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Fraser River Action Plan

FRASER RIVER

FREMP Estuary Management Program

EFFLUENT CHARACTERIZATION STUDY

TECHNICAL REPORT SERIES
FREMP WQWM-93-05
DOE FRAP 1993-13

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

February 1994

EFFLUENT CHARACTERIZATION STUDY

Volume 1: Report

for

FRASER RIVER ESTUARY MANAGEMENT PROGRAM
New Westminster, BC

by

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October, 1993

Report No.: F07201RP.J11

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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 coordination of monitoring of the environmental quality of the Fraser River Estuary. In this role, Technology Resource Inc. (TRI) was contracted to characterize the effluent from eleven industrial sites. McLeay Associates Ltd. (McLeay) co-ordinated the aquatic toxicity and fish bio-uptake tests. Chemical analysis was provided by Analytical Services Ltd. (ASL) and biological tests were performed by BC Research.

This project was co-ordinated by Eric McGreer of FREMP. Scientific authorities were 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 expresses 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 industries: Lafarge Canada Inc., Scott Paper Ltd., International Forest Products (IFP) Ltd. Fraser Mills, Fraser Wharves Ltd., MacMillan Bloedel (MB) Ltd. New Westminster, IFP Ltd. Hammond Cedar, Tree Island Industries, Domtar Inc. (Coquitlam), Tilbury Cement Ltd., Hilinex Packaging Inc. and Westshore Terminals Ltd.

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EXECUTIVE SUMMARY

The purpose of this study was to undertake an initial characterization of effluent discharges at 11 industrial site within the Fraser River Estuary. The discharges were sampled for general parameters such as pH and suspended solids, chemical contaminants, acute and chronic toxicity, and bioavailability. This study represents one in a series being carried out under the Water Quality Plan of the Fraser River Estuary Management Program (FREMP) on behalf of its member agencies.

The following industries participated in this study:

Lafarge Canada Inc.	IFP Hammond Cedar
Scott Paper Ltd.	Tree Island Industries
International Forest Products Ltd. (IFP) Fraser Mills	Domtar Inc. (Coquitlam)[1]
	Tilbury Cement Ltd.
Fraser Wharves Ltd.	Hilinex Packaging
MacMillan Bloedel (MB) Ltd. New Westminster	Westshore Terminals Ltd.

Operational assessments showed that all but one of the discharges to the Fraser River were under permit by the BC Ministry of Environment, Lands and Parks (BCELP). The exception was at Tilbury Cement where a discharge to a ditch draining to the Fraser River was noted, which is not described on the BCELP permit. Scott Paper, Fraser Wharves and Hilinex have made changes to their discharges which are not reflected in their current permits. Scott Paper no longer discharge effluent from their groundwood mill to the Fraser River. This discharge is connected to the GVS&DD sewer. Fraser Wharves no longer discharge to the Fraser because they no longer operate a vehicle de-waxing facility. They retain their permit in the event that waxed cars are again imported and the facility might be needed. Hilinex are connected to the GVS&DD storm sewer and do not discharge directly into the Fraser River. Hilinex have applied for an amendment to their permit to reflect their current operation.

Samples of effluent were collected on three days at each of 17 discharge locations at the 10 industrial sites. There is no discharge from Fraser Wharves. All of these samples were analyzed for a wide range of chemical and parameters. One discharge per site was designated as a primary effluent sample.

The acute toxicity of the ten primary effluents was measured using both water fleas (*Daphnia magna*) and rainbow trout (*Oncorhynchus mykiss*). These samples were also tested for effects on

[1]now Stella-Jones Inc.

reproduction and survival of the daphnid *Ceriodaphnia dubia*. Eight-day tests to measure muscle bio-uptake of heavy metals, polycyclic aromatic hydrocarbons and chlorinated phenolic compounds were performed.

The results of the chemical analyses indicated that the effluents were, in general, in compliance with their permitted discharge limits; however some excursions were noted. All three boiler blowdown samples collected at IFP Hammond had a pH of greater than 9 (versus a permitted maximum of 8.5). One sample of the septic discharge at Westshore had a total suspended solids concentration of 194 mg/L, which was above the permitted 130 mg/L.

Polycyclic aromatic hydrocarbons (PAHs) were detected in only a few samples. The two discharges at MacMillan Bloedel showed slightly higher PAH concentrations than noted in the other effluents. Resin acids were only detected at Scott Paper. In all effluents tested, dioxins, furans, chlorinated phenolics and anti-sapstain chemicals were either not detected or were found at very low concentrations. Total phenols were detected in virtually all samples, including dechlorinated Vancouver City water. This result leads to the conclusion that trace concentrations of phenols are likely present in the water supply.

Six of the ten effluent samples tests were shown to be acutely toxic in tests with *Daphnia magna*. Results for the acute lethal tests with *Daphnia magna* showed that primary effluent samples from Scott Paper, IFP Hammond, Tree Island Industries and Domtar were not acutely toxic. One or more of the three samples of primary effluent discharged by Lafarge, MB New Westminster and Westshore Terminals were also non-toxic; LC50s for the toxic samples of these effluents ranged from 7% to 71%. The samples of primary effluent discharged by IFP Fraser Mills, Hilinex Packaging, and Tilbury Cement showed LC50s ranging from 35% to 71%.

Only two samples, one each from IFP Fraser Mills and Hilinex Packaging were acutely lethal in tests with rainbow trout. The remaining 8 effluent sources were shown to be non-toxic to rainbow trout. For IFP Fraser Mills and Hilinex Packaging, one of the two samples from each source was non-toxic, and the other was only slightly toxic with LC50s of 80 and 88%, respectively.

Each of the ten primary effluents proved to be toxic to *Ceriodaphnia dubia* in the chronic assays which tested for effects on daphnid survival and reproduction. Inhibiting concentrations (IC25s) ranged from 1% to 80% effluent concentration. Effluents discharged by Westshore Terminals, IFP Hammond and Domtar were the most toxic in this test, with IC25s of 1% or 2%.

The acute and chronic toxicity data were appraised with respect to the chemical analyses for the same samples, current provincial water quality criteria for the protection of sensitive freshwater life, and the literature on lethal and sublethal toxic effects of each chemical on sensitive species of salmonid fish or freshwater invertebrates. Chemical constituents in the samples of each primary effluent were identified which, alone or together, were present at concentrations that could account for the toxic effects observed. Depending on sample type and source, these included copper, zinc, iron, manganese, aluminum, resin and fatty acids, total suspended solids, and specific PAHs. The pH of one effluent source was adverse to sensitive freshwater life. Brackish river water used as process water by two industries which likely contributed to the toxic effects noted for two of the ten primary effluents studied. Limits of detection for some heavy metals, chlorinated phenolics and resin and fatty acids were higher than concentrations shown to be toxic to aquatic species. Future studies which are designed specifically to identify the causes of the observed toxicity should ensure that analytical detection limits are employed which are significantly lower than concentrations known to be toxic. Determination of the causes of the chronic, sublethal toxicity observed was outside the scope of this initial study.

As part of this study, concurrent acute and chronic toxicity tests were performed with *Daphnia magna* and *Ceriodaphnia dubia* to assess the tolerance of these species to varying water hardness. These results indicated that soft water was not stressful to the test organisms, and water hardness *per se* was not responsible for the toxic effects observed. A separate series of acute and chronic "QA/QC" toxicity tests with these two daphnid species confirmed that no biologically-significant concentrations of plasticizers were leached from the plastic containers used to transport and store the effluent samples.

Bio-uptake tests to assess bioavailability of heavy metals, chlorinated phenolics and PAHs in muscle tissue of juvenile rainbow trout were conducted using a procedure standardized for this study. This procedure included the use of 800-L volumes of effluent, a fish-loading density of ~2 L/g fish, and transfer of exposed fish to fresh samples after four days. Concentrations of specific heavy metals, chlorinated phenolics and PAHs were elevated in the muscle tissue of effluent-exposed fish relative to corresponding values for groups of control fish. Nickel and chromium concentrations in muscle tissue of fish held in samples of Lafarge's effluent were elevated relative to control values. Certain PAHs (fluorene, naphthalene and phenanthrene) showed evidence of bioconcentration in muscle tissue of fish held in papermill effluent samples from Scott Paper. Bioconcentration of one or more of the chlorinated phenolics 2,4,6-3CP, 2,3,4,6-4CP, 5CP, 3,4,5-3CG, and 4CG occurred in the muscle tissue of fish held in primary effluents from Scott Paper, IFP Hammond, MB New Westminster and Domtar. All other tissue analyses were unremarkable.

For all primary effluents studied, the extent of accumulation of contaminants in fish muscle tissue was only at trace amounts or was non-detectable. Provincial water quality objectives (Swain & Holms, 1985) for maximum recommended concentrations of total or specific chlorophenolics in edible (muscle) tissue of fish in fresh water were not exceeded in any instance, and detected quantities were appreciably lower than the recommended maxima. The detection limit for benzo(a)pyrene in muscle tissue achieved in this study was inadequate to confirm that the provincial recommended maximum concentrations of this PAH was not exceeded.

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1.0 INTRODUCTION

1.1 Scope of Work

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 FREMP is the coordination of monitoring of the environmental quality of the Fraser River Estuary.
The present project is part of a three year monitoring cycle to generate environmental trend data for the Fraser River Estuary. The study includes three components of effluent characterization: chemistry, toxicity and bio-uptake, in addition to assessments of the operations at the 11 participating industries.

An operational assessment of each operation was made, including a description of the process, permitted discharges, effluent treatment works, and potential fugitive discharges. In addition, an inventory of historical information was made. At the time of the operational assessment, discharge locations were verified and sample collection points confirmed.

Some of the sites have more than one permitted discharge. Samples were collected at 17 different discharges to the Fraser River. It is important to note that many of the subject industries discharge their process water to the GVS&DD sewer and that many of the discharges to the Fraser River are non-contact cooling water. Fraser Wharves no longer discharges to the Fraser River; therefore, no effluent samples were collected at this site.

Three samples (one on Monday, one on Wednesday and one on Friday of a given week) were collected at each of the 17 discharge locations. All samples were submitted for chemical analysis, as appropriate. One discharge location at each industry (for a total of 10) was chosen as the primary effluent sample. Primary effluent samples were tested for acute and chronic toxicity, and subjected to an 8-day bio-uptake experiment.

Results are presented in summary form in the body of this report. All analytical data and other Appendices are presented in a companion volume.

1.2 FREMP Water Quality Plan

A major component of the Fraser River Estuary Management Program is the Water Quality Plan. The Water Quality Plan is a coordinated monitoring program designed to operate on a three-year cycle with specific schedules for the monitoring of effluent, water, sediments, invertebrates, and fish. The three-year monitoring cycle will generate environmental trend data on the fate and effects of contaminants in the Estuary, and will permit assessment of the relative degree of contamination of receiving waters and biota.

The effluent characterization component in Year One (1992/93) will be used as a basis for establishing priorities for the subsequent monitoring of contaminants and toxicity in water, sediments and biota, and to recommend priorities for pollution abatement. The number and location of sampling sites, species of biota, contaminants to be analyzed, number of replicates and quality assurance/quality control procedures within each program are carefully selected to provide the optimum level of information required to adequately assess the quality of the environment.

The present project represents the effluent characterization component carried out under Year One of the Water Quality Plan. Funding to carry out this component was supplied by the Fraser River Action Plan as an initiative under Canada's Green Plan, Fraser River Action Plan. The industries selected for investigation were among those recommended in FREMP's Water Quality Plan: Monitoring and Objectives report (April, 1991). The present work complements monitoring of other industrial effluents along the river and carried out by BCELP in partnership with FRHC (Brush *et al*, 1987; Swain and Walton, 1993)

1.3 Canadian Water Quality Guidelines and BC Approved and Working Criteria for Water Quality

The Canadian Council of Resource and Environment Ministers (CCREM) have published the Canadian Water Quality Guidelines (CCREM, 1987). These guidelines are used to assess water quality problems and to manage competing uses of water resources. The preface to these guidelines cautions that they do not constitute values for uniform national water quality and that their use requires consideration of local conditions. Guidelines are given in the document for the following water uses: drinking, recreation, freshwater aquatic life, agricultural and industrial.

The Water Quality Branch of BCELP has prepared "Approved and Working Criteria for Water Quality" (Nagpal and Pommen, 1993) to be used in assessing water quality data and preparing site-specific water quality objectives. Until the criteria are approved by the Ministry, the working criteria are being used for these purposes. The working criteria are intended to be used as a water quality data screening tool. A number of water uses are covered by these guidelines, including, drinking, aquatic life (both freshwater and marine), livestock, irrigation, recreational and industrial.

In this report, both the Canadian Water Quality Guidelines and the BC Criteria for Water Quality are used to assist in the interpretation of effluent toxicity test results in relation to sample chemistry.

The concentrations of chemical substances detected in the discharges are compared to the criteria and guidelines to identify potential contributors to toxicity.

1.4 Permits and the Permit Process

In British Columbia, discharges to the environment are regulated under the BC *Waste Management Act*. The provisions of this Act and the accompanying regulations are administered by BCELP. All point source discharges require a Waste Management Permit. The terms of the permit are decided by BCELP, in consultation with the applicant and other regulatory agencies, and usually include routine monitoring of the discharge. The type and frequency of the monitoring depends on the nature of the discharge and the potential for impact on the receiving environment. In the evaluation of discharges for permit, the waste type objectives are used and/or a comparison to precedent is made.

The eleven industries who participated in this study all hold a Permit to Discharge issued by the Environmental Protection Division of BCELP. Some of the industries are permitted more than one discharge, as outlined in the permit appendix. In this report, discharges are labelled by the permit appendix number. For instance, the effluent described by Waste Management Permit PE-42, Appendix 02 is termed Discharge 02.

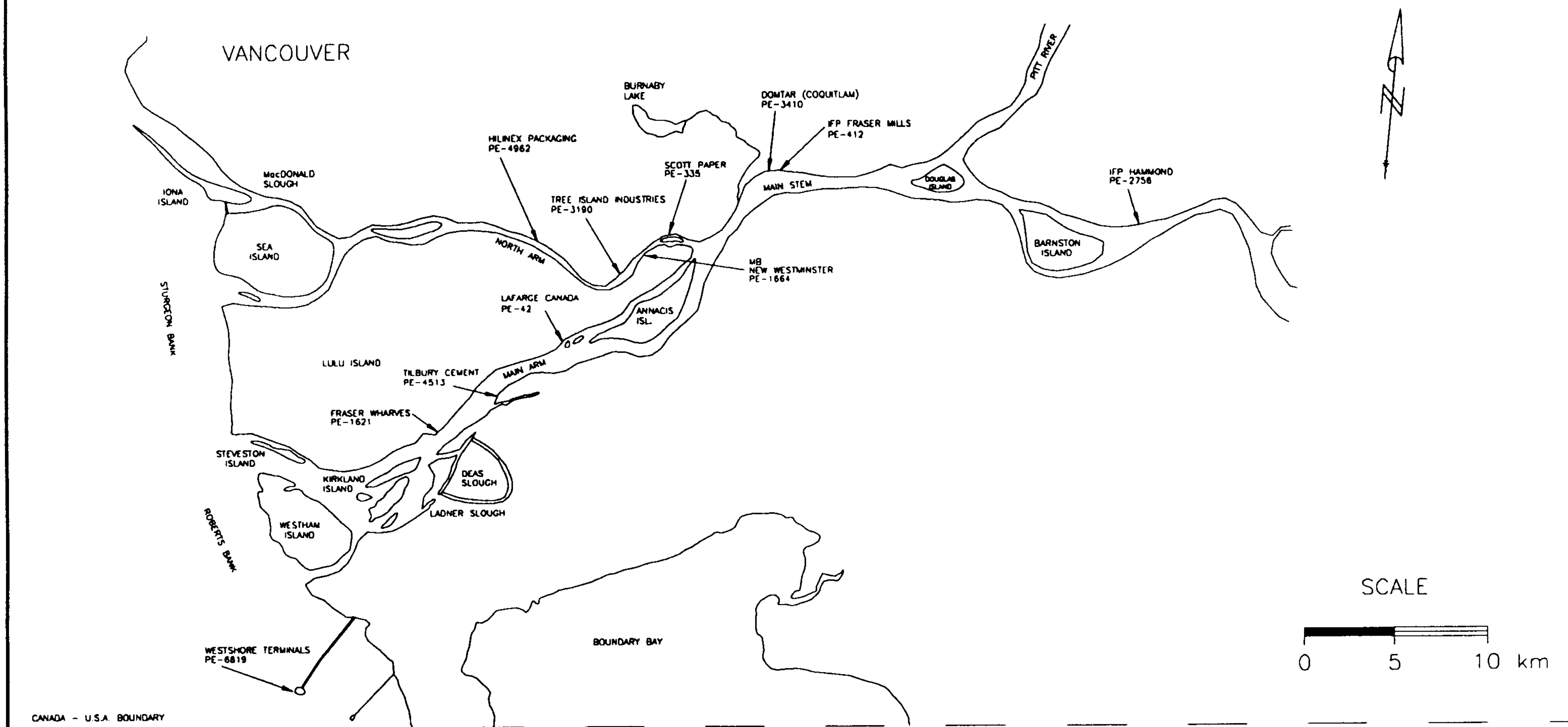
Discharge permits are a matter of public record and copies can be obtained from BCELP.

1.5 Participating Industries

The industries which participated in this study and the discharge types which were sampled are shown in Table 1-1. These sites are indicated on Figure 1-1.

Table 1-1: Participating Industries

Sample	Industry	Discharge Sampled
A	Lafarge Canada Inc.	non-contact cooling and storm water
B	Lafarge Canada Inc.	non-contact cooling and surface runoff
D	Scott Paper Ltd.	paper mill effluent
E	IFP Ltd. Fraser Mills	non-contact cooling and storm water
none	Fraser Wharves Ltd.	no discharge
N	MB Ltd. New Westminster	cooling water, boiler blowdown and runoff
O	MB Ltd. New Westminster	storm water and kiln condensate
G	IFP Ltd. Hammond Cedar	non-contact cooling water
H	IFP Ltd. Hammond Cedar	kiln condensate
I	IFP Ltd. Hammond Cedar	boiler blowdown
J	Tree Island Industries	process effluent
K	Tree Island Industries	non-contact cooling water
P	Domtar Inc. (Coquitlam)	steam condensate, boiler blowdown
L	Tilbury Cement Ltd.	non-contact cooling water
U	Tilbury Cement Ltd.	ditch discharge (non-permitted)
Q	Hilinex Packaging Inc.	effluent
M	Westshore Terminals Ltd.	runoff discharge
T	Westshore Terminals Ltd.	septic



Drawn By: RB

Date: 24/06/93

File: FRASER.DWG

FIGURE 1-1

FRASER RIVER
INDUSTRIAL DISCHARGE SITES

TRI

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.

1.6 Overview of Report Structure

This report is printed in two volumes. Volume 1 contains the text and figures of the report, and the tables described in the Table of Contents. Volume 2 contains all of the appendices. The titles of these appendices are shown in the Table of Contents. In addition to these two documents, a database which contains all of the analytical data from this project has been prepared in Excel format for Windows. Access to this database can be gained by contacting FREMP, 301-960 Quayside Drive, New Westminster, BC, V3M 6G2, phone (506) 525-1047.

Due to the quantity of figures presented in this report, all figures are provided at the end of the chapter in which they are referenced. Tables are included as soon as possible after first reference.

Chapter 1: The scope of work, the FREMP Water Quality Plan, the BC and CCREM water quality guidelines and Waste Management Permits are outlined. The participating industries are listed.

Chapter 2: An operational assessment was conducted at each participating facility. The assessment includes a process description and process flow diagram and/or site plan. An inventory of historical discharge information, including spills, is provided in this chapter. Effluent treatment works are described, fugitive discharge sources discussed and expected discharge characteristics given.

Chapter 3: Sampling and analytical methods and procedures are given, including information regarding study QA/QC.

Chapter 4: Results of the field work and operational assessments (Section 4.1), the chemical characterization of the 17 effluent streams (Section 4.2), the toxicity tests on the 10 primary effluents (Section 4.3), the bio-uptake study (Section 4.4) and the quality control/quality assurance program (Section 4.6) are presented. In Section 4.1, effluent flow measurement is discussed. Section 4.2 deals with the overall results of chemical analysis. A discussion and summary tables are provided. Section 4.3 summarizes the results of the *Daphnia magna*, rainbow trout and *Ceriodaphnia dubia* toxicity tests. A discussion of the effluents from each industry, including the relationship between toxicity and the chemical characteristics, is provided in Section 4.5.

Chapters 5 and 6: Conclusions and recommendations are given

References, a list of abbreviations and chemical formulae and a list of terminology are given at the back of the report.

2.0 OPERATIONAL ASSESSMENTS

2.1 Lafarge Canada Inc. - PE-42

2.1.1 Process Description and Operational Assessment

Lafarge Canada Inc.
7611 No. 9 Rd.
Richmond, BC.

Date of site visit: February 11, 1993
Status of operation at that time: During the site visit, the plant was operating at capacity with both kilns running. On February 12, 1993, TRI was informed that one of the kilns was being shut down for 2-3 weeks for maintenance. This shutdown was unscheduled. Only one kiln was running when effluent samples were collected.

A plan of the Lafarge Canada Inc. (Lafarge) site is shown in Figure 2-1.

The cement plant was constructed in 1958. This facility uses a wet process to produce four types of portland cement: Type 10 CSA, Type I ASTM, Type II AASHTO and Type 60 (masonry). They operate two rotary kilns 24 hours per day, 7 days per week, with one major and one minor scheduled annual maintenance shutdown. The annual production is rated at 450,000 (metric) tonnes per year. For the last four years they have been operating at capacity.

A simplified process flow diagram is given in Figure 2-2. Raw materials are stored on the site, either in the storage hall or in piles, as indicated on the site plan (Figure 2-1). These piles are open to the atmosphere and subject to the elements. The chemical components necessary for the manufacture of portland cement are calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3). The percentage of each component is shown in Table 2-1.

The raw materials are proportioned and water added to form a slurry which is 32 to 35% water. This slurry is mixed and fed to the rotating kilns. The kilns operate at roughly 1500E C and are capable of using various fuels. At present Lafarge is permitted to use natural gas (primary source), coal (not used), coke (use limited by sulphur emissions), gasses from a landfill (3% of Kiln 2 fuel) and tire-derived fuel (2% of Kiln 1 fuel).

Material from the kilns is termed "clinker". Dust laden gases from the process (including water vapour) are cleaned by an electrostatic precipitator and discharged; dust is returned to the kiln. Clinker is air-cooled and sent to storage. Occasionally clinker is sold as a product.

Table 2-1: Raw Materials in Lafarge Cement

Material	Source Of...	Percent of Feed
Limestone	CaO	76
Shale	Al_2O_3 / SiO_2	18 combined
Conglomerate	SiO_2	
"True Grit"	Fe_2O_3	3
Coal Tailings	SiO_2 / Al_2O_3	2
Kawasaki Slag	SiO_2 / Al_2O_3	1

Cement is formed from clinker with the addition of gypsum and limestone. These materials are mixed in proportions determined by the end product and fed to a ball mill. The outlet cement is cooled with non-contacting water coolers and the product stored in silos for shipping by barge, truck or rail.

Water used in the manufacture of clinker evaporates and discharges with the hot gases from the kiln through the stack. Most of the water used on the site is drawn from the Fraser River. This water is pumped into a reservoir located on the roof of the dust control units. Cooling water from the mills, compressors, glands, and other non-contact cooling services is returned to the river through permitted Discharges 01 and 02. Water is not used for dust control.

Surface runoff from the site will collect fugitive dust and can cause transport of raw materials from the storage piles to the river. In the summer of 1992, a series of six to eight 4 foot diameter by 4 foot deep concrete casings were installed to form cascading "pools" in the areas around the raw material storage to remove suspended solids from this water stream before it joins Discharge 01. Discharge 01 is an open ditch which runs through the facility (see Figure 2-1).

Stormwater which is collected in storm drains around the facility is combined with cooling water and leaves the facility at discharge 02. Direct flow of stormwater to the river is blocked by an elevated roadway.

There is a truck wash facility which is used on an "as-need" basis by customers of Lafarge. Water from this facility passes through a dual settling pond before discharge to an exfiltration field. At the time of the assessment, this pond was full of particulates and water was short-circuiting the pond and discharging in a small trickle flow directly to the exfiltration field.

In general, housekeeping around the site was good. Much care is taken to contain and recover fugitive dust. All dust is either raw material or product and has a significant value associated with it. The storage of raw materials in the yard is the most likely source of inadvertent discharge to the river. Effort has been made to contain and treat the stormwater and routine monitoring of the effluent will indicate the success of this treatment. The monitoring of suspended solids in Discharges 01 and 02 would provide interesting data to assess the effectiveness of this treatment, although this analysis is not required by permit.

2.1.2 Permitted Discharges

Lafarge has three permitted discharges under BC Ministry of Environment Waste Management Permit No. PE-42. This permit was issued April 25, 1984 and most recently amended on July 29, 1991. Discharge 01 is process cooling water with a maximum flow of 2 950 m^3/day, Discharge 02 is process cooling water and stormwater with a maximum flow of 3 410 m^3/day, and Discharge 03 is from the truck wash facility, which operates on an "as-need" basis with a maximum flow of 11 m^3/day. Discharge 03 is discharged to an exfiltration field and does not flow directly into the Fraser River.

Discharges at 01 and 02 are sampled monthly and the flow rate measured quarterly. Flow is measured by recording the water height in Parshall flumes. It should be noted that field personnel were informed that the height measurement was made at the narrowest point in the flume and the flow calculated based on the equation $Q=3.07D^{1.53}$. TRI has been unable to verify this formula, but would like to point out that water height measurements in Parshall flumes are usually taken upstream of the narrowest point. Unless the formula has been developed to correct for the difference in height measurement locations, Lafarge could be reporting flow rates which are higher than actual flows.

Waste Management Permit PE-42 requires that the following limits be met for discharges 01 and 02:

- temperature not to exceed 32 C
- oil & grease not to exceed 2 mg/L above the concentration of O&G at the water intake from the Fraser River, or 10 mg/L, whichever is less.

There are no limits or monitoring required at discharge 03.

2.1.3 Inventory of Historical Discharge Data

A summary of the monitoring data submitted to BCELP for 1990, 1991 and 1992 is provided in Table 2-2. In these three years, Lafarge has been out of compliance a total of four times: twice due to O&G concentrations above the limit and twice for failure to report data. A study on effluent from Lafarge was done as part of Brush, *et al*, 1987, and is detailed by Jacob (1987). Jacob reports that the data show non-toxic discharges with characteristics similar to river water with two exceptions: turbidity was slightly elevated and the oil & grease contamination outside the 100 m initial dilution zone was found. Jacob reports that the oil & grease contamination might be the result of river traffic. Metal concentrations are reported to be associated with particulate matter. Since the date of that report, a series of settling ponds have been installed to address the issue of particulates.

Lafarge has had two spills: in February of 1992, a slurry tank overflowed resulting in a release of approximately 5 cubic metres of slurry; and a small spill of diesel fuel also occurred in 1992 when a diesel truck was overfilled.

2.1.4 Treatment Works and Expected Discharge Characteristics

Other than the above-mentioned settling "ponds" for stormwater and those at the truck wash facility, there is no effluent treatment.

Discharge 01 is non-contacting cooling water. The characteristics of this discharge stream would be expected to be consistent with Fraser River water, with a slightly elevated temperature. No additional chemical components are expected to be added to this stream by the Lafarge process.

Discharge 02 is non-contacting cooling water and stormwater. On dry days, the characteristics of this discharge stream would be expected to be consistent with Fraser River water, with a slightly elevated temperature. On rainy days, stormwater which is released from this facility would be expected to have elevated concentrations of oil & grease, suspended solids and total metals, particularly aluminum, calcium, silicon and iron.

Discharge 03 does not discharge to the Fraser River and will not be discussed further in this report.

2.1.5 Fugitive Discharge Sources

Fugitive dust from raw material piles may be collected in stormwater. Stormwater is collected and discharged as part of Discharge 02. No fugitive stormwater is expected from this site due to the layout of the facility and the surrounding elevated roadways.

