ASSESSMENT OF EQUILIBRIUM CONCENTRATION ENHANCEMENT

Caolas Loch Portain Finfish Pen Site, Lochmaddy

Prepared for

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The data used in this document and their input and reporting have undergone a quality assurance review which follows established TransTech Ltd procedures. The information and results presented herein constitute an accurate representation of the data collected.

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1. EXECUTIVE SUMMARY

This report contains an assessment of equilibrium concentration enhancement (ECE) for nitrogen for the modification of Loch Duart Ltd's Caolas Loch Portain pen site on Loch Portain from 14 x 80 m circumference circular pens to 12 x 100 m circumference circular pens.

Along with the change to the equipment production at the site will increase from a maximum standing biomass of 1,060 tonnes to 1,720 tonnes. The proposal is to decommission Loch Duart's, Ferramus site should the modification to the Caolas Loch Portain site be consented. This will result in an overall decrease of 10 tonnes in the maximum biomass in the Lochmaddy Production Area. Nevertheless, Ferramus has been included in the calculations as it is currently an active site.

The calculations reported within this document indicate that the proposed increase in biomass at the Caolas Loch Portain site is not predicted to significantly change the nutrient enhancement index of the Lochmaddy water body i.e., enhancement will rise from a maximum of 0.23 to 0.31 µmol N l^{-1} which, although borderline, remains close to the 0.3 µmol N l^{-1} upper limit of index 1. Thus, only marginal change to the water body's nutrient enhancement index is predicted.

The water body is predicted to remain within OSPAR and UKTAG threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account as the ECE value for Caolas Loch Portain and Ferramus is estimated to be a maximum of 2.6% of the background level for coastal waters.

2. INTRODUCTION

The Lochmaddy production area, which includes Loch Portain, is not catergorised in the Locational Guidelines for the Authorisation of Marine Fish Farms in Scottish Waters[1]. As Loch Duart will increase the biomass at the Caolas pen site there is a requirement for additional supporting information on the resulting increase in nutrient loading.

Within the Lochmaddy production area there are two CAR licenced seawater finfish farms i.e., the subject Caolas Loch Portain site and Ferramus (figure 1), albeit the latter will be decommissioned should the modification to the Caolas Loch Portain site be consented. However, Ferramus has been included in the calculations as it is currently an active site.

