A PRELIMINARY REVIEW OF CHEMICAL AND PHYSICAL DATA FOR Y2000 INTERIM MONITORING PROGRAM

JULY, 2001

By

Lloyd Erickson, James Dalby, Bernie Taekema, and Eric McGreer

FOREWORD

Development of Performance Based Waste Management Standards

In October of 1999, the provincial government announced a new policy framework for the management of the salmon aquaculture industry. This framework was designed to address a number of issues identified in the 1997 Environmental Assessment Office comprehensive study of the salmon aquaculture industry.

The new policy framework focussed on 5 key issues:

- Development of performance based waste management standards;
- Reduction of escapes from salmon farms;
- Pilot projects to test new closed containment and other green technology;
- Development of fish health monitoring and reporting system; and
- Relocation of poorly sited farms without expanding the number of sites.

With regards to waste management standards, the government agreed to move from the existing input based regulations to establishing performance-based standards. Based on these new standards, the industry would be allowed to manage their aquaculture operations to maximize the production while ensuring the assimilative capacity of the surrounding area is not unduly affected.

The concept was to develop a set of chemical and physical indicators that could be used to determine the health of the benthic community (bottom b dwelling organisms). These indicators would then be used as standards to ensure that there are no significant long-term changes to the benthic communities within the vicinity of the salmon aquaculture operation compared to background levels in the general area. The government did not have sufficient information for determining the relationship between benthic community health and the chemical and physical indicators. Therefore, in the spring of 2000 the industry was required to undertake an extensive monitoring program designed to collect a set of chemical and physical data from all existing salmon farming locations. Samples were also collected at control station(s) in the area to determine the background data levels that might exist in the areas. Data collection and monitoring was also conducted by staff of the Ministry of Water, Land and Air Protection.

In addition, in the summer of 2000, the industry undertook a comprehensive study of the benthic communities in a number of representative areas. The data from the detailed benthic studies would be examined in order to establish a relationship between the chemical and physical indicators and the health of the benthic community.

A technical advisory group (TAG) was established with representatives of both the provincial and federal government and the salmon aquaculture industry to assist in the development of the year 2000 monitoring program. TAG is now assisting in review of the year 2000 monitoring data and TAG will help guide the development of the performance based standards.

A draft report on the detailed focus studies was provided by the consultants in July 2001 and is currently being reviewed by the technical staff in both government agencies and industry. The

technical team is scheduled to meet in September 2001 to review the results of the sampling program and the benthic analysis. The working group will focus on what the next steps are required in order to develop the new performance based standards.

The results of the first round of chemical and physical sampling data collected by industry and government were collated by staff from the Ministry of Water, Land and Air Protection in May 2001 and are summarized in the report entitled" A Preliminary Review of Chemical and Physical Data for Y2000 Interim Monitoring Program" attached. Statistical analysis of the data has not been completed nor has the farm site data been fully evaluated against the control point sampling data. The results of the Preliminary Analysis will be however be used to establish monitoring priorities for Y2001, to pinpoint areas where operational practices can be improved and in confirming sites where relocation is desirable.

It is important to recognize that information collected in this initial sampling program and the chemical thresholds used in the Preliminary Analysis may not necessarily reflect the final requirements of the new performance based standards. Until the physical and chemical data are evaluated with the benthic sampling program it is not possible to draw any conclusions regarding the impact of any individual farm operation. This is simply the first step in a program designed to guide the development of standards. The information will also be used in the development of simulation models that will guide the industry in new siting decisions.

Bud Graham
Assistant Deputy Minister
Fisheries and Aquaculture Division
Ministry of Agriculture, Food and Fisheries

Dick Roberts
A/ Assistant Deputy Minister
Regional Operations
Ministry of Water, Land and Air Protection

A PRELIMINARY REVIEW OF CHEMICAL AND PHYSICAL DATA FOR Y2000 INTERIM MONITORING PROGRAM JULY, 2001

By: Lloyd Erickson, James Dalby, Bernie Taekema, and Eric McGreer

Summary

- This is a preliminary review of a large volume of physical, chemical monitoring data and video survey records for 94 fishfarm sites for the year 2000 (Y2000).
- Statistical analysis and other on-going work are yet to be completed and included to complete the review.
- Chemical thresholds were chosen for the discrete function of sorting sites into categories for use in discussion with industry and in establishing priorities for year 2001 monitoring.
- These thresholds were **not** derived as scientifically defensible objectives, protective of the environment. However, the descriptions of the categories are reasonable, since the thresholds are higher than published toxicity levels, and were supported by other data.
- Concentrations observed at reference stations were taken into consideration but not yet compared in a statistical manner.
- Where available, data collected by the Ministry of Water, Land and Air Protection (WLAP) were used to assist in the evaluation.
- Biological data are required to confirm impacts on the benthic communities.
- A report on an industry Focused Study, to determine the relationship between the physical and chemical measures and the biological response, is not yet complete therefore this review does not include results of the Focused Study.

Introduction

Rapid growth of the salmon aquaculture industry in the 1980s was accompanied by increasing public concerns about its impact on the marine environment and on other coastal users. The Salmon Aquaculture Review (EAO 1997) recommended the development of a regulation that implements a Performance Based Waste Management Model. Standards in this regulation would replace the existing input based controls in the *Aquaculture Waste Control Regulation*. Until the regulation is amended, fishfarms in British Columbia continue to be regulated according to the existing regulation and other controls under the *Waste Management Act.*

Purpose

This document summarizes an overview or review conducted by WLAP of the chemical and physical data collected for the Interim Monitoring program. The purposes for the review were:

1. To determine whether potential environmental impacts could be identified so that government and industry could pro-actively work towards improvements.
2. To identify priorities for ministry monitoring and inspection programs in Y2001.
3. To identify sites that may have impacts that might not be suitable for fishfarms and propose candidates for relocation.
4. To review site specific information to address recommendations for industry monitoring in Y2001.

The results of this review have been shared with the salmon farming industry, and it is the intention of this document to inform agency managers, the Salmon Aquaculture Implementation Committee, and other interested parties both our results and the background leading to them.

Background

In March 2000, the Vancouver Island Regional Waste Manager required salmon aquaculture companies to conduct an *Aquaculture Information Request and Interim Monitoring Program* at all fishfarm sites. This was slightly modified in a letter in May 2000. The May 19 amalgamation of the March request and May revision are noted in Attachment 1. The purpose of the request was to gather operational information on individual fish farms, gather environmental data regarding potential impacts, and to determine whether chemical parameters could be used as an indirect measure of the health of the seafloor communities. Physical and chemical characteristics in the sediments were measured, or where grab samples could not be collected, a video survey was conducted. Also, a Focused Study at 6 fishfarm sites was conducted by the industry to determine the response of bottom-dwelling organisms to changes in the physicochemical parameters. These initiatives were conducted in support of the development of new performance-based standards.

The measurement of physicochemical characteristics and determination of their relationship with the health of sediment communities are important steps in the development of a performance-based standard. The existing regulation provides constraints to fishfarms based on the amount of feed used. By contrast, performance based standards would regulate fishfarms based on effects on the environment, or health of the seafloor communities.

Experience in other jurisdictions indicated that chemical measurements might be more amenable as a regulatory tool due to more rapid and economical analysis and reporting, compared to taxonomic identification of seafloor communities. Indications from other jurisdictions are that biological analysis should be done if chemical triggers are exceeded.

The approach to developing performance-based standards includes examination of tools used in other jurisdictions. The interim monitoring program measured total volatile solids (TVS), sediment free sulphide ($S^{=}$), oxidation-reduction potential (ORP), sediment grain size (SGS), and pH. In addition, zinc (Zn) and copper (Cu) analyses were required based on findings of increased levels of these chemicals associated with fishfarms in the Broughton area (Deniseger & Erickson 1998).

Industry provided Y2000 chemical and physical data, and video survey records to WLAP. However, at the time of this review, all biological data were not available so it was not currently possible to determine environmental impacts to the benthic communities.

To address the purpose of this review, the results of the preliminary review of environmental data were compiled in a report to inform industry about the possible effects on the environment. The categories “acceptable”, “potentially impacted” and “probably impacted” were used. Report cards for sites in the latter two categories are included in Attachment 2. Subsequently, meetings were arranged with all fishfarms to discuss compliance, discuss mitigation approaches when required and establish monitoring programs for Y2001. Results will also be input to the relocation process.

Methods

Interim monitoring data analysis.

The principle purpose for collecting sediment chemistry data was to determine whether it could be used to predict health of seafloor communities. This hypothesis could not be tested because the required biological data had yet to be analysed. This is on going. Similarly, comparisons with feed usage, production, or current velocities could not be tested due to lack of supporting information.

A common procedure used by the Pollution Prevention program to determine compliance is whether a regulatory threshold was exceeded. The term "exceedances" is used by WLAP to describe such conditions. Since such thresholds have not yet been set for the performance-based standards, some very high thresholds of sediment free sulphides were chosen for a quick screening tool. The results of this quick screening prompted a review for corroborative data. Concentrations observed in reference stations were taken into consideration, although they were not yet compared in a statistical manner. This was developed into a ranking approach, which was applied to the entire data set. Although the principal parameter used for the initial screening was sediment free sulphides, the review of additional chemical information (e.g. redox potential) suggested that various combinations of factors warranted including some sites in the "potentially impacted" category. Where available, data collected by the ministry was used to assist in the evaluation. The results of this ranking process were provided to individual aquaculture companies in a report using the descriptive categories "acceptable", "potentially impacted", and "probably impacted".

It is important to note that the sediment free sulphide thresholds were **not** derived as scientifically defensible objectives, protective of the environment. These thresholds were chosen for the discrete function of sorting data; however, the descriptions of the categories are reasonable since the sulphide thresholds are higher than published toxicity levels and were supported by other chemical data.

The sulphide threshold for the "probably impacted" category was 1500 micromoles of sulphide at a distance from the pens of 30 meters or greater. Supporting evidence included low ORP (less than 0 mV), and measurements of zinc or copper that exceeded thresholds (270 and 108 μg/g dry wt respectively) and field observations.

The "potentially impacted" threshold was 600 micromoles of sulphide at a distance from the pens of 30 meters or greater. Corroborative evidence included low ORP (less than 0 mV), exceedances of zinc or copper criteria (BC 1995), and field observations.

Video surveys were conducted at sites where sediment grabs could not be completed. The video surveys were reviewed for the presence of waste feed, fish faeces and the presence of *Beggiotoa* mats. In addition, videos were also reviewed for lost nets, feed bags, or other fish farm originating refuse. The *Waste Management Act* prohibits the introduction of all industrial waste or litter into the environment, without authority of a permit or regulation. Evidence of litter or industrial waste on the bottom was also utilised to identify potentially impacted sites. Notes from the video operator or consultant were also reviewed. Additional video surveys are currently being reviewed and technical protocols for conducting video surveys in support of performance-based standards are currently being discussed.

Results

Environmental monitoring data were submitted for 94 fishfarm sites. Video surveys were conducted at 29 of those sites (31%).

Fifty (50) farms were classified as “acceptable”.

Twenty six (26) sites exceeded the ranking criteria to be classified as “potentially impacted” based on sediment samples. In 22 cases, the sulphide levels exceeded 600 micromoles. In most of those cases (19/22) the ORP was less than –50 mV; in fact, the “potentially impacted” sites had a similar range of ORP measurements as was found at the “probably impacted” sites. In 4 cases, the reference sites had highly negative ORP which had to be considered. In 2 cases, sites were classified as “potentially impacted” based on highly negative ORP plus sediment zinc concentrations exceeding the provincial criteria. In an additional 7 sites, (all exceeding the sulphide threshold) sediment zinc concentrations exceeded the provincial criteria. The sediment copper criterion was exceeded at 3 sites.

Four (4) sites were classified as “potentially impacted” based on evidence solely from video surveys, including waste feed, feed bags, and other debris. (Note: 12 sites had both video and grab sample data.) A single (1) site also had elevated zinc values and ‘synthetic lines”.

