposition in the Sound of Barra shown therefore represent worst case scenarios.

3.3 In-feed Medicine Modelling

The in-feed medicine model of NewDepomod was run using both the existing layout of 12 x 120m pens and the proposed 5 x 200m pens. This was done to determine whether the change in equipment would have an effect on the deposition shown from the site with the current consented EMBZ mass of 752.5 g. The resulting footprints from the maximum treatment quantity (MTQ) are shown in Figure 11.

The in-feed medicine model of NewDepomod was also run using the consented TAQ amount of EMBZ of 2187.5 g, for both the existing, interim layout of 3 x 200m and the proposed layout. Figure 12 shows the footprints from each layout. It is worth noting that this is an unrealistic quantity of EMBZ to be used in a single treatment.

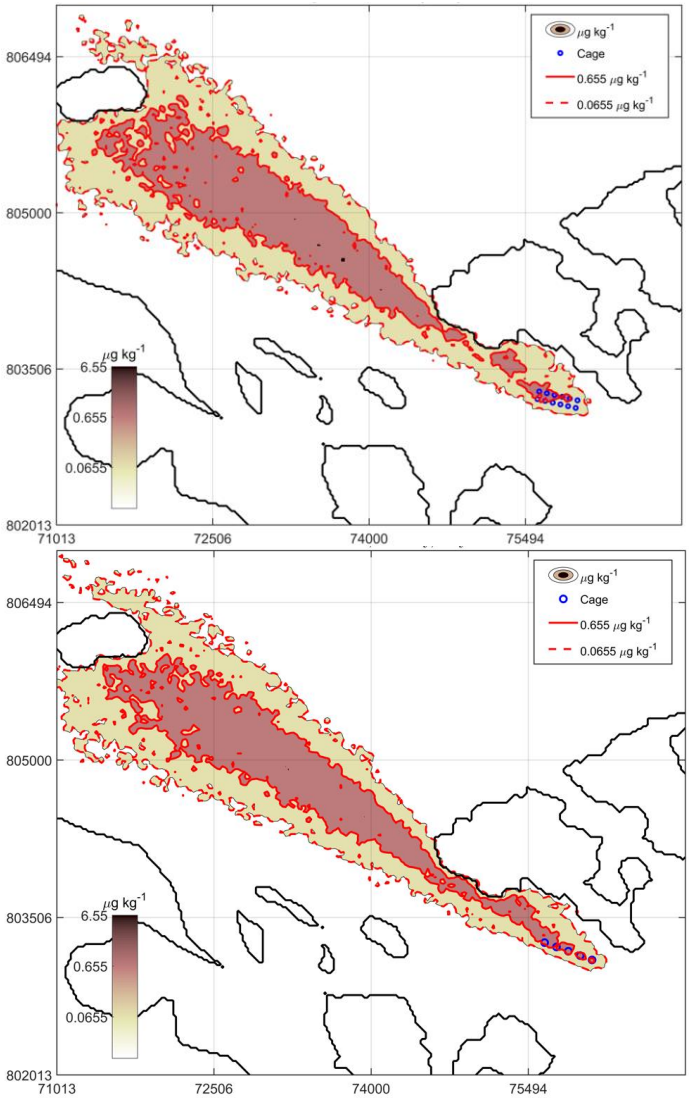

Figure 11: Predicted mean Emamectin Benzoate deposition over days 116 – 118 for the existing 12x120m pens at Hellisay (top) and the proposed 5x200m pens (bottom) following a consented treatment of 752.5g (MTQ).

