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FRASER RIVER
FREMP Estuary Management Program

# WASTEWATER CHARACTERIZATION OF FISH PROCESSING PLANT EFFLUENTS

TECHNICAL REPORT SERIES
FREMP WQWM-93-10
DOE FRAP 1993-39

Fraser River Estuary Management Program
Suite 301 - 960 Quayside Drive
New Westminster, B.C.
V3M 6G2

March 1994

# WASTEWATER CHARACTERIZATION OF' FISH PROCESSING PLANT EFFLUENTS

TECHNICAL REPORT SERIES
FREMP WQWM 93-10
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Prepared for FREMP
Water Quality/Waste Management Committee

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# WASTEWATER CHARACTERIZATION OF FISH PROCESSING PLANT EFFLUENTS

## PREFACE

The Fraser River Estuary Management Program (FREMP) was established to co-ordinate and build consensus on balancing the environment and economy along the Fraser Estuary, and has placed emphasis on integrating the needs of key users in the estuary. There are six funding partners: Environment Canada, Fisheries and Oceans Canada, Greater Vancouver Regional District (GVRD), the BC Ministry of Environment, Lands and Parks (BCELP), the Fraser River Harbour Commission (FRHC), and the North Fraser Harbour Commission (NFHC).

The main focus of the Water Quality/Waste Management Committee of the Fraser River Estuary Management Program is the co-ordination of monitoring of the environmental quality of the Fraser River Estuary. In this role, NovaTech Consultants Inc. was contracted to characterize the eff luent from a number of fish processing plants.

This project was co-ordinated by Eric McGreer of FREMP. Scientific authorities were Bert Kooi and Lisa Walls of Environment Canada and Doug Walton of the BC Ministry of Environment, Lands and Parks.

Funding for this project was provided by Environment Canada through the Fraser River Action Plan. One component of the Fraser River Action Plan is pollution abatement. This project helps to achieve a first step in the Action Plan strategy for pollution abatement, which is to determine contaminant loadings from all origins in the Fraser River Basin. The views expressed herein are those of the authors and do not necessarily state or reflect the policies of Environment Canada.

This study would not have been possible without the full co-operation of the participating companies cited in the Acknowledgements.

## EXECUTIVE SUMMARY

This document describes a preliminary effluent sampling program carried out at four fish processing plants which discharge to the Fraser River. The overall purpose of the study was to evaluate existing data together with new, site specific data on effluent characterization. The purpose of collecting the information was to provide an estimate of contaminant loading from this industry into the lower Fraser River. In addition to the four plants at which samples for effluent chemistry and toxicity were collected, four other fish processing plants were assessed base upon existing, in-house data.

The eight fish processors included: B.C. Packers (Richmond), Bella Coola (Delta), Great Northern (North Vancouver), Lions' Gate (Delta), Ocean Fisheries (Richmond), New West Net (New Westminster), Shearer (Delta) and SM Products (Delta). Effluent field sampling for wastewater characterization included the four processors: B.C. Packers, Bella Coola, LIons' Gate and Ocean Fisheries. In addition, effluent toxicity was determined for the effluent from three facilities.

Considerable variability was found within and among processing plants in terms of water consumption, and effluent characteristics. Contaminant concentrations ranged from 128 to 2680 mg/L BOD, 316 to 3460 mg/L COD, 74 to 3640 mg/L TSS, and 0.7 to 70 mg/L ammonia. The estimated annual contaminant loadings for 1993 from all fish processing facilities to the Fraser River Estuary are 216 tonnes of biochemical oxygen demand (BOD), 380 tonnes of chemical oxygen demand (COD), 121 tonnes of total suspended solids (TSS) and 13 tonnes of ammonia. The annual contaminant loading from these facilities is equivalent to approximately one percent of the loading from the Annacis and Lulu Island wastewater treatment plants.

The fish processing and waste management practices encountered during the study are typical for similar processing plants located in other parts of North America. Areas for improvement at all facilities were identified, and a number of operating and equipment changes were described that would lower the existing contaminant concentrations, and reduce loads to the environment. However, in the absence of site specific receiving environment information it is not possible to predict whether such changes would reduce potential impacts in the receiving waters.

Effluent toxicity was demonstrated at all sites, and the range of toxicity observed at each site varied between processing days. Only four of the nine toxicity samples collected passed the 96-hr LC50 100% criteria for rainbow trout. Of the four toxicity tests carried out, the Microtox *Photobacterium* bacteria test was generally found to be the most sensitive to effluent samples. The wide variation in toxic responses by several organisms to a single sample illustrates that the use of a single toxicity test is not recommended. Rather, the use of a number of tests with both chronic and acute endpoints is more predictive of the toxicity of the effluent from fish processing facilities. Continued use of the algal bioassay *Selenasrum* test for fish processing effluent testing is not recommended as nutrients contained in the effluent stimulated algal growth, interfering with the test endpoint.

## ACKNOWLEDGEMENTS

This document was prepared by the following two consulting firms:

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The authors gratefully acknowledge the involvement, technical, and editorial review contribution input of Mr. Eric R. McGreer of FREMP, Mr. Bert E. Kooi and Ms. Lisa A. Walls P.Eng. of Environment Canada, and Dr. Doug Walton of MOELP.

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Mr. Charlie Burton (Great Northern Packing Ltd.)
Mr. Carl Caunce (Lions' Gate Fisheries Ltd. - Long Beach Shellfish Facility)
Mr. Fred Gerak (New West Net Co. Ltd.)
Mr. Douglas Moore (Ocean Fisheries Ltd.)

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Mr. Jorn U. Nordmann (S.M. Products Ltd.).

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**Note:**

Subcontractor toxicity laboratory data reports from EVS Environment Consultants and B.C. Research Corporation are available for inspection at the Fraser River Estuary Management Program offices (New Westminster, B.C.), and Environment Canada - Fraser Fiver Pollution Abatement Office (North Vancouver, B.C.).

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## GLOSSARY OF ABBREVIATIONS

GENERAL

| | |
|---|---|
| BOD | Biochemical Oxygen Demand (five day) |
| COD | Chemical Oxygen Demand |
| DFO | Department of Fisheries and Oceans |
| DO | Dissolved Oxygen |
| FAS | Frozen at Sea |
| GVRD | Greater Vancouver Regional District |
| LLW | Low Low Water |
| MOELP | Ministry of Environment, Land and Parks |
| MPN | Most Probable Number |
| NTS | National Topographic System |
| O&G | Oil and Grease |
| TKN | Total Kjeldahl Nitrogen |
| TDS | Total Dissolved Solids |
| TS | Total Solids |
| TSS | Total Suspended Solids |
| USEPA | United States Environmental Protection Agency |
| UTM | Universal Transverse Mercator |
| app. | approximately |
| m | metre |
| mm | millimetre |

FISH PROCESSING FACILITIES

British Columbia Packers Limited (Richmond)
BELLA Coola Fisheries Ltd. (Delta)
GREAT NORTHERN Great Northern Packing Ltd. (North Vancouver)
LIONS' GATE Lions' Gate Fisheries Ltd. - Long Beach Shellfish Facility (Delta)
NEW WEST NET Co. Ltd. (New Westminster)

| | |
|---|---|
| OCEAN | Ocean Fisheries Ltd. (Richmond) |
| SHEARER | Shearer Seafood Products (Delta) |
| SM PRODUCTS | S.M. Products Ltd. (Delta) |

# 1 INTRODUCTION

## 1.1 Background

In June 1993 the Fraser River Estuary Management Program (FREMP) retained NovaTec Consultants Inc. (NovaTec), and their subconsultants EVS Environmental Consultants, to carry out an effluent sampling program at a select group of fish processing plants which discharge to the Fraser River Estuary. This study was to form part of an inter-agency coordinated three-year (cyclical) monitoring program, described by the Water Quality Plan of the Fraser River Estuary Management Program. The monitoring program is intended to generate environmental trend data on the fate and effects of contaminants in the Fraser Estuary, and to permit assessment of the relative degree of contamination of receiving waters and biota. The work carried out as part of the present study will be used in conjunction with data gathered from other industrial operations (forestry, metal finishing and cement industries) evaluated in February/March of 1993. The fish processing wastewater characterization program was carried out at a later date than the other industrial operations due to the seasonal nature of their operation.

## 1.2 Objectives

The objectives of the present study include the following components:

1. To compile and summarize recent available information on the physical and chemical characteristics, toxicity, volume of discharge, and discharge frequency of permitted effluents and other discharges entering the Fraser River, and Burrard Inlet from the fish processing industries listed below (see Figure 1 for location of fish processing facilities):

    Bella Coola Fisheries (Permit #5400)
    B.C. Packers (Permit #1830)
    Great Northern Packing (Permit #7810)

Lions Gate Fisheries (Permit # 3139)
New West Net Company (Permit #8167)
Ocean Fisheries (Permit #1975)
Shearer Seafood Products (Permit #7785)
S.M. Products Ltd. (Permit #8430)

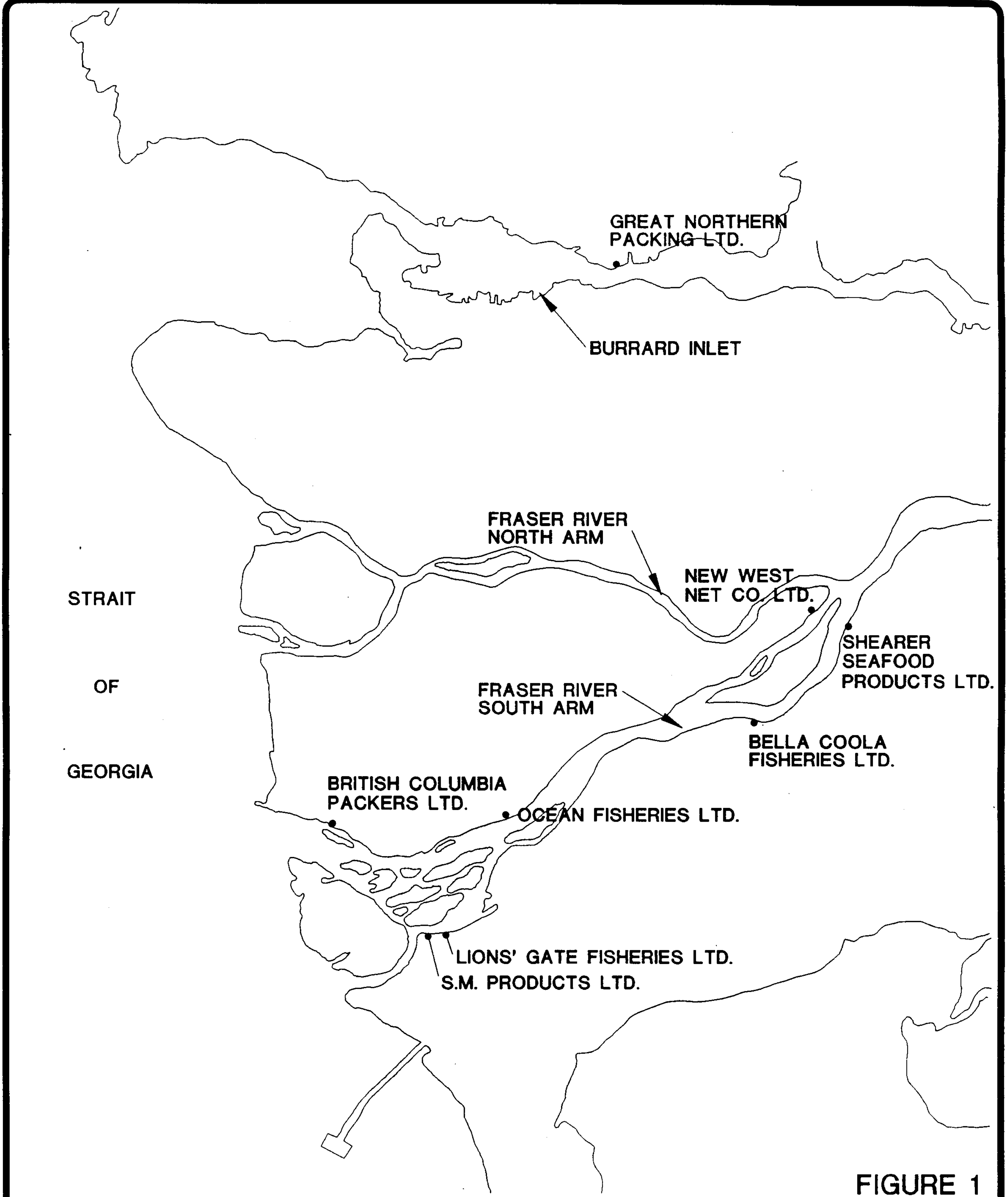



FIGURE 1

LOCATION OF FISH PROCESSING PLANTS

The terms of reference also included site assessment of the Great Northern Packing facility which discharges into Burrard Inlet.

2. To conduct a one to two day site assessment of the operational practices at all processing facilities listed above on the basis of the information gathered in Task 1. The operational assessments were intended to assist in determining the frequency and quantity of chemical and waste streams reaching the receiving water environment. The site assessments were to include the following:

- Document the process streams from raw materials handling to final product shipment at each facility.
- Provide an overview of waste management practices for pollution control at source, and comment on the relative effectiveness of the technologies employed.
- Describe waste treatment facilities including physical structures, design principles, controlling parameters, and overall system capacity.
- Identify and classify wastewater streams including process discharges and site runoff, potential contaminants, spill containment structures, and point(s) of release to the receiving environment.
- Review and describe (if available) the wastewater collection system.
- Identify relevant analytical parameters and adequacy of flow measurement techniques.
- Identify final effluent sample collection and flow measurement stations, and any specific field equipment needs.
- Describe any proposed changes to the wastewater treatment process which may affect future effluent quality.

## 1.3 Scope

The scope of the study was to evaluate the waste management practices at eight selected fish processing operations and to characterize the effluent from four of these plants. The study period was limited to the salmon processing period, but was to include all processing that took place during that period (i.e. including any processing of other fish occurring during the study period).

The wastewater characterization phase of the project included the determination of a number of physical and chemical wastewater quality parameters, as well as the carrying out of four different toxicity tests. Due to budget constraints toxicity tests were conducted only with the effluents from three plants, whereas the determination of physical and chemical wastewater quality parameters involved effluent from four plants.

## 1.4 Report Structure

The report is structured into the following eight sections:

- *Section 1*: presents background information and states the report objectives;
- *Section 2*: provides a description of typical fish processing operations at visited facilities;
- *Section 3*: provides a review of typical waste management practices and flow measurement techniques at visited facilities;
- *Section 4*: provides a description of each of visited fish processing facilities and outlines the differences of their practices as compared to typical processing operations described in section 2;
- *Section 5*: provides a description of sampling methodology;
- *Section 6*: presents discussion of physical/chemical and biological testing results;

- *Section 7*: provides an estimate of contaminant loadings to the environment and potential receiving water impacts;
- *Section 8*: presents conclusions.

Sections 2 and 3 are general descriptions of fish processing operations, waste management practices and flow measurement techniques encountered at the fish processing facilities visited. To avoid repetition, reference to these sections is made in the descriptions of the individual facilities. Any deviations from the typical operating modes at individual facilities are noted in the description of these facilities (Section 4).

Report Appendices including MOELP Permit information, analytical test results, contaminant loading calculations, and QA/QC protocols are attached to this Report.

Copies of subcontractors toxicity laboratory data reports are available for inspection at the Fraser River Estuary Management Program offices (New Westminster, B.C.), and at the Fraser Pollution Abatement Office of Environment Canada (North Vancouver, B.C.).

## 2 REVIEW OF TYPICAL FISH PROCESSING OPERATIONS

### 2.1 Vessel Unloading

Vessel unloading can be done with wet or dry pumps, or with buckets or baskets. Dry pumps result in rough handling of the fish and are generally only used for ground fish due to the relatively low commercial value of the fish. Wet pumps are much gentler and are used for freshly caught salmon which are kept in water inside the holds of fishing boats and fish packer vessels during transport. The pumps use large diameter hoses to pump water and whole fish out of the vessels' holds. Water and fish are then discharged onto grating to allow the separation of fish and water. A certain amount of water is recirculated to the vessels to ensure sufficient water for the operation of the pumps and to be able to remove all fish. The water level in the vessel is continually lowered during the unloading operation and the vessel, generally, is almost completely empty when all fish have been unloaded.

Conveyors pick up the fish after their separation from the vessel hold water and transport them to grading stations, where the fish are manually sorted according to their species. After sorting, fish are kept in chilled water for intermediate storage until they can be further processed.

Baskets or buckets are also used to unload vessels but are, generally, used only if small quantities of fish need to be unloaded, or to offload frozen fish. Baskets are lowered into the vessels holds by a crane and filled with frozen fish.

### 2.2 Butchering for the Fresh and Frozen Fish Market

A typical flow diagram depicting freezer - dressing of salmon and associated processes is shown in Figure 2. The equipment used for salmon butchering (also referred to as "dressing") depends on the requirements for further processing. Dressing fish for freezing involves the removal of the head and gutting of the fish. The tails, fins and the collar bone immediately behind the head are not cut off.  The eggs (or roe) of the female fish are generally removed for further processing, and the milt of the male fish may also be removed at this stage.

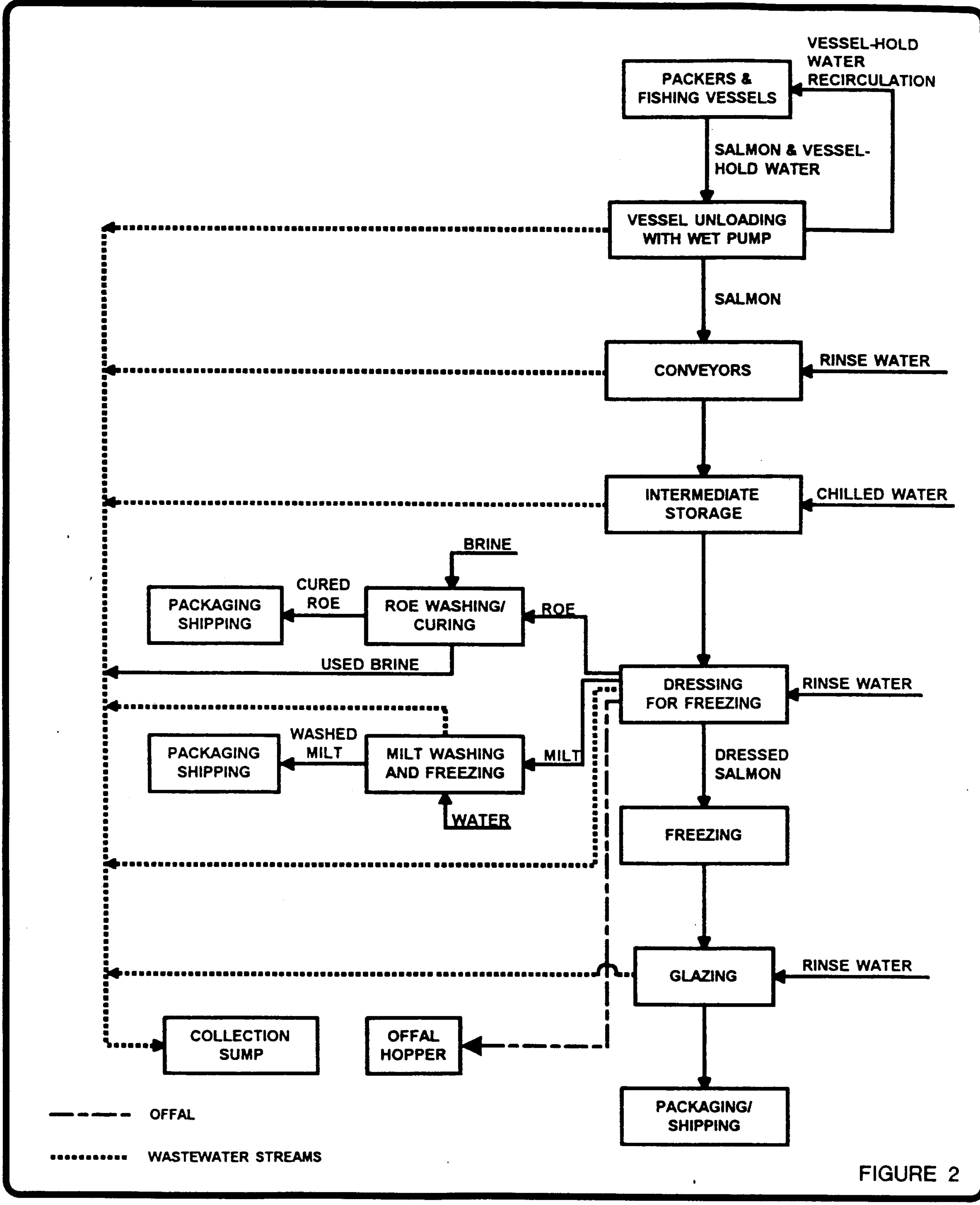



FIGURE 2

SALMON DRESSING FOR FREEZING (TYPICAL PROCESS FLOW CHART)

Butchering for freezing is done manually or with semiautomatic dressing lines. The manual dressing lines consist of a large table and fish cleaning station, where workers are responsible only for specific tasks, such as:

- head removal
- belly slitting
- removal of viscera and separation of milt and/or roe
- removal of the kidney
- cleaning of fish

The final cleaning of the fish is done with a spoon which is directly attached to a small water hose to both scrape and flush remaining viscera and blood away.

Offal from the dressing may be dropped on the floor, into totes for collection, or chutes which discharge to a flume or dedicated offal conveyance system.

On the semi-automatic processing lines fish are placed belly up in a pocket conveyor after their heads have been removed. Head removal can be achieved manually or automatically. The bellies are then slit manually; guts, and roe or milt are removed by hand and separated for waste disposal, or further processing, followed by the cutting of the kidney. The fish are then cleaned with nozzles attached to suction hoses which remove remaining guts and blood by vacuum, and with spoons attached to small water hoses as in the case of manual cleaning. The dressed fish are then washed, graded, and frozen (Section 2.7), or are stored on ice for sale on the fresh fish market.

Troll-caught fish are already dressed at sea, stored on ice, or frozen at sea (FAS). Further processing may involve the removal of heads.

## 2.3 Butchering for Canning

A typical flow diagram for salmon canning is shown in Figure 3. Dressing for canning is generally done with an iron butcher which cuts off heads (including the collar bone), tails and fins.

Although the iron butcher can be used to slit and remove the viscera, this is usually done by gutting and washing machines which results in better cleaning.  Entrails are removed with rotating wheels and brushes. Final cleaning is with water sprays.  The

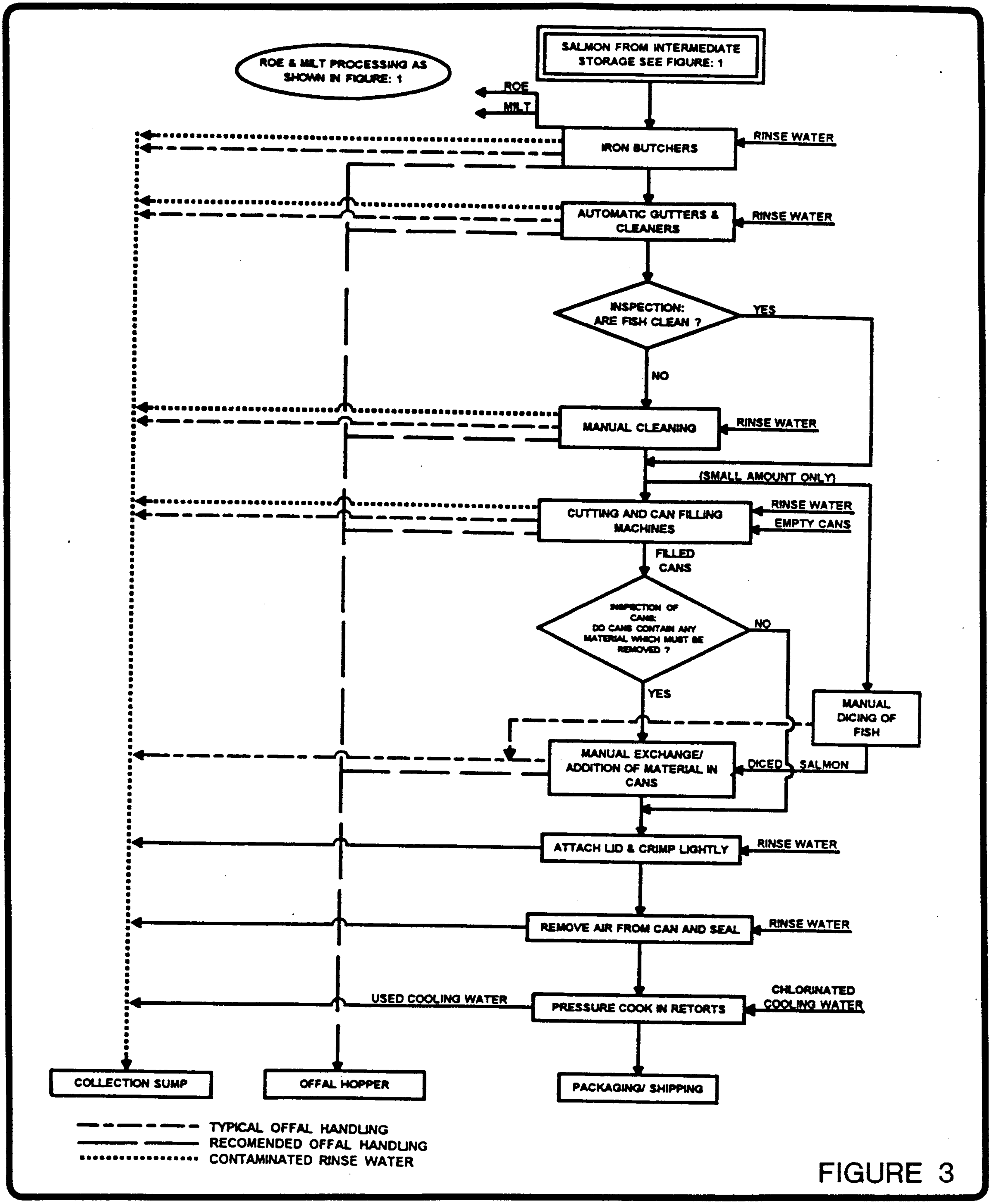



FIGURE 3

TYPICAL SALMON CANNING

wash water, mixed with guts and blood, drains out at the bottom of the gutting machines.

The fish are inspected after the gutting process and are further manually cleaned if necessary. During this cleaning step, workers scrape and cut off remaining entrails and fins. Typically, each manual cleaning station is equipped with a small, constantly running, water hose to rinse off any offal and/or blood.

## 2.4 Salmon Canning

The salmon butchered, as described in Section 2.3, is fed into cutting machines which cut the fish into sections of appropriate size for the cans to be used in the canning machines. Canning machines then press the salmon sections into cans which are subsequently inspected by workers who rearrange the material in the cans for aesthetic reasons and add additional material to under-weight cans if necessary (patching). Lids are then lightly clinched onto the cans, and the cans are sealed in seamers which operate under vacuum.

Following the sealing, the cans are washed and placed in busses (slatted metal buggies with movable bottoms) and pressure cooked in large retorts. After the cooking process the cans are cooled with water which must be chlorinated to a concentration of at least 2 mg/L for a minimum of 20 minutes to ensure disinfection.

## 2.5 Salmon Roe Processing

The roe collected during the fish dressing (butchering for freezing or canning) is further processed by washing and curing in a concentrated brine solution for 20 minutes. Washing and curing takes place in agitated, circular tubs. The brine is replaced after each five batches of roe processed.

## 2.6 Salmon Milt Processing

Milt processing only involves washing the milt in water and freezing prior to shipping.

## 2.7 Glazing

Frozen salmon generally receive a smooth coating of clear ice glace prior to final packing and shipping. This glazing is accomplished by either spraying already frozen fish with a fine water spray, or by dipping the frozen fish into chilled water. After glazing the frozen fish are packed in plastic bags and placed in boxes for shipment.

## 2.8 Shrimp Processing

Frozen shrimp are separated from ice and are processed in a precooker, where live steam is injected to provide optimum peeling and recovery of meat. The precooked shrimp fall onto the oscillating rollers of the peeler which pull extraneous parts from the meat. Water sprays loosen and wash away waste. Waste and the sprayed water are flumed away to floor drains.

After further mechanical cleaning, the shrimp are transported to a table or "picking belt" where workers hand sort and clean the shrimp. The peeled and washed shrimp are then frozen for shipment.

