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SCOTLAND

North Gravir CAR Application

Hydrodynamic Simulation Method Statement

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1 Introduction

This document has been prepared by Bakkafrost Scotland (BFS) to outline the methodology to simulate discharges from a proposed marine pen fish farm (North Gravir) as part of an application under The Water Environment (Controlled Activities) (Scotland) Regulations 2011 ('CAR') to the Scottish Environment Protection Agency (SEPA). This report will outline the approach to simulate the dispersal of regulated discharges from the farm location and how these discharges impact sensitive features within the area. The releases proposed to be assessed are outlined below and discussed in greater detail in the remainder of the document:

- Feed and Faeces
- Emamectin Benzoate (EmBz): assessed solely within NewDepomod
- Azamethiphos (AZA)
- Deltamethrin (DEL)

The simulation framework will be comprised of two distinct work packages, as per contemporary SEPA guidance[1]. NewDepomod simulations risk assess the proposed tonnage and review the benthic impact of the proposal in the near field. This will be supplemented by a larger scale particle tracking simulation framework ('Marine modelling'), aimed at reviewing the potential medium to far-field impact of the development on sensitive features and identify the permissible quantities of bath treatment quantities.

1.1 Summary

This document was written in response to SEPA's screening report[2], in which SEPA outlined next steps to adequately review the impact of the proposed farm for assessment under CAR. These are summarised in Table 1.1 below and BFS' proposed methodologies (developed in collaboration with SEPA) are outlined in the remainder of this document.

[1] SEPA (2022) Interim modelling guidance 20220916
[2] SEPA (2022) Aquaculture modelling screening & risk identification report: Gravir North (GVRN1)

Table 1.1: SEPA's recommendations for "Further Modelling" and BFS' proposals

SEPA recommendation	BFS Response
"Due to the risks associated with the large tonnage proposed at this site, and the overly conservative nature of BathAuto at sites with high current speeds, 2D marine modelling of sediment and bath medicine plumes should be carried out. This marine modelling will also help with the calibration of NewDepomod, should this site wish to expand in the future."	BFS propose to use a 3D hydrodynamic simulation package with coupled atmospheric, heat exchange and turbulence to review the dispersal of sediment and medicines from the proposed site. This model will be subject to an independent review from model developers (DHI)
"The size of the marine model should include discharges from sites ODH1 and GVRW1 as well as GVRN1. (Cumulative modelling is not required for baths)."	The marine modelling will include the licenced bath medicines released from North Gravir. Solid releases at the proposed site will be simulated with the addition of Gravir Outer (ODH1) and Gravir West (GVRW1) discharges.
"The resolution of the marine model should be relatively fine around the proposed site and identified features at risk."	The hydrodynamic model will have a resolution to appropriately represent bathymetric features in the area of interest. The particle tracking mesh will be of greater resolution than the hydrodynamic simulations, approximately 1,250m^2 in the area of interest.
"NewDepomod modelling should be undertaken for the proposed site. It is strongly recommended that default NewDepomod modelling is undertaken prior to any marine modelling, to ensure the local impacts of the proposed biomass are acceptable."	NewDepomod simulations have been undertaken by BFS and provided to SEPA for review at Pre-Application stage.

2 NewDepomod simulation framework

As part of SEPA's pre-application framework, BFS has submitted Standard Default Method simulations of the proposed site layout in NewDepomod, based on 90 days of hydrographic data collected at the site. These have been used to define the total biomass able to be farmed sustainably at the site under the contemporary regulatory framework and identify the licenced quantity of Emamectin Benzoate (EmBz) that can be used as an in-feed treatment at the site. It should be noted that, whilst feed and faeces will be assessed in marine modelling, the dispersal of EmBz will not. Should SEPA have any comments on the modelling performed, these will be reviewed and addressed. SEPA have confirmed that the model simulations are deemed appropriate, therefore no further simulations in NewDepomod are proposed[3].

[3] Via email to BFS staff; SEPA

3 Hydrodynamic simulation framework

The hydrodynamic (HD) modelling is proposed to be undertaken completely using the MIKE 3 FM ver2023 modelling package. Developed by DHI, the package allows the integration of physical, chemical, or biological processes in the marine environment.