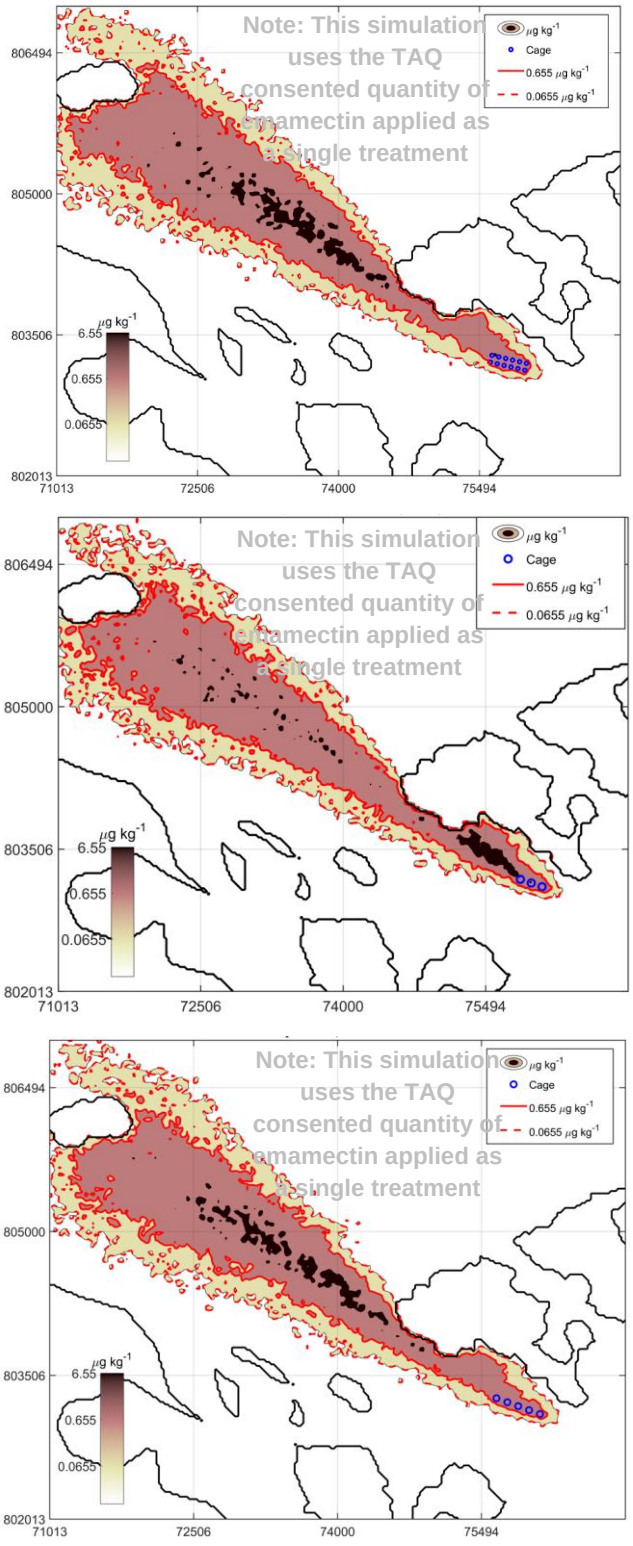

Figure 12. Predicted mean Emamectin Benzoate deposition over days 116 – 118 for the existing 12x120m pens at Hellisay (top), interim 3x200m pens (middle) and the proposed 5x200m pens (bottom) following a single treatment comprising the total allowable quantity (TAQ) of emamectin (2187.5 g).

Figures 13 – 18 show the EMBZ footprints of the existing, interim and proposed layouts with both MTQ and TAQ overlain. These plots highlight minimal variance in footprint size from the equipment changes.