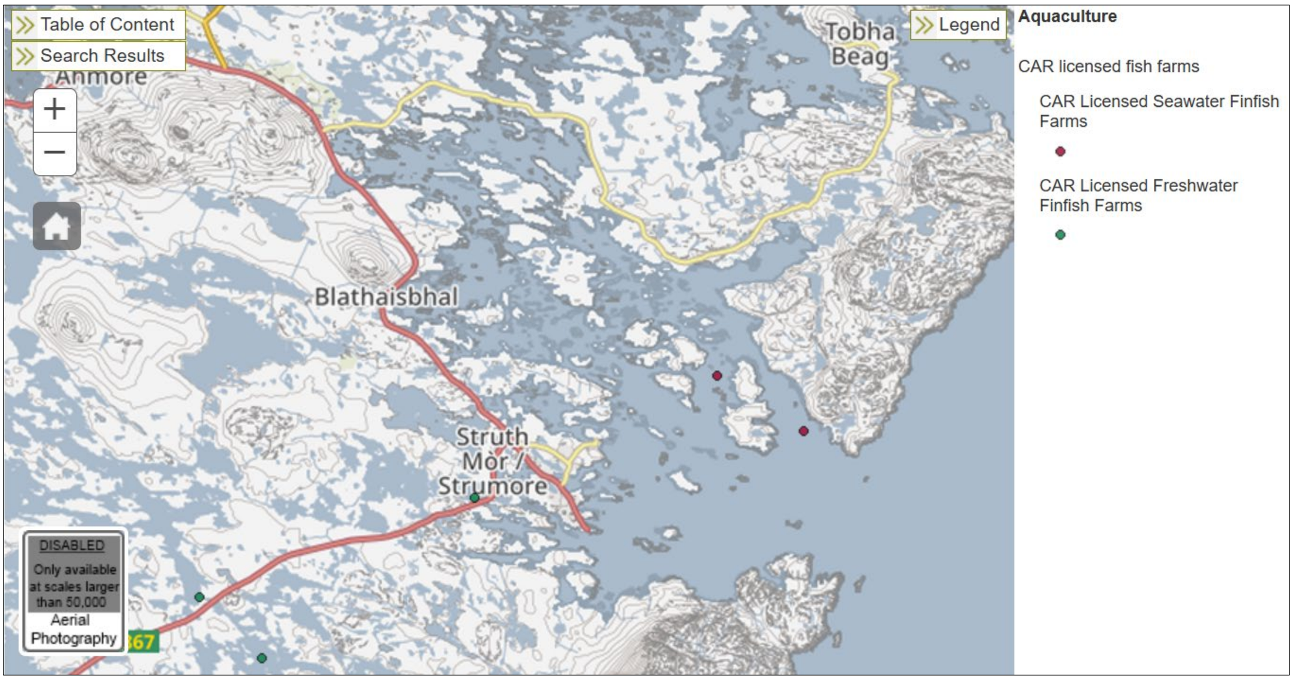


Figure 1. CAR licenced seawater finfish farms within the Lochmaddy production area.
(Source: http://aquaculture.scotland.gov.uk/map/map.aspx)

Table 1. CAR licenced seawater finfish farms within the study area.
(Source: http://aquaculture.scotland.gov.uk/map/map.aspx)

#	Farm name	Operator	Active Licence No.
1	Caolas Loch Portain	Loch Duart	CAR/L/1002994
2	Ferramus	Loch Duart	CAR/L/1003024

3. NUTRIENT ENHANCEMENT CALCULATIONS

Nutrient enhancement calculations were carried out for the modified Caolas Loch Portain and the Ferramus sites by applying the same methodology as that used by Marine Scotland Science in their Locational Guidelines(1) for other sea lochs.

Through the discharge of nutrients and chemicals, finfish production may have adverse, though currently poorly understood, effects on the plankton and bacterial populations of sea lochs and coastal waters.

Farmed salmonids excrete soluble nitrogen (in the form of ammonia) into the water column as a by-product of metabolism. The quantity emitted by each fish varies due to a number of factors, including food composition, fish age and size, and water temperature. The total quantity of ammonia emitted from a finfish farm then depends on the level of production and the stage of the production cycle. In order to estimate correctly the effects of nutrient emissions on the local ecosystem, it is imperative to have an accurate assessment of the quantities of nutrients being released.

To determine the enhancement of dissolved nitrogen above background levels within the Lochmaddy production area a box model was used.

