McCann FitzGerald
Solicitors
Riverside One
Sir John Rogerson's Quay
Dublin 2
D02 X576
Tel: +353-1-829 0000
Fax: +353-1-829 0010
Email: inquiries@mccannfitzgerald.com
Dx 31 Dublin
www.mccannfitzgerald.com

McCANN FITZGERALD

OUR REF	YOUR REF	DATE
RJB\25085778.1	NR	16 January 2017

Ms. Noeleen Roche
Environmental Licensing Programme
Environmental Protection Agency
P.O. Box 3000
Johnstown Castle Estate
Wexford

DaS Permit Application S0028-01 Dumping at Sea of Dredgings from Smooth Point, Killybegs Harbour Centre by Department of Agriculture, Food & Marine (the "Application")

Public notices published on 15 December 2016 and on 17 December 2016

Dear Ms Roche

We act on behalf of Gallagher Brothers (Fish Merchants) Limited and Ocean Farm Limited, on whose behalf we submit the following observations and concerns in respect of the submission of the Application for the Disposal at Sea of Dredging Spoil from works related to the proposed pier extension at Smooth Point, on the new pier at Killybegs Fishery Harbour Centre dated November 2016 by Doran Consulting on behalf of the Minister for Agriculture, Food & Marine.

Our clients are a major fish processing enterprise located in Killybegs and Teelin and also have significant marine caged fish rearing installations in McSwynes Bay and Inver Bay, Killybegs County Donegal.

Whilst our clients welcome development in the Killybegs Harbour, they are extremely concerned at the proposed location of the Dumping at Sea site A, in light of the loss in 2003 of 850,000 salmon in their business and the damage to other similar businesses in the area. As a result of those events, our clients are no longer able to acquire insurance for their fish. Their bank is also concerned about the risk posed to our clients' business by the proposed dumping at site A.

Our clients submit that there is considerable credible evidence that the 2002-2003 dredging activities in the harbour, and in particular the dumping at sea at site A in 2002, caused these losses.

Although our clients note that the applicant proposes that mainly class 1 material would be dumped, the Application asserts that a wide redistribution of fine fractions will not occur and that in any case those fractions will not impact sensitive receptors in the bay such as caged fish. We set out below considerations which cast doubt on that.

Our clients urge, on the basis of the irreducible uncertainty about the cause of the 2003 fish losses, the potential for catastrophe and the precautionary principle, that the site for the proposed dump be west of site C as identified in the Application (or indeed be taken onshore), rather than at site A or site B.

The 2003 fish kill

Our clients and their advisors have reviewed the report of Doran Consulting dated May 2016 on the investigations into salmon mortalities in Donegal Bay 2003, which has been filed with the Application. Our clients dispute the reported assertions that the risk of a connection between the 2002 dumping and the 2003 fish kill was "extremely remote" or was "in no way related". Our clients submit that while the immediate cause of the fish kills could not be proven after the fact, there was credible evidence that local re-deposition and movement of turbid water masses containing fine silts and clays after the dredging dump at site A was implicated in the deaths.

After the fish kill in 2003, our clients and many other local fishing and shell fishing and crustacean enterprises supplied sworn affidavits of the widespread presence and coating of gear with fine fraction sediments for an extended period up to the time of the fish deaths. We can give you copies of this evidence if required.

We are instructed that similar kills depositions of fine sediment and resulting kills had never occurred in the preceding 15 or so years since salmon farms were established in the area, and none have occurred since the 2003 events.

The fish kill in 2003 was accompanied by similar extensive deaths of conger eel and decapods and other species in the Donegal Bay area with the common characteristic that the locations, cages and pots were covered in fine sediment.

The Marine Institute investigation at the time discounted the involvement of sediment from the dredge spoil. That conclusion was based on a statement that they did not know how the fine deposits could have been transported by resuspension from the dump site to the cage areas in McSwyne's Bay and Inver.

It is worth noting, however, references to deposition, distribution and resuspension of fine sediments in the Application which includes the Aquafact Post Dumping Monitoring Report. These show that in the year following the dumping, an increase of between 50-100% occurred in the presence of the fine sub 63-micron fraction over a wide area surrounding the dump site.

The Marine Institute suggested at the time that the fish kills may have been due to other factors. Our client commissioned experts from the University of Sterling to examine the cause or causes of these events. Those experts concluded that (1) fish died from an acute gill effect related to a water quality incident; (2) there was no persuasive evidence that algal bloom, siphonophore swarm or poor husbandry caused the fish kill; (3) there was evidence of dispersal of sludge from the dumpsite and a mechanism for flow in an E-NE direction towards the fish farms; and (4) the analysis of the sludge on nets suggested a link to Killybegs Harbour. The experts concluded that there were grounds to conclude that dispersal from the disposal site A coupled with upwelling were implicated in the cause of fish kill. We **enclose** a copy of a report by Professor Richards and Dr Telfer dated 26 November 2006 which set out these conclusions.

Subsequent investigations did not establish sufficient evidence to show, on the legal test of balance of probabilities, that such dispersal and transport of the dredged materials was the likely cause of the fish deaths.

However, whilst the cause or causes of the fish deaths in 2003 have never been established, our clients submit that the circumstantial evidence shows, at minimum, that the dumped material at site A could not be ruled out as a cause of the deaths.

The Application

Our clients welcome many aspects of the proposals of the Application for a Dumping at Sea permit for this development including the maximisation of reuse of the dredge spoil where economically feasible and the decision to exclude the dumping of the top 750mm of the dredge area and confining the material to be dumped to Class 1 material only. These all contribute to minimising chemical toxicity risks in the receiving environment and lessening the redistribution of some highly enriched and organically contaminated material at the same time. However, these modified proposals still involve: -

- The nomination of Site A as the dump site;
- Only consider chemical characterisation of the sediments as the sole determinant of toxic potential;
- Do not consider biological hazards or leachate potential;
- Assume that a wide redistribution of fine fractions will not occur and that in any case those fractions will not impact on caged fish or other sensitive receptors in the bay;
- Do not specifically address the sedimentation rate and re-distribution potential of a declared peat fraction within the fine fraction;
- Do not consider other ongoing mechanisms of fine sediment remobilisation other than wave, wind, and storm action, such as trawling.

Our clients' concern is about the repeated nomination of Site A as the dredging dump site. Our clients submit that reliance on the TELEMAC 3D model as the sole assessment criterion is flawed, based on the evidence of the mobility of those fine fractions in 2002-2003. Worryingly, the data provided in the granulometry for the Application states that the sub 63-micron fraction additively will comprise up to 60 % of the dumped dredge material and that an unquantified fraction of that will be organic peat fraction. It is also noted in the SPI penetration tests and other tests that an anomalous low redox is recorded in some of those areas. Our clients cannot ascertain from the Application if specific regard has been had to the percentage of the peat fraction and if a specific separate measured sedimentation rate was used in the model.

Our clients submit that an additional factor that is not considered in the Application is the continuing disturbance of and remobilisation of those finer fractions and that the entire area is subject to bottom trawling.

Aquafact appear to have been supplied with information to the effect that only a small muddy patch south east of St John's Point is trawled as a prawning ground. We are instructed that in fact the entire area is used for fishing and that the ground gear at trawling speeds would significantly disturb and re-suspend those finer fractions.

Based on subsequent work under the OSPAR convention, and the significant alteration of the recommended assessment criteria developed by OSPAR, particularly under the JAMP Study 2009, our clients submit that focusing mainly on toxic compounds such as heavy metals and TBT and derivatives, and based on concentration alone (which was the regulatory approach in 2003), is insufficient to assess the impact of dredging spoil disposal. Our clients submit that other factors such as toxicity mass loading, silt load, turbidity, particle size angularity, entrainment of anaerobic sediments and bacterial and viral burden are all cumulative factors to be considered.

Our clients therefore request that the Agency, in examining the proposed dredging disposal application for this development, look at the other likely significant impacts that can occur from the aspects cited in this submission and to take these into consideration when considering the obvious lessening of risk by specification of the dump site further off-shore.

Presumably the Agency will carry out its assessment of the likely significant effects on the environment (including any Natura 2000 sites) which forms part of the wider development of Killybegs Harbour and which we understand is subject to an on-going application for planning permission. Our client urges you to take account of all of the potential impacts (direct, indirect and cumulative) from this development, which includes impacts to not only our clients and other businesses but potentially to the wider marine habitat.

Minimisation of risk

For all of the above reasons, our clients' main contention is that based on the previous experience, the irreducible risk of a catastrophe and the proper application of the precautionary principle, only a dump site at least at Site C and preferably to the West of Site C where oceanic dispersal can occur, or on-shore disposal, should be authorised. This is necessary as Site B remains within the bay area where trawling occurs.

Our clients have noted the cost differentials quoted for nominating disposal sites at Sites B and C versus Site A. As they have no means of verifying these costs, or understanding the basis of the differentials, they can only observe that whilst the quoted cost of changing the dump site from Site A to B seems credible, the differential from Site A to Site C seems excessive even if a doubling of split bottomed barge is required. In any case, these costs are marginal in the overall project cost versus on-shore alternatives and the potential impacts on jobs and loss of business that our clients and others experienced in 2002-2003.

Our clients submit that while the nomination of a dump site westwards at Site C or further west would entail additional costs, such as an additional split bottomed barge to compensate for steaming distance to maintain a 28 day programme, costs would be saved by a reduction in the level and nature of monitoring required and post dumping surveillance that would be required for such a less risky location.

Appropriate supervision and suitable monitoring clauses will of course be necessary even if the dredging application is granted on the basis of dumping west of site C, to ensure that an adequate baseline is established and contemporaneous with dredging spoil dumping and post dumping, that measurements are taken of relevant parameters.

Our clients are very concerned that in accordance with the DaS Permit Flowchart provided by the Agency the time limit for being notified and then preparing a technical submission on any application is exceptionally short. In their respectful view this, and the cost for third parties of investigating the complex issues, requires the Agency to ensure that any concerns indicated in advance or during the notification period are fully inquired into by the Agency.

If you require any further information or clarification on any of the points raised, please do not hesitate to ask.

Yours faithfully

McCann FitzGerald

McCann FitzGerald

A REVIEW OF THE ENVIRONMENTAL INFORMATION COLLECTED WITH REGARD TO SALMON MORTALITIES AT INVER BAY AND Mc SWYNE'S BAY FINFISH FARMS DURING 2003

A report by: Professor Randolph H Richards, *MA, VetMB, PhD, MRCVS, FI Biol, FRSM, FRAgS*
&
Dr Trevor C Telfer, *BSc, PhD, CBiol. MIBiol. MIEEM*

Address: Institute of Aquaculture
University of Stirling
Stirling, UK.
FK13 4LA

Date: 25 November 2006

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1. INTRODUCTION

1.1 Preamble

This report was commissioned by Sunderland Marine Ltd to review the available environmental and histopathological information and to comment on likely causes of a major mortality of farmed salmon within Donegal Bay (Inver and McSwynes Bays) in July 2003.

This review is based on data, and reports compiled largely by consultants and marine scientists of the DCMNR, Ireland. In addition, anecdotal information, based on eyewitness accounts of events, is used. Consultants have been employed by both the DCMNR, the fish farmers of Donegal Bay and Sunderland Marine Ltd. Much of the data presented and reviewed in this report was collected during and within a few months after the mortality incident, as a commissioned review or compilation of collected data. The power and relevance of this data will be discussed individually.

There is a paucity of raw data available for review, with most of this data being interpreted by others or part of an overview report. To a large extent it has not been possible to obtain these raw data or the original reports in which it is contained. This is important, as it would have provided the opportunity for a re-analysis of the original data help address apparent anomalies in the compiled reports. This review encompasses information presented by 35 - 40 reports, statements and written anecdotal information, whereas over 60 reports have been written in association with the sludge dumping from Killybegs Harbour and its longer terms effects (Costello, pers. comm.). It is clear therefore that this review can only be based on the information made available to the authors.

1.2 The fish farms and fish mortalities

Fish farming in Donegal Bay is concentrated in inner McSwynes Bay, and close by Inver Bay. Both are near to the town of Killybegs. Three companies operate fish farms within these bays, Ocean Farms Ltd in both McSwynes and Inver Bays and Eany Fish Products and Creevin Salmon Farms in Inver Bay (see Figure 1.1). All of these farms were affected by the salmon mortalities and have ascribed this to an environmental impact (see Table 1.1). All fish farms have provided information in the form of records and statements on the series of events and observations during the fish kill events.

In addition, there are shellfish farms (primarily mussels), within Inver Bay. Though these farmers were consulted, they added little information to the overall debate. It is clear that any implications of poor water quality within the area (no matter what the reason) could influence markets for the mussels.

There is considerable debate, at present, as to whether the fish mortalities were associated with the dumping of metal- and fish (?) oil-enriched sediments from Killybegs Harbour. These sediments were dredged from Killybegs Harbour, in 2002, and dumped at a site approx 15 km southwest from McSwynes Bay and 20 km from Inver Bay fish farms (see Figure 1.2).

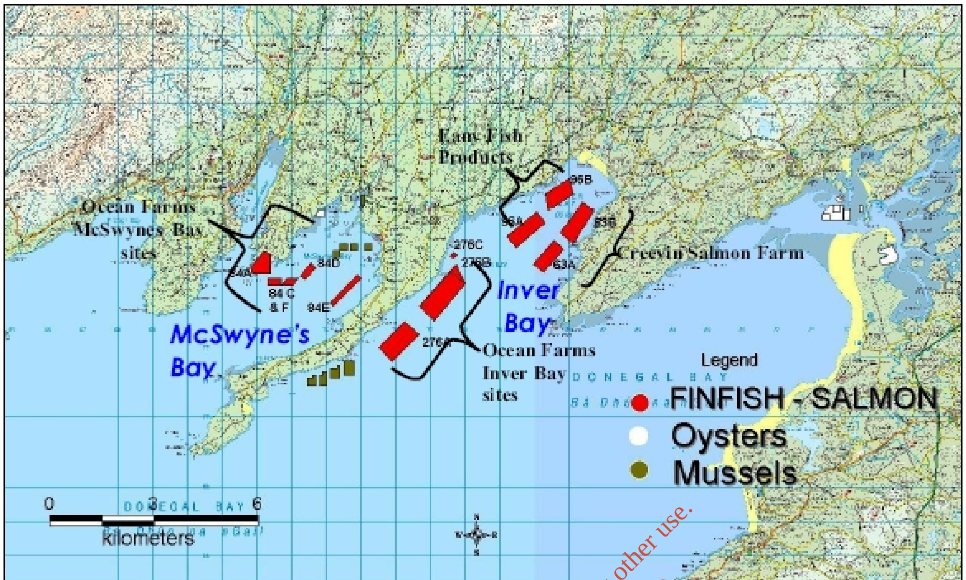

Figure 1.1 Fish farming areas in Donegal Bay (after Cronin et al, 2004).