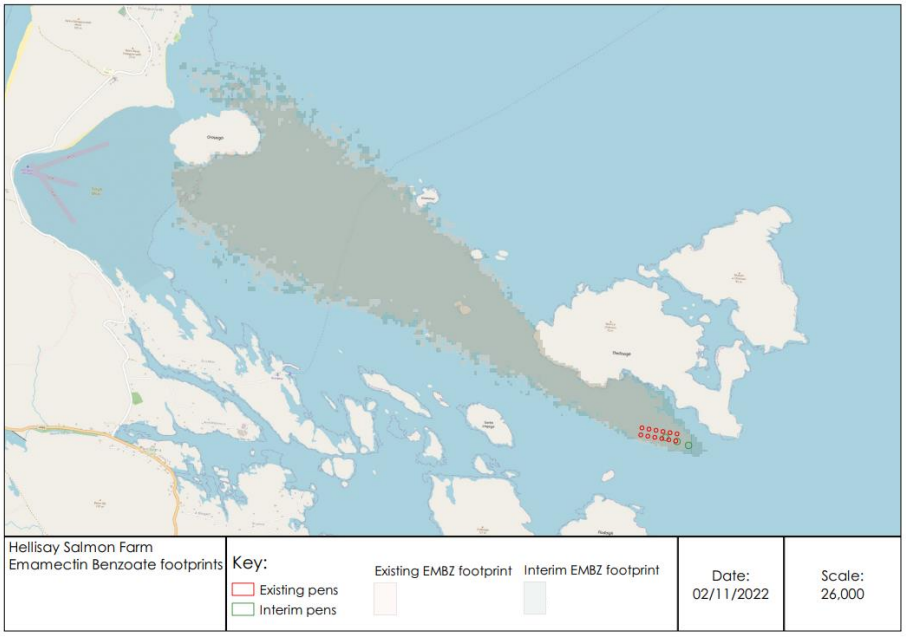

Figure 13. Predicted mean EMBZ deposition over days 116-118 for both existing 12x120m and interim 3x200m pens overlain following a single treatment comprising of the maximum treatment quantity (MTQ) of 752.5g.

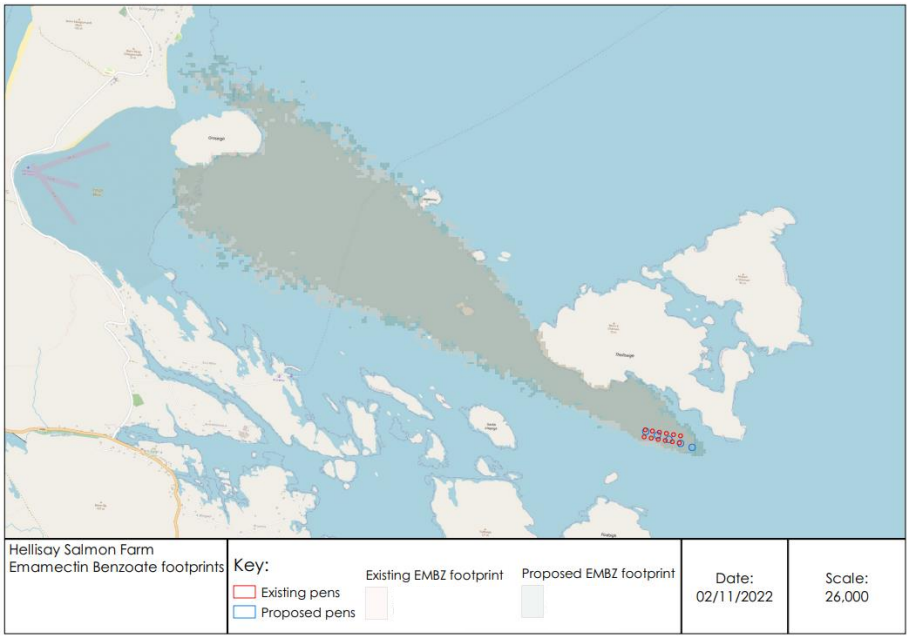

Figure 14. Predicted mean EMBZ deposition over days 116-118 for both existing 12x120m and proposed 5x200m pens overlain following a single treatment comprising of the maximum treatment quantity (MTQ) of 752.5g.