Table 1: Potentially Impacted Sites

Sediment free Sulphide $S^{=}$>600 µmoles	ORP 0 mV	Zinc (Zn) 271 µg/g	Copper (Cu) 108 µg/g	Video Tape
22 sites	22 sites	9 sites	3 sites	5 sites

Table 2: Potential Problems at the Sites

Parameters	Number of Sites
Sediment free Sulphide, Oxidation Reduction Potential Zinc and Copper	3 sites
Sediment free Sulphide, Oxidation Reduction Potential and Zinc (Zn)	2 sites
Sediment free Sulphide and Oxidation Reduction Potential	14 sites
Sediment free Sulphide and Zinc	1 site
Oxidation Reduction Potential and Zinc	2 sites
Oxidation Reduction Potential	1 site
Zinc and video	1 site
Sediment free Sulphide	2 sites
Debris on bottom	4 sites

Fourteen (14) fish farm sites were classified as “probably impacted” based on sediment free sulphide measurements greater than 1500 micromoles. Within the data set, 6 sites measured concentrations in at least one replicate that exceeded 5000 micromoles. Every site where sulphide measurements exceeded the threshold, low ORP measurements (less than –50 mV) was also found. However, in 4 cases, low ORP was also found at reference sites and was taken into consideration. At 8 sites sediment zinc concentrations at the edge of the footprint

exceeded provincial criteria. Sediment copper concentrations exceeded the provincial criteria at only 1 site.

Table 3: Probably Impacted Sites

Sediment free Sulphide $S^{=}$>1500 µmoles	ORP 0 mV	Zinc (Zn) 271 µg/g	Copper (Cu) 108 µg/g
14 sites	14 sites	8 sites	1 site

Table 4: Probable Problems at the Sites

Parameters	Number of Sites
Sediment free Sulphide, Oxidation Reduction Potential Zinc and Copper	1 site
Sediment free Sulphide, Oxidation Reduction Potential and Zinc (Zn)	7 sites
Sediment free Sulphide and Oxidation Reduction Potential	6 sites

Discussion

The changes in marine sediment chemistry and infaunal communities under conditions of excessive organic loading are well known. As organic materials begin to decay they consume oxygen. After aerobic bacteria deplete oxygen, sulphide production occurs by anaerobic sulphate-reducing bacteria. The resultant anoxic sediments are black in colour, and have an odour of hydrogen sulphide. Anoxic sediments are characterised by high sediment free sulphides and negative oxidation-reduction potential (ORP).

The field sampling protocols specified sampling at defined distances from the edge of the netpens; 0 m, 30 m, and 100 m. Furthermore, these are measured "upstream" or "downstream" of the net pens, aligned with the dominant current directions.

The *Waste Management Act* recognises an initial dilution zone (100 m) when dealing with point source industrial discharges. However, net pens are considered to be diffuse sources (or "non-point" sources) and discussions have entertained setting standards at 30 m or 100 m; therefore, observations at these distances have been applied in the sorting process.

The province is working with Fisheries and Oceans Canada to attempt to harmonize approaches to regulation and specifically what may be considered harmful alteration or destruction of fish habitat.

Hydrogen sulphide (H_2S) is a toxic material for which water quality standards have been applied. The US Environmental Protection Agency criterion for marine **water** is 2 µg/L of undissociated H_2S. At pH 8.0, typical of seawater, approximately 9% of sulphide is in the form of H_2S. Wang and Chapman (1999) have reviewed sulphide toxicity to marine invertebrates and show toxicity measurements varying from 6 to 153 micromoles total sulphides for amphipods, and 169 to 470 micromoles total sulphides for polychaetes.

Benthic invertebrate communities may respond differently due to adaptation. It can be inferred that where sediment sulphides exceed 600 micromoles that the invertebrate communities may not contain all the same species as found at reference sites.

Changes in abundance or diversity cannot be predicted, and will be a topic for the Focused Study.

Brooks (2000c) reports data from 30 reference sites showing mean background total sulphides of 159 micromoles, with a 90% confidence interval of ±281 micromoles. The highest values were found in sediments with 30 to 53% silt and clay. This data indicates high existing natural sulphide concentration and high natural variability. Future standards may need to take into consideration the characteristics of background concentrations associated with reference sites for each farm.

The total sulphides measurement protocol, adapted from Hargrave et al (1995), uses an ion specific electrode. The calibration procedures for use of this electrode are complex, and must be repeated every 2 hours to avoid measurement error. The addition of preservatives to the sediment sample provides an additional potential point for error. Our review of the sulphides data showed considerable variability, and there was insufficient information to determine whether this variability was due to the methods or to real variability in the sediments.

Oxidation-reduction potential (ORP) was a significant parameter used to confirm that sediments had become anoxic. Negative ORP values less than 0 mV are anoxic, and sediments with highly negative ORP (-150 to –200) may be depauperate of benthic invertebrates. In all cases where sulphides exceeded 1500 micromoles the ORP was less than –50 mV, and in many cases ORP was highly negative (-150 to –200) when sulphides were between 600 and 1500 micromoles.

Total volatile solids (TVS), also called Total Volatile Residues (TVR) or Loss on Ignition (LOI), has been recommended by Brooks (2000a) for the standard rather than Total Organic Carbon (TOC) which is the standard for Washington State's salmon farm regulation. TVSs are essentially the difference in weight between dried and ashed material after ignition, and are considered the organic fraction of sediment samples. TOC must be measured in a laboratory, but TVS analysis can be done on site, allowing the operator quick feedback of environmental conditions. However, TVSs are not directly toxic and the relationship with the presence of toxic compounds such as H_2S and species diversity (i.e. use as an indicator) has not been established. It is expected that results from the Focused Study will provide further clarification.

The approach regarding thresholds for zinc and copper, that is, using the Provincial Water Quality sediment criteria, is a different approach. These criteria include a "safety factor" to protect aquatic organisms and are considered to be a non-toxic level.
Zinc was chosen because previous sampling (Deniseger and Erickson 1998) showed significant zinc levels in sediments associated with fish farms. Subsequent review determined that zinc sulphate was added to fish feed as a preventative measure for cataracts. The British Columbia Salmon Farmers Association have informed the Regional Manager that their members have now changed the formula for the zinc additive to zinc methionine. Brooks (2000b) noted that this new formula is assimilated very quickly in association with sediment remediation. However, the high zinc values found in this study indicate that zinc should continue to be monitored.

The probable source of copper in sediments is from the anti-foulant coating put onto the nets. It is possible that the copper observed in sediments was released when the nets were washed (or it may be from ablation of the paint as it ages and flakes off the nets). The question needs

further investigation and different management practices might be required. Investigation of the relative rate of copper assimilation and sediment remediation is also required.

On the basis of the exceedances of sulphide or ORP criteria or observations of the colour and odour of the sediments, it appears that all of the fish farms that received "probably impacted" or "potentially impacted" rating had anoxic sediments extending to at least 30 meters. This applied to 39 of the 77 fish farms where sediment monitoring occurred using grab samples.

It is anticipated that the future regulation will specify a different statistical approach to test the chemical data. Further work towards development of performance based standards awaits review of the Focused Studies.

References

BC 1995. Approved and Working Criteria for Water Quality. British Columbia Water Quality Branch Environmental Protection Department. Ministry of Environment Lands and Parks.

Brooks, K.M. 2000a. Background and Recommended Protocols for British Columbia Focused Salmon Farm Studies in 2000. Submitted to the Technical Advisory Group formed by the British Columbia Ministry of Environment Lands and Parks. 24pp.

Brooks, K.M. 2000b. Sediment concentrations of zinc near salmon farms in British Columbia, Canada during the period June through August, 2000. Submitted to the Technical Advisory Group formed by the British Columbia Ministry of Environment Lands and Parks. 15 pp.

Brooks, K.M. 2000c. Recommended Interim Sediment Quality Guidelines for evaluating the environmental response to marine Neptune culture operations. Submitted to the Technical Advisory Group formed by the British Columbia Ministry of Environment Lands and Parks. 11pp.

Deniseger, H.J. and L.J. Erickson 1998. Salmon Aquaculture in the Broughton Archipelago-The Results of a Sediment Sampling Program –1996/97—A Data Report. British Columbia Ministry of Environment Lands and Parks, Pollution Prevention and Pesticides Program.

Environmental Assessment Office 1997. Salmon Aquaculture Review. British Columbia Environmental Assessment Office

Hargrave, B.T., G.A. Philips, L.I. Doucette, M.J. White, T.G. Milligan, D.J. Wildish, and R.E. Cranston. 1995. Biogeochemcial Observations to Assess Benthic Impacts of Organic Enrichment from Marine Aquaculture in the Western Isles Region of the Bay of Fundy, 1994, Canadian Technical Report of Fisheries and Aquatic Sciences 2062. 159pp.

Wang, F. and P.M. Chapman. 1999. Biological Implications of Sulphide in Sediment –A Review Focusing on Sediment Toxicity. Environmental Toxicology and Chemistry, Vol. 18(11), pp.2526-2532.

Attachments:

Attachment 1:

Aquaculture Information Request and Imterim Monitoring Program
May 29, 2000 amalgamation with amendment.
Includes appendices for sampling protocols

AQUACULTURE INFORMATION REQUEST AND INTERIM MONITORING PROGRAM

This is the May 29, 2000 amalgamation of the original Aquaculture Information Request and Interim Monitoring Program document, dated March 14, 2000, and its May 16, 2000 amendment document.

Introduction

The Government of British Columbia has accepted the Salmon Aquaculture Review recommendation to change the regulatory framework for managing fish farm wastes from the existing "input based" regulations to "performance based" or effects based regulations. The enclosed requirements will bridge the regulatory processes during the transition period.

This information request is consistent with existing requirements within the *Aquaculture Waste Control Regulation*. However, the monitoring program (as determined by the Regional Waste Manager) adopts the performance based management strategy outlined in
the "Salmon Farm Waste Accumulation Monitoring" program of the Sectoral Strategy Framework.

The performance based strategy is based on the following principles:

- Chemical and physical triggers may act as reliable indicators to determine the health of benthic communities;
- If bottom characteristics preclude sediment sampling, a photographic survey will be conducted;
- Standards will be designed to ensure there are no significant changes to benthic infaunal communities within the vicinity of the salmon farm compared to background levels; and
- Farms which have exceeded the environment's assimilative capacity will be required to implement remedial measures.

The interim monitoring program is designed to provide the necessary information with which to meet government's commitment to protect the environment and to provide information for use in developing final performance based standards. Such information will assist in maintaining the long-term viability of the industry.

At the present time government does not have sufficient information for determining the correlation between benthic community health and the chemical indicators identified in the Sectoral Strategy. A number of focused studies are planned for the summer of year 2000 which will include intensive monitoring in order to provide the necessary

information to establish the relationship between chemical and physical indicators and the health of benthic communities. Information collected through the interim monitoring program will support this initiative and at the same time provide information on existing environmental conditions at farm sites.

It is intended that environmental performance will be evaluated against interim performance based standards which are currently under development. Industry and other stakeholder input will be considered during the development of the interim standards.

Information submitted will be input into a database shared between British Columbia Assets and Land Corporation (BCAL), the Ministry of Environment, Lands and Parks (MELP) and the Ministry of Agriculture, Fisheries and Food (MAFF). MELP has committed to manage the incoming information.

Release of information will be subject to the provisions of the *Freedom of Information and Protection of Privacy Act* and is potentially releasable under this *Act*. Companies are requested to indicate which information they feel would be considered harmful to their interests if disclosed. If a company wishes some parts of information supplied to be maintained confidential, they must make a special notation and the Regional Waste Manager will consult with the Freedom of Information Commissioner. The company will be given an opportunity to provide evidence why the information should remain confidential. Adjudication by the Freedom of Information Commissioner will be requested to guide government regarding the release of this information.

These requests will require a number of submissions of information or data collected over a period of time. Each submission should clearly be identified in the head of the cover page with the following information:

- BCAL or Lands Branch file number;
- Legal name of company or licensee;
- Common name for the farm or site; and
- Contact name and telephone number for a person responsible for the submission.

Information from the interim monitoring program will be used to support the development of the performance based standards. In addition, this information will facilitate decisions regarding site remediation and/or relocation and will aid development of facility siting criteria.

It must be noted that the interim monitoring program (e.g. parameters, sampling locations) and other criteria specified in the interim monitoring program are not necessarily reflective of what may be required in the final regulatory requirements.

For existing tenures, if the site is not presently stocked with fish and the farm owner confirms in writing that the site will not be restocked, then the owner is relieved from the **Aquaculture Information Request and Interim Monitoring Program** requirement.

1.0 Materials Handling Information

1.1 Rationale

This information is required by the existing *Aquaculture Waste Control Regulation*. Information will provide guidance to MELP for receiving environment monitoring criteria, as well as aid in the development of proposed farm management practices.