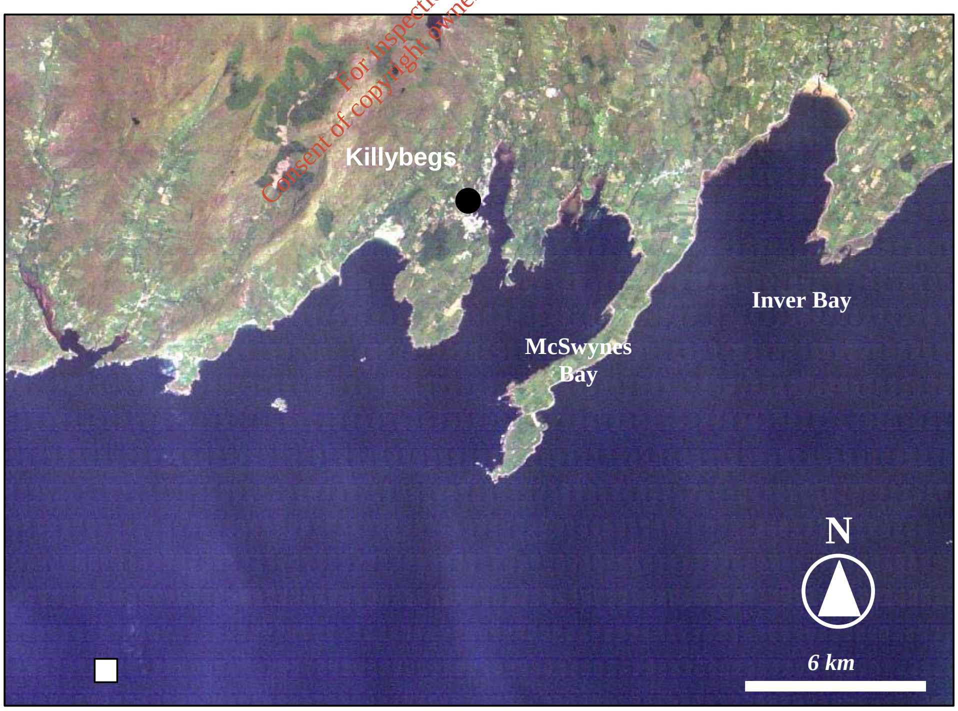

Figure 1.2 Approximate position of dumping site of spoil from Killybegs Harbour. Approximate position of the sludge-dumping site (□).

Table 1.1 shows the numbers of mortalities of both growers and smolts, which are considerably higher in Inver Bay than McSwynes Bay. The pattern of mortalities in the adult fish at the "grower" sites is shown in Figure 1.3 for both Inver and McSwynes Bay (data provided by Ocean Farms Ltd.). These data show the onset of fish mortality in week 26/27 for both sites (last week on June/first week in July) reaching their peak in week 29 in Inver Bay and week 32 in McSwynes Bay.

Table 1.1 Mortalities reported by each fish farm company to 11/09/2003 (*) and to 04/11/2003 (Cronin et al, 2004)

Farm	Smolts		Growers	
	Pre-event standing stock	% loss	Pre-event standing stock	% loss
Ocean Farm - Inver	483019	94	323172	73
Ocean Farm – McSwynes	665545	23	479982	24
Eany Fish Prducts	262000	86*	11000	71*
Creevin Fish Farm	233000	94*	180000	76*

The fish farmer has divided the mortality records into various headings. At Inver Bay the majority of the mortalities are attributed to "Environmental Factors". These occur largely between weeks 26 and 33. In McSwynes Bay there is a significant mortality event(s) towards the beginning of the year (weeks 1 to 15), which has been attributed to largely unspecified causes but also to losses (weeks 1 to 9), PD (Pancreatic Disease - weeks 10 to 12), and SDS (Sudden Death Syndrome - weeks 14 and 15). Initially the mortalities after week 28 are attributed to unspecific causes or "old" fish, whereas it was not until week 32 that the mortalities were attributed to environmental factors.

The reason for the mortalities of the fish was clearly due to severe gill damage with, in many fish, associated liver damage. The rapid onset of the mortality has been attributed to a toxic incident caused either by pollution or another environmental vector (McLoughlin, 2004; Branson, 2004). Bacterial and viral vectors were ruled out following analysis of fish samples (16th July 2003) (Branson, in KMM, 2004).

Alternatively, observations of environmental conditions at the time of the mortalities made by fish farmers, found that there was a considerable presence of suspended solid material within the waters of McSwynes and Inver Bays, and this manifest itself by the collection of "oily" black particulate material adhering to the fishnets at Ocean Farms Ltd's Inver Bay fish farms. The sediments had a very distinct hydrogen sulphide (H_2S) smell and had slightly elevated levels of heavy metals (Cu, Zn and Cd). Visually, this substance was similar in nature to the muds within Killybegs Harbour before removal, which were enriched with fish oils due to effluent from adjacent fish processing facilities.

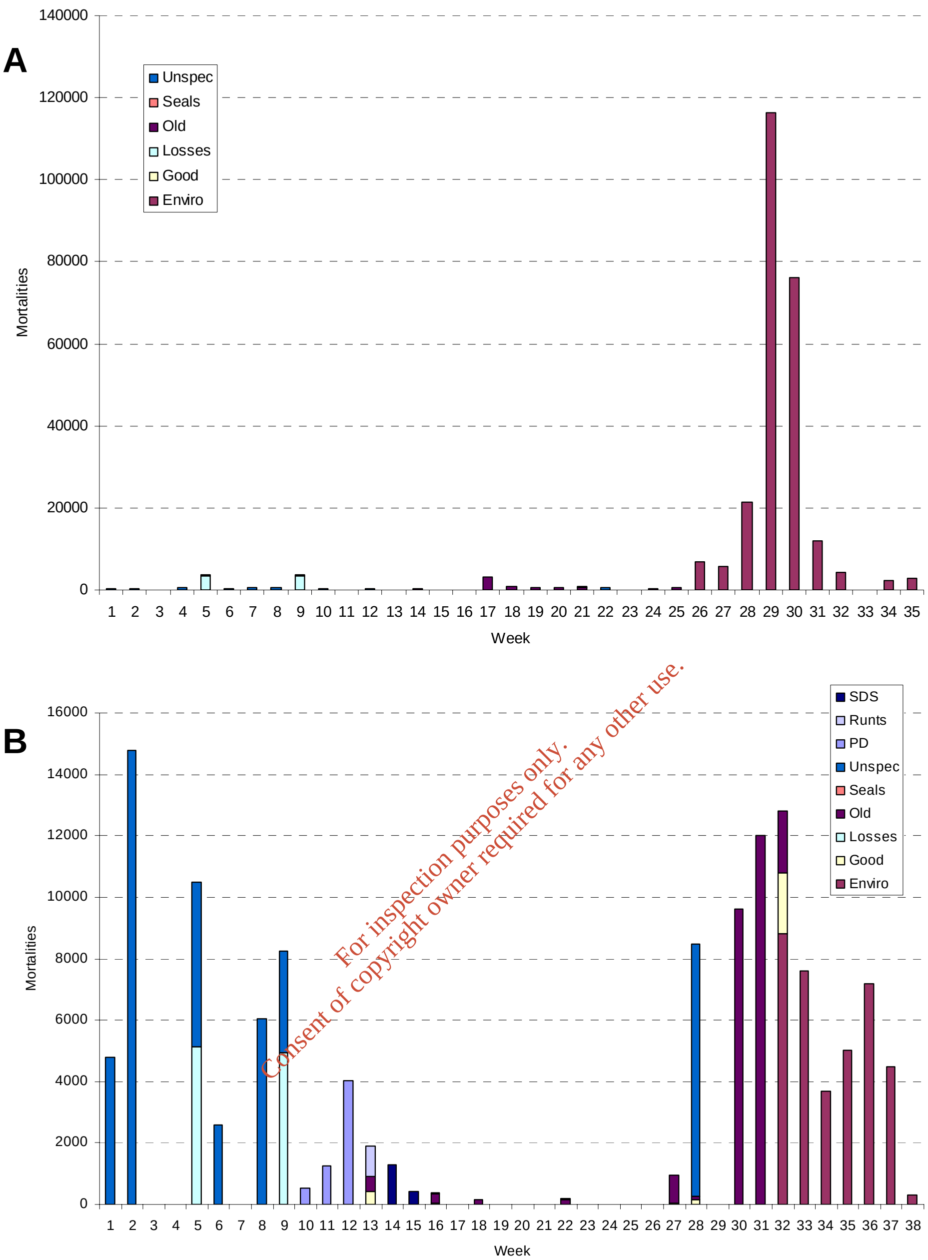

Figure 1.3 Mortality of grower fish in Inver Bay (A) and McSwynes Bay (B)

In light of the evidence and information provided in the various reports (see Cronin *et al*, 2004), several scenarios are postulated for these mortalities:

- Fish pathogens
- Husbandry practices
- Discharge of toxic chemicals including misuse of veterinary medicines
- Contamination of sediments from Killybegs dredge spoil dumping site
- Other environmental factors in the locality

- Sediment disturbance resulting in release of toxicants from the benthic environment
- Biotoxins or irritation through a algal bloom
- Jellyfish/siphonophore bloom

The Marine Institute report concludes that the most likely cause of the mortalities during July 2003 was due to jellyfish/siphonophore interaction with the fish. This conclusion was made through discounting the other potential causes rather than direct evidence.

2. THE PHYSICAL ENVIRONMENT

The physical environment can be characterised by environmental surveys, several of which have been done in the dumping area and within McSwynes and Inver Bays. These surveys consist of hydrographic (current flow) studies using current meters and drogues, and sediment surveys of both at the sediment type and biology. Results from these can be used to characterise water flow and the physical nature of the seabed environment. Surveys were undertaken from before the period of dredge spoil dumping in 2002 and immediately after the mortality incident (July, Sept and Oct, 2003). In addition, other physical phenomena, such as an upwelling event, have the potential for incursion of water flow towards the fish cages within the bay.

2.1 Hydrographic surveys and characteristics of the environment

Hydrographic characterisation of a water body can be used to measure or predict the movement of water currents and transport of soluble and particulate materials within them. A two-dimensional hydrographic and sediment transport model was used to assess the spread of spoil waste (mentioned in the KMM (2004) Cronin *et al*., (2004) reports). In addition, a review of Killybegs harbour dredge and disposal operations is provided in Cronin *et al* (2004) p 71-78.

The dumpsite was chosen by DCMNR following consultation with Killybegs Fishermen's Organisation and local aquaculture groups. The choice of the site south of Teelin was made principally because a) it was not usually fished and b) the site showed low hydrodynamic activity where very little re-suspension of dumped materials was expected from current or wave action.

Heavier materials from the dredging operation such as sand, gravel and clay were used for building materials at Killybegs and only the lighter silt was dumped.

Sampling sediment from areas for future dredging in Killybegs Harbour demonstrated high levels of heavy metals, with particular elevation of organotin and copper. This resulted in a decision not to dredge the most heavily contaminated areas from the area north of Smooth Point. Water Quality monitoring to detect increased turbidity and decreased oxygen levels in the fish farming areas was also carried out during May to September 2002 during dredging and dumping operations and no particular problems were detected.

Irish Dredging Ltd carried out hydrographic surveys during July 2002 (pre-dumping) and August 2002 (post-dumping). It is unclear from the reports as to exactly what data were collected (KMM, 2004). These data, though not available for further analysis, were used to predict the tidal flows and the spread of waste from the dumped spoil using a modelling approach:

1) The initial sediment transport of dumped material was modelled using the TIDEWAY-2D suite of hydrodynamic models to define the hydrographic

conditions and flow and sediment dispersal using SEDPLUME-RW (KMM, 2001a). Four potential dump sites were modelled to find the most suitable.

The original hydrodynamic model for the area was an extension of that developed as part of the environmental impacts assessment report for fish farms within Inver Bay (Aquafact 1998). Due to lack of hydrographic data it was validated as being similar to flows shown by the "Irish Pilot". The SEDPLUME-RW model estimated both the spread of material on dumping under different tidal conditions over short time periods etc single tides. This model assumed that "***all material is released into suspension as individual particles, which then combine and settle to the seabed. The settling behaviour of any large agglomerations of dredged material is likely to be significantly different from the behaviour modelled above and has not been investigated as part of this study***" (KMM, 2001a). It is unclear whether this potential "agglomeration" would refer to sticky or oily mud as described by the EIA as being present in Killybegs Harbour, or whether these muds would disassociate in water when dumped from the dredging boat. The models of the actual dumpsite used showed localised dispersal (KMM2001a, Runs 2a to 2e). The modelling was redone in June 2002, but without collected hydrographic data being used (KMM, 2002) [this was collected 1 month later by Irish Dredging Ltd], with similar results.

These models showed that the spread of waste was likely to be local (within 4.5 – 6.5 km) to the dumpsite. There was a slight skewing of the finer materials on the periphery of the settled area towards the south-west. It is unclear whether this modelling was for the dumping period, i.e. the spread during initial settlement, or post-settlement redistribution of the material and what timescale this was over.

2) Tidal flow was modelled using the MIKE21 HD flow model (Danish Hydrological Institute) (KMM, 2004). This is a two-dimensional tidal flow model commonly used for prediction of tidal currents in unstratified (well mixed) marine systems. It was concluded from the model's results that the tidal currents were weak (averaging 0.15 to 0.2 m/s), poorly dispersive and that the residual current was in an anticlockwise direction in Donegal Bay, taking dispersed material away from the fish farming areas. Data from a single satellite-tracked current drifter in 2001 confirmed an anticlockwise current drift (Cronin *et al*, 2004).

There are a number of further issues with regard to the use of these models in these circumstances. The KMM report (KMM, 2004) suggests that the water column at the time of dumping of sludge was unstratified or well mixed, thus two dimensional transport and tidal flow models were used. However, Donegal Bay was more likely to be stratified, as confirmed by the information provided within Cronin *et al* (2004) and suggested by White (2004), through density fronts which are common in the west of Ireland during the summer. These are generated by a sharp change in temperature over short distances and intersect the seabed at about 80 m. The current then runs along the front. At the dumpsite this would be to the northwest (White, 2004). However, as also pointed out by White (2004), secondary currents are often generated perpendicular to the frontal direction giving a drift to the northeast (in the direction of the fish cages). Two-dimensional models are therefore probably inappropriate for Donegal Bay, unrepresentative of bottom currents and unlikely to estimate accurately the dispersion of particulate materials. In addition, there was no apparent validation/calibration performed for these models. Reference is made to the tidal streams in the "Irish Pilot" only. This has been seen as an unacceptable form of model validation (White, 2004), and does not allow for stratification of the water column (see above).