Table 2-2: Lafarge Canada - Monitoring Data Summary

YEAR	PARAMETER	UNITS	PERMIT LIMIT	MAX	MEAN	MONTHS OUT OF COMPLIANCE
Discharge 01						
1990	Flow O&G	m^3/d mg/L	2,950 10*	2,600 9.8	2,358 <2.8	0 0
1991	Flow O&G TSS	m^3/d mg/L mg/L	2,950 10*	2,600 7.0 22	2,388 2.1 15	1 (no data) 0 0
1992	Flow O&G TSS	m^3/d mg/L mg/L	2,950 10*	2,670 3.0 49	2,465 1.1 24	0 0 -
Discharge 02						
1990	Flow O&G	m^3/d mg/L	3,410 10*	2,910 5.7	2,653 <2.5	0 0
1991	Flow O&G TSS	m^3/d mg/L mg/L	3,410 10*	2,560 11.5 26	2,043 3.0 15	1 (no data) 2 -
1992	Flow O&G TSS	m^3/d mg/L mg/L	3,410 10*	3,330 1.9 59	2,596 <0.9 35	0 0 -

* 10 mg/L or 2 mg/L above the concentration of O&G at the water intake, whichever is less.

2.2 Scott Paper Ltd. - PE 335

2.2.1 Process Description and Operational Assessment

Scott Paper Ltd.
1625 - 5th Ave.
New Westminster, BC

Date of site visit: February 11, 1993
Status of operation at that time: normal

Scott Paper manufactures tissue and household paper products at a mill located at the foot of Fifth Avenue in New Westminster (Figure 2-3). Four separate paper machines are operated at this location, each producing a defined range of products. Approximately 22 - 25% of the furnish is provided by groundwood pulp produced from cottonwood logs, on site at the groundwood mill. 70% of the furnish is purchased Kraft pulp. This mill uses 5 - 7% secondary or recycled fibre supplied by Newstech and by the Scott Paper Mill in Crabtree, Que. A simplified schematic of the manufacturing process is presented in Figure 2-4.

2.2.1.1 Water Supply and Discharge

Approximately 17,500 m^3/d of water is required to maintain production. The main supply of water comes from the Fraser River, with supplemental process water from the New Westminster municipal system. City-supplied water consumption increases in the winter months because the clarifier for Fraser River water is less efficient at these times.

Approximately 16,750 m^3/d of water is drawn from the Fraser River and is treated in a silt bed clarifier. A flocculant (polyaluminum silicate sulphate, PASS) is added to the incoming water prior to the silt bed filter, as shown in Figure 2-5. The clarified water then passes through a bed of charcoal, is disinfected with chlorine and is added to the process water as required. It is necessary to backwash the filter from time to time. This is accomplished by passing clarified water through the filter to remove excess solids and debris. This wash water is discharged to the Fraser River through the effluent caisson. There is no net additional loading of solids to the Fraser River as a result of the water treatment. Solids discharged during filter backwash originated in the water obtained from the river and are therefore being returned to their source.

Water supplied through the city system is used to supplement shortfalls in supply from the Fraser River filtration system. This make up occurs primarily as an addition to the clear well source, but water can be added directly to the paper making and groundwood processes, when required. The white water (water containing pulp fibre) system in the groundwood area discharges to the city sewer as authorized by a permit administered by GVS&DD. The white water systems at the paper mills discharge to the effluent treatment works and subsequently to the Fraser River as authorized by Waste Management Permit PE-335.

2.2.1.2 Groundwood Mill

Cottonwood logs are debarked, cut to length and converted to pulp fibre. This fibre is screened and transferred to a stock chest at 1.5% fibre content as shown in Figure 2-6. The bark and screen rejects are directed to landfill for disposal. Filtration plant water and white water are added in the grinding process and act as carriers for the groundwood fibre. Reject logs are directed to a chipper. The chips and coarse rejects from grinding are mixed with white water in a refiner, which pulps the wood. The groundwood pulp undergoes several additional steps, including passage through a fine screen and cleaners which remove solids of higher density. The pulp (approximately 1% fibre) is de-watered at the Kamyr vacuum cylinder mould, bleached with hydrogen peroxide and placed in storage. Liquid from the cleaners is passed through a screen. Screen rejects are pressed to remove the remaining water. Solids from the press are directed to the Scott Paper hog fuel boiler and the liquid from the screen and press are discharged to the GVS&DD sewer system. White water from the Kamyr vacuum cylinder mould is collected in the white water chest for re-use.

Excess white water is discharged to the GVS&DD sewer system. Effluent, storm drainage and fugitive runoff from the groundwood operations is not discharged to the Fraser River, but is collected in a sump and pumped directly to the GVS&DD sewer. Scott Paper is authorized to discharge cooling water and fibre-free effluent from the groundwood mill as Discharge 01 (Waste Management Permit PE-335). This discharge is no longer used. Sanitary sewer discharge from this area is managed separately from the white water. There is no discharge to the Fraser River from the groundwood mill.

2.2.1.3 Operation, Paper Mills

Each of the four paper machines uses stock which is prepared in essentially the same manner, as illustrated in Figure 2-7. The furnish (consisting of Kraft pulp, secondary fibre, groundwood pulp and pulp slush from the broke chests) is mixed in a batch operation with recycled white water and water from the filtration plant. Following agitation, the pulp is pumped to the machine chest where additional water is added as required. After this stream passes through the refiners, the pH is adjusted using carbon dioxide. Slimicides, defoamer, optical whiteners, colorants and wet strength chemicals are added only as required. The pulp is distributed to the fabric at the head box. Water passing through the fabric is collected in one of three sumps. White water from the fan pit is recycled to the fan pump or is combined with the discharge from the wire pit and directed to the saveall. Discharge from the saveall is directed to the showers where it is used for dilution.

2.2.1.4 Fibre Recovery

The surplus effluent from the saveall is collected in the lean effluent tank. Water from the press pit and floor drains is also collected in the lean effluent tank. All of the water from the lean effluent tank is directed to the effluent system shown in Figure 2-8.

Spills or overflows from the process tanks, should they occur, are collected in the floor drains and directed to the lean effluent tank. Spills of chemicals or other potentially harmful materials are contained. All spills and discharges from the paper mills are directed to fibre recovery and/or the effluent treatment system.

2.2.1.5 Waste Water Treatment, Paper Mills

The flow diagram for the effluent treatment and discharge system is shown in Figure 2-9. The lean effluent tank receives flows from the sludge dewatering press, DSM screens and overflow from the filtrate chest. Water is discharged from the lean effluent tank to the filtrate chest. Overflows from the lean effluent tank are directed to the rich tank. Lean white water from the filtrate chest flows to the Krofta flotation cell, where non-recoverable fibre is floated to the surface, then directed to the sludge holding tanks. Clarified effluent from the Krofta flotation cell is discharged as an underflow, either to the effluent weir or recirculated to the filtrate chest. Overflows from the sludge holding tanks are directed to the rich tank. Sludge is further de-watered at the sludge press. Discharge from the sludge press is pumped to the lean effluent tank. Water discharged to the effluent weir overflows to a diffuser in the Fraser River. Waste solids from sludge dewatering are landfilled.

2.2.2 Permitted Discharges

Approximately 15,000 m^3/d (of the permitted 23,000 m^3/d) of effluent is discharged to the Fraser River as Discharge 02. Effluent quality must satisfy the more stringent requirement of either Permit No. PE-355 or the B.C. Pulp & Paper Effluent Regulation, as indicated in Table 2-3. Total suspended solids are monitored frequently throughout the day and plotted to ensure that daily maximum loadings do not exceed 2,700 kg/d. Temperature and pH are also monitored frequently throughout the day. Dissolved oxygen and biochemical oxygen demand are measured daily, while a bioassay of the effluent using rainbow trout is completed monthly. Effluent discharge flow rate is measured with magnetic flow meters. These parameters are suitable for general characterization of the effluent quality. Although additional chemical analyses could be done if the effluent proved to be toxic, there is no need to consider these at the present time.

Waste Management Permit PE-355 also permits the discharge of 910 m^3/d of cooling water and fibre-free effluent from the groundwood mill. This discharge has been discontinued by Scott Paper; water recycling has been implemented and all residual discharges from the groundwood mill are sent to the GVS&DD sewer.

Table 2-3: Permit and Regulation Limits

Characteristic	Permit	BC Pulp and Paper Effluent Regulation Limit
pH range	6.0 to 8.0	
Temperature	not to exceed 35 C	
Total Suspended Solids	not to exceed 2,700 kg/d	207 mg/L (3,454 kg/d, monthly average)
Dissolved oxygen	not less than 2.0 mg/L	
BOD_5	not to exceed 2,700 kg/d	138 mg/L (2,303 kg/d)
Toxicity	96-h LC50 = 100%	

2.2.3 Inventory of Historical Information

Scott Paper representatives advised that money is spent, as required, for capital expenditures or improvements in the process and effluent treatment systems. These improvements are made on a continuing basis. For example, the process flow has changed significantly since the Fraser River Harbour Commission report (Brush *et al*, 1987) was issued. During 1992, containment systems were installed for several chemicals, pH controls were installed in the process, improvements were made in the piping at several areas and the computer control system was modified. In 1993, a major re-fit of the groundwood system will be undertaken. Scott Paper representatives have indicated that this type of improvement will continue.

Monitoring data submitted to BCELP for 1991 and 1992 are summarized in Table 2-4. During this period, Scott Paper has been out of compliance on only one day, as indicated in Table 2-4. In this instance, the TSS limit was exceeded.

Two spills of lubricants were reported to BC Environment, Lands & Parks in 1992. Both spills were lubricants which inadvertently mixed with the white water. Scott Paper representatives believe that the oil was adsorbed by the fibres recovered in the Krofta cells and, therefore, was not discharged to the Fraser River.

Table 2-4: Scott Paper Permit Monitoring Data Summary

YEAR	PARAMETER	UNITS	PERMIT LIMITS	MAX	MEAN	DAYS OUT OF COMPLIANCE
Discharge 01						
1991	Flow	m^3/d	910	818	553	0
1992	Flow	m^3/d	910	818	547	0
Discharge 02						
1991	Flow	m^3/d	23,000	18,244	12,462	0
	TSS	kg/d	2,700	5,828	1,192	1
	BOD5	kg/d	2,700	2,554	1,101	0
	NVS*	kg/d		424	130	-
1992	Flow	m^3/d	23,000	19,633	14,123	0
	TSS	kg/d	2,700	2,461	1,337	0
	BOD5	kg/d	2,700	2,484	1,271	0
	NVS*	kg/d		410	105	-

* Non-Volatile Solids

2.2.4 Treatment Works and Expected Discharge Characteristics

The treatment works are detailed above in Section 2.2.1.5. The primary contaminants in effluent from the paper mills are suspended solids and biochemical oxygen demand. The treatment process consists of removal of suspended solids using a dissolved air flotation system after all usable fibre has been recovered and recirculated to the process. The flotation system removes most of the suspended solids. A fraction of the biologically oxidizable content of the effluent is associated with the cellulose fibre and, thus, is also removed by the flotation system. Based on records and data inspected during the site visit, the treatment works appear to work efficiently.

2.2.5 Fugitive Effluent Sources

All spills in the mills are collected in trenches and sent to either the fibre recovery system or the effluent system (as appropriate). The facility is inside a building and stormwater does not have the opportunity to contact any of the processing equipment. There are no sources of fugitive effluent from the Scott Paper facility.

2.3 International Forest Products Ltd. Fraser Mills - PE-412

2.3.1 Process Description and Operational Assessment

International Forest Products Ltd.
Fraser Mills
2 King Edward
Coquitlam, BC

Date of site visit: February 19, 1993
Status of operation at that time: normal, two of three compressors running

IFP Fraser Mills is a white wood sawmill and planer which has recently been converted to cut lumber for the Japanese market. Plywood manufacturing facilities located on the site have been permanently closed, although the buildings and structures associated with these operations remain on site. The lumber from the sawmill is planed and treated either with NP-1 anti-sapstain chemical or kiln dried. The lumber kilns are located on an adjoining property owned by another company. A site plan is given in Figure 2-10.

Lumber is treated in a spray facility located inside a building. Lumber emerging from the spray booth is stacked by a J-bar sorter until a full load is obtained. Full loads are transported outside for storage on a paved surface. There is no roof over the treated lumber storage area. Stormwater flows to a series of collection trenches, detailed in Figure 2-10.

As required by the BC Antisapstain Regulation, samples of stormwater runoff from the sawmill yard are collected at two locations (indicated in Figure 2-10) and analyzed for anti-sapstain chemicals. NP-1 anti-sapstain chemical is applied to lumber at both the sawmill and planer. Stormwater runoff samples were collected quarterly and analyzed for anti-sapstain chemicals until December, 1992. Because anti-sapstain chemicals have been below the analytical detection limit in these samples, BCELP has reduced the required frequency for sample collection to once per year.

There are two water discharges from the site, as indicated in Figure 2-10. Waste Management Permit PE-412 authorizes the discharge of 60 m^3/d of cooling water from three compressors in the sawmill as Discharge 03. The water used in the non-contact heat exchangers is chlorinated city water supplied through the Coquitlam distribution system. This water passes through the heat exchangers in a single pass and is discharged to the Fraser River. The second discharge is from a 54 inch diameter culvert which drains Plywood Creek to the Fraser River. Stormwater runoff is discharged through this culvert located under the sawmill. Flow in the culvert is in two directions, as a result of tidal fluctuations in the Fraser River. TRI cannot confirm whether or not the cooling water and the stormwater discharges are connected.

Domestic sewage from the operations is discharged to the GVS&DD sewer.

2.3.2 Permitted Discharges

Fraser Mills has one permitted discharge (Discharge 03) under BC Ministry of Environment Waste Management Permit No. PE-412. This permit was issued October 16, 1991 and most recently amended on March 18, 1992. Discharge 03 is non-contact cooling water with a maximum flow of 60 m^3/day.

The water quality requirements for the heat exchanger effluent are summarized below.

- Temperature not to exceed 35 C
- Oil & grease not to exceed 5 mg/L

The flow rate is estimated by IFP Fraser Mills staff based on a maximum compressor cooling water flow of 20 m^3/d per compressor (x 3 compressors).

2.3.3 Inventory of Historical Information

A summary of the monitoring data submitted to BCELP is provided in Table 2-5. IFP Fraser Mills has not been out of compliance during this period.

Table 2-5: IFP Fraser Mills Permit Monitoring Data Summary

YEAR	PARAMETER	UNITS	PERMIT LIMIT	MAX	MEAN	QUARTERS OUT OF COMPLIANCE
Discharge 03						
1992	Flow*	m^3/d	60	50	50	0
	O&G	mg/L	5	4.95	<2.09	0

* Estimated flow rate submitted by IFP Fraser Mills.

2.3.4 Treatment Works and Expected Discharge Characteristics

There are no effluent treatment works at IFP Fraser Mills. Treatment works are not required because the cooling water used in the process is non-contacting. The characteristics of this discharge stream would be expected to be consistent with that of the water source, chlorinated Vancouver City water. A slightly elevated temperature would be expected. No additional chemical components are expected to be added to this stream by IFP Fraser Mills.

Stormwater might be expected to contain NP-1 antisapstain chemicals, resin acids, suspended solids and oil & grease. However, monitoring of the stormwater at this facility has shown that the concentration of anti-sapstain chemicals in the stormwater is below the analytical detection limit.

2.3.5 Fugitive Effluent Sources

Stormwater runoff is collected in a series of trenches. In addition to this collection, Plywood Creek runs through the property. There are no physical barriers to prevent transfer of chemicals from the site into the river. However, routine sampling by IFP Fraser Mills has indicated that anti-sapstain chemicals are not present in stormwater.

2.4 Fraser Wharves Ltd. - PE-1621

Fraser Wharves Ltd.
13800 Steveston Highway
Richmond, BC

Date of site visit: February 25, 1993
Status of operation at that time: normal

Fraser Wharves is located at the corner of Steveston Highway and No. 6 Road in Richmond. A site plan is given as Figure 2-11.

Fraser Wharves operates a vehicle processing facility. Honda, Hyundai, Suzuki and Toyota cars and trucks arrive from the Orient by ocean carrier. In addition, vehicles which are built in Canada by these manufacturers and intended for western markets arrive at Fraser Wharves by rail. Between 130,000 and 150,000 vehicles are processed on an annual basis.

Vehicles which arrive by ocean carrier are unloaded into the first-point-of-rest (shown in Figure 2-11). The documents are checked and the vehicles are fuelled. The fuelling pumps are calibrated to dispense the small quantity of fuel which is required.

Fraser Wharves has full shop testing and PIO (Port Installed Option) facilities. These facilities include a trim shop, paint shop, mechanical shop, test track and installation area for options such as stereos, fog lamps, *etc*. Degreasing solvents and other liquid wastes are removed by a disposal company.

A vehicle de-waxing facility is also located on site. The discharge for this facility is authorized under Waste Management Permit PE-1621. This facility is not in use at present because cars and trucks are no longer waxed before they are shipped and, therefore, de-waxing is not required. Fraser Wharves has not amended the permit because there may be a need for the facility in the future. At the time of the site assessment, Fraser Wharves was not discharging to the Fraser River. Sanitary wastes are discharged to the GVS&DD sewer.

2.5 MacMillan Bloedel Ltd. New Westminster - PE-1664

2.5.1 Process Description and Operational Assessment

MacMillan Bloedel Ltd.
New Westminster Lumber Division
ft. Jardine Street
New Westminster, BC

Date of site visit: February 23, 1993
Status of operation at that time: normal, high production

The New Westminster sawmill division operates a sawmill and planers which cut cedar and cyprus lumber. Water for both domestic and boiler use is supplied by the GVWD system. Two sources of effluent are authorized for discharge. Discharge 02 includes runoff from an equipment washing area, boiler blowdown and cooling water from the planer mill and a compressor. Discharge 03 is stormwater and cooling water from the "quad" mill.

The treatment works are small, but are apparently reasonably efficient. There is some discrepancy between the sample collection point and the flow measurement location. This can be seen in Figure 2-12. The flow rate is measured with a Parshall flume, located next to the maintenance facilities. This flow includes non-contact cooling water from the compressors and equipment washdown water. This discharge flows southeast through a trench which connects to other trenches carrying kiln condensate, boiler blowdown and stormwater. These streams all connect at the eastern edge of the property, where they are sampled before discharge. The effluent monitoring point is suitable to characterize the discharge from the site, but the monitored flow rate can be significantly higher than the actual flow discharge. Intermittent discharges are discussed in Section 2.5.5.

2.5.2 Permitted Discharges

MB New Westminster has two permitted discharges under BC Ministry of Environment Waste Management Permit No. PE-1664. This permit was issued December 31, 1974 and most recently amended on March 15, 1993. Discharge 02 is cooling water from the planer mill, lumber dry kiln, and compressor, equipment washdown water and boiler blowdown. The maximum permitted flow is 91 m^3/day.

Discharge 03 is storm water and cooling water from the "quad" mill. This discharge was added to the Waste Management Permit during the latest revision. A discharge rate of 320 m^3/day is permitted.

The authorized water quality for the Discharges 02 and 03 are presented below.

< Temperature not to exceed 35 C
< Oil & grease not to exceed 5 mg/L

The flow rate for Discharge 02 is measured with a Parshall Flume. As noted above, significant water flows are added to the discharge after flow measurement.

2.5.3 Inventory of Historical Information

The data submitted to BCELP for 1991 and 1992 are summarized in Table 2-6. The concentration of oil & grease has exceeded the authorized limit on only one occasion since January, 1991.

Table 2-6: MB New Westminster Permit Monitoring Data Summary

YEAR	PARAM-ETER	UNITS	PERMIT LIMIT	MAX	MEAN	MONTHS OUT OF COMPLIANCE
Discharge 02						
1991	Flow O&G	m^3/d mg/L	91 5	90 6.0	55 <4.2	0 1
1992*	Flow O&G	m^3/d mg/L	91 5	51 5.0	38 4.7	0 0

2.5.4 Treatment Works and Expected Discharge Characteristics

Cooling water, runoff and boiler blowdown waters are collected in a settling basin which removes solids. Synthetic adsorbent pads are placed on the surface of the water to adsorb any petroleum materials which may be entrained in the water. The flow is discharged through a submerged pipe to a second settling basin, also equipped with adsorbent pads. Water from the second settling pond is discharged through a small Parshall flume to a nearby storm drain. Boiler blowdown from the dry kiln boiler is discharged to a storm drain near the southwest corner of the site and combines with the flow from settling basins at the effluent monitoring point, as shown in Figure 2-12. Stormwater, boiler blow down and treated effluent are discharged to a nearby ditch (Figure 2-12).

Discharge 02 would be expected to contain oil & grease, boiler chemicals (oxygen scavengers, metal chelants, phosphates and pH control chemicals) and, potentially, some heavy metals, resin acids and PAHs.

2.5.5 Fugitive Effluent Sources

Kiln condensate and stormwater runoff from the kiln and sawmill area are discharged to the Fraser River, as indicated in Figure 2-12. Kiln condensate constitutes a small fraction of the total discharge from this source. This flow is combined with the treated water from the maintenance area and the non-contact cooling water. While the total flow rate is not measured, the effluent quality is checked on a routine basis. This discharge was recently added to the Waste Management permit as Discharge 03.

There are a number of intermittent discharges in the facility. Both the boiler blowdown and the water from the equipment wash area are non-continuous discharges. It is possible that the effluent quality differs during these events.

2.6 International Forest Products Ltd. Hammond Cedar - PE-2756

2.6.1 Process Description and Operational Assessment

International Forest Products
Hammond Cedar
20580 Maple Crescent
Maple Ridge, BC

Date of site visit: March 1, 1993
Status of operation at that time: normal

IFP Hammond is a sawmill and planer which cuts approximately 500 Mbfm/d cedar. The mill has recently undergone significant changes, including the replacement of a hydraulic barking unit with a mechanical unit and replacement of the hog fuel boilers with a new steam plant. These changes have resulted in a reduction of the volume of effluent discharged to the Fraser River to approximately 6% of previous volumes. Water for compressor cooling and the steam plant is supplied by the GVWD system. Sewage is discharged to the GVS&DD system. Discharges to the Fraser River are authorized from three sources: kiln condensate (Discharges 01 and 02), compressor cooling water (Discharge 03) and boiler blowdown (Discharge 04). These are shown in Figure 2-13. None of the wood products are treated with wood preservation chemicals.

2.6.2 Permitted Discharges

IFP Hammond has four permitted discharges under BC Ministry of Environment Waste Management Permit No. PE-2756. This permit was issued December 31, 1974 and most recently amended on June 26, 1992.

Discharges 01 and 02 (kiln condensate) may be discharged without treatment. The total flow permitted from this stream is 50 m^3/d. A permit amendment assessment report states that the condensate is slightly contaminated but does not require treatment. The authorized water quality is presented below.

< Temperature not to exceed 35E C
< Oil & grease not to exceed 5 mg/L
< Toxicity: 96 hr LC50 = 100%

Temperature and oil & grease are monitored quarterly, while toxicity is monitored semi-annually. Kiln condensate flows are typically much less than the permitted 50 m^3/d.

Up to 2,500 m^3/d of compressor cooling water may be discharged (Discharge 03). The cooling water originates from non-contact heat exchangers. The effluent from this source is monitored quarterly and the authorized water quality is summarized below.

< Temperature not to exceed 35E C
< Oil & grease not to exceed 5 mg/L

The discharge of up to 40 m^3/d of boiler blowdown water is authorized as Discharge 04, with the quality presented below. Small quantities of chemicals are added to the water supply to prevent corrosion and scaling of the boiler. These chemicals include oxygen scavengers, metal chelants, phosphates and pH control chemicals. The boiler water is analyzed daily, while effluent quality must be analyzed quarterly.

< Temperature not to exceed 35E C
< pH not less than 6.5 and not greater than 8.5

Discharge flow rates are estimated by site personnel.

2.6.3 Inventory of Historical Information

Permit monitoring data since June, 1992 which were submitted to BCELP are summarized in Table 2-7. IFP Hammond has not been out of compliance during this period.

Table 2-7: IFP Hammond Permit Monitoring Data Summary (Data Reported Since Permit Amendment - June, 1992)

DISCHARGE	PARAMETER	UNITS	PERMIT LIMIT	MAX	MEAN	QUARTERS OUT OF COMPLIANCE
Discharge 01	Flow O&G	m^3/d mg/L	50* 5	8.64 <1	4.43 <1	0 0
Discharge 02	Flow O&G	m^3/d mg/L	50* 5	16.20 <1	13.99 <1	0 0
Discharge 03	Flow O&G	m^3/d mg/L	2,500 5	18.51 <1	9.98 <1	0 0

* Total flow from Discharge 01 plus Discharge 02 is 50 m^3/d.

2.6.4 Treatment Works and Expected Discharge Characteristics

There are no treatment works at IFP Hammond.

Discharges 01 and 02, as kiln condensate, might be expected to have elevated concentrations of oil & grease and resin acids.

Discharge 03 is non-contact cooling water and would be expected to have the characteristics of the source water, chlorinated Vancouver City water. The temperature would be expected to be slightly elevated.

Discharge 04 would be expected to contain boiler chemicals (oxygen scavengers, metal chelants, phosphates and pH control chemicals).

2.6.5 Fugitive Effluent Sources

The site is paved and stormwater runoff is collected in storm drains and discharged without treatment. This is the only pathway for fugitive effluent sources to the river. The only potential contamination from rainwater would be chemicals leached from maintenance areas. Fugitive effluent from this facility is not anticipated to be a source of contamination.

2.7 Tree Island Industries - PE-3190

2.7.1 Process Description and Operational Assessment

Tree Island Industries
3933 Boundary Road
Richmond, BC

Date of site visit: February 26, 1993
Status of operation at that time: normal

Tree Island Industries Ltd. (Tree Island) is located at the northeast corner of Lulu Island (Figure 2-14). The plant manufactures a variety of wire products and nails from steel rod. Two sources of effluent are permitted from these facilities. Discharge 01 process water is treated in a waste water treatment plant prior to discharge to an exfiltration lagoon. Sewage from the septic system is also directed to the exfiltration lagoon. Discharge 02 contains cooling water for the wire draw machines which passes through non-contact heat exchangers, prior to discharge to the Fraser River. A simplified schematic of the process and waste water system is presented in Figure 2-15. Water used on the site is drawn from the GVWD system.

Steel rod is passed through a hydrochloric acid pickle bath to remove scale, rust and other surface contaminants which may affect the quality of the final product. Following the pickle bath, the rod is passed through the pickle rinse and a borax/lime bath before being dried. The "drag-out" from the pickle bath (liquid which emerges with the rod from the pickle bath) is washed off the rod in the rinse. The rod is then drawn through the wire draw machines to produce wire of various gauges. The wire can be used to manufacture the various products, which include pulp baling wire, wire fencing, barbed wire, wire mesh products, bright nails, hot galvanized nails, conventionally-galvanized nails, phosphate-coated nails and vinyl-coated nails.

Spent pickle liquors contain less than 4% hydrochloric acid and 11% to 18% ferrous chloride. These liquors are collected for resale. Approximately 3,000,000 litres are sold annually to sewage treatment plants in western Canada for control of hydrogen sulphide and phosphate. An additional 1,000,000 litres are neutralized using caustic soda to generate iron hydroxide sludge. The neutralized spent pickle liquor is separated from the sludge in a centrifuge. The liquid is pumped to the waste water treatment plant for final treatment and the sludge is presently stored on site as special waste.

Additional process effluent is generated in the preparation of galvanized and coated products. Wire is galvanized in a hot dip continuous process, while nails are galvanized by both the hot dip and electroplating processes. Coating of nails with phosphate is achieved with nitric and phosphoric acids.

Solids from the clarifiers are collected, centrifuged and are presently stored in drums in the vicinity of the waste water treatment plant. Tree Island Industries is seeking markets for these metal-bearing solids. Processes are presently being sought to segregate the iron, lead and zinc.

2.7.2 Permitted Discharges

Tree Island Industries is authorized to discharge 2,500 m^3/d of cooling water to the Fraser River. The effluent (Discharge 02) must satisfy the conditions below:

< pH range 6.0 to 8.5
< Dissolved lead not to exceed 0.2 mg/L
< Dissolved zinc not to exceed 0.3 mg/L
< Temperature not to exceed 27 C
< Toxicity: 96 hr LC50 = 100%

Effluent from the waste water treatment system (2,000 m^3/d) which satisfies the water quality requirements listed below may be discharged to the lagoon system (Discharge 01). This effluent exfiltrates the lagoon system and is thought to move laterally to either the main river channel or the Blind Channel.

< pH range 8.0 to 10.5
< Suspended Solids not to exceed 20 mg/L
< Dissolved lead not to exceed 0.1 mg/L
< Dissolved zinc not to exceed 0.2 mg/L
< Ammonia not to exceed 30 mg/L

The flow rate from the waste water treatment system is measured with a magnetic flowmeter. The cooling water flow rate is calculated as the inflow of city water minus the water which is discharged to the treatment system. This calculation is expected to overestimate the flow rate, since no allowance for spillage is made.