1.2 Requirements

Record the following information monthly and submit quarterly, to the Regional Waste Manager, within 90 days of the date of this order or permit amendment and quarterly thereafter:

- Feed type, brand and dry weight [kg] used;
- Additives to the feed; such as, zinc, antibiotics or pesticides [Zn as % of total feed by weight; antibiotics and pesticides as total weight active ingredient];
- The total number of fish on site and commencing with the second report, the number of fish added or removed from the site subsequent to those previously reported;
- Estimated biomass of fish at the beginning and end of each month [kg]; and feed conversion ratio (FCR); and
- Number and biomass of mortalities [kg].

Note: all data for 1999 must be submitted. You may contact MELP (250-751-3100) to confirm your data has been received.

2.0 Annual Operating Parameters

2.1 Rationale

This information is required by existing regulation (as noted in Section 1.1).

2.2 Requirements

The following must be reported annually, no later than with the first quarterly report. Submit the following information, to the Regional Waste Manager, within 90 days of the date of this order or permit amendment:

- Mortalities disposal information: location and method for temporary storage at the farm, method of disposal, location of disposal, name of contractor for disposal, phone number of contractor or other person responsible for disposal (location of storage put on the site characteristics map);
- Contingency plan for handling a major fish kill and the mortalities resulting;
- Description of sewage disposal facility, method of treatment, location and depth of outfall (put location on map);
- Quantity of other materials used on site such as disinfectants, anaesthetics, cleaning agents, net cleaning agents, wood preservatives, antifoulants, mort ensilaging chemicals or petroleum products;
- Storage and handling information for feed and other materials (as noted above) and disposal practices where applicable;
- Information regarding the handling and disposal of solid wastes such as feed bags, municipal type refuse and other discarded materials;
- How the feed is applied (by hand or automated; if automated, note method of dispersion such as air driven from feed shed or from feed boat; use of pellet detection devices); and
- Net cleaning information: method of cleaning, location of cleaning and schedule for cleaning (put net cleaning location on map).

Changes to information required in this section during the calendar year must be reported to the Regional Waste Manager in the following quarterly report.

Note: Information in this section was previously required in quarterly reports. The reporting requirement is being changed to reflect infrequent changes in these details. Quarterly reports are still required for “Materials Handling Information”.

3.0 Site Characteristics and Operational Plan

3.1 Rationale

This information is required by existing legislation and will also support the development of biophysical modeling for farm siting.

3.2 Requirements

Submit the following information, to the Regional Waste Manager, within 90 days of the date of this request (a one-time submission). Note: this information will be required for all new tenure applications.

All maps must include standard cartographic information such as the location of true north, scale, projection, etc.

- A cadastral map of the tenure to show the general location (scale 1:50 000 or larger); the location of other fishfarms within 2 km should be noted;
- "Site characteristics map" showing features within the tenure including: net pen layout, buildings, anchors, storage areas, septic tank location, sewage outfall, net cleaning location, location where currents were measured (1:5000). The latitude and longitude, using differential Global Position System (GPS) [digital GPS (dGPS)], must be specified for any independent floating structures (location of this measurement noted on the map). If the net pens are moved more than 20 m, the Regional Waste Manager must be notified.
- Depth and net pen profile;
- Net pen information including: number of net pens, area and depth of each net pen and location of net pens;
- Bottom features map showing bottom contours and bottom substrates within the tenure area. Contours are to be shown at no greater than 10 meter intervals of depth and may be submitted on marine charts. The information may utilize existing marine charts if the bottom contour interval is no greater than 10 meters. The amount of substrate detail on this map should correspond to the variability of the types and the depths covered by the tenure. Substrate types should be in the categories: mud/silt, sand, gravel, cobble, bedrock. Indicate the method used to determine this information. Owners may use data gathered from the sediment grain size analysis, Section 5.2.3 Sediment Substrate Analysis: Physical, or can use other means of collecting this data. If sampling shows that sediments cannot be collected, then other methods of gathering substrate information may be necessary (such as echo sounding) and more effort should be made to characterize the variability of bottom substrates within the tenure. Very often marine substrates will vary by depth or by geological features, and this characterization should be able to identify that. (Bottom substrate information is required to determine feasibility of conducting the benthic environmental monitoring program, to verify whether the sediments exist which can be sampled using conventional sampling equipment and also to provide some understanding of the flushing capabilities of the site. It also

may be used as one factor in assessing the suitability of new tenures.); and

- Production plan including number of fish to be stocked, production schedule, proposed feeding schedule, species of fish, rearing density [kg/m^3].

Any changes in the above operational information must be reported to the Regional Waste Manager with the next quarterly report and any emergency changes (e.g. towing cages from the site) must be reported within 24 hours to the Regional Waste Manager (250-751-3176) or within non-working hours to the Provincial Emergency Program (1-800-663-3456).

4.0 Currents Speed and Direction

4.1 Rationale

The currents speed and direction information has and continues to be a requirement in the "Environmental Monitoring Program for Marine Fish Farms". Most fish farms already have this information for the 15 meter depth. This information can be re-submitted but needs to be accompanied with supporting data of location, sample dates, make and model of the current meter used and the name of the person collecting the information (as required in the program noted).

Currents information near the bottom (5-10 meters above the bottom) is a new requirement, and reflects recommendations of the Salmon Aquaculture Review. This information is needed for an updated waste loading model (to be developed).

4.2 Requirements

All operations must characterize the current regime at the site for a period of 30 days. Currents speed and direction are to be recorded at a minimum frequency of once per hour during the 30-day period and at two depths, 15 meters below the surface and 5-10 meters above the bottom. The currents measurements must be made during a month of average tidal fluctuations.

The currents measuring instrument must be located away from the attenuation effects of the netcages or other structures. In most cases the instrument should be moored 30 meters from the offshore side of the netcage. Record the current direction in degrees true and current speed in cm/sec. Either vector averaging or instantaneous type meters may be used. The location for these measurements are to be noted on the site characteristic map and dGPS coordinates reported. The data must be submitted in a format approved by the Regional Waste Manager (**protocols are in Appendix A**; these are extracted from "Environmental Monitoring Program for Marine Fish Farms", 1988).

The question has been raised whether acoustic doppler information can suffice for the bottom depth measurement, given that the 15 meter measurement has been done. The principle use of this information is to assist estimation of the dispersal of wastes at the site. For the purposes of this information request, doppler information is acceptable if it is accompanied with the consultants interpretation of the data, and assessment of the dispersal/accumulation pattern of wastes regarding potential for wastes to accumulate and become anoxic. Note, **all** operations are still required to submit currents information for the 15 metres depth. Previously submitted currents information is acceptable if accompanied with "supporting information" as specified in Appendix A.

BCSFA has agreed to conduct a detailed acoustic doppler measurement program at the six focussed study sites. This should be done early in the

project in order to identify the optimum location for representative transects. The long-term objective of including the doppler information is to identify what current information is required in order to establish a computer model for waste dispersion.

For operations that already have collected this data, it must be submitted to the Regional Waste Manager within 90 days of the date of this order or permit amendment. For operations that have not yet collected this data, it must be submitted within one year from the date of this order or permit amendment.

The Regional Waste Manager may provide written approval of alternative methods of conducting this monitoring, or timing beyond 90 days if provided information to show a contractual commitment to conduct the work.

5.0 Interim Environmental Monitoring Program

5.1 Rationale

The purpose for the following programs are to provide support information leading to development of fin fish performance based environmental standards and monitoring program. Information gathered will be used to determine the feasibility of the performance based monitoring program, to determine the number of fish farms that are amenable to the chemical/biological program, to clarify data handling requirements, to substantiate the premise of using chemical indicators to predict benthic community health and to help calibrate models used in developing fishfarm production plans which are environmentally sensitive. The interim monitoring program will not necessarily be reflective of monitoring the industry will be required to undertake once the standards are developed.

The information reported in the bottom features map (Section 3) will determine whether the site characteristics in the vicinity of the net pen are depositional and whether the physical, chemical and benthic environmental monitoring program is feasible. If the bottom substrates can be sampled the "Physical, Chemical and Benthic Environmental Monitoring" sampling must be done; otherwise the Photographic Survey Program must be done.

5.2 Physical and Chemical Environmental Monitoring Program

Conduct two environmental monitoring programs, the first in the spring between March 1 and June 30, 2000, (conceptually prior to saltwater entry of smolts); and the second in the summer between August 1 and September 30, 2000. The sampling program is to be conducted by a registered professional biologist or a person with recognized capabilities for doing this type of work (published reports).

The spring program will include all the physical and chemical sampling and analysis outlined in Sections 5.2.2 to 5.2.3. The summer monitoring program will duplicate the spring monitoring program. However, if the "interim standard" (to be developed following consultation with industry and stakeholders) is exceeded, the Regional Waste Manager may require additional sampling, including benthic community analysis, as outlined in Sections 5.2.2 to 5.2.4. The Regional Waste Manager may require additional physical or chemical sampling in the summer monitoring program dependent on the results from the spring program.

If a reasonable effort of sampling to collect sediment samples determines the substrates within the tenure are not collectable, the Photographic Survey Program as outlined in Section 5.3 shall be conducted ("*reasonable effort" means 3 successive unsuccessful grab attempts at the first station at 0 m and two alternate transects similarly attempted*).

Protocols for sampling and analysis are appended (**Appendix B**). As a generality, the following methods require the use of a 0.1 m^2 sampler (e.g. the van Veen or

Smith-McIntyre) which can be opened from the top without disturbing the sediments when collecting the chemistry samples.

Submit the physical and chemical monitoring data to the Regional Waste Manager, within 45 days of collecting the sample. The benthic community sampling data, if required, must be submitted within 180 days of collecting the sample. The final report must include a map showing the location and dGPS coordinates of sample stations and locations of the transects.

Regarding the question of whether two close netpen complexes can use the same monitoring program if combined feed usage does not exceed 1260 tonnes of feed use (close being less than 200 metres from each other). This question can only be answered through a site specific request to the Regional Waste Manager. Any deviation from the approved program needs the Regional Waste Manager's approval.

5.2.1 Sampling Sites

Sample sites for the interim environmental monitoring program are to include:

- Minimum of two (2) background stations; these stations are to be chosen as reference stations for comparison with the monitoring stations, so must have similar depth and substrates. They must be clearly away from the influence of the fishfarm. It is acceptible that two or more fish farms monitoring programs may share one site provided that the depths and substrates are similar. This factor needs to be reported with each farm report;

- Minimum of eight (8) monitoring stations, four (4) on each of a minimum of two (2) transects (upstream and downstream in the two prominent current directions); one at the edge of the net-pen (0 m), one at 30 m from the edge of the net-pen and one at 100 m from the edge of the net-pen; and

- Two additional transects (each with 4 stations) may be required on large net-pen layouts as indicated by letter from the Regional Waste Manager. The submission is to include sufficient information to show that these additional transects are sited appropriately to show effects from active netpens. The salmon farmers are invited to discuss the additional requirement with the Regional Waste Manager.

Alternatively, where data has previously been collected to serve a regression analysis for the data, the sampling locations were done on at least 2 transects, and the sample sites extended from 0 metres to at least 100 metres, then the same sampling protocols as previous may be used. In this latter case, data and analysis should include previous information.

5.2.2 Sediment Substrate Analysis: Chemical

Conduct chemical analyses on subsamples from the top 2 cm of sediment in each of three replicate grabs at each station (similar to the Sectoral Strategy) for the following parameters:

- Total volatile solids or total organic carbon;
- Hydrogen sulfide (both chemical measurement and olfactory protocols);
- Feed additives; such as zinc or pesticides as reported in Section 1.2; and
- Redox potential.

If the owner of feed additives has previously conducted zinc analyses in sediments, and the concentrations of zinc were less than 187 mg/kg, (which is the mean of the PEL and TEL), then the owner may submit this data in lieu of conducting additional sampling.

Antibiotics sampling and analysis is no longer required because it will be conducted in a focussed study.

Redox potential is to be measured by inserting the redox probe directly into undisturbed sediments held in the grab sampler with each grab. The pH is to be measured concurrently with the redox potential in order to calculate undissociated H_2S using the total sulfide data.

The laboratory that conducts the chemical analysis must comply with the requirements of the *Environmental Data Quality Assurance Regulation*.