White (2004) also points out that the water flow model allows for wind driven forcing but does not account for modification of direction of flow by Corriolis forces (caused by the Earth's rotation). This generally changes flow to 45 degrees to the right of the wind direction (in the northern hemisphere). This would mean that a more realistic direction of water flow, particularly in the deeper waters, was to the right of the wind direction. In addition, the model uses (it is presumed) mean wind speeds and directions, and bases current flow on this. Clearly, this is not relevant for all conditions within the bay, such as those that preceded the mortality event (northerly winds), which have the potential to cause NW currents in the deeper waters. It should be noted that though 5 days of northerly winds preceded the mortality events, this in itself would be unlikely to transport considerable quantities of the dumped material all the way to the fish farms but may have had the potential to bring already mobile materials further into Inver or McSwynes Bay. The northerly winds also give potential for upwelling. This will be addressed in Section 2.2.

The currents modelled by MIKE21 (0.15 to 0.2 ms^{-1}) are considered as dispersive conditions for settling fine particulate materials (Gillibrand, *et al*, 2000; Beveridge, 2004). It is presumed that these are water column averaged, but no information is given as to the differences between surface and seabed currents. This can be considerable even in unstratified conditions. Seabed currents greater than 0.11 ms^{-1} have the potential to re-suspend settled materials from the seabed (Chen *et al*, 2001; Cromey *et al*, 2002). The initial water flow models give no information on the length of time seabed currents would exceed this threshold.

More detailed hydrographic data were obtained after the fish mortality event in 2003. This consisted of measurements of water column currents using an Acoustic Doppler Current Profiler (ADCP) and Current Drifters or Drogues (reported in KMM, 2004). The data from the ADCP are difficult to understand as no deployment information is given. It is unclear whether the current meter was deployed at the seabed or measurements made from the surface from a drifting boat. The latter gives the more robust data, as it is not as influenced by weather conditions during deployment. The graphs presented within the KMM report (2004), see Figure 2.1, demonstrate rapid changes in current speeds and direction with depth, suggesting that the meters were deployed from a drifting boat, rather than on the seabed (White, 2004).

The rapid and large changes in current speed and direction over short depth increments may indicate poor quality data, weather influences or irregular stratification with depth. Assuming the data are valid (to validate this properly the raw data are required), the water column was anything but unstratified at this time of the year and that the site is far from "sluggish" with flows often exceeding 0.3 m/s with a large degree of vertical current sheer, which is characteristic of turbulent/strong current sites (White, 2004). This casts considerable doubt on the validity of the initial dispersion models and its results.

Residual currents can be estimated from current meter data by constructing cumulative vector plots. These have been plotted in Figure 2.2 for 60 m and 40 m depth throughout the current meter deployment (data obtained from graphs within KMM 2004). These depths were chosen as those used by Hydrographic Surveys Ltd (suggested by the Marine Institute) for the drogue study. These data are far from complete but suggest that the overall residual flow at 60 m would be to the northeast, with the main residual direction being toward the east. The residual direction at 40 m is to the west. Calculation of residual current speed and direction gave values of 0.036 m/s at 271^{o}N and 0.023 m/s at 68^{o}N for 40 m and 60 m depth, respectively. This confirms that the water conditions are clearly stratified in terms of water flow and direction with depth.

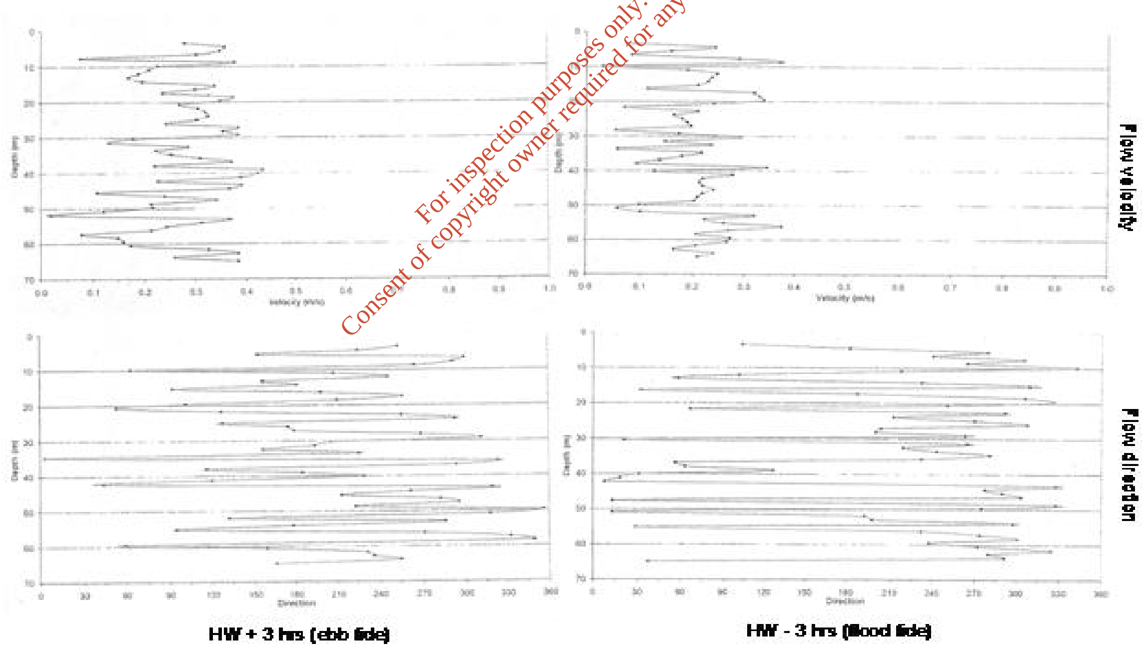

Figure 2.1 Current speeds and direction measured at HW + 3 hrs (ebb tide) and HW – 3 hrs (flood tide) 2 October 2003, Hydrographic surveys Ltd (reported in KMM, 2004).

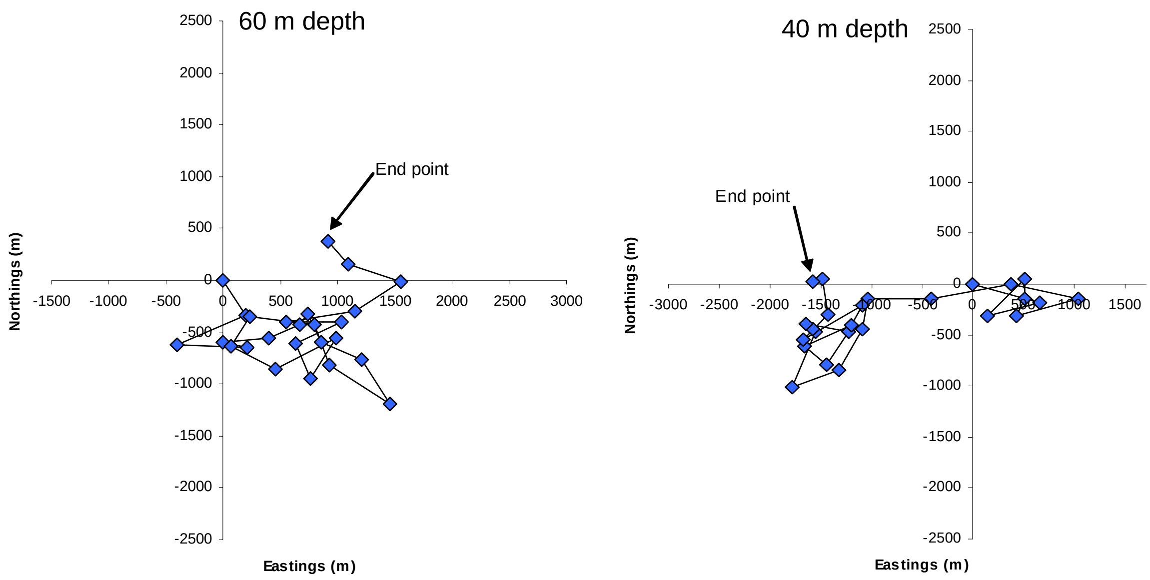

Figure 2.2 *Cumulative vector plots for current readings taken from 60 m and 40 m depths over the whole deployment period HW-LW-HW at the dump site 2 October 2003, Hydrographic surveys Ltd (plotted from extracted data in KMM, 2004).*

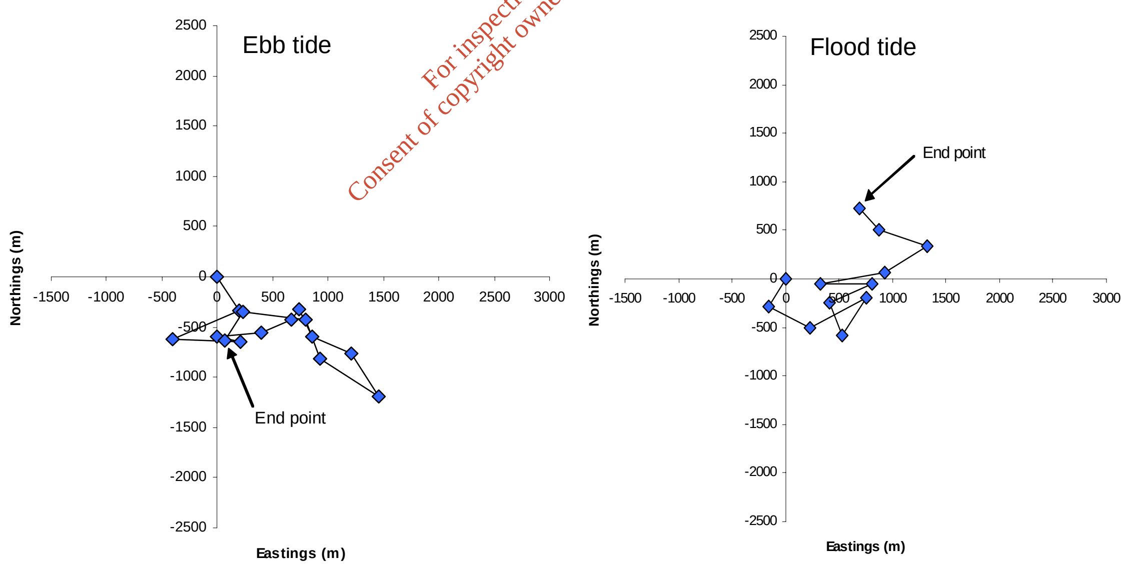

Figure 2.3 *Cumulative vector plots for current readings taken from 60 m depth from HW to LW (ebb tide) and from LW to HW (flood tide) at the dumpsite 2 October 2003, Hydrographic surveys Ltd (plotted from extracted data in KMM, 2004).*

Figure 2.3 divides the ebb and flood tide components of the vector plot using data from HW to LW and LW to HW respectively. This indicates that the ebb tide has a current initially to the southeast but returning to the northwest towards the time of LW, suggesting that any particle removed during the ebb tide would tend to remain within the area of the dumpsite. The flood tide, however, has a residual direction to the east then northeast, suggesting that particles would be carried in this direction during flood tides.

These current meter data are only recorded over a 12-hour period and only representative of a single tidal cycle. It is unclear why such a limited dataset was taken, as more representative current characteristics of the dumpsite would have been obtained if current meter data had been recorded over a 15-day (Spring-Neap) tidal cycle. It is recommended that this is done at some point in the future as even retrospectively this may be useful.

Hydrographic Surveys Ltd deployed current drogues between 29 and 30 September 2003 at the dumpsite at 40 m and 60 m depth. These were released at HW and LW (see Figure 2.4; **the full plot of drogue movement is not available**). Both drogues deployed at HW initially headed northwest for a short period returned to the southeast. The drogue at 40 m depth travelled some distance to the southeast (reported in KMM, 2004). Both drogues released at LW moved in the same general east then northeast direction during deployment. The speeds of all drogues are described as “quite” or “very” low, ranging between < 0.1 m/s to 0.28 m/s (KMM, 2004). However, these current speeds on the seabed could lead to re-suspension and potential dispersion of settled material.

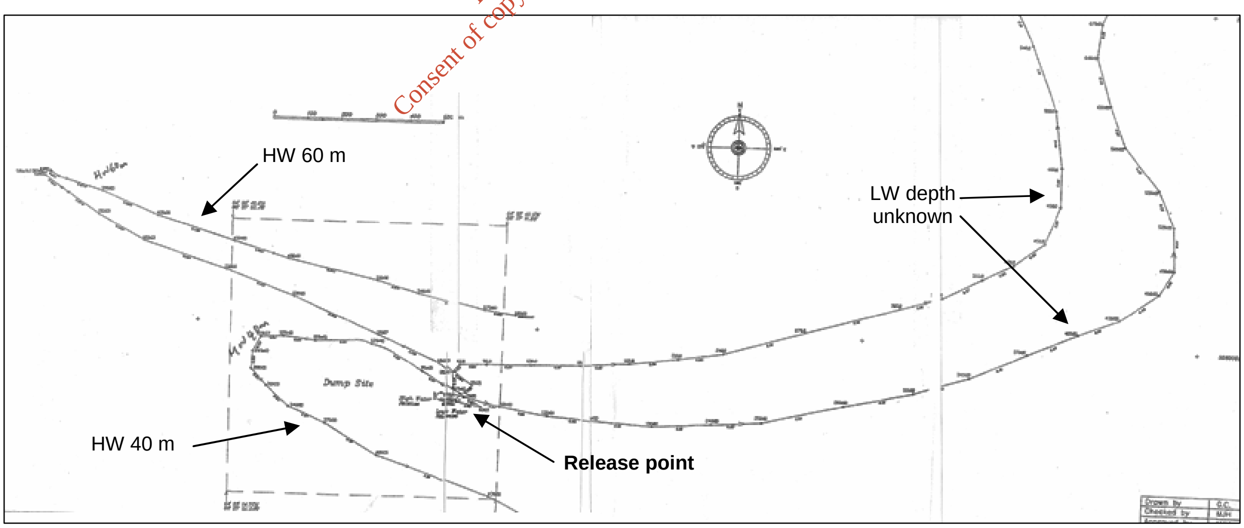

Figure 2.4 Scanned image of drogue tracks taken by Hydrographic Surveys Ltd on 29 and 30 September 2003. The dumpsite is shown as a dashed line.

There is not enough information available to confirm a consistent drift to the northeast during the low water periods, which could transport settled waste towards Inver and/or McSwynes Bay. Clearly the mechanism is there.

Comparison of the 60 m depth drogue tracks with the 60 m depth cumulative vector plots, over the first 6 hours, shows little similarity for those begun at HW. However, those begun at LW were both similarly towards the northeast. **These trends are formulated from limited data sets for a single tidal period. It is difficult to reach firm conclusions unless longer-term data are available, both to investigate current characteristics and validate the tidal flow and dispersion models completed**.

Wave climate predictions and wind directions between August 2002 and July 2003 indicate that there were no storm waves greater that 4 m originating from the southwest to transport material toward the fish farms. It is unlikely therefore that any sediment transport from the spoil site was due to waves or turbulent mixing through wave action.