## 2.9 Herring Processing

### 2.9.1 General

The primary product of herring processing of fish processing facilities in the B.C. Lower Mainland is cured herring roe. Due to the relatively short fishing season and the necessity for freezing herring to preserve fish shape and quality of the roe, herring processing is divided into two distinct phases:

- Vessel unloading and freezing, and
- Thawing, roe "popping", and roe processing.

These phases take place at different times. The fish processing operations that occur during the individual phases are described in detail in the following sections.

### 2.9.2 Vessel Unloading and Freezing

Herring are delivered to the fish processors suspended in chilled seawater in the holds of fishing boats and fish packer vessels. Vessel unloading is done with wet pumps, as described in Section 2.1. Intermediate storage of the herring may be required, as the capacity of the vessel unloading pumps may exceed the throughput of subsequent handling steps.

Herring may undergo additional washing steps to remove blood, slime, and scales, before being frozen and sent to cold storage. Freezing generally takes place in brine freezing channels which contain a saturated sodium chloride solution at -18EC followed by tunnel freezing to rapidly freeze the individual fish.

Herring sex sorters are available to separate male from female herring. The use of such sorters results in reduced water consumption and wastewater contaminant loadings. Also reduced are labour requirements for subsequent handling steps, as all male fish would be sent to a reduction plant rather than undergoing additional treatment (washing, freezing, and belly slitting - see below). Ideally, sex sorting of herring should take place immediately after vessel unloading.

### 2.9.3 Thawing and Roe Popping

Herring may be thawed in water or in air. Air thawing is substantially more labour intensive than water thawing and requires placing the frozen herring on racks for thawing. Air thawing also generates wastewater, as the thawed herring are generally stored in water until roe popping takes place.

When the thawing process is complete, the fish are separated from the tote water using tote dumpers. Conveyors then transport the fish to popping stations for roe removal. At manual popping stations the fish are split, and the roe is removed and collected. The fish carcasses are collected separately.

Automatic roe popping machines which only require the fish to be manually placed on an infeed belt are also available. These machines also separate the roe from the milt of the male herring, although this separation is not without errors, and further manual separation of milt from roe and vice versa is required. The milt is collected with the carcasses and generally is directly transported to offal hoppers.

The roe from manual and/or automatic popping is rinsed with water, and washed and cured with three different solutions of brine, followed by the curing of the roe in concentrated brine for four to seven days.

After curing and separation from the brine, the roe is manually graded, packed in pails to which concentrated brine and salt is added, and shipped.

# 3 REVIEW OF TYPICAL WASTE MANAGEMENT PRACTICES

## 3.1 General

As the waste management practices observed in the fish processing facilities visited were very similar (depending on the throughput of the facility), they are described in detail in the following sub-sections. Detailed information specific to each facility is presented in Section 4. The sub-sections also include a discussion of the principles of the waste management practices encountered and their advantages and disadvantages. The description of the practices are divided in offal transport methods, and screening, which is the typical form of treatment encountered at the facilities reviewed.

## 3.2 Offal Transport

A flow diagram of a typical waste treatment scenario is shown in Figure 4. Generally, fish processing facilities make use of water not only for fish cleaning, but also to flush offal and blood from equipment and floors, and to transport or flume the offal to floor drains and collections sumps. Automated processing equipment generally have permanently installed water sprays to keep the equipment clean and to flush offal away. Typically, large chunks of offal (heads, tails, fins, etc.) fall into chutes which direct the offal to flumes, or are washed into flumes, which transport the offal to a collection sump. However, a certain amount of offal generally falls onto the floor where it accumulates and must be removed manually. This is typically done by hosing the offal into a nearby drain or flume.

Apart from resulting in high water consumption, this method of equipment cleaning and offal transport causes the mixing of the rinse water with offal and blood, which has two main disadvantages:

1) Any soluble biological oxygen demand (BOD) components (i.e. blood) will be dissolved in the water. Dissolved BOD cannot be removed by physical treatment such as screening and is discharged unchanged by such treatment.

2) In all facilities which used rotary sidehill screens (Section 3.3), the wastewater had to be pumped to an elevated screen from where it was

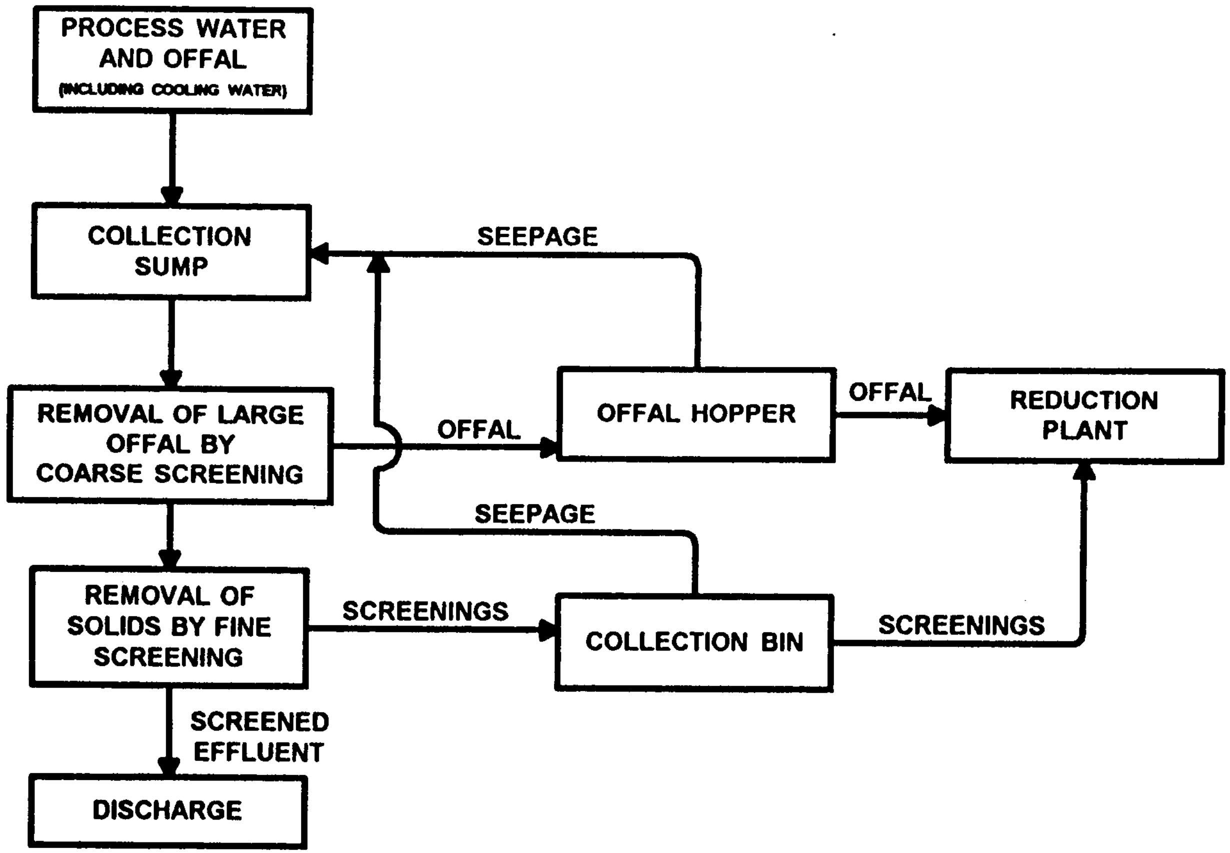



FIGURE 4

TYPICAL WASTE TREATMENT SCENARIO

discharged by gravity. The pumping action is rough on offal chunks resulting in an increase of smaller particles which may pass through the following screen. In addition, pumping is believed to increase the dissolved BOD by solubilizing suspended organic material.

The shortcomings of offal fluming have been identified and addressed in many European fish processing facilities, and modifications have been and are being implemented at several fish processing facilities in the B.C. Lower Mainland. The main processing principles include:

1) Use of suction to remove entrails and to clean fish.

This method represents a very effective means for reducing the contaminant loading, as well as the volume of wastewater discharged from fish processing facilities. However, to fully realize the potential of this processing method, the offal removed must be discharged directly into an offal hopper or bin. Discharging the offal into the wastewater collection system (including discharge directly to the screen) allows the mixing of the soluble fraction of the BOD with the effluent and will result in an increased contaminant loading.

The suction method for dressing fish is at present only practised for freezer-dressed fish, as mechanised equipment available for cannery dressed fish has a higher throughput than can be achieved with the semiautomatic vacuum dressing lines.

2) Dry transport of offal and separation of offal from water prior to pumping.

These waste handling methods are very similar and can result in a major reduction in contaminant loading and water consumption. Dry offal transport refers to the use of conveyors for the transport of offal rather than fluming offal. As water sprays are generally still required, both for equipment cleaning, and because of Department of Fisheries and Oceans' requirements, the conveyors generally are constructed with a belt made of wire mesh which allows water to drain, but retains large chunks of offal.

A more extreme version of offal separation from wastewater prior to pumping includes screening of all, or major sources of, wastewater prior to pumping. Such a setup requires sufficient clearance below the floor flumes to install a screen and to collect screenings. None of the major fish processing facilities visited screened the wastewater prior to pumping. The smaller processors (New West Net, Shearer and S.M. Products) discharged their wastewater by gravity flow, but used coarse screens only.

## 3.3 Screening

All of the large processing facilities visited screen their effluent before discharge. Screening is a physical wastewater treatment process and removes solids which cannot pass through the openings of the screen. Solids removal is an important step in wastewater treatment, as solids of organic origin contribute to the BOD of a wastewater. However, a substantial fraction of the BOD of wastewaters is due to dissolved substances (such as blood) which, together with particles smaller than the screen openings, cannot be removed by screening.

Dissolved BOD cannot be removed by simple physical means, but must be removed by a combination of chemical and/or biological treatment. Therefore, the separation of waste material from water, as outlined above, is an important means of reducing contaminant loadings if only physical treatment processes are employed.

All of the large fish processors use rotary screens, although a sidehill screen is used at Ocean. The rotary screens are available in two configurations. In one configuration the untreated wastewater is delivered into a headbox which distributes the flow evenly across the rear, upper surface of a horizontal, rotating cylindrical screen. Effluent passes through the screen twice. First, through the top of the screen where the removal of solids takes place. Second, through the bottom of the screen in order to drain away. This second step also causes the screen to be backwashed as a result of the cascading action of the screened water. Retained particles are transported by the rotation of the screen to a doctor blade which scrapes off screenings. The screenings are generally collected in a bin or hopper. Internal high pressure sprays (spraying from the inside of the screen) may be installed for additional backwashing of the screen.

The second type of rotary screen receives influent through a headbox on one of the circular sides of a horizontal rotating screen drum. Effluent is screened as it drains through the drum. Retained particles are transported, by blades mounted on the inside, to the opposite end of the drum, where the screenings are discharged and collected. The drums are generally mounted at an incline, with the influent side being lower than the solids discharge end, to prevent influent from being discharged with the solids rather than draining through the screen.

A sidehill screen is an inclined flat screen which is curved at the bottom. Wastewater is delivered into a distribution chamber on the top of the screen from where it overflows onto the screen. Due to the inclination of the screen, water can drain through it while large size particles tumble down on the upper side. A brush moving back and forth on the front side of the screen removes any accumulated particles. The action of the wastewater as it flows over the screen also helps in cleaning the screen and transporting solids. Screenings are collected at the bottom of the screen.

### 3.4 Review of Flow Measurement Techniques

The flow measurement and flow estimation techniques used by the facilities visited during this study were (presented in order of decreasing accuracy):

1) Parshall flume (BC Packers);
2) V-notch weir (Great Northern);
3) pump hour meter readings (Lions' Gate); and
4) water consumption data (remaining facilities).

Parshall flumes, in conjunction with an accurate water level measuring device, are generally accepted as reliable and reasonably accurate flow measurement devices, if installed, maintained, and operated correctly. Pump hour meters in conjunction with pump discharge curves can be used to determine discharge flows, as long as the flow rates of the pumps are known with sufficient accuracy. If more than one pump is in use, the pump rate of both pumps must be measured separately as well as together, to account for differences between individual pumps, and to account for the fact that the pump rate of two pumps pumping into the same pipe is less than the sum of the pump rates of the individual pumps.

It has been the project team's experience that estimating the effluent volume based on the water consumption is the most inaccurate of the three methods. The problem with this method is that the actual effluent flow is not measured, as is the case for the other two methods. However, this method does comply with provincial permit requirements. Where the flows measured exceed permit flows, the facility may wish to introduce more accurate means of measurement. Its primary drawback is that loading estimate may be inaccurate (high).

Some of the factors affecting the accuracy of this flow measurement technique are listed below:

1. Discharge of water not measured by water meter:
   - Vessel hold water;
   - Melt water from ice delivered together with frozen fish; and
   - Storm water (if collected and discharged together with process effluent).

2. Metered water not discharged together with process effluent, such as water used:
   - For ice making (for shipping of frozen fish);
   - As cooling water (if separate outfall); and
   - For sanitary use.

# 4 WASTE MANAGEMENT PRACTICES AT STUDY FACILITIES

## 4.1 Bella Coola Fisheries Ltd.

### 4.1.1 Facility Description

Bella Coola Fisheries Ltd. (Bella Coola) is located in Delta, British Columbia, on the shores of the Fraser River. A site plan of the Bella Coola plant is shown in Figure 5. The facility has a permit for two separate discharges to the Fraser River. One of the discharges is for the effluent from the fish processing plant and effluent from a sanitary treatment plant. The other permitted outfall is for discharge of cooling water from a refrigeration house and storm water.

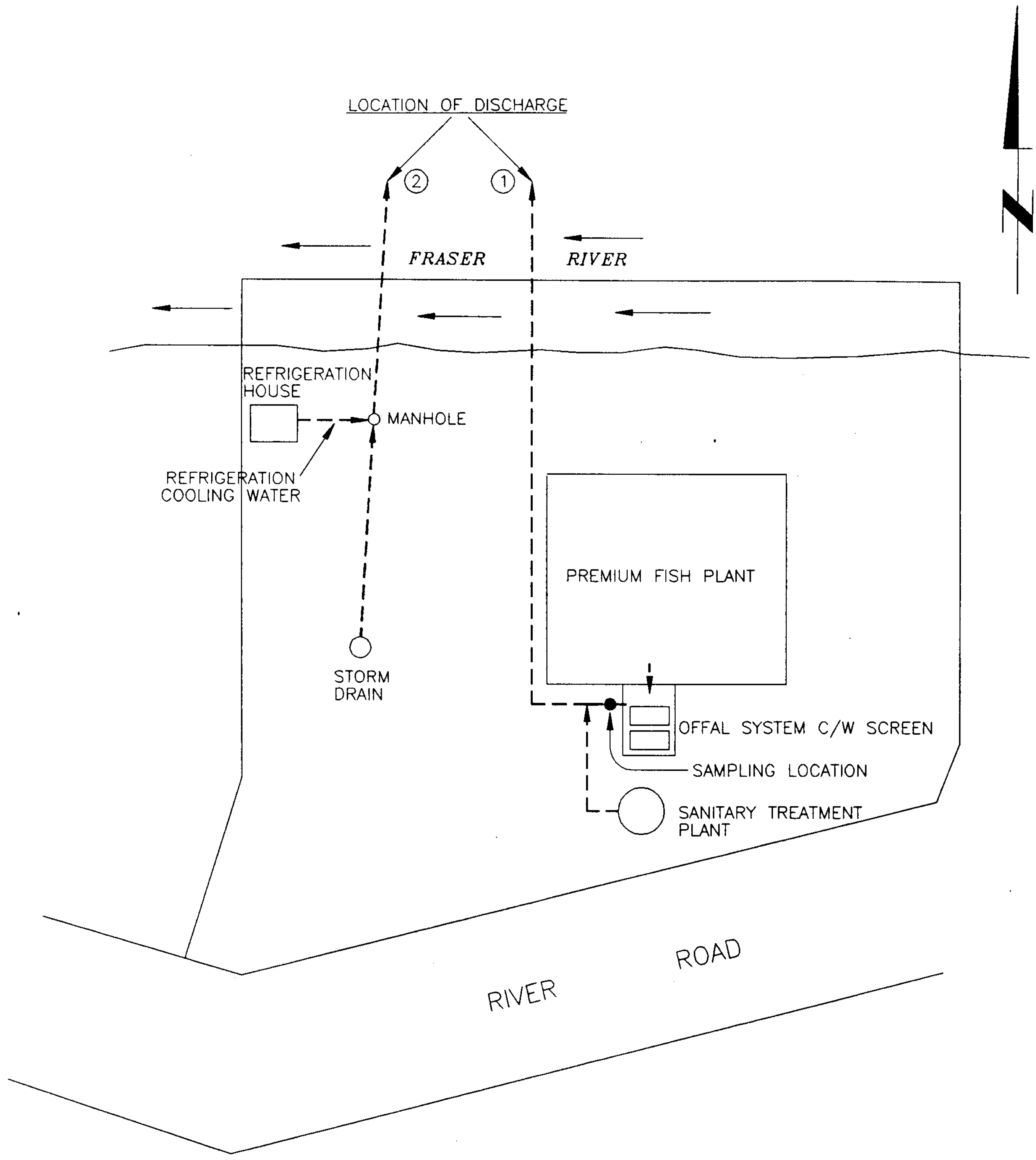
### 4.1.2 Description of Processes

Although herring roe processing takes place in early spring, Bella Coola only processed salmon during the study period. The processing operations include: vessel unloading with a wet pump, fish grading and intermediate storage in totes, dressing for freezing, or canning; roe and milt removal; and roe processing. Bella Coola is not equipped to carry out canning, and cannery dressed fish are stored on ice and shipped to other fish processing facilities for further processing.

Dressing of fish may be done manually, semi-automatically using suction hoses, or with an iron butcher. Bella Coola does not have gutters for removal of entrails. Processing of roe and milt is done as described in Sections 2.5 and 2.6.

### 4.1.3 Description of Waste Management Practices

All yard drains are connected to the main wastewater sump, with the exception of a storm water drain on the west side of the facility. This drain is located in an area where no processing or vessel unloading takes place and has a separate outfall which also receives condensate from the on-site refrigeration unit. A low concrete curb and the general slope of the dock area prevent any spillage of process or unloading water from the dock into the Fraser River.




LEGAL DESCRIPTION: Lot 12 of District Lot 119, Group 2, New Westminster District, Plan 63777

N.T.S

**FIGURE 5**

**BELLA COOLA - SITE PLAN**

| | |
|---|---|
| **NAME** | Bella Coola Fisheries Ltd. |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-5400 |
| **ADDRESS** | 9829 River Road, Delta, V4G 1B4 |
| **TELEPHONE/FAX NUMBER** | 583-3474/583-4940 |
| **CONTACT PERSON** | Aki Sakai, Plant Manager |
| **RECEIVING WATER BODY** | Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Richard Cermak |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 09.179' N, 122E 57.096' W |
| **NTS MAP SHEET NUMBER** | 92 G2 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | 6 m |
| @ length (from shore @ low water) | 45 m |
| @ pipe diameter | 200 mm |
| @ age | 14 years |
| @ material | concrete sewer pipe |
| @ diffuser configuration | Y pipe |

Floor drains inside the processing building direct all process water to the wastewater sump. Large offal is either collected directly in totes, or is flumed to the wastewater sump, where it is separated from the effluent by an inclined wire mesh conveyor which transport the offal to a container. Seepage from this container cannot drain back to the sump and is hosed into a yard drain, which is connected to the sump.

Effluent from the sump is pumped over a rotating screen prior to discharge. Drainage from the screenings which are collected in a tote underneath the screen is allowed to drain back into the sump. Blood and offal removed with vacuum suction is discharged directly to the screen. All offal is sent to BC Packers for reduction.

### 4.1.4 Review of Existing Data

A summary of MOELP Permit requirements and existing data is presented in Appendix A, and Appendix B respectively. The maximum daily process discharge rate for the Bella Coola plant authorized by the MOELP Permit is 1400 $m^3$/day. Recorded flow at the plant during 1990, 1991, and 1992 seasons indicate the maximum permitted flow was not exceeded. Water consumption ranged from 20 to 75 $m^3$/tonne of processed fish with a geometric mean value of 24 $m^3$/tonne of processed fish.

The MOELP Permit requires quarterly monitoring of BOD, TSS, oil and grease, residual chlorine and temperature. Recorded effluent concentrations ranged from 60 to 2180 mg/L for BOD and from 23 to 2180 mg/L for TSS, and most of the time exceeded Permit limits (Appendix A).

Reported oil and grease concentrations ranged from 1 to 511 mg/L.

## 4.2 British Columbia Packers Limited

### 4.2.1 Facility Description

BC Packers, located in Richmond B.C., is the largest of the fish processing facilities studied in this project, and includes a reduction plant which processes fish offal from the B.C. Packers facility, and other fish processing facilities. A site plan of the BC Packers fish processing plant is shown in Figure 6. The facility processes both salmon and herring. At the present time the facility discharges screened effluent and uncontaminated cooling water from the reduction plant to Cannery Channel. However, plant management has committed themselves to redirecting the discharge of process effluent either to the South  Arm of the Fraser River (which is separated from Cannery Channel by Steveston

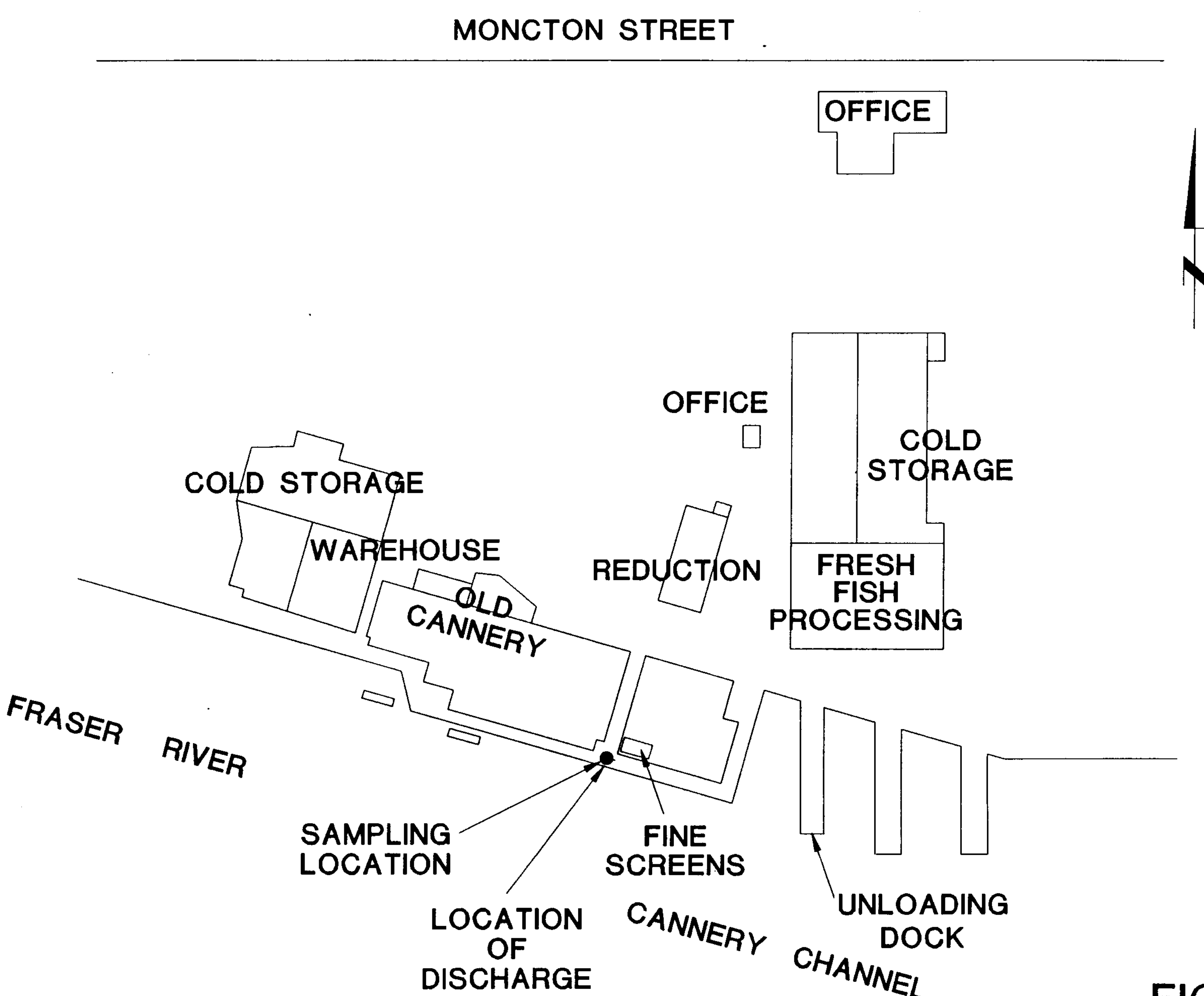



FIGURE 6

B.C. PACKERS - SITE PLAN

| | |
|---|---|
| **NAME** | British Columbia Packers Limited |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-01830 |
| **ADDRESS** | 4300 Moncton Street, Richmond, V7E 3A9 |
| **TELEPHONE/FAX NUMBER** | 277-2212/277-8122 |
| **CONTACT PERSON** | Roger D. Gibb, Vice President, Quality Assurance |
| **RECEIVING WATER BODY** | Cannery Channel, Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Roger Gibb and Sam Akyeampong |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 07.345' N, 123E 10.730' W |
| **NTS MAP SHEET NUMBER** | 92 G3 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 3 m |
| @ length (from shore @ low water) | app. 5 m |
| @ pipe diameter | 500 mm |
| @ age | app. 20 years |
| @ material | steel |
| @ diffuser configuration | open pipe |

Island), or to the GVRD sewer system. The cooling water used in the reduction plant is extracted from Cannery Channel, and BC Packers is authorized to discharge it back to cannery channel. The screened effluent consists of process water from the fish processing and condensate from the reduction plant. The facility has two main 100 mesh rotary screens (maximum openings of 0.15 mm), and one 60 mesh backup screen (maximum openings of 0.25 mm). A Parshall flume in conjunction with an ultrasonic level sensor measure the combined flow of process effluent and cooling water. Effluent sampling, as required by BC Packers' MOELP discharge permit takes place with the combined streams. The cooling water flow is also measured separately.

### 4.2.2 Description of Processes

BC Packers uses wet pumps for the unloading of vessels, which are surrounded by a concrete curb for containment of any spills. Due to an agreement with Canadian Fishing Company, which does the canning for BC Packers in the B.C. Lower Mainland, no canning takes place at the BC Packers' Richmond plant. Salmon are dressed for canning or freezing as described in Sections 2.2 and 2.3. All cleaning of freezing-dressed fish is carried out with vacuum suction. In addition, the facility processes salmon roe and milt as described in Sections 2.5 and 2.6.

### 4.2.3 Description of Waste Management Practices

BC Packers employs the most refined waste management practices of all facilities visited. The facility makes extensive use of dry transport of offal to minimize wastewater contaminant loadings. Conveyors for offal transport are located next to the iron butchers, and below the gutting machines. Some fluming of offal and flushing away of offal, such as fluming of the heads and flushing of tails and fins from the iron butchers is still practised, but greatly reduced, as the offal is only flumed to the offal conveyor where it is separated from the water for further transport. These conveyors convey the offal to bins which are then transported to the reduction plant.

In addition, the entrails and blood removed through vacuum suction are directly discharged into an offal hopper and are not mixed with any washwater.

Seepage from the offal receiving hopper and fish bins of the reduction plant are currently combined with process effluent prior to screening. Plans are under way to redirect this highly contaminated waste stream to the reduction plant. This is expected to result in a substantial reduction of the BOD, TSS, oil and grease, and other pollutant loadings from the BC Packers facility. The vast majority of the BOD in blood is due to dissolved organic material which cannot be removed by screening.

### 4.2.4 Review of Existing Data

Monthly monitoring of BOD, TSS, oil and grease, temperature and residual chlorine is required by MOELP Permit (Appendix A). A review of the historical data indicates that BC Packers facility is operating within the limits of its discharge permit. Recorded flows were in compliance with the average flow limit of 4500 and maximum flow limit of 11800 $m^3$/day specified in the Permit. Water consumption ranged from 0.3 to 111 $m^3$/tonne of processed fish with a geometric mean value of 15 $m^3$/tonne of processed fish.

Recorded residual chlorine concentrations ranged from 0.01 to 3.29 mg/L. The records show the residual chlorine concentration decreased from 1990 through 1992. In 1992 the residual chlorine concentration of 0.05 mg/L (specified by Permit) was met most of the time as a result of operation of a dechlorination facility. The permit limit was never exceeded during the 1993 processing year. It is expected that the limit for residual chlorine will be met in the future as BC Packers has stopped canning salmon (the salmon canning process uses chlorinated retort cooling water).