2.7.3 Inventory of Historical Information

The effluent permit authorizing Discharges 01 and 02 was recently amended. Among the changes in permit conditions was an increase in discharge volumes for both the cooling water and waste water treatment effluent. Prior to June, 1992, Tree Island Industries was out of compliance with permit conditions on several occasions because discharge volumes exceeded the previous permitted daily limits. On two occasions, the concentration of iron exceeded the previous permitted limits in the waste water treatment plant effluent. A summary of the monitoring data is provided in Table 2-8. Compliance with both the pre- and post- permit amendment conditions is indicated in the table.

Table 2-8: Tree Island Permit Monitoring Data Summary

YEAR	PARAMETER	UNITS	NEW LIMITS	MAX	MEAN	WEEKS OUT OF COMPLIANCE*
Discharge 01						
1991	Flow	m³/d	2,000	1,995	1,778	34 (0)
	Fe	mg/L	-	0.50	<0.16	0 (-)
	Pb	mg/L	0.1	0.20	<0.15	0 (1)
	Mn	mg/L	-	0.47	<0.12	0 (-)
	Zn	mg/L	0.2	0.63	0.12	0 (7)
1992[P]	Flow	m³/d	2,000	1,871	1,527	16 (0)
	Fe	mg/L	-	0.90	<0.34	0 (-)
	Pb	mg/L	0.1	0.20	<0.11	0 (3)
	Mn	mg/L	-	0.17	<0.09	0 (-)
	Zn	mg/L	0.2	0.40	0.16	0 (7)
Discharge 02						
1991	Flow	m³/d	2,500	2,126	1,673	29 (0)
	Fe	mg/L	-	0.30	<0.15	0 (-)
	Pb	mg/L	0.2	<0.15	<0.15	0 (0)
	Zn	mg/L	0.3	0.24	<0.12	0 (0)
1992[P]	Flow	m³/d	2,500	1,974	1,625	16 (0)
	Fe	mg/L	-	2.00	<0.25	1 (-)
	Pb	mg/L	0.2	0.10	<0.11	0 (0)
	Zn	mg/L	0.3	0.19	0.07	0 (0)

P To June, 1992

* The Permit was amended in July, 1992. Number in () indicate compliance with new limits. No data has been submitted to BCELP since the permit amendment.

The waste water treatment system is authorized to operate until 1997. In the interim, TRI believes that the waste water treatment process and facilities are adequate to achieve the discharge requirements. Tree Island Industries is presently seeking systems which will improve effluent quality.

One spill has been reported. A leak in a heat exchanger developed over the weekend of November 29 - 30, 1991 and ten litres of thermal oil overtopped a containment dyke. The oil entered a storm drain sump before being detected. The oil was cleaned out of the sump and from the surface materials.

Tree Island Industries stated that several studies pertaining to the effluent treatment system have been completed or were in progress. An assessment of the containment dyke stability for the lagoons was completed by Thurber Engineering Ltd. in 1992.

2.7.4 Treatment Works and Expected Discharge Characteristics

Discharge from the pickle rinse is pumped to the waste water treatment plant where it passes through a three stage neutralization process using caustic as a neutralizing agent. Following neutralization, a flocculant is added and solids are separated in a clarifier. Clarified water is passed through a sand filter before discharge to the exfiltration lagoon.

Effluent generated from the galvanizing and coating processes is directed to a second waste water treatment line which is identical in process to that described above. The discharges from the two clarifiers are combined at the sand filter and are discharged as a common flow to the lagoon. This combined stream comprises Discharge 01.

There are no treatment works associated with Discharge 02, a non-contact cooling water.

Discharge 01 would be expected to have elevated concentrations of heavy metals and suspended solids (although a sand filter would be expected to be effective in the removal of suspended solids).

Discharge 02 is non-contact cooling water and would be expected to have the characteristics of the source water, chlorinated Vancouver City water. The temperature would be expected to be slightly elevated.

2.7.5 Fugitive Effluent Sources

No potential fugitive effluent sources from this facility were detected.

2.8 Domtar Inc. (Coquitlam) - PE-3410[2]

2.8.1 Process Description and Operational Assessment

Domtar Inc. Wood Preserving Division
25 Braid St.
New Westminster, BC

Date of site visit: February 26, 1993
Status of operation at that time: normal, Cylinder House #5 shut down (has been down for last 10-12 months)

Domtar manufactures preserved wood products (lumber, timbers and poles). These wood products are preserved with creosote, pentachlorophenol (PCP), chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) preservatives. A site plan is given in Figure 2-16.

ACA and CCA are water-based preservatives used in the manufacture of lumber, timbers and line poles. Creosote and PCP are oil-based preservatives used in the manufacture of railroad cross ties, marine pilings and utility poles.

Water-Based Preservative Streams

Lumber, timbers and poles are treated with CCA or ACA preservative using an open cell process. These wood products are introduced ("charged") into the retort (pressure cylinder) where the preservative is applied. The charge is removed from the pressure cylinder at the completion of the treatment cycle and allowed to drip on a concrete pad. All water from this area is recovered, including storm runoff. Fixation of the treatment chemical to the product is completed through a fixation tunnel. The retorts are under a roof, but the drip pads and storage area are open to the atmosphere.

CCA and ACA are purchased in concentrated form and must be diluted prior to their use as treatment solutions. CCA concentrate must be diluted from the 50% concentrate to approximately 3% to 6% in the working solution. The strength of the working solution is tested periodically and adjusted with the addition of fresh ACA or CCA solution. Make-up water includes the drip water and stormwater runoff collected from the drip pad, as well as collected steam condensate. Additional fresh water is added from the GVWD system, as needed.

Periodically, solids are removed from the water-based preservative solutions. The recovered aqueous solutions are used to dilute preservative concentrate solution to the required treatment concentration. There is no discharge to the Fraser River from the water-based preservative process.

[2] now Stella-Jones Inc.

Oil-Based Preservative Streams

Creosote and carrier oil are delivered to the site in rail cars. The solution is then transferred from the rail cars to the storage tanks. During this transfer, the tank car is located above a collection and containment pit, to ensure that preservative does not contaminate soil, storm runoff or groundwater. Creosote is diluted to the appropriate concentration with carrier oil in the working tanks where it is stored until required.

PCP is received as a solid and is dissolved in carrier oil inside the treatment cylinder. The working solution is stored in one of the working tanks located inside containment dykes. Treatment of the wood products with oil-based preservatives is similar to that described for water-based preservative. The retorts are under cover but treated wood storage is outside.

Water is recovered from the oil-based preservative system from several sources. These include storm runoff collected from both the drip pads and containment dykes, as shown in Figure 2-17. The collected water is temporarily stored in the dyke tank. Oil is skimmed from this tank and returned to the treatment system. The water is treated and then discharged to the GVS&DD sewer (treatment is described in Section 2.8.4, below). There is no discharge to the Fraser River from the oil-based preservation process.

Steam Condensate

Water used to produce steam is drawn from the GVWD distribution system. Steam is used to heat treatment solutions in the pressure cylinders and in the storage tanks. Condensate from the tank heating system is discharged to a stilling well with a submerged outflow, and then to an oil-water separator, as shown in Figure 2-17. If oil is detected on the water surface, flow can be pumped to the dyke sump where it is mixed with oily water from the oil preservative containment system and passes through an oil/water separator. Under normal operating conditions, water is discharged through an activated carbon/sand system which flows to the Fraser River.

2.8.2 Permitted Discharges

Domtar has one permitted discharged under BC Ministry of Environment Waste Management Permit No. PE-3410. This permit was issued December 29, 1976 and most recently amended on February 10, 1986. Discharge 01 is condensate from the heating tank system. A monthly average discharge of 415 m^3/d (daily maximum of 465 m^3/d) is authorized by a permit which requires the effluent to satisfy the criteria below.

< pH range not lower than 0.2 units below supply water and not higher than 8.5
< Temperature not to exceed 35 C
< Oil & grease not to exceed 5.0 mg/L
< Phenolics as phenol not to exceed 0.2 mg/L
< Pentachlorophenol not to exceed 1.0 µg/L
< Tetrachlorophenols not to exceed 1.0 µg/L

< Trichlorophenols not to exceed 1.0 μg/L
< Arsenic, total not to exceed 0.05 mg/L
< Copper, total not to exceed 0.10 mg/L

Analysis of the above parameters is required on monthly grab samples of the effluent. The discharge flow rate is estimated at 0.8 times the city water inflow rate. Domtar is in the process of installing a flow meter on this discharge.

2.8.3 Inventory of Historical Information

On three occasions in 1991, the concentration of oil & grease marginally exceeded the specified maximum. This is shown in Table 2-9. The concentration of wood preservative chemicals in those samples was substantially lower than the authorized discharge limits.

Domtar participated in a study conducted for BCELP and Environment Canada entitled "Lower Mainland Region Wood Preservation Facilities: Assessment of Operational Practices and Environmental Discharges Study" (Envirochem, 1992). As part of this investigation, the facility was evaluated relative to the recommended design and operation criteria for wood preservation facilities. In addition, surface runoff samples were collected and analyzed. The report summarized practices of the industry in general terms and commented that design and installation of environmental protection measures were good; operational features were generally consistent with the recommended practices; administrative environmental practices (contingency planning, *etc.*) were weak; and environmental monitoring was not scored well although improvements had been demonstrated. Microtox testing was done on stormwater samples but the authors report that this test did not appear to be a promising method of assessing compliance of stormwater runoff toxicity.

2.8.4 Treatment Works and Expected Discharge Criteria

The water collected from the drip pads in the oil-based preservative area is passed through an anthracite/sand filter to remove solids, then through a carbon tower where entrained preservatives are absorbed on activated carbon. When phenol is detected in the discharge from the primary carbon tower, the flow is switched so that the secondary carbon tower becomes the primary treatment unit. The spent carbon is replaced and the tower of fresh carbon becomes the secondary absorption unit. Effluent from the treatment system is discharged to GVS&DD sewer.

Table 2-9: Domtar Permit Monitoring Data Summary

YEAR	PARAMETER	UNITS	PERMIT LIMIT	MAX	MEAN	MONTHS OUT OF COMPLIANCE
Discharge 02						
1991	Flow	m^3/d	415	359	206	0
	O&G	mg/L	5	7.0	<3.4	3
	Phenol	mg/L	0.2	0.014	<0.005	0
	5CP	µg/L	1.0	0.33	<0.15	0
	4CP	µg/L	1.0	0.83	<0.12	0
	3CP	µg/L	1.0	<1.0	<0.18	0
	As	mg/L	0.05	0.002	<0.001	0
	Cu	mg/L	0.10	0.015	<0.005	0
1992*	Flow	m^3/d	415	145	127	0
	O&G	mg/L	5	<5	<3.7	0
	Phenol	mg/L	0.2	0.011	<0.007	0
	5CP	µg/L	1.0	0.41	<0.20	0
	4CP	µg/L	1.0	<0.05	<0.05	0
	3CP	µg/L	1.0	<0.5	<0.2	0
	As	mg/l	0.05	<0.001	<0.001	0
	Cu	mg/L	0.10	0.16	<0.009	0

* Data for January, February and March only.

Steam condensate and boiler blowdown are passed through an oil/water separator prior to discharge. Effluent at Discharge 01 is presently analyzed for oil & grease, phenolics as phenol, pentachlorophenol, tetrachlorophenols, trichlorophenols, arsenic and copper. These parameters are representative of contaminants from the preservatives ACA, CCA and CP. While phenolic compounds are one group of compounds found in creosote, PAHs are also found. Some PAH compounds are known carcinogens and upper concentration limits for many PAH compounds are included in water quality guidelines for aquatic life. TRI believes that PAH compounds, as well as phenolic compounds, can become entrained in the steam condensate effluent. Thus, consideration should be given to analysis of monitoring samples for the presence of PAH compounds in addition to the above parameters.

Domtar has recently increased their cooling water discharge pipe from 6" to 18", which will reduce the effluent discharge temperature. An amine injection system has been added to the boiler to improve pH control. This addition should result in a more constant pH at the discharge.

2.8.5 Fugitive Effluent Sources

All stormwater is collected and used as make-up water in the ACA and CCA preservation area, or filtered and discharged to the GVS&DD sewer. Since the treated lumber is stored on bare ground, open to the elements, it is possible that some of the wood preservation chemical could leach into the ground. It is doubtful whether a stream of surface runoff contaminated with wood preservation chemical would occur; transfer via seepage into the ground and groundwater would be more likely.

2.9 Tilbury Cement Ltd. - PE-4513

2.9.1 Process Description and Operational Assessment

Tilbury Cement Ltd.
7777 Ross Road
Delta, BC

Date of site visit: February 24, 1993
Status of operation at that time: normal

Tilbury is located just off River Road, halfway between the Alex Fraser Bridge and the George Massey Tunnel. The site plan is given in Figure 2-18.

Tilbury uses a dry process to produce portland cement. A simplified process flow sheet is provided as Figure 2-19. The plant capacity is roughly 1.0 to 1.1 million metric tonnes/year. Tilbury operates one direct-fired rotary kiln 24 hours per day, 7 days per week.

The raw materials used in the production of portland cement are limestone, shale, high-grade silica, low-grade silica (river sand) and iron slag. Limestone, shale, high-grade silica and slag are brought to the site by barge, as is the coal which is used as a fuel. Barges are unloaded by front-end loader. Material is transported by conveyor or truck to storage on site. River sand is brought to the site by truck. Limestone and shale are stored in the raw material storage building while the other raw materials are stored in piles on the site.

The facility is highly automated. Raw materials are transferred by conveyer into silos and proportioned as they enter the roller mill. Ground particles from the roller mill are swept to a classifier by hot gasses from the kiln. Large particles are recycled back into the mill and the fines (raw meal) are separated from the gas stream by an electrostatic precipitator. The raw meal is transported to homogenizing silos where it is blended with compressed air and then falls into the storage silos. This stream is the kiln feed. The gases are discharged through a stack.

The preheater kiln heats the kiln feed to 800EC. The feed then passes into the rotary kiln, which has a peak temperature of 1500E to 1600EC. The kiln is 5.2 metres in diameter and 80 metres in length, with a residence time of 30 minutes. Three fuels are used to fire the kiln: natural gas, ground coal and tire-derived fuel (shredded tires). Tire-derived fuel is used as a fuel source approximately 60% of the time but was not being used at the time of the site visit. Twenty percent of the total fuel is fired in the preheater.

Clinker (kiln output) is cooled from the outlet temperature of 1300EC to 100EC in a grate cooler. From there it is conveyed into silos for storage. Two types of clinker are normally produced.

Clinker, gypsum and a small amount of liquid grinding aids are fed into two finish grinding mills which are two-compartment ball mills operating at 4500 hp. These mills operate in a closed circuit. Coarse material is separated out and recirculated and the fine material is the product cement. The product is blown to either the dock silos from where it can be loaded onto barges, or to the pack silos which are used to load rail cars, trucks or bags.

River water is pumped to the site through two pumps located in a pumphouse near the docks. River water is used for indirect cooling of the mills in a once-through loop and returned to the river. Fire hydrants on the site are also connected to the river water feed. City water from the GVWD is used in some water spray applications and as bearing cooling water. Discharges are collected in a sump and are discharged to the river as Discharge 01.

2.9.2 Permitted Discharges

Tilbury has one permitted discharge under BC Ministry of Environment Waste Management Permit No. PE-4513. This permit was issued April 15, 1977 and most recently amended on February 22, 1988.

Waste Management Permit PE-4513 requires the following monitoring:

< Grab samples collected once per year and analyzed for oil & grease

< Temperature continuously measured and recorded at the effluent discharge, cooling water intake and in the Fraser River at a downstream location. The temperature of the effluent is not to exceed 10 C above the background temperature of the Fraser River.

< Effluent flow rate not to exceed 18,200 m^3/d.

The process is computer monitored and controlled. Water discharge flow rates are recorded by the computer on a continuous basis.

2.9.3 Inventory of Historical Information

A summary of the data submitted to BCELP for 1991 and 1992 is given in Table 2-10. During this period Tilbury was not out of compliance.

2.9.4 Treatment Works and Expected Discharge Characteristics

Discharge 01 is non-contacting cooling water. The characteristics of this discharge stream would be expected to be consistent with Fraser River water mixed with Vancouver City water, with a slightly elevated temperature. No additional chemical components are expected to be added to this stream by the Tilbury process.

Table 2-10: Tilbury Monitoring Data Summary

YEAR	PARAMETER	UNITS	PERMIT LIMITS	MAX	MEAN	DAYS OUT OF COMPLIANCE
Discharge 01						
1991	Flow O&G	m^3/d mg/L	18,200 -	10,320 4.0	7,702 3.1	0 -
1992	Flow O&G	m^3/d mg/L	18,200 -	13,300 15.8	7,645 15.8	0 -

2.9.5 Fugitive Effluent Sources

Surface drainage is collected in a ditch which surrounds the site. This ditch discharges to the river. At the time of the site assessment, a layer of fine powder was noticed in the ditch where solids washed from the site had settled out. Material storage piles were located within 0.5 metre of the ditch and any rainfall will result in some washing of these materials into the ditch. Any material which is washed into the ditch could be transported to the river if the ditch water flow rate were sufficient. A pipe was noted running from the west side of the facility which discharges to the ditch. During the site assessment and at all three sample collection visits water was discharging from this pipe into the ditch. This flow is not a permitted discharge. Because of the obvious relationship between the ditch water discharge to the river and Tilbury Cement, ditch water was sampled as part of the sampling program.

The only other potential source of discharge to the river is fugitive dust from the cement facility and from the barge loading and unloading operations. However, this potential source is outside the scope of this study because it is not an effluent stream. It is noted as a potential source which may warrant further study at a later date.

2.10 Hilinex Packaging Inc. - PE-4962

2.10.1 Process Description and Operational Assessment

Hilinex Packaging Inc.
foot of Greenal Avenue
Burnaby, BC

Date of site visit: 18 February, 1993
Status of operation at that time: normal

A plan of the Hilinex site is shown in Figure 2-20.

Hilinex manufactures a large range of paper and plastic bags. The layout of the facility is shown in Figure 2-21. The capacity for plastic bags is 1.2 million T-shirt bags per day. T-shirt bags are most commonly used to bag groceries and are so named because they resemble T-shirts. Hilinex are not operating at capacity for paper bags, and have not done so for ten years. The water used on site is distributed by the GVWD.

Paper bags are manufactured from rolls of kraft paper. The paper is fed into folding and cutting machines which form the bags and cut them to size. Two types of glue are used in the process (one for side seams and one for the bottom). These glues are mixed on-site, according to the requirements listed below.

Side Glue:	700	lbs	dextrine (corn starch)
	2	lbs	dowicide (fungicide)
	16	lbs	caustic (to make sticky)
	88	lbs	borax
	1.5	qt	formaldehyde (fungicide)
	1	qt	corn oil (flow enhancer)
	to make up to 260	gal	finished product

Bottom Paste:	400	lbs	corn starch (durabend A)
	2	lbs	dowicide
	4	lbs	caustic
	2.5	lbs	soap powder
	1	qt	formaldehyde
	to make up to 200	gal	finished product

These glues are mixed in batches in large mixing tanks which are heated with hot water. A boiler is used to provide hot water for this purpose. Boiler chemicals are used in the boiler and are added by a company who hold a service contract.
Once the glue is mixed, it is transferred to holding tanks which are cooled with cooling water. The glues are pumped from the holding tanks to each bag machine.

Once the glue has been transferred into the holding tanks, the mixing tank is washed out. This wash water is supposedly discharged to a settling tank, which discharges to an exfiltration field (Discharge 02).

There are a number of non-contact cooling water uses at Hilinex, including cooling water for the starch tank, compressor, converters and extruders. This water is Discharge 01. In 1988 the property in the area was subdivided and a municipal storm sewer was installed. Apparently Discharge 01 was connected to the GVS&DD sewer at that time. Neither the City of Burnaby or the GVS&DD were aware of the connection of Hilinex to this sewer line. (In fact, Hilinex was made aware of the connection to the sewer as a result of this study and have applied for an amendment to their permit.) TRI has been unable to confirm whether there is any process water connected to this discharge.

Water-based ink is used on both paper and plastic bags. Any spillage goes onto a concrete floor where it is wiped up. Cloths are washed by Nelson Laundry and returned to the plant. Any wash water is collected in drums and treated in equipment which separates the water from the contaminants. Water from the distillation apparatus is discharged to the septic drain field. The City of Burnaby have requested that Hilinex connect this discharge to the sanitary sewer.

2.10.2 Permitted Discharges

Hilinex has two permitted discharges under BC Ministry of Environment Waste Management Permit No. PE-4962. This permit was issued September 18, 1978 and most recently amended on July 11, 1986.

Permit PE-4962 describes two discharges: (01) to a ditch surrounding the property which discharges to the river; and (02) which discharges to the exfiltration field. No evidence of the ditch or discharge 01 was found. However a manhole was encountered in the reported area of Discharge 01 and samples were collected there. A later study by Hilinex confirmed that this discharge was cooling water from the compressor and other pieces of equipment and is, indeed, Discharge 01. Permit requirements for Discharge 01 involve the monitoring of temperature and flow rate once per quarter, to be reported annually. This data has not been submitted to BCELP since 1988, and no monitoring is conducted by Hilinex. There are no monitoring requirements for Discharge 02. Hilinex have applied to BCELP for an amendment of their permit to reflect the present operation.

2.10.3 Inventory of Historical Information

No historical information on discharges from Hilinex was found.

2.10.4 Treatment Works and Expected Discharge Characteristics

Process and wash-up water are discharged to a settling tank, with the overflow passing to the exfiltration field. TRI was unable to confirm whether process or wash-up water discharges to the GVS&DD sewer.

Ink wash water is treated to facilitate the separation of the ink solids from the liquid stream. The solids are filtered out of the stream in a plate-and-frame filter press and are sent for disposal at a landfill with other solid wastes from the plant. The liquid is drained to the septic field. This stream is not discharged to the Fraser River.

Discharges from Hilinex would be expected to have elevated concentrations of oil & grease, sugars, and anti-bacterial agents.

2.10.5 Fugitive Effluent Sources

Stormwater from the site is not collected. However, a depression is noticeable on the east of the property. It appears that stormwater from the paved area discharges in this direction. Hilinex has been asked by the Burnaby Health Department to investigate the possible contamination of soil in this area. The soil may have become contaminated when rainwater overfilled some uncovered barrels which were stored on the pavement. These barrels had contained ink wash. All barrels stored outside have had lids installed. It is doubtful that stormwater from Hilinex would enter the river undiluted, because the site is approximately 250 metres from the river.

Water which is separated from ink solids is discharged to the septic system. This stream is not monitored.

2.11 Westshore Terminals Ltd. - PE-6819

2.11.1 Process Description and Operational Assessment

Westshore Terminals Ltd.
Roberts Bank
Delta, BC

Date of site visit: February 24, 1993
Status of Operation at that time: normal

Westshore Terminals operates a bulk coal storage and shipping terminal located in the Fraser Estuary. Coal is received by unit train, dumped in automated facilities and stacked for storage using bucket wheel stacker reclaimer units. Coal is reclaimed from the piles and loaded on deep-sea vessels. Dust is controlled by spraying the stored coal with high volume water sprays. A simplified schematic and site plan is presented in Figure 2-22.

2.11.2 Permitted Discharges

Westshore Terminals has two permitted discharges under BC Ministry of Environment Waste Management Permit No. PE-6819. This permit was issued June 28, 1983 and most recently amended on December 23, 1992.

Westshore Terminals operates a sewage treatment plant and septic tank from which up to 32 m^3/d of treated sewage is discharged to a submerged outfall in the Strait of Georgia (Discharge 01). The effluent quality must not exceed the limits stipulated below.

< BOD_5 not to exceed 130 mg/L
< Total suspended solids not to exceed 130 mg/L

The permit authorizes discharge of up to 10,000 m^3/d from the waste water treatment system (Discharge 02), provided that the effluent quality at the discharge weir satisfies the criteria below.

< Suspended solids not to exceed 50 mg/L
< Oil & grease not to exceed 10 mg/L
< Toxicity: 96 hr LC50 = 100%

Discharges from the effluent treatment facilities occur on an as-need basis. The discharge is monitored for suspended solids weekly, oil & grease monthly and toxicity quarterly.

The flow rate at Discharge 01 is estimated based on the number of hours that the pump operates. The pump discharges at a roughly constant rate, therefore this method of estimating flow rate is reasonably accurate. The flow from Discharge 02 is totalled by a meter connected to the discharge weir. Neither of these discharges is continuous.

2.11.3 Inventory of Historical Information

Monitoring data that has been submitted by Westshore to BCELP for 1990, 1991 and 1992 are summarized in Table 2-11. While Westshore exceeded their permit limits for TSS in 1990 and 1991, all monitoring data from 1992 show full compliance.

In 1992 BCELP commissioned a study of bulk loading terminals (Norecol, 1992). The principal findings indicated that wastewater treatment facilities at the four participating terminals were not able to operate in compliance with their permit on a consistent basis; all terminals had made efforts in the past few years to improve effluent quality; compliance at all sites had improved over the last one to two years; and the major fugitive sources of contamination to the waterway were potential spills from ship loading/unloading operations.

2.11.4 Treatment Works and Expected Discharge Characteristics

Water for dust control consists of recovered precipitation and water supplied by the GVWD system. Surface runoff (including both precipitation and dust control spray) is collected for treatment and recycle. There are five slurry collection sumps, located as shown in Figure 2-22. Water from the slurry collection sumps is pumped either to supply reservoirs for the dust control sprays or to the waste water treatment plant. Water directed to the waste water treatment plant is mixed with flocculants and coagulants to promote settling of suspended solids. The solids are settled in the primary chamber. Final polishing in the secondary chamber occurs prior to discharge of clarified water over an effluent weir to a submerged outfall in the Fraser River Estuary.

Norecol (1992) found that the sewage effluent (Discharge 01) contained BOD_5 (with two excursions over the permitted limit in the last three years), and TSS (a number of excursions). Discharge 02 exhibited numerous high TSS concentrations. Oil & grease concentrations were generally below the permitted level. Four out of five samples were found to have a 96-h LC50 >100%. The fifth sample had a 96-h LC50 of 13.3%

2.11.5 Fugitive Effluent Discharges

All rain water and other water on the site is collected, treated and reused due to the high cost of purchased water. No fugitive water discharges were sighted. TRI agrees with the report by Norecol (1992) which stated that the major uncontrolled fugitive source of contamination to the waterway is potential spills from ship loading/unloading operations.