5.2.3 Sediment Substrate Analysis: Physical

Sediment grain size analysis is to be conducted on single samples collected in the top 2 cm of sediment in one grab at each station using protocols outlined in Appendix B. Laboratory analysis will involve sieve sizes:
2.0 mm, 0.89 mm, 0.25 mm and 0.063 mm.

Physical observations (before samples are removed) are to be recorded for the following:

- Odour of hydrogen sulfide;
- Gas bubbles;
- Description of the sediment, odour, colour, texture, etc.; and
- A colour photograph must be taken.

5.2.4 Benthic Community Assessment

- Three samples must be collected at each station, sieved and submitted for analysis;
- Grab samples are to have all taxa retained on a 1 mm sieve identified to species or the lowest feasible taxonomic level; and

- Counts for adults and juveniles must be recorded separately.

Physical observations (before samples are removed) must be recorded for the following:

- Odour of hydrogen sulfide;
- Gas bubbles;
- Description of the sediment, odour, colour, texture, etc.; and
- A colour photograph shall be taken.

5.3 Photographic Survey Program

This monitoring program is to be conducted on substrates such as cobble or bedrock which preclude the collection of grab samples.

The tenure holder shall conduct an underwater photographic survey that is representative of the size and number of net pens and variables of depth and substrate. A minimum of two transects during the two sampling periods are required; however, additional transects may be required to adequately represent the size and number of netpens.

These surveys can be completed by scuba divers where water depths are less than 25 meters. Where depths exceed 25 meters, a cabled drop camera or remotely operated vehicle (ROV) may be used. The survey transects begin at the perimeter of the containment nets and proceed away from the farm to the boundary of tenure or to a distance of at least 50 meters beyond any observable adverse effect.

Short transects (20 m) at two background or reference sites with similar depth and substrate shall also be conducted.

Photographs may be made with either a still or video camera and should include additional lighting for clarity. The camera shall be positioned to provide optimum resolution of the bottom - but at a distance no greater than 1.5 meters above the substrate. A reference subject should be used to show scale. A minimum of one minute of motion colour photography, colour video or four to five colour still photographs shall be obtained at each station requiring evaluation and at the reference stations.

Photographs must be obtained at least every 10 meters along each transect. If a video camera is used, the camera shall be maneuvered at a maximum speed of 0.25 meters per second with stops of at least five seconds every 10 meters along each transect. Photographs (still or video) must either be annotated to indicate the distance and transect bearing from the perimeter of the operation or a log will be required describing distance as a function of position on the tape.

The monitoring report must include a written assessment by an independent registered professional biologist evaluating benthic conditions at the sample station.

The report must enable the viewer to identify the location of each picture or section of video. Photographs (still or video) shall either be annotated to indicate the distance and transect bearing from the perimeter of the cage structure, or a log will be required describing distance as a function of position on the tape. The monitoring report must be submitted within 90 days of completion of the beginning of each of the two surveys.

APPENDIX A

CURRENTS SPEED AND DIRECTION PROTOCOL

Adapted from "Environmental Monitoring Program for Marine Fish Farms" MELP 1988.

Under the existing regulatory framework (*Aquaculture Waste Control Regulation*), all fishfarm operations are required to conduct the "Currents Speed and Direction" specified in the monitoring program. All farms must characterize the current regime at the farm site for a period of one month only. Current speed and direction are to be recorded at a minimum frequency of once per hour during the one month (30 days) period, so an automatic recording device is a necessity.

For the "Interim Monitoring Program" all fishfarms are required to provide currents speed and direction characterization at two depths, 15 meters down and 5-10 meters above the bottom. This information is needed to help provide better resolution for waste loading models, especially for deep sites where the bottom currents are different than the shallow ones. The "Waste Discharges" discussion paper in the Salmon Aquaculture Review states that the model include data for "currents at the bottom of nets [data required for the Ministry of Environment, Lands and Parks (MELP)] and maximum water depth over an entire lunar tidal cycle in spring and fall".

In some cases, the current monitoring requirements for the 15 meters depth may have already been met as a requirement in the existing regulation. If so, these data may be re-submitted subject to inclusion of the **supporting information**.

The precise timing of the current assessment is left to the discretion of the operator, but current measurements must be made during a month of average tidal fluctuations. Measurements of current speed and direction must be made at intervals of one hour or less until a full 30 days have elapsed.

The current measuring instrument should be located away from the attenuation effects of the netcages or other farm structures. In other words, it should not be located immediately adjacent to the netcages and not in line with prevailing currents such that the current meter is measuring currents that have been "dampened" by the nets themselves. In most cases, the current meter should be moored about 30 meters from the offshore side of the netcages. Record current direction in degrees true and current speed in cm/sec. Either vector averaging or instantaneous type meters may be used.

Upon completion, compiled data is to be forwarded to the Regional Waste Management office. Raw data indicating current speed and direction for each sampling interval should be provided in an American Standard Code for Information Interchange (ASCII) computer format (diskette) and must be accompanied by adequate format documentation. Submitters should also include a hardcopy summary of the data in the form of a tabular frequency distribution of both current speed and current direction (see

examples pages 13-15). Summary information should include a calculated average current velocity.

Electronic current meters capable of determining both speed and direction are available from several manufacturers (Aanderaa, Applied Microsystems, General Oceanics, InterOcean Systems, etc). Since the Environmental Monitoring Program requires that currents be measured at a minimum of one hour intervals for a period of one month, it is advisable to use a meter which can be pre-set for the correct interval and record the results automatically (i.e., the meter should possess an internal "datalogger").

These devices are expensive and often require some expertise to program and deploy properly, in addition to extracting the data appropriately. It is therefore recommended that the services of a qualified consultant (who already has the necessary equipment and expertise) be retained to fulfill this monitoring requirement.
Support should include the following:

START DATE:
Record the date that the current meter commenced current monitoring.

START TIME:
Record the time that the current meter commenced current monitoring. Use local time and a 24 hour clock.

END DATE:
Record the date that current monitoring was terminated.

END TIME:
Record the time that current monitoring was terminated. Use local time and a 24 hour clock.

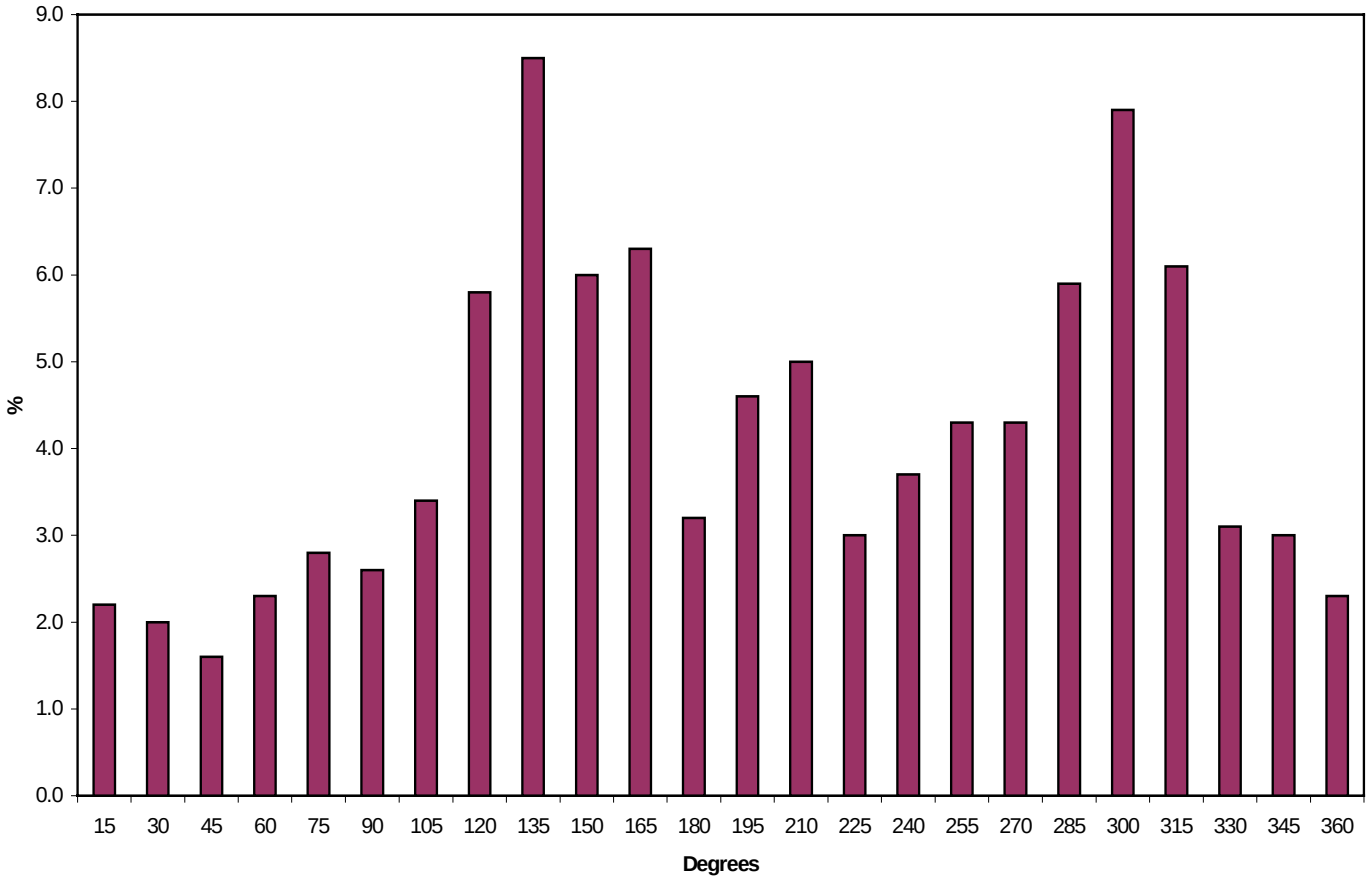
SAMPLE INTERVAL:
Report the sample interval in minutes between consecutive measurements made by the meter. Sample interval cannot be greater than sixty minutes.

INSTRUMENT:
Provide details as to the make and model of current meter employed to conduct the monitoring.

DATA:
Indicate whether current meter averages current speed and direction over the selected interval, or if it provides instantaneous measurements.

NAME:
Provide the name of the person and/or consulting company that is performing the current monitoring.

LOCATION OF DEPLOYMENT:
Supply differential Global Positioning System (GPS) coordinates for the meter deployment location, provide a written description of the location (e.g. 30 meters 270º from the southwest corner of the netpens) and provide the location on a map.



CURRENT SPEED/DIRECTION MATRIX

Site name: John's Point
Location: 49°40'29" 126°20'57"

Instrument: Aanderaa model # 12345
Number of data points: 1353

Average current speed (cm/s): 2.2

Lands file #: 01401234
Description: 30m 270° from SW corner of netpens
Start date/time: 13:42 -12 Sept-97
Sample Interval: 30 minutes

Contact name: John Noname of JN Consultants

MAFF #: 12
Depth of Me

End date/tir
Data (circle
instantaneou

	0-1	3	4	5	6	8	10	15	25	50	75	100	% Direction
15	27	3	0	0	0	0	0	0	0	0	0	0	2.2
30	15	12	0	0	0	0	0	0	0	0	0	0	2.0
45	17	5	0	0	0	0	0	0	0	0	0	0	1.6
60	21	10	0	0	0	0	0	0	0	0	0	0	2.3
75	29	9	0	0	0	0	0	0	0	0	0	0	2.8
90	24	11	0	0	0	0	0	0	0	0	0	0	2.6
105	25	19	1	0	0	0	0	0	0	0	0	0	3.4
120	30	44	4	0	0	0	0	0	0	0	0	0	5.8
135	40	58	13	2	0	0	0	0	0	0	0	0	8.5
150	34	33	12	1	0	0	0	0	0	0	0	0	6.0

165	35	39	9	1	0	0	0	0	0	0	0	0	6.3
180	19	19	5	0	0	0	0	0	0	0	0	0	3.2
195	29	27	3	2	0	0	0	0	0	0	0	0	4.6
210	37	25	5	0	0	0	0	0	0	0	0	0	5.0
225	21	17	2	0	0	0	0	0	0	0	0	0	3.0
240	23	24	2	0	0	0	0	0	0	0	0	0	3.7
255	29	27	1	0	0	0	0	0	0	0	0	0	4.3
270	27	28	2	0	0	0	0	0	0	0	0	0	4.3
285	26	35	13	1	2	1	1	0	0	0	0	0	5.9
300	35	45	15	5	2	3	0	0	0	0	0	0	7.9
315	28	36	13	4	0	0	0	0	0	0	0	0	6.1
330	24	16	20	0	0	0	0	0	0	0	0	0	3.1
345	24	16	0	0	0	0	0	0	0	0	0	0	3.0
360	24	7	0	0	0	0	0	0	0	0	0	0	2.3
Sum	48.2	42.3	7.6	1.2	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	100.0