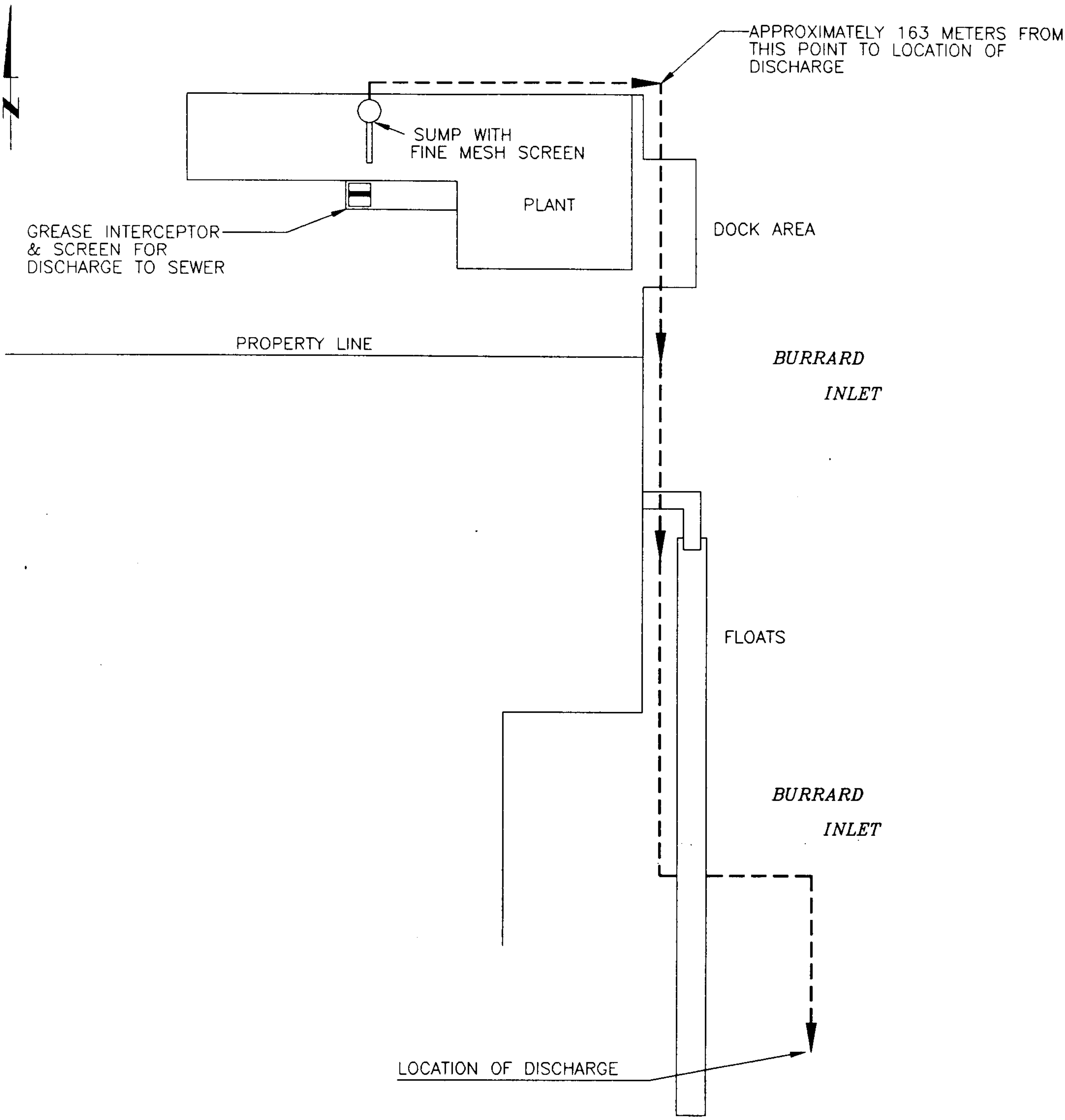
The Permit requirement for the cooling water temperature to be below 32 EC was always satisfied.

The effluent BOD and TSS concentrations ranged from 13 to 1290 mg/L, and from 20 to 787 mg/L, respectively.

## 4.3 Great Northern Packing Ltd.

### 4.3.1 Facility Description

Great Northern is located in North Vancouver, immediately west of the Second Narrows Bridge. A site plan of the Great Northern facility is shown in Figure 7. The company processes salmon, herring, and occasionally black cod, and generally discharges its process water to the GVRD sewer system. However, Great Northern maintains a MOELP




LEGAL DESCRIPTION:

Parcel 9 and Parcel 10 of Indian Reserve No.2 and 7.6 meter strip to the east and 15.2 meter strip to the west, both extending south from extension of north boundary of Parcels 9 and 10

N.T.S

**FIGURE 7**

# GREAT NORTHERN PACKING LTD. - SITE PLAN

permit for the discharge of process water to Burrard Inlet, mainly to be able to legally discharge thaw water during herring processing which could not be handled by the GVRD sewer, and for emergency use. The outfall to Burrard Inlet has not been used since the herring processing season in 1991, as the company has switched to air thawing of herring. The outfall runs approximately 163 metres along the docks, and floats and discharges in the centre of the access channel to a nearby marina.

| | |
|---|---|
| **NAME** | Great Northern Packing Ltd. |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-7810 |
| **ADDRESS** | 20 Orwell Street, North Vancouver, V7J 2G1 |
| **TELEPHONE/FAX NUMBER** | 980-6536/986-0296 |
| **CONTACT PERSON** | Charlie R. Burton |
| **RECEIVING WATER BODY** | Burrard Inlet |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Charlie R. Burton |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49° 18' 53.8" N, 123° 1' 43.5" W |
| **NTS MAP SHEET NUMBER** | 92 G/6 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | at the bottom of the channel |
| @ length (from shore @ low water) | app. 80 m |
| @ pipe diameter | 250 mm |
| @ age | 14 years |
| @ material | PVC |
| @ diffuser configuration | open pipe |

### 4.3.2 Description of Processes

Great Northern does custom fish processing (herring in spring and salmon canning in summer). Salmon processing consists of dressing and canning as described in Sections 2.3 and 2.4. Fish are delivered to Great Northern in totes. The facility processes cannery dressed fish and round (undressed) fish. Roe processing does not take place on-site, but roe is collected and returned to customers for further processing, if required.

Fish dressed for canning delivered to Great Northern bypass the iron butchers and gutters, and are directly fed into the cutting machines upon delivery.

### 4.3.3 Description of Waste Management Practices

Offal from the iron butchers and automatic gutting machines is collected on conveyors which transport the offal to a hopper for storage. Permanent water sprays and regular hose downs ensure that all other offal is flushed away. All floor drains are connected to a collection sump from where the effluent is pumped to an elevated 25 mesh size (maximum openings 0.7 mm) rotary screen before it passes through a three chamber grease trap. The effluent flow is measured with a v-notch weir and is discharged to the GVRD sewer system. In addition to the water from water sprays and hose downs, the effluent also includes the cooling water from the retorts.

Offal from the screen is collected in a container which is emptied into the main offal container when full. The screen is surrounded by a concrete curb for containment of spills which may happen if the screen clogs up, and to redirect any seepage from the container collecting the screenings back to the sump. The drain at the main offal pad is also connected to the collection sump. Other drains in the yard are connected to a storm sewer which discharges to Burrard Inlet. Offal and screenings are sent to Unican Industry Ltd. in Langley, B.C. for further processing. During the peak salmon processing season, the grease trap is pumped out twice per week. All sludge is taken to the GVRD's Iona Wastewater Treatment Plant.

Wastewater to be discharged to Burrard Inlet (during herring thawing) is screened by a fine mesh screen placed on top of the sump used for wastewater collection. The volume of this waste stream is estimated based on water consumption.

#### 4.3.4 Review of Existing Data

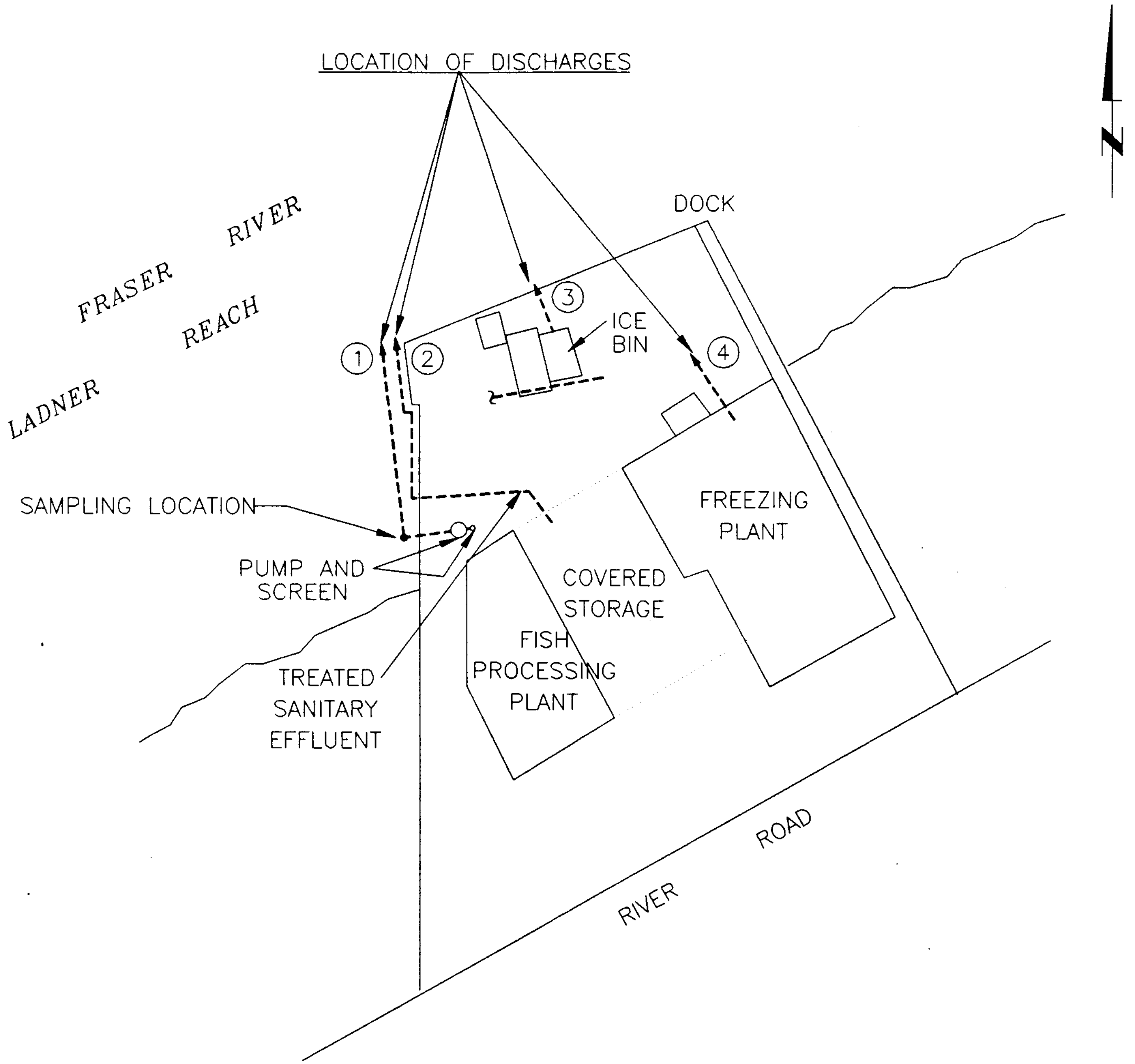
Monthly monitoring of pH, BOD, TSS and ammonia-nitrogen at Great Northern plant is required by MOELP Permit (Appendix A). Water consumption ranged from 3.6 to 89.0 $m^3$/tonne with a geometric mean value of 105 $m^3$/tonne. On low production days water consumption reached 1457 $m^3$/tonne. Available data base for this plant is very limited with respect to its discharge to Burrard Inlet (Appendix B), and no conclusion about effluent characteristics discharged to Burrard Inlet can be made.

Effluent BOD and TSS concentrations discharged to GVRD collection system ranged from 240 to 2100 mg/L and from 105 to 1390 mg/L respectively. Reported oil and grease concentrations ranged from 9 to 340 mg/L.

### 4.4 Lions' Gate Fisheries Limited

#### 4.4.1 Facility Description

The Lions' Gate (Long Beach Shellfish) facility is located on River Road in Delta, B.C. The processing facility is located adjacent to its dock on the Fraser River, and processes salmon, ground fish, herring and shrimp. A site plan is shown in Figure 8. The facility has a permit for four separate discharges, including two for non-contact cooling water from refrigeration units, one for treated sanitary effluent and one for process effluent. The plant is not discharging any sanitary sewage but applied for a permit for such discharge to have this option of wastewater disposal available in the future. The cooling water flows are minor and discharge directly into the river (one at the dock and one at the shore of the river). The outfall used for process effluent discharge runs along the west side of the dock. A vertical tee in the outfall allows the collection of effluent samples and was used as a sampling location for this study. The area between the processing plant and the dock is surrounded by a low curb for containment and is sloped towards yard drains which are connected to the main wastewater collection sump.




LEGAL DESCRIPTION:

E (P8554BE) of District Lot 96, New Westminster District, Group Two, Plan 12416 and Water 585, Water Lot 616, Water Lot 825, all of Group Two, New Westminster District

N.T.S

**FIGURE 8**

**LIONS' GATE FISHERIES LIMITED - SITE PLAN**

4.4.2 Description of Processes

Vessel unloading takes place with wet or dry pumps, or with the bucket method (generally for frozen fish and shrimp). Shrimp processing is as described in Section 2.6. Salmon processing includes dressing for freezing, and filleting. All dressing is done manually (no use of vacuum suction). A machine is used for skinning of fillets. Salmon roe is collected

| | |
|---|---|
| **NAME** | Long Beach Shellfish |
| **OWNER** | Lions' Gate Fisheries Limited |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-3139 |
| **ADDRESS** | 4179 River Road, Delta, |
| **TELEPHONE/FAX NUMBER** | 946-1361/946-0944 |
| **CONTACT PERSON** | Carl Caunce, Plant Manager |
| **RECEIVING WATER BODY** | Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Carl Caunce |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 05.130' N, 123E 06.520' W |
| **NTS MAP SHEET NUMBER** | 92 G3 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 1 m |
| @ length (form the shore @ low water) | app. 7 m |
| @ pipe diameter | 150 mm |
| @ age | 8 years |
| @ material | PVC |
| @ diffuser type | open pipe |

during dressing, but is not processed on-site.  Lions' Gate also does custom unloading of vessels and processes fish delivered by truck.

### 4.4.3 Description of Waste Management Practices

Lions' Gate makes extensive use of water for fluming offal, although fish heads and other large chunks of offal are sometimes directly collected in offal totes. Flumes for the transport of offal are directed to a collection sump, where a conveyor picks up large offal and transports it to an offal container. From this sump the wastewater flows to the main collection sump which also receives flow from the floor drains and the yard drains between the processing facility and the dock. From the main sump the wastewater is pumped to a rotary screen prior to discharge. The screenings are collected in a tote below the screen and are sent to the solid waste disposal site at Burns Bog, or are picked up by farmers as fertilizers. The offal separated during dressing and from the offal container is sent to B.C. Packers for reduction.

### 4.4.4 Review of Existing Data

Parameters required by the MOELP Permit to be monitored on a quarterly basis for the Lions' Gate plant are BOD, TSS, oil and grease and residual chlorine (Appendix A). The permitted flow (500 $m^3$/day average and 800 $m^3$/day maximum) was not exceeded during 1990, 1991, and 1992.  Water consumption ranged from 6 to 37 $m^3$/tonne of processed fish with a geometric mean value of 13 $m^3$/tonne of processed fish.  Effluent BOD and TSS concentrations ranged from 67 to 1365 mg/L and from 42 to 514 mg/L respectively. Recorded oil and grease concentrations were from 1 to 179 mg/L and residual chlorine from 0.01 to 1.07 mg/L.  A summary of the existing data is presented in Appendix B.

## 4.5 New West Net Co. Ltd.

### 4.5.1 Facility Description

New West Net is located on a dock on Annacis Channel of the Fraser River in New Westminster, B.C. The processing building includes a small dock area for vessel unloading and a retail store. A site plan of the facility is shown in Figure 9. The outfall of the processing facility is located at the southwest pile of the building and is submerged even at low low water tidal level (LLW). A boat is required to collect effluent samples.

### 4.5.2 Description of Processes

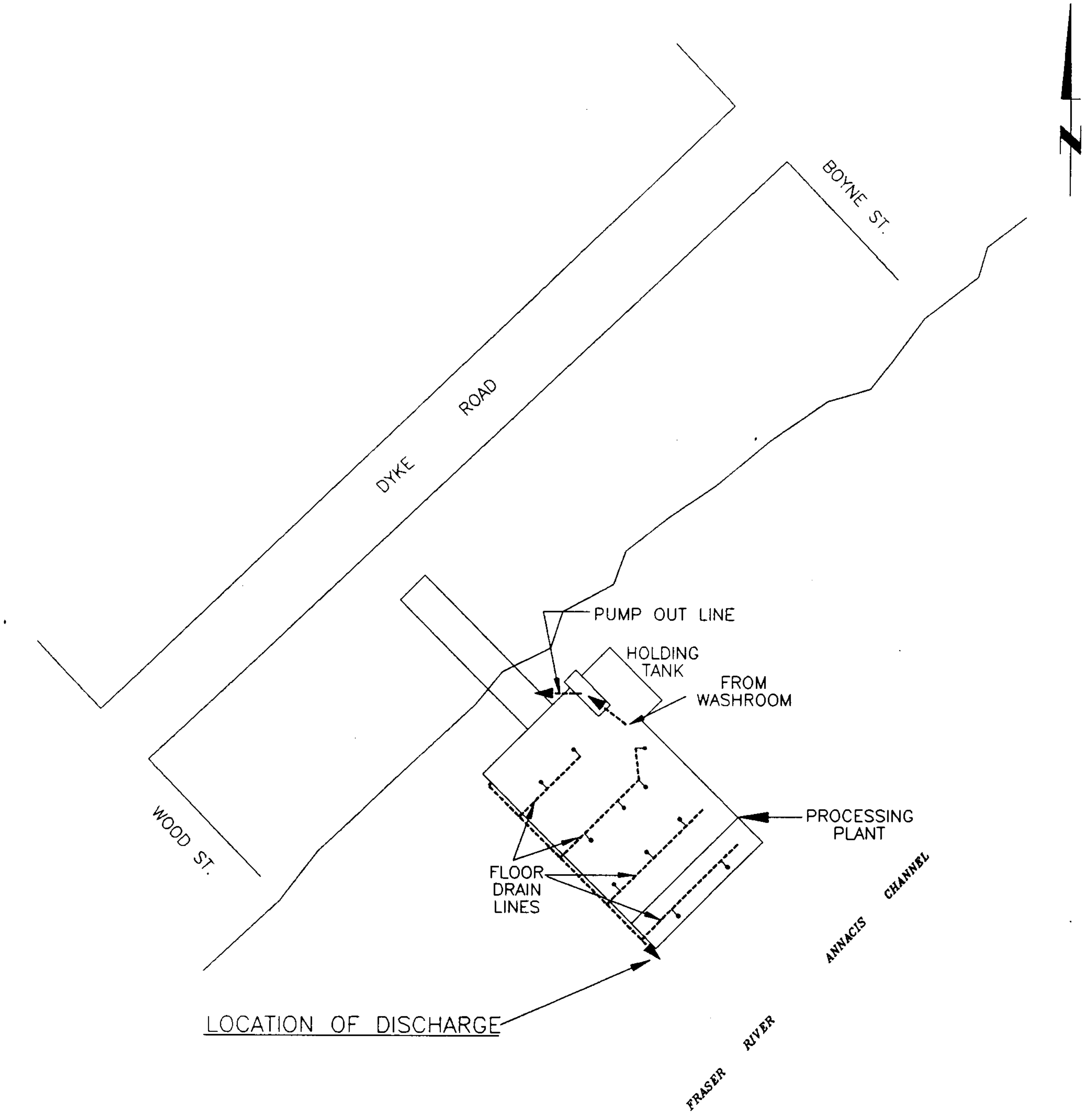
New West Net processes salmon and cod only, and sells dressed fish at the on-site retail store. The bucket method is used for vessel unloading. All processing is done manually and involves dressing and cleaning (without use of suction hoses), followed by retail sale or freezing. The extent of cod processing depends on the customers' requirements, and may involve cutting off heads of predressed fish, freezing of whole fish, or dressing as for salmon. Only approximately 10% of the cod unloaded is further processed.

### 4.5.3 Description of Waste Management Practices

Large offal, such as heads, is collected in totes which are located next to the dressing and cleaning tables. However, offal and blood also fall on the floor. To avoid clogging of the floor drains, this offal is collected prior to hosing down the floor. The floors are sloped towards drains which are covered with lids with approximately 3 mm diameter holes. Effluent and solids which pass through the holes are discharged directly to the Fraser River. All collected offal is sent to West Coast Reduction for further processing.

### 4.5.4 Review of Existing Data

Quarterly monitoring of pH, BOD, and TSS is required by MOELP Permit for this plant (Appendix A). However, there are no available data for any of the parameters.




LEGAL DESCRIPTION:

0.198ha portion of the foreshore and bed of the Fraser River fronting on Lot 65 of District Lot 757, Group 1, New Westminster District, Plan 40829

N.T.S

**FIGURE 9**

# NEW WEST NET CO. LTD. - SITE PLAN

| | |
|---|---|
| **NAME** | New West Net Co. Ltd. |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-8167 |
| **ADDRESS** | 34 South Dyke Road, New Westminster, V3M 4Z8 |
| **TELEPHONE/FAX NUMBER** | 524-5016/522-6269 |
| **CONTACT PERSON** | Fred Gerak |
| **RECEIVING WATER BODY** | Annacis Channel, Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Fred Gerak |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 11.148' N, 122E56.120' W |
| **NTS MAP SHEET NUMBER** | 92 G2 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 4.5 m |
| @ length (from shore @ low water) | app. 15 m |
| @ pipe diameter | 150 mm |
| @ age | 4 years |
| @ material | PVC |
| @ diffuser configuration | holes every 150 mm for 1 m |

## 4.6 Ocean Fisheries Limited

### 4.6.1 Facility Description

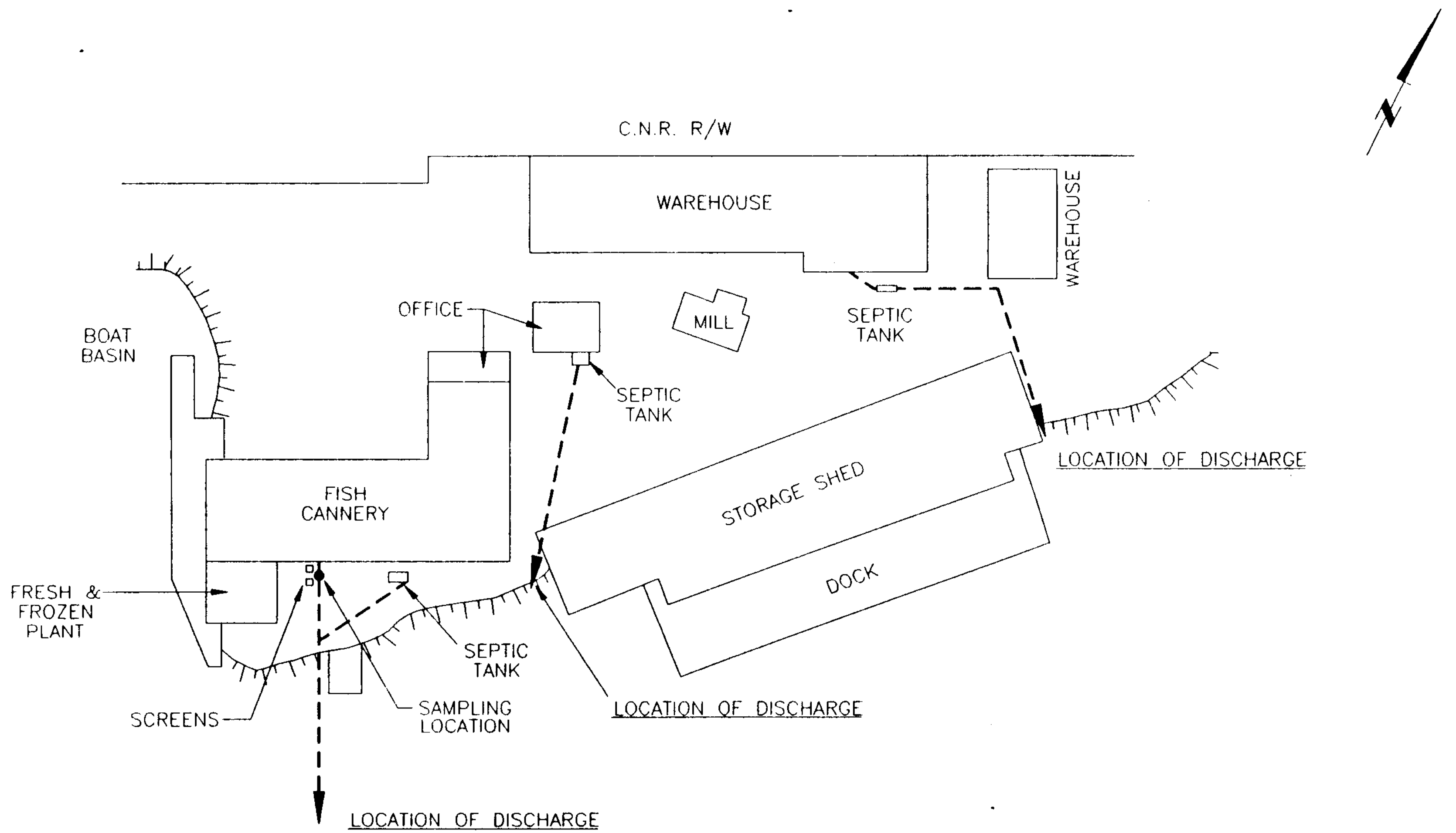
Ocean is located in Richmond B.C. on the shores of the Fraser River, and processes herring and salmon. A site plan is shown in Figure 10. The facility has a MOELP permit for three discharges to the Fraser River (two for septic tank effluent and one for processing and septic effluent). The effluent from the processing facility and one of the on-site septic tanks is combined downstream of the screens used for effluent treatment and the tap used for the collection of effluent samples as required by Ocean's discharge permit. The facility includes an unloading dock located in a boat basin on the north west side of the processing building, a fish cannery, and two large tanks for preparation and storage of the cooling water used during canning.

### 4.6.2 Description of Processes

Salmon processing at Ocean consists of dressing and canning fish as described in Sections 2.3 and 2.4. Roe is separated for processing as described in Section 2.5. No freezer-dressing of salmon takes place. A wet pump is used for vessel unloading.

### 4.6.3 Description of Waste Management Practices

There is no containment around the wet pump used for vessel unloading and any overflowing vessel hold water spills directly into the Fraser River. Inside the processing building, water sprays are used to keep equipment clean and to flush offal away. Any offal which collects on the floor is hosed to flumes from time to time and during regular clean-ups. All flumes and floor drains in the processing building are connected to a collection sump where large offal chunks are removed to an offal hopper by a conveyor. From the collection sump the effluent is pumped over one or two elevated screens, depending on the level of wastewater in the sump. The screened wastewater from both screens is combined, and is discharged by gravity to the Fraser River after having been combined with sanitary effluent.




LEGAL DESCRIPTION:

Parcel F of Section 5, Plan 7642
Parcel G of Section 5, Plan 11155
Parcel H of Section 5, Plan 11747
Parcel K of Section 5 & 8
Lots 3 & 4 of Section 8, Plan 36483
1.78 Acres Lot 5741 Fronting Section 5
Block 3 North, Range 5 West, New Westminster District

N.T.S

FIGURE 10

OCEAN FISHERIES LIMITED - SITE PLAN

| | |
|---|---|
| **NAME** | Ocean Fisheries Ltd. |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-1975 |
| **ADDRESS** | 13140 Rice Mill Road, Richmond, V6W 1A1 |
| **TELEPHONE/FAX NUMBER** | 272-2552/272-5220 |
| **CONTACT PERSON** | Douglas Moore, General Manager Richmond Plant |
| **RECEIVING WATER BODY** | Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Douglas Moore |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 09.472' N, 123E 04.571' W |
| **NTS MAP SHEET NUMBER** | 92 G3 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 6 m |
| @ length (from shore @ low water) | app. 24 m |
| @ pipe diameter | 250 mm |
| @ age | 29 years |
| @ material | steel |
| @ diffuser type | holes in pipe |

Two screens, a sidehill and a rotary screen, are in place. The sidehill screen is used as the main screen while the rotary screen is only used when both sump pumps operate at the same time. Screenings from both screens fall onto the inclined conveyor which transports large offal to the offal hopper, but some of the screenings fall back into the sump. Screenings which are smaller than the mesh size of the conveyor may also drain back into the sump.