Table 2-11: Westshore Terminals Monitoring Data Summary

YEA R	PARAM-ETER	UNITS	PERMIT LIMIT	MAX	MEAN	MONTHS OUT OF COMPLIANCE
Discharge 01						
1990	Flow TSS BOD_5	m^3/d mg/L mg/L	32 130 130	34.0 1,550.0 129.0	27.2 230.8 57.1	1 5 0
1991	Flow TSS BOD_5	m^3/d mg/L mg/L	32 130 130	20.7 153.6 81.0	12.7 79.3 52.7	0 1 0
1992	Flow TSS BOD_5	m^3/d mg/L mg/L	32 130 130	11.6 94.0 119.0	10.0 40.0 <45.0	0 0 0
Discharge 02						
1990	Flow TSS O&G	m^3/d mg/L mg/L	10,000 50 10	4,320 462.0 10.7	833 66.4 <2.4	0 17 weeks 1 week
1991	Flow TSS O&G	m^3/d mg/L mg/L	10,000 50 10	3,060 108.0 17.0	638 <14.5 <2.1	0 5 weeks 3 weeks
1992	Flow TSS O&G	m^3/d mg/L mg/L	10,000 50 10	3,780 32.0 6.0	627 <10.1 <3.0	0 0 0

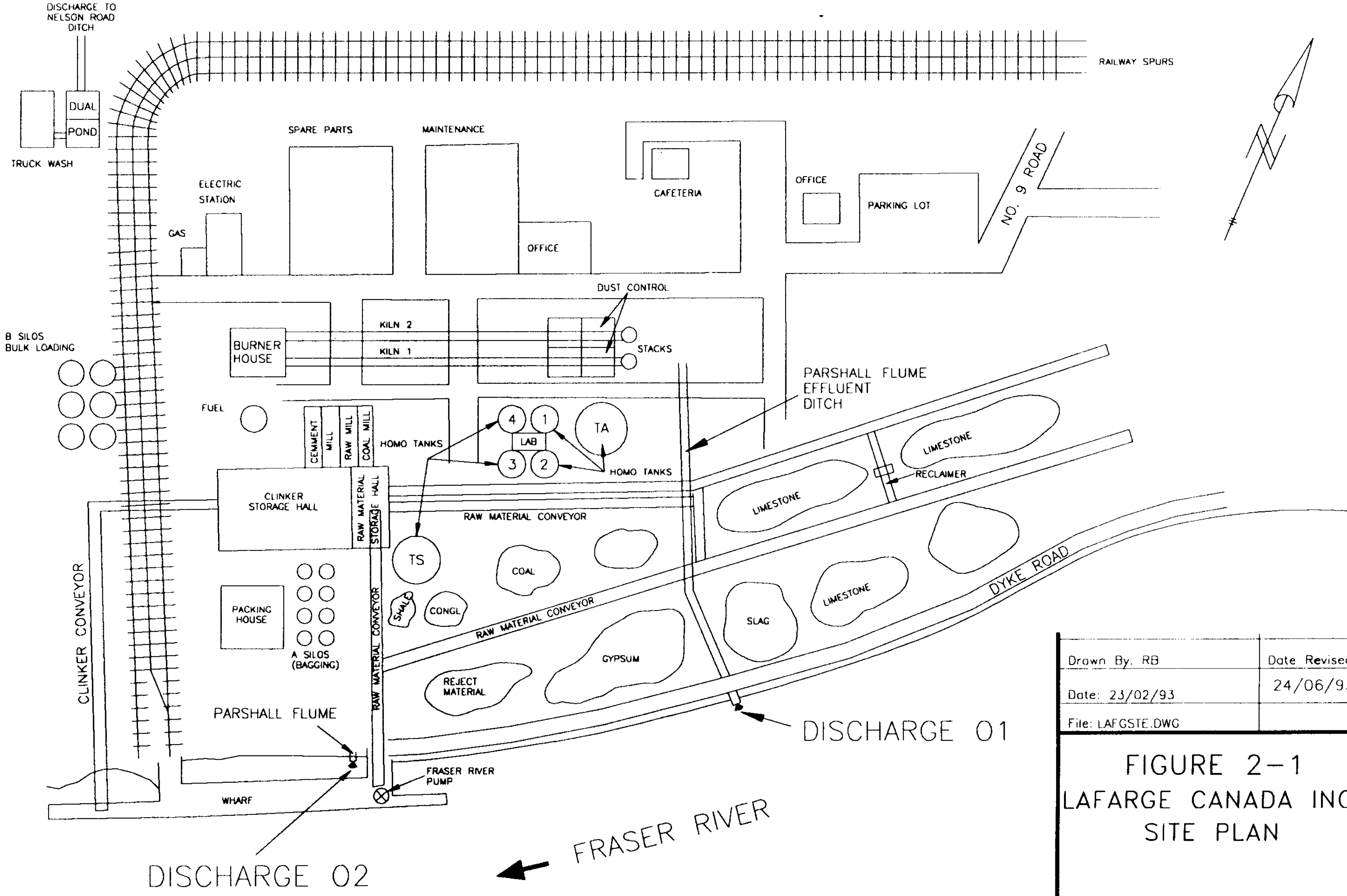
2.12 Summary of Discharges

A summary of the discharges described in Sections 2.1 to 2.11 is presented in Table 2-12.

Table 2-12: Summary of Discharges at the 10 Facilities

Industry	Discharge	Type	Water Source
Lafarge Canada	01	non-contact cooling water	Fraser
Lafarge Canada	02	non-contact cooling water, storm	Fraser
Lafarge Canada	03	truck wash*	Fraser
Scott Paper	01	discontinued*	-
Scott Paper	02	process	Fraser/city
IFP Fraser Mills	03	non-contact cooling water, storm	city
Fraser Wharves	01	discontinued*	-
MB New Westminster	02	cooling, boiler blowdown, runoff	city
MB New Westminster	03	storm, kiln condensate, cooling	rain/city
IFP Hammond Cedar	01/02	kiln condensate	city
IFP Hammond Cedar	03	non-contact cooling water	city
IFP Hammond Cedar	04	boiler blowdown	city
Tree Island Industries	01	process	city
Tree Island Industries	02	non-contact cooling water	city
Domtar (Coquitlam)	01	steam condensate	city
Tilbury Cement	01	non-contact cooling water	Fraser/city
Tilbury Cement	none	?	?
Hilinex Packaging	01	effluent	city
Hilinex Packaging	02	process wash-up*	city
Westshore Terminals	01	septic	city
Westshore Terminals	02	runoff	city

* Not considered further in this study

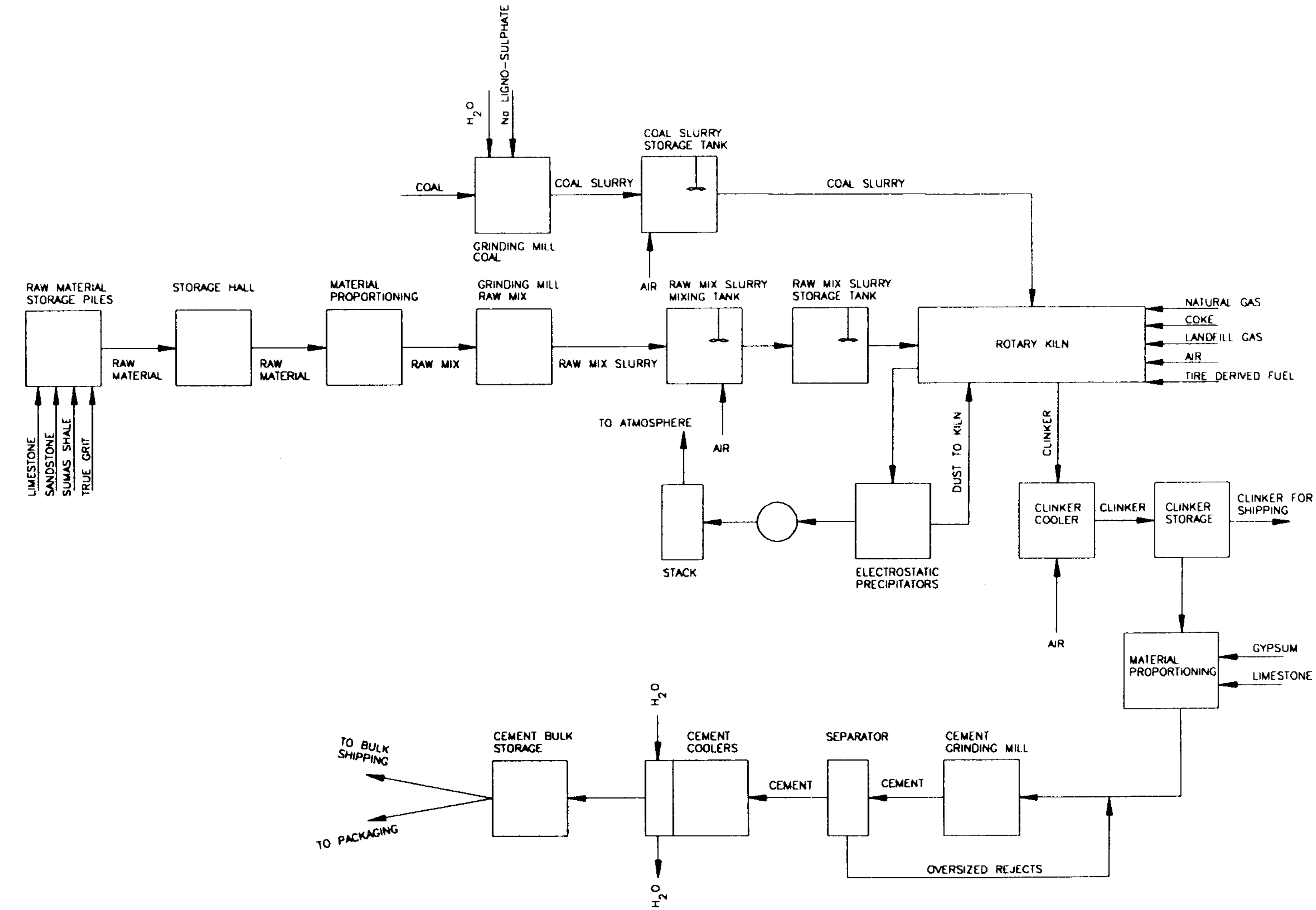


NOT TO SCALE

Drawn By: RB	Date Revised:
Date: 23/02/93	24/06/93
File: LAFGSTE.DWG	

FIGURE 2-1
LAFARGE CANADA INC.
SITE PLAN

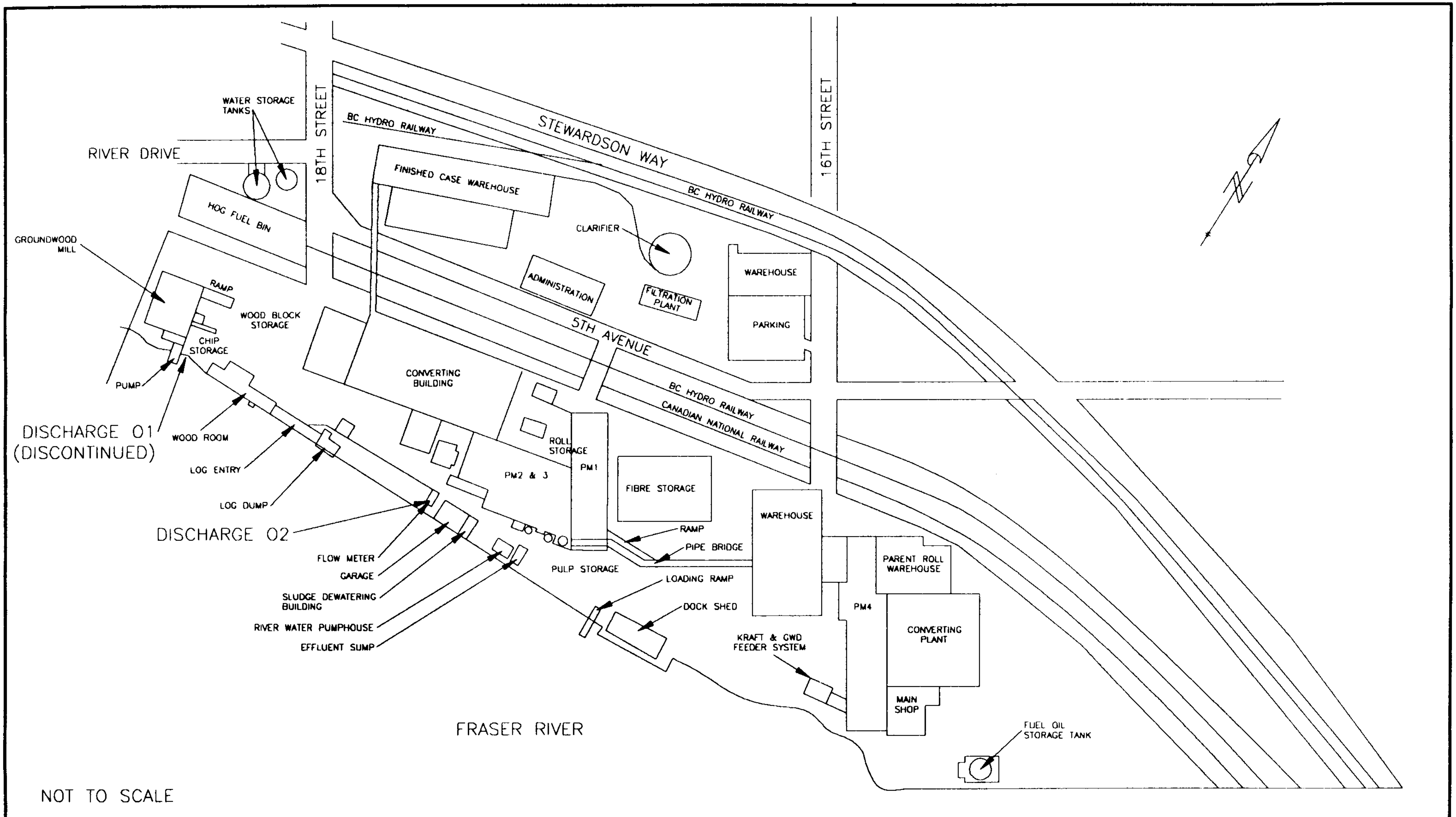
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:
30/09/93
Drawn By: RB
Date: 22/02/93
File: LAFCMENT.DWG

FIGURE 2-2
LAFARGE CANADA INC.
PROCESS FLOW DIAGRAM

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	

Drawn By: RB

Date: 22/02/93

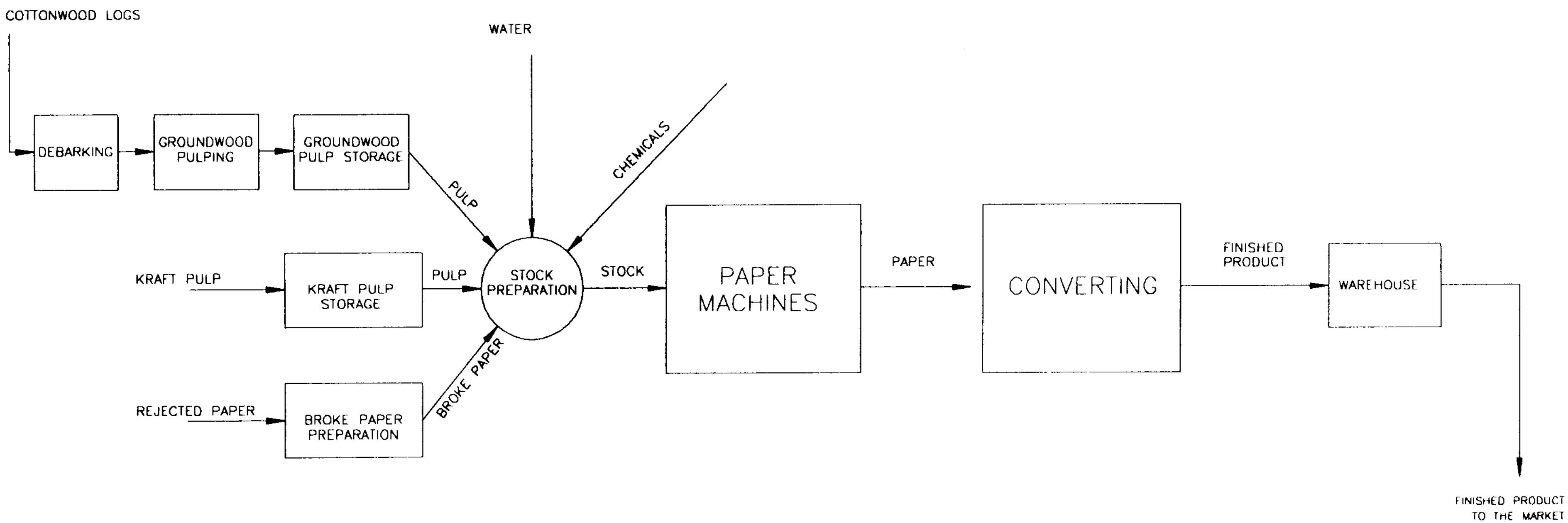
File: SCOTT.DWG

FIGURE 2-3
SCOTT PAPER LTD.
SITE PLAN

TRI

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.



Date Revised: 05/05/93

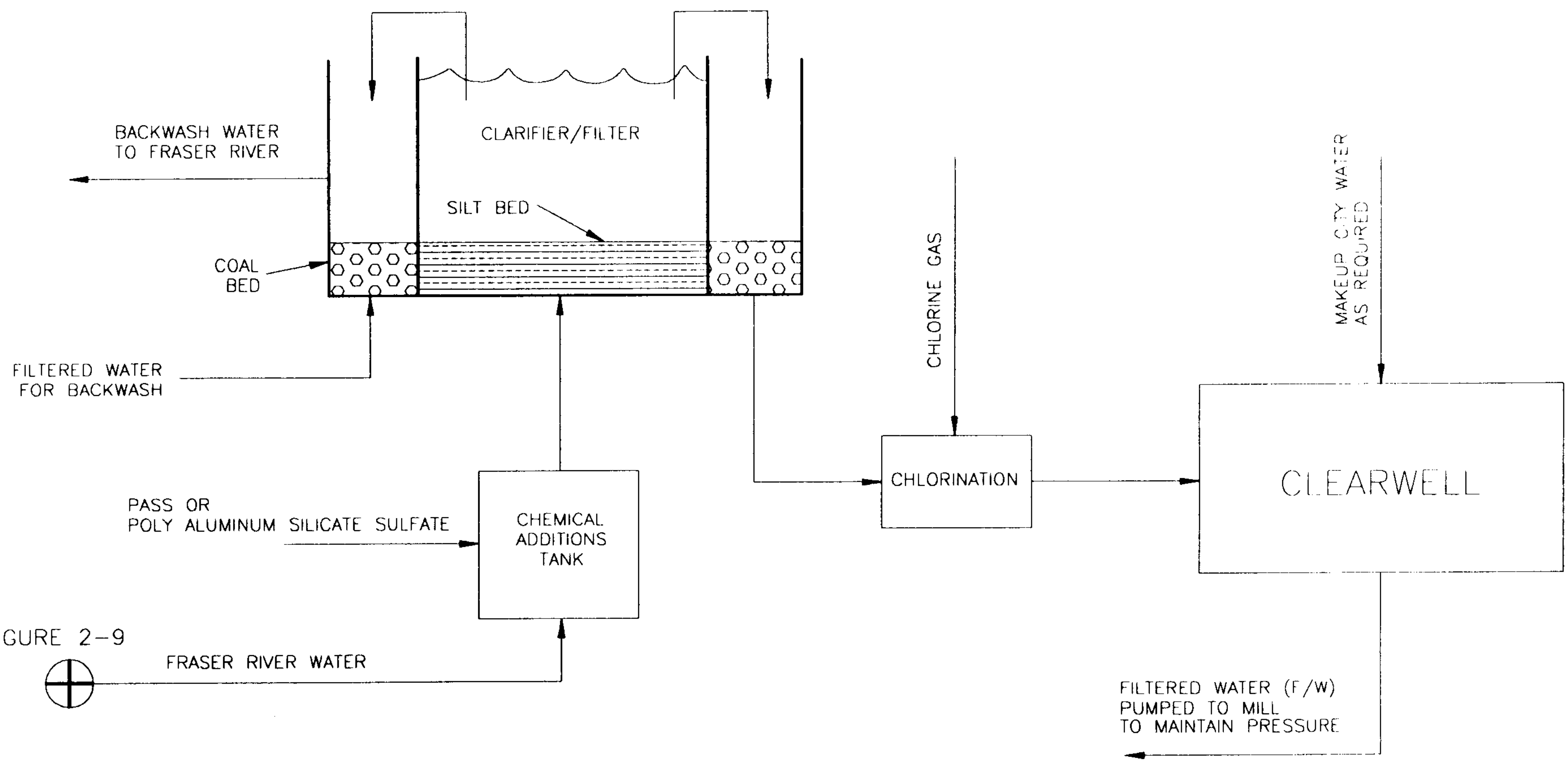
Drawn By: RB

Date: 22/02/93

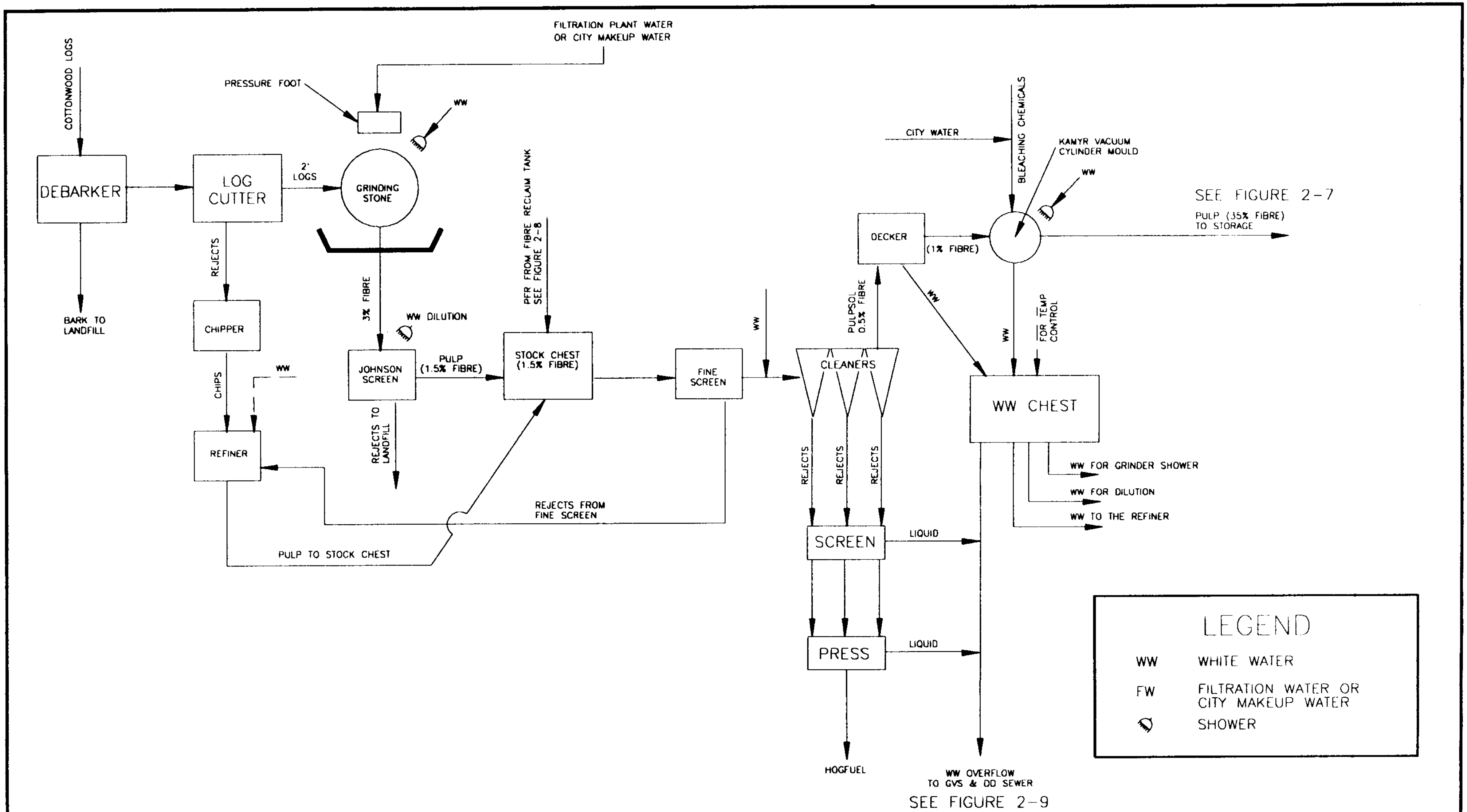
File: SCOTT.DWG

FIGURE 2-4
SCOTT PAPER LTD.
SIMPLIFIED PROCESS SCHEMATIC

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



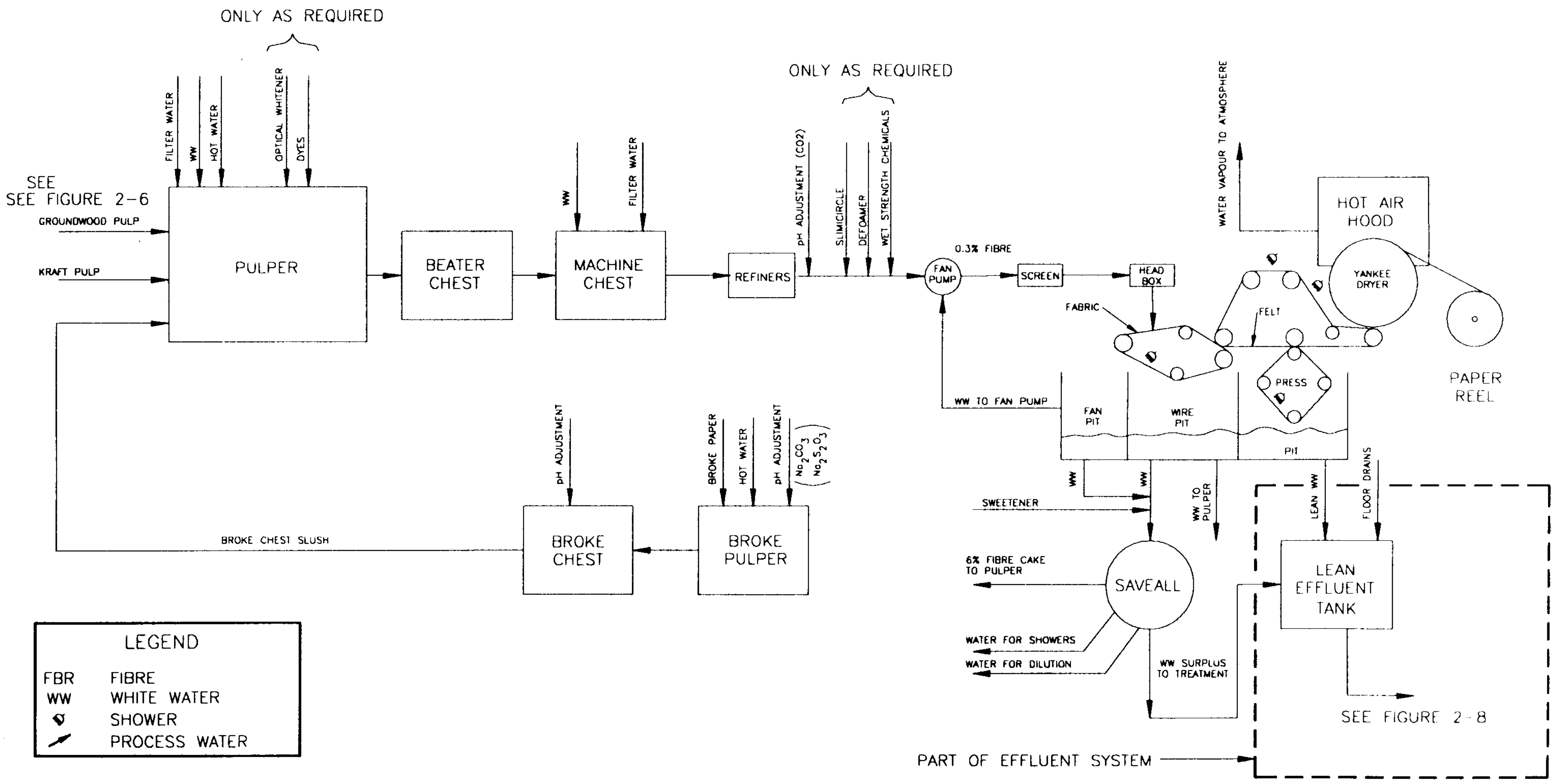
Date Revised: 05/05/93 Drawn By: RB Date: 22/02/93 File: SCOTT.DWG	FIGURE 2-5 SCOTT PAPER LTD. WATER CLARIFIER PROCESS	TRI 502 Kapilano 100 West Vancouver, B.C. V7T 1A2 (604) 925-2323 TECHNOLOGY RESOURCE INC.