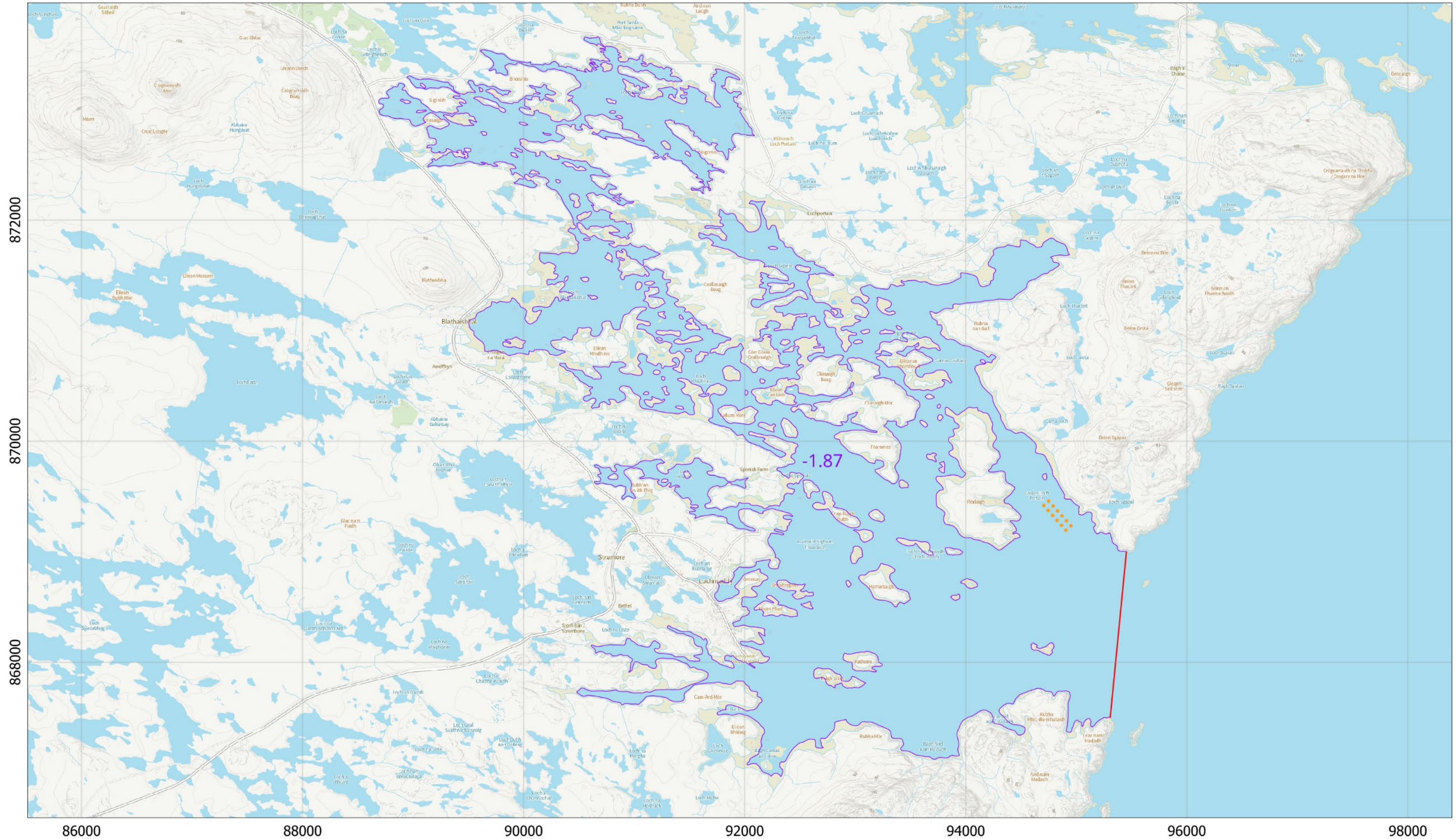
3.1. Loch area and volume

The area and volume of Lochmaddy is not listed in the Locational Guidelines(1), the Scottish Sea Lochs Catalogue(2) or, as far as we can determine, any other source.

Therefore, to derive area, the Mean Low Water Springs (MLWS) contour was obtained from Ordnance Survey OS Terrain® 50 data (https://osdatahub.os.uk/downloads/open/Terrain50), see figure 2. This lies at -1.87 m Ordnance Datum Newlyn (ODN) which when converted to Chart Datum (CD) is 0.72 m above CD. This is calculated by subtracting -1.87 m from 2.59 m which is the ODN conversion for Lochmaddy(3).

To determine volume, an OceanWise MT Digital Elevation Model (DEM) to 1-arc second resolution tiles was purchased from the Emapsite (https://marine.emapsite.com/landing-page?guid=8c2483f4-b924-437c-b8db-2ec9f861b529) and clipped in GIS to lie within the extents of the surface water area.

However, as shown in figure 3, bathymetric data does not exist for much of the water body. Indeed, when investigating other sources of data, that from OceanWise appears to be the best available. Thus, to derive a volume for the water body the area within the MLWS contour that contains depth measurements was delineated. This is 10,131,395 m^2 and the remaining un-surveyed area within the MLWS contour is 2,941,141 m^2 (see figure 4)



Legend

- Proposed Circular Pens
- MLWS Contour
- Study Area Boundary Line

Drawing Title:	MLWS Contour West Of Entrance To Study Area
Drawing No:	CLP-0524-1
Drawn By:	[redacted]
Date:	01/05/2024