3.1 Hydrodynamic simulation

BFS will commission a validated 3D hydrodynamic (HD) model for the North Gravir area of interest as displayed in Figure 3.1. The model will use the MIKE 3 simulation suite and covers most of the North Minch. The proposed site itself is located east of the Isle of Lewis (north of Loch Odhaim). Using 10 sigma layers, the model is forced from the East Coast of Lewis and Harris (ECLH) climatology model, developed by Marine Science Scotland (MSS), with additional options of data assimilating water levels signals from 'A-Class' tide gauges from the UK Tide Gauge Network and temperature and salinity fields from the ECLH itself. The model uses as forcing for atmospheric conditions adopted climatologically averaged meteorological parameters derived from the ERA-40 and ERA-Interim re-analysis product developed by the UK Met Office[4]. This setup has been validated by model developers at DHI against observational campaigns provided by BSF. There is the option to update the setup with an additional hindcast version, forced from the North-West Shelf Reanalysis (NWSR)[5,6,7] model, developed by the UK Met Office and hosted by the Copernicus Marine Service with similar to the aforementioned data assimilation workflows in place. The model will then be calibrated/validated against congruent datasets.

The 3D hydrodynamic simulations are being developed by DHI and a full report itemising model setup, the datasets applied, and the calibration/validation of the model will be provided with the final application.

Model validation

The model hydrodynamics will be validated directly against flow vectors observed over a 60-day period at the North Gravir site and calibrated against the observed velocity profile from 60 days at the second deployment at North Gravir, 30 days at the Grosebay data collection location and 30-days at the Procrapol data collection location, respectively.

Additionally, modelled water levels will be directly validated against water-level observations from BFS measurement campaigns and at the BODC A-Class gauge at Stornoway[8], outlined in Figure 3.1. Model performance will be outlined in the accompanying model report.

[4] similarly to the atmospheric forcing of the climatological Scottish Shelf Model (SSM)

[5] Tonani, M., Sykes, P., King, R.R., McConnell, N., Péquignet A-C., O'Dea, E., Graham, J.A., Polton, J., Siddorn, J.: The impact of a new highresolution ocean model on the Met Office North-West European Shelf forecasting system], Ocean Sci., '''15''', 1133–1158, 2019. https://doi.org/10.5194/os-15-1133-2019

[6] Lewis, H., Castillo Sanchez, J. M., Siddorn, J., King, R., Tonani, M., Saulter, A., Sykes, P., Péquignet, A.-C., Weedon, G., Palmer, T., Staneva, J., and Bricheno, L.: Can wave coupling improve operational regional ocean forecasts for the North-West European Shelf], Ocean Sci., '''15''', 669–690. https://doi.org/10.5194/os-15-669-2019

[7] Crocker, R., Maksymczuk, J., Mittermaier, M., Tonani, M., and Péquignet A-C.: An approach to the verification of high-resolution ocean models using spatial methods], Ocean Sci., '''16''', 831–845, 2020. https://doi.org/10.5194/os-16-831-2020

[8] BODC (2021): UK tide gauge network; Download Processed Data. [accessed 23/04/2021: https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/processed/]