Date Revised:	05/05/93
Drawn By: RB	
Date: 22/02/93	
File: SCOTT.DWG	

FIGURE 2-6
SCOTT PAPER LTD.
GROUNDWOOD FIBRE AND WATER PROCESS SCHEMATIC

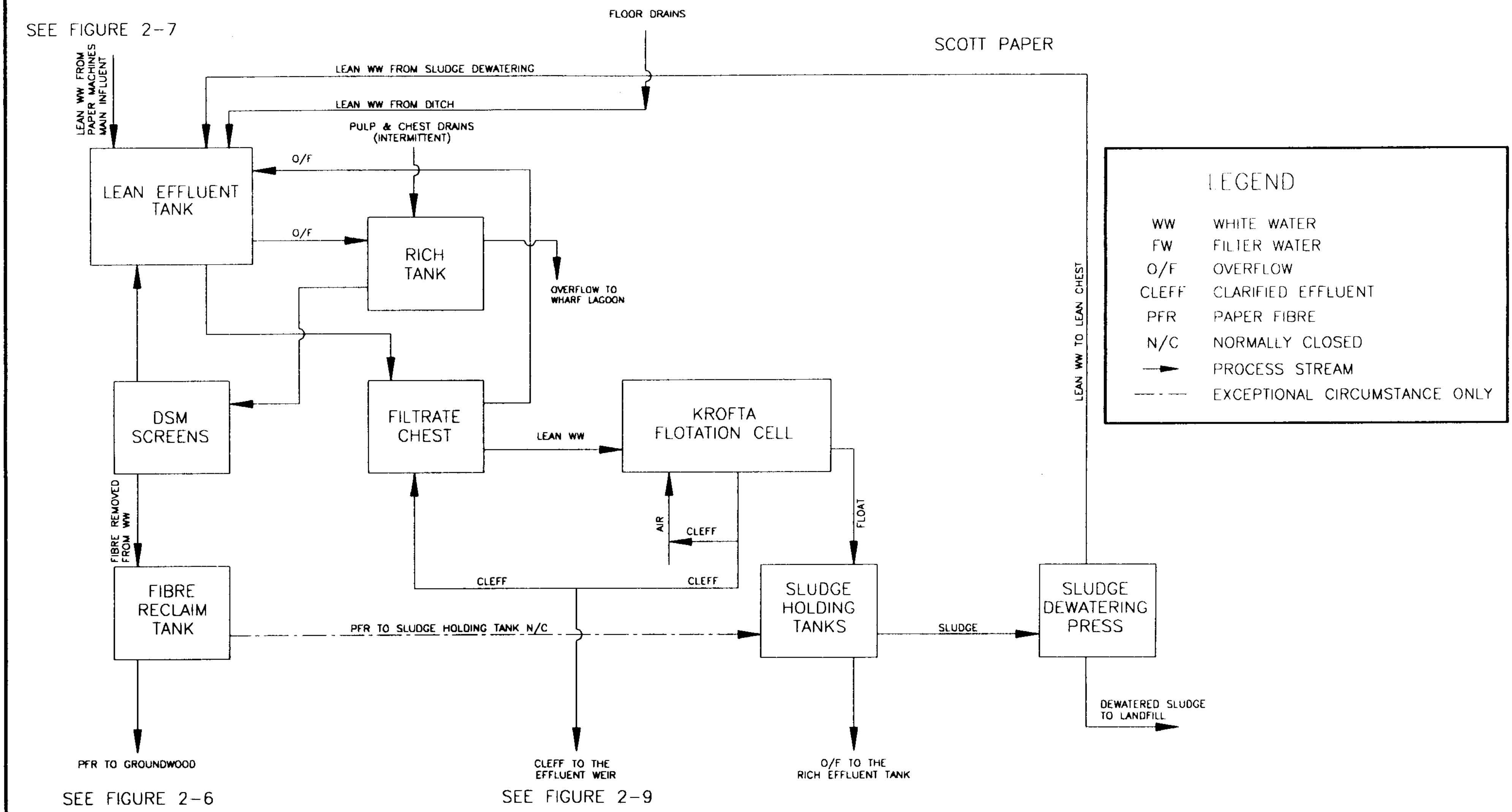
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	05/05/93
Drawn By:	RB
Date:	22/02/93
File:	SCOTT.DWG

FIGURE 2–7
SCOTT PAPER LTD.
PULP TO PAPER SCHEMATIC
FOR WATER FLOW

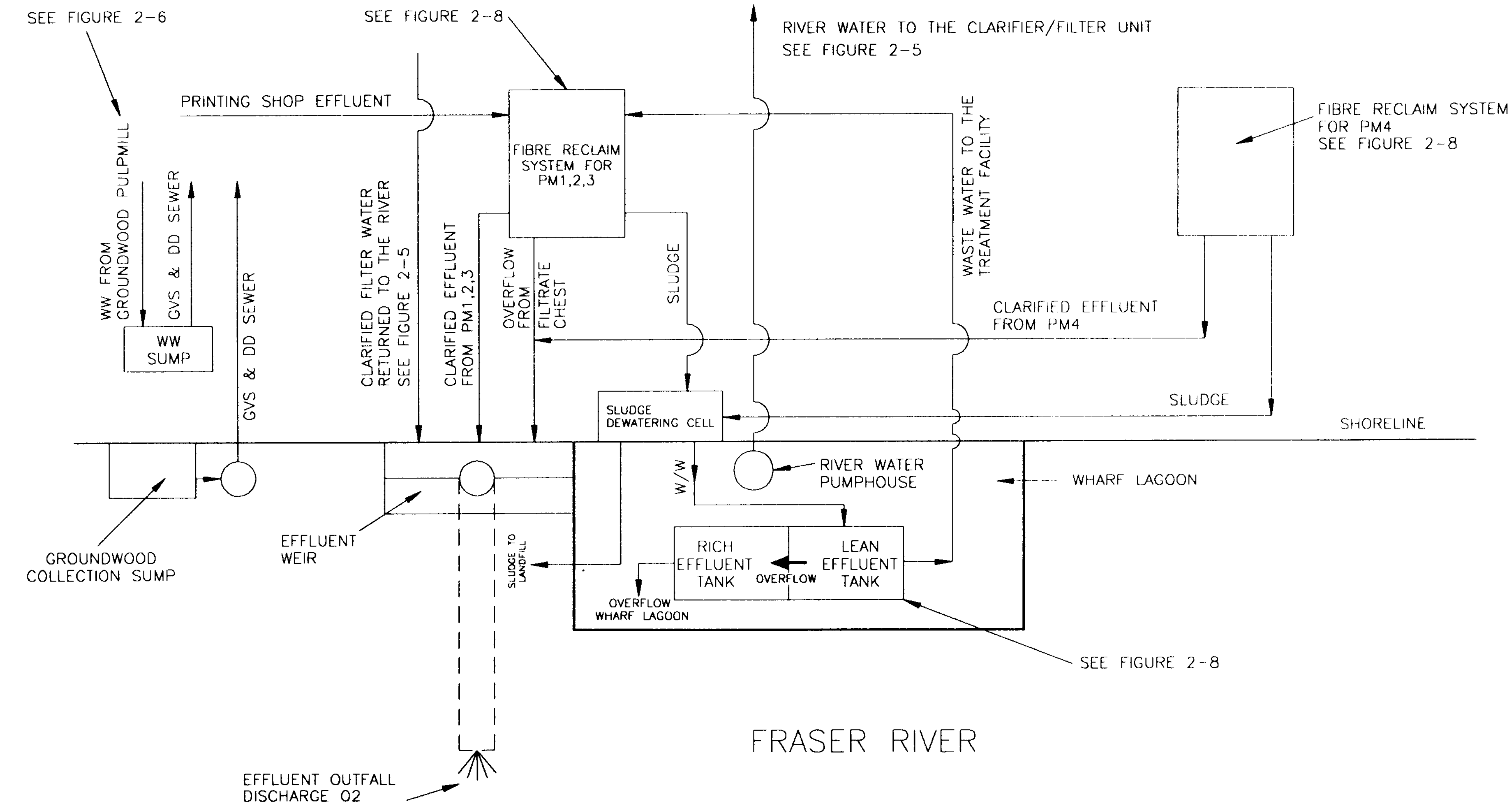
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925–2323
TECHNOLOGY RESOURCE INC.



Date Revised: 05/05/93	
Drawn By: RB	
Date: 22/02/93	
File: SCOTT.DWG	

FIGURE 2-8
SCOTT PAPER LTD.
FIBRE RECOVERY PROCESS
PROCESS SCHEMATIC

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	24/06/93

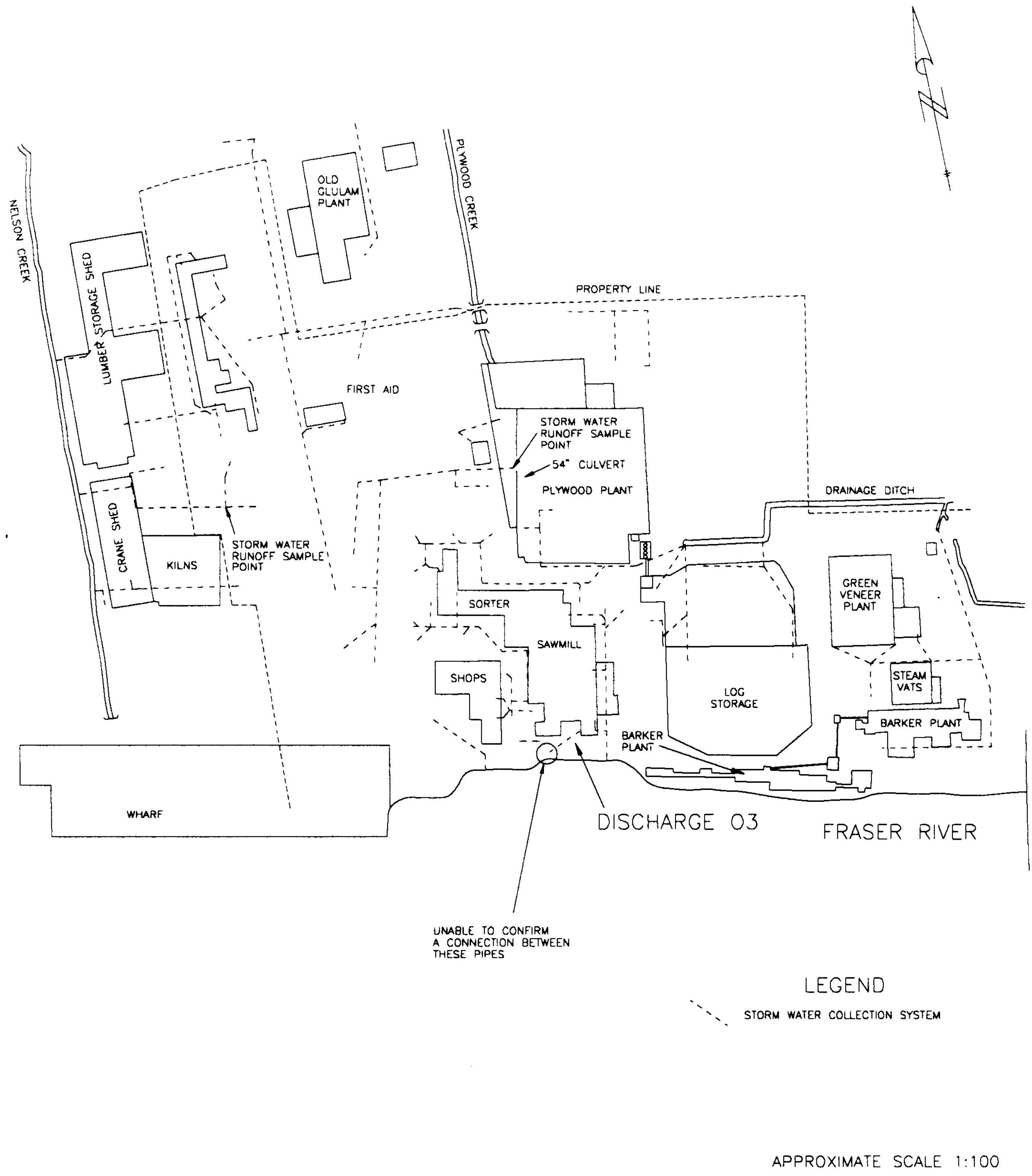
Drawn By: RB

Date: 22/02/93

File: SCOTT.DWG

FIGURE 2-9
SCOTT PAPER LTD.
WASTE WATER COLLECTION AND DISCHARGE SYSTEM

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised: 01/10/93

Drawn By: RB

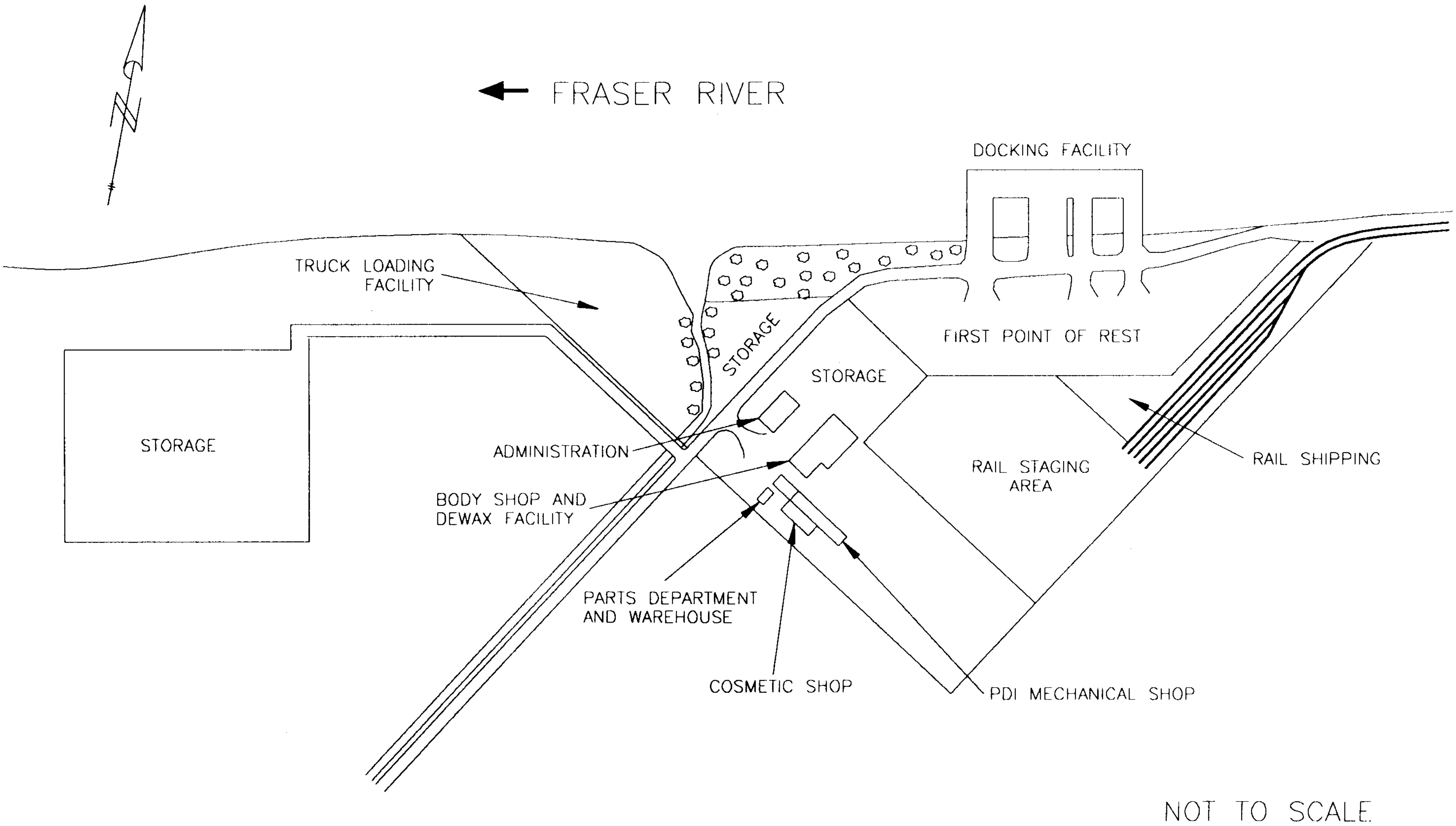
Date: 12/02/93

File: FRASERML.DWG

FIGURE 2-10
IFP FRASER MILLS
SITE PLAN

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

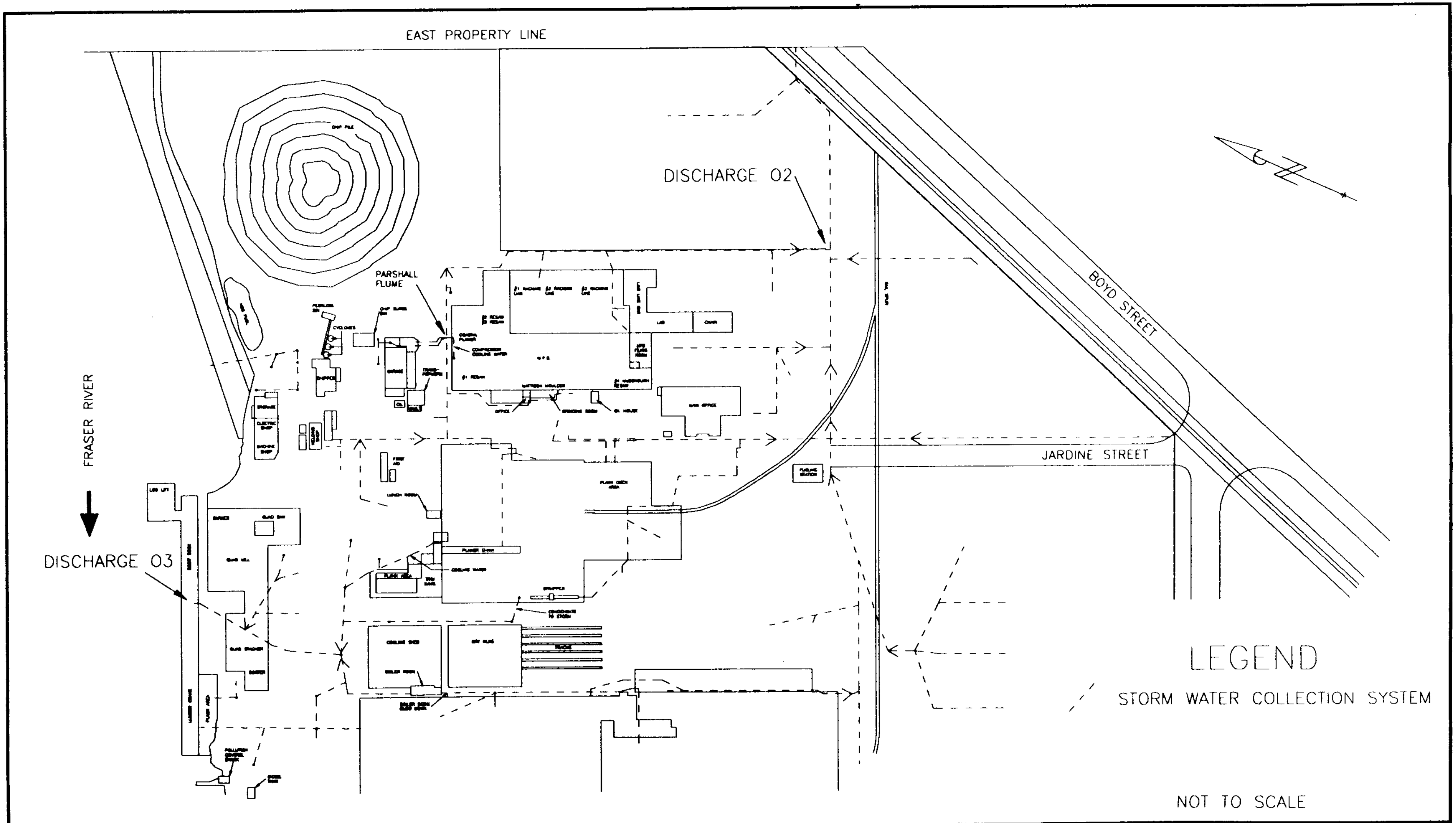
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	
Drawn By: RB	
Date: 30/03/93	
File: FRSRWHF.DWG	

FIGURE 2-11
FRASER WHARVES LTD.
SITE PLAN

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised: 24/06/93

Drawn By: RB

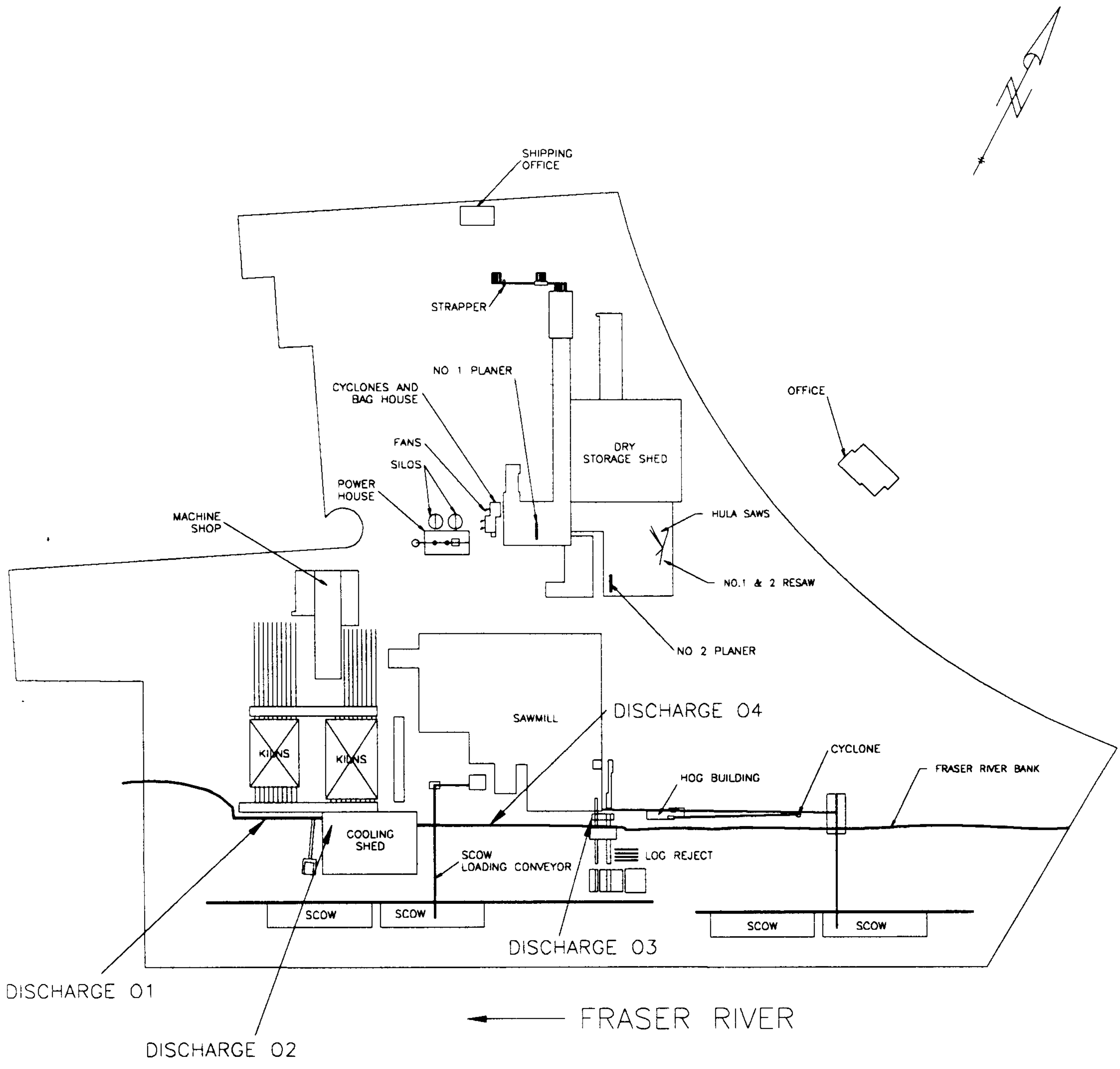
Date: 04/03/93

File: MACBLOST.DWG

FIGURE 2-12 MACMILLAN BLOEDEL NEW WESTMINSTER SITE PLAN

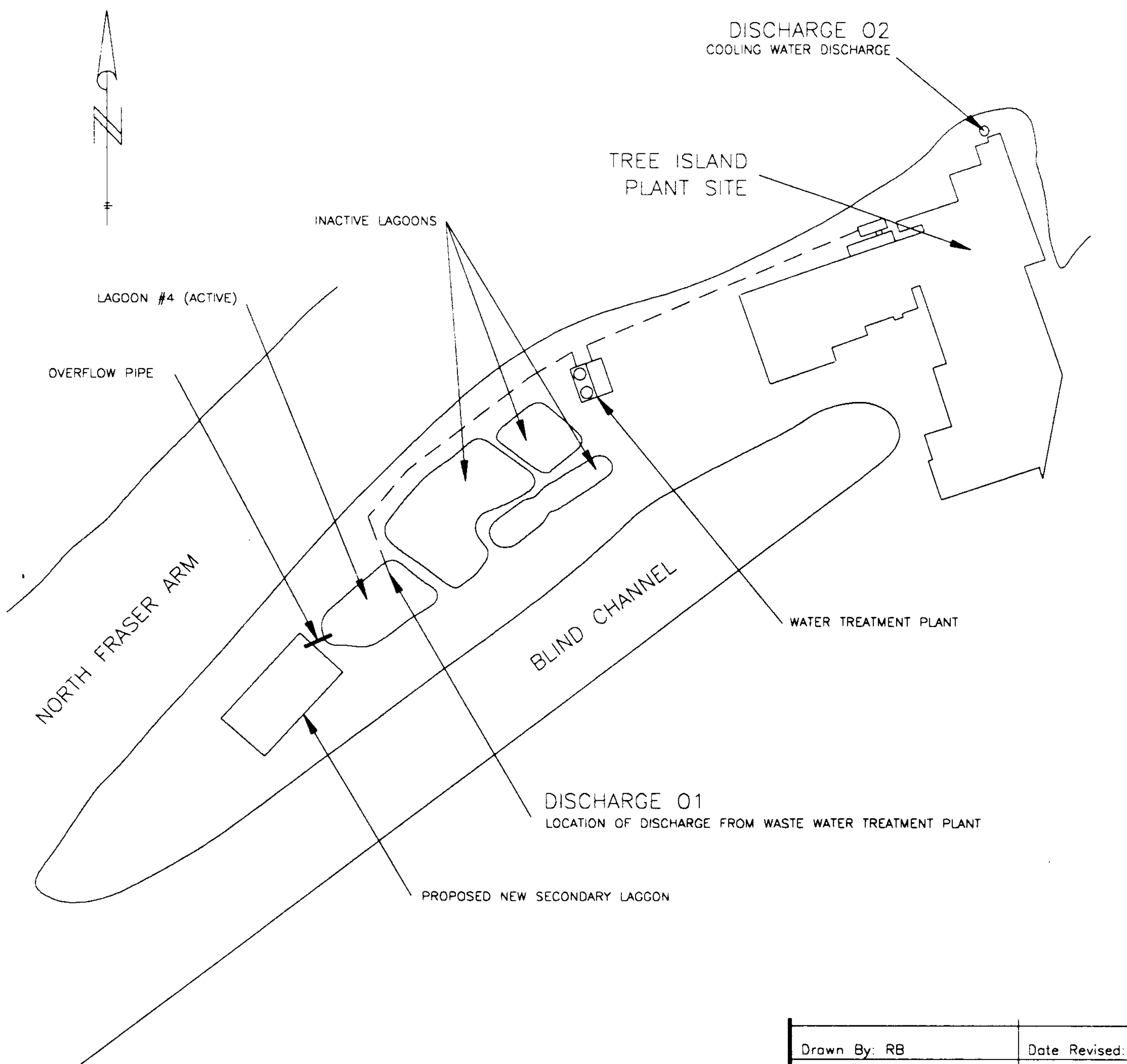
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.



SCALE 1:1100

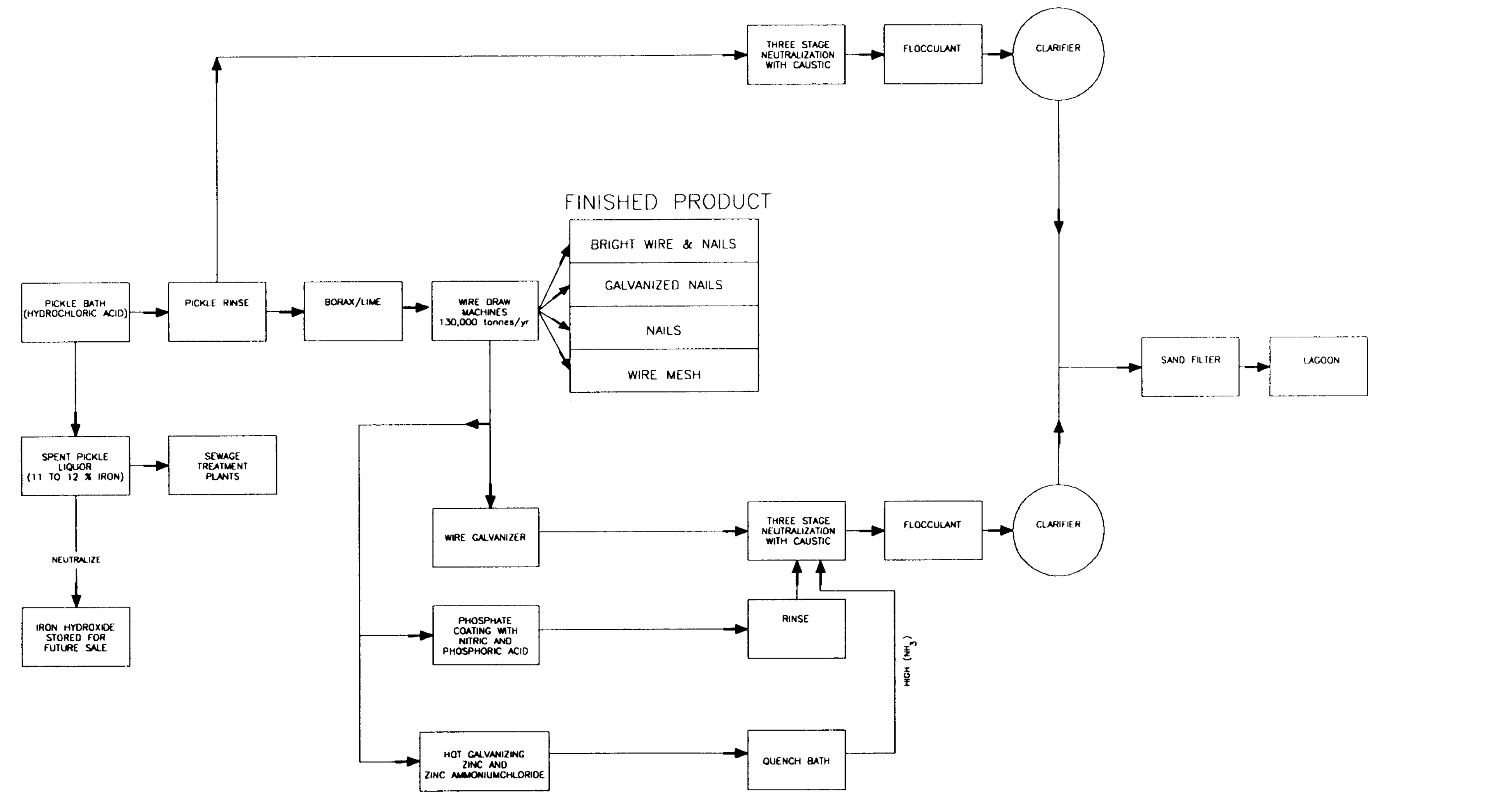
Date Revised: 30/09/93 Drawn By: RB Date: 08/04/93 File: HAMMND.DWG	FIGURE 2-13 IFP HAMMOND SITE PLAN	TRI 502 Kapilano 100 West Vancouver, B.C. V7T 1A2 (604) 925-2323 TECHNOLOGY RESOURCE INC.