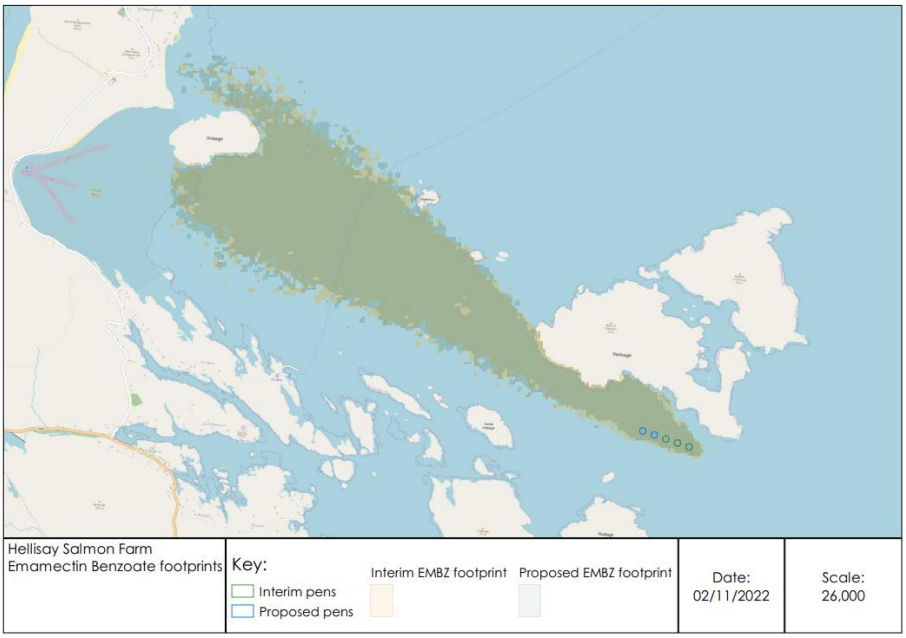

Figure 15. Predicted mean EMBZ deposition over days 116-118 for both interim 3x200m and proposed 5x200m pens overlain following a single treatment comprising of the maximum treatment quantity (MTQ) of 752.5g.

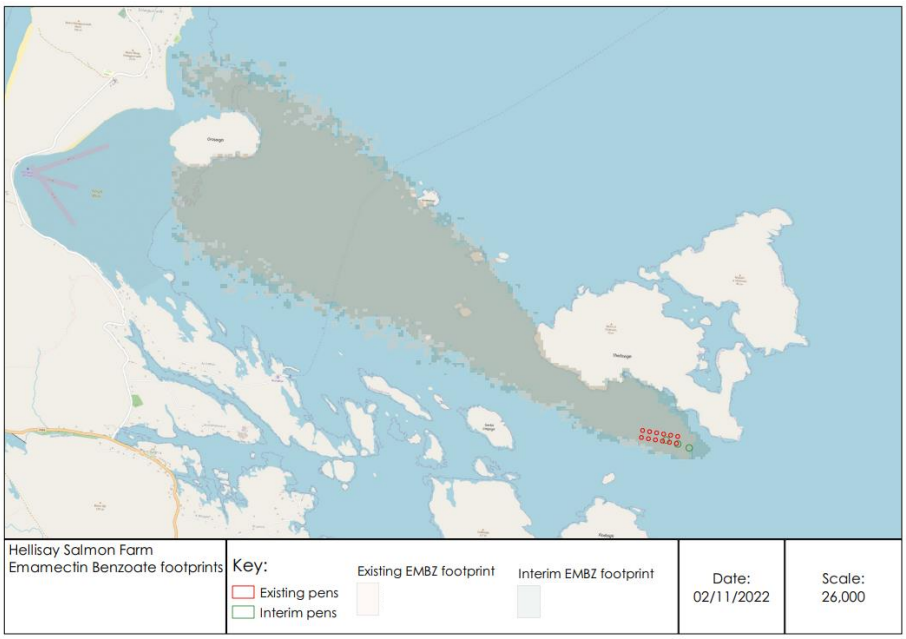

Figure 16. Predicted mean EMBZ deposition over days 116-118 for both existing 12x120m and interim 3x200m pens overlain following a single treatment comprising of the total allowable quantity (TAQ) of 2187.5g.