A steady stream of bloody water generally seeps from the offal hopper and is continually flushed by permanently mounted water sprays to a drain which is connected to the wastewater sump.

### 4.6.4 Review of Existing Data

Monitoring of temperature, residual chlorine and 24 hour effluent volume is required by MOELP for Ocean (Appendix A). The available data base is limited to a few flow records and residual chlorine concentrations. Flow was in compliance with the Permit during 1990, 1991, and 1992. Recorded residual chlorine was approximately 0.1 mg/L.

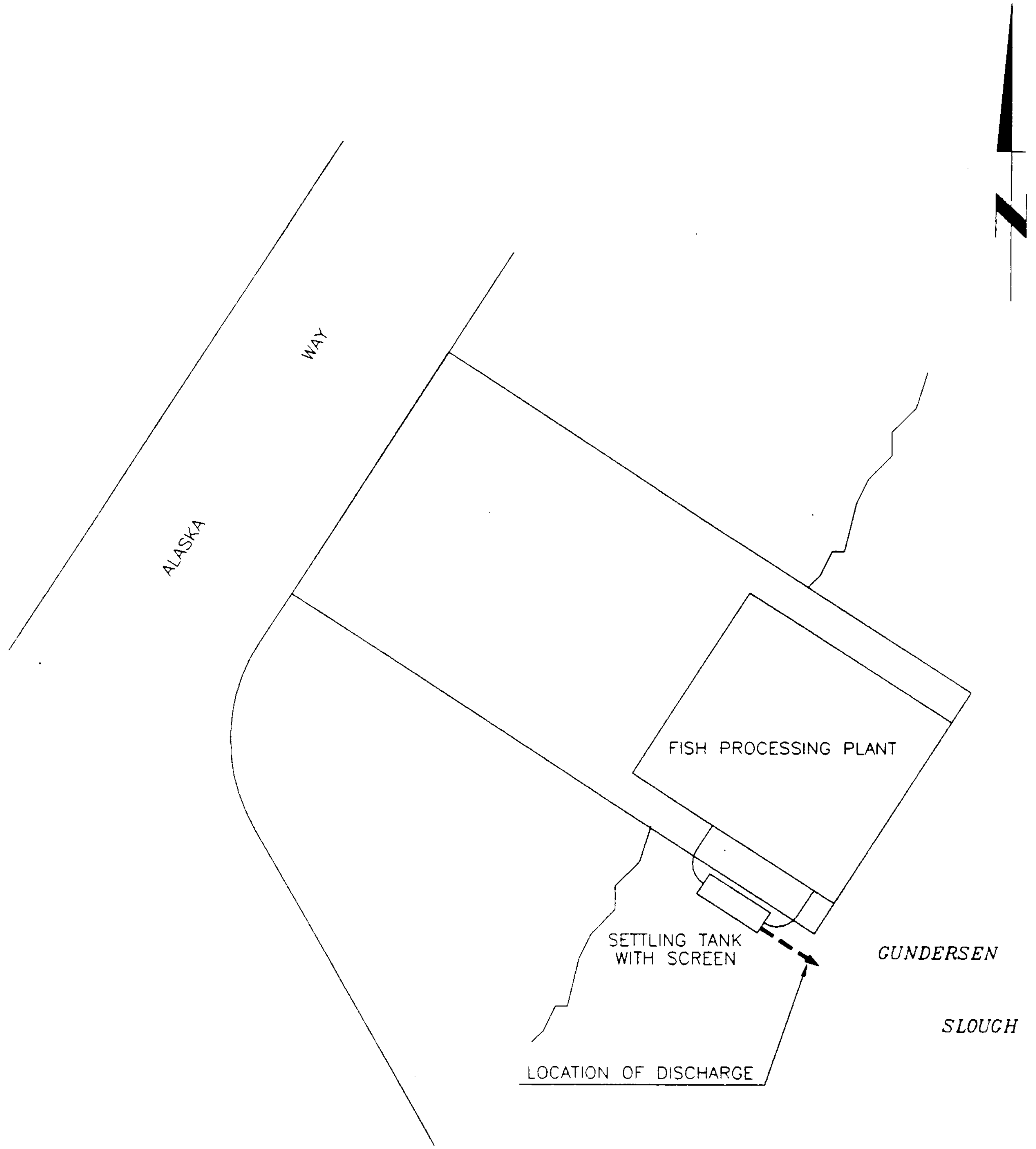
## 4.7 Shearer Seafood Products Ltd.

### 4.7.1 Facility Description

Shearer Seafood is located on the shores of Gunderson Slough of the Fraser River. The facility includes a small covered dock area, a butchering area, and a 2,700 L holding tank for effluent treatment. The facility site plan is shown in Figure 11.

### 4.7.2 Description of Processes

Shearer mainly unloads fishing boats and freezes whole fish for the retail market. Only a small amount of dressing takes place, generally when requested by customers. Unloading is done with a wet pump. Any dressing carried out on-site is manual dressing only (without suction hoses).




LEGAL DESCRIPTION: FSF GUNDERSON SPIT SOUTH SIDE OF ALASKA WAY .172 AC.

N.T.S

**FIGURE 11**

SHEARER SEAFOOD PRODUCTS LTD. - SITE PLAN

| | |
|---|---|
| **NAME** | Shearer Seafood Products Ltd. |
| **OWNER** | (same) |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-7785 |
| **ADDRESS** | 9300 Alaska Way, Delta, V4C 4R6 |
| **TELEPHONE/FAX NUMBER** | 588-2456/583-1548 |
| **CONTACT PERSON** | Robert Shearer |
| **RECEIVING WATER BODY** | Gunderson Slough, Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Robert Shearer |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 10.271' N, 122E 55.302' W |
| **NTS MAP SHEET NUMBER** | 92 G2 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 3.6 m |
| @ length (from shore @ low water) | app. 15 m |
| @ pipe diameter | 75 mm |
| @ age | 6 years |
| @ material | steel |
| @ diffuser configuration | open pipe |

### 4.7.3 Description of Waste Management Practices

During unloading, a 100 mm (4") rubber hose is placed around the wet pump to prevent vessel hold water from spilling into Gunderson Slough, and to direct the water to floor drains. The floors inside the processing building are sloped towards drains which are connected to a 2,700 L holding tank. Two sets of wire mesh at the overflow of the holding tank are used to screen the effluent. The meshes have openings of approximately 4 and 2 mm. During herring unloading, the holding tank is pumped out once or twice daily due to the accumulation of scales and herring roe. During salmon unloading, the tank is pumped out once per month only, as it mainly collects scales. All sludge is taken to the GVRD's wastewater treatment plant on Annacis Island. All offal collected during salmon dressing is frozen and disposed of in a landfill.

### 4.7.4 Review of Existing Data

The MOELP Permit requires monitoring of pH, BOD, TSS and residual chlorine at the Shearer plant (Appendix A). Only two BOD and residual chlorine data points are reported and no conclusions about effluent quality can be made.

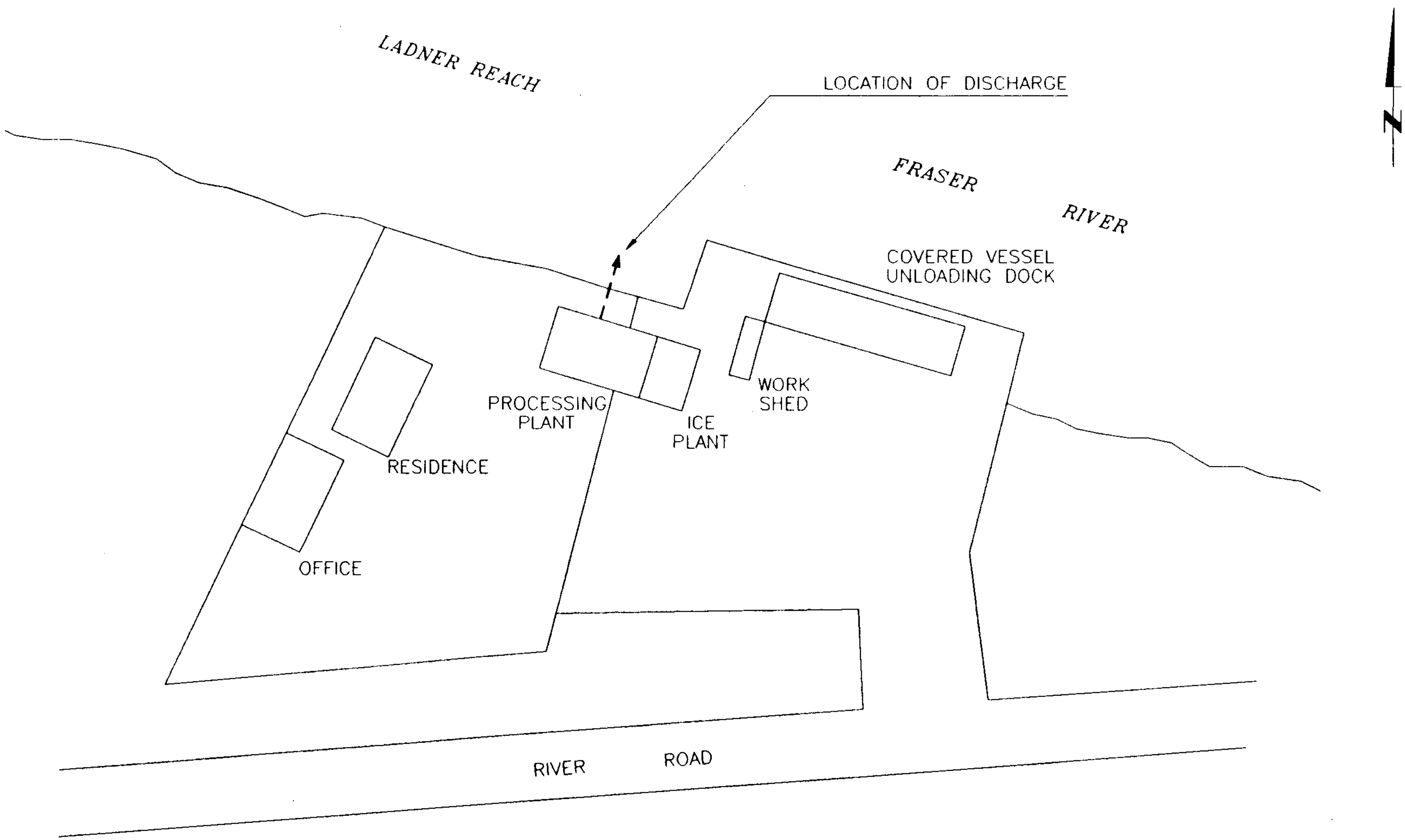
## 4.8 S.M. Products Ltd.

### 4.8.1 Facility Description

SM Products is located on the Ladner Reach of the Fraser River in Delta, B.C. The facility includes a roofed dock area for fish unloading, an ice plant and a processing building. A site plan is shown in Figure 12.

### 4.8.2 Description of Processes

SM Products serves the fresh fish market only and handles herring, salmon, halibut and ground fish. Generally, only vessels unloading, fish grading, and icing for subsequent shipment takes place on-site. The processing building was empty at the time of the site visits, and is mainly used for boxing of halibut and cheeking of halibut heads. Cutting off heads of halibut dressed-at-sea takes place on the covered dock. Vessel unloading is done with a wet pump and also with a bucket.




LEGAL DESCRIPTION:

LOT 1 OF BLOCK 29 OF DISTRICT LOT 54,
GROUP 2, NEW WESTMINSTER DISTRICT, PLAN 19817

N.T.S

FIGURE 12

## S.M. PROPERTIES LTD. - SITE PLAN

| | |
|---|---|
| **NAME** | S.M. Products Ltd. |
| **OWNER** | S.M. Properties Ltd. |
| **MOELP DISCHARGE PERMIT NUMBER** | PE-8430 |
| **ADDRESS** | 3827 River Road West, Delta, V4K 3N2 |
| **TELEPHONE/FAX NUMBER** | 946-7665/946-0176 |
| **CONTACT PERSON** | Jorn Nordmann |
| **RECEIVING WATER BODY** | Fraser River |
| **TREATMENT PROCESS DESCRIPTION** | Screening |
| **SOURCES FOR INFORMATION** | Jorn Nordmann |
| **DATE OF LAST INFORMATION UPDATE** | August 27, 1993 |
| **OUTFALL LOCATION COORDINATES** | 49E 05.158' N, 123E 07.205' W |
| **NTS MAP SHEET NUMBER** | 92 G3 |
| **OUTFALL DATA** | |
| @ depth (@ low water) | app. 1 m |
| @ length (from shore @ low water) | app. 1m |
| @ pipe diameter | 100 mm |
| @ age | 1 year |
| @ material | PVC |
| @ diffuser configuration | open pipe |

4.8.3 Description of Waste Management Practices

Generally the only wastewater discharged from the facility is the hold water of packers and fishing vessels which directly spills from the dock into the River.

The floor drains in the processing building are directly connected to the outfall. Between site visits basket stainers with approximately 6 mm ($^1/_4$ inch) openings were prepared for installation in the floor drains, and the outfall was extended to ensure that its end is below the water level at LLW.

### 4.8.4 Review of Existing Data

The MOELP Permit requires quarterly monitoring of BOD, TSS, oil and grease and toxicity for SM Products plant (Appendix A). However, there are no available data on any of the parameters.

# 5 SAMPLE COLLECTION AND TESTING METHODOLOGIES

## 5.1 Site Selection

The facilities where effluent samples were collected were selected mainly based on size and discharge volume. As Great Northern generally discharges to sanitary sewer, this facility was ruled out as one of the sampling sites. Of the remaining large processing facilities, effluent from Bella Coola was selected for determination of physical/chemical parameters only, as the fish processing carried out is similar to the one encountered at BC Packers. BC Packers effluent was sampled, as this is the largest processing facility among all the facilities visited as part of this project. Ocean and Lions' Gate were sampled because these facilities employed processes which are not in use at BC Packers or Bella Coola (Ocean: canning with fish dressing for canning only and discharge of chlorinated cooling water; Lions' Gate: shrimp and groundfish processing).

## 5.2 Sample Collection

### 5.2.1 Method

Two ISCO automatic samplers (models 1580 and 3700) were used for the collection of all composite samples. The composite samples were collected on a time-composite basis, and were pumped into a large covered container made of low density polyethylene (LDPE) to be able to collect a sample of sufficient size to carry out all chemical analyses and all toxicity tests with one sample. The sample container was stored inside another with ice placed between two containers for cooling. Subsampling of the composite sample was done with the pump of the automatic sampler following thorough mixing of the sample.

Oil and grease samples are typically collected as grab due to concern over losses of grease on sampling equipment during collection. However, the decision was made to subsample the composite sample using a glass bottle for the following reasons:

1. Concern over whether a single grab sample would be representative of overall oil and grease concentrations during an 8 to 24 hour production period.

2. Insufficient budget and manpower availability to collect multiple grab sample to assess variations in oil and grease over a production period.

3. The large 70 L composite sample volume was expected to minimize the effect of any losses on equipment which may occur.

All sampling equipment was cleaned as outlined in "Recommended Guidelines For Wastewater Characterization in the Fraser River Basin" (Norecol Environmental Consultants Ltd. and Zenon Environmental Laboratories, June 1993, volume II) with the exception of an acetone rinse, which was not carried out as no organochlorines were analyzed.

### 5.2.2 Sampling Locations

The individual sampling locations coincided with the locations used for permit sampling and included process effluent only. At BC Packers, screened effluent from one of the three screens was collected to avoid sampling effluent which had been mixed with cooling water from the reduction plant.

At Lions' Gate access to the screened effluent was gained through a vertical tee in the outfall pipe. The permit sampling points at Bella Coola and Ocean were taps in the discharge pipe. At both of these sites effluent from the taps discharged into a plastic sample bottle which contained the inlet hose of the automatic sampler. The sample bottle had a hole in the bottom to allow the effluent to drain from the bottle, thus preventing an accumulation of solids. However, the hole was small enough to force the bottle to overflow during times the outfall pipes carried effluent (and supplied effluent to the bottles). This ensured that a sufficient volume of effluent was available for sampling. The effluent discharged from the taps caused vigorous mixing in the reservoir bottles which, together with the overflow and the complete draining of the bottle during the times the outfall pipes did not carry any wastewater, ensured that representative samples of the actual suspended solids concentration of the effluent could be obtained.

At Ocean, only effluent screened by the sidehill screen was collected, as the outfall pipe did not have sampling taps to sample the combined effluent from both screens, and because the rotary screen is used as a backup screen only.

### 5.2.3 Sampling Duration and Schedule

Samples were collected during processing only (excluding washdowns after shifts). Flow measurement at the different fish processing facilities was as indicated in Section 3.4. In the case of BC Packers, the discharge volume of the cooling water was subtracted from the discharge volume of the combined effluent as determined by the Parshall flume.

Table 1 summarizes the program sampling schedule.

**Table 1 Sampling Schedule Summary**

| Facility | Sample | Sampling Date | Sample Type |
|---|---|---|---|
| BC Packers | BCP-1 | September 2, 1993 | composite |
| | BCP-2 | September 8, 1993 | composite |
| | BCP-3 | October 13, 1993 | composite |
| Bella Coola | Bell-1 | August 31, 1993 | composite |
| | Bell-2 | September 9, 1993 | composite |
| | Bell-3 | September 10, 1993 | composite |
| Lions' Gate | LG-1 | August 30, 1993 | composite |
| | LG-2 | September, 7, 1993 | composite |

| | | | |
|---|---|---|---|
| | LG-3 | September 14, 1993 | composite |
| Ocean | OC-1 | September 1, 1993 | composite |
| | OC-2 | September 10, 1993 | composite |
| | OC-3 | September 29, 1993 | composite |
| | OC-4 | October 20, 1993 | composite |

### 5.2.4 Rainfall Effects

Precipitation, which would be expected to affect the analytical results for those facilities which discharge storm water together with process water (BC Packers, Bella Coola, and Lions' Gate) did not occur during any of the sampling events. Precipitation would be expected to affect the contaminant concentrations, but not the loading. However, for facilities which use water consumption to estimate the discharge volume, the calculation of loading based on the contaminant concentrations determined during a storm event, and the water consumption could result in under estimating the contaminant loading.

## 5.3 Analytical Parameters and Tests

### 5.3.1 Field Measurements

The effluent temperature, DO, pH, and total residual chlorine concentration were determined on-site using a freshly collected grab sample during the composite collection (the pH of the composite sample was also determined in the laboratory). Total residual chlorine was only determined for effluent from Ocean, as this was the only facility discharging chlorinated retort cooling water.

### 5.3.2 Laboratory Analyses

All laboratory analyses were conducted according to the "Standard Methods for the Analysis of Water and Wastewater" (APHA, 1992). Sample filtrations for the determination of TDS and DOC took place in the laboratory immediately upon sample delivery. All laboratory analyses were conducted by Analytical Service Laboratories Ltd. (ASL), except for fecal coliform enumeration which was conducted by EVS Consultants. The following parameters were determined:

- Alkalinity
- Ammonia
- Biochemical Oxygen Demand
- Chemical Oxygen Demand
- Conductivity
- Dissolved Organic Carbon
- Metals, dissolved
- Metals, total
- Nitrate and Nitrite
- Oil and Grease

- pH
- Total Solids
- Total Suspended Solids
- Fecal Coliform Enumeration (most probable number)

### 5.3.3 Toxicity Testing

In order to obtain coopration of the processing facilities to permit sampling on site for toxicity, it was agreed to report the toxicity information without direct reference to the site. For this reason toxicity data are reported as Facility A, B, and C.

Acute and chronic testing of effluent from Facility A, Facility B, and Facility C was carried out between August 30 and October 20, 1993. Three samples of effluent were tested from Facility A and Facility B, while four samples were tested from Facility C. As noted in the following table, toxicity was assessed using rainbow trout (*Oncorhynchus mykiss*), *Ceriodaphnia dubia* (a freshwater daphnid), *Selenastrum capricornutum* (a freshwater alga), and *Photobacterium phosphoreum* (a luminescent bacterium). Rainbow trout and *Ceriodaphnia* testing was carried out by EVS Consultants, *Selenastrum* testing by B.C. Research Corp., and *Photobacterium* testing (using the Microtox method) by Integrated Resource Consultants Inc.

| TEST/ANALYSIS | LABORATORY |
|---|---|
| Bacterial Luminescence Inhibition | Integrated Resource Consultants Inc. |
| Ceriodaphnia Survival and Reproduction | EVS Consultants |
| Rainbow Trout Lethality | EVS Consultants |

| Algal Growth Stimulation/Inhibition Test | B.C. Research Corp. |
| --- | --- |

Detailed protocols of the tests listed above are given in EVS Environment Consultants report "Wastewater Characterization of Fish Processing Plant Effluents" (November, 1993) and B.C. Research report "72-hr Algal Growth Inhibition Tests" (November, 1993). Both reports are available at the FREMP office and Fraser Pollution Abatement Office of Environment Canada.

The sampling protocol for the 7-day *Ceriodaphnia* toxicity test requires that fresh samples (refresh samples) for the test be collected on days 2 and 4 of the test and used within 72 hours of sampling. Because the effluent characteristics may change either between samples, or during storage, the following parameters were determined for each refresh sample collected:

- Ammonia
- COD
- Dissolved metals;

The analytical results for refresh samples are included in Appendix C. In addition, the pH and the temperature of the refresh sample was recorded at the time of collection. The refresh sample consisted of one grab sample only.

On several occasions it was not possible to collect a refresh sample, as the fish processing facility was not operating on the days scheduled for refresh sampling. In these cases subsamples of the original composite sample, which were kept in cold storage (4 EC), were used as refresh samples, and the parameters identified above were determined on the stored sample.

Rainbow Trout toxicity tests followed standard toxicity test procedures in accordance with "Standard Methods for the Examination of Water and Wastewater" (1989) and Environment Canada (1990). Methods described in Environment Canada were used for the Microtox (1992 c) and the *Ceriodaphnia dubia* tests (1992 b). The *Selenastrum* tests were performed using the Environment Canada protocol (1992 a).

## 5.4 Quality Assurance/Quality Control Procedures

Quality assurance/quality control (QA/QC) procedures include field and laboratory quality assurance and quality control.

### 5.4.1 Field Quality Assurance/Quality Control

Field QA/QC procedures begin by ensuring that all instruments used in the field to measure a quantity, or which have an expected performance level, are calibrated prior to use.

Instruments used in characterization of fish processing plant effluents in the field included the Dissolved Oxygen (DO) probes, and pH probes, and meters.

The DO probe was calibrated in the field before the reading. Calibration was done for each sampling site and each sampling event. In addition to this, two readings of each sample were recorded.

The pH probe was calibrated and readings taken in the same manner as DO readings. In addition, the pH meter calibration was also confirmed after each reading.

Field QA/QC samples, such as bottle blanks, field blanks, and surrogate spikes in field samples, were not included in the sampling protocol due to the limited sampling budget. Field duplicate samples and travel blanks recommended in "Recommended Guidelines for Wastewater Characterization in the Fraser River Basin" (Norecol, 1993) were not taken. For this particular study it was recommended, and agreed to by the FREMP, scientific authorities, that field duplicates should be replaced with replicate samples at each site and that travel blanks were not appropriate for the parameters measured in this study.

### 5.4.2 Laboratory Quality Assurance/Quality Control

In addition to the field QA/QC program, laboratory QA/QC measures were used for quality assurance of the analytical results.

Detailed description of laboratory QA/QC protocols for ASL, BC Research, and EVS are included in Appendix E.

Applied laboratory QA/QC procedures performed by ASL include:

- Method blanks: performed for all tests. At least one method blank was tested per batch.
- Duplicates: performed for all tests. At least one duplicate was tested per batch, but for this study one or two samples have been a part of a larger batch of samples analyzed for a given test and, therefore, may not have been duplicated.
- Check standard: performed in metal analysis, DOC, conductivity, pH, alkalinity, ammonia, nitrate, nitrite and BOD. Check standards were not used in TS, TSS, COD, and oil and grease.
- Surrogate compounds: not used since none of the tests employed gas chromatography or mass spectrometry.
- Spikes: performed in oil and grease, metal, nitrate, nitrite, ammonia and DOC analysis.
- Standard reference materials: performed for all tests except for oil and grease.

Results of QA/QC procedures were used to estimate precision and accuracy of the analysis. Sample analysis was repeated if necessary.

Toxicity tests QA/QC procedures performed by EVS include:

- Negative controls: performed for all tests.

- Test organisms: five different batches of rainbow trout, obtained from Sun Valley Trout Farm were used for testing. Each batch of fish was tested with the standard reference toxicant. Daphnids used in the toxicity tests were obtained from an in house culture.

- Replication: in the LC50 rainbow trout test, one replicate was prepared for each concentration. Ten replicates were prepared for each concentration in the *Ceriodaphnia* tests.

- Instrument calibration: all instruments were calibrated at the start of each test day.

- Water quality measurement/maintenance: initial dissolved oxygen in all the samples was below the acceptable range and therefore required aeration prior to testing.

QA/QC practices employed in algal growth inhibition tests conducted by B.C. Research include:

- Equipment maintenance and calibration: instrument sensitivity is checked with a known standard

- Facilities: the algal growth test is conducted in a chamber where temperature and light can be controlled and monitored continuously.

- SOP manuals: SOP manuals are maintained for all tests conducted.

- Test organisms: a new starter culture of *Selenastrum capricornutum* was used.

- Replication: at least three replicates and in most cases five replicates of each concentration of the sample was run in each test. Intergroup statistical analyses and hypothesis testing was performed on values obtained from all replicates of sample concentrations.

Microtox test was carried out by IRC Integrated Resource Consultants Inc. and the QA/QC procedure involved assessment of the bacterial cultures' health using a reference toxicant. Reference toxicant tests using phenol were run with each sample to ensure that the bacteria were responding normally.

## 5.5 Outfall Coordinates

The outfall coordinates of each fish processing facility visited were determined with a Trans Pak GPS (Global Positioning System) manufactured by Trimble Navigation. The readings were taken on shore or on floats as close as possible to the actual discharge. Readings, taken every thirty seconds over a period of 10 minutes, were averaged to improve the accuracy.

# 6 DISCUSSION OF RESULTS

## 6.1 Physical/Chemical Results

A summary of all analytical sampling results is presented in Appendix C. Generally, all data collected in the past and during this study at each of the four facilities relevant to the permit requirements (Appendix A) were within their permitted discharge levels.

### 6.1.1 Water Consumption

A summary of water consumption for the 1993 season is presented in Table 2. Very high water consumption per tonne of fish processed occurs on days when the amount of processed fish is low, and is due to a high base line water consumption. For example, the water consumption per tonne of fish processed can range from 11.9 $m^3$/tonne during high production days to 228 $m^3$/tonne during low production days at BC Packers.

The lowest water consumption per unit of production was recorded at Bella Coola plant, from 2.9 to 5.6 $m^3$/tonne. The significant decrease in water consumption at this plant during 1993 salmon processing season (approximately 90 % over 1991 and 1992 seasons) appears to be largely related to the introduction of vacuum suction for fish cleaning.

### 6.1.2 Solids

The effluent total solids (TS) concentrations were generally high except for Lions' Gate. At the Ocean, much lower concentrations of TS were recorded on days without unloading (samples D-3 and D-4, Table 2).

Only a small fraction of TS was in total suspended solids (TSS) form.  TSS accounted for approximately 10 to 30 % of TS.  At the Lions' Gate the TSS fraction increased to approximately 50 % on days when groundfish or shrimp were processed together with salmon.