Drawn By: RB	Date Revised:
Date: 29/03/93	24/06/93
File: TREESITE.DWG	

FIGURE 2-14
TREE ISLAND
SITE PLAN

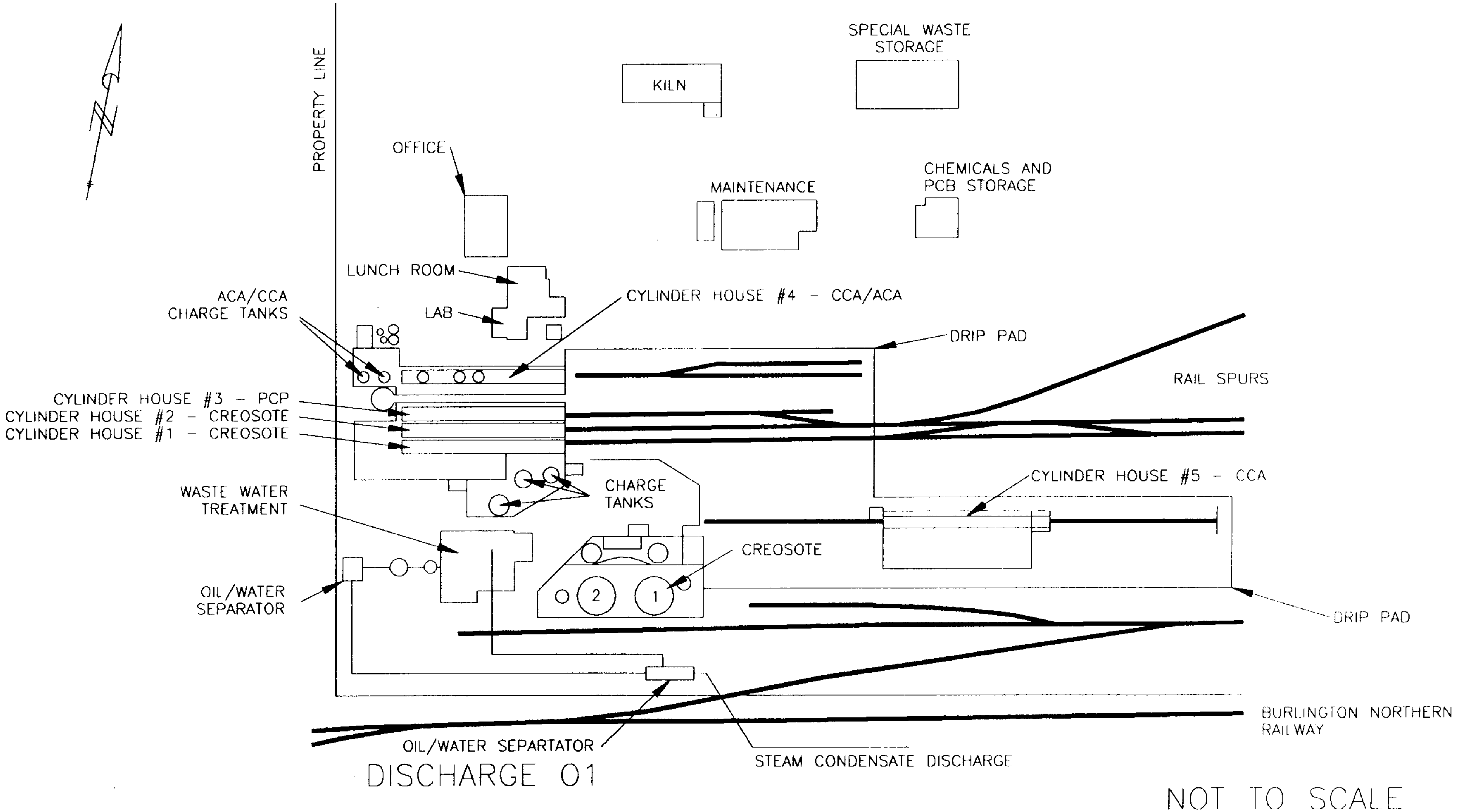
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	28/04/93
Drawn By: RB	
Date: 26/03/93	
File: TREEISLD.DWG	

FIGURE 2-15
TREE ISLAND
PROCESS & WASTE WATER
SCHEMATIC FLOW DIAGRAM

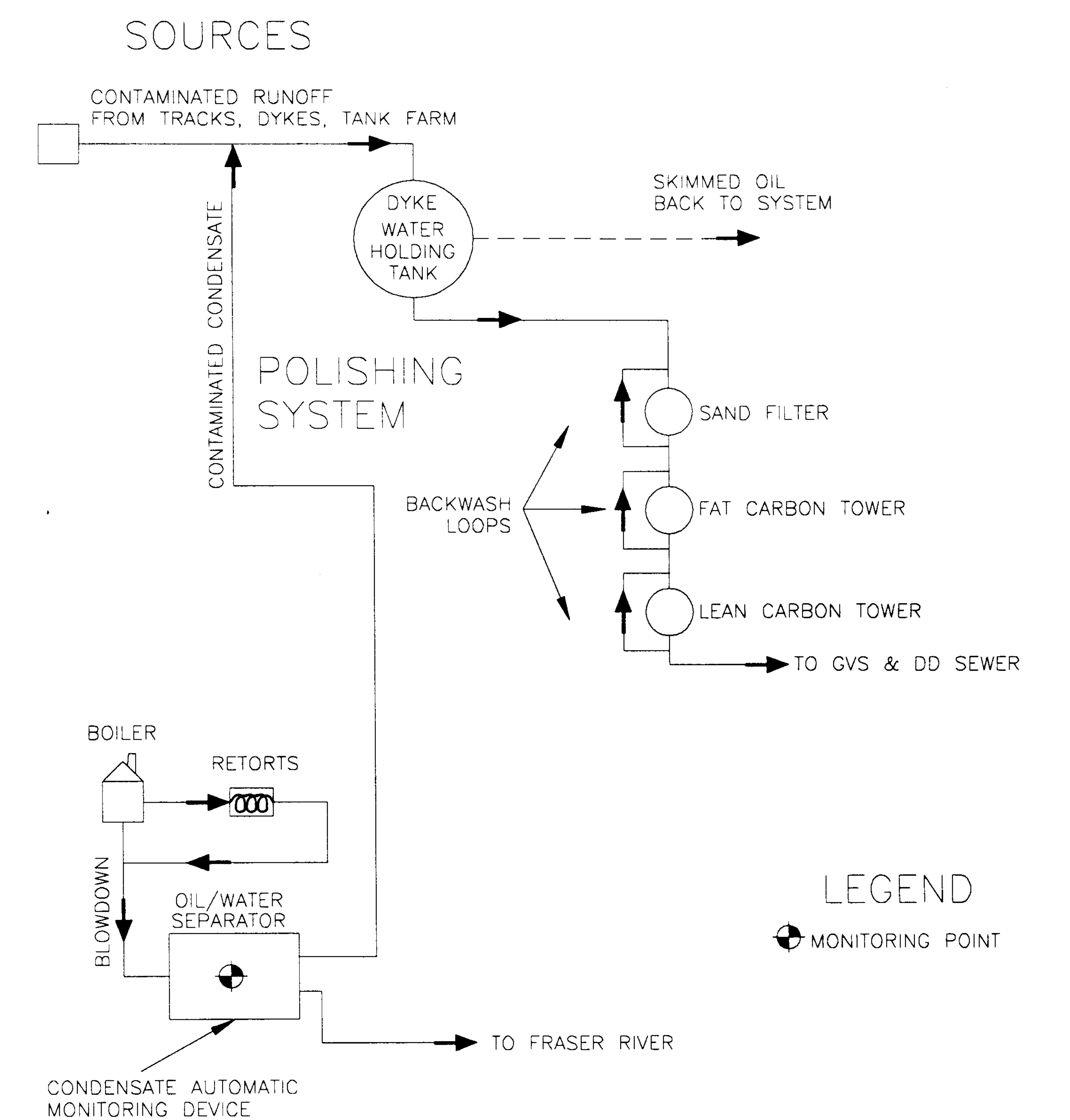
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	31/03/93
Drawn By: RB	
Date: 16/03/93	
File: DOMTAR.DWG	

FIGURE 2-16
DOMTAR CHEMICALS LTD.
DETAILED SITE PLAN

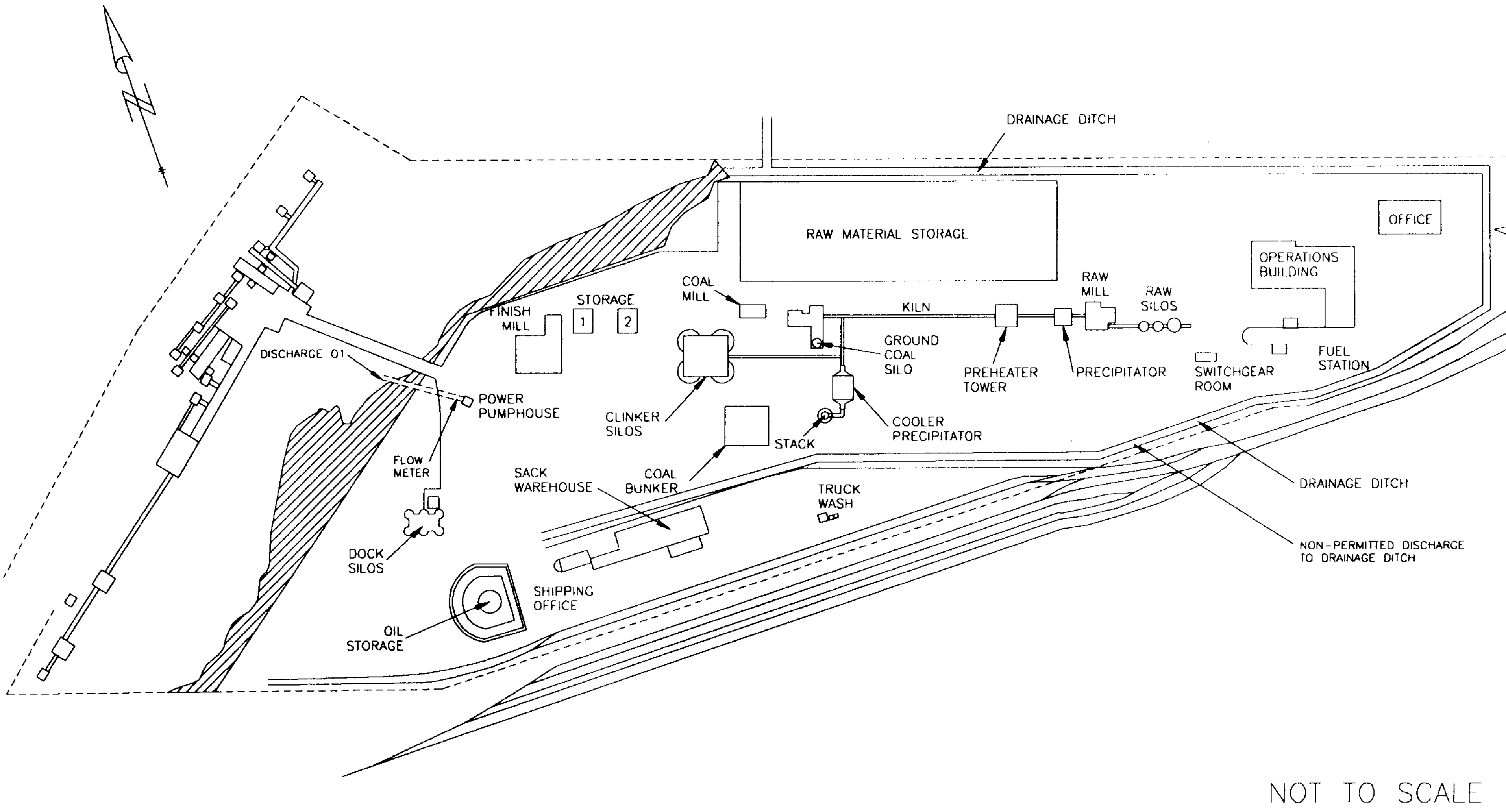
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Drawn By: RB
Date: 31/03/93
File: DOMPRO.DWG

FIGURE 2–17
DOMTAR CHEMICALS LTD
WASTEWATER TREATMENT
SCHEMATIC DIAGRAM

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925–2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	

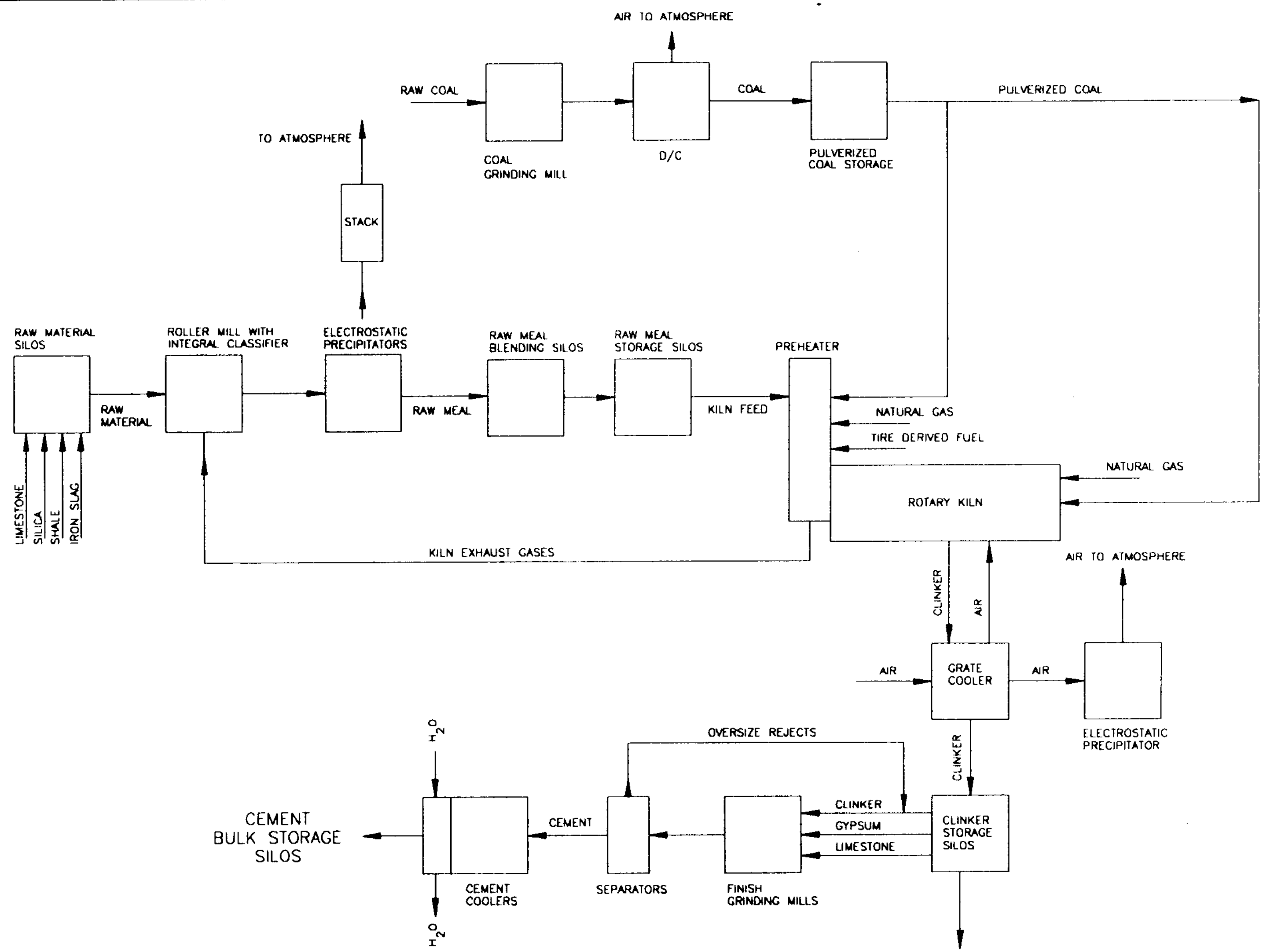
Drawn By: RB

Date: 15/03/93

File: TILBURY.DWG

FIGURE 2-18
TILBURY CEMENT LTD
SITE PLAN

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
15/04/93	

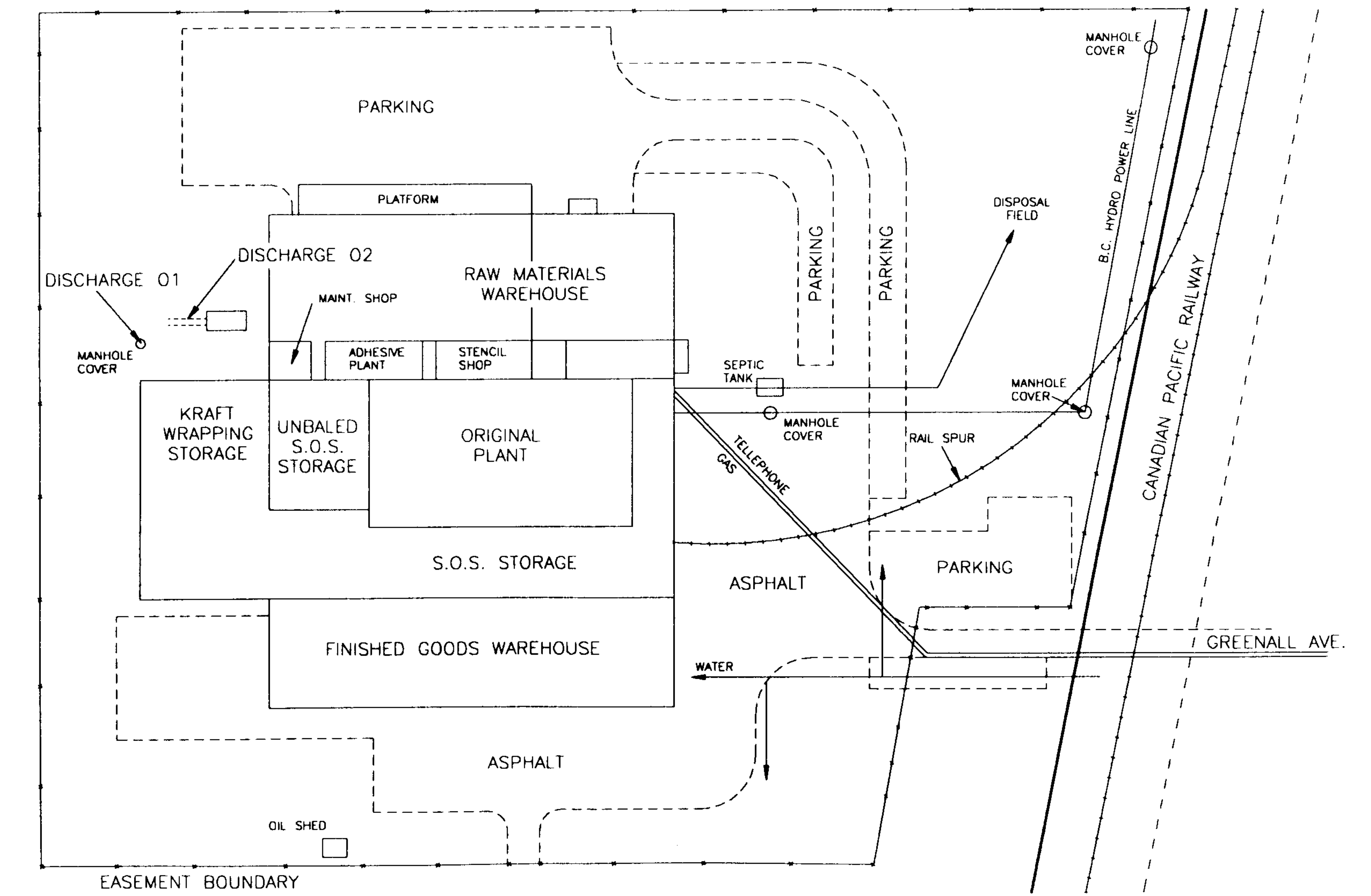
Drawn By: RB

Date: 22/02/93

File: TILPRO.DWG

FIGURE 2-19
TILBURY CEMENT
PROCESS FLOW DIAGRAM

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.

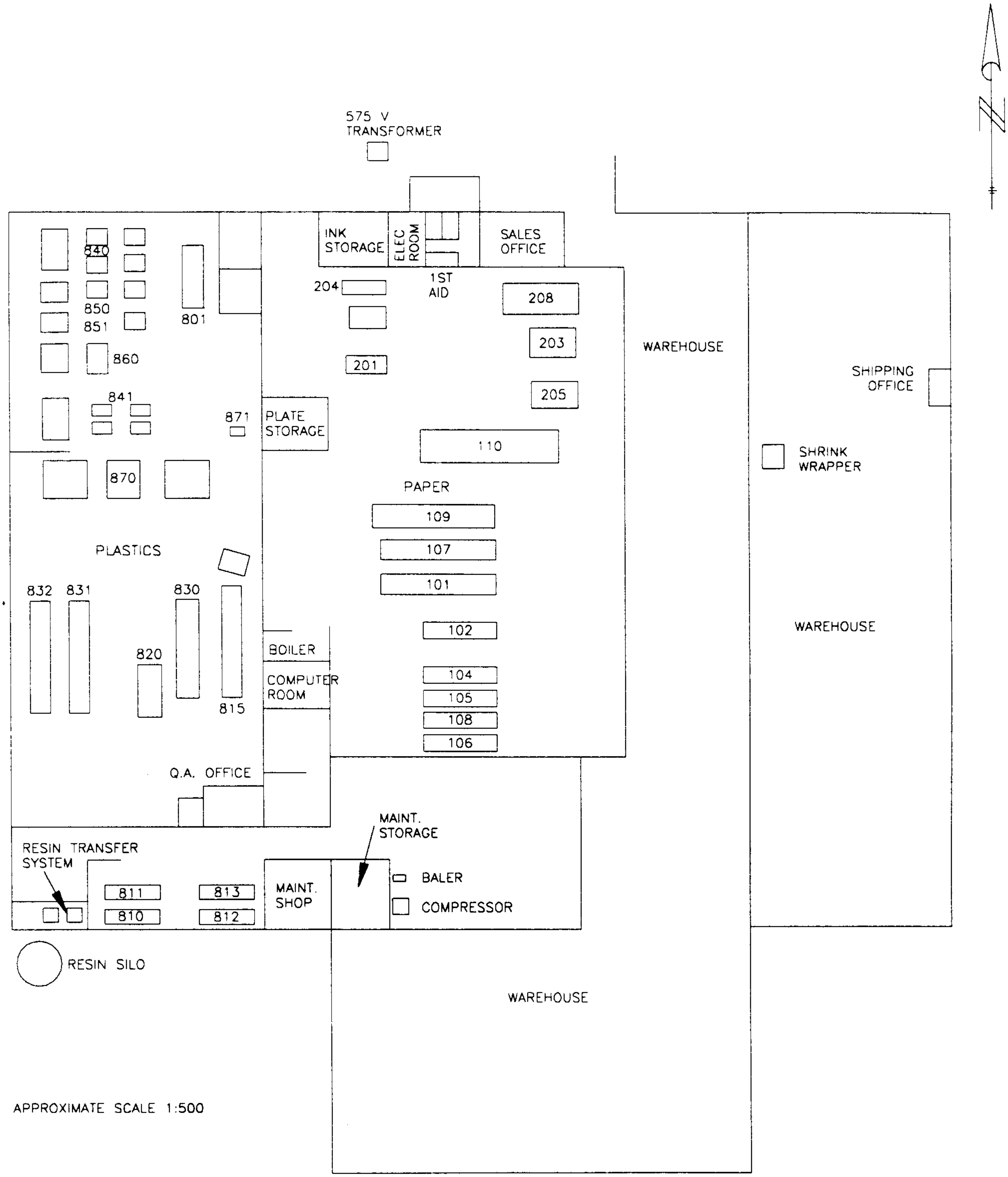


APPROXIMATE SCALE 1:1200

Drawn By: RB	Date Revised:
Date: 25/02/93	01/10/93
File: HILNXSTE.DWG	

FIGURE 2-20
HILINEX PACKAGING
SITE PLAN

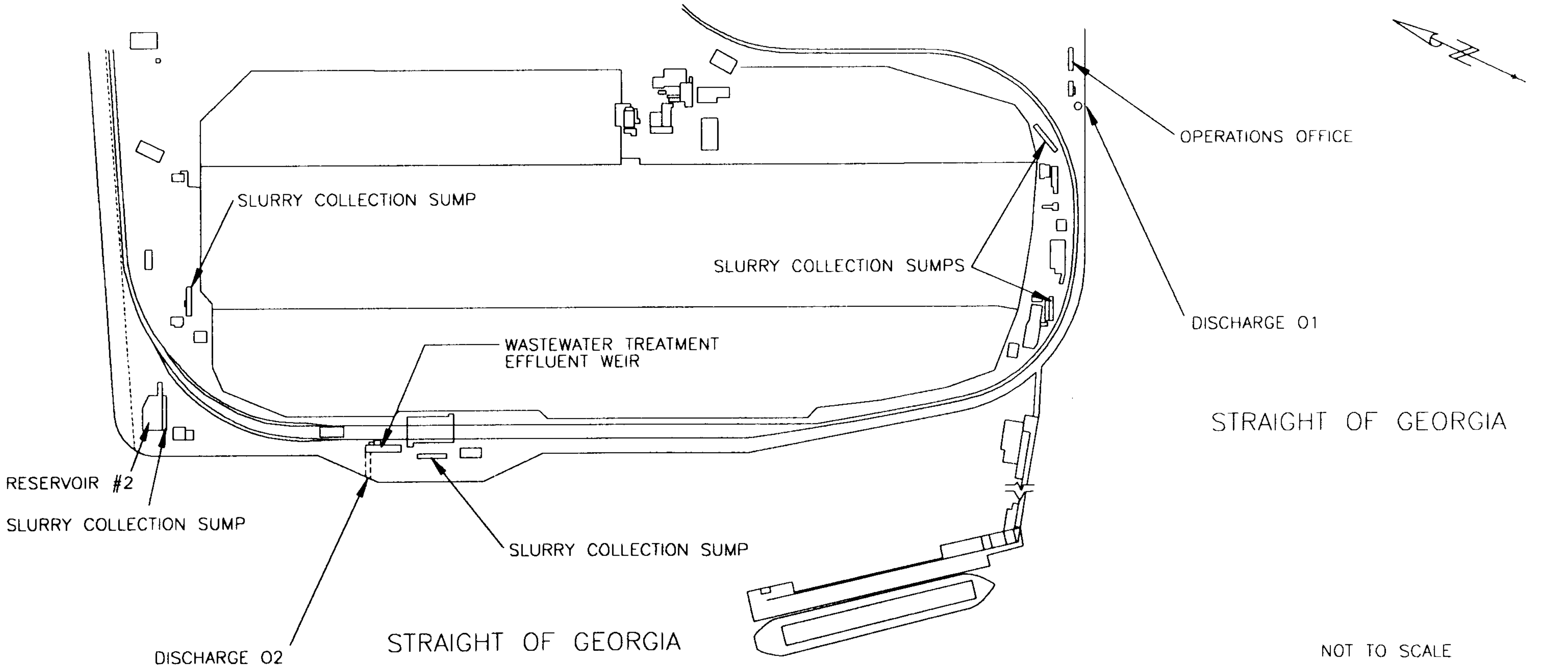
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	31/03/93
Drawn By:	RB
Date:	24/02/93
File:	HILINEX.DWG

FIGURE 2-21
HILINEX PACKAGING LTD.
FACILITY LAYOUT

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
01/10/93	

Drawn By: RB

Date: 16/03/93

File: WESTSHR.DWG

FIGURE 2-22
WESTSHORE TERMINALS LTD.
ROBERTS BANK
SITE PLAN

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.