CURRENT SPEED BAR CHART

Site name: John's Point

Location: 49°40’29” 126°20’57”

Instrument: Aanderaa model # 12345

Number of data points: 1353

Average current speed (cm/s): 2.2

Lands file #: 01401234

Description: 30m 270° from SW corner of netpens

Start date/time: 13:42 -12 Sept-97

Sample Interval: 30 minutes

Contact name: John Noname of JN Consultants

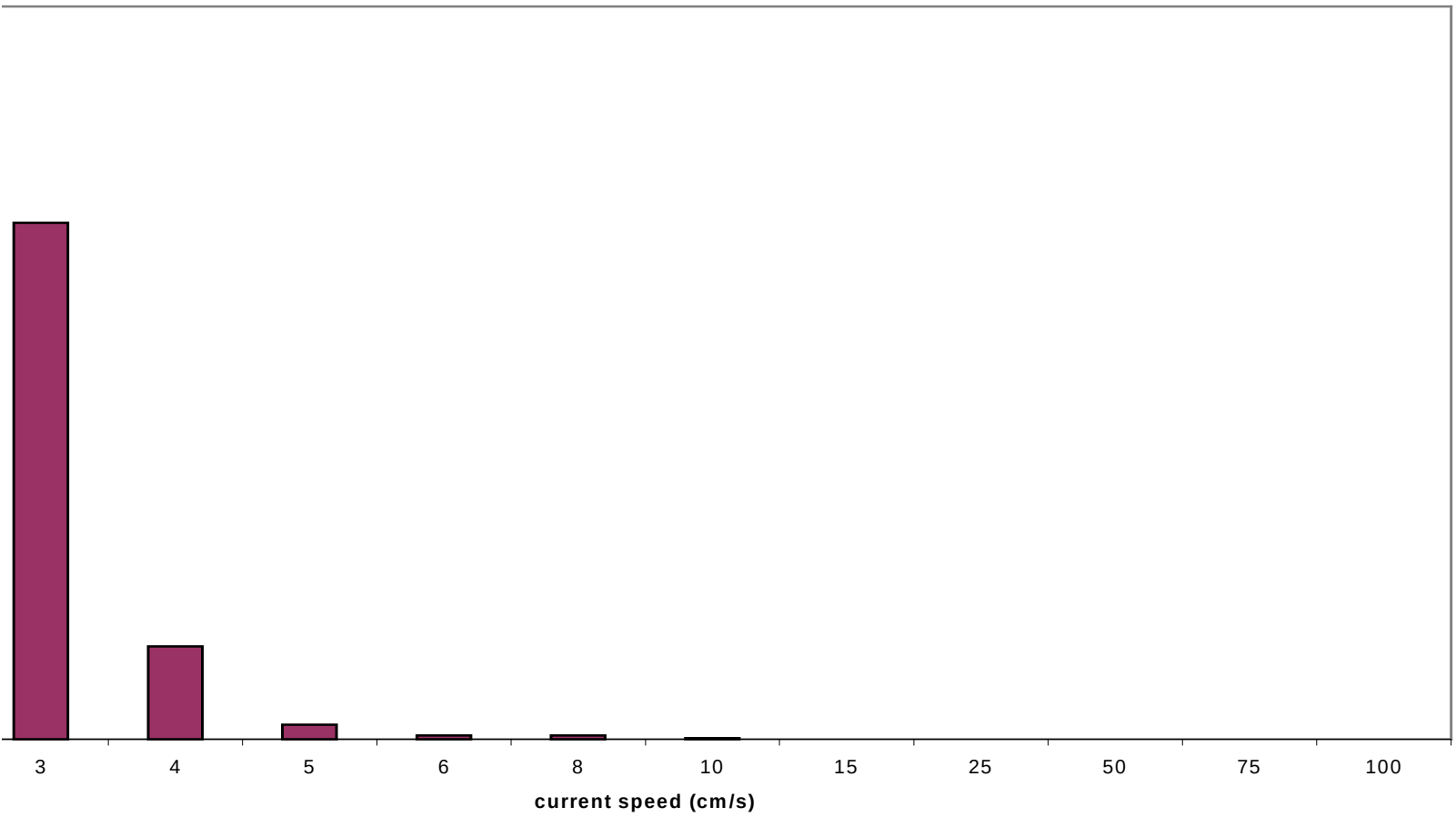
MAFF #: 12

Depth of Me

End date/tir

Data (circle

instantaneou



CURRENT DIRECTION BAR CHART

Site name: John's Point
Location: 49°40'29" 126°20'57"

Instrument: Aanderaa model # 12345
Number of data points: 1353

Average current speed (cm/s): 2.2

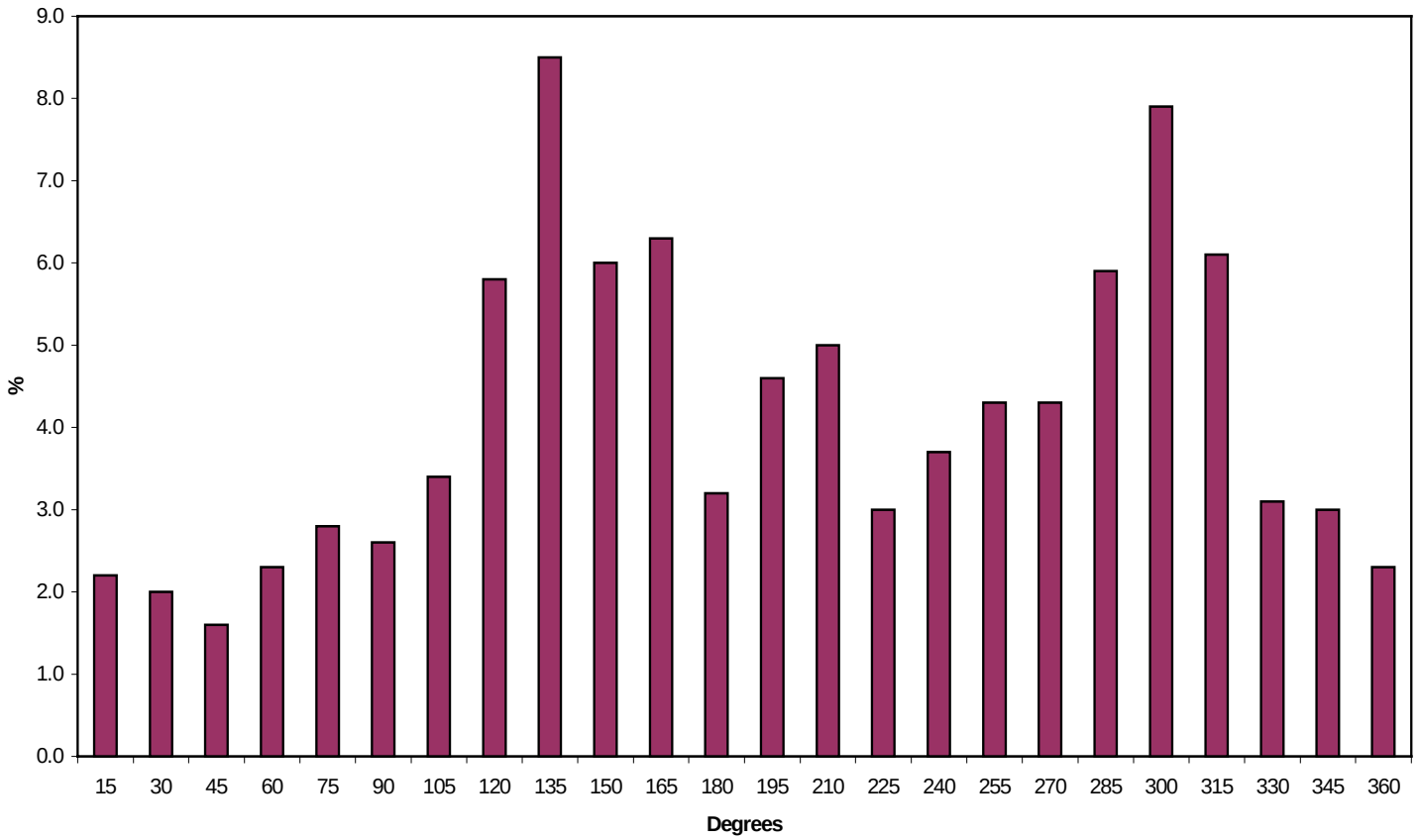
Lands file #: 01401234
Description: 30m 270° from SW corner of netpens

Start date/time: 13:42 -12 Sept-97
Sample Interval: 30 minutes

Contact name: John Noname of JN Consultants

MAFF #: 12
Depth of Me

End date/tir
Data (circle
instantaneou


9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
%
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
270
285
300
315
330
345
360
Degrees

APPENDIX B

COLLECTION OF SURFICIAL SEDIMENTS FOR PHYSICAL, CHEMICAL AND BIOLOGICAL VARIABLES

Adapted from "Sectoral Strategy Framework for the BC Salmon Farming Industry. June 1998" Appendix B: Salmon Farm Waste Accumulation Monitoring.

I Introduction

The following protocols define procedures for collecting and analyzing subtidal surficial sediment samples Sediment Grain Size distribution (SGS), Total Volatile Solids (TVS), Total Organic Carbon (TOC), Redox Potential (ORP), Total Sulfides and Infaunal Community Analysis.

II General Sampling Considerations

Station positioning. It is recommended that the survey vessel be positioned using a polypropylene (or other minimum stretch material) transect line secured at the proper distance from the perimeter of the net pens (0, 30, 60 and 100 meters). The transect line can be lined up relative to the dominant current direction. The line should be secured at a location where the sampler is deployed. The location of each sample station should be recorded using differential Global Positioning System (GPS) with an accuracy of ±3.0 meters. In areas where Differential Beacons are not available, uncorrected GPS positions are acceptable.

Acceptable samplers. Samples shall be collected using a self-closing grab such as the Petite Ponar or modified van Veen grab which can sample 0.1 m^2. Other samplers are acceptable providing they completely enclose the sample during transit through the water column and can be opened from the top for collecting chemistry samples. The primary criterion for an adequate sampler is that it consistently collects undisturbed samples to the required depth below the sediment surface without contaminating the samples. Collection of undisturbed sediment requires that the sampler:

- Create a minimal bow wake when descending;
- Form a leak proof seal when the sediment sample is taken;
- Prevent winnowing and excessive sample disturbance when ascending; and
- Allow easy access to the sample surface.

The required penetration depth below the sediment surface is a function of the desired sample depth. It is better to penetrate below the desired sample depth to minimize sample disturbance when the sampling device closes. Penetration depth of most sampling devices varies with sediment character and generally is greatest in fine sediments and least in coarse sediments. Sampling devices generally rely upon either gravity or a piston mechanism to penetrate the sediment. In both cases, penetration depth can be modified by adding or subtracting weight from the sampler. Thus, it is optimal to use a sampler that has a means of weight adjustment. If a sampler cannot

consistently achieve the desired penetration depth, an alternate device should be used or the sampling effort suspended.

Once the sampler is secured on board the survey vessel, it is essential that the surface of the sample be made accessible without disturbing the sample. Samples are very accessible through the flaps of a 0.1 m^2 van Veen grab and less accessible in a modified Petite Ponar. In either case, accessibility is considered adequate.

Penetration depth. The top 2 cm of the sediment column shall be used for characterizing surficial sediments at salmon farms. A minimum sampler penetration depth of four to 5 cm is recommended. This will ensure that:

- Relatively recent sediments are sampled;
- Adequate volumes of sediment are obtained for field or laboratory analysis; and
- Data from different studies will be comparable.

Operation of the sampler. The sampling device should be attached to the hydrowire using a suitable swivel. The swivel will minimize the twisting forces on the sampler during deployment and help ensure that proper contact is made with the bottom. For safety, the hydrowire, swivel and all shackles should have a load capacity at least three times greater than the weight of a full sampler.