**Table 2 Summary of Physical/Chemical Results**

| Facility | Water Consumption $m^3$/tonne | TS mg/L | TSS mg/L | BOD mg/L | COD mg/L | DOC mg/L | NOx mg/L | Ammonia mg/L | Fecal Coliform MPN/100mL |
|---|---|---|---|---|---|---|---|---|---|
| BCP-1 | 11.9 | 3640 | 1240 | 2680 | 3460 | 268 | 0.021 | 69.7 | 1,700,000 |
| BCP-2 | 105.3 | 1770 | 482 | 493 | 1150 | 145 | < 0.006 | 35.6 | 130,000 |
| BCP-3 | 228.4 | 2280 | 730 | 920 | 2420 | 131 | < 0.006 | 38.9 | 612,333 |
| Bell-1 | 3.5 | 3200 | 545 | 740 | 1670 | 113 | < 0.008 | 29.1 | 700 |
| Bell-2 | 5.6 | 2960 | 187 | 230 | 712 | 62 | 0.222 | 3.4 | 300 |
| Bell-3 | 2.9 | 2790 | 212 | 260 | 1070 | 88 | < 0.009 | 13.1 | 2300 |
| LG-1 | 10.8 | 218 | 100 | 175 | 364 | 32 | 0.014 | 5.5 | 230 |
| LG-2 | 14.6 | 488 | 74 | 128 | 316 | 25 | < 0.019 | 20.2 | 80 |
| LG-3 | 14.3 | 734 | 353 | 668 | 1140 | 133 | 0.016 | 35.5 | 300 |
| OC-1 | 19.1 | 2630 | 931 | 2080 | 2290 | 182 | < 0.019 | 38.9 | 23 |
| OC-2 | 15.3 | 2380 | 544 | 565 | 1510 | 134 | < 0.006 | 17 | 300 |
| OC-3 | 36.4 | 399 | 108 | 160 | 321 | 31 | 0.014 | 0.7 | 50 |
| OC-4 | 37.0 | 288 | 40 | 230 | 344 | 32 | 0.012 | 0.9 | 170 |

continued...

**Table 2    Summary of Physical/Chemical Results (cont'd)**

| Facility | Conductivity umhos/cm | pH | Temperature EC | Dissolved Oxygen mg/L | Alkalinity mg/L as $CaCO_3$ | Res. Chlorine mg/L | O&G mg/L |
|---|---|---|---|---|---|---|---|
| BCP-1 | 3660 | 6.3 | 17.2 | 9.7 | 253 | 0.00 | 54 |
| BCP-2 | 2730 | 6.8 | 21.0 | 8.5 | 235 | 0.01 | 39 |
| BCP-3 | 2960 | 6.4 | 14.2 | 9.6 | 161 | * | 98 |
| Bell-1 | 4670 | 6.6 | 15.7 | 9.4 | 268 | 0.00 | 47 |
| Bell-2 | 4710 | 6.5 | 10.3 | 10.7 | 59 | * | 17 |
| Bell-3 | 4580 | 6.3 | 17.0 | 8.9 | 88 | * | 13 |
| LG-1 | 215 | 6.5 | 14.5 | 9.2 | 106 | 0.08 | 8 |
| LG-2 | 713 | 6.7 | 16.1 | 8.8 | 62 | 0.15 | 8 |
| LG-3 | 683 | 7.4 | 18.1 | 8.6 | 185 | * | 80 |
| OC-1 | 3670 | 6.3 | 12.5 | 9.8 | 215 | 0.00 | 60 |
| OC-2 | 2640 | 6.3 | 17.8 | 9.1 | 1410 | * | 19 |
| OC-3 | 461 | 5.7 | 14.5 | 9.1 | 41 | * | 11 |
| OC-4 | 420 | 6.5 | 13.3 | 9.4 | 94 | 0.13 | 16 |

Note:    * Measurements not taken

As expected, the high total dissolved solids (TDS) concentrations observed were reflected in increased conductivity levels.

### 6.1.3 Carbon

Most of the BOD usually originates from hold water and from the butchering process. Effluent total biochemical oxygen demand (BOD) to chemical oxygen demand (COD) ratios varied widely within and among processing plants ranging from 1.1:1 at Ocean to 3:1 at Bella Coola.

The Lions' Gate had the lowest BOD and COD concentrations with average values of 325, and 610 mg/L, respectively. This BOD concentration is at the low end of reported BOD concentrations in the literature of 390 mg/L (Riddle and Shikaze, 1973). At the Ocean much lower BOD and COD concentrations were observed for the days without unloading (D-3 and D-4, Table 2), on average 195 and 230 mg/L respectively. Total BOD and COD concentrations on unloading days averaged 1300, and 1900 mg/L, respectively.

Dissolved organic carbon (DOC) mostly originates from hold water and from the butchering process. Recorded concentrations varied from 31 to 268 mg/L and the Lions' Gate had the lowest average.

### 6.1.4 Nitrogen

Recorded effluent nitrate and nitrite (NOx) concentrations were low at all facilities. Concentrations ranged from less than 0.006 to 0.222 mg/L (Table 2). Most of the nitrogen was in the ammonia form. High ammonia concentrations were due to the high blood and slime content in the wastewater streams.

The lowest ammonia concentrations were recorded at the Ocean on days without unloading, on average only 0.8 mg/L. On days when unloading occurred, ammonia levels increased up to 38.9 mg/L. Overall, ammonia concentrations ranged from 0.7 to 69.7 mg/L.

High BOD concentrations are generally associated with high ammonia concentrations. This correlation is observed in effluent samples collected at all the fish processing facilities sampled.

High ammonia concentrations are of potential concern with respect to toxicity. The degree of ammonia toxicity depends primarily on the total ammonia concentration, and pH. The pH level determines what proportion of that total ammonia present is in the toxic unionized form.

### 6.1.5 Fecal Coliform

With the exception of BC Packers, the concentrations of fecal coliforms detected in effluent from all fish processing plants, were generally low (see Table 2). Although, there were no sources of sanitary sewage upstream of any of the sampling locations used in this study, fecal coliforms may be partly due to bird droppings in areas from which runoff is discharged together with process effluent (containment around wet pumps, yard drains connected to the main wastewater sump, etc.). However, it is believed that the majority of the organisms detected are non-sanitary sewage related. A possible cause could be the dominant presence of *Klebsiella*, an organism which is commonly a major component of the coliform population in paper mill, textile and other industrial wastes. Confirmation of *Klebsiella* presence was beyond the scope of this report.

### 6.1.6 Total and Dissolved Metals

A summary of metal concentrations is presented in Appendix C. The results indicate that metals are not of concern at any of the plants monitored.

## 6.2 Biological Testing Results

A summary of the results from toxicity testing of the fish processing plant wastewater are presented in Table 3. All results are expressed as percent volume to volume (%vol/vol) dilution of effluent (e.g., 6.25 % vol/vol means effluent has been diluted to 6.25 % of total volume).

## Table 3 Summary of Toxicity Test Results

| Sample Identification | Rainbow trout | | *Ceriodaphnia dubia* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Survival | | | | Reproduction | | | |
| | LC50 | LC25 | LC50 | LC25 | NOEC | LOEC | IC50 | IC25 | NOEC | LOEC |
| A-1 | 42 | 37 | <6.25[1a] | <6.25 | <6.25 | 6.25 | [2] | [2] | [2] | [2] |
| A-2 | 75 | 65 | 50 | <6.25[1b] | 50 | 100 | 11 | 8 | 12.5 | 25 |
| A-3 | 42 | 37 | 0.5 | 0.4 | 0.4 | 0.8 | [1c] | [1c] | 0.4 | [1c] |
| B-1 | >100 | >100 | 31 | 15 | 25 | 50 | 15 | 4 | 12.5 | 25 |
| B-2 | >100 | >100 | >100[1d] | >100[1d] | 100 | >100 | 13 | 9 | 12.5 | 25 |
| B-3 | 70 | 62 | 44 | 32 | 25 | 50 | [2] | [2] | [2] | [2] |
| C-1 | 42 | 37 | 20 | 9 | 12.5 | 25 | 5 | 3 | <6.25 | 6.25 |
| C-2 | N/A | N/A | <6.25[1e] | [1f] | <6.25 | 6.25 | [2] | [2] | [2] | [2] |
| C-3 | >100 | 91 | >100 | 63[1g] | 100 | >100 | 60 | 21 | 50 | 100 |
| C-4 | >100 | >100 | 6.25 | [1f] | 6.25 | 12.5 | [1c] | [1c] | [1c] | [1c] |

continued...

## Table 3  Summary of Toxicity Test Results (continued)

| Sample Identification | *Selenastrum capricornutum*[3] | | *Photobacterium phosphoreum* | |
|---|---|---|---|---|
| | NOEC | LOEC | 15 Minute IC50 | 15 Minute IC20 |
| A-1 | 25 | 50[4] | 0.67 | 0.077 |
| A-2 | 25 | 50[4] | 1.30 | 0.16 |
| A-3 | 25 | 50 | 0.70 | 0.077 |
| B-1 | 25 | 50 | >100 | 65.1 |
| B-2 | 12.5 | 25 | >100 | 8.96 |
| B-3 | 25 | 50 | 6.18 | 0.60 |
| C-1 | [5] | 100[4] | 2.62 | 0.41 |
| C-2 | 12.5 | 25 | 1.70 | 0.42 |
| C-3 | 25 | 50 | >100 | 8.01 |
| C-4 | 100 | [6] | >100 | >100 |

1 *Ceriodaphnia* LCp results include outlying data as follows:
- a - 12.5% dilution showed 20% mortality
- b - No mortality occurred at 25% concentration.
- c - Reproductive endpoints not calculated as only the lowest concentration was analyzed for reproduction.
- d - survival of 50% and 60% were observed in 12.5% and 6.25% concentrations, respectively, but survival was $80% in higher concentrations.
- e - 25% concentration had 20% mortality
- f - LC25 could not be calculated due to data variability
- g - Concentrations above 50% had less than 25% mortality

2 Samples A-1, B-3, and C-2 (*Ceriodaphnia*) met control criteria for survival ($80% survival), but did not meet control criteria for reproduction (minimum 3 broods by 60% of control animals and an average of $15 young per surviving adult).

3 ICp values are not reported for *Selenastrum capricornitum* as enhanced growth occurred in all test samples.

4 LOEC values for samples A-1, A-2 and C-1 are estimates without comparison to the quality control plate as control criteria were not met.

5 An NOEC value is not reported for C-1 as there was no significant difference in growth amongst concentrations below 100% and the possible effects of the control medium could not be ruled out in dilutions of the effluent.

6 No statistically significant effects found at any test concentration.

N/A Results not available.

### 6.2.1 Rainbow Trout

The endpoints measured in the acute rainbow trout test are the LCp, where p is percent, normally represented as LC50 and LC25. For this study these endpoints are defined as the median lethal concentration (in %vol/vol) of effluent that is estimated to be lethal to 50% (for LC50) or 25% (LC25) of the test organisms over a 96h period. The LC50 and LC25 values were derived by statistical analysis of mortalities in the following effluent concentrations: 100 %, 56 %, 32 %, 18 % and 10 %.

The QA/QC procedures outlined in Section 5.4.2 were followed for this test and the QA/QC results are detailed in the EVS Laboratory Report. The criteria for validity were met and the QA/QC results judged to be acceptable. Therefore, the test results are considered to be valid.

Three of the effluent samples were non toxic (B-1, B-2, C-4) while the remaining samples exhibited some toxicity to rainbow trout. Over the three sample sites, acute lethality (as 96-h LC50) of effluent samples to rainbow trout ranged from an estimate of 42 % to >100 % effluent. The effluent from Facility A was generally more acutely toxic than effluent from Facility B and Facility C. LC50 estimates for samples from Facility A were between 42 % and 75 %, between 42 % and >100 % for samples from Facility C, and from 70 % to >100 % for samples from Facility B. Estimates of LC25 values for each sample were only slightly lower than the LC50 values, ranging from 37 % to >100 % across the sites.

### 6.2.2 *Ceriodaphnia dubia*

The endpoints for chronic testing using *Ceriodaphnia* are based on the adverse effects of the effluent on survival of first generation daphnids and on reproduction, in terms of the number of live neonates produced by the first generation. In both cases the adverse effect is assessed relative to controls. Reproduction is normally the more sensitive of the two measurements and so is taken as the indication of chronic toxicity of the effluent. The endpoints reported for each sample in this study are:

- no-observed-effect concentration (NOEC): highest concentration of effluent that does not cause any significant adverse effects in comparison with the control; used for assessing survival and reproduction

- lowest-observed-effect concentration (LOEC): the lowest concentration of effluent that causes adverse effects in comparison with the control; used for assessing survival and reproduction

- LCp (i.e., LC25, 50): the median lethal concentration of effluent that is estimated to be lethal to p% of the daphnids over the duration of the test

- ICp (i.e., IC25, 50): the inhibiting concentration for a p% effect; concentration of effluent estimated to cause p% reduction in mean number of young produced relative to the control.

The LCp and ICp values were derived by statistical analysis of the effect (survival and reproduction) in the following effluent concentrations: 100 %, 50 %, 25 %, and 6.25 %.

The QA/QC procedures outlined in Section 5.4.2 were followed for this test and the QA/QC results are detailed in the EVS Laboratory Report. The criteria for test acceptability for the survival endpoint were met for all samples. However, the criteria for test acceptability for reproduction were not met for three samples: A-1, B-3 and C-3. As a result, the reproductive endpoints for these three samples are not reported.

Water hardness of the effluent samples was a concern in the initial *Ceriodaphnia* toxicity tests. Water hardness among all samples ranged between 8 mg/L as $CaCO_3$ in C-3 to 178 mg/L as $CaCO_3$ in sample A-3. Facility B samples 1, 2, and 3; Facility C samples 1, 3, and 4; and Facility A-1 all had low (#20 mg/L as $CaCO_3$) water hardness. Since the test water hardness requirement (± 20% of culture water hardness) was 60-80 mg/L (± 20%) for the *Ceriodaphnia* test, hardness-adjusted samples were also run with B-1 and C-1 for *Ceriodaphnia*. For those two samples the hardness was adjusted up to the optimal range using standard reagent grade chemicals and procedures. Results from these side-by-side comparisons of adjusted and non-adjusted effluent samples showed that water hardness was not an important factor in the toxicity of the samples (both B-1-A and C-1-A were more toxic to *Ceriodaphnia* than were the unadjusted B-1 and C-1) and no further adjustments were made. It should be noted, however, that low water hardness was prevalent in the samples, and also that hardness varied substantially between samples, both within and between sites.

Survival

All samples exhibited some toxicity. *Ceriodaphnia* mortality in effluent samples over seven days resulted in LC50 estimates of #50% effluent across all samples, with the exceptions of C-3 and B-2 (>100 %). A-3 was so acutely toxic to *Ceriodaphnia* that all animals were dead at all concentrations (100 % through 6.25 % effluent) after one day of exposure to the effluent. This sample was then retested at a lower concentration range (see EVS Consultants report, 1993). Estimates of LC50 values ranged from 0.5 % to 50 % for Facility A samples, from 31 % to >100 % for Facility B samples, and from <6.25 % to >100 % for Facility C samples. LC25 values ranged from 0.4 % to >100 % across all samples. Survival NOEC values were within the following ranges: 0.4 % to 50 % for Facility A samples, 25 % to 100 % for Facility B samples, and <6.25 % to 100 % for Facility C samples. LOEC values for survival ranged from 0.8 % to >100 % across the sites: from 0.8 % to 100 % for Facility A samples, from 50% to >100 % for Facility B samples, and from 6.25 % to >100 % for Facility C samples.

Reproduction

ICp, NOEC and LOEC values could not be determined for samples A-1, B-3 and C-2 because reproduction in the controls for these samples did not meet the criteria for test acceptability. IC50 estimates for reproduction in the remaining effluent samples ranged from 5 % to 60 % effluent and were always considerably lower than their corresponding LC50 estimates. The IC50 estimates were #11 % for Facility A samples, # 16 % for Facility B samples, and from 5 % to 60 % in the Facility C samples. NOEC and LOEC values were #25 %, with the exception of C-3 for which the NOEC was 50 % and the LOEC was 100 %. ICp and LOEC values for sample A-3 were not reported because reproductive data could be analyzed for only the lowest concentration. Reproductive endpoints are calculated using only those concentrations for which survival is not significantly different (p#0.05) from the test control.

### 6.2.3 *Selenastrum capricornutum*

The endpoints for the *Selenastrum* microplate growth inhibition test are IC25, IC50, NOEC and LOEC. The ICp is an estimate of the effluent concentrations causing a p% reduction in the growth of the algal population relative to the control over a 72 h period.

Toxicity of the samples was non-determinable in all of the fish processing plant samples. Enhancement of growth was found in all samples, therefore ICp values were not determined and only LOEC and NOEC values are reported. These NOEC and LOEC values are based on an enhancement, as opposed to inhibition, of growth. NOEC values for the samples ranged from 12.5 % to 100 % effluent across the sites. LOEC values ranged from 25 % to 50 % with the exception of C-1 at 100 %. In Facility C effluent, NOEC values in samples C-2, C-3, and C-4 were between 12.5 % and 100 %. LOEC values (given for C-1, C-2, and C-3) ranged from 25 % to 100 %. Note that LOEC and NOEC values for A-1, A-2, and C-1 are estimates without comparison to quality control plates as there was no significant growth in the associated quality control plates. These endpoints were derived from inter-group statistical comparisons of the effluent concentrations without comparison to test controls. While data for the A-1, A-2, and C-1 samples are reported, they should only be considered in a qualitative manner because control growth did not meet test criteria.

### 6.2.4 *Photobacterium phosphoreum*

The endpoint for this test is the ICp (in this case IC20, IC50), or the concentration of effluent causing p% inhibition of luminescence over a 15 minute test duration.

Effluent samples exhibited a wide range of toxicity in this test. Facility A samples, as well as samples B-3, C-1, and C-2 were toxic, resulting in ICp estimates of <7 % effluent. By contrast, C-4 was non toxic and IC50 estimates for samples B-1, B-2, and C-3 were >100 %.

### 6.2.5 Biological Interpretation

The use of toxicity tests to evaluate the biological toxicity of effluent wastewaters is common in industrial monitoring and environmental assessment. Toxicity test data complement sample chemistry by providing information on the effects of the effluent on members of the aquatic community. Toxicity testing also presents an opportunity to assess the effects of complex mixtures of contaminants and their bioavailability to organisms in the real world (Chapman, 1989). In order to estimate toxicity at a number of levels within the ecosystem, a battery approach is often taken to toxicity testing in which several species are tested and a variety of endpoints are measured. In this case representative species were tested from bacterial, algal, zooplanktonic, and fish groups. Because each of the test organisms exhibits differing sensitivity to various components of wastewater, the battery approach provides a much better evaluation of true effects of the effluent once it discharges into the receiving water environment.

The toxicity test data summarized previously show several important trends in terms of the acute and chronic biological effects of the effluent. The data also illustrate some of the inherent benefits of using a battery of toxicity tests to analyze effluent toxicity. The toxicity test data show trends in water quality (i.e., dissolved oxygen and hardness) which can be used to help characterize the effluent and which affect toxicity. There is considerable variability within and among processing plants in effluent toxicity as well as variation in the response to effluent samples across tests. These issues are discussed below in more detail.

Water quality (pH, dissolved oxygen, conductivity, and water hardness) was measured for each water sample tested. One consistent factor in all of the test samples was high oxygen demand, seen as high BOD and COD in the analytical data, and apparent in low dissolved oxygen readings recorded during the *Ceriodaphnia* and rainbow trout toxicity tests. Low dissolved oxygen was likely a factor in the toxicity observed in some samples, especially in A-1, A-3, B-3, and C-1. Water hardness ranged widely between samples (as above), but the simultaneous testing of hardness-adjusted and unadjusted samples during the *Ceriodaphnia* test showed that hardness was not a factor in toxicity.

Temporal variability in sample toxicity at a site is demonstrated by the range in values for toxicity test endpoints. Facility A samples were consistently toxic across all toxicity tests. By contrast, there was a considerable range in toxicity for Facility B and Facility C samples. Some Facility B and Facility C samples were non toxic in all tests (B-1, B-2, C-3, C-4) while other samples from these sites were toxic in all tests (B-3, C-1, C-2). Changes in effluent toxicity at a site over time reflect changing effluent quality. Effluent quality is most likely altered by the nature and volume of fish being processed at the plant.

Effluent toxicity also changes among sites. Facility A samples were more consistently toxic than samples from Facility B and Facility C. However, effluent toxicity is demonstrated at all sites and it is likely that toxicity at each site varies considerably over time. Testing of a larger number of samples from each processing plant over time would be more representative of the true variation in effluent quality.

A variety of organisms and endpoints were used to assess the toxicity of each effluent sample. This is recognized as an effective approach in testing for sensitivity of organisms to effluents containing a complex mixture of chemicals. The following comparisons of endpoints do not include endpoints for the *Selenastrum* test for which the toxicity endpoint (growth inhibition) was obscured by growth enhancement.

Effluents which produced a toxic endpoint response in one test generally produced a response in the other tests (e.g., samples A-1, A-3, B-3, C-1, C-2). However, there were considerable differences for some of these samples. For example, although sample A-3 was quite toxic to rainbow trout (LC50 = 42 % effluent), it was much more toxic to *Ceriodaphnia* (LC50 = 0.5% effluent) and *Photobacterium* (IC50 = 0.7 % effluent).

Generally, the *Photobacterium* test was more sensitive to effluent samples than the other two tests. Munkittrick et al. (1991) suggest that for complex effluent mixtures (as opposed to individual contaminants), the Microtox test provides a more sensitive assessment of toxicity than do rainbow trout, *Daphnia*, or fathead minnow (*Pimephales promelas*). The exceptions for this study are samples B-1 and C-3 for which *Ceriodaphnia* was much more sensitive than either rainbow trout or *Photobacterium*. Rainbow trout and *Photobacterium* had similar acute responses (i.e. LC50 > 100 %, and IC50 >100 %, respectively). However, the *Ceriodaphnia* test is the only test to require replacement of the initial effluent sample by freshly collected "refresh" effluent during the test period (Environment Canada, 1990, 1992a,b,c). Both refresh samples for *Ceriodaphnia* test for B-1 sample were freshly collected (Appendix C). As a result, the elevated toxicity of this sample to *Ceriodaphnia* may be a response to a more toxic "refresh" sample than the initial sample. Replacement of the initial effluent sample by freshly collected refresh sample in the *Ceriodaphnia* test makes it difficult to compare results of this test to other toxicity tests since effluent quality at fish processing facilities varies widely on a day to day basis. Thus, exhibited toxicity may be due to a refresh sample rather than initial sample. Complete chemical analyses were performed only on the initial sample. Stored sample for *Ceriodaphnia* test for C-3 was used as refresh sample (Appendix C) since the facility did not operate on days when refresh samples were supposed to be collected. C-3 refresh samples analysis did not show significant difference between initial and stored samples and exhibited toxicity may be due to components not determined in this study.

Reproduction is considered to be a more sensitive endpoint than survival in the chronic *Ceriodaphnia* test (Environment Canada, 1992b) and regulations based on chronic endpoints are generally accepted as being more protective of the environment. This is supported by the response of *Ceriodaphnia* to samples A-2, B-1, and B-2 for which the reproduction response occurs at a much lower effluent concentration than the survival response.

It is clear from the variation in responses by several organisms to a single sample that a single toxicity test would not be completely predictive of the toxicity of the effluent from fish processing plants. This may be due to differing sensitivities of test organisms to the range of possible contaminants in the wastewater. It is known that sensitivity to chemical substances varies widely among toxicity test organisms (Cairns and Mount, 1990). The battery approach of using a series of acute and chronic toxicity tests provides information on the effects of the effluent across a range of taxa which are representative of major trophic levels in the Fraser River. Rainbow trout survival appears to be the most robust endpoint in response to the effluents, while *Ceriodaphnia* reproduction and *Photobacterium* luminescence are the most sensitive endpoints.

The *Selenastrum* toxicity test is not particularly useful for assessing fish processing plant effluents which are enriched with algal nutrients (primarily nitrogen and phosphorus). While excessive algal growth could be considered a deleterious effect in some aquatic situations (i.e., eutrophic lakes), the *Selenastrum* test (Environment Canada, 1992a) uses inhibition of growth as the measure of toxicity. Also, in an ecosystem such as the Fraser River, with high flushing rates, it is unlikely that excessive algal growth would cause significant detrimental effects. The *Selenastrum* test is an important component of the wastewater characterization, however, and would likely be a good indicator of toxicity for other effluent types (e.g., pulp mill effluent, mining and mineral processing wastes), in which algal nutrients are less likely to be present.

The ability to resolve patterns in effluent toxicity at each processing plant over time and among processing plants is limited by the number of samples collected. The initial characterization of effluent toxicity in this study involved collecting a few samples over time at each site. The results provide insights into the nature of effluent toxicity, but more sampling over a longer time period is required to obtain a complete picture of patterns in effluent toxicity within and among sites (e.g., Chapman et al., in press).

# 7 ESTIMATION OF CONTAMINANT LOADINGS AND POTENTIAL RECEIVING WATER IMPACTS

Due to confidentiality, detailed monthly production data for the facilities, and any other data that could be used to calculate production from the individual facilities (i.e. water consumption per day or season, average annual or seasonal daily flows and monthly discharge volumes, since water consumption per unit of production is reported) are not shown.

Statistical analysis of available data indicates that contaminant loadings (BOD, COD, TSS and ammonia) are log-normally distributed. Consequently, the more representative geometric mean values have been used to estimate annual loading to the Fraser River Estuary rather than arithmetic averages. The values for BOD, COD, TSS and $NH_4$-N per 1000 kg of processed fish for BC Packers, Bella Coola and Lions' Gate, as well as for the fish processing industry as a whole, are presented in Appendix D. A summary of the arithmetic average and geometric mean values are presented in Table 4.

The higher arithmetic averages are biased by only a few extremely high data values, as illustrated by the wide range of values indicated in the table.

Total solids (TS) loading is not included since only a limited number of TS data points exist (three TS samples per facility taken during this study; no historical data on TS concentrations were found and the GVRD and MOELP data bases do not include TS). The arithmetic average and geometric mean values for the industry as a whole are estimated using a combination of data collected during this study for four processing plants, historical data and data for Hokkai Marine, Billingsgate, Great Northern, Orca, Scanner, Seven Seas and Sealand facilities obtained from GVRD and MOELP files. Data for the facilities that discharge into the GVRD sewer system were used to obtain a wider data base for characterization of fish processing effluents, resulting in a more representative contaminant level estimate for the fish processing industry as a whole.

Data presented in Appendix D indicate that BOD, COD, TSS, and $NH_4$-N per 1000 kg of fish varies widely, from day to day within the same facility, and are different between facilities. All facilities discharged less BOD, COD, TSS and $NH_4$-N per unit of production on high-production days than on low-production days. This is due to a high minimum base-line water usage and less efficient water use during low production days. Therefore, facilities with high daily production would have lower contaminant loading rates than indicated in Table 4.

**Table 4 Geometric Mean, Range and Average Contaminant Levels per Weight of Fish Processed**

| Facility | Statistical Parameter | Loading [kg/tonne] BOD | COD | TSS | $NH_4$-N |
|---|---|---|---|---|---|
| **BC Packers** | Average | 24 | 75 | 14 | 9.3 |
| | Range | 0.1 - 210 | 0.5 - 553 | 0.1 - 167 | 0.0 - 111 |
| | Geo. Mean | 7 | 18 | 4 | 0.7 |
| **Bella Coola** | Average | 15 | 4 | 14 | 0.1 |
| | Range | 0.7 - 69 | 3 - 6 | 0.6 - 69 | 0.02 - 0.1 |
| | Geo. Mean | 6 | 4 | 5 | 0.04 |
| **Lions' Gate** | Average | 7 | 14 | 3 | 0.3 |
| | Range | 0.6 - 28 | 3 - 39 | 0.5 - 10 | 0.1 - 0.5 |
| | Geo. Mean | 7 | 9 | 2 | 0.2 |
| **Industry** | Average | 34 | 78 | 22 | 6.5 |
| | Range | 0.1 - 1830 | 0.1 - 2575 | 0.1 - 1415 | 0.0 - 111 |
| | Geo. Mean | 6 | 9 | 3 | 0.4 |

Variations in daily production, water use and waste concentration make it difficult to calculate precisely the amount of waste generated per unit of production. Geometric mean values for BC Packers, Bella Coola and Lions' Gate, and industry geometric mean values for other facilities, presented in Table 4 have been used to estimate annual contaminant loading to the Fraser River Estuary. It was not possible to estimate daily loadings based on month by month seasonal variations due to insufficient existing information.

Table 5 presents estimated annual contaminant loads to the Fraser River Estuary. The calculations are based on the 1993 production data. Estimated annual contaminant loads to the Fraser River Estuary represent population equivalent of approximately 6,000.

**Table 5 Annual Contaminant Loadings to the Fraser River Estuary**

| Production [tonne] | Total Loading [kg/year] | | | |
|---|---|---|---|---|
| | BOD | COD | TSS | $NH_3$-N |
| 33,070 | 216,000 | 380,000 | 121,000 | 13,000 |

Table 6 illustrates the wide range of loading estimates which can be made using different data base sets for one of the facilities. Consequently, caution should be exercised in using the above data for comparing the fish processing industry with other industries. It is felt that the annual loads shown in Table 5 represent reasonable estimate of presently discharged loads to the Fraser River Estuary. For example, if the arithmetic average is used to estimate annual contaminant loadings, then the estimated BOD loading would be twice as high, and COD and TSS loadings approximately three times higher, than values presented in Table 5.