3.0 METHODS AND PROCEDURES

3.1 Sample Locations

A total of 17 discharges were sampled from the ten industries which participated in this study. Sample collection dates, nomenclature and locations are outlined in Table 3-1. A stormwater sample was collected from Tilbury Cement. In addition to the industrial effluents, two quality control samples were prepared and analyzed. These samples are also shown in Table 3-1. The procedures involved in the preparation of these samples are outlined in Section 3.2. Individual sample locations are indicated on the Figures 3-1 through 3-10, provided at the end of Section 3. Due to budgetary restraints, not all samples could be subjected to toxicity and bio-uptake testing. One discharge per industry was designated as a primary effluent sample and subjected to acute and chronic toxicity tests, as well as bio-uptake analysis. The primary effluent samples are indicated with an asterisk (*) in Table 3-1.

3.2 Sampling Protocol

Primary effluent samples were collected for chemical, toxicity and bio-uptake analyses. The total effluent volume for each primary sample was 800 L on Monday and Friday and 20 L on Wednesday. Additional discharges are termed secondary effluent samples. These samples were collected for chemical analysis only. A total of 20 L of secondary effluent sample was collected. In addition to the above, one stormwater sample was collected at Tilbury Cement. This sample is labelled "Tilbury Storm" in the data tables provided in the appendices.

Primary effluent samples were collected in two types of vessels. On Mondays and Fridays, 800-L samples were collected in four 200-L steel drums. Each drum was fitted with a new (rinsed) polyethylene liner. The drum liner consisted of a form-fitted bag inside the drum and a top cover sheet under the drum lid. Wednesday samples were collected in 20-L plastic jerricans. Secondary effluent samples and/or storm water samples were collected in 20-L plastic jerricans on all occasions.

The polyethylene liners and jerricans were pre-soaked in water from the Capilano River for a period of at least 24 hours prior to sample collection to remove any leachable plasticizers. Immediately prior to sample collection, the drum liners or jerricans were rinsed with effluent.

Sample collection techniques varied from location to location. A submersible electric pump ("Little Giant") with food-grade vinyl tubing was the preferred sample collection method. The submersible pump and tubing were purged with effluent prior to sample collection and transfer. If the sample could not be pumped directly from the sample port or discharge point, a cleaned and rinsed 20-L bucket was used as a collection reservoir. The effluent collected in the buckets was transferred to the drum or jerrican by hand or by using a submersible electric pump. Each container was filled to capacity, leaving no room for air.

Table 3-1: Discharge Numbering and Sample Collection

Sample	Week of	Industry	Discharge Permit		Discharge Type	Sample Volume (L)		
			Permit #	Discharge #		Mon	Wed	Fri
A*	15 Feb	Lafarge Canada	42	02	cooling & storm	600	18	600
B	15 Feb	Lafarge Canada	42	01	cooling & runoff	15	15	15
D*	15 Feb	Scott Paper	335	02	paper mill discharge	800	18	800
E*	22 Feb	IFP Fraser Mills	412	03	cooling & storm	800	18	800
N*	1 Mar	MB New Westminster	1664	02	cooling, boiler, runoff	800	18	800
O	1 Mar	MB New Westminster	1664	03	storm, kiln condensate	15	15	15
G	8 Mar	IFP Hammond Cedar	2756	03	cooling water	15	15	15
H	8 Mar	IFP Hammond Cedar	2756	01/02	kiln condensate	15	15	15
I*	8 Mar	IFP Hammond Cedar	2756	04	boiler blowdown	800	18	800
J	8 Mar	Tree Island Industries	3190	01	process water	15	15	15
K*	8 Mar	Tree Island Industries	3190	02	cooling water	800	18	800
P*	8 Mar	Domtar (Coquitlam)	3410	01	condensate, boiler	800	18	800
L*	1 Mar	Tilbury Cement	4513	01	cooling water	800	18	800
U	1 Mar	Tilbury Cement	4513	none	ditch discharge	15	15	15
Q*	22 Feb	Hilinex Packaging	4962	01	cooling water	800	18	800
M*	1 Mar	Westshore Terminals	6819	02	discharge	800	18	800
T	1 Mar	Westshore Terminals	6819	01	septic	15	15	15
R	15 Feb	dup. sample D			field QA/QC	15	15	15

S	15 Feb	BC Research			water QA/QC	800	18	800

[*] Indicates primary effluent sample, subjected to chemical analysis, toxicity characterization and bio-uptake tests.

After filling, containers were labelled, sealed and transported to B.C. Research (BCR). The sample containers were delivered to BCR within a two to four hour period after collection. At a maximum, the samples remained in the lined drums or jerricans at room temperature for a period of four to six hours prior to transfer to bioassay tanks and other sample containers.
At BCR, each fibreglass fish tank was cleaned and rinsed thoroughly with dechlorinated water just before use (see Subsection 3.6.4). The 800-L samples were transferred from the four lined 200-L drums to separate 800-L semi-circular fibreglass fish tanks. The submersible pump and vinyl tubing which had been used to collect the effluent sample were also used to transfer the four 200-L subsamples from the drums to the tank. To ensure sample homogeneity, the pump was then placed in the tank to circulate the 800-L sample.

Following a few minutes of mixing, aliquots for chemical analysis were withdrawn from the tank and preserved according to the analytical requirements. Samples destined for chemical analysis were collected and preserved as described in Table 3-2. Subsamples for dissolved metals were delivered unpreserved to ASL. Glass sampling containers had been cleaned and baked at 250 C. Plastic sampling containers were made of high density polyethylene and preservation materials were reagent grade.

BCR personnel then withdrew required volumes for the scheduled acute and chronic toxicity tests (see Section 3.4). Two 1-L aliquots were placed in clean high density polyethylene bottles and stored in the dark at 4 ± 2 C until required for the *Daphnia magna* and *Ceriodaphnia dubia* tests[3]. A 25-L sample was transferred directly to a clean glass aquarium and held overnight in the fish-testing laboratory at 15 ± 1 C in preparation for the 96-h LC50 with rainbow trout (see Section 3.4). The remainder of the sample in the tank (~775 L) was held, un-aerated, in a separate fish-testing facility until used in a bio-uptake study with juvenile rainbow trout (see Section 3.5).

Samples collected in 20-L jerricans were homogenized by inverting the container several times. Sample aliquots for chemical analyses were poured from the jerricans to the appropriate containers and preserved as required. A subsample was also withdrawn for determination of pH, dissolved oxygen content (DO) and conductivity. Two 1-L subsamples were placed in separate 1-L plastic bottles and stored in the dark at 4 ± 2 C until required the next day for the *Daphnia magna* and *Ceriodaphnia dubia* tests.

[3]These subsamples were used for toxicity tests with *Daphnia magna* and *Ceriodaphnia dubia* starting the next morning.

Table 3-2: Sample Collection and Preservation for Chemical Analysis

Analytical Parameter	Sample Container	Preservation
Physical parameters (TSS, DO, nitrate + nitrite, NH_3, nitrite, BOD_5, alkalinity)	1 x 1 L plastic	none
Phenol	1 x 250 mL glass	H_2SO_4
Oil & Grease	2 x 500 mL glass	HCl
Total Metals	1 x 250 mL plastic	HNO_3
Dissolved Metals	1 x 250 mL plastic	filter + HNO_3*
Dioxin and Furan	1 x 1 L glass	none
PAH	1 x 1 L glass	none
Resin Acids	1 x 1 L glass	none
CP, chloroguaiacols, chlorocatechols	1 x 1 L glass	none
TCMTB	1 x 1 L glass	100 mL DCM in 900 mL sample
Cu-8	1 x 1 L glass	100 mL DCM in 900 mL sample
DDAC	1 x 500 mL plastic	

* Filtration and preservation done at ASL.

3.3 Methods for Chemical Analysis

When the samples were delivered to the lab, they were catalogued against field submission forms and kept cool until analyzed. Samples for dissolved metals were filtered and preserved immediately upon arrival at ASL. All analyses were carried out within the standard holding time. Prior to analysis, the samples were shaken to ensure representative sub-sampling. As part of the bio-uptake study, frozen samples of tissue were submitted for analysis. Prior to analysis, samples were thawed and blended using a high-speed laboratory tissue blender. The blender was cleaned between each sample with several solvents and water. Homogenization method blanks were also prepared to monitor for introduction of contaminants and cross-over contamination.

Analytical parameters varied depending on industry type and the waste stream sampled. ASL provided the required sample-collection kits, complete with coolers, sample bottles, deionized water, sample log-in sheets and the required preservation solutions. A list of the chemical analysis preformed on each discharge is provided in Table 3-3. Details regarding analytical methods and equipment are provided in Appendix II.

3.4 Methods for Toxicity Analysis

3.4.1 Tests with *Daphnia magna*

The acute lethal toxicity of each primary effluent sample collected on Mondays, Wednesdays and Fridays (*ie:* three samples per industrial site) was determined using *Daphnia magna* as test organisms. This species of freshwater invertebrate is used routinely for acute lethality tests and is recognized by federal and provincial scientists as a standard test organism for this purpose. The test method followed was that developed by Environment Canada (1990a, 1990b). In particular, the procedures specified in Environment Canada (1990b) for evaluating the acute toxicity of effluent samples were adhered to without exception, as were other test specifics identified in the document as universal (including QA/QC) test procedures.

Table 3-3: Parameters for Chemical Analysis

#	Nit	TSS	BOD_5	Alk	O&G	Metals	Dioxin	PAH	Phenol	RA&FA	CP	Sap
A	T	T	T	T	T	T						
B	T	T	T	T	T	T						
D	T	T	T	T	T	T	T	T	T	T	T	
E	T	T	T	T	T	T						
G	T	T	T	T	T	T						
H	T	T	T	T	T	T						
I	T	T	T	T	T	T	T	T	T	T	T	T
J	T	T	T	T	T	T						
K	T	T	T	T	T	T						
L	T	T	T	T	T	T						
M	T	T	T	T	T	T		T				
N	T	T	T	T	T	T	T	T	T	T	T	T
O	T	T	T	T	T	T	T	T	T	T	T	T
P	T	T	T	T	T	T	T	T	T	T	T	T
Q	T	T	T	T	T	T	T	T	T	T	T	
R	T	T	T	T	T	T	T	T	T	T	T	T
S	T	T	T	T	T	T	T	T	T	T	T	T
T	T	T	T	T	T	T						
U	T	T	T	T	T	T						

Nit=nitrate, nitrite and ammonia, TSS=total suspended solids, BOD_5=biochemical oxygen demand, Alk=alkalinity, O&G=oil & grease, PAH=polyaromatic hydrocarbons, RA&FA=resin and fatty acids, CP=chlorophenol, Sap=antisapstain chemicals

The toxicity tests with *Daphnia magna* were normally started within 24 h of sample collection and all tests were initiated within 72 h of collection. Sample pre-treatment included adjustment for hardness (to 25 ± 5 mg/L) for those samples with hardness values less than 25 mg/L (Environment Canada, 1990b)[4]. Effluent samples were not normally pre-aerated, although this was done according to Environment Canada (1990b) in those instances where sample DO was less than 40% saturation or greater than 100% saturation following warming of the samples to the test temperature. No adjustments were made for sample pH.

For each effluent sample, the following concentrations were prepared using *D. magna* culture water (hardness, ~120 mg/L) as the dilution and control water: 100%, 50%, 25%, 12.5%, 6.3%, 3.2%, 1.0% and 0.0% (control). Ten neonate daphnids were exposed to each test solution for 48 h, under static conditions (*i.e:* no replacement of solutions during the test). Test temperature was 2 ± 1 C. Observations of unusual behaviour (*e.g.*, immobility or circling) in each test solution were made during each assay. Additional observations included routine measurements of pH and DO concentrations in each solution at the beginning and end of the test. Zinc (as reagent-grade zinc sulphate) was used as a reference toxicant for the test (Environment Canada, 1990a, 1990b). Additional control and blank tests were performed with *Daphnia magna*, as detailed in Subsection 3.6.2. Further information regarding culture and test conditions and procedures used routinely by BCR for acute lethality tests with *Daphnia magna* are given in Appendix III.

The biological endpoint for each test was the number (and percentage) of daphnids which died in each test solution during the 48-h exposure. These data were used to estimate the 48-h LC50 (median lethal concentration). As recommended in Environment Canada (1990a), the computer programs of C.E. Stephan (U.S. Environmental Protection Agency; Duluth, MN) were used for calculating the 48-h LC50 and its 95% confidence interval. Acute Toxic Units (ATU)(McLeay *et al.*, 1987) were calculated to provide a measure of acute toxicity that was related directly to concentration of toxicants. Data permitting, Acute Toxicity Emission Rates (ATER) were also calculated. Details regarding these terms and their calculation are given in Section 4.3.

3.4.2 Tests with Rainbow Trout

---

[4]*Daphnia magna* is found naturally only in hard water, and the acute survival of this species in wastewater samples with low hardness values might be reduced due to hardness alone. A separate series of tests was conducted to assess the effect of water hardness (within the range 25 mg/L to 120 mg/L) on the tolerance of *D. magna* (see Subsection 3.6.2.3).

Each primary effluent sample collected on Monday and Friday was tested for its acute lethality using rainbow trout (*Oncorhynchus mykiss*). The primary purpose for this series of tests was to provide guidance in selecting concentrations for use in the 8-day bio-uptake studies with this fish species (Section 3.5). Additionally, use of this test method provided further information regarding the acute toxicity of each effluent sample. The acute (96-h) lethality test with rainbow trout is used routinely in Canada and elsewhere for appraising the toxicity of effluent samples.

The generic (Environment Canada, 1990c) and effluent-specific (Environment Canada, 1990d) documents published by Environment Canada, which describe conditions and procedures to be followed in performing acute lethality tests with rainbow trout, were adhered to in this study. The "standard operating procedure" used by BCR for static 96-h LC50s with rainbow trout is provided in Appendix IV.

Each sample evaluated in this test was adjusted on the day of collection or overnight to the test temperature (15 ± 1 C), then pre-treated (as required) for low DO (Environment Canada, 1990c, 1990d). Sample pH was not adjusted.

All trout toxicity tests were initiated as soon as possible following sample collection[5]. For each effluent sample, the following concentrations were prepared, using dechlorinated municipal water as the dilution (and control) water: 100%, 56%, 32%, 18%, 10% and 0.0% (control). The four samples of dechlorinated water (S-1, S-3, S-4, S-5), held in 200-L polyethylene-line barrels for a few hours before use in control/blank tests for the bio-uptake study (see Subsection 3.6.2.6), were also examined for lethal or sublethal toxic effects on rainbow trout. The standard test method for measuring acute toxicity of samples to rainbow trout (Environment Canada, 1990c) was used to evaluate these control/blank samples.

Ten underyearling (swimup fry or young fingerling) trout were exposed to each test concentration, under static conditions (no solution replacement) for 96 h (4 days). Fish were observed daily for mortalities and signs of distress (Environment Canada, 1990c) and any dead fish were removed. Additional observations included routine measurements of pH and DO concentrations in each solution at the beginning and end of the test. Phenol (analytical grade) was used as a reference toxicant for the test (Environment Canada, 1990c, 1990d).

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[5]Trout LC50s were started within 4 to 16 h of sample collection. Use of samples in the trout bio-uptake test was delayed for the minimum period (24 to 48 h) required to obtain preliminary information regarding the acute toxicity of the sample to this fish species. Based on the observations of fish mortalities or signs of stress in each concentration at 24 h, a decision was made regarding the concentration of the sample to be used in the bio-uptake test (see Section 3.5).

The biological endpoint for each toxicity test with trout was the number (and percentage) of fish which died in each test solution during the 96-h exposure. These data were used to estimate the 96-h LC50. As recommended in Environment Canada (1990c), the computer programs of C.E. Stephan (U.S. Environmental Protection Agency; Duluth, MN) were used for calculating the 96-h LC50 and its 95% confidence interval.

3.4.3 Tests with *Ceriodaphnia dubia*

The freshwater daphnid invertebrate *Ceriodaphnia dubia* was used to measure the chronic toxicity of primary effluents from each industrial site studied. The test method was that initially developed by the U.S. Environmental Protection Agency (EPA, 1989) as a rapid (7 ± 1 days) test for assessing the chronic toxicity of samples of effluent or receiving water. Further development and standardization of this biological test method by Environment Canada resulted in the approved Federal procedure (Environment Canada, 1992) which was followed for this test program. Details regarding the conditions and procedures used by B.C. Research in culturing these daphnids and performing this test are given in Environment Canada (1992) and in BCRs "standard operating procedure" (see Appendix V).

For this test, the combined influence of the three samples of primary effluent collected on a Monday, Wednesday and Friday at each site investigated (*ie:* three samples per industrial site) on *Ceriodaphnia dubia* was determined. An aliquot of the large-volume (800 L) sample collected on a Monday was used for Days 1 and 2 of the test; an aliquot of the small-volume (20 L) sample collected on a Wednesday was used for Days 3 and 4 of the test; and an aliquot of the 800-L sample collected on a Friday was used for Days 5, 6 and 7 (as necessary)[6] (Environment Canada, 1992)[7]. The test was initiated within 24 h of sample collection.

For each effluent sample, the following concentrations were prepared, using *C. dubia* culture water (hardness, ~50 mg/L) as the dilution (and control) water: 100%, 50%, 25%, 12.5%, 6.3%, 3.2%, 1.0% and 0.0% (control). For each concentration, ten replicate solutions were prepared and a single neonate daphnid transferred to each replicate. Each test solution (including the 10 replicate controls) was renewed daily throughout the test period, using the appropriate effluent sample (see previous paragraph). Test temperature was 25

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[6]The duration of this test is 7 ± 1 days. The test is continued until at least 60% of the first-generation daphnids in the control solutions have produced three broods (Environment Canada, 1992).

[7]See Section 3.2 for further information regarding sample collection, handling, subsampling, and storage.

± 1 C (Environment Canada, 1992). Unused portions of subsamples for this test, stored at 4 ± 2 C, were warmed to the test temperature just before use. Effluent samples were not normally pre-aerated, although this was done according to Environment Canada (1992) in those instances where sample DO was greater than 100% saturation following warming of the samples to the test temperature. Sample pH was not adjusted.

Additional control and blank tests were performed with *Ceriodaphnia dubia*, as detailed in Subsection 3.6.2. Reagent-grade sodium chloride was used as a reference toxicant for this test (Environment Canada, 1992).

Each day throughout the test, the first-generation daphnids were observed and the number (and percentage) of mortalities recorded for the ten replicate solutions. The number of live young produced by each first-generation daphnid in each replicate solution was also determined and recorded daily. Following these observations, all surviving first-generation daphnids were transferred to fresh solutions (same concentration) each day. Observations of solution pH and DO were made daily, in the high, medium and low concentrations and in the control, at the beginning and end of each 24-h period (Environment Canada, 1992).

The following statistical endpoints were calculated for this test (Environment Canada, 1992): 6- or 7-day LC50, NOEC, LOEC, TEC and IC25 (see Terminology for definition of each endpoint). The computer program "TOXSTAT" was used to derive the no-observed-effect concentrations (NOECs) and lowest-observed-effect concentrations (LOECs). The program "BOOTSTRP" was used to determine IC25 and its 95% confidence limits (Environment Canada, 1992). The threshold-effect concentration (TEC) was calculated as the geometric mean of NOEC and LOEC. The computer programs of C.E. Stephan (U.S. Environmental Protection Agency; Duluth, MN) were used for calculating the LC50 and its 95% confidence interval.

Using the derived IC25s, Chronic Toxicity Units (CTU) were calculated for the primary effluent streams studied. These values, together with the estimated mean discharge rate of the effluent streams during the study period, were used to calculate the Chronic Toxicity Emission Rate (CTER).

3.5 <u>Methods for Bio-Uptake Study</u>

3.5.1 Study Design

The current fish bio-uptake tests were designed to provide comparative data regarding the bioavailability and accumulation of specific aquatic contaminants in selected industrial wastewaters. As such, it was imperative that conditions for each fish-exposure study with each wastewater source be standardized; that the biological procedures and associated tissue analyses employed be practical, manageable and appropriate; and that they meet acceptable criteria regarding quality assurance and quality control. The bio-uptake study was designed in consideration of the wet-tissue requirements for the selected chemical analyses, together with the associated fish biomass and effluent-volume requirements, and time and budgetary constraints.

Fish weighing approximately 90 grams (wet weight) were targeted for the fish bio-uptake study. Based on preliminary dissections, it was determined that four fish of this weight would provide enough muscle tissue for the intended chemical analyses. This biomass (~360 grams of fish per tank) dictated a requirement for ~800 litres of sample/solution for each four days of the test. Such a large volume of effluent was considered necessary to provide an acceptable fish-loading density of approximately 2 litres wastewater or dilution thereof per gram fish over four days (Environment Canada, 1990c). Although more manageable, a higher loading density could allow for the significant and variable depletion of effluent constituents by the fish during the exposure,
and the lack of comparable results from test to test. Such a compromise was considered unacceptable for the present experiment.

Given the foregoing limitations, the study was limited to an examination of the bioaccumulation of selected contaminants in fish (rainbow trout) muscle tissue. However, the livers of exposed fish were dissected (Subsection 3.5.3), and stored at -20 C for possible micro-analyses of certain contaminants[8].

3.5.2 Exposure Conditions and Procedures

All primary industrial discharges included in this research program were evaluated in eight-day bio-uptake tests with juvenile rainbow trout. For each of the primary effluents studied, the large-volume (800-L) samples taken on Monday and Friday were used for assessing the bio-uptake of selected contaminants in fish muscle tissue. The Monday samples were used for Days 1 to 4 of the exposure, and the Friday samples for Days 5 to 8 of the exposure (see Section 3.2 for additional information). Two control/blank tests were included as part of the bio-uptake tests (see Subsection 3.6.2.6). Conditions and procedures for these control/blank tests were identical to those for the bio-uptake tests with effluent samples.

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[8]Liver tissue comprises approximately 1% of the whole-body wet weight of fish. In order to preserve adequate limits of detection for metals, chlorinated phenolic compounds, and PAHs, analysts at ASL estimated a wet-tissue requirement of ~100 to 150 g per (composite) sample. This equates to 10 - 15 kg of whole fish if sufficient quantity of liver were to be obtained. Even with restrictive analyses of liver tissue, the quantity of liver tissue required (and associated effluent volume requirements) was considered to beyond the limitations of this test program. However, the stored liver tissue from fish exposed to primary effluents in this bio-uptake study is being held at -20EC for a limited period of time, in the event that certain analyses of this tissue may be feasible and required. Such analyses are beyond the scope and budget for this project.

Before use in the bio-uptake tests, each composite sample (~775 L) was held in a clean 800-L capacity fibreglass fish tank until preliminary results of the fish-toxicity test were available (see Subsection 3.4.2). The effluent was not aerated during this period in order to minimize sample detoxification during storage. Each tank was covered with black plastic to prevent sample contamination and photodegradation. Air temperature within the facility housing these tanks was regulated at 15 ± 1 C (the temperature used for the fish bio-uptake and toxicity tests). Fish were exposed to each large-volume effluent sample within 48 h of collection.

Based on the observations of fish mortalities or signs of distress in each sample concentration, after the initial 24-h period of exposure of the 96-h LC50 test (Subsection 3.4.2), a decision was made regarding the concentration of the sample to be used in the bio-uptake test. If all fish were alive and no signs of distress were evident, the juvenile trout used in the bio-uptake test were exposed to undiluted (100%) sample. If, on the other hand, adverse effects on the (underyearling) trout were evident at 24 h in the 100% or lower concentrations, the highest concentration showing no overt (lethal or sublethal) toxic effects was selected for the bio-uptake test. Any required dilutions of sample were made using dechlorinated Vancouver City tap water.
Concentrations of effluent to which fish were exposed in each bio-uptake test are shown in Table 3-4.

Table 3-4: Concentrations of Sample to Which Juvenile Rainbow Trout Were Exposed During 8-Day Bio-Uptake Tests

Sample Code	Sample Conc'n (%) For Days 1 to 4	Sample Conc'n (%) for Days 5 to 8
S	100	100
A	100	100
D	100	100
E	50	50
Q	100	30
L	100	100

M	30	100
N	50	50
K	100	100
I	100	100
P	100	100
S	100	100

Just before starting exposure of juvenile trout to a particular effluent sample (or dilution thereof), sample temperature was measured and, if required, adjusted to attain the test temperature (15 ± 1 C). Sample DO was then measured. Effluent samples with a dissolved oxygen content <70% or >100% of air saturation were pre-aerated for no more than 120 minutes, at a rate of 7.5 mL / min / L (Environment Canada, 1990c). If DO was within the range 70% to 100%, no pre-aeration of sample was provided. Oil-free compressed air was bubbled into each tank through a commercial (aquarium-supply) airstone, which was weighted with stainless steel nuts. All pre-aerated samples reached DO saturation within 120 minutes. During the bio-uptake tests, each test solution was aerated continuously at a rate of 6.0 mL / min / L.

For purposes of this bio-uptake study, a population of hatchery-reared juvenile rainbow trout was obtained from Sun Valley Trout Farms (Langley, B.C.) on February 9, 1993. Individual fish weighed between 60 and 120 g. These fish were held at B.C. Research in an outdoor circular fibreglass tank (capacity, 10,000 L). This tank received a continuous flow of dechlorinated municipal water, tempered to the test temperature (15 ± 1 C). Holding conditions, including fish loading densities and water replacement rates in the tank, were within the limits specified in Environment Canada (1990c). Fish were fed daily (minimum ration of commercial pelleted fish food) during the holding / acclimation period before their use in the bio-uptake tests.

To initiate a bio-uptake test, four fish were selected from the outdoor holding tank, and transferred quickly to the indoor test tank using a clean transfer pail and control / dilution water. The 800-L tank was then covered with a frame consisting of clear and black polyethylene[9]. The stand pipe acted as a "tent pole" to keep the polyethylene cover from contacting the surface of the test solutions. The sides of the frames were weighted down to prevent escapees. The average weight of fish used in the tests, as determined during the autopsy procedure, was 89 ± 19.83 g.

The photoperiod used during the test was 16-h daylight and 8-h darkness (Environment Canada, 1990c). Lights were controlled with a dimmer during switching the lights on and off. Light intensity was minimal, to minimize fish activity including their attempts to escape from the tank.

During each bio-uptake test, the dissolved oxygen and pH of each test solution were monitored. Where possible, observations were made to determine the condition (and

[9]The cover was necessary to prevent fish escaping from the tanks. A combination of black and clear plastic was used to provide minimal lighting conditions during the 8-day exposure.

survival) of the fish in the tanks. In many cases, however, the effluent in the tanks was opaque and, under the dim overhead lighting, it was not possible to observe the fish.

Fish in the test tanks were not fed during the 8-day exposures, nor during the day when they were transferred from the stock tank.

Upon completion of the initial 4-day period of exposure, fish were netted and transferred quickly to an adjacent tank containing a fresh sample of undiluted or diluted effluent (Friday's sample). Changeovers were achieved by lowering the volume of solution in the tank using a perforated stand-pipe. Fish were then netted, and moved directly to the fresh solution (volume, ~775 L) in a separate tank.

3.5.3 Fish Dissections

Upon completion of each 8-day effluent exposure, the fish in the exposure tank were netted and transferred quickly to a 50-L aquarium containing aerated control/dilution water at 15 ± 1 C. Fish were allowed to "surface depurate" in this water for a period of 2 hours[10]. Thereafter, the fish were again netted, killed quickly by a blow to the head, and placed in labelled polyethylene bags. Bags containing fish were held chilled on crushed ice until the dissections were completed (within 2 hours of sacrificing). All fish were dissected in a positive-pressure "clean" laboratory facility which was free from contamination from the general laboratory.

The dissection instruments used were all washed, rinsed with deionized water, and then rinsed with OmniSolv™ hexane. This procedure was repeated before each set of dissections with fish from differing treatments.