The sampler should be lowered through the water column at a controlled speed of approximately 1 foot/second. Under no circumstances should the sampler be allowed to "free fall" to the bottom, as this may result in premature triggering, an excessive bow wake, or improper orientation upon contact with the bottom. The sampler should contact the bottom gently and only its weight or piston mechanism should be used to force it into the sediment.

After the sediment sample is taken, the sampler should be raised slowly off the bottom and then retrieved at a controlled speed of approximately 1 foot/second. Before the sampler breaks the water surface, the survey vessel should head into the waves (if present) to minimize vessel rolling. This maneuver will minimize swinging of the sampler after it breaks the water surface. If excessive swinging of the sampler occurs or if the sampler strikes the vessel during retrieval, extra attention should be paid to evaluating for sample for disturbance when assessing acceptability.

Sample acceptability criteria. After the sampler is secured on deck, the sediment sample should be inspected carefully before being accepted. The following acceptability criteria should be satisfied:

- The sampler should not be over-filled so that the sediment surface is pressed against the top of the sampler;
- Overlying water should be present indicating minimal leakage.
- The overlying water should not be excessively turbid indicating minimal sample disturbance;

- The sediment surface should be relatively flat indicating minimal disturbance or winnowing; and
- The desired penetration depth should be achieved (i.e., 4 to 5 cm for a 2.0 cm deep surficial sample).

If a sample does not meet all of these criteria, it should be rejected. In general, a minimum of four deployments of the grab should be made in an attempt to obtain a suitable sample.

If a suitable sample is not obtained in four deployments, an alternative transect location should be attempted. If additional sampling shows that substrates are too large, then the alternate photographic assessment technique may have to be used.

Sample evaluation. After a sample is judged acceptable, the overlying water should be siphoned off. Methods such as decanting the water or slightly cracking the grab to let the water run out are not recommended, as they may result in unacceptable disturbance or loss of fine-grained surficial sediment and organic matter. The following observations should be noted on the field log sheet:

- Station location. This should be recorded using Differential GPS with an accuracy of ±3.0 meters.
- Water depth.
- Gross characteristics of the surficial sediment to include:
  - Texture
  - Color
  - Biological structures (shells, tubes, macrophytes)
  - Presence of debris (wood chips, wood fibers, trash, etc.)
  - Presence of bacterial mats, waste feed, feces, oily sheens, etc.
  - Odor (hydrocarbons or hydrogen sulfide)
- Gross characteristics of the vertical profile (determined by a viewing a small clear corer extracted from the sample).
  - Vertical changes in sediment characteristics
  - Presence and depth of any apparent redox potential discontinuity (RPD) layer
- Penetration depth.
- Comments related to the sample's quality.
  - Leakage
  - Winnowing
  - Disturbance

Sub-sampling for specific analyses. It is recommended that sub-samples be taken using a flat scoop shaped like a coal shovel. The shoulders of the scoop should be two cm high. This device will allow a relatively large sub-sample to be taken accurately to a depth of two centimeters. Coring devices are not recommended because they collect small amounts of surficial sediment and therefore require repeated extractions to obtain a sufficient volume of material for analysis of conventional sediment variables. A curved scoop is not recommended because it does not sample to a uniform depth. Because

accurate and consistent sub-sampling requires practice, it is advisable that an experienced person perform this task.

When sub-sampling surficial sediments, unrepresentative material should be removed in the field under the supervision of the chief scientist and noted on the field log sheet. Unrepresentative material includes mollusk shells, large organisms, woody debris and pieces of macroalgae.

Replicate samples. Required replicates for the same analysis should be obtained from different grab samples. A single grab sample should not be repeatedly sub-sampled to provide material for replicates. The exception is that two sub-samples may be taken from the same grab for redox potential.

Cleaning of equipment between samples. All equipment (dredge, sampling fixtures, etc.) shall be thoroughly rinsed with ambient seawater between grab deployments to remove sediment and organisms. No other special cleaning requirements are considered necessary for infaunal samples, TVS (or TOC), redox, total sulfide or sediment grain size analyses.

III Collection and analysis of sediment physicochemical characteristics.

The top two centimeters of the retrieved sediment should be placed in a stainless steel bowl and gently homogenized for approximately 10 seconds. The homogenate should be sub-sampled into a 100 ml glass or plastic container for Sediment Grain Size and Total Volatile Solids or Total Organic Carbon analysis. Two additional 100 ml sub-samples should completely fill a pair of 100 ml containers. These samples will be analyzed in the field for Total Sulfides and Redox Potential. Large pieces of macroalgae and animals should be removed in the field under supervision of the senior scientist. Samples should be stored in the field on ice in a closed cooler. If the samples are to be shipped to a laboratory for Total Sulfides analysis, then two separate sub-samples should be collected in the field for Redox evaluation. (*Note: other sizes of sample containers may be used such as might be supplied by a laboratory. The key point is that they must be filled and capped, with no air.)*

Sediment Grain Size analysis. The sieve and pipette method of Plumb (1981) described in the Puget Sound Estuary Program (1986) should be used to determine the sediment grain size distribution in each sample. Samples for SGS analysis can be stored in the dark at 4° C for a maximum of 6 months. These samples should not be frozen. Wet sieving should be on a 0.063 mm screen followed by dry sieving on 2, 0.89, 0.25 and 0.063 mm screens. Quality assurance involves triplicate analyses on one of every 20 samples or on one sample per batch if fewer than 20 samples are analyzed. A maximum of 35 percent Relative Standard Deviation (RSD) is allowed between the replicates.

Total Volatile Solids analysis. Approximately half (50 ml) of the sample collected for SGS and TVS is available for this analysis. Samples may be stored at 4° C for 14 days or frozen at -18°C for a maximum of six months. Standard Method 2540 E or

Environmental Protection Agency (EPA) Method 160.4 should be used for this analysis. Quality assurance involves triplicate analyses on one of every 20 samples or on one sample per batch if fewer than 20 samples are analyzed. A maximum of 20 percent Relative Percent Difference (of the percent silt-clay fraction) is established as the Data Qualification Control Limit.

Total Organic Carbon analysis. This is an alternative to doing TVS, with similar sampling protocols and sent to the lab for analysis. Consult with the laboratory doing the analysis for specific requirements.

Redox potential. This analysis should be conducted in the field using the following, or similar, procedures. An Orion® (9678BN) combination redox (platinum) electrode and an Accumet 1003 millivolt meter were used by Hargrave et al. (1995) to determine the oxidation-reduction (redox) potential in sediments collected in the vicinity of salmon farms. Similar instruments, providing a minimum resolution and accuracy of ±0.1 mV may be substituted.

Calibration of the Redox Electrode: Calibration reagents should be prepared 12 to 24 hours before use and held refrigerated. Redox Standard A (0.1 M potassium ferrocyanide and 0.05 M potassium ferricyanide) is prepared by weighing 4.22 g $K_4Fe(CN)_6(3H_20$ and 1.65 g $K_3Fe(CN)_6$ into a 100-ml volumetric flask. Approximately 50 ml of distilled water is added with swirling to dissolve the solids. The solution is then diluted to volume (100 ml) with distilled water. Standard B (0.01 M potassium ferrocyanide, 0.05 M potassium ferricyanide and 0.36 M potassium fluoride) is prepared by weighing 0.42 g $K_4Fe(CN)_6(3H_20$,1.65 g $K_3Fe(CN)_6$ and 3.39 g $KF(2H_20$ into a 100 ml volumetric flask. 50 ml of distilled water is added to dissolve the solids and the solution is diluted to 100 ml with distilled water. A KCl filling solution for the internal reference electrode is prepared by placing 2.5 ml of 4 M KCl in 50 ml and diluting with distilled water to give a 0.2 M KCl solution.

Redox standards are used to calibrate electrodes at room temperature (20º C) at the start and end of measurements for each sample station. Standard A is transferred to a 150-ml beaker and the electrode placed in the solution until the reading stabilizes with stirring (1 to 2 minutes). The potential of Standard A is approximately +147 ± 9 mV. The electrode is rinsed with distilled water and the measurement repeated with Standard B (potential of +216 ±9 mV). The potential in Standard A is approximately + 66 mV greater than in Standard B. Quinhydrone (pH 7.0, +31 mV) can also used as a standard.

The potential of the reference electrode (+244 mV at 20ºC), corrected for the average difference between measured potentials of standard solutions and their calibration values, is added to the mV reading to determine the actual Eh potential in sediment samples. Eh potentials of approximately +300 to +350 mV are typical of oxygenated seawater. The redox electrode should be rinsed with distilled water after use and stored for short periods (a few weeks) in tap water. For longer periods, the electrode should be drained, rinsed with distilled water and stored dry.

Measurement of sediment redox potential. A 100 ml sample shall be collected for measurement of sediment redox and total sulfides. It is recommended that redox be measured before sub-sampling for total sulfide analysis. Note: some researchers suggest measuring redox directly in the sampler without removing (and disturbing) the sample.

A hole should be drilled in six spare sediment container lids. The size of the holes should be sufficient to accommodate the redox probe. The lids on all samples from the same station should be replaced with the drilled lids for analysis. The Eh electrode should be inserted into the first sediment sample and a mV reading recorded after 1-2 minutes. The electrode should then be removed, gently wiped free of sediment and used to measure the next sample in the series of six required at each sampling station.

The probe should then be rinsed in distilled water, recalibrated and stored in pH 7.0 buffer while the next series of samples is prepared. The redox probe should be calibrated at the beginning and end of each series of measurements.

Quality assurance procedures for the measurement of redox potential. Triplicate analyses shall be conducted on one of every 20 samples, or on one sample per batch if less than 20 samples are analyzed. The results should be reported. However, no Data Qualification Control Limit is established for this test at this time.

Total sulfide analysis. Samples can be collected in glass or plastic containers. A minimum sample size of 50 grams is recommended. If unrepresentative material is to be removed from the sample, it should be removed in the field under the supervision of the chief scientist and noted on the field log sheet. Samples that will not be analyzed in the field within 24 hours should be preserved by adding 2 N zinc acetate solution (approximately 5 ml per 30 grams of sediment) and swirling the mixture. Samples should fill the sample container with no overlying air space. The caps should be tightly secured to prevent the entry of air.

Samples should be stored in the dark at 4° C and analyzed as soon as possible. It is important that air contact with the samples be minimized and that samples be kept moist to minimize oxidation. A maximum holding time of 7 days is recommended for preserved samples.

A total of six samples should be collected from each farm sample station and the reference location. Two sub-samples can be collected from each of three grabs at each required sample station. This will require a minimum of 30 samples per farm during each evaluation.

Laboratory analysis of total sulfides. These analyses must be accomplished within seven days using Standard Method 4500S^{2-} E, EPA Method 376.1/9030 or an approved alternative procedure.

Calibration of the total sulfides Field probe. Because of the short (7 day) holding time and the remoteness of many salmon farms, it is recommended that this parameter be

measured in the field using a specific ion meter and a silver/sulfide electrode with a combination pH/reference electrode. Procedures for the calibration and use of these electrodes may be provided in the manufacturer's documentation. Hargrave et al. (1995) provide a detailed description of the calibration of an Accumet 1003 specific ion meter and Orion silver/sulfide electrode (9416BN) with a combination pH/reference electrode (Fisher 13-620-111). These procedures are repeated here; however, alternate procedures, applicable to different meter-probe combinations are acceptable.

A sulfide anti-oxidant buffer solution (SAOB) is prepared in 250-ml plastic screw-top jars by adding 20.00 g of NaOH and 17.90 g EDTA ($Na_2C_{10}O_8N_2.2H_20$) and diluting to 250 ml with distilled water. The 2 M NaOH and 0.2 M Na_2EDTA solution should be stored in a refrigerator or cooler at 4°C. Immediately before sample analysis, 8.75 grains L-ascorbic acid (pre-weighed in scintillation vials) is added to each 250 ml of the NaOH-EDTA solution. The SAOB buffer solution is stable for up to 3.0 hours after addition of L-ascorbic acid. As 5 ml of this solution was used for each sample analyzed (described below), 250 ml was sufficient for 50 samples.