0 500 1,000 1,500 2,000 m

Scale 1 : 45,000 @ A4

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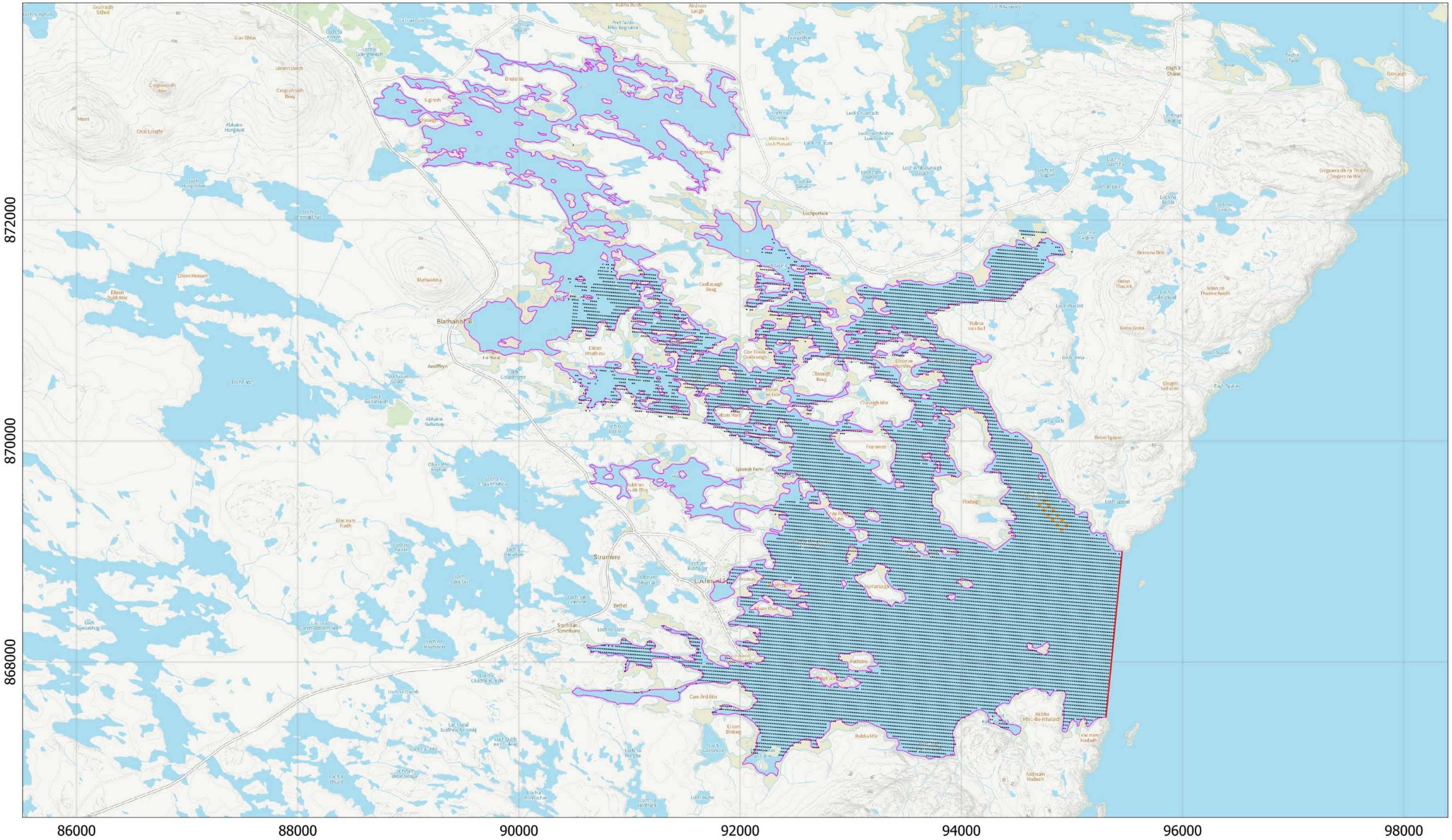
Figure 2. MLWS contour within study area.



Legend

- Proposed Circular Pens
- MLWS Contour
- Study Area Boundary Line
- DEM Depths Below MLWS

Drawing Title: Surveyed Depth Within Loch Maddy Surface Water Area

Drawing No: CLP-0524-2

Drawn By: [redacted]

Date: 01/05/2024

0 500 1,000 1,500 2,000 m

Scale 1 : 45,000 @ A4

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Figure 3. Depth locations within the study area.