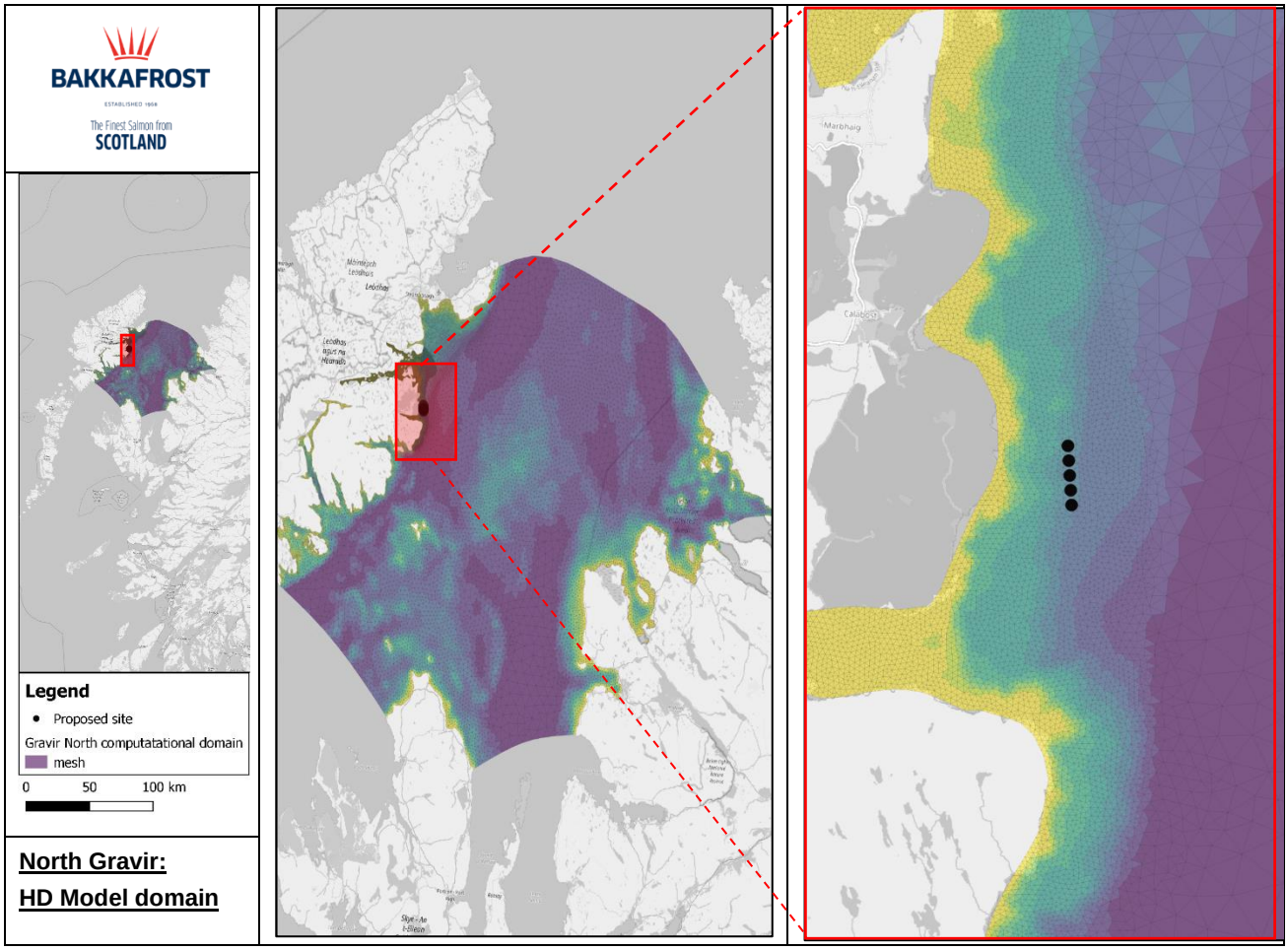

Figure 3.1: BFS Site Domain with proposed Site location

Model credibility

It should be noted that the model is currently under development by DHI UK. DHI will assess the appropriateness of the model for the intended use within the area of interest and this process is aimed at providing confidence in model function and appropriateness for application.

It is proposed this 3D HD model and its output be used offline to drive particle tracking simulations of bath treatments which will be performed in the MIKE modelling suite and are outlined in the following sections.

3.2 Particle tracking

Particle tracking will be used to assess the medium scale (0.5-5 km) to far-field (<10 km) impact of farm associated releases of solids (feed & faeces) and Bath treatments. A supplementary risk assessment (NewDepomod) will assess the near-field impact of feed and faeces.

It is proposed a Lagrangian framework be adopted to track the diffusion, dispersal and fate of the simulated releases from the farm. In this context, four different types of particles are released from the production site with their behaviour define by physical properties or following specific SEPA guidance where available; these are summaries in Table 3.1 and discussed in greater detail below.

Table 3.1: 90-day observed dataset summary data

Type	Particle	Buoyant	Resuspension	Decay	Release type	Inputs	Simulation period
Bath Medicine	Azamethiphos	Neutral	-	Yes	Instantaneous	Vet defined	Spring & Neep
	Deltamethrin	Neutral	-	No			
Waste Solids	Feed	No	Yes	No	Continuous	SEPA defined	1 year
	Faeces	No	Yes	No			

***General model setup*:**

Two general model setups will be applied to review the dispersal of the four simulated particles releases. These releases will be simulated based on the output flow vectors and stratification properties generated from hydrodynamic simulations reviewed by model developers DHI. Some minor modifications will be undertaken to increase the suitability of the model assets to improve the simulation approach and bring the methodology in line with regulatory requirements. Selected significant modifications are outlined briefly in Table 3.2 along with selected parameters applied in the particle tracking module.

Table 3.2: General particle tracking model setup

Parameter	Modification
Mesh	Mesh used in parent 3D HD simulations refined. Each cell will be divided into three cells, yielding an average approximate cell size of 1,250 m2 (equivalent to a 35x35 m cartesian grid), within the area of interest.
Vertical mesh	The vertical mesh of the model will modify the sigma layers used to increase resolution in the surface and bed.
Horizontal diffusion	Set to 0.1 m/s. This is considered a conservative parameter and has been established. *
Vertical diffusion	Set to 0.001 m/s.
Release position	Pen centres will be considered the source of all releases with depth of release varying depending on the class of particle release
HD Spin-up	The spin-up period for the model is proposed to be seven days to establish general 2D flow patterns and an additional 21 days to establish small scale variation and stratification throughout the domain. Spin up will be reviewed in the modelling report.

* Sensitivity testing will be undertaken to review model sensitivity to this parameter

Bath treatment simulations

The impact of bath treatments will be from the proposed site will be simulated over both spring and neap cycles with MTQ and EQS standards used to define total quantities of permissible medicine.