Hydrographic Surveys Ltd between 28th September and 2nd October 2003 carried out three bathymetric surveys. They concluded that the results of the post dumping surveys agreed well with the survey undertaken pre-dumping in June 2001 (see Figure 2.5, plotted by Aquafact in 2004). However, conclusions were difficult as the post-dumping survey was carried out in difficult sea conditions (reported in KMM, 2004). This should have been repeated in calmer conditions. The hydrographic survey in October 2003 (+1 year) demonstrates an apparent removal of surface materials particularly from the western side of the dumping area (see Figure 2.5). This is indicative of a dynamic and dispersive environment. There is also a clear change in direction of the seabed gullies from E-W in the previous two surveys to N-S in the later survey, suggesting a change in the direction in dispersive currents. The maximum difference in depth to the sediment surface between the bathymetric profiles was approximately 1 m, which should be within the accuracy of the recording echo sounders used.

Data on the hydrography of the dumpsite needs to be revisited. The initial current data used for modelling dispersion may have been modelled using erroneous assumptions (White, 2004). The current meter and drogue measurements taken subsequently are limited and largely inadequate to reach firm conclusions regarding the current characteristics of the area or validate the models. However, they do suggest that there could be a mechanism for movement of dumped waste to the east and northeast, towards McSwynes and Inver Bays.

Aquafact Ltd undertook hydrographic surveys at inner and outer Inver Bay over a neap and spring tidal cycle between 21 August and 4 September (reported in Cronin *et al*, 2004), presumably in mid water (information not given). The average current speed at the outer Inver Bay site was 0.06 m/s with maximum currents of 0.18 m/s, and quiescent waters (<0.02 m/s) found for 16% of the deployment. The inner site had an average current speed of 0.04 m/s, a maximum current of 0.18 m/s, with quiescent waters found for

35% of the deployment. These current measurements are indicative of low energy conditions, though generally satisfactory for salmon farming. The current direction within the outer Inver Bay was bimodal N-E and W-N. The cumulative vector plot (see Cronin *et al*, 2004), gives a weak residual flow to the NNW, though there was a clear change in residual direction over the deployment. This suggests that suspended material at approaches to Inver Bay is likely to slowly enter the Bay.

The cumulative vector plot for inner Inver Bay shows a weak residual movement to the NE, suggesting that suspended material within the Bay may be retained within the inner Bay when considering tidal flow patterns. However, the weak currents within the bay would cause minimal tidal incursions (White, 2004). It is likely therefore that the dominant source of residual flow in these shallow bays is due to local wind effects (White, 2004) and is therefore likely to be highly variable.

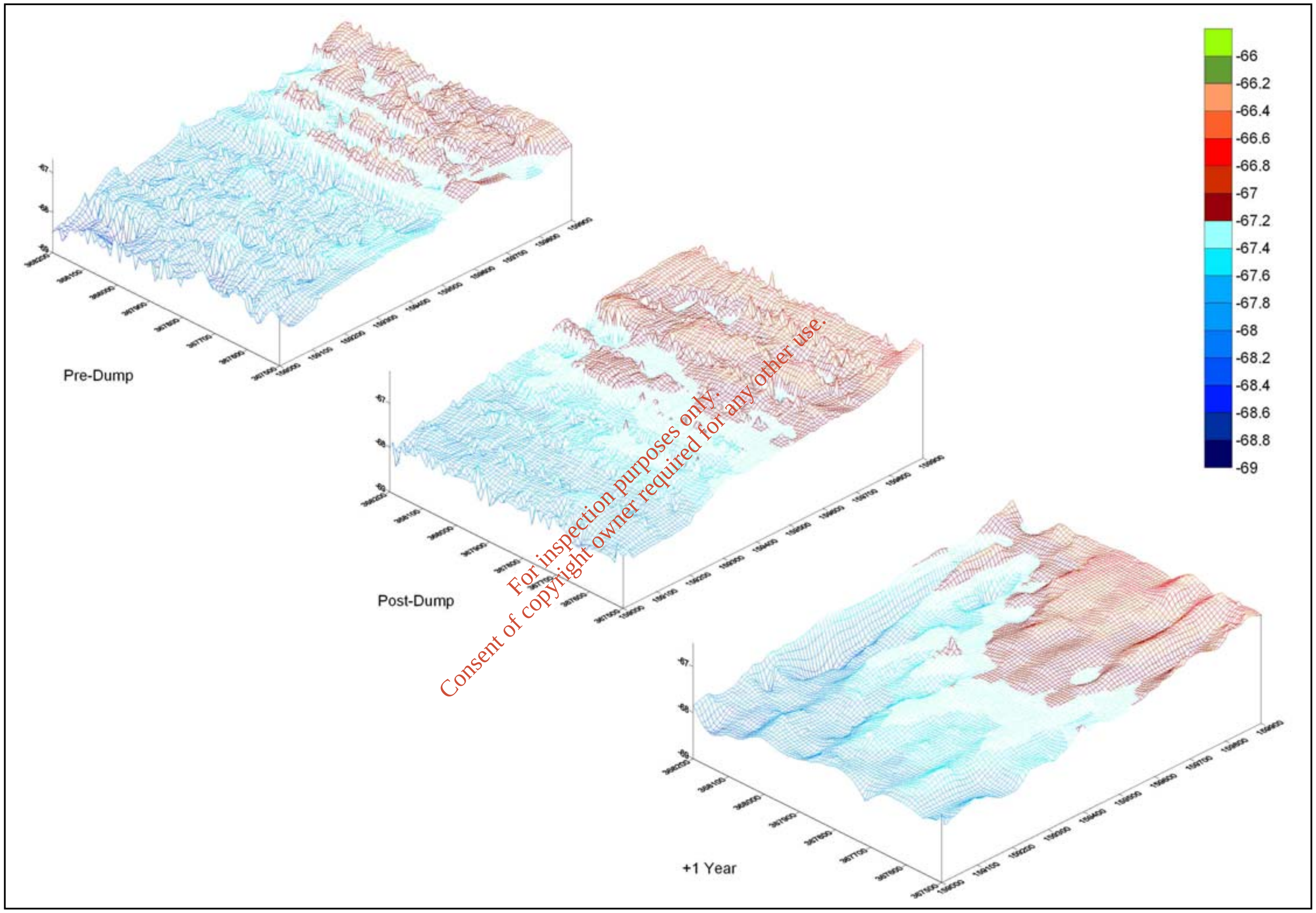

Figure 2.5 Plots for bathymetry taken pre-dump (Jun 2001), post-dump (August 2002) of material from Killybegs Harbour, and +1 year (Sept/Oct 2003), at the dumpsite. The colour scale shows water depth in metres.

2.2 Potential for an upwelling event

There is some evidence to suggest an upwelling event, indicated through a cold-water intrusion, immediately before the mortalities in Inver and McSwynes Bays (see Figure 2.6). It is hypothesised that this upwelling, which brings colder water from the seabed to the surface, may have brought contaminated sediments into contact with the fish. The intrusion occurs around the 3 July to the 7 July 2003, and shows a drop of approximately 1.5 ^{o}C at the surface.

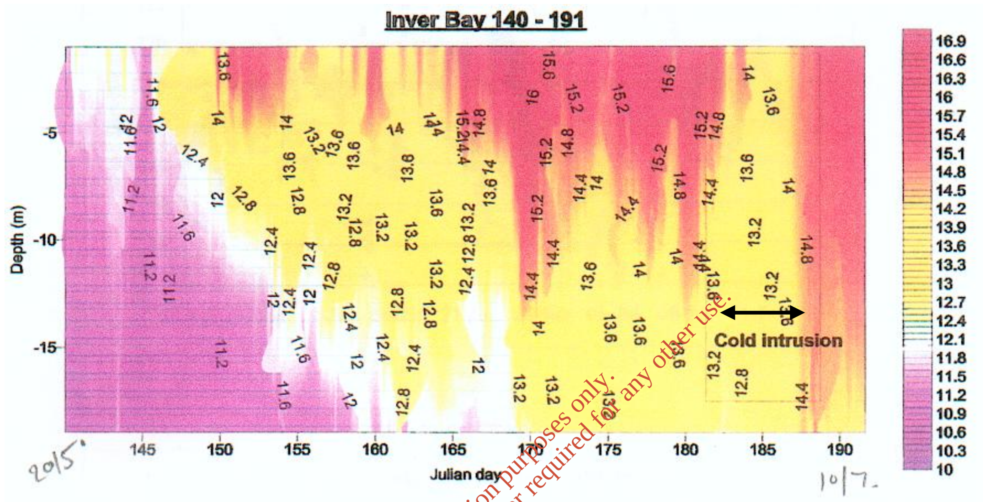

Figure 2.6 Water temperature variation with depth at Marine Institutes M4 monitoring buoy between 20 May and 10 July 2003 (after DCMNR, 2004)

Further potential evidence for this can be seen from salinity records from Inver Bay. A plot of the salinity within Inver Bay between the 19 June and 20 July 2003 (Figure 2.7) shows that there was an increase in salinity value and a parity between salinities at 1 m and 10 m depth during early July, at around the period of the coldwater intrusion. This could be indicative of more saline deeper waters coming to the surface during this period. Afterwards there is a distinct decrease in the salinity at 1 m depth, coinciding with the end of the intrusion. This should be compared with rainfall data before firm conclusions can be reached.

One of the causes for a coastal upwelling event is that offshore winds (in this case easterly or northerly) may locally "push" surface waters away from the shore. This has been noted in Bantry Bay (Edwards *et al*, 1996) as a transient coastal upwelling, which can reverse the normal current patterns within the bay. The temperature variation within Bantry Bay was similar (2 ^{o}C) to that found in Donegal Bay in July 2003, occurring at approximately the same time of the year.

This type of upwelling event is caused by prolonged, consistent or strong offshore winds. KMM (2004) state that these winds are likely to be solely easterly. However, rotational effects on wind forced surface currents mean that NE or N winds would also be highly significant in terms of upwelling events. Observation of wind data recorded on the Marine Institute's M4 buoy (see Figure 2.8) shows that there were northerly to north-easterly winds in early July 2003, coinciding with the time of the cold water intrusion. However, whether this was of long enough duration (2 to 6 July) or had strong enough winds (approximately 15 to 20 knots over the period) is unknown. The winds during the Bantry Bay upwelling event recorded in Edwards *et al* (1996) were between 20 and 30 knots. There is the potential for modelling of this upwelling event using the method of Edwards *et al* (1996).

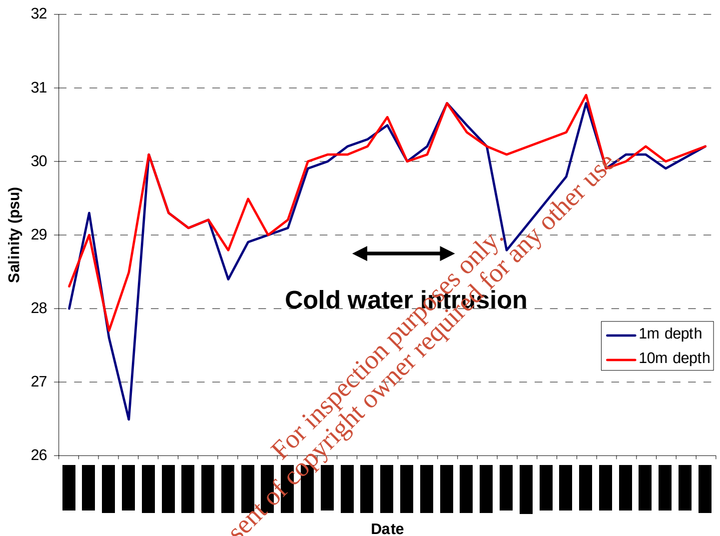

Figure 2.7 Salinity measurements at 1 m and 10 m depths within Donegal Bay between April and October 2003.

The KMM report (2004) concludes that a large-scale upwelling event did not take place as there would be surface water temperatures of less than 13 ^{o}C (surface temperatures were approx 13 ^{o}C, see Figure 2.6) and a surface salinity of greater than 31 psu (surface salinity range between 30 and 30.8 psu during the cold water intrusion, see Figure 2.7). The KMM report (2004) also concludes that there would have been a greater incursion of marine phytoplankton species than there was. However, coastal shelf-water species of dinoflagellates *Ceratium macroceros* and *Oxytoxum caudatum* were found at all sampling stations within Inver Bay on 16 July 2003, and may be indicative of a coastal upwelling or oceanic intrusion. There are still preserved plankton samples that can be analysed to give better data, which may shed further light of the variation in the water body at the time of the fish mortality (KMM, 2004). This should be done.

The question of the occurrence of an upwelling event is complex, but there is enough combined evidence to suggest that on the balance of probabilities there were environmental conditions causing deeper colder water to intrude at the surface. It is unclear whether the water flow associated this intrusion would be strong enough to bring suspended solid materials to the surface. It does illustrate though that the wind has a large role to play in the local hydrodynamic environment of the shallow water bays adjacent to Donegal Bay. The water flow and currents caused are unpredictable and prone to sudden change.

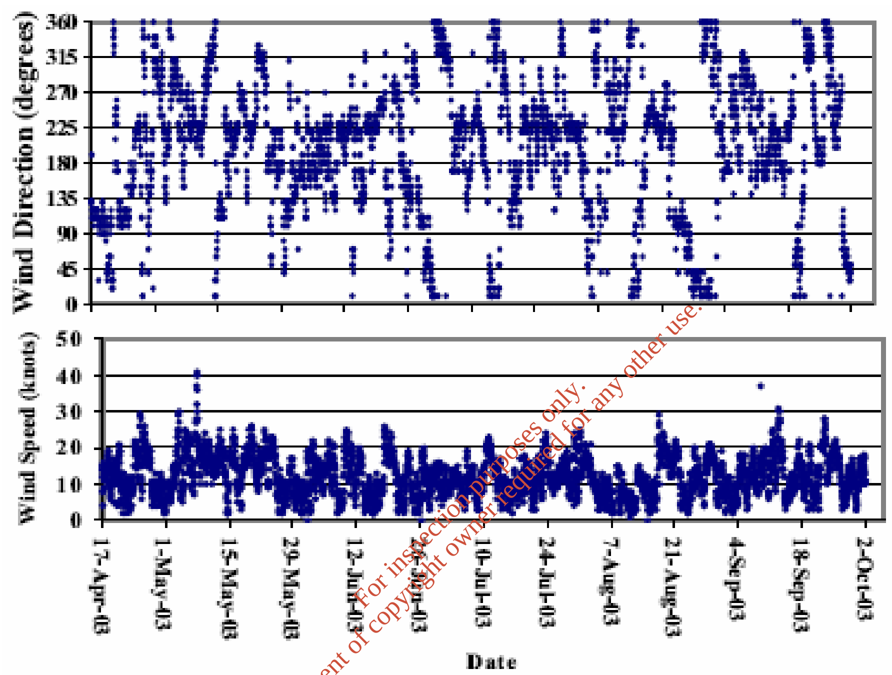

Figure 2.8 Wind direction and strength at the Marine Institute M4 monitoring buoy between April and October 2003.