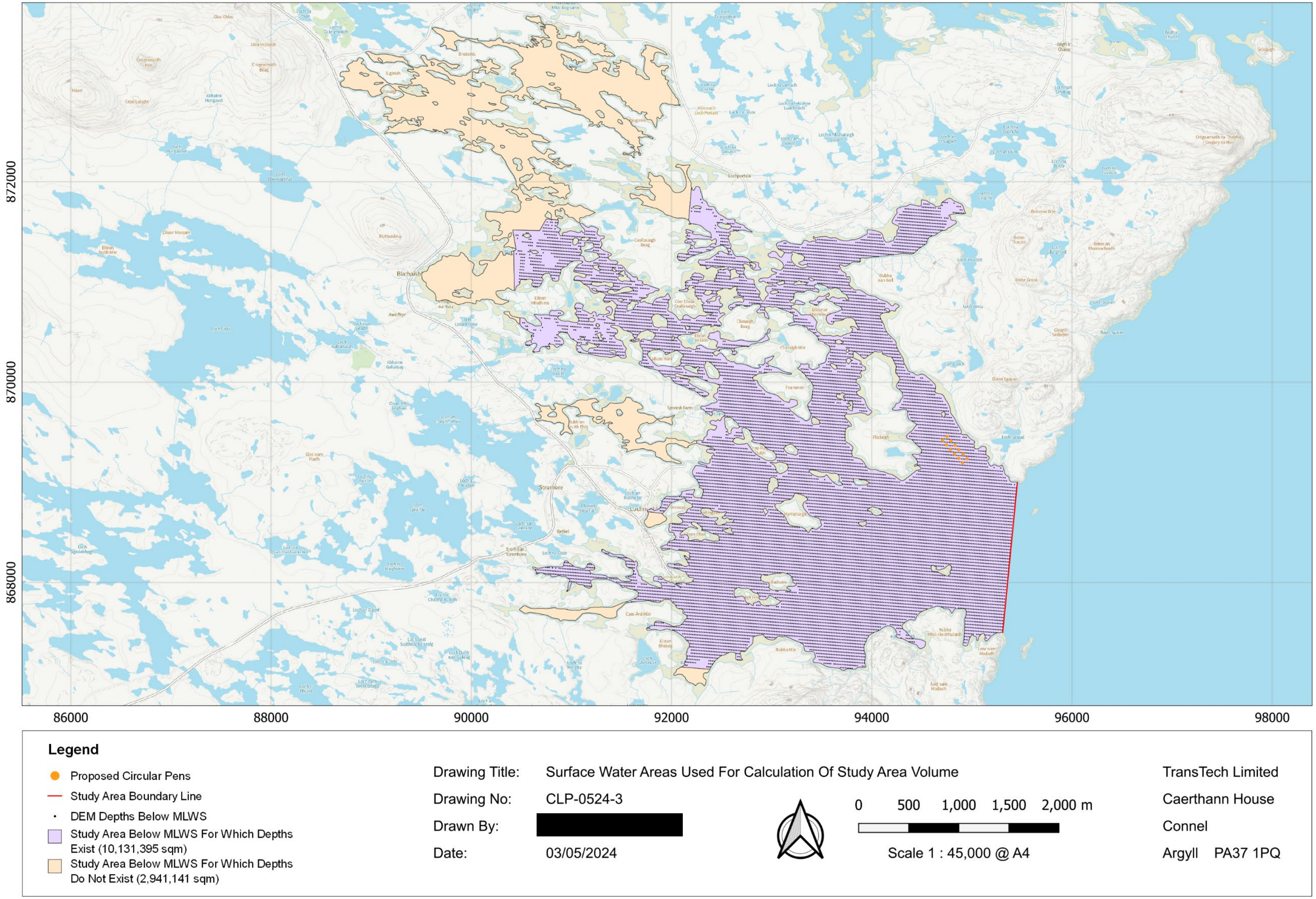

Figure 4. Surface water areas used in the calculation of volume.

3.1.1. Volume within study area that has depth soundings

GIS was used to clip all DEM depths below 0.72 m above CD i.e., those within the MLWS contour. Within this area there are 17,245 depth readings. Average depth was determined from the attribute table for the depths. This is 9.33747 m and multiplying this by 10,131,395 m^2 gives a volume of 94,601,597 m^3.

3.1.2. Volume within study area that does not have depth soundings

Given that average depth below MLWS within the remaining un-surveyed area is unknown, what is deemed to be a conservatively low value of 2 m was applied. Thus, for the un-surveyed area (2,941,141 m^2) the volume is 5,882,282 m^3. It should be noted here that it is water body area rather than volume that affects the ECE value.

3.1.3. Total volume of study area

Adding 94,601,597 m^3 to 5,882,282 m^3 gives a volume for the whole study area of 100,483,879 m^3.