Table 7 presents annual contaminant loadings to the Fraser River from Annacis and Lulu Island wastewater treatment plants (Fraser River Estuary Management Program, 1990). Loading from wastewater treatment plants is several orders of magnitude higher than loading from all fish processing facilities that discharge into the Fraser River. However, when comparing loadings form wastewater treatment plants and fish processing facilities, it should be kept in mind that discharge from fish processing plants occurs only during short period of time (4 to 6 moths per year), whereas wastewater treatment plants discharge continuously on a year-round basis.

The loads presented in Table 5 indicate that decreased dissolved oxygen levels in the receiving environment may occur on a localized basis. Since sampling of the receiving environment was not part of the scope of works of this study, it is not possible to estimate what oxygen levels can be expected around the specific discharge points. In a system like the Fraser River, with high flows and flushing rates, it is not expected that the estimated BOD, COD, or nutrient loads, will pose a problem.

**Table 6 Example of Potential Variation in BOD Loading Estimated for One Facility**

| Data Set Used | BOD [kg/year] |
|---|---|
| USING ARITHMETIC AVERAGE | |
| 1993 FREMP Study data only | 1,274,000 |
| Historical data including 1993 FREMP Study data | 312,000 |
| Historical data without 1993 FREMP Study data | 195,000 |
| Industry average | 442,000 |
| USING GEOMETRIC MEAN | |
| 1993 FREMP Study data only | 910,000 |
| Historical data including 1993 FREMP Study data | 91,000 |
| Historical data without 1993 FREMP Study data | 73,000 |
| Industry geometric mean | 78,000 |

**Table 7 Annual Contaminant Loading to the Fraser Estuary form Annacis and Lulu Island Wastewater Treatment Plants**

| Facility | Loading [kg/year] | | |
|---|---|---|---|
| | BOD | TSS | $NH_4$-N |
| Annacis Island | 16,614,435 | 7,561,705 | 1,704,185 |
| Lulu Island | 2,091,815 | 963,235 | 298,205 |
| **Total** | **18,706,250** | **8,524,940** | **2,002,390** |

## 8 CONCLUSIONS

# 8 CONCLUSIONS

The fish processing and waste management methods encountered during the study are typical for the kind of processing taking place in North America. However, the industry is moving towards water conservation, and in-house modifications to improve the quality of the process effluent. The changes are driven by the desire to reduce water costs, to meet expected tougher regulatory requirements, and to avoid expensive end-of-pipe treatment. Some of the required modifications are advanced by the industry-wide necessity for further mechanization to reduce labour costs, such as the semi-automatic salmon dressing machines, and herring sex sorters, which both may result in a reduction of the water consumption and wastewater contaminant concentrations and loadings. There is still considerable room for improvement, and it is expected that modifications which will result in a reduction of the contaminant load to the Fraser River will continue to be made in the future.

There is considerable variability within and among processing plants in water consumption, effluent characteristics and toxicity. Variability among processing plants may be due to the different type of processing taking place at these plants, whereas variability of these parameters for the same plant may be due to the processing of different species of fish. All facilities used less water and discharged less contaminants per tonne of fish on high-production days than on low-production days. Annual loads of contaminants to the Fraser River system from all facilities, based on individual (where available) and industry geometric mean values for contaminants, amounted to approximately 216 tonnes BOD, 360 tonnes COD, 121 tonnes suspended solids, and 13.5 tonnes ammonia nitrogen per year.

Based on the battery of toxicity tests conducted with samples from Different facilities, it is believed that effluents from all fish processing plants may be toxic during certain processing days. As low dissolved oxygen in the effluent samples was likely one of the factors in the toxicity, emphasis should be placed on implementing the recommendations made in the report to reduce organic strength and loading.

Rainbow trout survival appeared to be the least sensitive endpoint in response to the effluents, while *Ceriodaphnia* reproduction and *Photobacterium* luminescence were the most sensitive endpoints. The Selenastrum test resulted in growth enhancement rather than inhibition, and so is not particularly useful for assessing fish processing plant is not particularly useful for assessing fish processing plant effluents which are enriched with algal nutrients (primarily nitrogen and phosphorus). Since the analytical data indicate the effluent quality can vary widely between production days, the refresh samples used for the chronic *Ceriodaphnia* test may result in a toxicity response which in not directly comparable to the other bioassay test responses, as the refresh samples may contain toxic components not present in the initial sample. It is recommended that a modified *Ceriodaphnia* protocol, which uses stored samples for refresh purposes, be considered for future fish processing plant monitoring programs. In general, the battery approach of using a series of acute and chronic toxicity test is well suited to providing information on the effects of effluent across a range of taxa. However, the continued use of the *Selenastrum* test for fish processing effluents is not recommended.

**REFERENCES**

APHA, AWWA and WEF. 1992. Standard Methods for the Examination of Wastwater . 18th Edition, American Public Health Association, Washington, DC.

Cairns, J. Jr. and D.I. Mount. 1990. Aquatic toxicology. Environ. Sci. Technol. 24(2):15 4-161.

Chapman, P.M. 1989. Toxicity measurement and reduction procedures (biomonitoring and TRE programs). Water Poll. Res. J. Canada. 24(3):425-434.

Chapman, P.M., M.D. Paine, T. Moran and T. Kierstead. In Press. Refinery water (intake and effluent) quality - update of 1970s with 1990s toxicity testing. Environ. Toxicol. Chem.

Environment Canada. 1990. Biological Test Method: Acute Lethality Test Using Rainbow Trout. Report EPS 1/RM/9. 51 pp.

Environment Canada. 1992a. Biological Test Method: Growth Inhibition Test Using the Freshwater Alga *Selenastrum capricornitum*. Report EPS 1/RM/25. 41 pp.

Environment Canada. 1992b. Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*. Report EPS 1/RM/21. 72 pp.

Environment Canada. 1992c. Biological Test Method: Toxicity Test Using Luminescent Bacteria (*Photobacterium phosphoreum*). Report EPS 1/RM/24. 61 pp.

Munkittrick, K.R., E.A. Power, and G.A. Sergy. 1991. The relative sensitivity of Microtox, daphnid, rainbow trout, and fathead minnow acute lethality tests. Environ. Toxicol. Water Quality. 6:35-62 (1991)

Norecol Environmental Consultants Ltd. and Zenon Environmental Laboratories. 1993. Recommended Guidelines for Wastewater Characterization in the Fraser River Basin, volume I and II. Report prepared for Environment Canada, Fraser Pollution Abatement Office.

Riddle M.J. and K. Shikaze. 1973. Characterization and treatment of fish processing plant effluents in Canada. Proceedings: 4th National Symposium on Food Processing Wastes, Washington, DC, 400 pp.

# APPENDIX A

## MOELP Permit Summary

## MOELP PERMIT SUMMARY

| | | | | | Flows (m3/d) | | | | | Effluent Quality | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Permit No. | Issue Date | Last Amendment | Permitted Outfall | Process Ave | Process max | cooling | sanitary | Effluent Type | BOD mg/L | TSS mg/L | O&G mg/L | Temp C | Res CL2 mg/L | Toxicity % |
| Bella Coola | PE-5400 | 10-Apr-79 | 11-Sep-92 | 01 | - | 1400 | - | comb | P/S | 45 (1) | 60 (1) | - | - | <= 0.05 | - |
| | | 10-Apr-79 | 11-Sep-92 | 02 | - | - | 340 | - | C | - | - | - | <= 32 | - | - |
| BC Packers | PE-1830 | 26-Oct-73 | 23-Apr-93 | 01 | 4500 | 11800 | - | - | - | | | | <= 32 (3) | <= 0.05 | - |
| Lions Gate | PE-3139 | 06-Jul-74 | 26-Aug-92 | 01 | 500 | 800 | - | - | P | - | - | - | - | <= 0.05 | - |
| | | 06-Jul-74 | 26-Aug-92 | 02 | - | - | - | 5 | S | 45 (1) | 60 (1) | - | - | - | - |
| | | 06-Jul-74 | 26-Aug-92 | 03 | - | - | 20 | - | C | - | - | - | <= 35 (3) | - | - |
| | | 06-Jul-74 | 26-Aug-92 | 04 | - | - | 20 | - | C | - | - | - | <= 35 (3) | - | - |
| Ocean | PE-1975 | 25-Jan-74 | 11-Apr-86 | 01 | 960 | 7240 | yes | 40 | P/S/C | - | - | - | <= 32 (3) | <= 0.5 | - |
| | | 25-Jan-74 | 11-Apr-86 | 02 | - | - | - | 7.5 | S | - | - | - | - | - | - |
| | | 25-Jan-74 | 11-Apr-86 | 03 | - | - | - | 1.5 | S | - | - | - | - | - | - |
| SM Properties | PE-8430 | 17-Jul-90 | - | 01 | - | 23 | - | - | - | | | | | | 100 or <tox |
| Shearer | PE-7785 | 25-Sep-87 | - | 01 | - | 4.6 | - | - | - | | | | | | |
| Great North | PE-7810 | 13-Apr-89 | - | 01 | - | 3960 | - | - | - | - | - | - | - | - | - |
| New West | PE-8167 | 19-Oct-89 | - | 01 | - | 22.7 | - | - | - | 100 | 70 | - | - | - | - |

(1) - Sewage effluent limits
(2) - Toxicity not currently monitored; required monitoring on most recent amendment
(3) - Cooling water

C - Cooling
P - Process
S - Sewage

## MOELP PERMIT SUMMARY (cont'd)

| | | | | | Authorized works | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Monitoring | | | | | | | | | | |
| Name | Freq | Parameters | Type of Sample | Rep | Outfall | Discharge Depth low water | Distance from shore | screen mm (mesh)si | septic tank hrs | other | Type of fish processed |
| Bella Coola | Q (4) | BOD,TSS, | C, G | Q | yes | | | 0.25 (60) | | pkg aer | fr, fz, hr |
| | Q | Temp | | | | | | | | | - |
| BC Packers | M | BOD,TSS, | C, G | Q | yes | | | 0.15 | | * 2 | |
| Lions Gate | Q | BOD,TSS, | G | Q | yes | | | 0.25 (60) | | | fr, fz, hr, sh |
| | Q | BOD,TSS | G | | yes | | | | pkg STP | | - |
| | | - | | | | | | | | dischar | - |
| | | - | | | | | | | | dischar | - |
| Ocean | S | Temp, Res | G | A | yes | | | 0.7 (25) | 48 | diffuser | |
| | S | 24-hr efflue | - | | yes | | | - | 48 | - | |
| | S | 24-hr efflue | - | | yes | | | - | 48 | - | |
| SM Properties | Q | BOD,TSS, | G | Q | yes | | | 0.7 (25) | - | - | |
| Shearer | S | pH, BOD,T | G | S | yes | 3.6 m | 15 m | 0.7 (25) | - | - | |
| Great North - | M (5) | pH, BOD,T | G | A | yes | | | 0.7 (25) | - | - | |
| New West | Q | pH, BOD, T | G | A | yes | 1 m | 5 m | 0.7 (25) | - | - | |

(4) - All analyses on process effluent; only BOD and TSS on sanitary discharge

(5) -

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A = Annually, S = Semi-annually, Q = Quarterly, M = Monthly

G = Grab sample, C = Composite sample

## APPENDIX B

## Historical Data

## Biochemical Oxygen Demand (BOD5) - historical data

| Dates | Bella Coola Fish | | | BC Packers | | | Great North | Lions Gate | | | Shearer |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgBOD/tonne) | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgBOD/tonne) | BOD kg/d | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgBOD/tonne) | BOD kg/d |
| Jan 1990 | | | | | | | | | | | |
| Feb 1990 | | | | | | | | | | | |
| Mar 1990 | | | | 1.4 | H | 1.320 | | 5.7 | G S Sh | 1.460 | |
| Apr 1990 | 49.7 | H | 8.453 | 1.4 | H | 1.326 | | 7.8 | H Sh S H | 7.624 | 1 |
| May 1990 | 46.9 | F | 10.329 | 5.6 | H | 1.759 | 163 | 7.4 | G | 1.751 | |
| Jun 1990 | | | | 5.6 | D | 0.519 | | | | | |
| Jul 1990 | 33.6 | H | 9.910 | 4.2 | S | 3.027 | | | | | |
| Aug 1990 | | | | 6.4 | S | 5.469 | | | | | |
| Sept 1990 | 19.8 | F | 6.930 | 2.7 | D | 0.068 | | | | | |
| Oct 1990 | | | | 2.7 | S | 3.484 | | | | | |
| Nov 1990 | | | | 1.8 | S | 0.286 | | | | | |
| Dec 1990 | | | | | | | | | | | |
| Jan 1991 | | | | 210.1 | D | 20.487 | | | | | |
| Feb 1991 | | | | 120.5 | D | 18.563 | | | | | |
| Mar 1991 | | | | 4.8 | H | 7.188 | no | | | | |
| Apr 1991 | 22.6 | H | 6.328 | 16.5 | H | 16.569 | data | 14.3 | | 3.004 | |
| May 1991 | 18.5 | H | 1.887 | 15.7 | H | 23.599 | | | | | |
| Jun 1991 | | | | 35.1 | D | 66.312 | | | | | |
| Jul 1991 | | | | 26.9 | D | 5.498 | | 8.1 | Sh S | | |
| Aug 1991 | 326.4 | S | 69.190 | 6.7 | S | 2.099 | | 31.5 | S | 2.113 | |
| Sept 1991 | 28.1 | S | 61.208 | 25.2 | D | 10.690 | | 8.2 | S | | |
| Oct 1991 | 30.4 | S | 4.200 | 23.9 | D | 7.811 | | 14.1 | S | 12.620 | |
| Nov 1991 | | | | | | | | 7.2 | S | 0.631 | |
| Dec 1991 | | | | | | | | | | | |
| Jan 1992 | | | | | | | | | | | |
| Feb 1992 | | | | | | | | | | | |
| Mar 1992 | | | | 15.8 | H | 9.510 | | | | | |
| Apr 1992 | | | | 41.2 | H | 30.418 | no | 10.1 | S | 5.200 | 3 |
| May 1992 | | | | 26.6 | H | 13.722 | data | 37.1 | H | 9.837 | |
| Jun 1992 | | | | 6.8 | H | 5.275 | | 20.2 | S | 27.594 | |
| Jul 1992 | | | | 14.3 | D | 5.164 | | | | | |
| Aug 1992 | | | | 25.1 | S | 22.401 | | | | | |
| Sept 1992 | | | | 297.5 | D | 110.973 | | 10.6 | G S HI | 4.423 | |
| Oct 1992 | 74.8 | S | 4.338 | | | | | | | | |
| Nov 1992 | | | | | | | | 31.9 | S Sh | 12.105 | |
| Dec 1992 | 44.7 | H | 0.440 | | | | | | | | |

* H - Herring  Sh - Shrimp
S - Salmon  HI - Halibut
D - Dressing fresh/frozen  G - Groundfish

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## Chemical Oxygen Demand (COD)- historical data

| Dates | | Bella Coola Fish | | | BC Packers | | | Great Northern | Lions Gate | | | Shearer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgCOD/tonne) | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgCOD/tonne) | kg/d | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgCOD/tonne) | COD kg/d |
| Jan | 1990 | | | | | | | | | | | |
| Feb | 1990 | | | | | | | | | | | |
| Mar | 1990 | | | | 1.4 | H | | | 5.7 | G S Sh | | |
| Apr | 1990 | 49.7 | H | | 1.4 | H | | | 7.8 | H Sh S HI | | 1 |
| May | 1990 | 46.9 | F | | 5.6 | H | | 118 | 7.4 | G | | |
| Jun | 1990 | | | | 5.6 | D | | | | | | |
| Jul | 1990 | 33.6 | H | | 4.2 | S | | | | | | |
| Aug | 1990 | | | | 6.4 | S | 5.615 | | | | | |
| Sept | 1990 | 19.8 | F | | 2.7 | D | | | | | | |
| Oct | 1990 | | | | 2.7 | S | 4.510 | | | | | |
| Nov | 1990 | | | | 1.8 | S | 0.503 | | | | | |
| Dec | 1990 | | | | | | | | | | | |
| Jan | 1991 | | | | 210.1 | D | 29.102 | | | | | |
| Feb | 1991 | | | | 120.5 | D | 19.166 | | | | | |
| Mar | 1991 | | | | 4.8 | H | 7.235 | | | | | |
| Apr | 1991 | 22.6 | H | | 16.5 | H | 16.585 | | 14.3 | | | |
| May | 1991 | 18.5 | H | | 15.7 | H | 23.457 | | | | | |
| Jun | 1991 | | | | 35.1 | D | | | | | | |
| Jul | 1991 | | | | 26.9 | D | | | 8.1 | Sh S | | |
| Aug | 1991 | 326.4 | S | | 6.7 | S | | | 31.5 | S | | |
| Sept | 1991 | 28.1 | S | | 25.2 | D | | | 8.2 | S | | |
| Oct | 1991 | 30.4 | S | | 23.9 | D | | | 14.1 | S | | |
| Nov | 1991 | | | | | | | | 7.2 | S | | |
| Dec | 1991 | | | | | | | | | | | |
| Jan | 1992 | | | | | | | | | | | |
| Feb | 1992 | | | | | | | | | | | |
| Mar | 1992 | | | | 15.8 | H | | | | | | |
| Apr | 1992 | | | | 41.2 | H | | | 10.1 | S | 2.767 | 3 |
| May | 1992 | | | | 26.6 | H | | | 37.1 | H | 12.659 | |
| Jun | 1992 | | | | 6.8 | H | | | 20.2 | S | 39.117 | |
| Jul | 1992 | | | | 14.3 | D | | | | | | |
| Aug | 1992 | | | | 25.1 | S | | | | | | |
| Sept | 1992 | | | | 297.5 | D | | | 10.6 | G S HI | 5.526 | |
| Oct | 1992 | 74.8 | S | | | | | | | | | |
| Nov | 1992 | | | | | | | | 31.9 | S Sh | 25.165 | |
| Dec | 1992 | 44.7 | H | | | | | | | | | |

* H - Herring  
S - Salmon  
D - Dressing fresh/frozen  
Sh - Shrimp  
HI - Halibut  
G - Groundfish

## Total Suspended Solids (TSS) - historical data

| Dates | | Bella Coola Fish | | | BC Packers | | | Great Northern | Lions Gate | | | Shearer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgTSS/tonne) | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgTSS/tonne) | TSS kg/d | Water Consumption (m3/tonne) | Fish* Process | Mass Loading (kgTSS/tonne) | Tss kg/d |
| Jan | 1990 | | | | | | | | | | | |
| Feb | 1990 | | | | | | | | | | | |
| Mar | 1990 | | | | 1.4 | H | 0.081 | | 5.7 | G S Sh | 0.680 | |
| Apr | 1990 | 49.7 | H | 1.989 | 1.4 | H | 0.856 | | 7.8 | H Sh S Hl | 1.220 | 0 |
| May | 1990 | 46.9 | F | 3.380 | 5.6 | H | 1.855 | 36 | 7.4 | G | 0.846 | |
| Jun | 1990 | | | | 5.6 | D | 0.405 | | | | | |
| Jul | 1990 | 33.6 | H | 12.766 | 4.2 | S | 2.934 | | | | | |
| Aug | 1990 | | | | 6.4 | S | 4.960 | | | | | |
| Sept | 1990 | 19.8 | F | 4.356 | 2.7 | D | 0.190 | | | | | |
| Oct | 1990 | | | | 2.7 | S | 2.055 | | | | | |
| Nov | 1990 | | | | 1.8 | S | 0.194 | | | | | |
| Dec | 1990 | | | | | | | | | | | |
| Jan | 1991 | | | | 210.1 | D | 15.234 | | | | | |
| Feb | 1991 | | | | 120.5 | D | 7.474 | | | | | |
| Mar | 1991 | | | | 4.8 | H | 1.683 | no | | | | |
| Apr | 1991 | 22.6 | H | 6.328 | 16.5 | H | 5.396 | data | 14.3 | | 1.488 | |
| May | 1991 | 18.5 | H | 1.887 | 15.7 | H | 2.464 | | | | | |
| Jun | 1991 | | | | 35.1 | D | 27.642 | | | | | |
| Jul | 1991 | | | | 26.9 | D | 0.874 | | 8.1 | Sh S | 0.000 | |
| Aug | 1991 | 326.4 | S | 69.190 | 6.7 | S | 1.238 | | 31.5 | S | 1.325 | |
| Sept | 1991 | 28.1 | S | 61.208 | 25.2 | D | 2.163 | | 8.2 | S | 0.000 | |
| Oct | 1991 | 30.4 | S | 4.200 | 23.9 | D | 4.257 | | 14.1 | S | 6.689 | |
| Nov | 1991 | | | | | | | | 7.2 | S | 0.486 | |
| Dec | 1991 | | | | | | | | | | | |
| Jan | 1992 | | | | | | | | | | | |
| Feb | 1992 | | | | | | | | | | | |
| Mar | 1992 | | | | 15.8 | H | 2.281 | | | | | |
| Apr | 1992 | | | | 41.2 | H | 14.087 | no | 10.1 | S | 1.592 | 1 |
| May | 1992 | | | | 26.6 | H | 5.358 | data | 37.1 | H | 3.415 | |
| Jun | 1992 | | | | 6.8 | H | 2.284 | | 20.2 | S | 10.391 | |
| Jul | 1992 | | | | 14.3 | D | 2.404 | | | | | |
| Aug | 1992 | | | | 25.1 | S | 14.433 | | | | | |
| Sept | 1992 | | | | 297.5 | D | 48.049 | | 10.6 | G S Hl | 1.803 | |
| Oct | 1992 | 74.8 | S | 4.862 | | | | | | | | |
| Nov | 1992 | | | | | | | | 31.9 | S Sh | 5.320 | |
| Dec | 1992 | 44.7 | H | 0.000 | | | | | | | | |

* H - Herring — Sh - Shrimp
S - Salmon — Hl - Halibut
D - Dressing fresh/frozen — G - Groundfish

## Ammonia Nitrogen: NH3-N - historical data

| Dates | | BC Packers Water Consumption (m3/tonne) | BC Packers Fish* Process | BC Packers Mass Loading (kgNH3/tonne) | Great Northern Conc NH3-N mg/L | Great Northern kg/d | Lions Gate Fish* Process | Lions Gate Mass Loading (kgNH3/tonne) |
|---|---|---|---|---|---|---|---|---|
| Jan | 1990 | | | | | | | |
| Feb | 1990 | | | | | | | |
| Mar | 1990 | 1.4 | H | | | | G S Sh | no data |
| Apr | 1990 | 1.4 | H | | | | H Sh S Hl | |
| May | 1990 | 5.6 | H | | | | G | |
| Jun | 1990 | 5.6 | D | | | | | |
| Jul | 1990 | 4.2 | S | | | | | |
| Aug | 1990 | 6.4 | S | 0.020 | | | | |
| Sept | 1990 | 2.7 | D | | | | | |
| Oct | 1990 | 2.7 | S | 0.038 | | | | |
| Nov | 1990 | 1.8 | S | 0.003 | | | | |
| Dec | 1990 | | | | | | | |
| Jan | 1991 | 210.1 | D | 0.346 | | | | |
| Feb | 1991 | 120.5 | D | 0.410 | | | | |
| Mar | 1991 | 4.8 | H | 0.109 | no | | | |
| Apr | 1991 | 16.5 | H | 0.100 | data | | | |
| May | 1991 | 15.7 | H | 0.108 | | | | |
| Jun | 1991 | 35.1 | D | 1.022 | | | | |
| Jul | 1991 | 26.9 | D | 0.042 | | | Sh S | |
| Aug | 1991 | 6.7 | S | 0.053 | | | S | |
| Sept | 1991 | 25.2 | D | 0.295 | | | S | |
| Oct | 1991 | 23.9 | D | 0.188 | | | S | |
| Nov | 1991 | | | | | | S | |
| Dec | 1991 | | | | | | | |
| Jan | 1992 | | | | | | | |
| Feb | 1992 | | | | | | | |
| Mar | 1992 | 15.8 | H | 9.510 | | | | |
| Apr | 1992 | 41.2 | H | 30.418 | no | | S | |
| May | 1992 | 26.6 | H | 13.722 | data | | H | |
| Jun | 1992 | 6.8 | H | 5.275 | | | S | |
| Jul | 1992 | 14.3 | D | 5.164 | | | | |
| Aug | 1992 | 25.1 | S | 22.401 | | | | |
| Sept | 1992 | 297.5 | D | 110.973 | | | G S Hl | |
| Oct | 1992 | | | | | | | |
| Nov | 1992 | | | | | | S Sh | |
| Dec | 1992 | | | | | | | |

* H - Herring; S - Salmon; D - Dressing fresh/frozen; Sh - Shrimp; Hl - Halibut; G - Groundfish

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## APPENDIX C

## Analytical Test Results

## B.C. PACKERS
### Conventional Contaminants

| Parameter | Sample | | | Average |
| --- | --- | --- | --- | --- |
| | BCP-1A | BCP-2A | BCP-3A | Concentration |
| Water Consumption (m3/1000 kg) | 11.9 | 105.3 | 228.4 | 115.2 |
| Conductivity (umhos/cm) | 3660 | 2730 | 2960 | 3117 |
| pH | 6.29 | 6.79 | 6.45 | 6.51 |
| Total Suspended Solids (TSS) | 1240 | 482 | 730 | 817 |
| Total Solids (TS) | 3640 | 1770 | 2280 | 2563 |
| Alkalinity - Total (as CaCO3) | 253 | 235 | 161 | 216 |
| Ammonia Nitrogen (NH3-N) | 69.7 | 35.6 | 38.9 | 48.1 |
| Nitrate Nitrogen (NO3-N) | 0.016 | <0.005 | <0.005 | <0.016 |
| Nitrite Nitrogen (NO2-N) | 0.005 | <0.001 | <0.001 | <0.005 |
| Oil and Grease (O&G) | 54 | 39 | 98 | 64 |
| Biochem.Oxygen Demand-Tot (BOD5) | 2680 | 493 | 920 | 1364 |
| Chemical Oxygen Demand (COD) | 3460 | 1150 | 2420 | 2343 |
| Dissolved Organic Carbon (DOC) | 268 | 145 | 131 | 181 |
| Residual Chlorine | 0.00 | 0.01 | - | 0.00 |
| Fecal Coliforms (MPN/100 ml) | 1,700,000 | 130,000 | 7,000 | 612,333 |

Note: all concentrations in mg/L except pH and as noted

## B.C. PACKERS
### Metal (total and dissolved)

| Metal | Total Sample BCP-1A | Total Sample BCP-2A | Total Sample BCP-3A | Average Concentration | Dissolved Sample BCP-1A | Dissolved Sample BCP-2A | Dissolved Sample BCP-3A | Average Concentration |
|---|---|---|---|---|---|---|---|---|
| Aluminum Al | <0.20 | 1.41 | 0.59 | <1.41 | <0.20 | 0.22 | <0.20 | < 0.22 |
| Antimony Sb | <0.20 | <0.40 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Arsenic As | <0.20 | <0.40 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Barium Ba | <0.010 | <0.020 | <0.010 | | <0.010 | <0.010 | <0.010 | |
| Beryllium Be | <0.005 | <0.01 | <0.005 | | <0.005 | <0.005 | <0.005 | |
| Bismuth Bi | <0.10 | <0.20 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Cadmium Cd | <0.010 | <0.020 | <0.010 | | <0.010 | <0.010 | <0.010 | |
| Calcium Ca | 9.62 | 14.2 | 14.3 | 12.707 | 7.92 | 7.65 | 11 | 8.86 |
| Chromium Cr | <0.015 | <0.030 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Cobalt Co | <0.015 | <0.030 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Copper Cu | 0.159 | 0.086 | 0.053 | 0.099 | 0.015 | 0.031 | <0.010 | <0.031 |
| Iron Fe | 0.923 | 3.91 | 1.39 | 2.074 | 0.277 | 0.555 | 0.718 | 0.517 |
| Lead Pb | <0.050 | <0.10 | <0.050 | | <0.050 | <0.050 | <0.050 | |
| Lithium Li | <0.015 | <0.030 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Magnesium Mg | 10.3 | 20.6 | 21.9 | 17.6 | 9.62 | 10.9 | 21.3 | 13.94 |
| Manganese Mn | 0.007 | 0.06 | 0.025 | 0.031 | 0.005 | 0.028 | 0.021 | 0.018 |
| Molybdenum Mo | <0.030 | <0.060 | <0.030 | | <0.030 | <0.030 | <0.030 | |
| Nickel Ni | <0.020 | <0.040 | <0.020 | | <0.020 | <0.020 | <0.020 | |
| Phosphorus P | 30.3 | 13.4 | 32.2 | 25.3 | 27.7 | 6.72 | 28.1 | 20.84 |
| Potassium K | 51 | 16.9 | 42.9 | 36.9 | 49.1 | 9.5 | 42 | 33.5 |
| Selenium Se | <0.20 | <0.40 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Silver Ag | <0.015 | <0.030 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Sodium Na | 668 | 201 | 495 | 455 | 653 | 170 | 494 | 439 |
| Strontium Sr | 0.086 | 0.175 | 0.156 | 0.139 | 0.079 | 0.088 | 0.149 | 0.105 |
| Thallium Tl | <0.10 | <0.20 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Tin Sn | <0.30 | <0.60 | <0.30 | | <0.30 | <0.30 | <0.30 | |
| Titanium Ti | <0.010 | 0.036 | 0.018 | <0.036 | <0.010 | <0.010 | <0.010 | |
| Tungsten W | <0.10 | <0.20 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Vanadium V | <0.030 | <0.060 | <0.030 | | <0.030 | <0.030 | <0.030 | |
| Zinc Zn | 0.433 | 0.33 | 0.293 | 0.352 | 0.08 | 0.154 | 0.057 | 0.097 |