2.3 Discussion

In conclusion, considerable doubt can be cast on the modelling approach used in the initial hydrographic and settlement modelling of the dumped waste. A 2D model was inappropriate for this complex inshore system, and did not allow for stratification. Follow-up hydrographic data using drogues and current meters at the sludge dumping site is limited (longer term current meter data should have been taken) but suggested that the water column was fairly dynamic (contrary to the findings of the models), with seabed current speeds up to 0.38 m/s which was likely to disperse the settled materials (again contrary to the findings of the initial models). This is in agreement with the observation of a rapid regeneration of the seabed biology and sediment particle profiles within the dumping area (see Section 3).

Both current meters and drogue data suggested that at certain states of the tide there was potential for movement of suspended materials to the east and north-east, towards McSwynes and Inver Bay. This is in apparent conflict with the observation of the oceanic drifter buoy which was anticlockwise within the bay. The anticlockwise direction would conform to the production of near seabed density currents (White, 2004) which forces the currents to run along the density front parallel to the coastline (NW at the dumpsite). However, a secondary circulation may be generated by these fronts perpendicular to the frontal direction - across the depth contours (White, 2004). This would cause a current in a **northeasterly** direction as suggested by the drogue tracks and plotted residual current on the flood tides. Thus there is a hydrographic mechanism for transport of material to the **northeast** from the dump site. Whether this flood tide flow was strong enough or prolonged enough to move spoil to the vicinity of the fish farms is unknown. If material is moved towards or within McSwynes and Inver Bay it is likely to be transported to the north or north-east, as indicated by the residual currents measured within the bay (Aquafact, 2003). This material is only likely to be transported to the surface through extreme turbulence or a transient hydrodynamic episode, such as an upwelling event.

There was no evidence of any climatic conditions, such as storms, which would have caused enough turbulence to bring settled material to the surface within the bays. Data showing a temperature incursion and an increase in salinity following a period of offshore winds in Donegal Bay suggested conditions which would occur during an upwelling event. The potential for upwelling in Irish coastal waters can be modelled further (see Edwards *et al*, 1996). It is unknown whether this upwelling would have been strong enough to bring settled material to the surface. There is a possibility that disturbed materials through trawling or dredging may have caused increase in turbidity. There was no evidence of this from any of the surveys, but only from limited eyewitness information.

3. WATER AND SEDIMENT QUALITY

Surveys of water and seabed sediments were undertaken both as a part of the EIA for the dumping of sludge waste from Killybegs Harbour and subsequent monitoring. In addition, after the fish mortalities a number of other studies were completed on behalf of both DCMNR (reported in KMM, 2004 and Cronin *et al*, 2004) and the Sunderland Marine Insurance Company.

The original EIA, published in January 2001 (KMM, 2001) was completed for the impacts of removing the sludge from Killybegs Harbour. Little information within the EIA though is given on the likely impacts of the physical dumping of the fine (unusable) material at see. It mentioned that sea dumping of this material was considered environmentally and economically the best option for disposal of the unusable materials from Killybegs Harbour (see p144). Data on metals within the harbour were collected and show an elevation in the levels of several heavy metals and organotins. There were extensive measurements of sediment characteristics, smell and nature of the sediments. **Results of the odour and visual testing of the sediments were (see EIA p 102) indicate that for three out of four samples taken throughout the Harbour area (locations were only given in a very vague map Figure 10.4, p101) were "black sticky sediments, sands and gravel" with a "rotten eggs" (indicative of hydrogen sulphide) or "fishy ammonia smell"**.

This EIA included a modelled assessment of the sediment transport throughout the harbour system but not modelling of dispersion of dumped materials. The EIA states that "it is extremely unlikely that the dredging and dumping operations will impact on the fish farms in McSwynes and Inver Bays". Modelling of the spread of dumped material was done in June 2001 (KMM, 2001a).

Further baseline surveys of sediments and water within Killybegs Harbour was undertaken by Aquafact International Services in Feb 2002 (Aquafact, 2002), on behalf of KMM, which showed the presence of heavy metals – arsenic, chromium, copper, zinc and mercury – and TBT throughout the sediments within the bay, and TBT contamination in half of the water samples taken. These surveys suggest that the spoil to be taken from the bay and dumped offshore contained a mixture of toxic metal contaminants and was highly anoxic in nature.

3.1 Seabed sediment surveys at the dump site

A number of seabed surveys have been undertaken as part of the monitoring framework at the sludge dumping site in Donegal Bay on behalf of the DCMNR. These are listed below in chronological order beginning with the pre-dumping baseline survey:

- Aquatic Services Unit (June 2001) – Baseline survey of the disposal site
- Wood Environmental Management Ltd (November 2002 – 20 days post-dump) – Benthic monitoring of the dredge spoil disposal site, phase 1

- Wood Environmental Management Ltd (April 2003 – 5 months post-dump) - benthic monitoring of the dredge spoil disposal site – phase 2
- Aquafact International Services Ltd (August 2003) – sediment profile imagery
- Wood Environmental Management Ltd (September 2003) – benthic monitoring of the dredge spoil disposal site – phase 3

The pre-dumping baseline survey by Aquatic Services Unit, Cork (ASU, 2001), set up a detailed monitoring protocol consisting of 16 sampling stations each of which was sampled 6 times for replication of data. Five sample sites were within the dumping area, ten stations along four transects (see Figure 3.1) and a single, distant reference station. Samples were taken using a 0.1 m^2 Day Grab and sediments analysed for particle size (PSA), carbon levels (using an LOI technique) and biological community structure. Findings were that there was a clear association between sediment type and biological community as would be expected in unimpacted areas. Sediments consisted of moderately sorted very fine sand (63 to 125 µm) containing 2.2 to 3.3% organic carbon. The fauna and sediment conditions found were deemed to represent an "area of good current speed" (contrary to the conclusions from hydrographic modelling – see Section 2).

Dredging and dumping then took place between 18 July and 2nd August 2002. Twenty days after cessation of dumping sludge, Woods Environmental Management Ltd repeated the sediment survey to give the immediate environmental impacts and area of influence of the dumped material. This would also be at approximately the same time of the year as the previous survey and thus mitigate for seasonal effects. Only six of the sixteen original stations used in 2001 were re-sampled including the reference station (see open circles in Figure 3.1). The reason for this is unclear. Sediments were analysed for biology, PSA and carbon (by LOI). It is unclear why so few stations were re-sampled and why these sediments were not analysed for heavy metals when it was known that the sludge was rich in metal contamination. Biological results were compared to previous surveys using a multivariate analysis approach; however, this will only show the change in biological community unless there is a full range of environmental data (including pollutants) to statistically compare results. Comparisons were made using a different multivariate analytical technique to the baseline survey; it is unclear why both datasets were not analysed in the same way.

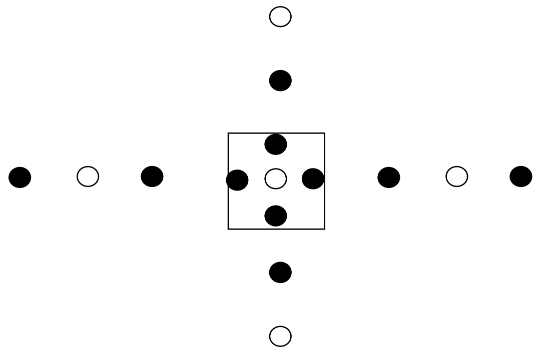

Figure 3.1 Diagrammatic representation of the sampling strategy for sediment monitoring of the sludge dumping area. Not to scale. An additional reference station was sampled remote from the sludge dumping area.

The results for this survey show a slight increase in the grain size of the sediments at all stations, including the reference station. This could be within normal laboratory errors. However, the sediments at the centre of the dump area coarsened considerably and showed no characteristics of the dumped spoil. The benthic community showed an increase in diversity and number of taxa at all stations, except for the middle of the sludge dumping area. This is normally indicative of either good environmental conditions or a very slight nutrient enrichment. Only at the centre of the dump site does there appear to be some biological impact through dumping of the sludge. This is very surprising as dispersion models (see Section 2, and KMM report Appendix 1) shows that the spread of metal enriched dumped material should have affected all of the stations within or immediately adjacent to the dumping area. These results suggest that either the dumped sludge was initially confined to the dumping area and has since been at least partially dispersed, or that it was widely dispersed during the dumping process and settlement to the seabed. In either case these results suggest that the initial modelling was flawed and should have been validated.

A second post-dumping survey was carried out by Woods Environmental Management Ltd, 5 months after dumping (Woods Environmental Management, 2003). This sampled the same stations and used the same methods as the baseline survey, but there was an addition of a further sampling station (station 16) approximately half way between the dump site and Killybegs Harbour. It is unclear why this additional site was commissioned unless this was to check if spoil was moving towards a shoreline SAC, which should have been under no threat according to the initial EIA, and hydrographic and dispersion modelling. The results were reported as showing good comparison with pre-dumping levels, with the exception of the station at the middle of the dump area. The new sampling station was also reported as being similar to the reference station, suggesting no impacts. However, observation of the multivariate analysis results shows clear differences between the new sampling station 16 and the reference (and other nonimpacted stations as well), if anything station 16 showed similarities with the station at the centre of the dumping area. It is clear that the numerical analyses could benefit from quality assurance (QA) by someone who understands them. The PSA data also shows that the sediments at station 16 were finer than those at the reference station.

The third monitoring survey completed by Wood Environmental Management Ltd was completed in August 2003 (Wood Environmental Management Ltd, 2003). Again the same stations were sampled in the same way as the second survey. Observation of the data of all of the surveys shows clear trends in the stations sampled, except the reference station which is consistent, suggesting changing biological communities. Again the analysis of the results is suspect and would benefit from some QA. Trends in the data are attributed to seasonal effects. This is unlikely as three of the four surveys were done at approximately the same time of the year. It is also clear from the results that sediments at the extra station had become coarser, but it is unclear why. No sediment metals were analysed in any of these studies, this would have enabled comparison between benthic communities and sediment characteristics and metal elevation through dispersion of dumped sludge. The sediments at station 16 (additional sampling station) were coarser than previously found. This suggests considerable sediment transport with seabed sediments changing in nature. This is further evidence of the area being a dynamic and dispersive environment. It has been suggested that this may also be evidence of fine sediment transport from the dump site towards Inver Bay. There is no baseline data for comparison and this cannot be proved.

The general results for the post-dumping sediment analysis are inconsistent and it is likely that some of the more complex data analysis has been misinterpreted, partly due to lack of sediment chemistry at the sampling stations. Some of the information in these reports was criticised by O'Beirne in his review (O'Beirne, 2002), in particular the first post-dumping report.

Benthic conditions at the fish farms were considered in the Cronin *et al* (2004) report p 40-44. Regular sampling indicated impact to the seabed beneath and immediately adjacent to the cages at all sites, with, as expected, lesser effects at the smolt sites than the grower sites. Conditions appeared relatively constant and in fact showed an improvement at the Oceanfarms McSwyne's Bay sites prior to the mortality event. See section 3.3.

Particular comment was made on seabead conditions at Oceanfarms Inver Bay cage 10 following a mortality event in June 2002. Following this event, between 6000-8000 salmon was left to decompose on the sea bed. Although a major impact was first produced, by May and June 2003 there was little evidence of the incident with good seabed recovery. A dive survey carried out by the Marine Institute on July 16th 2003 (cage 10) showed no evidence of organic enrichment and no evidence of fishing activity. A continuation of the dive survey to examine the seabed adjacent to the other grower cages showed no disturbance or re-suspension of material but also, no evidence of deposition of material from elsewhere (such as the black silty material reported on the Oceanfarm sites). See section 3.3.

Video surveys undertaken by Aquafact in August 2003 (Aquafact, 2003; reported in KMM 2004) showed that seabed conditions near to the fish farms in Inver Bay demonstrate normal organic enrichment and no evidence of anoxia and were within allowable limits. An SPI survey carried out during August showed the seabed to be in good condition at both Inver Bay and McSwyne's Bay with no evidence of a large reservoir of anoxic sediments, no evidence of large scale disturbance by fishing activity and no evidence of recent deposition of sediment. Limited evidence of fish activity was found between licence areas 276B and 96A.

Likewise the sediment conditions within McSwynes Bay showed no evidence of environmental disturbance. Video observation of the sludge dump site showed some disturbance to the north-west (compare with bathymetry profiles in Section 2, Figure 2.5), possibly due to dredging activity reported within this area. The remainder of the dumping area showed no evidence of disturbance with a healthy community indicative of re-colonisation having taken place.

Sediment samples were taken from near the spoil dumpsite and from near the fish cages (KMM, 2004). The sediments were analysed for redox potential (an indication of the amount of oxygen within the sediments) and a series of chemical contaminants. The redox results showed the sediments to be generally well oxygenated, and slightly less oxygenated than the "control" station towards the middle of Donegal Bay. The lowest levels occurred at sampling stations closest to the fish farms. This is usual for these conditions and is probably due to the nutrient input from the fish farm enhancing utilisation of sediment O_2 through heightened bacterial activity.

White Young and Green (WYG) carried out heavy metal analysis on sediments dredged from Killybegs Harbour, McSwynes Bay and Inver Bay, and the dump site. The results indicate that similar levels of certain metals were found in McSwynes and Inver Bay as within Killybegs Harbour. These were not found in the same quantities at the dump site. It is reported that the black, oily sludge found on the cages within Inver Bay also contained similar levels of heavy metals as material from Killybegs Harbour (especially for copper, zinc and cadmium (see Costello pers comm.). Unfortunately, there is no baseline data from Inver or McSwynes Bay, taken at the same time, for comparison so the obvious conclusion that this is evidence of transport of dumped material into the bay cannot be fully corroborated. It is suggested by WYG that background metal data may be obtained from bays with similar geographic formations to Inver Bay. These bays though should also have a similar level of aquaculture activity as Inver Bay, as fish farming is a source for metal contamination of sediment, particularly copper and zinc. This would still be inconclusive.

SEAS Ltd performed heavy metal analysis on sediments collected (in October 2003; SEAS, 2004) near to the fish farms and near the spoil dumping area. They found that, with the exception of manganese, all the metals analysed were slightly elevated over those found at the site nearest the spoil dumping area. However, none of these metal levels was particularly high, and all were considerably lower than those found in the Firth of Clyde, which though high are considered acceptable. There appeared to be a trend of increasing levels of metals the closer samples were taken to the fish farms. This is normal and correlates to sediment reduction/lowered sediment O_2. Reduced sediments tend to chemically bind metals to particulate organic material, thus metals tend to accumulate (though not necessarily at notable levels) near to or under fish cages. None of the metal levels found were in excess of environmental regulatory frameworks or action levels.