Stock and diluted $S^=$ solutions used as standards for electrode calibration standards should be kept in the refrigerator and diluted just before use. As with NH_4^+ standards, dilute $S^=$ standards are unstable when exposed to air. Diluted standards are stable for up to 3 hours, thus they should be made up in the morning and at mid-day on the day of sample analysis. The $S^=$ electrode shall be calibrated before and after analysis of the samples from a single station. Two $S^=$ standards (100 and 1000 µM) are used for a two-point electrode calibration. A stock $S^=$ solution of 0.01 M Na_2S is prepared by weighing 0.2402 g $Na_2S.9H_20$ into a Biotight jar and diluting to 100 ml with distilled water. $Na_2S.9H_20$ is hygroscopic and should be handled with rubber gloves in a fume hood. The solution should be made fresh every 48 hours and stored at 4°C in a dark bottle. A 1000 µM $S^=$ standard (10^{-3} M) is prepared by transferring 10 ml of the 0.01 M Na^2S stock solution into a Biotight jar and diluting to 100 ml with distilled water. A 100 (M $S^=$ standard (10^{-4} M) is prepared by transferring 10 ml of the 1000 µM standard to a Biotight jar and diluting to 100 ml with distilled water. Both dilution standards should be mixed thoroughly before use. A two-point (100 and 1000 µM) calibration procedure shall be performed following instructions in manufacturer's instruction manual for the meter being used. A three-point (10 µM, 100 µM and 1000 µM) calibration procedure is recommended for sediment samples with low sulfide concentrations (1.0 µM to 10 µM). Just before calibration of the $S^=$ electrode, 25 ml of each standard is transferred to a dark bottle and 25 ml of SAOB (containing ascorbic acid) added. The combined solution was kept tightly capped until used for standardizing the $S^=$ electrode.

The $S^=$ and pH reference electrodes should be rinsed with distilled water after use and stored in pH 7.0 buffer for periods of a few days. For longer periods, the electrodes should be stored dry.

Measurement of sediment total sulfides. Following the measurement of redox potential, the sample container's lid should be removed and the sample homogenized

using a stainless steel spatula. A 5 ml sub-sample should then be extracted using a cut-off syringe. The sub-sample is expelled into a 100 ml Biotight wide-mouth plastic jar and 5 ml of the previously described SAOB buffer (to which L-ascorbic acid has been added) is added to the 5 ml sub-sample for sulfide determination.

A flat-tip stainless steel spatula should be used to mix and homogenize the sediment sample with the SAOB buffer. Following this, the $S^{=}$ electrode is used to further stir the sediment. The $S^{=}$ electrode reading should stabilize in two to four minutes.

Electrodes do not need to be cleaned or re-calibrated between analyses of sediments from the same station; however, after completing all six analyses for a single station, the electrode should be gently cleaned, rinsed with distilled water and re-calibrated before analyzing the next set of samples. The sulfide electrode should be re-calibrated at least once every two hours.

Quality assurance for sediment total sulfide analyses. Each sample should be thoroughly homogenized in the laboratory before a sub-sample is taken for this analysis. Laboratory homogenization should be conducted even if the samples were homogenized in the field.

Triplicate analyses shall be conducted on one of every 20 samples, or on one sample per batch if less than 20 samples are analyzed. The Data Qualification Control Limit is 20% Relative Percent Difference. Fresh standards should be used to calculate a calibration curve for each batch of samples. The analytical balance should be inspected daily and calibrated at least once per week.

Collection and analysis of infaunal samples. The following procedures shall be used for processing and evaluating infaunal samples. A minimum of <u>three</u> replicate samples per station is required. Each of these replicates must be handled as independent samples. No sub-sampling is permitted in this analysis.

Field processing 0.1 m^2 grab samples for infaunal analysis. Overlying water should be siphoned off through a 1.0 mm sieve to retain floating organisms. Sediments should be scraped and rinsed from the grab into a pre-cleaned container. Rinse water should be filtered to a minimum of 250 microns. Each infaunal sample shall be sieved on one-millimeter screens and preserved in 10% formalin in seawater buffered with borax (or a suitable alternate fixative). Following fixation for approximately four days, the samples should be rinsed over a 0.5 mm screen and preserved in 70% isopropyl or ethyl alcohol. All material, including coarse gravel and cobble retained on the sieve should be retained for infaunal analysis. Adhering infaunal organisms should be mechanically removed from exceptionally large cobble in the field and included in the sieved sample. Megafauna (large cnidarians, echinoderms and tubeworms) are noted on the field log sheets and returned to the sea.

Sorting and identification of Benthic Organisms. All organisms will be picked from the sieved material under a microscope providing at least 10x magnification.

Identification will be to the lowest level possible, generally to species. Following identification, organisms shall be archived, by sample, for a minimum period of 3 years.

Quality assurance procedures for invertebrate taxonomy. Samples should be picked by a single technician. A second technician shall re-pick twenty percent of each sample. If greater than five percent of the organisms are missed by the first sorter, then the entire sample is re-picked by the second technician.

Reference collection. A reference collection, including representative specimens from each identified species, should be maintained by each laboratory conducting taxonomic identification. All species identified in a study should be compared with a reference collection or identified by an outside expert.

REFERENCES

Biochemical observations to Assess Benthic Impacts of Organic Enrichment from Marine Aquaculture in the Western Bay of Fundy, 1994. B.T. Hargrave, 1995. Canadian technical report of Fisheries and Aquatic Sciences 2062. Fisheries and Oceans. Canada

Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound. March 1986. Puget Sound Estuary Program.

Attachment 2:
Report card for monitoring results.

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Farside (Omega Salmon) (Tenure 2402966)

- High total sulfide concentrations (1590 to 2590 µmol) were recorded at 30 m from netpens by Aquametrix

- Low redox potentials were recorded at 30 m (-240 to -290 mV) and 100 m (-145 to -256 mV) from netpens, and at reference stations (-20 to –226 mV) by Aquametrix

- Black sediments were noted at 30 and 100 m from netpens by Aquametrix

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Centre Cove (Marine Harvest) (Tenure 1404284)

- Extremely high total sulfide concentrations (5063 to 6025 µmol) were recorded at 30 m from netpens by Aquametrix
- Extremely high total sulfide concentrations (8030 to 11600 µmol) were recorded at 100 m from netpens by BCE
- Extremely low redox potentials (-270 to -310 mV) were recorded at 30 m from netpens by Aquametrix
- Low redox potentials (-116 to -222 mV) were recorded at 100 m from netpens by BCE
- High zinc concentrations were recorded at 0 m (680 to 810 µg/g) and 30 m (820 to 1015 µg/g) from netpens by Aquametrix
- High zinc concentrations were recorded at 0 m (856 to 1040 µg/g) and 100 m (9076 to 1070 µg/g) from netpens by BCE
- Chunky yellowish white material (sulfur?) associated with black, gassy sludge/sediment, and strong odour, were noted at 100 m from netpens by BCE

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Sir Edmund Bay (Heritage Aquaculture) (Tenure 1404179)

- High total sulfide concentrations were recorded at 30 m (2770 µmol) and 100 m (2345 µmol) from netpens by Aquametrix
- Low redox potentials were recorded at 30, 60, and 100 m from netpens (-332 to –350 mV), and at reference stations (-42 to –126 mV), by Aquametrix
- A high zinc concentration (315 µg/g) was recorded at 0 m from netpens by Aquametrix
- A high zinc concentration (281 µg/g) was recorded at 30 m from netpens by BCE
- Grey/black sediment was recorded at 30 and 100 m from netpens by Aquametrix

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Shaw Point (Omega Salmon) (Tenure 1406628)

- High total sulfide concentrations were recorded at 30 m (2130 to 2650 µmol) and 100 m (1790 to 2820 µmol) from netpens by Aquametrix

- Low redox potentials were recorded at 30 m (-240 to –318 mV) and 100 m (-290 to –325 mV) from netpens, and at reference stations (-64 to –134 mV), by Aquametrix

- Black sediment and strong odours were noted at 30 m from netpens by Aquametrix

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Cypress (Heritage Aquaculture) (Tenure 1405381)

- High total sulfide concentrations (4460 to 6240 µmol) were recorded at 30 m from netpens by Aquametrix

- Elevated total sulfide concentrations were recorded at 60 m from netpens (838 to 908 µmol) and at reference stations (670 to 686 µmol) by BCE

- Extremely low redox potentials were recorded at 30 m from netpens (-212 to –330 mV) and a low redox potential (-19 mV) was recorded at reference stations by Aquametrix

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Cecil (Heritage Aquaculture) (Tenure 1405181)

- A high total sulfide concentration (1590 µmol) was recorded at 30 m from netpens by Aquametrix
- Low redox potentials were recorded at 30 m from netpens (-50 to –200 mV) and at reference station (-38 to –45 mV) by Aquametrix
- Low redox potentials (-82 to –120 mV) were recorded at 30 m from netpens by BCE
- High zinc concentrations were recorded at 0 m (300 to 404 µg/g) and 30 m (288 µg/g) from netpens by BCE
- Black streaking over sediments was noted at 30 m from netpens by Aquametrix
- Moderate odour and *Beggiatoa* were noted at 30 m from netpens by BCE

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Jane Bay (Omega Pacific) (Tenure 1403261)

- High total sulfide concentrations were recorded at 30 m (3120 to 5540 µmol) and 100 m (2060 to 5650 µmol) from netpens, and at reference stations (2180 to 2740 µmol) by Aquametrix

- Extremely low redox potentials were recorded at 30 m (-371 to -392 mV) and 100 m (-345 to -392 mV) from netpens, and at reference stations (-326 to –378 mV) by Aquametrix

- Black soupy mud with moderate to strong odour was noted at 30 and 100 m from netpens, and black/grey sediment with moderate odour was noted at reference stations, by Aquametrix

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Indian Bay (Creative Salmon) (Tenure 1401621)

- High total sulfide concentrations (1504 to 1826 µmol) were recorded at 30 m from netpens by Aquametrix

- High total sulfide concentrations were recorded at 30 m (2210 to 2710 µmol), 60 m (731 to 1310 µmol), and 100 m (991 to 2310 µmol) from netpens, and at a reference station (891 µmol) by BCE

- Extremely low redox potentials were recorded at 30 m (-312 to -348 mV) and 100 m (-312 to –336 mV) from netpens, and at reference stations (-35 to –175 mV) by Aquametrix

- A high zinc concentration (341 µg/g) was recorded at 0 m from netpens by Aquametrix

- Black layer over fine silt/clay mud was noted at 30 m from netpens by Aquametrix and BCE

Rating: probably impacted

- Extremely high total sulfide concentrations (1640 to 6740 µmol) were recorded at 30 to 75 m from netpens by AES

- Low redox potentials (-12 to -80 mV) were recorded at 30 to 75 m from netpens by AES

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Upper Retreat (Stolt) (Tenure 1404379)

- Extremely high total sulfide concentrations were recorded at 30 to 105 m (2500 to 13300 µmol) from netpens by AES
- High total sulfide concentrations (694 to 1630 µmol) were recorded at 30 m from netpens by BCE
- Low redox potentials (-3 to -130 mV) were recorded at 30 to 105 m from netpens by AES
- Extremely low redox potentials (-259 to -270 mV) were recorded at 30 m from netpens by BCE
- High zinc concentrations (285 to 437 µg/g) were recorded at 0 m from netpens by BCE
- Black to dark green sediments with *Beggiatoa* were noted at 30 to 105 m from netpens by AES
- Dark sediments, *Beggiatoa*, feces, feed, and strong odour, were noted at 30 m from netpens by BCE

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Arrow Passage (Stolt) (Tenure 1404681)

- High total sulfide concentrations were recorded at 30 m (3210 to 5370 µmol) and 100 m (1530 µmol) from netpens by AES
- Low redox potentials were recorded at 30 m (-5 to -178 mV) and 100 m (-28 to –128 mV) from netpens, and at reference stations (-24 to –100 mV) by AES
- Low redox potentials were recorded at 30 m (-101 to -120 mV), 60 m (-26 to –119 mV), and 100 m (-13 to –107 mV) from netpens by BCE
- High zinc concentrations (290 to 350 µg/g) were recorded at 0 m from netpens by AES
- A high copper concentration (230 µg/g) was recorded at 0 m from netpens by AES
- Dark green to black sediments with feces were noted at 30 to 100 m from netpens by AES

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Hohoae Island (Marine Harvest) (Tenure 1405003)

- High total sulfide concentrations were recorded at 60 m (4430 µmol), and elevated concentrations (690 to 917 µmol) were recorded at 30 m from netpens by BCE

- Low redox potentials were recorded at 30 m (-20 to -91 mV) and 60 m (-110 mV) from netpens by BCE

- High zinc concentrations (272 to 377 µg/g) were recorded at 0 m from netpens by BCE

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Bawden Point (Pacific National Aquaculture) (Tenure 1403647)