Note: all concentrations in mg/L

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FREMP

Fsih Processing Effluent

# BELLA COOLA
## Conventional Contaminants

| Parameter | Sample | | | Average Concentration |
|---|---|---|---|---|
| | Bell-1A | Bell-2A | Bell-3A | |
| Water Consumption (m3/1000 kg) | 3.5 | 5.6 | 2.9 | 4.0 |
| Conductivity (umhos/cm) | 4670 | 4710 | 4580 | 4653 |
| pH | 6.56 | 6.46 | 6.29 | 6.44 |
| Total Suspended Solids (TSS) | 545 | 187 | 212 | 315 |
| Total Solids (TS) | 3200 | 2960 | 2790 | 2983 |
| Alkalinity - Total (as CaCO3) | 268 | 59.4 | 88 | 138.5 |
| Ammonia Nitrogen (NH3-N) | 29.1 | 3.4 | 13.1 | 15.2 |
| Nitrate Nitrogen (NO3-N) | <0.005 | 0.077 | <0.005 | <0.077 |
| Nitrite Nitrogen (NO2-N) | 0.003 | 0.145 | 0.004 | 0.051 |
| Oil and Grease (O&G) | 47 | 17 | 13 | 26 |
| Biochem.Oxygen Demand-Tot (BOD5) | 740 | 230 | 260 | 410 |
| Chemical Oxygen Demand (COD) | 1670 | 712 | 1070 | 1151 |
| Dissolved Organic Carbon (DOC) | 113 | 61.5 | 88 | 88 |
| Residual Chlorine | 0.00 | - | - | - |
| Fecal Coliforms (MPN/100 ml) | 700 | 300 | 2300 | 1100 |

Note: all concentrations in mg/L except pH and as noted

# BELLA COOLA
## Metals (total and dissolved)

| Metal | Total Sample | | | Average | Dissolved Sample | | | Average |
|---|---|---|---|---|---|---|---|---|
| | Bell-1A | Bell-2A | Bell-3A | Concentration | Bell-1A | Bell-2A | Bell-3A | Concentration |
| Aluminum Al | <0.40 | <0.20 | <0.40 | | <0.20 | <0.20 | <0.20 | |
| Antimony Sb | <0.40 | <0.20 | <0.40 | | <0.20 | <0.20 | <0.20 | |
| Arsenic As | <0.40 | <0.20 | <0.40 | | <0.20 | <0.20 | <0.20 | |
| Barium Ba | <0.020 | <0.010 | <0.020 | | <0.010 | <0.010 | <0.010 | |
| Beryllium Be | <0.01 | <0.005 | <0.01 | | <0.005 | <0.005 | <0.005 | |
| Bismuth Bi | <0.20 | <0.10 | <0.20 | | <0.10 | <0.10 | <0.10 | |
| Cadmium Cd | <0.020 | <0.010 | <0.020 | | <0.010 | <0.010 | <0.010 | |
| Calcium Ca | 13.6 | 11.6 | 6.38 | 10.53 | 13.6 | 11.3 | 6.37 | 10.42 |
| Chromium Cr | <0.030 | <0.015 | <0.030 | | <0.015 | <0.015 | <0.015 | |
| Cobalt Co | <0.030 | <0.015 | <0.030 | | <0.015 | <0.015 | <0.015 | |
| Copper Cu | 0.034 | 0.018 | 0.041 | 0.031 | 0.015 | <0.010 | <0.010 | <0.015 |
| Iron Fe | 1.04 | 0.735 | 1.27 | 1.015 | 0.326 | 0.497 | 0.548 | 0.457 |
| Lead Pb | <0.10 | <0.050 | <0.10 | | <0.050 | <0.050 | <0.050 | |
| Lithium Li | <0.030 | <0.015 | <0.030 | | <0.015 | <0.015 | <0.015 | |
| Magnesium Mg | 20.2 | 20.6 | 5.38 | 15.4 | 19.5 | 20.6 | 4.7 | 14.9 |
| Manganese Mn | 0.01 | 0.016 | 0.04 | 0.022 | <0.005 | 0.014 | 0.007 | <0.014 |
| Molybdenum Mo | <0.060 | <0.030 | <0.060 | | <0.030 | <0.030 | <0.030 | |
| Nickel Ni | <0.040 | <0.020 | <0.040 | | <0.020 | <0.020 | <0.020 | |
| Phosphorus P | 21.7 | 8.17 | 10.2 | 13.36 | 16.8 | 8.01 | 8.06 | 10.96 |
| Potassium K | 45.6 | 21.7 | 20.8 | 29.4 | 45.2 | 21.7 | 20.8 | 29.2 |
| Selenium Se | <0.40 | <0.20 | <0.40 | | <0.20 | <0.20 | <0.20 | |
| Silver Ag | <0.030 | <0.015 | <0.030 | | <0.015 | <0.015 | <0.015 | |
| Sodium Na | 931 | 951 | 887 | 923 | 913 | 951 | 887 | 917 |
| Strontium Sr | 0.152 | 0.145 | 0.063 | 0.12 | 0.144 | 0.145 | 0.059 | 0.116 |
| Thallium Tl | <0.20 | <0.10 | <0.20 | | <0.10 | <0.10 | <0.10 | |
| Tin Sn | <0.60 | <0.30 | <0.60 | | <0.30 | <0.30 | <0.30 | |
| Titanium Ti | <0.020 | <0.010 | <0.020 | | <0.010 | <0.010 | <0.010 | |
| Tungsten W | <0.20 | <0.10 | <0.20 | | <0.10 | <0.10 | <0.10 | |
| Vanadium V | <0.060 | <0.030 | <0.060 | | <0.030 | <0.030 | <0.030 | |
| Zinc Zn | 0.24 | 0.104 | 0.13 | 0.158 | 0.091 | 0.013 | 0.028 | 0.044 |

Note: all concentrations in mg/L

H:\1362\01\ASLDATA\BELL-RES.WB1

FREMP

Fsih Processing Effluent

## LION'S GATE
### Conventional Contaminants

| Parameter | Sample | | | Average |
|---|---|---|---|---|
| | LG 1A | LG 2A | LG 3A | Concentration |
| Water Consumption (m3/1000 kg) | 10.8 | 14.6 | 14.3 | 13.2 |
| Conductivity (umhos/cm) | 215 | 713 | 683 | 537 |
| pH | 6.5 | 6.72 | 7.41 | 6.88 |
| Total Suspended Solids (TSS) | 100 | 74 | 353 | 176 |
| Total Solids (TS) | 218 | 488 | 734 | 480 |
| Alkalinity - Total (as CaCO3) | 106 | 61.6 | 185 | 117.5 |
| Ammonia Nitrogen (NH3-N) | 5.5 | 20.2 | 35.5 | 20.4 |
| Nitrate Nitrogen (NO3-N) | 0.013 | 0.018 | 0.007 | 0.013 |
| Nitrite Nitrogen (NO2-N) | 0.001 | <0.001 | 0.009 | <0.009 |
| Oil and Grease (O&G) | 8 | 8 | 80 | 32 |
| Biochem.Oxygen Demand-Tot ( BOD5) | 175 | 128 | 668 | 324 |
| Chemical Oxygen Demand (COD) | 364 | 316 | 1140 | 607 |
| Dissolved Organic Carbon (DOC) | 31.9 | 25.2 | 133 | 63 |
| Residual Chlorine | 0.08 | 0.15 | - | 0.11 |
| Fecal Coliforms (MPN/100 ml) | 230 | 80 | 300 | 203 |

Note: all concentrations in mg/L except pH and as noted

**LION'S GATE**
**Metals (total and dissolved)**

| Metal | Total Sample | | | Average Concentration | Dissolved Sample | | | Average Concentration |
|---|---|---|---|---|---|---|---|---|
| | LG-1 | LG-2 | LG-3 | | LG-1 | LG-2 | LG-3 | |
| Aluminum Al | 0.22 | 0.41 | <0.20 | <0.41 | <0.20 | <0.20 | <0.20 | |
| Antimony Sb | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Arsenic As | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Barium Ba | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | |
| Beryllium Be | <0.005 | <0.005 | <0.005 | | <0.005 | <0.005 | <0.005 | |
| Bismuth Bi | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Cadmium Cd | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | |
| Calcium Ca | 5.3 | 4.64 | 14.5 | 8.15 | 4.57 | 4.64 | 12 | 7.07 |
| Chromium Cr | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Cobalt Co | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Copper Cu | 0.029 | 0.042 | 0.145 | 0.072 | 0.013 | 0.038 | 0.079 | 0.043 |
| Iron Fe | 0.596 | 0.764 | 0.526 | 0.629 | 0.073 | 0.415 | 0.365 | 0.284 |
| Lead Pb | <0.050 | <0.050 | <0.050 | | <0.050 | <0.050 | <0.050 | |
| Lithium Li | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Magnesium Mg | 1.59 | 1.25 | 2.69 | 1.843 | 1.28 | 1.23 | 2.69 | 1.73 |
| Manganese Mn | 0.023 | 0.028 | 0.021 | 0.024 | 0.009 | 0.024 | 0.014 | 0.016 |
| Molybdenum Mo | <0.030 | <0.030 | <0.030 | | <0.030 | <0.030 | <0.030 | |
| Nickel Ni | <0.020 | <0.020 | <0.020 | | <0.020 | <0.020 | <0.020 | |
| Phosphorus P | 6.06 | 5.9 | 8.73 | 6.90 | 4.43 | 5.4 | 8.73 | 6.19 |
| Potassium K | 14.1 | 13 | 18.5 | 15.2 | 12.5 | 13 | 18.5 | 14.7 |
| Selenium Se | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | |
| Silver Ag | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | |
| Sodium Na | 23.5 | 119 | 33.9 | 58.8 | 23.5 | 119 | 33.9 | 58.5 |
| Strontium Sr | 0.032 | 0.026 | 0.18 | 0.079 | 0.027 | 0.026 | 0.18 | 0.078 |
| Thallium Tl | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Tin Sn | <0.30 | <0.30 | <0.30 | | <0.30 | <0.30 | <0.30 | |
| Titanium Ti | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | |
| Tungsten W | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | |
| Vanadium V | <0.030 | <0.030 | <0.030 | | <0.030 | <0.030 | <0.030 | |
| Zinc Zn | 0.104 | 0.15 | 0.109 | 0.121 | 0.034 | 0.15 | 0.028 | 0.071 |

Note: all concentrations in mg/L

H:\1362\01\ASLDATA\LG-RES.WB1

## OCEAN FISHERIES
### Conventional Contaminants

| Parameter | Sample | | | | Average |
|---|---|---|---|---|---|
| | OC-1A | OC-2A | OC-3A | OC-4A | Concentration |
| Water Consumption (m3/1000 kg) | 19.1 | 15.3 | 36.4 | 37 | 27.0 |
| Conductivity (umhos/cm) | 3670 | 2640 | 461 | 420 | 1798 |
| pH | 6.33 | 6.32 | 5.73 | 6.5 | 6.22 |
| Total Suspended Solids (TSS) | 931 | 544 | 108 | 40 | 406 |
| Total Solids (TS) | 2630 | 2380 | 399 | 288 | 1424 |
| Alkalinity - Total (as CaCO3) | 215 | 1410 | 40.8 | 93.5 | 439.8 |
| Ammonia Nitrogen (NH3-N) | 38.9 | 17 | 0.698 | 0.96 | 14.390 |
| Nitrate Nitrogen (NO3-N) | <0.005 | <0.005 | 0.011 | 0.006 | <0.011 |
| Nitrite Nitrogen (NO2-N) | 0.014 | <0.001 | 0.003 | 0.006 | <0.014 |
| Oil and Grease (O&G) | 60 | 19 | 11 | 16 | 27 |
| Biochem.Oxygen Demand-Tot (BOD-5) | 2080 | 565 | 160 | 230 | 759 |
| Chemical Oxygen Demand (COD) | 2290 | 1510 | 321 | 344 | 1116 |
| Dissolved Organic Carbon (DOC) | 182 | 134 | 30.9 | 32.1 | 94.8 |
| Resudual Chlorine | 0.00 | - | - | 0.13 | 0.06 |
| Fecal Coliforms (MPN/100 ml) | 23 | 300 | 50 | 170 | 136 |

Note: all concentrations in mg/L except pH and as noted H:\1362\01\ASLDATA\OC-RES.WB1

FREMP

Fish Processing Effluent

# OCEAN FISHERIES

## Metals (total and dissolved)

| Metal | Total Sample | | | | Average Concentration | Dissolved Sample | | | | Average Concentration |
|---|---|---|---|---|---|---|---|---|---|---|
| | OC-1A | OC-2A | OC-3A | OC-4A | | OC-1A | OC-2A | OC-3A | OC-4A | |
| Aluminum Al | <0.20 | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | <0.20 | |
| Antimony Sb | <0.20 | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | <0.20 | |
| Arsenic As | <0.20 | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | <0.20 | |
| Barium Ba | <0.010 | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | <0.010 | |
| Beryllium Be | <0.005 | <0.005 | <0.005 | <0.005 | | <0.005 | <0.005 | <0.005 | <0.005 | |
| Bismuth Bi | <0.10 | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | <0.10 | |
| Cadmium Cd | <0.010 | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | <0.010 | |
| Calcium Ca | 5.48 | 8.27 | 3.29 | 2.94 | 5.00 | 5.18 | 7.3 | 2.47 | 2.46 | 4.35 |
| Chromium Cr | <0.015 | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | <0.015 | |
| Cobalt Co | <0.015 | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | <0.015 | |
| Copper Cu | 0.064 | 0.031 | 0.013 | 0.05 | 0.040 | <0.010 | <0.010 | <0.010 | <0.010 | |
| Iron Fe | 0.727 | 0.516 | 0.323 | 0.431 | 0.499 | 0.133 | 0.095 | <0.030 | <0.030 | <0.133 |
| Lead Pb | <0.050 | <0.050 | <0.050 | <0.050 | | <0.050 | <0.050 | <0.050 | <0.050 | |
| Lithium Li | <0.015 | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | <0.015 | |
| Magnesium Mg | 3.97 | 12.1 | 1.1 | 1.13 | 4.58 | 3.63 | 11.8 | 0.833 | 0.971 | 4.309 |
| Manganese Mn | 0.008 | 0.01 | 0.009 | 0.028 | 0.014 | <0.005 | <0.005 | <0.005 | 0.006 | |
| Molybdenum Mo | <0.030 | <0.030 | <0.030 | <0.030 | | <0.030 | <0.030 | <0.030 | <0.030 | |
| Nickel Ni | <0.020 | <0.020 | <0.020 | <0.020 | | <0.020 | <0.020 | <0.020 | <0.020 | |
| Phosphorus P | 26.1 | 17 | 6.39 | 8.93 | 14.61 | 18.4 | 13.1 | 4.48 | 6.87 | 10.71 |
| Potassium K | 41.4 | 29 | 10.7 | 11 | 23.0 | 40.4 | 28.8 | 9.3 | 10.5 | 22.3 |
| Selenium Se | <0.20 | <0.20 | <0.20 | <0.20 | | <0.20 | <0.20 | <0.20 | <0.20 | |
| Silver Ag | <0.015 | <0.015 | <0.015 | <0.015 | | <0.015 | <0.015 | <0.015 | <0.015 | |
| Sodium Na | 764 | 501 | 52.9 | 53.9 | 343.0 | 757 | 501 | 47.4 | 52.7 | 339.5 |
| Strontium Sr | 0.042 | 0.086 | 0.008 | 0.01 | 0.037 | 0.039 | 0.082 | 0.008 | 0.01 | 0.035 |
| Thallium Tl | <0.10 | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | <0.10 | |
| Tin Sn | <0.30 | <0.30 | <0.30 | <0.30 | | <0.30 | <0.30 | <0.30 | <0.30 | |
| Titanium Ti | <0.010 | <0.010 | <0.010 | <0.010 | | <0.010 | <0.010 | <0.010 | <0.010 | |
| Tungsten W | <0.10 | <0.10 | <0.10 | <0.10 | | <0.10 | <0.10 | <0.10 | <0.10 | |
| Vanadium V | <0.030 | <0.030 | <0.030 | <0.030 | | <0.030 | <0.030 | <0.030 | <0.030 | |
| Zinc Zn | 0.263 | 0.197 | 0.082 | 0.072 | 0.154 | 0.078 | 0.043 | 0.035 | 0.03 | 0.047 |

Note: all concentrations in mg/L

H:\1362\01\ASLDATA\OC-RES.WB1

# CERIODAPHNIA TEST
## REFRESH SAMPLE EXPLANATION

| SITE | SAMPLE ID | DATE SAMPLED | TYPE | SAMPLE USED | REFRESH # | DATE USED FOR REFRESH | TIME TAKEN (if noted) |
|---|---|---|---|---|---|---|---|
| **Facility A** | | | | | | | |
| | A 1A | | COMPOSITE | A 1A | INITIAL | | |
| | A 1B | 930905 | GRAB | A 1B | 1R | 930905 | |
| | A 1C | 930907 | GRAB | A 1C | 2R | 930907 | |
| | A 2A | | COMPOSITE | A 2A | INITIAL | | |
| | A 2A | 930908 | STORED | A 2A | 1R | 930911 | 12:00 |
| | A 2A | " | STORED | A 2A | 2R | 930913 | 14:00 |
| | A 3A | | COMPOSITE | A 3A | INITIAL | | |
| | A 3A | 931013 | STORED | A 3A | 1R | 931017 | 07:25 |
| | A 3A | " | STORED | A 3A | 2R | 931019 | 15:00 |
| **Facility B** | | | | | | | |
| | B 1A | | COMPOSITE | B 1A | INITIAL | | |
| | B 1B | 930901 | GRAB | B 1B | 1R | 930901 | 10:30 |
| | B 1C | 930904 | GRAB | B 1C | 2R | 930904 | 08:30 |
| | B 2A | | COMPOSITE | B 2A | INITIAL | | |
| | B 2B | 930910 | GRAB | B 2B | 1R | 930910 | 08:45 |
| | B 2B | " | STORED | B 2B | 2R | 930912 | 15:00 |
| | B 3A | | COMPOSITE | B 3A | INITIAL | | |
| | B 3B | 930917 | GRAB | B 3B | 1R | 930917 | |
| | B 3B | " | STORED | B 3B | 2R | 930920 | |
| **Facility C** | | | | | | | |
| | C 1A | | COMPOSITE | C 1A | INITIAL | | |
| | C 1B | 930904 | GRAB | C 1B | 1R | 930904 | 09:30 |
| | C 1C | 930907 | GRAB | C 1C | 2R | 930907 | |
| | C 2A | | COMPOSITE | C 2A | INITIAL | | |
| | C 2A | 930910 | STORED | C 2A | 1R | 930915 | 03:30 |
| | C 2A | " | STORED | C 2A | 2R | 930917 | 13:30 |
| | C 3A | | COMPOSITE | C 3A | INITIAL | | |
| | C 3B | 931001 | GRAB | - | - | - | |
| | C 3B | " | STORED | C 3B | 1R | 931003 | 06:45 |
| | C 3B | " | STORED | C 3B | 2R | 931005 | 09:00 |
| | C 4A | | COMPOSITE | C 4A | INITIAL | | |
| | C 4B | 931022 | GRAB | - | - | - | |
| | C 4B | " | STORED | C 4B | 1R | 931023 | 04:30 |
| | C 4B | " | STORED | C 4B | 2R | 931025 | 11:30 |

H:\1362\01\ASLDATA\REFRESH.WB1

## FACILITY A RESULTS

| | A 1B 1R | A 1C 2R | A 2A 1R | A 2A 2R | A 3A 1R | A 3A 2R |
|---|---|---|---|---|---|---|
| Ammonia Nitrogen | 5.2 | 41.3 | 37.8 | 41.1 | 39.4 | 43.4 |
| COD | 1220 | 2480 | 722 | 655 | 1300 | 2620 |
| **Dissolved Metals** | | | | | | |
| Aluminum D-Al | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Antimony D-Sb | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Arsenic D-As | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Barium D-Ba | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Beryllium D-Be | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Bismuth D-Bi | 0.12 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Cadmium D-Cd | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Calcium D-Ca | 22.6 | 5.42 | 12.9 | 12.1 | 11.5 | 10.7 |
| Chromium D-Cr | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Cobalt D-Co | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Copper D-Cu | 0.022 | 0.012 | 0.01 | <0.010 | 0.041 | 0.016 |
| Iron D-Fe | 0.183 | 0.302 | 0.414 | 0.738 | 0.156 | 0.121 |
| Lead D-Pb | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 |
| Lithium D-Li | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Magnesium D-Mg | 48.9 | 2.66 | 23.2 | 22.3 | 21 | 19.6 |
| Manganese D-Mn | 0.006 | 0.008 | 0.024 | 0.033 | 0.012 | 0.013 |
| Molybdenum D-Mo | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Nickel D-Ni | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 |
| Phosphorus D-P | 10.5 | 20.9 | 11.2 | 11 | 27.1 | 17.7 |
| Potassium D-K | 33.7 | 39.8 | 23.5 | 22.6 | 41.6 | 39.8 |
| Selenium D-Se | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Silver D-Ag | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Sodium D-Na | 882 | 97.5 | 404 | 382 | 490 | 457 |
| Strontium D-Sr | 0.319 | 0.033 | 0.16 | 0.145 | 0.147 | 0.139 |
| Thallium D-Tl | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Tin D-Sn | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 |
| Titanium D-Ti | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Tungsten D-W | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Vanadium D-V | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Zinc D-Zn | 0.1 | 0.108 | 0.103 | 0.08 | 0.16 | 0.162 |

## FACILITY B RESULTS

| | B 1B 1R | B 1C 2R | B 2B 1R | B 2B 2R | B 3B 1R | B 3B 2R |
|---|---|---|---|---|---|---|
| Ammonia Nitrogen | 27.9 | 5.48 | 1.8 | 7.55 | 0.565 | 2.26 |
| COD | 1490 | 752 | 365 | 266 | <20 | 33 |
| Dissolved Metals | | | | | | |
| Aluminum D-Al | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Antimony D-Sb | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Arsenic D-As | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Barium D-Ba | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Beryllium D-Be | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Bismuth D-Bi | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Cadmium D-Cd | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Calcium D-Ca | 5.56 | 7.98 | 3.29 | 3.4 | 2.5 | 3.24 |
| Chromium D-Cr | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Cobalt D-Co | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Copper D-Cu | 0.015 | <0.010 | <0.010 | 0.011 | <0.010 | <0.010 |
| Iron D-Fe | 0.497 | 0.31 | 0.429 | 0.367 | 0.083 | 0.154 |
| Lead D-Pb | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 |
| Lithium D-Li | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Magnesium D-Mg | 3.2 | 7.22 | 1.08 | 0.978 | 0.232 | 0.339 |
| Manganese D-Mn | 0.01 | 0.012 | 0.011 | 0.006 | 0.011 | 0.011 |
| Molybdenum D-Mo | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Nickel D-Ni | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 |
| Phosphorus D-P | 15.8 | 7.98 | 5.14 | 4.45 | 0.68 | 1.17 |
| Potassium D-K | 40.1 | 24.4 | 11 | 11.6 | <2.0 | 2.9 |
| Selenium D-Se | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Silver D-Ag | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Sodium D-Na | 39.6 | 102 | 13.4 | 14 | 36.9 | 64.7 |
| Strontium D-Sr | 0.038 | 0.062 | 0.02 | 0.019 | 0.006 | 0.007 |
| Thallium D-Tl | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Tin D-Sn | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 |
| Titanium D-Ti | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Tungsten D-W | <0.10 | <0.10 | 0.31 | <0.10 | <0.10 | <0.10 |
| Vanadium D-V | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Zinc D-Zn | 0.098 | 0.075 | 0.016 | 0.023 | 0.159 | 0.269 |

## FACILITY C RESULTS

| | C 1B 1R | C 1C 2R | C 2A 1R | C 2A 2R | C 3B 1R | C 3B 2R | C 4B 1R | C 4B 2R |
|---|---|---|---|---|---|---|---|---|
| Ammonia Nitrogen | 3.06 | 2.14 | 25.4 | 22.7 | 1.02 | 2.42 | 1.04 | 1.15 |
| COD | 1580 | 1280 | 1660 | 1440 | 114 | 228 | 123 | 139 |
| **Dissolved Metals** | | | | | | | | |
| Aluminum D-Al | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Antimony D-Sb | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Arsenic D-As | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Barium D-Ba | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Beryllium D-Be | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Bismuth D-Bi | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Cadmium D-Cd | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Calcium D-Ca | 4.73 | 2.59 | 8.94 | 8.37 | 3.03 | 3.12 | 2.35 | 2.42 |
| Chromium D-Cr | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Cobalt D-Co | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Copper D-Cu | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Iron D-Fe | 0.037 | 0.036 | 0.083 | 0.115 | <0.030 | <0.030 | <0.030 | <0.030 |
| Lead D-Pb | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 |
| Lithium D-Li | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Magnesium D-Mg | 2.34 | 1.66 | 11.4 | 11.5 | 1.6 | 0.36 | 0.548 | 0.543 |
| Manganese D-Mn | <0.005 | <0.005 | 0.006 | 0.009 | <0.005 | <0.005 | <0.005 | <0.005 |
| Molybdenum D-Mo | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Nickel D-Ni | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 |
| Phosphorus D-P | 15.5 | 12.9 | 14.9 | 16.5 | 1.32 | 1.35 | 1.97 | 2 |
| Potassium D-K | 30 | 24.3 | 32.2 | 33.8 | 3.4 | 3.2 | 5.3 | 4.9 |
| Selenium D-Se | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Silver D-Ag | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Sodium D-Na | 51.4 | 23.7 | 550 | 574 | 16.7 | 5.9 | 18.8 | 17.3 |
| Strontium D-Sr | 0.022 | 0.01 | 0.088 | 0.084 | 0.005 | 0.006 | 0.011 | 0.011 |
| Thallium D-Tl | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Tin D-Sn | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 | <0.30 |
| Titanium D-Ti | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Tungsten D-W | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Vanadium D-V | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Zinc D-Zn | 0.073 | 0.024 | 0.055 | 0.055 | 0.022 | 0.021 | 0.019 | 0.013 |