MARENCO undertook an extensive chemical analysis on sediments collected in September 2003 throughout McSwynes Bay and Inver Bay. In addition, the "control" station was within the vicinity of the spoil dumping area in the direction of the residual water currents (see Section 2), thus the integrity of this station as a "control" should be questioned. As with the SEAS Ltd study, there were slightly elevated levels of lead, mercury, cadmium, copper, zinc, tributyl-tin and dibutyl-tin at the sampling stations nearest to the fish farm. These were of similar levels to those found by SEAS Ltd and confirm higher metal levels near to the cages, probably due to accumulation in the reduced sediments. With the exception of arsenic at the station at the mouth of McSwynes Bay, all sediment metal concentrations were within regulatory action levels (Canadian Probable Effects Levels; SEPA, 2003). Sediments were also analysed by gas chromatograph – Mass spectrometry (GCMS) for organic compounds. These were typical for marine sediments. The highest levels of metals and organic compounds found in sediments during this survey were from a sample taken from Killybegs Harbour, illustrating that these sediments are still prone to contamination and may be a source of pollution to fish farms under certain hydrodynamic conditions.

As pointed out by Boelens (2004) these metal samples had not been normalised therefore were difficult to compare, particularly with regulatory levels. However, the absolute levels taken throughout the area should be comparable. In addition, metal levels should be able to be used as indicators or sludge movement. Costello (2004) combined data from sediment metal studies for MARENCO and Aquafact International Ltd taken 13 and 15 months post-dumping, respectively. Results of metal analysis for nickel, chromium, manganese, copper, zinc, arsenic, lead, mercury and cadmium were taken from the dumping area, 200 m west of the dump site, 5 km NW from the dump site and at the reference station sampled by MARENCO, also used a reference by Wood Environmental Management Surveys. In addition, metal analysis results were taken from three randomly selected dredge sites within Killybegs Harbour. Results clearly show that all metal levels from sediments in Donegal Bay were very similar including the control station, but (with the exception of manganese) were considerably lower than the metal levels found within samples taken from the dredging sites. Only nickel and chromium showed an increase at station 7 to the north-west of the dump area, none of the other metals showed this. Metal levels within sediments in Donegal Bay were very low and below levels found within McSwynes and Inver Bays (Aquafact 2003). It was concluded that, though the findings would require evaluation by marine chemists, the fine material from the Harbour containing elevated levels of metal contaminants were no longer resident at the dump site 13 – 15 months post dumping (Costello, 2004). Metal levels within Inver Bay are reported in KMM (2004). Sediment levels were given for sampling stations near to the fish farm (stations 27, 20, 13 and 5), and approx 500 m (station 90) and 1000 m (station 86) from the farms. Sediments at 500 m showed a small elevation in some metals, whereas the sediments 1000 m to the south of the fish farms showed similarly low levels to those within Donegal Bay at both the dumping site and the control station. This suggests that the elevated metals within Inver Bay were associated with the presence of the fish farm, not surprising as these metals would tend to accumulate in sulphur-reduced sediments near to the farms. However, the source of these metals is unclear, as no baseline data is available for Inver Bay from before the dumping to enable comparison.

Heavy metal toxicity was also reviewed extensively by McLoughlin (2004) in relation to the salmon mortalities at McSwynes Bay and Inver Bay. She highlighted heavy metal toxicity to fish in water and reported on analysis of sediment samples for heavy metals in relation to their toxicity to salmonids. There was a considerable elevation (generally an order of magnitude) in levels of copper, zinc and cadmium in the "oily" black sediment taken from the deposits on fish cage nets compared to sediments at the fish farms. While zinc and copper levels, though high, were still below action levels demanded by SEPA (2003) but those for zinc was higher than those recommended for action by NOAA AET. The levels of cadmium in this deposited material were high, ranging from 1.32 to 1.89 mg/kg dry weight sediments.

There is thus clear evidence that the black mud/silt seen attached to nets at the Ocean Farm site did not originate from the sediments beneath the cages which were due to the fish farming activity. The presence of this material coincides in time with deposits reported on fishing gear (see McLoughlin October 2003) and the reports of black particulate material in the water at Inver Bay prior to the mortality event. Analysis suggests similarities to silt from Killybegs Harbour, which was deposited at the dump site and subsequently dispersed.

The deposits collected on smolt nets in McSwynes Bay at the same time as the salmon mortalities were due to be analysed for H_2S production by the Marine Institute. However this sample was lost. The evidence of eyewitnesses suggests that there would have been significant amounts of H_2S within the sediments through the smell. Without additional sample analysis this cannot be discussed further. It has been suggested that H_2S may have caused or contributed to the mortalities of the salmon (see Section 4). While this may have been the case where sediments were deposited it is unlikely that high H_2S levels, even in disturbed sediments beneath the cages, would solely cause the levels of mortality found, as this gas is readily oxidisable and highly water soluble, normally making it unlikely to pass through cages in significant amounts.

Analysis of fish tissues for Inver Bay fish showed levels of copper and chromium in gills and copper, cadmium, aluminium and arsenic in liver that were higher than "control" fish from Clare Island Sea Farms (Dec 2003). There was some elevation of metals in gill, liver and muscle tissues of fish farmed in Inver Bay in February 2003, indicating that this phenomenon was present before the mortalities in July 2003.

3.2 Water samples

Water samples for soluble heavy metals, dissolved nutrients and water volatile organic compounds were collected by MARENCO in September 2003. These showed very low levels for all parameters analysed, which were well below regulatory quality standards (SEPA, 2003; Canadian Probable Effects Levels). These measurements gave no trend in relation to the fish farms or spoil dumping ground. Only at station S3 in McSwynes Bay were any analytical peaks for water volatile organic compounds found.

3.3 Seabed monitoring surveys at the fish farms (McSwynes Bay and Inver Bay)

It had been suggested that there was a potential for the environmental conditions at the fish farms, combined with certain weather conditions, to have had an influence on the fish and contributed to the mortalities seen. This has been twofold; firstly, that the sediment condition under fish farms is highly sulphur enriched and oxygen depleted and if brought into the water column may affect fish, secondly that there had been a fish kill in Inver Bay during June 2002 which caused 6-8000 dead fish to be left on the seabed (Oceanfarm Grower site Cage 10) (Aquafact, 2002 d), and left to rot.

The sediment conditions beneath farms within McSwynes and Inver Bays have been extensively investigated through the statutory monitoring procedures and surveys. These have been carried out for all Oceanfarm, Eany and Creevin company fish farms between 2001 and 2003 (reports provided; Aquafact, 2001, 2001a, 2001b, 2002, 2002a, 2002b, 2002c). These are surveys based on photographic images of the seabed taken at various fixed distances from the cages. Some of these surveys also included measurement or estimation of the depth to the redox discontinuity layer (RDL) which can be considered as indicative of sediment quality (Aquafact, 2002d). These reports are consistent in their format given the photographs taken, a description of each and conclusions. Noticeable effects, or indicators of impacts, can be found by judging the colour of the sediment and the type of surface organisms found, including fauna and white bacteria mats (*Beggiatoa* sp). Unfortunately, while this type of survey is good for looking at gross changes, it does not give quantitative data to allow statistical analysis of the temporal changes in the nature of the seabed to be done. Therefore many conclusions are by nature subjective. In addition, the positions of the transects are taken from the fish cages to allow statutory environmental quality standards to be implemented. To compare impacts over time presupposes that the cages have not moved. There was no information within the reports on the positions of the cage blocks and thus that they have not been moved during between the surveys.

Inver Bay has five fish farm sites being surveyed; Oceanfarm Smolt, Oceanfarm Grower (Aquafact, 2001, 2002), Creevin Smolt, Creevin Grower (Aqufact, 2001b, 2002b), and Eany fish farm (Aquafact, 2001a, 2002a). The Oceanfarm Smolt site was a relatively new site in 2001 and showed noticeable impact only beneath the cage area, this impacted area increasing to 20 m in 2002 due to additional input of waste. The Oceanfarm Grower site during both 2001 and 2002 showed noticeable sediment impacts to 20m beyond the area of the cages. The Creevin Smolt site again was a new site in 2001 and showed no impacts, whereas in 2002 the noticeable sediment impacts extended to 20 m beyond the cage block. The Creevin grower site also had an apparent increase in impact between 2001 and 2002, with the noticeable area of effect extending initially from 10 m to 20 m beyond the cages. The Eany fish production site showed similar sediment conditions in 2001and 2002, with the zone of noticeable effect extending to about 20 m in both years. In fact, there was a slight improvement noticed in the sediment animal community structure between the two years at this site. The results given above for the fish farms within Inver Bay show that there was generally a slight increase in area of impact from most fish cages or no change. This is not surprising as some of these farms were relatively new, being set up after the environmental impact statement for fish farms in Inver Bay (Aquafact, 1998). All of the environmental conditions seen beneath and near to the cages were typical for fish farms of this size and production, and are within the standards set by marine environmental regulatory authorities.

McSwynes Bay has three fish farms, all operated by Oceanfarm Ltd. These were surveyed for environmental quality in 2002 and one (grower) in 2003 (Aquafact, 2002c, 2003e). Again the methods used were underwater photography to characterise the sediment type and impact. The noticeable impacts on sediment beneath the Smolt and Harvest sites were limited to 20 m from the cages. The Grower site in McSwynes Bay has been present for many years. Impacts were noted at this site out to 100 m in 2002 (at time of maximum biomass) and 50 m in 2003. This is a greater distance than would be expected as normal but may be due to the more dispersive and dynamic nature of this site, compared to Inver Bay and the time of sampling in relation to the fish biomass. The decrease in distance of effect in 2003 suggests that the significant impacts are more localised but still considerable.

The results given above in the Aquafact environmental monitoring reports show that at most of the fish farm sites within Inver and McSwynes Bays that the sediment conditions near the farms are typical. They were only slightly a typical at the McSwynes Grower site. Therefore it is very unlikely that these sediment conditions, based on this data, would affect the fish within the cages. The sediment conditions did not appear degraded enough to produce significant environmental conditions such as severe outgassing by hydrogen sulphide, or would cause conditions to cause such mass mortality within the time period seen if brought up into the water column through environmental conditions. If this had been the case such mortalities would certainly have been seen at other sites as these sediment conditions were so typical of those beneath fish cages in Ireland and Scotland, where conditions (current flow, weather, bathymetry etc) are so similar. There was some circumstantial evidence of trawling within Inver Bay noted from the photographs. However, the report states that these were by there nature shallow depressions and difficult to interpret as such and quick to recover often within 52 hours (Fonteyne et al, 1998,in Aquafact, 2003).

At the Inver Bay Oceanfarm Grower site cage 10, 6-8000 fish left on the bottom after a significant fish kill were left to degrade naturally. Assuming that these fish would have been approaching market size (3 kg), there would have been about 24 tonne of fish on the seabed. Initial environmental conditions (2 months afterwards) were very poor with hypoxic sediment noted (Aquafact 2002d). Gassing and surface oil from the decaying fish were noted and fish health within the adjacent cages assessed (Moss Veterinary Partners, in Aquafact 2002d). No significant effects were seen. The extent of this sediment degradation was monitored closely and frequently by Aquafact (Aquafact, 2002d, e, f, 2003a, b, c, d). There was extensive initial impact on the sediment beneath the cage where the fish were maintained in the net. The net was removed to a location several hundred metres from the fish cages in September and both cage and net locations monitored. The monitoring studies used both sampling and photographic techniques and showed that over the course of the next year to June 2003 the fish degraded successfully and became incorporated into the sediments through degradation and bioturbation processes (Aquafact, 2003d). While one mechanism for the decrease in fish found at the site could have been removal due to currents, this process would have been gradual and would be very unlikely to give environmental conditions poor enough to cause the fish mortalities encountered in July 2003.

3.4 Discussion

There were no apparent impacts on sediments either in the vicinity of the fish farms or the spoil dumping area, as indicated by video and benthic community analysis (KMM, 2004). Equally these surveys showed no evidence of disturbance due to trawling in the vicinity of the fish farms. Anecdotal observations by fish farmer workers suggest that there has been some trawling in the area. It may be that the video transects missed the trawl tracks, but these surveys were generally long and extensive. There was some sediment disturbance which may have been attributable to trawling/dredging in the area.

The sediment characteristics and sediment fauna indicate that this is a fairly dynamic environment, rather than a depositional area as proposed. This result concurs with the post-mortality hydrographic measurements but disagrees with the pre-dumping tidal flow and dispersal modelling, which clearly should have been validated in light of these findings.

There was no elevation of metals within sediments near to the spoil dumping area. The highest recorded levels of sediment metals during this survey were in Killybegs Harbour, these were significantly higher than sediments at the dump site. These results strongly suggest that the contaminated sediments have been physically removed from this area, as it is unlikely that the metals have been stripped from the sediments as they become oxidised, over such a short time period.

The elevation of heavy metals near to the fish farm sites is typical of elevation of metals within areas of sulphur-reduced sediments, such as where nutrients from fish farms are deposited. No baseline data are available for sediment metal levels before dumping occurred; therefore it is difficult to conclude whether the elevation in sediment metals (compared to outer Donegal Bay) is due to influx of metal rich materials from the dump site. The elevation of metals within these sediments was not significant in terms of regulatory action levels.

Elevated levels of copper, zinc and cadmium were found in the "oily-black" material deposited on cages in McSwynes Bay. While this may come from micronutrient or antifoulant these levels were considerably higher than those found in the sediments near or beneath the fish farms. Cadmium was elevated to levels higher than action levels. It is unclear where this material comes from. Though sediments of this nature can exist beneath fish farms in extreme conditions, results from surveys near Inver Bay and McSwynes fish farms indicate that conditions beneath these cages are not extreme. In fact the latter, where material deposition was greatest, had been described as a "healthy" environment (Aquafact, 2003). However, without further observation and analyses of these deposits for nutrients, total sulphide and lipid/fatty acid profile it is not possible to definitively attribute the source of this material.

Water samples were not contaminated and showed low levels of all parameters measured.

The metal levels found of the tissues of the fish (compared to those of Clare Island) and other fauna collected in at Inver Bay suggests some contamination. This could be through water, suspended materials or feed.

Was Hydrogen Sulphide from sediments below the cages a possible cause of the gill lesions seen?

The environmental reports for the annual photographic monitoring of the seabed near fish cages in Inver and McSwynes Bay showed that impacts were typical for fish farms of the size and while some gassing occurred it would be very unlikely, from the state of the sediments shown, to be significant amounts of hydrogen sulphide produced. There may have been some impact in this respect due to the fish decay beneath Inver Bay Oceanfarm Grower cage 10, however, the fish in the cages were monitored for health and the sediment appeared to have recovered to a "normal" level of impact from fish farm inputs by June 2003.

In addition, it is unlikely that the sediments beneath the fish cages were degraded enough (from the visual observations) to have caused the 2003 fish mortalities even is brought up into the water column.