3.2. Calculation of flushing time and flushing rate

(source: http://www.scotland.gov.uk/Uploads/Documents/Report63.pdf)

The predominant exchange mechanism is assumed to be the semi-diurnal tide. The flushing time of the study area can be calculated by assuming that the water volume is replaced by the volume of water entering and leaving on each tide (the “tidal prism”, see Gillibrand *et al*, 2002[4]) giving:

$$\mathrm{TF} = \frac{0.52 * \mathrm{V}}{0.7 * \mathrm{A} * \mathrm{R}}$$

Where:

TF is the Flushing Time (days)
V is the volume of the marine system basin (m^3)
A is the surface area of the marine system (m^2)
R is the spring tidal range (m)

The factor 0.52 is the number of days per tidal cycle (1 tidal cycle = 12.4 hours = 0.52 days), and the factor 0.7 approximates the mean tidal range from the spring tidal range (see Gillibrand *et al*, 2002[4]).

Using the above equation TF for the study area was calculated as follows:

A = 13,072,536 m^2	(MLWS area derived as per the methodology described in §3.1)
V = 100,483,879 m^3	(MLWS volume derived as per the methodology described in §3.1)
R = 4.08 m	(Tidal range between the MLWS (-1.87 m) and MHWS (2.21 m) OS contours)

Calculation:

$$\mathrm{TF} = \frac{0.52 * 100{,}483{,}879}{0.7 * 13{,}072{,}536 * 4.08}$$

= 1.399528304 days

The tidal prism method of calculating flushing times is known to overestimate the exchange of water and therefore under predict the flushing time[4, 5, 6]. The exchange rate of sea lochs, voes and bays can also be affected by wind strength and direction, and fluctuations in river flow. However, these variations are difficult to predict and vary from system to system. Tidal exchange is a steady and persistent process, not subject to meteorological fluctuations, and therefore forms the core exchange mechanism of these systems. The tidal prism method, therefore, while not complete, forms the best available method for estimating the flushing of marine systems.

The nutrient enhancement is strongly dependent on the flushing rate, Q ($m^3\ y^{-1}$), of the marine system, which is given by:

$$Q = \frac{365 * V}{TF}$$

where the factor 365 converts the units from $m^3\ d^{-1}$ to $m^3\ y^{-1}$. The flushing rate, then, is the total quantity of water that is exchanged over a year.

Calculation:

$$Q = \frac{365 * 100{,}483{,}879}{1.399528304}$$

$$= 26{,}206{,}412{,}361\ m^3\ y^{-1}$$

3.3. Nutrient model parameters and calculated equilibrium concentration enhancement for current and proposed maximum biomass

The maximum biomass that could be held within the Lochmaddy production area pre and post modification of the Caolas Loch Portain site is 1,730 tonnes and 2,390 tonnes respectively, albeit Ferramus will be decommissioned should the modification to the Caolas Loch Portain site be consented. A breakdown of these figures is provided in table 2.

Table 2. Maximum biomass at each farm within study area (current and proposed*).

#	Farm name	CURRENT Maximum biomass (tonnes)	PROPOSED* Maximum biomass (tonnes)	PROPOSED** Maximum biomass (tonnes)
1	Caolas Loch Portain	1,060	1,720	1,720
2	Ferramus	670	670	0
	TOTALS:	**1,730**	**2,390**	**1,720**

Notes for table 2:

* This includes Ferramus which will be decommissioned post consent of the modification to Caolas Loch Portain.
** This excludes Ferramus post consent of the modification to Caolas Loch Portain.

The parameters required by the model were defined as follows (table 3):

Table 3. Model parameters.

Parameter	CURRENT	PROPOSED (including Ferramus)	PROPOSED (excluding Ferramus)
M (Tonnes)	1,730	2,390	1,720
S (kgN/T/year)	48.2*		
Q (m^3/year)	26,206,412,361		
ECE (kg N m^{-3})	3.18189×10^{-6}	4.39579×10^{-6}	3.16350×10^{-6}
ECE (μmol N l^{-1})	0.23	0.31	0.23

Notes for table 3:

* This value has been obtained from Gillibrand *et al*, 2002(4) and assumes a feed wastage of 5%, 90% digestibility of the diet and a mean feed nitrogen content of 7.2% (wet weight). The figures were derived in 2002. Feed wastage and digestibility has improved since the Gillibrand *et al* study was undertaken and due to advances in the composition of fish

feeds the nitrogen content has reduced from a mean of 7.2% to a current mean of approximately 6.5%. The nitrogen enhancement calculated above is therefore likely to overestimate what will occur in reality.

To be robust we have also performed the calculations for the 10,131,395 m^2 area of the loch (94,601,597 m^3 volume) within which there are depth soundings. These are given in table 4.

Table 4. Model parameters.