Model hydrodynamics

Bath treatment scenarios simulating the releases from the proposed North Gravir site will be reviewed in two scenarios with treatment of the farm occurring over a Peak Spring and a Peak Neap tidal cycle to review the different influence of these flow regimes on the dispersal of bath treatments. Hydrodynamic forcing will be generated.

Model setup

Bath treatment scenarios simulating the releases from all farms will be reviewed in two scenarios with treatment of all pens occurring over a Peak Spring and a Peak Neap tidal cycle. Table 3.3 outlines the general model setup, specifically for bath treatments.

Table 3.3: Bath treatment model setup

	Proposed Site
Release position	Pen centres, 3m below surface*
Dosage	Released as a medicinal dose based on tarpaulin volume at specified depth
Releases	Three releases per day at three-hour intervals during daylight: 1100, 1400, 1700
Particle representation	1000 particles/gram of active ingredient **
Release format	Instantaneous release of treatment quantity at pen centre
Simulation period	Six days
Azamethiphos decay	5.6 days Half-Life[9]
Deltamethrin decay	Not applied

* Sensitivity testing will be undertaken to review model sensitivity to this parameter
** Particle representation will be reviewed based on computational capability

Review
The particle dispersal from the proposed farm will be assessed against the calculated EQS and MAC and will be reviewed and solved according to the specification in Table 3.4) to identify the maximum permissible treatment quantity at each of the relevant time periods will be reviewed. The permissible quantity will then be identified as the smallest quantity that satisfies all standards for both hydrographic climates.

Table 3.4: Bath treatment review partitions and standard assessed against

Time since last treatment:	3 hr	6 hr	72 hr
Azamethiphos	EQS	-	EQS & MAC
Deltamethrin	-	EQS	-

Feed & faeces
The rate of feed and faeces input into the model will be defined by accompanying NewDepomod iterations that have been reviewed by SEPA at pre-application stage and outlined in Section 2. The dispersal of the waste particles will be assessed against Mixing Zone requirements and the dispersal of waste feed and faeces will be reviewed against the spatial distribution of known benthic Priority Marine Features (PMF) and active CAR licences in the area.

The influence of feed and faeces will be reviewed "in combination" with discharges from marine pen fish farms outlined in SEPA's Screening Report[2], assumed to be at peak biomass for 365 days, using standard feed rates (7kg/t/d) and feed conversion ratios. These existing farms and their consented biomass are outlined in Table 3.5.

Table 3.5: Sites included in Feed and Faeces simulations

Time since last treatment:	Consented Biomass (T)
North Gravir (proposed)	4,680
West Gravir	515.7
Outer Gravir	2,285.2

[9] DEFRA (2020) Summary of Product Characteristics: Vet, 500 mg/g Powder for Suspension for Fish Treatment. [Available online 25/01/2022: https://www.vmd.defra.gov.uk/productinformationdatabase/files/SPC_Documents/SPC_720682.PDF]

Review

As with NewDepomod, the average deposition over the final 90-days of simulation will be taken to review the impact of the annual deposition of the farm and mitigate the impact of any migratory depositional features.

This will be supplemented with the daily average and maximum feed and faeces concentrations the entire simulation time period (post spin-up), in .dfsu file format.

3.3 Sensitive features

The Screening Report outlines a list of PMFs that should be reviewed by the hydrodynamic modelling undertaken. This list is visible in Table 3.6: Sensitive features within the areaTable 3.6 with the addition of existing CAR licences within the area. The impact of the five released particle classes will be reviewed at these sensitive features and presented within the final modelling report.

Table 3.6: Sensitive features within the area

Feature Name	Distance to proposal (km)	Feature Type	Location: BNG	Brief Reason for Identification
European Spiny Lobster	9.9	PMF	142780, 925987	At risk from sediment and bath influence
Burrowed Mud (associated with burrowing crustaceans and tall sea pens)	0.86 – 23.9	PMF	Shapefile provided by SEPA[2]	At risk from sediment (and EmBz) influence
West Gravir	2.3	Marine Pen Fish Farm	141310, 914410	At risk from bath and sediment influence
Outer Gravir	1.9	Marine Pen Fish Farm	141750, 914500	At risk from bath and sediment influence

4 Conclusion

This document outlines the proposed approach to simulating the discharges from the proposed North Gravir site in context with existing CAR licence discharges. The hydrodynamic simulation methodology proposes using a custom, validated 3D hydrodynamic simulation package with appropriate particle tracking to assess the large-scale impact of the proposal on the larger sea area and at seven sensitive receptors.

The approach proposes to assess the discharge of solid waste from the proposed farm within the context of additional discharges from West Gravir and Gravir Outer farms at peak biomass for 365 days. Additional modelling will identify the maximum permissible bath treatment quantities for Azamethiphos and Deltamethrin.