There is a cause for concern in that there was no data to show that the fish farms had not been moved due to degradation of the seabed. Circumstantial observation though from the surveys indicate that the impacts were largely to 20 m from the cages, in some cages this was consistent and in some the noticeable impacts increased from 10 to 20 m distances. Significant impacts of 20 to 25 m from the cages are typical and the time taken to achieve impacts at this distance would take some time. Therefore it is likely that the farms had not been moved over the survey period (2001 to 2003). The exception to this is the Grower site in McSwynes Bay. Here there were noticeable effects to 100 m in 2002 (decreasing to 50 m in 2003), this could be either that there was larger impact from this large farm or that the impacts had been spread over a larger area through movement of cages, more dynamic environmental conditions.

Another conclusion from the sediment monitoring was that there was no evidence of the sludge on the seabed near the cages. This agrees with findings of other surveys throughout the whole area assessed in this report (KMM, 2004) and by the DCMNR (sees Cronin et al, 2004). This shows there is no direct evidence of the sludge in association with the seabed within either McSwynes or Inver Bays during the period immediately before the fish mortalities. However, the photographic monitoring surveys only extend (or were available) to 2002 for Inver bay.

Mr Dermot Sparrow, veterinary consultant, made a visit to the Ocean Farms Inver site on 9/7/03. During the visit he observed two nets which had recently been removed from the Inver smolt site and were coated with black sludge. The raw sludge had a strong odour of hydrogen sulphide. Water samples in the vicinity of cage 15 taken on 10/7/03 showed hydrogen sulphide levels up to 13.85mg/l – higher levels may have been present.

Water samples taken on 16/7/03 were negative for sulphide.

David Cox, a biologist working with Fish Vet Group commented that lesions were similar to those seen experimentally following H_2S exposure. (It should be noted that such changes are non-specific – RHR personal observation).

H_2S toxicity has been previously seen at fish farm sites with an extremely polluted seabed beneath the cages and would be a local effect. All surveys suggested the seabed was in good condition at the large number of sites affected and the effect was indeed, not local, but widespread across all the sites.

As the black sludge-like material was principally organic in nature, it could well have smelled of H_2S and may locally have produced toxic effects. The sludge is more likely to be indicative of a more widespread suspended solids event (as was noted by a number of people in the fish farming area).

H_2S is unlikely to be the sole source of the mortality as the gas is readily oxidizable and highly water-soluble normally making it unlikely to pass through cages in significant amounts.

In conclusion, there was some evidence to suggest higher metal concentrations in sediments near to fish cages and within fish tissues. There was also clear evidence that the sediments at the dumping area recovered very quickly and that the sediment dumped from Killybegs Harbour had been removed rapidly after initial dumping. The monitoring carried out has failed to demonstrate exactly where this material went to but there are clear mechanisms for water flow to be to the NW and E-NE in the direction of the fish farms (see Section 2).

There is no evidence that water quality defects were produced by re-suspension of material from beneath the fish cages, bottom conditions were good and there was no evidence that the H_2S apparent from the “black sludge” was of fish farm origin. H_2S is also unlikely to have been the primary cause of gill damage.

4. VETERINARY INVESTIGATIONS

Dr Marian McLoughlin produced the first review (McLoughlin 2003) of the range of veterinary investigations and reports for the period prior to, during, and after fish mortalities took place, principally between 6th and 19th July 2003. Ocean Farms, Creevin Salmon Farm and Eany Fish Products all had smolt and growers sites in Inver Bay and all were involved in the mortality event. Ocean Farm sites in McSwyne's Bay were involved similarly at a slightly later date.

Signs of ill health began with a drop in feed intake at all sites followed by mortalities at 6-8 days later. After the peak mortality in week 29, mortalities continued over a prolonged period. Consistent clinical signs and gross and histological lesions were found in all cases indicating a common causation. Lesions principally involved the gills and oral cavities with varying degrees of acute gill pathology (haemorrhage and separation and oedema of epithelia) and areas of hyperplastic response. Gill necrosis and sloughing of tissues to expose cartilage was also increasingly seen. As the mortality episodes progressed, bacterial infections of the necrotic gill area and from time to time, epitheliocystis infection and some parasitic infections were also seen.

Areas of focal liver necrosis were also variably present.

A number of veterinary consultants visited sites and examined samples and included Dr McLoughlin of Aquatic Veterinary Services, scientists at the Fish Health Unit of the Marine Institute, Mr Dermot Sparrow, Dr Francis Scullion, Mr Leo Foyle and Dr Hamish Rodger of Vet-Aqua International, Mark Jones of the Fish Vet Group.

All veterinary consultants are of the opinion that the cause was an acute water-borne irritant probably present in weeks 26-27.

No evidence examined supports the likelihood of fish pathogens being the primary source of the mortalities. Histological analysis strongly supports the deaths being caused by a water quality problem with major lesions affecting the gills and to a lesser extent, the liver. During August, infection with Epitheliocystis became a complicating factor, but extensive primary gill damage during July appeared to be the primary lesion.

In addition to the lack of isolation or observation of fish pathogens associated with mortalities, the very acute nature of the losses would also not support the possibility of fish pathogens being a primary cause.

The nature of the gill pathology is certainly severe but not specific as to cause. The pathological responses seen in the gill are unusual with regard to the vessel lesions but a range of causes can produce such change. The liver pathology can be explained as due to anoxia secondary to the gill damage produced or possibly as a result of toxin damage (e.g. heavy metal or hydrogen sulphide toxicity).

Husbandry Practices and Discharge of Toxic Chemicals

These causes are unlikely as a number of sites with different management practices are involved and there is no evidence of toxic chemicals being used.

Application of treatment chemicals does not appear to have taken place at all sites.

Fish feed was ruled out as the cause as feed from four different companies was being used in the various farms affected.

Dr McLoughlin explains that the mortality pattern seen also implies pollution or toxicity. She also describes concisely the nature of development of the gill lesions and their effects on the host.

Differential diagnosis is described as a) algal bloom b) jellyfish c) release of material from the seabed or d) discharge of irritant from a point source.

Of particular significance is the information concerning water samples taken on 10/7/03 from the surface water which were black and had dense silt suspended in the water column. Thick deposits of mud/silt were found adhering to Ocean Farm smolt nets and dog fish fishermen reported their tangle nets to be fouled by a similar substance. A salmon drift net fisherman reported black sticky material on his salmon nets on the 7th and 9th July off Mullaghmore Head and a lobster fisherman reported similar residues on his lobster pot ropes off Doorin Point in mid-July and on his store pot off Port pier in Inver Bay. Other users in the bay reported a foul smell and black deposits in the water around the end of June. There was also some evidence of fishing activity at 2 points north east of Ocean Farms grower site and evidence of sole trawling close to, if not on top of the dump site since early June 2003.

Dr McLoughlin comments that the irritant must have originated in Donegal Bay and not locally in Inver Bay as an explanation of the effects in McSwyne's Bay.

There was no evidence of a freshwater source as a cause of the pathology.

Independent histological examination of all available microscope slides was subsequently undertaken by Professor Ferguson of the Institute of Aquaculture at Stirling (report of 10/1/06; Ferguson, 2006). The material was examined "blind" without detail of the background history involved. Professor Ferguson's analysis concurs with that of the veterinary surgeons reported above in that "There is little doubt that gill damage was the major cause of the problems seen, and in many fish would almost certainly have led to clinical disease and mortality". In samples taken up to July16th from Ocean Farm "pathological changes were most consistent with reduced water quality, with lamellar epithelial damage and lamellar vascular damage and thrombosis being at the root of the changes". Later changes at Eany and Creevin had

Epitheliocystis at the root of the gill damage – early damage to gills could have predisposed them to infection.

I have personally reviewed the slide material and agree with these findings.

Potential for algal or jellyfish blooms to be the cause of mortality

Algae can produce fish mortality in a number of ways. Certain species produce toxins which directly affect gill or liver function, others produce irritation and physical damage through their physical structure and it is also possible to produce death from anoxia during bloom respiration (usually at night) or during bloom die off and decay. Algal blooms generally develop during periods of calm weather and thermal stratification.

The possibility of an algal cause was discussed in the Marine Institute report of February 2004 (p 56-64) and is referred to in the McLoughlin report of July 2004. Extensive sampling was undertaken by the Marine Institute during June, July and August in the area of the fish kills. On p 63 of the report, the MI scientists conclude that "Water samples . . . showed a mixed population of diatoms and dinoflagellates, typical of midsummer phytoplankton in Irish coastal waters. The water samples showed **no evidence of a harmful algal bloom**."

Most species recorded were diatoms, which produce few toxins. Through if occurring in huge numbers diatoms may act as irritants the data, as reported, shows that they did not occur in large enough numbers to do so (KMM, 2004). No data or abundance or species composition of the samples analysed is given in the report.

The presence of certain algal species in the samples suggested some evidence of a degree of thermal stratification at the end of July/beginning of August but total algal numbers were low, there was no evidence of extensive bloom development which would have been apparent as red/green water discolouration and there was no evidence of major bloom die-off which would have been reflected as low oxygen measurements at the farm sites. Additionally, there were no mortalities evident in shore invertebrates which would have been expected had the cause of the farmed fish mortalities been related to a major algal bloom.

It has been suggested that the gill and mouth lesions are similar to those found in significant salmon mortalities at Deenish in the autumn of 2003, where the siphonophore, *Muggiaea atlantica* was identified as a possible cause. The Deenish fish showed similar but not identical pathology (KMM, 2004) to the fish in Inver Bay and McSwynes Bay. In addition, similar pathology was also observed in another fish kill caused by siphonophores in Norway. From this evidence, and lack of clear evidence for another cause, it was suggested that the fish mortalities in July 2003 were probably due to a siphonophore bloom (Cronin *et al*, 2004). This was backed up by the presence of *Muggiaea* in plankton samples collected in Donegal Bay in the summer of

2003, and in that the cleanest cages were the most affected by mortalities (allowing entry of the zooplankton). *Muggiaea* is small (~3 mm) and can be difficult to see with the naked eye when in low densities. Cronin *et al* (2004) states that "…. has been implicated in severe gill damage at relatively low concentrations", but gives no source for this information.

5. HARMFUL ALGAE OR JELLYFISH BLOOMS?

Preserved plankton samples collected in July and September 2003 have been used to estimate the maximum abundance of *Muggiaea* at 160/m^3 (Cronin *et al*, 2004). These numbers are not excessive and are well within previously recorded densities in this area (Aquafact, 2004). The suggestion of reduced filtering efficiency through use of a phytoplankton net (KMM, 2004) remains to be proved, and unlikely to cause an underestimate to the level of *Muggiaea* found in Norway. As in Norway, highest counts were found in Ireland (in Galway Bay) in the autumn – in September and November reaching approximately 200 individuals/m^3. In addition, this density is considerably lower than the abundances recorded at Deenish (470/m^3) and in Norway (~2000/m^3) during the previous incidents. It is argued, though, that limitations in the sampling procedure would have caused a significant under estimate in the counts of zooplankton (KMM, 2004), and that higher numbers of siphonophores may be related to a local incursion in Donegal Bay in early July 2003. McLoughlin (2004) also points out that there was a considerable temperature difference between Ireland (15^{o}C in July 2003) and Norway (20^{o}C in August/September). The Norwegian report also states "*Muggiaea atlantica* is a warm water species". There is some evidence for the possibility of an oceanic incursion or upwelling event in Inver Bay that could have brought numbers of organisms towards the shore (see Section 2), but this would have involved **cool** water at temperatures much lower than expected during the development of jellyfish blooms. This is important as increased temperatures often trigger blooms of planktonic organisms.

Numbers of *Muggiaea* found in Donegal Bay in July 2003, though towards the maximum levels normally found in Irish coastal waters (~200/m^2) (Aquafact, 2004), were an order of magnitude lower than those found in Norway during the fish kill, though the gill lesions appeared worse in Inver Bay than in Norway. This is surprising as *Muggiaea* is not a virulent stinger (Aquafact, 2004) suggesting that any impact by this siphonophore would be through gill-clogging, requiring densities of at least an order of magnitude higher than those found in Donegal Bay in July 2003 to effect the fish (Aquafact, 2004). Furthermore, *Muggiaea* is found around the Irish coast for the majority of the time and has never been recorded in very high numbers.

The possibility of *Muggiaea* being a cause at Deenish seems to be because of the lack of clear evidence of an alternative explanation though there was evidence of algal bloom in the area (McLoughlin 2003).

No siphonophore material was detected in skin and gill specimens obtained from dead fish in the Inver case (Aquafact 2004) or by histology where nematocyst remains would be expected. Lesions were not commonly found affecting external surfaces such as the eyes and skin.

The Marine Institute Investigations at Inver Bay and McSwyne's Bay revealed no external damage to the fish and empty intestinal tracts. Also in the Norwegian report, the respiratory epithelium was usually intact and eosinophilic granular cells were prominent in chronic cases. This contrasts with the Inver Bay case. Photographs of the histopathology from Donegal Bay examined by the Norwegian Veterinary Institute was evaluated as being "within the range observed in Norway, **but not typical**".

Page 69 of the MI report states that "jellyfish" were **not** noted at the time of the fish mortalities in Inver Bay but reports of stings and skin irritation were noted (M. Cronin, pers. comm. Quoted). Page 87 also refers to "reports of stings and skin irritation" in August (Seamus Hopkins, DCMNR, pers. comm.. quotes). Neither of the above personal communications made clear whether reference was made to affected people or fish and whether the stings were related to the presence of *Muggiaea atlantica* or another species. People and fish were stung in the Norwegian case.

The McLoughlin report (2003) further points out the lack of evidence for jellyfish causation:-

- Jellyfish not detected by feed-monitoring cameras (They would have been obvious had they been present in numbers likely to cause damage)

- There were no signs of irritation such as increased jumping. (The extreme irritation caused by jellyfish stings would have caused rapid, poorly coordinated swimming and jumping in an attempt to escape the irritation – this has been present during jellyfish damage experienced in Scotland also)

- Acute lesions continue over a prolonged period (which if due to jellyfish, would have required a prolonged high jellyfish population which would have been evident visually)

- Absence of prawns and wild fish after the event. (Such animals would physically move away from high concentrations of jellyfish but then return to repopulate the area when numbers decreased).

- Sludge on nets and oily deposits on lobster cages not explained.

- Eye and skin damage would be expected in addition to gill damage – this was not found.

In conclusion, there are arguments for and against the case for *Muggiaea* as being the causal agent in the salmon mortalities. While there is a precedent for siphonophore blooms causing salmon mortalities conditions (Norway and possibly Deenish), and some similarities between the established pathological symptoms of siphonophore blooms, there were also distinct differences. To obtain gill lesions of the severity of those at Inver Bay siphonophore densities in the region of those found in Norway (an order of magnitude higher than those found) would be expected. Neither fish farmers nor other users of the bay noticed any evidence of this (witness statements made to McCann etc). Water temperature was also an important factor. Though there was some evidence for an oceanic incursion or upwelling event that may have brought these organisms towards the shore, the water was cool and generally below that which would be expected jellyfish/siphonophore blooms to occur.