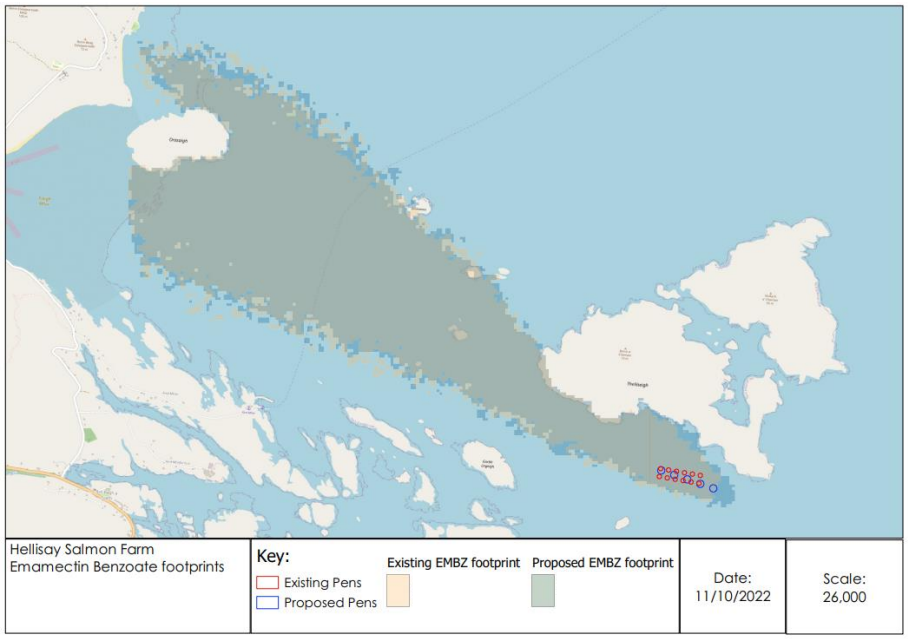

Figure 17. Predicted mean EMBZ deposition over days 116-118 for both existing 12x120m and proposed 5x200m pens overlain following a single treatment comprising of the total allowable quantity (TAQ) of 2187.5g.

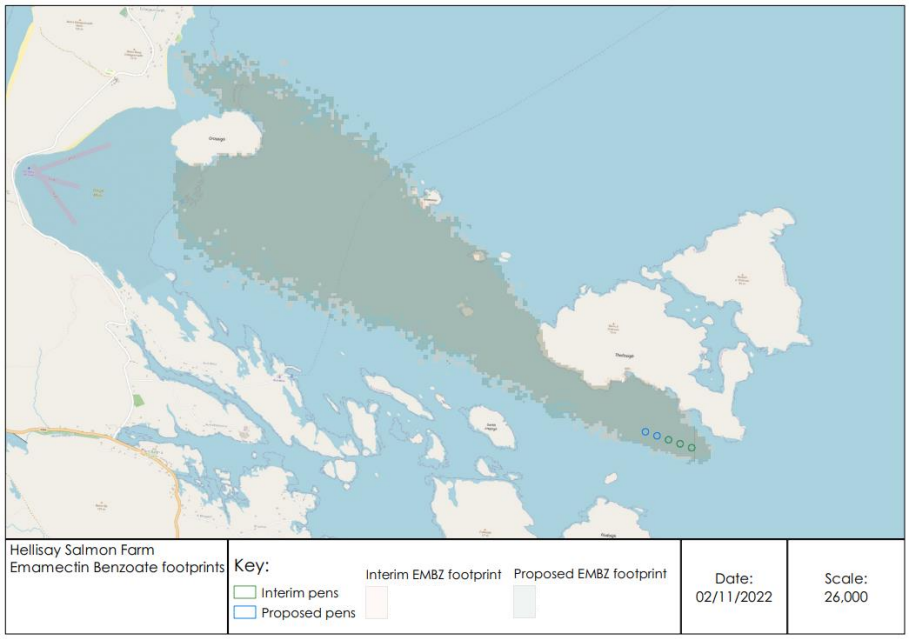

Figure 18. Predicted mean EMBZ deposition over days 116-118 for both interim 3x200m and proposed 5x200m pens overlain following a single treatment comprising of the total allowable quantity (TAQ) of 2187.5g.