# APPNEDIX D

## Contaminant Loadings

## CONTAMINANT LOADINGS

| Facility | Sampling Date | Loading [kg/1000 kg of fish] BOD | COD | TSS | NH4 | Water Consumption [m3/1000 kg of fish] | Sampling Agency | Sample Type |
|---|---|---|---|---|---|---|---|---|
| Bella Coola | Apr-90 | 8.5 | | 2.0 | | 49.7 | Bella Coola | C1 |
| | May-90 | 10.3 | | 3.4 | | 46.9 | Bella Coola | C1 |
| | Jul-90 | 9.9 | | 12.8 | | 33.6 | Bella Coola | C1 |
| | Sep-90 | 6.9 | | 4.4 | | 19.8 | Bella Coola | C1 |
| | Apr-91 | 6.3 | | 6.3 | | 22.6 | Bella Coola | C1 |
| | May-91 | 1.9 | | 1.9 | | 18.5 | Bella Coola | C1 |
| | Aug-91 | 69.2 | | 69.2 | | 326.4 | Bella Coola | C1 |
| | Sep-91 | 61.2 | | 61.2 | | 28.1 | Bella Coola | C1 |
| | Oct-91 | 4.2 | | 4.2 | | 30.4 | Bella Coola | C1 |
| | Oct-92 | 4.3 | | 4.8 | | 74.8 | Bella Coola | C1 |
| | Aug-93 | 2.6 | 5.9 | 1.9 | 0.10 | 3.5 | NovaTec | C2 |
| | Sep-93 | 1.3 | 4.0 | 1.0 | 0.02 | 5.6 | NovaTec | C2 |
| | Sep-93 | 0.7 | 3.1 | 0.6 | 0.04 | 2.9 | NovaTec | C2 |
| | min | 0.7 | 3.1 | 0.6 | 0.0 | 2.9 | | |
| | max | 69.2 | 5.9 | 69.2 | 0.1 | 326.4 | | |
| | avg | 14.4 | 4.3 | 13.4 | 0.1 | 51.0 | | |
| | geo. mean | 6.0 | 4.2 | 4.6 | 0.0 | 23.8 | | |
| BC Packers | Mar-90 | 1.3 | | 0.1 | | 1.4 | BC Packers | C3 |
| | Apr-90 | 1.3 | | 0.9 | | 1.4 | BC Packers | C3 |
| | May-90 | 1.8 | | 1.9 | | 5.6 | BC Packers | C3 |
| | Jun-90 | 0.5 | | 0.4 | | 5.6 | BC Packers | C3 |
| | Jul-90 | 3.0 | | 2.9 | | 4.2 | BC Packers | C3 |
| | Aug-90 | 5.5 | 5.6 | 5.0 | 0.02 | 6.4 | BC Packers | C3 |
| | Sep-90 | 0.1 | | 0.2 | | 2.7 | BC Packers | C3 |
| | Oct-90 | 3.5 | 4.5 | 2.1 | 0.04 | 2.7 | BC Packers | C3 |
| | Nov-90 | 0.3 | 0.5 | 0.2 | 0.00 | 1.8 | BC Packers | C3 |
| | Jan-91 | 20.5 | 29.1 | 15.2 | 0.35 | 210.1 | BC Packers | C3 |
| | Feb-91 | 18.6 | 19.2 | 7.5 | 0.41 | 120.5 | BC Packers | C3 |
| | Mar-91 | 7.2 | 7.2 | 1.7 | 0.11 | 4.8 | BC Packers | C3 |
| | Apr-91 | 16.6 | 16.6 | 5.4 | 0.10 | 16.5 | BC Packers | C3 |
| | May-91 | 23.6 | 23.5 | 2.5 | 0.11 | 15.7 | BC Packers | C3 |
| | Jun-91 | 66.3 | | 27.6 | 1.02 | 35.1 | BC Packers | C3 |
| | Jul-91 | 5.5 | | 0.9 | 0.04 | 26.9 | BC Packers | C3 |
| | Aug-91 | 2.1 | | 1.2 | 0.05 | 6.7 | BC Packers | C3 |
| | Sep-91 | 10.7 | | 2.2 | 0.29 | 25.2 | BC Packers | C3 |
| | Oct-91 | 7.8 | | 4.3 | 0.19 | 23.9 | BC Packers | C3 |
| | Mar-92 | 9.5 | | 2.3 | 9.51 | 15.8 | BC Packers | C3 |
| | Apr-92 | 30.4 | | 14.1 | 30.42 | 41.2 | BC Packers | C3 |
| | May-92 | 13.7 | | 5.4 | 13.72 | 26.6 | BC Packers | C3 |
| | Jun-92 | 5.3 | | 2.3 | 5.28 | 6.8 | BC Packers | C3 |
| | Jul-92 | 5.2 | | 2.4 | 5.16 | 14.3 | BC Packers | C3 |
| | Aug-92 | 22.4 | | 14.4 | 22.40 | 25.1 | BC Packers | C3 |
| | Sep-92 | 111.0 | | 48.0 | 110.97 | 297.5 | BC Packers | C3 |
| | Sep-93 | 31.8 | 41.0 | 14.7 | 0.80 | 11.9 | NovaTec | C2 |
| | Sep-93 | 51.9 | 121.1 | 50.8 | 3.80 | 105.3 | NovaTec | C2 |
| | Oct-93 | 210.0 | 552.7 | 166.7 | 8.90 | 228.4 | NovaTec | C2 |
| | min | 0.1 | 0.5 | 0.1 | 0.0 | 1.4 | | |
| | max | 210.0 | 552.7 | 166.7 | 111.0 | 297.5 | | |
| | avg | 23.7 | 74.6 | 13.9 | 9.3 | 44.5 | | |
| | geo.mean | 7.3 | 17.7 | 3.4 | 0.7 | 14.8 | | |

## CONTAMINANT LOADINGS (cont'd)

| Facility | Sampling Date | Loading [kg/1000 kg of fish] BOD | COD | TSS | NH4 | Water Consumption [m3/1000 kg of fish] | Sampling Agency | Sample Type |
|---|---|---|---|---|---|---|---|---|
| Lion's Gate | Mar-90 | 1.5 | | 0.7 | | 5.7 | Lions Gate | G |
| | Apr-90 | 7.6 | | 1.2 | | 7.8 | Lions Gate | G |
| | May-90 | 1.8 | | 0.8 | | 7.4 | Lions Gate | G |
| | Apr-91 | 2.1 | | 1.3 | | 14.3 | Lions Gate | G |
| | Aug-91 | 12.6 | | 2.7 | | 31.5 | Lions Gate | G |
| | Oct-91 | 0.6 | | 0.5 | | 14.1 | Lions Gate | G |
| | Nov-91 | 5.2 | 2.8 | 1.6 | | 7.2 | Lions Gate | G |
| | Apr-92 | 9.8 | 12.6 | 3.4 | | 10.1 | Lions Gate | G |
| | May-92 | 27.6 | 39.1 | 10.4 | | 37.1 | Lions Gate | G |
| | Jun-92 | 4.4 | 5.5 | 1.8 | | 20.2 | Lions Gate | G |
| | Sep-92 | 12.1 | 25.2 | 5.3 | | 10.6 | Lions Gate | G |
| | Aug-93 | 1.9 | 3.9 | 1.1 | 0.06 | 10.8 | NovaTec | C2 |
| | Sep-93 | 1.9 | 4.6 | 1.1 | 0.30 | 14.6 | NovaTec | C2 |
| | Sep-93 | 9.5 | 16.2 | 5.0 | 0.51 | 14.3 | NovaTec | C2 |
| | min | 0.6 | 2.8 | 0.5 | 0.1 | 5.7 | | |
| | max | 27.6 | 39.1 | 10.4 | 0.5 | 37.1 | | |
| | avg | 7.0 | 13.7 | 2.6 | 0.3 | 14.7 | | |
| | geo.mean | 7.0 | 9.3 | 1.8 | 0.2 | 12.7 | | |
| Ocean | Sep-93 | 39.7 | 43.7 | 17.8 | 0.74 | 19.1 | NovaTec | C2 |
| | Sep-93 | 8.6 | 23.0 | 8.3 | 0.26 | 15.3 | NovaTec | C2 |
| | Sep-93 | 5.8 | 11.7 | 3.9 | 0.03 | 36.4 | NovaTec | C2 |
| | Oct-93 | 8.5 | 12.7 | 1.5 | 0.04 | 37.0 | NovaTec | C2 |
| | min | 5.8 | 11.7 | 1.5 | 0.0 | 15.3 | | |
| | max | 39.7 | 43.7 | 17.8 | 0.7 | 37.0 | | |
| | avg | 15.7 | 22.8 | 7.9 | 0.3 | 27.0 | | |
| | geo.mean | 11.4 | 19.7 | 5.4 | 0.1 | 25.0 | | |
| Hokkai Marine | Aug-92 | 1.5 | 45.0 | 9.8 | | 15.0 | Hokkai M. | C4 |
| | Sep-92 | 1.4 | 29.2 | 7.7 | | 13.3 | Hokkai M. | C4 |
| | Oct-92 | 1.6 | 27.4 | 6.8 | | 12.7 | Hokkai M. | C4 |
| | Apr-93 | 2.7 | 3.9 | 0.9 | | 6.7 | Hokkai M. | C4 |
| | May-93 | 0.2 | 0.3 | 0.0 | | 7.8 | Hokkai M. | C4 |
| | Jul-93 | 70.0 | 90.6 | 23.6 | | 137.4 | Hokkai M. | C4 |
| | Aug-93 | 3.4 | 6.6 | 1.9 | | 7.7 | Hokkai M. | C4 |
| | Sep-93 | 7.8 | 16.4 | 4.4 | | 21.9 | Hokkai M. | C4 |
| | min | 0.2 | 0.3 | 0.0 | | 6.7 | | |
| | max | 70.0 | 90.6 | 23.6 | | 137.4 | | |
| | avg | 11.1 | 27.4 | 6.9 | | 27.8 | | |
| | geo.mean | 2.8 | 11.9 | 2.6 | | 15.3 | | |

## CONTAMINANT LOADINGS (cont'd)

| Facility | Sampling Date | Loading [kg/1000 kg of fish] BOD | COD | TSS | NH4 | Water Consumption [m3/1000 kg of fish] | Sampling Agency | Sample Type |
|---|---|---|---|---|---|---|---|---|
| Billingsgate | Dec-91 | 2.1 | 1.1 | 0.4 | | 11.9 | Billingsgate | C5 |
| | May-92 | 7.6 | 18.3 | 3.9 | | 13.7 | Billingsgate | C5 |
| | Jun-92 | 6.1 | 11.3 | 2.8 | | 9.7 | Billingsgate | C5 |
| | Jul-92 | 3.4 | 4.5 | 1.2 | | 11.5 | Billingsgate | C5 |
| | Aug-92 | 0.7 | 0.8 | 0.3 | | 10.5 | Billingsgate | C5 |
| | Sep-92 | 1.9 | 2.5 | | | 35.3 | Billingsgate | C5 |
| | Oct-92 | 18.7 | 24.6 | 4.0 | | 32.2 | Billingsgate | C5 |
| | Nov-92 | 12.9 | 24.8 | 1.9 | | 108.0 | Billingsgate | C5 |
| | Dec-92 | 5.6 | 9.4 | 4.1 | | 26.2 | Billingsgate | C5 |
| | Feb-93 | 9.6 | 8.8 | 0.7 | | 11.9 | Billingsgate | C5 |
| | Mar-93 | 1.1 | 1.6 | 0.3 | | 10.0 | Billingsgate | C5 |
| | Apr-93 | 0.5 | 0.6 | 0.5 | | 8.3 | Billingsgate | C5 |
| | May-93 | 0.1 | | 0.0 | | 4.4 | Billingsgate | C5 |
| | Jun-93 | 1.8 | 2.4 | 0.6 | | 4.9 | Billingsgate | C5 |
| | Jul-93 | 0.4 | 0.5 | 0.2 | | 4.2 | Billingsgate | C5 |
| | Aug-93 | 0.3 | 0.5 | 0.3 | | 4.0 | Billingsgate | C5 |
| | Sep-93 | 1.8 | 2.3 | 1.2 | | 6.8 | Billingsgate | C5 |
| | min | 0.1 | 0.5 | 0.0 | | 4.0 | | |
| | max | 18.7 | 24.8 | 4.1 | | 108.0 | | |
| | avg | 4.4 | 7.1 | 1.4 | | 18.4 | | |
| | geo.mean | 2.0 | 3.2 | 0.7 | | 11.7 | | |
| Great Northern | Sep-92 | 27.5 | 31.2 | 24.6 | | 17.7 | Great N. | C1 |
| | Oct-92 | 7.6 | 8.6 | 1.8 | | 3.6 | Great N. | C1 |
| | Nov-92 | 9.3 | 9.6 | 1.2 | | 17.2 | Great N. | C1 |
| | Jan-93 | 1831.1 | 2038.7 | 1415.9 | | 1064.6 | Great N. | C1 |
| | Feb-93 | 349.8 | 728.7 | 215.7 | | 1457.3 | Great N. | C1 |
| | Mar-93 | 187.6 | 2575.7 | 146.0 | | 1014.1 | Great N. | C1 |
| | Apr-93 | 242.2 | 329.9 | 160.8 | | 378.4 | Great N. | C1 |
| | May-93 | 106.1 | 288.6 | 18.7 | | 169.7 | Great N. | C1 |
| | Jun-93 | 21.6 | 51.8 | 9.3 | | 89.0 | Great N. | C1 |
| | Jul-93 | 49.5 | 62.7 | 36.9 | | 46.8 | Great N. | C1 |
| | Aug-93 | 94.2 | 95.3 | 51.0 | | 53.5 | Great N. | C1 |
| | Sep-93 | 60.4 | 150.4 | 50.2 | | 72.0 | Great N. | C1 |
| | min | 7.6 | 8.6 | 1.2 | | 3.6 | | |
| | max | 1831.1 | 2575.7 | 1415.9 | | 1457.3 | | |
| | avg | 248.9 | 530.9 | 177.7 | | 365.3 | | |
| | geo.mean | 75.9 | 137.0 | 36.8 | | 104.9 | | |

## CONTAMINANT LOADINGS (cont'd)

| Facility | Sampling Date | Loading [kg/1000 kg of fish] BOD | COD | TSS | NH4 | Water Consumption [m3/1000 kg of fish] | Sampling Agency | Sample Type |
|---|---|---|---|---|---|---|---|---|
| Orca | Jan-92 | 3.1 | 3.7 | 0.4 | | 5.6 | Orca | C1 |
| | Feb-92 | 1.3 | 1.6 | 0.3 | | 5.4 | Orca | C1 |
| | Mar-92 | 1.0 | 0.7 | 0.3 | | 2.3 | Orca | C1 |
| | Apr-92 | 6.1 | 4.6 | 1.9 | | 8.3 | Orca | C1 |
| | May-92 | 3.6 | 4.9 | 1.4 | | 8.3 | Orca | C1 |
| | Jun-92 | 5.9 | 8.8 | 2.2 | | 10.3 | Orca | C1 |
| | Jul-92 | 6.9 | 14.0 | 2.2 | | 11.5 | Orca | C1 |
| | Sep-92 | 8.6 | 11.6 | 1.9 | | 24.3 | Orca | C1 |
| | Oct-92 | 6.2 | 8.2 | 1.9 | | 20.1 | Orca | C1 |
| | Nov-92 | 10.0 | 21.0 | 6.2 | | 21.3 | Orca | C1 |
| | Dec-92 | 22.6 | 28.3 | 3.1 | | 35.9 | Orca | C1 |
| | Jan-93 | 2.2 | 2.2 | 0.9 | | 13.2 | Orca | C1 |
| | Feb-93 | 0.9 | 1.5 | 0.6 | | 19.6 | Orca | C1 |
| | Mar-93 | 6.0 | 7.3 | 3.2 | | 17.7 | Orca | C1 |
| | Apr-93 | 1.3 | 1.5 | 0.2 | | 6.0 | Orca | C1 |
| | May-93 | 3.1 | 0.9 | 0.6 | | 4.8 | Orca | C1 |
| | Jun-93 | 1.5 | 2.2 | 0.7 | | 6.4 | Orca | C1 |
| | Jul-93 | 3.2 | 5.2 | 0.9 | | 7.0 | Orca | C1 |
| | Aug-93 | 1.8 | 2.5 | 0.7 | | 6.5 | Orca | C1 |
| | Sep-93 | 2.2 | 2.7 | 1.1 | | 13.0 | Orca | C1 |
| | min | 0.9 | 0.7 | 0.2 | | 2.3 | | |
| | max | 22.6 | 28.3 | 6.2 | | 35.9 | | |
| | avg | 4.9 | 6.7 | 1.5 | | 12.4 | | |
| | geo.mean | 3.4 | 4.1 | 1.1 | | 10.0 | | |
| Scanner | Apr-92 | 25.1 | 25.7 | 5.0 | | 2.1 | Scanner | C1 |
| | May-92 | 72.8 | 163.5 | 35.7 | | 4.2 | Scanner | C1 |
| | Jun-92 | 245.2 | 271.9 | 59.3 | | 3.5 | Scanner | C1 |
| | Jul-92 | 0.3 | 1.6 | 0.2 | | 12.2 | Scanner | C1 |
| | Aug-92 | 0.3 | 0.3 | 0.1 | | 3.7 | Scanner | C1 |
| | Sep-92 | 9.4 | 7.1 | 2.2 | | 1.3 | Scanner | C1 |
| | Oct-92 | 0.1 | 0.2 | 0.1 | | 7.3 | Scanner | C1 |
| | Jan-93 | 75.2 | 88.0 | 45.4 | | 311.0 | Scanner | C1 |
| | Mar-93 | 0.2 | 0.7 | 0.1 | | 0.4 | Scanner | C1 |
| | Apr-93 | 0.9 | 1.3 | 0.6 | | 1.4 | Scanner | C1 |
| | May-93 | 0.9 | 1.8 | 1.4 | | 4.8 | Scanner | C1 |
| | Jun-93 | 5.6 | 6.9 | 1.4 | | 7.0 | Scanner | C1 |
| | Jul-93 | 0.4 | 0.5 | 1.4 | | 2.3 | Scanner | C1 |
| | Aug-93 | 1.9 | 0.8 | 1.1 | | 1.2 | Scanner | C1 |
| | min | 0.1 | 0.2 | 0.1 | | 0.4 | | |
| | max | 245.2 | 271.9 | 59.3 | | 311.0 | | |
| | avg | 31.3 | 40.7 | 11.0 | | 25.9 | | |
| | geo.mean | 2.8 | 4.0 | 1.5 | | 3.9 | | |
| Seven Seas | Apr-92 | 0.4 | 0.4 | 0.1 | | 2.4 | Seven Seas | C4 |
| | Aug-92 | 13.5 | 12.8 | 4.1 | | 13.4 | Seven Seas | C4 |
| | Sep-92 | 6.6 | 3.4 | 1.9 | | 11.9 | Seven Seas | C4 |
| | Jan-93 | 16.4 | 21.9 | 8.0 | | 72.7 | Seven Seas | C4 |
| | Feb-93 | 14.3 | 13.1 | 1.8 | | 26.5 | Seven Seas | C4 |
| | Mar-93 | 26.7 | 63.2 | 23.8 | | 162.6 | Seven Seas | C4 |
| | min | 0.4 | 0.4 | 0.1 | | 2.4 | | |
| | max | 26.7 | 63.2 | 23.8 | | 162.6 | | |
| | avg | 13.0 | 19.1 | 6.6 | | 48.3 | | |
| | geo.mean | 7.8 | 8.3 | 2.5 | | 22.2 | | |

## CONTAMINANT LOADINGS (cont'd)

| Facility | Sampling Date | Loading [kg/1000 kg of fish] BOD | COD | TSS | NH4 | Water Consumption [m3/1000 kg of fish] | Sampling Agency | Sample Type |
|---|---|---|---|---|---|---|---|---|
| Sealand | Feb-93 | 11.8 | 26.0 | 9.8 | | 59.0 | Sealand | C1 |
| | Mar-93 | 9.4 | 10.3 | 5.4 | | 62.5 | Sealand | C1 |
| | Apr-93 | 0.7 | 7.2 | 1.0 | | 30.1 | Sealand | C1 |
| | May-93 | 15.2 | 50.8 | 21.8 | | 37.9 | Sealand | C1 |
| | Jun-93 | 6.2 | 8.5 | 5.0 | | 77.6 | Sealand | C1 |
| | min | 0.7 | 7.2 | 1.0 | | 30.1 | | |
| | max | 15.2 | 50.8 | 21.8 | | 77.6 | | |
| | avg | 8.7 | 20.6 | 8.6 | | 53.4 | | |
| | geo.mean | 5.9 | 15.3 | 5.7 | | 50.4 | | |
| **Average** | | **33.7** | **78.5** | **21.8** | **6.5** | **93.2** | | |
| **Std.** | | **156.9** | **319.5** | **120.1** | **19.7** | **249.1** | | |
| **Geo. Mean** | | **5.5** | **9.2** | **2.7** | **0.4** | **19.9** | | |

Note:
C1 - 8 grabs in composite
C2 - Composite during the working shift
C3 - Composite consists of grabs taken every 2 hr over the processing time
C4 - 3 grabs in composite
C5 - 6 grabs in composite
G - Grab sample

# APPENDIX E

## QA/QC Protocols

## EVS CONSULTANTS LABORATORY QA/QC PROGRAM

EVS Consultants is a leader in developing Quality Assurance/Quality Control (QA/QC) programs for environmental toxicology. The Washington State Department of Ecology implemented a laboratory accreditation program to ensure that high standards of QA/QC are maintained for biological and analytical testing. The EVS Consultants bioassay laboratory is currently certified under this program.

For all our environmental monitoring studies, EVS Consultants has developed a rigorous in-house QA/QC program. A thorough and effective Quality Assurance Program is the principal means of maintaining the accuracy and precision of field and laboratory analyses to assure scientific credibility. Our comprehensive QA/QC Program ensures complete documentation and also standardizes and minimizes possible errors in computation and reporting of results. The details of our QA/QC Program are documented in our Laboratory QA/QC Manual, a copy of which is on file with the Washington Department of Ecology Quality Assurance Section. The Manual describes all aspects of our program, including such topics as corporate structure, facilities and equipment, development of Study Plans, instrument calibration, documentation, test procedures, criteria for test acceptability and data management.

All final data packages are reviewed by a member of our QA/QC committee. The following general QA/QC guidelines apply to all toxicity tests.

**Negative Controls** - All tests are conducted using well-established negative (clean) controls. For every toxicity test, one series of test chambers must contain clean diluent water (or clean diluent water and clean sediment) only. The complete test series is repeated if the mean control response does not meet the acceptability criteria for a particular test.

**Positive Controls (Reference Toxicants)** - All toxicity tests include positive (toxic) controls, conducted with well-established standard reference toxicants. For organisms obtained from outside sources, a positive control is tested for each new batch obtained. For organisms obtained from in-house laboratory cultures, positive controls are performed on a monthly basis. The cumulative mean value (re-calculated with successive data points until the results are stable) and upper and lower control limits (mean ± 2SD) are determined. The QA/QC Officer is responsible for monitoring the data for trends in increasing or decreasing sensitivity. If the results of a reference toxicant test fall outside the control chart limits, the test procedures and health/source of the test organisms are reviewed; subject to those findings, the test may be repeated.

**Test Organisms** - Only healthy organisms of similar size and life history stage are used for toxicity tests. All test organisms used for a batch of tests must be from the same source. Records of collection, shipping and holding are maintained for all species obtained outside of the laboratory.

**Replication** - The number of replicates required varies from one test protocol to another, but should always be sufficient to account for variability in test organism response. Unless otherwise specified in the experimental design, each treatment in a test series must begin with the same number of replicates.

**Instrument Calibration** - Calibration of instruments is required to ensure that accurate measurements are made throughout a test and to ensure the equipment is operating correctly. Each water quality instrument (dissolved oxygen, pH and conductivity meters, refractometers) or balance must be calibrated at the start of each day (and any time the environmental conditions are changed). Each piece of equipment has a logbook for daily recording of calibration information, repairs, replacement, etc. Each instrument is calibrated according to the manufacturer's instructions.

**Water Quality Measurement/Maintenance** - Toxicity tests involving exposure of organisms in aqueous media require that the media be uncontaminated and that proper water quality conditions be maintained to ensure the survival of the organisms, and to ensure that undue stress is not exerted on the organisms, unrelated to the test materials. Appropriate water quality parameters must be measured at the start and end of a test as a minimum, and preferably every 24 h. If acceptable limits are exceeded at any time, the data are reviewed by the Project Manager and QA/QC Officer and the latter will recommend appropriate action.

**Standard Laboratory Procedures** - Standard laboratory procedures are followed in all testing. These include use of established methods, proper documentation, proper cleaning, avoidance of contamination and maintenance of appropriate test conditions. All unusual observations or deviations from established procedures must be recorded and reported.

## BC RESEARCH QA/QC PROGRAM

The basic QA/QC procedures used in all biological tests performed in this laboratory are outlined below:

**Equipment Maintenance and Calibration** - Instrument sensitivity is checked with a known standard to ensure that a normal response is obtained. Instrument maintenance records, routine and repairs are kept on file.

**Facilities** - The algal growth test is conducted in a growth chamber where temperature and lighting can be controlled and monitored continuously. The growth chamber used is dedicated only to *Selenastrum capricornutum* tests and meets specifications outlined in the EPS protocol in algal growth inhibition studies.

**SOP Manuals** - SOP manuals are maintained for all biological tests conducted. The SOP used in this test is based on the EPS Biological Test Method: Growth Inhibition Test Using the Freshwater Alga *Selenastrum capricornutum* Report EPS 1/ RM/ 25 November 1992.

**Test Organisms** - A new starter culture of *Selenastrum capricornutum* was used in this study. Culture was regularly observed under the microscope to ensure purity of the algae.

**Conducting the Test** - At least three replicates and in most cases five replicates of each concentration of the sample is run in each test. A quality control plate is run concurrently with each sample run. A standard reagent control on each sample microplate is run and compared to the quality control microplate to determine any problems with volatility or with experimental procedures. A reference toxicant, reagent grade zinc sulphate, is used to assess the sensitivity of the algae and the precision of data produced. The dilution water used is the same as that used in the controls. Reference toxicant values are compared to values obtained at Environment Canada in Quebec to assess validity of results since we have not yet obtained reference toxicant values to prepare a standard warning chart for our lab use.

**Good Laboratory Practice** - Good laboratory practice is a method to ensure that studies are planned, conducted, supervised, recorded and reported are accurate and appropriate. B.C.

Research Inc. maintains instrument calibration and maintenance logbooks, organism culture logbooks, reference toxicant test logbooks, sample receipt logbooks, control/culture water analytical records and Standard Operating Procedures for all test conducted at out facility. All sample, reagents, solutions, and specimens are labelled properly. Raw data and study reports are archived for at least five years. A study director creates the study protocol and ensures compliance with GLP.

## ASL QA/QC PROGRAM

The U.S. EPA defines Quality Assurance (QA) as "the total program for assuring the reliability of monitoring data". Quality Control (QC) is defined as "the routine application of procedures for controlling the measurement process". QC is primarily concerned with the tools of the measurement system. Reagents used are of the highest quality and are checked for purity, strength, deterioration with time, and contamination. Class A volumetric glassware is thoroughly cleaned and calibrated when necessary. Balances are frequently checked with certified weights and record kept. All instruments are calibrated on a routine basis, with the maintenance of appropriate standards and operation logs on performance.

The QA program includes the analysis of quality assurance samples to define the precision and accuracy of the method for the type of sample under investigation. For trace analyses, the following quality assurance samples are commonly employed:

<u>Method Blank</u> - usually distilled water with added reagents, which is carried through the entire analysis as a check on laboratory contamination (also called a reagent blank).

<u>Duplicate</u> - a homogenous sample is split either in the field or in the laboratory with the duplicate presented to the analyst as an additional sample to check for precision. If more than two splits are analyzed the term replicate is normally used.

<u>Check Standard</u> - a procedure is standardized with calibration standards prior to analyzing the samples. The analytical response to the standards should be checked by frequently analyzing one or more standards along with the samples. The check standards should be prepared independently of the calibration standards.

<u>Surrogate Compounds</u> - are used when gas chromatography/mass spectrometry procedures are employed. The surrogate standards are deuterium labelled compounds that are added to the samples prior to the extraction. They can be quantified independently of the authentic compounds. In this way quality assurance is provided for each sample.

Spike - a known amount of analyte is added to a sample to provide information on matrix effects and apparent accuracy. Internal Standards are also used in this manner.

Standard Reference Material - a material that contains a known concentration of the analyte in question. Based upon reliable documentation of the analyte concentration, a reference material is certified by agencies such as the National Bureau of Standards and the National Research Council.

ASL believes that a good quality assurance program is imperative in production data of known and acceptable quality. Without a through and consistent QA program the data cannot be considered complete. The use of such quality assurance samples for a "typical" project involving 20 samples is outlined below.

| | |
|---|---|
| 20 | Samples |
| 4 | Duplicate |
| 3 | Standard Reference Material (or Spike in not available) |
| 4 | Method Blanks |

The quality control proposed above is very expensive. The information generated allows the determination of precision, accuracy and contamination control for all measurements. All data is normally presented along with sample results in the final reports.

Additional quality assurance measures include the supply and use of sample submission forms so pertinent field information is transferred to the laboratory. In addition a representative from ASL will often visit a test site to initially set up and ensure appropriate handling and storage of samples prior to pick up. If deemed appropriate, transportation blanks are supplied for handling in the field to ensure that field contamination is not an issue.

Also important is the participation by ASL in numerous inter-laboratory programs organized by agencies such as Environment Canada, U.S. Environmental Protection Agency, B.C. Ministry of Environment and the National Research Council of Canada. ASL is officially registered with the B.C. Ministry of Environment and is a member of CAEL (Canadian Association of Environmental