While siphonophores cannot be completely excluded as a cause of the salmon mortalities within McSwynes Bay and Inver Bay, the arguments for this are not convincing, relying on conjecture rather than empirical data. On the balance of probabilities, from the information available, siphonophores are unlikely to have been the cause of the fish mortalities.

6. CONCLUSIONS

Hydrographic and dispersion models indicated that the residual current flow of spoil dumped from Killybegs Harbour would have been primarily to the north-west or south-west, away from Inver Bay and McSwynes Bay. These were not validated using collected hydrographic data. The models used were inappropriate as they assumed that the water body was unstratified, which is clearly wrong, and more detailed information would have been obtained through more complex hydrodynamic modelling (e.g. using Delft 3D models). Wind and temperature variation will cause stratification in the summer in the locality concerned causing density front driving current to the NW and potentially cross density front currents driving water to the NE. Limited hydrographic data collected provides some evidence that under certain conditions both of these may occur. The hydrographic data were limited and should have been extended over a much longer period as they were only gathered over a very short period (1 tidal cycle). Drogue studies also show that there could be a water movement on the seabed and in mid water to both the NW and NE. Again the data is limited, but suggests that there is a mechanism for transport of material from the dumpsite towards the NE. In addition, the SEDPLUME-RW model may have had an introduced error in the sense that the oily/stick material from the harbour (as described by the EIA) may not have agglomerated rather than separated within the water as assumed by the model. This could be tested from materials still remaining within the Harbour which were not removed during dredging.

The hydrographic data at the dumpsite shows fairly dynamic conditions, contrary to the findings of the initial models. This is confirmed by observations of pre-dump sampling where the sediments and fauna found suggest significant water movement. This is also confirmed by the results from the post-dump surveys for biological metal analysis which show that dumped materials have clearly been moved from the dump site, presumably by water currents. The models used initially to estimate current flow and spread of dumped materials should clearly have been validated in light of this information.

There was some evidence for a localised coastal upwelling event immediately before the salmon mortalities. It is unknown whether the currents were strong enough to transport heavy particulate material towards the fish cages or to the surface. However, suspended material or neutrally buoyant material may be more influenced by these conditions. The density or settling velocity of the spoil from Killybegs Harbour is not reported, so it is unknown how this material would behave in low current conditions. Soluble substances may be transported from deeper waters.

The black sludge-like material analysed from the fishnets showed similar heavy metal levels to Killybegs Harbour sludge and was found to be principally organic in nature. Such oily, organic material would have a propensity to disperse rather than deposit, as it would naturally be more buoyant than other material dumped. Costello's report (2004) concludes that such material was no longer present at the dumpsite in samples taken 13-15 months post-dumping. Such material could certainly have accumulated near to the entrance of Inver and McSwyne's Bays and been moved into the proximity of the cages immediately prior to the mortality events. The material was no longer present in sufficient quantity to be remarked upon at later periods of investigation and could readily have been further dispersed.

Quantitative sediment surveys were of variable quality. However, the general trend of all results was that environmental impact of dumped spoil was confined to the centre of the dump area, and that recovery of the sediment environment largely took place very rapidly after dumping (within 20 days to 5 months). This suggests that spoil had largely moved from the dumpsite as if it had been incorporated into sediments there would have been much longer term impacts or longer lasting high metal residues within the dumping area. Bathymetric surveys suggest that there was little remaining dumped material in terms of depth to the sediment surface in the dump area 1 year after dumping. Video surveys confirm that there was little evidence of dumped spoil within the dumped area one year after dumping.

Sediments and water quality near to the spoil dumping site and within Mc Swynes Bay and Inver Bay were of acceptable quality. Video transects showed a healthy and mature benthic animal community living within the sediments near to the fish farms in McSwynes Bay, and "typically" effected sediments near to fish farms in Inver Bay. Heavy metal levels within sediments were elevated near to fish farms in Inver Bay, though not to actionable levels. This is typical for highly sulphur-reduced sediments such as those under fish farms, which create conditions conducive to metal accumulation. The source of these metals is unknown, though some (e.g. copper and zinc), but not all are likely come from addition of micronutrients to fish food or anti-foulants on nets.

The black "oily" material clogging some of the cages in McSwynes Bay contained high levels of organic carbon, hydrogen sulphide and certain metals, especially cadmium. The source of this was unclear. Potentially, sediments of this consistency could come from a highly polluted seabed beneath poorly managed fish cages. However, in this case surveys showed that sediments at these fish cages were healthy and unlikely to contain such elevated levels of cadmium unless from some external source. Therefore, where did the deposits come from, as there are few sources within this area of sediments with these characteristics? One report (WYG,????) concludes that the metal levels within this material were similar to those found in the dredged material from Killybegs Harbour, suggesting a link.

Further analysis of this oily sludge material was undertaken by the Nutrition Analytical Services of the Institute of Aquaculture, University of Stirling (report given as Appendix 1). Here the lipid profile in the black material was analysed and compared to control sediment from unimpacted seabed sediment collected from Mulroy Bay, Donegal. The first point to notice is that the lipid content of the test sample 45 times higher than the control sample suggesting significant lipid enrichment of the test sludge. The elevated levels of the monounsaturated fatty acids, 20:1n-9 and 22:1n-11 and of the long chain n-3 fatty acids, 20:5n-3 and 22:6n-3, confirms that there is enrichment with marine finfish products. Whether this has been due to fishery waste or aquafeed or waste feed is less easy to ascertain. **The only factor that might suggest wild fish over aquafeeds is the rather low level of 18:2n-6 in the test sludge.** This fatty acid is generally low in the marine ecosystem (0.5-2.0%) whereas fish feeds, due to them containing significant terrestrial products, tend to be in the range 2.5-8.0.

There was no absolute or direct evidence that the spoil dumped from Killybegs Harbour caused the salmon mortalities. However, there is considerable evidence to show that the initial impact assessment through models was flawed and should have been validated either at the time of in light of further findings. There is also clear evidence that there is a mechanism where light spoil or liberated metals from oxidized spoil could have been transported towards Inver Bay and McSwynes Bay. Clearly, the spoil has been widely distributed from the original dumping site, whether at the time of dumping or afterwards is unknown (probably a combination of the two). On the balance of probabilities from the information presented, it is likely that material was transported towards Inver and McSwynes Bay. It is, however, impossible to calculate the quantity of material that was transported in this direction.

Summary of overall findings:

1. The fish died from an acute gill effect related to a water quality incident. There is no evidence of a primary fish pathogen and an algal bloom or jellyfish/siphonophore affects are highly unlikely. There is no evidence of a husbandry or treatment based causation of the mortalities. There is evidence of a suspended solids problem which does not appear to have been generated from the sediments beneath the fish farms.

2. There is evidence of rapid dispersal of sludge from the dumpsite. Modelling carried out at the dump site was flawed and did not indicate that this was likely. Initial monitoring and modelling suggested water flow in an anticlockwise direction away from the fish farms. There is a clear mechanism for flow in an E-NE direction towards the fish farms.

3. Analysis of the oily materials adhering to the nets at the time of the mortalities suggests a link to the material from Killybegs harbour. The most likely explanation for its presence is dispersal from the dumpsite and sudden appearance at the fish farms linked to an upwelling event. This material is likely to be representative of the suspended materials leading to acute gill pathology.

4. On the balance of probabilities, contamination of the fish farm environment with material from the dumpsite is the likely cause of the mortalities. The monitoring and modelling carried out prior to and following dumping materials from Killybegs harbour was deficient in many respects. Lack of availability of reports and raw data prevents a more detailed investigation of the events surrounding the losses in Inver Bay and McSwyne's Bay in 2003.

Areas of concern

There are a number of concerns within the data and information given. These are:

1. McLoughlin (2003) suggests jellyfish would have been detected by feed monitoring cameras. Though this is generally true *Muggiaea atlantica* is small (c. 2 mm) and only just visible to the naked eye. Some feeding cameras can detect particles (2 mm pellets) of this size but we don't know the resolution available in the Inver Bay case – this should be checked. Had very large numbers of organisms been present (suggested as being necessary if *Muggiaea* is not considered a virulent "stinger") then an affect on water quality should have been evident on camera.

2. McLoughlin (2003) also suggests that prawns and wild fish would move away from high concentrations of jellyfish. Whilst this would be true of fish, prawns would be unlikely to move great distances and would tend to remain in the area of their "burrows". Perhaps they would remain in burrows to avoid the jellyfish and then re-emerge. A prawn expert should be consulted.

3. Cronin *et al* (2004) argue that their estimation of *Muggiaea* numbers may be an under-estimate. However, we have factors which act against this – typical situation in Ireland, temperature, season, lack of nematocysts in fish samples.

4. No proof of effect on shellfish operations.

5. We don't have direct measurements of sludge in the water body or remaining behind after the mortality event? Sampling was not carried out. What about SPI survey August 2003? [No conclusive evidence – checked, TCT] Any remaining material could have been flushed out in a winter storm – climatic conditions after the event need checking for this possibility.

6. McLoughlin suggests acute histological lesions continued over a long period and would suggest the cause outlived the life of a bloom. The same argument could be applied against a one-off incursion of sludge which rapidly disappeared. In fact, secondary effects, such as bacterial or epitheliocystis infection, could have produced the acute lesions seen at the later stages. There is evidence of an acute effect just before the initial dramatic mortalities followed by a range of secondary effects over a prolonged period.

APPENDIX 1

FAME and lipid analysis of “oily” material sample from nets

UNIVERSITY OF STIRLING

Nutrition Analytical Service
Institute of Aquaculture
University of Stirling
Stirling FK9 4LA
Scotland, UK.

Analysis:
FAME AND LIPID CONTENT

Prepared for:
Prof.R.Richards
Institute of Aquaculture
University of Stirling
Stirling

Compiled by:
Dr Gordon Bell
NAS
Institute of Aquaculture
University of Stirling
Stirling
FK9 4LA

Contract number: RHR 1

Date: 22/9/06

Nutrition Analytical Service, Institute of Aquaculture
University of Stirling, Stirling FK9 4LA Scotland, UK
Telephone: +44(0)1786 467930
Facsimile: +44(0)1786 472133

Customer name:	Prof.R H Richards	**PO number:**		TBC
Date:	22/9/06	**No. of samples:**		1
Analysis performed:	Total Lipid and FAME	**Sample type:**		Sediment
Analyst:	Jim Henderson/James Dick			
		Equipment no:		GLC 6
		Column:		ZB Wax 60mt
Certificate ref. no:	RHR 1	**Injector:**		On column
		Carrier Gas:		Hydrogen
		Temp Prog.	**TEMP. (^{o}C)**	**Rate (^{o}C/min.)**
		1	50	40
		2	150	2
		3	230	

Lipid content (% dry weight) of sediment material.

Test	12.69
Control	0.28

Analyst Signature

Approved

Date

	% total fatty acids		ug FA / mg lipid		mg FA / 100g material	
	Test	**Control**	**Test**	**Control**	**Test**	**Control**
14:0	8.2	4.4	50.2	6.9	636.9	2.0
15:0 br	1.3	2.1	8.6	2.7	108.6	0.8
15:0	0.9	1.1	6.2	1.7	79.0	0.5
16:0 br	0.2	0.3	1.2	0.4	14.9	0.1
16:0	27.2	29.6	168.5	44.1	2137.9	12.9
17:0 br	0.9	1.7	5.1	2.2	64.1	0.6
17:0	1.1	1.1	_	_	_	_
i-18:0	0.3	0.2	1.6	0.2	19.7	0.1
18:0	7.8	19.3	48.3	26.1	612.2	7.4
19:0	0.7	0.3	4.7	0.4	59.2	0.1
20:0	0.7	1.2	3.9	1.5	49.4	0.4
22:0	0.6	2.1	3.5	2.7	44.5	0.8
23:0	0.0	0.2	0.0	0.2	0.0	0.1
24.0	0.3	1.0	2.3	1.3	29.6	0.4
Total saturated	50.3	64.4	303.9	90.4	3856.1	26.2
14:1	0.2	0.2	1.6	0.3	19.7	0.1
16:1n-9	0.3	1.5	1.6	2.4	19.7	0.7
16:1n-7	5.8	3.9	36.6	5.2	464.2	1.5
i-17:1	0.4	0.3	3.1	0.5	39.5	0.1
17:1	0.6	0.8	3.1	1.2	39.5	0.3
18:1n-9	8.1	16.1	50.2	24.7	636.8	7.3
18:1n-7	5.5	4.3	33.5	6.0	424.6	1.7
20:1n-11	0.6	0.0	3.5	0.0	44.4	0.0
20:1n-9	3.5	0.7	21.8	1.1	276.5	0.3
20:1n-7	0.8	0.2	4.7	0.2	59.2	0.1
22:1n-11	3.8	0.3	23.0	0.4	291.2	0.1
22:1n-9	0.6	0.1	3.9	0.2	49.4	0.0
24:1n-9	1.4	0.2	8.6	0.2	108.6	0.1
Total monounsaturated	31.6	28.6	195.0	42.2	2473.3	12.3
18:2n-6	1.9	2.3	11.7	3.3	148.1	1.0
18:3n-6	0.4	0.1	2.3	0.1	29.6	0.0
20:2n-6	0.6	0.2	3.1	0.3	39.5	0.1
20:3n-6	0.3	0.1	1.6	0.2	19.7	0.0
20:4n-6	0.8	1.0	4.7	1.3	59.2	0.4
22:5n-6	0.9	0.1	5.4	0.1	69.1	0.0
Total n-6 PUFA	4.9	3.7	28.8	5.2	365.3	1.5
18:3n-3	0.7	0.8	4.3	1.1	54.4	0.3
18:4n-3	0.4	0.1	2.7	0.2	34.6	0.0
20:3n-3	0.1	0.1	0.8	0.2	9.9	0.0
20:4n-3	0.4	0.0	2.3	0.0	29.6	0.0
20:5n-3	1.7	1.2	10.1	1.6	128.4	0.4
22:5n-3	0.6	0.2	3.9	0.3	49.4	0.1
22:6n-3	2.4	0.9	14.4	1.3	182.6	0.4
Total n-3 PUFA	6.3	3.3	38.5	4.6	488.8	1.3
16:2	0.7	0.0	4.7	0.0	59.2	0.0
16:3	0.2	0.0	1.5	0.0	19.9	0.0
16:4	0.1	0.0	0.8	0.0	9.9	0.0
	1.0	0.0	7.0	0.0	89.0	0.0
Total PUFA	13.3	7.0	80.9	9.9	1027.0	2.8
C20 unidentified	4.8	0.0	29.6	0.0	375.2	0.0
C22 unidentified	1.1	0.1	6.6	0.1	83.9	0.0
Total	100.0	100.0	609.4	142.5	7731.6	41.3

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5. Standard operating procedures for all laboratory techniques.
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