Table 8 shows the changes in footprint area (seabed where the current EQS is exceeded) predicted for the proposed layout relative to the existing layout. For the MTQ, the footprint area shrank by 2%, whereas for the TAQ, the predicted area increased by 0.3%. The area of newly-

impacted seabed from the proposed layout, expressed as a percentage of the existing impacted area for both the MTQ and TAQ quantities, is also shown. The size of the newly impacted area for both footprints (MTQ and TAQ) was less than the 15% limit allowed under current guidelines (SEPA, 2022a, b).

Table 8. Modelled change in footprint areas and newly-impacted seabed area from the proposed layout as a percentage of the existing impacted area for both MTQ and TAQ treatments.

	Change in Footprint Area (%)	Newly Impacted Area (%)
MTQ	-2.04	+8.65
TAQ	+0.30	+8.62

4. SUMMARY AND CONCLUSIONS

The biomass of 2150 tonnes in 5 x 200m pens requested for consent at the Hellisay site, and the associated feed loading (Table 9), has been shown to comfortably meet pertinent Environmental Quality Standards. The SEPA standard default method, which is designed to provide a conservative prediction of particulate deposition, suggested no significant deposition will occur at the site, meeting both mixing zone and deposition intensity criteria.

The results indicated that the change in equipment from 12 x 120m pens to 5 x 200m pens will not significantly increase the EMBZ footprint size, but in fact with a predicted reduction in area exceeding the EQS of -2.04% for the MTQ and a small increase of 0.3% for the TAQ, well within the bounds of model variability. The area of newly impacted seabed for emamectin benzoate was 8.6%, well within the allowable change of 15% under current guidelines.

Table 9. Summary of Results

Site Details	
Site Name:	Hellisay
Site Location:	Sound of Hellisay
Peak Biomass (T):	2,150
Feed Load (T/year):	5,493
Pen Details	
Number of Pens:	5
Pen Dimensions:	200m Circumference
Working Depth (m):	10
Configuration:	1x5, 120m matrix
NewDepomod Results	
Allowable Mixing Zone (m^2):	176,646
Maximum Deposition (g m^{-2}):	2,332
Modelled Footprint Area (m^2):	83,750
Mean Footprint Deposition (g m^{-2}):	536.3
In-feed Medicine	
Emamectin Benzoate TAQ (g)	2187.5

5. REFERENCES

Gillibrand, P.A., 2021. Unptrack User Guide. Mowi Scotland Ltd., February 2021, 31pp. https://github.com/gillibrandpa/unptrack

Mowi Scotland Ltd. 2022. Appendix 7.1: Synthesis of Maerl Survey Data, Hellisay Environmental Impact Assessment (EIA) Report, October 2022

Mowi Scotland Ltd. 2022b. Hydrodynamic Model Description, Hellisay, Isle of Barra. 16 pp.

Scottish Association of Marine Science (SAMS), 2021, NewDepomod https://www.sams.ac.uk/science/projects/depomod/

SEPA, July 2019. Aquaculture Modelling. Regulatory modelling guidance for the aquaculture sector. Scottish Environment Protection Agency, Air & Marine Modelling Unit, July 2019, 68pp.

SEPA, 2021. Aquaculture modelling screening & risk identification report: Hellisay (HEL1). Scottish Environment Protection Agency, Air & Marine Modelling Unit, August 2021, 32 pp.

SEPA, 2022a. NewDepomod Draft Guidance – 25/01/2022. Scottish Environment Protection Agency, Air & Marine Modelling Unit, 25th January 2022.

SEPA, 2022b. Interim Marine Modelling Guidance for Aquaculture Applications. Scottish Environment Protection Agency, Air & Marine Modelling Unit, 25th January 2022.

SEPA, 2022c. Interim position statement for protecting the water environment in relation to emamectin benzoate in finfish farm regulation, Scottish Environment Protection Agency, Air & Marine Modelling Unit, July 2022.