- High total sulfide concentrations (2050 to 4220 µmol) were recorded at 30 m from netpens by BCE
- Low redox potentials (-199 to -213 mV) were recorded at 30 m from netpens by BCE
- A high zinc concentration (280 µg/g) was recorded at 0 m from netpens by AES
- A high zinc concentration (328 µg/g) was recorded at 0 m from netpens by BCE
- Moderate odour and *Beggiatoa* were noted at 30 m from netpens by BCE

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Westside (Pacific National Aquaculture) (Tenure 1408492)

- High total sulfide concentrations (2480 to 2930 µmol) were recorded at 30 m from netpens by AES
- Low redox potentials were recorded at 30 m from netpens (-111 to –35 mV) and at a reference station (-37 to –21 mV) by AES
- Black sediment was noted 30 m from netpens by AES

Rating: probably impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Shelter Bay (Omega Salmon) (Tenure 1407748)

- Elevated total sulfide concentrations (602 to 1220 µmol) were recorded at 30 m from netpens by Aquametrix

- Low redox potentials were recorded at 30 m (-79 to –206 mV) and 100 m (-84 to –203 mV) from netpens, and at reference stations (-19 to –44 mV) by Aquametrix

- Dark sediment and moderate odour were noted at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Ross Passage (Pacific National Aquaculture) (Tenure 1405933)

- Elevated total sulfide concentrations (767 to 1433 µmol) were recorded at 30 m from netpens by Aquametrix

- Extremely low redox potentials were recorded at 30 m (-341 to –365 mV) and 100 m (-207 to –280 mV) from netpens, and at reference stations (-78 to –214 mV), by Aquametrix

- A low redox potential (-47 mV) was recorded at 60 m from netpens by BCE

- Dark mud and moderate odour were noted at 30 m from netpens by BCE

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Wicklow Point (Stolt) (Tenure 1405183)

- Elevated total sulfide concentrations were recorded at 30 m (633 to 1090 µmol) and 100 m (665 µmol) from netpens by AES
- Low redox potentials were recorded at 30 m from netpens (-5 to –65 mV) and at reference station (-2 to –61 mV) by AES
- A high zinc concentration (330 µg/g) was recorded at 0 m from netpens by AES
- A high copper concentation (170 µg/g) was recorded at 0 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Port Elizabeth (Stolt) (Tenure 1403104)

- Elevated total sulfide concentrations (605 to 741 µmol) were recorded at 30 m from netpens by AES

- A high zinc concentration (405 µg/g) was recorded at 0 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Blunden Passage (Stolt) (Tenure 1403313)

- Elevated total sulfide concentrations were recorded at 30 m (623 to 776 µmol) and 100 m (885 to 907 µmol) from netpens by AES

- Low redox potentials were recorded at 30 m (-62 to –146 mV) and 100 m (-67 to –142 mV) from netpens, and at reference station (-3 to –34 mV) by AES

- Low redox potentials were recorded at 30 m (-138 to –144 mV), 100 m (-119 to –168 mV), and 150 m (-37 to –149 mV) from netpens by BCE

- High zinc concentrations (300 to 310 µg/g) were recorded at 0 m from netpens by AES

- A high zinc concentration (313 µg/g) was recorded at 30 m from netpens by BCE

- Extremely high copper concentrations (160 to 1500 µg/g) were recorded at 0 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Coal Harbour (Stolt) (Tenure 1407385)

- Elevated total sulfide concentrations were recorded at 30 m (918 to 1260 µmol) and 100 m (856 to 1260 µmol) from netpens by AES
- Low redox potentials were recorded at 30 m (-16 to –47 mV) and 100 m (-28 to –65 mV) from netpens, and at reference station (-1 to –50 mV) by AES
- High zinc concentrations (510 to 590 µg/g) were recorded at 0 m from netpens by AES
- High zinc concentrations (418 to 456 µg/g) were recorded at 0 m from netpens by BCE
- High copper concentrations (140 to 577 µg/g) were recorded at 0 m from netpens by AES
- Black sediment with *Beggiatoa* was noted at 30 and 100 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Glacier Falls (Stolt) (Tenure 1405180)

- Elevated total sulfide concentrations (630 to 959 µmol) were recorded at 30 m from netpens by AES

- Low redox potentials were recorded at 30 m (-7 to –48 mV) and 100 m (-2 to –10 mV) from netpens, and at reference station (-6 to –143 mV) by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Lilly Islets (Stolt) (Tenure 1405897)

- Elevated total sulfide concentrations were recorded at 30 m (958 to 1080 µmol) and 100 m (855 to 989 µmol) from netpens by AES

- Low redox potentials were recorded at 30 m (-17 to –76 mV) and 100 m (-6 to –82 mV) from netpens, and at reference station (-8 to –26 mV) by AES

- Black to dark green sediment was noted at 30 and 100 m from netpens by AES

Rating: potentially impacted

- A high zinc concentration (560 µg/g) was recorded at 0 m from netpens by AES
- "Synthetic lines" were frequently encountered at unspecified distances from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Deep Harbour (Stolt) (Tenure 1403326)

- Elevated total sulfide concentrations were recorded at 30 m (604 to 981 µmol), 75 m (637 µmol), and 90 m (685 µmol) from netpens by AES

- Low redox potentials were recorded at 30 m (-109 to –148 mV) and 100 m (-8 to –88 mV) from netpens, and at reference station (-2 to –34 mV) by AES

- High zinc concentrations (270 to 326 µg/g) were recorded at 0 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Chancellor Channel (Omega Salmon) (Tenure 1405245)

- Elevated total sulfide concentrations (1070 µmol) were recorded at 30 m from netpens by Aquametrix

- Low redox potentials were recorded at 30 m from netpens (-52 to –226 mV) and at a reference station (-5 to –28 mV) by Aquametrix

- Black sediment was noted 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Fortune (Pacific National Aquaculture) (Tenure 1403914)

- Elevated total sulfide concentrations were recorded at 45 m (613 µmol), 90 m (639 µmol), and 125 m (807 µmol) from netpens by AES

- Black sediment was noted 15-145 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Bedwell (Pacific National Aquaculture) (Tenure 1403980)

- Elevated total sulfide concentrations (602 - 875 µmol) were recorded 30 - 185 m from netpens by AES

- Green-black sediment was noted at 30 m from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Young Pass (Marine Harvest) (Tenure 1405768)

- An elevated total sulfide concentration (675 µmol) was recorded at 100 m from netpens by Aquametrix
- Low redox potentials were recorded at 30 m (-85 to –117 mV) and 100 m (-5 to –295 mV) from netpens by Aqumetrix
- Black sediment was noted at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Cyrus Rock (Marine Harvest) (Tenure 1406292)

- Elevated total sulfide concentrations (610 to 1040 µmol) were recorded at 30 m from netpens by Aquametrix
- Low redox potentials were recorded at 30 m (-110 to –250 mV) and 100 m (-12 to –170 mV) from netpens, and at reference stations (-7 to –65 mV) by Aquametrix
- Low redox potentials were recorded at 30 m (-31 to –86 mV), 60 m (-6 to –100 mV), and at 100 m (-55 mV) from netpens by BCE
- Black sediment was noted at 30 m from netpens by Aquametrix
- Dark patches in sediment at 30 m were noted by BCE

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Binns Island (Pacific National Aquaculture) (Tenure 1406648)

- Elevated total sulfide concentrations were recorded at 30 m from netpens (667 to 903 µmol) and at a reference station (717 to 1220 µmol) by Aquametrix

- Extremely low redox potentials were recorded at 30 m from netpens (-82 to –179 mV), and at reference station (-76 to –107 mV) by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Bell Island (Omega Salmon) (Tenure 1404918)

- Extremely low redox potentials were recorded at 30 m (-281 to –332 mV) and 100 m (-200 to –225 mV) from netpens, and at reference stations (-257 to –295 mV) by Aquametrix

- High zinc concentrations (278 to 794 µg/g) were recorded at 0 m by Aquametrix

- Dark sediment and moderate odour was noted at 30 m by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Brent Island (Heritage Aquaculture) (Tenure 1403267)

- Elevated total sulfide concentrations (703 to 1060 µmol) were recorded at 30 m from netpens by Aquametrix

- Extremely low redox potentials were recorded at 30 m (-55 to –137 mV) and 100 m (-180 mV) from netpens, and at a reference station (-141 mV) by Aquametrix

- Black streaks seen in sediment at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Maude (Heritage Aquaculture) (Tenure 1405739)

- Low redox potentials were recorded at 30 m (-120 to –288 mV) and 100 m (-22 to -99 mV) from netpens, and at a reference station (-2 to -23 mV) by Aquametrix

- Black streaks in sediment were noted at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Lees Bay (Omega Salmon) (Tenure 1401949)

- Elevated total sulfide concentrations (1020 to 1170 µmol) were recorded at 30 m from netpens by Aquametrix
- Low redox potentials were recorded at 30 m from netpens (-59 to –232 mV) and at reference stations (-26 to -144 mV) by Aquametrix
- A low redox potential (-6 mV) was recorded at 30 m from netpens by BCE
- Strong odour was noted at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Kanish-1 (Marine Harvest) (Tenure 1402860)

- Elevated total sulfide concentrations (858 to 1460 µmol) were recorded at 30 m from netpens by Aquametrix

- Low redox potentials were recorded at 30 m (-90 to –181 mV) and 100 m (-77 to –104 mV) from netpens, and at reference stations (-6 to -83 mV) by Aquametrix

- Black sediment was noted at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Jervis Cove (Target Marine) (Tenure 2402615)

- High zinc concentrations were recorded at 0 m (285 to 529 µg/g) and 30 m (321 µg/g) from netpens by Aquametrix

- Low redox potentials were recorded at 30 m (-96 mV) and 100 m (-55 mV) from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Raynor (Omega Salmon) (Tenure 1404089)

- Elevated total sulfide concentrations (632 to 884 µmol) were recorded at 30 m from netpens by Aquametrix

- Low redox potentials (-40 to –180 mV) were recorded at 30 m from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Orchard Bay (Marine Harvest) (Tenure 1405412)

- An elevated total sulfide concentration (792 µmol) was recorded at 30 m from netpens by Aquametrix
- Elevated total sulfide concentrations (750 to 1070 µmol) were recorded at 30 m from netpens by BCE
- Low redox potentials were recorded at 30 m (-141 to –266 mV) and 100 m (-19 to –99 mV) from netpens, and at reference stations (-6 to -83 mV) by Aquametrix
- Black sediment was noted at 30 m from netpens by Aquametrix and BCE

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Power Bay (Target Marine) (Tenure 2402613)

- An elevated total sulfide concentration (1480 µmol) was recorded at 30 m by BCE
- Low redox potentials were recorded at 30 m (-37 to –193 mV) and 100 m (-9 to –78 mV) from netpens by Aquametrix
- Low redox potentials (-63 to –152 mV) were recorded at 30 m from netpens by BCE
- High zinc concentrations (481 to 511 µg/g) were recorded at 0 m by Aquametrix
- High zinc concentrations were recorded at 0 m (287 to 294 µg/g) and 30 m (317 µg/g) from netpens by BCE

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Sediment Sampling
Phillips Arm (Omega Salmon) (Tenure 2403170)

- An elevated total sulfide concentration (676 µmol) was recorded at 30 m by Aquametrix

- Low redox potentials were recorded at 30 m (-160 to –265 mV) and 100 m (-190 to –310 mV) from netpens and at reference stations (-45 to –131 mV) by Aquametrix

- **Black layer on sediments were noted at 30 m by Aquametrix**

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Video Surveys
Doyle Island (Omega Salmon) (Tenure 1407325)

- Feces and feed were seen at an unspecified distance from netpens by Aquametrix

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Video Surveys
Dixon Bay (Pacific National Aquaculture) (Tenure 1403293)

- Several pieces of metal and PVC pipe and a feedbag were found at unspecified distances from netpens by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Video Surveys
South Shelter (Marine Harvest) (Tenure 1406837)

- One feedbag was found on farm perimeter by AES

Rating: potentially impacted

INTERIM MONITORING PROGRAM, SPRING/SUMMER 2000
Environmental Concerns Based on Video Surveys
Brougham Point (Stolt) (Tenure 1403301)

- Feedbags and ropes were seen to 125 m from netpens by AES
- *Beggiatoa* was found at 45 and 60 m from netpens by AES

Rating: potentially impacted