Parameter	CURRENT	PROPOSED (including Ferramus)	PROPOSED (excluding Ferramus)
M (Tonnes)	1,730	2,390	1,720
S (kgN/T/year)	48.2		
Q (m^3/year)	20,310,329,623		
ECE (kg N m^{-3})	4.10560×10^{-6}	5.67189×10^{-6}	4.08186×10^{-6}
ECE (µmol N l^{-1})	0.29	0.40	0.29

The above calculations reveal that the enhancement of dissolved nitrogen above background levels as a result of the current finfish farming operations is currently 0.23 to 0.29 µmol N l^{-1} for the whole study area and that which only has depth soundings respectively.

For the modified Caolas Loch Portain site there will be an overall increase in maximum biomass of 660.0 tonnes, albeit Ferramus will be decommissioned post consent of modification to the Caolas Loch Portain site. For the 660.0 tonnes increase in maximum biomass ECE is predicted to rise slightly from 0.31 to 0.40 µmol N l^{-1} for the whole study area and that which only has depth soundings respectively.

The index of nutrient enhancement using the model described by Marine Scotland Science is given in table 5.

The results of this assessment for Lochmaddy (i.e., the whole study area) indicate that it is currently within nutrient enhancement index 1 and the development proposal will cause it to marginally move into index 2 (i.e., a rise from 0.23 to 0.31 µmol N l^{-1}). The volume of the study area that contains depth soundings has a nutrient enhancement index that is marginally below 2 i.e., 0.29 µmol N l^{-1}) and the proposal will also fall within nutrient enhancement index 2 (i.e., 0.40 µmol N l^{-1}).

Table 5. Index of nutrient enhancement.

Predicted ECE for nitrogenous nutrients arising from finfish farming (µmol l^{-1})	Nutrient enhancement index
> 10	5
3 – 10	4
1 – 3	3
0.3 – 1	2
<0.3	1
0	0

Thus, the rise in ECE from the proposal (including Ferramus) causes a borderline change in the nutrient enhancement index categorisation.

4. NITROGEN INPUT ASSESSMENT AGAINST OSPAR & UKTAG THRESHOLD LEVEL

In Scottish sea lochs, voes and bays, under most conditions, algal growth is limited by dissolved nitrogen availability and the influence of phosphorus can safely be discounted[(7)].

Nitrogen inputs are assessed against OSPAR and UKTAG background levels. The calculated ECE from all fish farms in the water body is then added onto the background level for that water body and the result is then assessed as to whether it breaches the threshold, which is 50% above the background value (i.e., 252 µg N l^{-1}).

The enhancement of dissolved nitrogen above the background level as a result of the Ferramus and proposed Caolas Loch Portain finfish farming operations within the whole study area is predicted to be a maximum of 0.31 µmol N l^{-1} (4.40 µg N l^{-1}).

The background value for coastal waters is 168 µg N l^{-1}, adding the calculated ECE onto this value gives 172.4 µg N l^{-1}, which is below the 252 µg N l^{-1} threshold.

The ECE value does not account for nitrification and other removal mechanisms but is a maximum of 2.6% of the 168 µg N l^{-1} background level. This means that the study area will comfortably remain within threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account.

It is therefore concluded that nutrient enrichment associated with the increase in biomass at the Caolas Loch Portain site is unlikely to make a significant contribution to nutrient enhancement and consequently primary productivity.

5. MITIGATION

The particulate component of waste from finfish farms includes both uneaten feed and faeces. Fish feed is expensive, and it is therefore in Loch Duart's best interests to minimise waste. Feed wastage will be optimised by feeding fish to 80% satiation and monitored daily by surface appetite scoring. By optimising feeding less nitrogen derived from pellet waste will enter the water column.

6. CONCLUSIONS

In terms of the Locational Guidelines[(1)] the loch is unclassified.

The modification of the Caolas Loch Portain site, when Ferramus is included, in an overall increase in maximum biomass of 660 tonnes within the study area.

The modification is not predicted to significantly change the nutrient enhancement index of the Lochmaddy water body i.e., enhancement will rise from a maximum of 0.23 to 0.31 µmol N l^{-1} which, although borderline, remains close to the 0.3 µmol N l^{-1} upper limit of index 1. Thus, only marginal change to the water body's nutrient enhancement index is predicted.

The water body will also remain within OSPAR and UKTAG threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account as the ECE value is predicted to be a maximum of 2.6% of the background level for coastal waters.

REFERENCES

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