Initially, the wet weight of the fish was determined. The surface of the fish was patted dry before dissection, and dissections were performed on a polyethylene sheet. Clean sheeting was used for each group of fish from a tank. The edible muscle tissue was dissected by slitting the fish along the dorsal line, as well as along the lateral line and the ventral area of the belly. This allowed the skin to be stripped from both dorsal and ventral portions of the fish, on both sides. Care was taken to prevent scales from contaminating this muscle tissue. The muscle tissue was removed from the bone using a technique similar to filleting, making sure that the dissected muscle did not contact other parts of the fish or the work bench. Upon completion of the dissection of each group of fish, the dissected tissue from

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[10]A brief depuration period was provided to flush contaminants loosely adsorbed to the surface of the skin and gills of the fish.

each group was placed together in a labelled Whirl Pac™ polyethylene bag, weighed, and immediately frozen at -20 C.

Liver tissue was removed using a pair of forceps, taking care that the gall bladder was not punctured. The livers from each group of fish from the same tank were individually weighed, and stored together in a separate Whirl Pac™ bag as per the muscle tissue.

During dissection, observations were made on gross pathology of the fish. Any freshly dead or moribund fish were dissected and stored separately. Fish which were dead for more than 24 h and showed evidence of tissue breakdown were not suitable for muscle dissections and were frozen whole.

3.6 Quality Assurance/Quality Control

3.6.1 Field Quality Control

A 20-L sample was collected from site D concurrently with the 800-L effluent sample. The purpose of this extra sample was to determine if the use of plastic barrel liners and plastic jerricans could affect the results of the chemical analysis. This quality-control sample was collected in five 4-L amber glass bottles. The control sample was sealed at the site and delivered to ASL for determination of analytical parameters. This sample is labelled R in the accompanying tables.

Rust was noted to be accumulating between some of the drums and the liners. To determine if there was any contamination of the sample from this rust, a quality-control sample was collected in a 1-L amber glass bottle at sample locations L, M and N. These samples were collected concurrently with the regular samples at these locations and delivered to ASL for determination of total metals. This data may be compared to data for samples collected in the usual fashion from locations L, M and N.

3.6.2 Control and Blank Tests

3.6.2.1 Controls for Toxicity Tests

Preliminary toxicity tests were conducted to determine if Fraser River water, sampled upstream of the industrial discharges under investigation, would be suitable for use as control/dilution water in the definitive toxicity tests with daphnids (*Daphnia magna* and *Ceriodaphnia dubia*). On February 8, 1993, a 20-L sample of river water was collected at each of the three locations shown in Figure 3-11 and described in Table 3-5. Each riverwater sample was filtered through a 60-µm plankton net to remove potential predators or competitors of *C. dubia* or *D. magna* (Environment Canada, 1990a; 1992). The sample was then placed in a clean (new) 20-L plastic jerrican, previously filled with Capilano River water and purged with Fraser River water at the sampling site before filling and sealing. Each sample was transported directly to BCR, whereupon subsamples were taken and refrigerated (4 ± 2 C) until used (within 24 h) for the toxicity tests.

Table 3-5: Description of Fraser River Sites - February 8, 1993

Sample ID	Conductivity 1x scale	Time Collected	Volume (l)	Comments
FRC-1	62	12:45 pm	21	Sample from "Port Haney Pier" at intersection of River Rd and Haney bypass. Downstream from log sort operation. Sample from approx 15 m from shoreline. Cloudy, fine silts.
FRC-2	60	1:50 pm	21	Sample from side bar located at foot of Burbidge St near north end of Port Mann Bridge. Access via United Blvd. Cloudy, fine silts. Noticeably more suspended solids than FRC-1. Sample taken approx 12 m from low tide mark. Approx 5 km from Pitt River confluence.
FRC-3	71	2:25 pm	21	Sample from side bar approx 20 m from low tide mark. Access is through "Strick Lease Co" located at end of United Blvd. Approx 1.5 km downstream from FRC-2. Cloudy, with fine silts. Sample from 50 m upstream of storm sewer discharge. Log booms in vicinity of sample area.

Each of the three samples of "upstream" Fraser River water was tested in triplicate (undiluted river water only) for toxic effects, using the 48-h *Daphnia magna* test and the chronic toxicity test with *Ceriodaphnia dubia*. In each of these tests, daphnid responses to each Fraser River sample were compared to those for duplicate control solutions tested concurrently using the appropriate daphnid culture water.

Procedures for assessments of the suitability of upstream water as control/dilution water given in Environment Canada (1990a) and Environment Canada (1992) were followed. For the chronic toxicity tests with *Ceriodaphnia dubia*, aliquots of each refrigerated (4 ± 2 C) sample were used for the daily static renewals.

Appropriate controls were used for each trout LC50, daphnid LC50 and daphnid IC25 test. These included both negative controls (*ie:* 100% control / dilution water only) and positive controls (*ie:* reference toxicant tests). Instructions for preparing and conducting each negative and positive control test, given in Environment Canada's methodology documents for acute tests with *Daphnia magna* and rainbow trout and chronic tests with *Ceriodaphnia dubia*, were followed without exception (Environment Canada, 1990a, 1990c, 1992). Reference toxicants used for each positive control test were: acute trout test, phenol; acute *D. magna* test, zinc; and chronic *C. dubia* test, sodium chloride.

3.6.2.2 Toxicity of Leached Plasticizers on *Daphnia magna*

The potential toxicity of plasticizers leached from barrel liners or plastic jerricans during sample transport was studied. For this test, required quantities of the culture water normally used for *D. magna* were placed in a 20-L plastic jerrican, as well as in a glass beaker containing a piece of barrel liner ("coupon"). Since 2 litres (a convenient volume for use in replicate toxicity tests with daphnids) is 1% of the volume (200 L) of sample transported to BCR in a barrel, a coupon representing 1% of the surface area of a barrel liner was placed in a clean glass beaker containing 2 litres of *D. magna* culture water. Both the jerrican and the beaker containing the barrel liner coupon were filled with *D. magna* culture water early in the morning and the subsamples for subsequent toxicity tests transferred to separate glass jars at the end of the day. This procedure was intended to simulate the leaching of plasticizers that could occur from the jerricans and barrel liners when effluent samples were transported.

Separate *D. magna* toxicity tests were conducted with each of the above two samples ("jerrican leachate", "barrel liner leachate"). Each of the two leachates was tested at full strength only, in triplicate, using ten daphnids per replicate. Separate controls (test triplicate solutions of culture water) were tested concurrently. Observations of daphnids in each solution included behaviour as well as mortalities. Basic test conditions and procedures were as described in Environment Canada (1990a).

3.6.2.3 Effect of Water Hardness on *Daphnia magna*

A series of "blank" tests was performed to assess the performance of *D. magna* in effluent samples with hardness lower than that in the culture / control water (*ie:* hardness <120 mg / L). Information on how this species performed in control water adjusted to differing hardness values within the range 25 to ~120 mg / L was required.

This range was chosen because 25 mg/L was the lowest hardness to which the *D. magna* were exposed in any test with effluent[11] and 120 mg/L approximated the hardness of the culture/control water to which the organisms were acclimated. Solutions of reconstituted fresh water, adjusted to each of the following hardness values, were prepared and tested: ~25, ~50, ~75 and ~100 mg/L. A separate series of controls was run concurrently, using culture/control water at a hardness of ~120 mg/L. Waters adjusted to specific hardness values were prepared according to the formula given in Environment Canada (1990b).

Reconstituted water, adjusted to each hardness value, was tested in triplicate (10 daphnids per replicate). Three replicate control solutions (100% culture/control water) were included in this series of tests. Basic test conditions and procedures were as described in Environment Canada (1990a; 1990b). Results for each hardness-adjusted solution were compared to the triplicate controls (culture/control water at 120 mg/L).

3.6.2.4 Toxicity of Leached Plasticizers on *Ceriodaphnia dubia*

The intent of this blank test was to examine possible toxic effects on *C. dubia* due to contamination of samples held in barrels or jerricans when transported from the field to BCR. Because of the sample collection procedure (outlined in Section 3.2), *C. dubia* were exposed to three discrete samples. This same treatment was followed for a blank test, using *C. dubia* culture/control water only. Once again, the ratio of percent surface area of the barrel liner was downsized to scale and the 20-L sample of *C. dubia* culture/control water was held in a jerrican provided by TRI. No dilution of the culture/control water exposed to plastic was used (*ie:* replicates were exposed to 100% "barrel-liner leachate" and 100% "jerrican leachate").

The procedure followed for this "blank" test was much the same as that outlined in Subsection 3.6.2.2. The culture/control water for *C. dubia* was that used throughout the study for chronic toxicity tests with this daphnid species, (fresh water with a hardness of ~50 mg/L). Triplicate controls were performed using this water, with semi-static (daily) replacements of each control solution throughout the test period. Triplicate tests were also performed using 100% *C. dubia* culture/control water which had been previously exposed to coupons of barrel liner for several hours (on Monday and Friday) or held in a plastic jerrican (on Wednesday). Conditions and procedures for chronic toxicity tests with *C. dubia*, as described in Environment Canada (1992) and specified in BCRs Standard

[11]All effluent samples with hardness values <25 mg/L were adjusted to 25 ± 5 mg/L before testing commenced, whereas all samples with hardness values $25 mg/L were tested without adjustment for hardness. This is as per Environment Canada's reference method EPS 1/RM/14 (Environment Canada, 1990b).

Operating Procedure for this test (see Appendix V), were followed, and were identical to those used for the definitive tests with effluent samples.

3.6.2.5 Effect of Water Hardness on *Ceriodaphnia dubia*

Unlike *D. magna*, *C. dubia* is more tolerant of soft water (Environment Canada, 1992). Thus, for this species, effluent samples with hardness values less than 25 mg/L were not adjusted. However, a test using hardness "blanks" was required to assist in interpreting toxicity data derived for any samples of effluent with a hardness below the ~50 mg/L of the culture/control water used for this species.

C. dubia were exposed to triplicate solutions of deionized water reconstituted to specific pre-selected hardness values (~5, ~10 and ~25 mg/L). Test waters were reconstituted following the directions provided in Environment Canada (1992). Waters adjusted to each test hardness were stored in the dark at 4 ± 2 C and used for daily replacements throughout the test period. Triplicate control solutions, using *C. dubia* culture water (hardness ~50 mg/L), were included in the test, with daily renewal of each control solution. The performance (survival and number of neonates produced) of *C. dubia* in each of the hardness-adjusted waters was compared to that for the triplicate controls held in culture water with a hardness of ~50 mg/L.

3.6.2.6 Control/Blank Tests for Bio-Uptake Study

Two control/blank tests were performed as part of the bio-uptake studies with effluent samples (Section 3.5). The purpose of these tests was twofold: (1) to determine background levels of specific contaminants in the population of trout used for the study, in the absence of any effluent exposure; and (2) to serve as a positive control (blank test) for any contaminants accumulated in fish tissues from plasticizers leached from the plastic barrel liners. The first control/blank test was conducted during the first week of the bio-uptake tests. The second control/blank test was undertaken during the week following completion of the last series of bio-uptake tests. Conditions and procedures for each of these two tests were identical and, according to those pre-test and test conditions and procedures, used for the definitive bio-uptake tests with effluent-exposed fish (Section 3.5).

The laboratory supply of dechlorinated municipal water used routinely for culturing and testing rainbow trout was used for these control/blank tests. Samples of laboratory water designated as S-1 and S-3 were used for the first control/blank test and water samples labelled S-4 and S-5 for the second test. Each of these 800-L samples was handled in the same manner as the large-volume effluent samples. For each control/blank test, four barrels were lined with pre-soaked barrel liners and filled with dechlorinated municipal water on a Monday morning. That afternoon, the water was transferred to a clean fish tank and subsamples collected for chemical analyses. On the morning of the following Friday (*ie:* four days later), new liners were placed in four 200-L barrels and the barrels re-filled with fresh dechlorinated municipal water. That afternoon, the contents of the barrels (800 L) were transferred to a separate (clean) fish tank and subsamples collected for chemical analyses and toxicity tests. Exposure conditions and fish dissections were as described in Section 3.5 for fish held for 8 days in the effluent samples.

3.6.3 Chemical Laboratory Quality Assurance

The QA program for this project included 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 were used:

Reagent Blank - usually distilled water with added reagents, which was carried through the entire analysis as a check on laboratory contamination (also called a method blank).

Duplicate - a homogenous sample was split either in the field or in the laboratory with the duplicate presented to the analyst as an additional sample to check for precision.

Check Standard - a procedure was standardized with calibration standards prior to analyzing the samples. The analytical response to the standards was checked by frequently analyzing one or more standards along with the samples. The check standards were prepared independently of the calibration standards.

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

Spike - a known amount of analyte was added to a sample to provide information on matrix effects and apparent accuracy. Internal Standards were 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.

For the purposes of this project, analytical batches were defined as all samples submitted on a given day. Each of these batches was given its own QC samples, including a reagent blank, a Standard Reference Material and/or a spike. In addition, each batch contained at least one sample duplicate. The certification sheets for the reference materials used are included in Appendix X. Several parameters do not have an available reference material. For these, sample spikes or reagent spikes were analyzed as part of the QA/QC program and the results reported as percent recovery. These parameters are: PAH, chlorinated phenols, resin acids, oil and grease, and anti-sapstain chemicals. The amount of QA/QC performed on tissue samples was lower than originally proposed, due to limited sample mass available for analysis. Table 3-6 summarizes the laboratory QA/QC program.

Table 3-6: Chemical Laboratory Quality Control Summary for Chemical Analysis

Number of	Samples	Blanks	Dup.	CRM/ SRM	Spikes	% QC
Water Samples						
Physical Tests	60	12	12	12	-	60
Dissolved Anions	60	12	12	12	-	60
Nutrients	60	12	12	12	-	60
Total Metals	63	12	13	12	-	59
Dissolved Metals*	60	12	12	-	-	40
PAHs	27	12	11	-	12	130
Chlorinated Phenols	24	12	12	-	12	150
Resin Acids	24	12	12	-	12	150
Extractables	60	11	11	-	11	55
Antisapstain Chemicals	13	7	6	-	7	154
BOD_5	60	12	12	12	-	60
Phenols	38	12	12	12	-	95
Dioxins/Furans+	26	12	-	-	-	46
Tissue Samples						
Physical Tests	11	-	1	-	-	9
Total Metals	11	1	1	3	-	45
PAHs#	11	1	-	-	2	27
Chlorinated Phenolics^	11	1	1	-	-	18

* "Blank" data reported for dissolved metals refers to the analysis of filter blanks.

[+] These analyses were preformed by Axys Analytical Services Ltd. of Sidney, B.C. The QC data was not reported.

[#] Due to limited sample mass, duplication of this analysis was not possible.

[^] These analyses were performed by Axys Analytical Services Ltd. of Sidney, B.C.

3.6.4 Biological Laboratory Quality Control

Quality control is an integral part of each of the biological test methods used in this investigation (see Environment Canada, 1990a, 1990b, 1990c, 1990d, 1992). Each test method has specified negative and positive (*ie:* reference toxicant) controls, as well as specific criteria which define valid and invalid test results. The technicians performing the biological tests were fully familiar with these quality controls and endeavoured to follow the specified QC procedures integral to each test without exception.

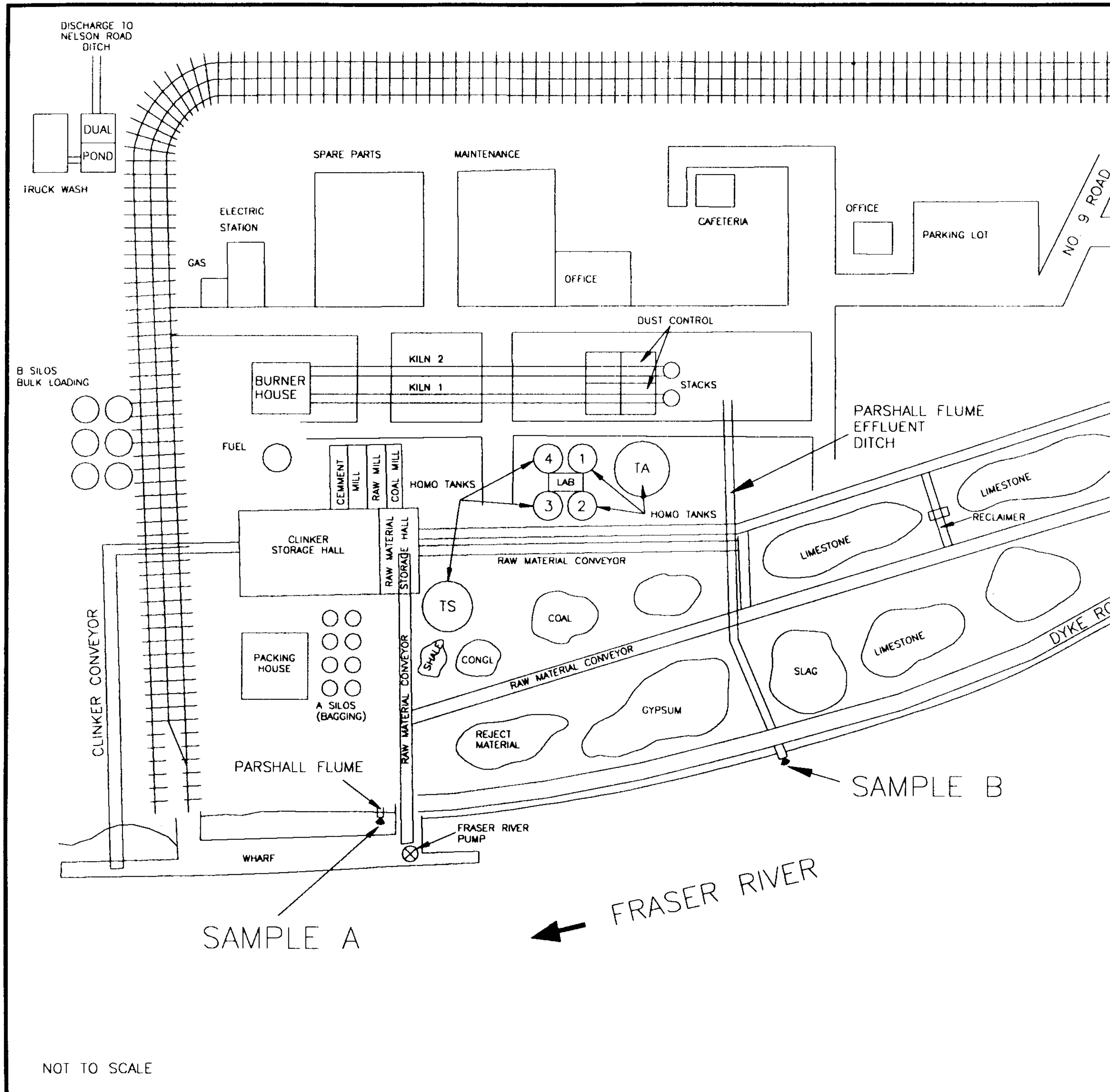
Proper quality control for biological tests includes vigorous attention to cleaning all apparatus contacting test substances, solutions and organisms. For all tests with daphnids (*Daphnia magna* and *Ceriodaphnia dubia*), all beakers, pipettes, measuring cylinders, *etc.* were rinsed after each use with deionized water. All labels were removed with acetone, and the apparatus washed in a laboratory glass washer. After machine washing, all glassware was rinsed with deionized water and placed in nitric acid overnight. Following the acid bath, the glassware was rinsed ten times with deionized water and dried upside down in a drying oven.

All aquaria used in the toxicity tests with rainbow trout were well rinsed with dechlorinated municipal water. The aquaria were then washed in a large glass-washing machine. The following washing cycle was used: rinse with tap water, wash with laboratory detergent, follow with three rinses with tap water. Each aquarium was then rinsed manually with deionized water five times, inverted and allowed to dry. Aquaria were stored in a dust-free environment between uses.

The 800-L fish tanks used for compositing effluent samples and for the bio-uptake tests with juvenile rainbow trout were cleaned as follows. After use, each tank was scrubbed vigorously using copious quantities of dechlorinated municipal water and a scrub brush. Tanks were then rinsed with 2N HCl, followed by three rinses with dechlorinated water. Each tank was then filled brim-full and allowed to soak in dechlorinated water for at least two hours, then drained and re-labelled for receipt of the next sample.

Attention to quality control was implicit in the method used for dissecting tissues of fish from each bio-uptake study. Details regarding this method are given in Section 3.5.

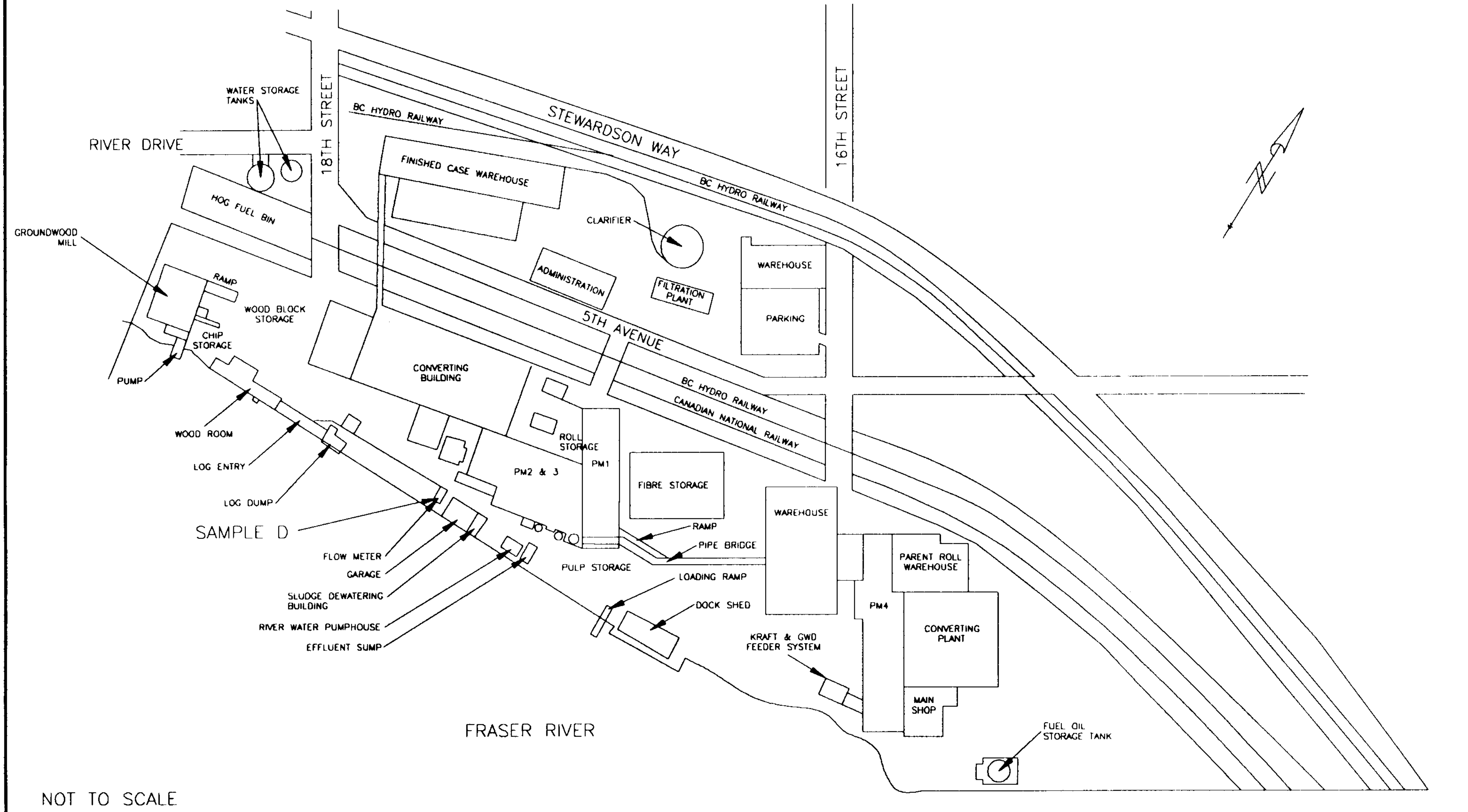
Quality control procedures were also included as part of the analytical techniques used with the fish tissues from the bio-uptake studies. Due to the nature of tissue samples, most routine external QC samples were inappropriate. In addition, samples sizes were limited. ASL provided Certified Tissue Reference Materials (CRM) which acted as "blind" samples and were submitted with the other tissue samples. These CRMs were chosen to reflect the tissue matrix being analyzed and were only analyzed for the parameters for which they were certified.



Drawn By: RB	Date Revised:
Date: 23/02/93	24/06/93
File: LAFGSTE.DWG	

FIGURE 3-1
LAFARGE CANADA INC.
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	

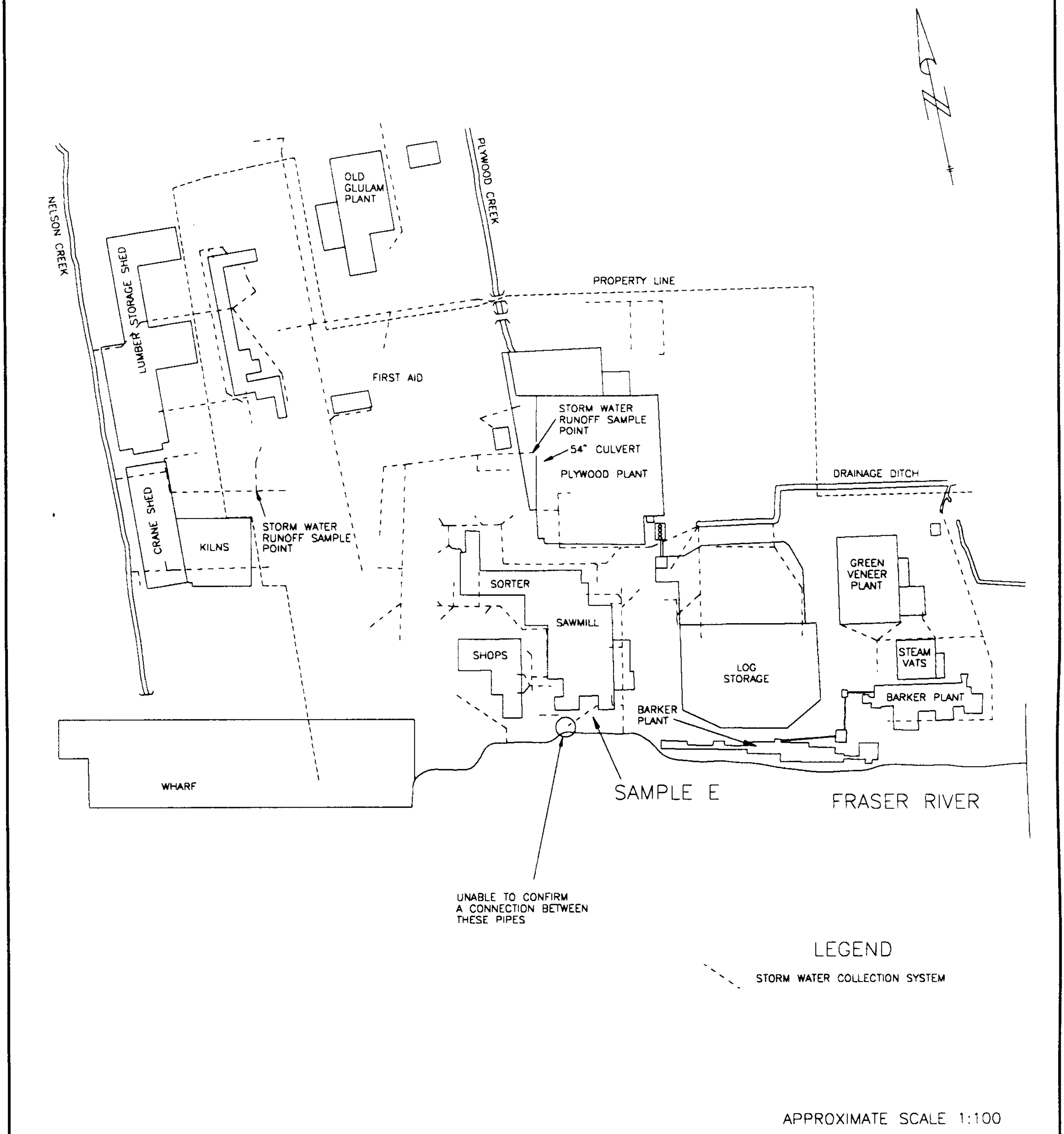
Drawn By: RB

Date: 22/02/93

File: SCOTT.DWG

FIGURE 3-2
SCOTT PAPER LTD.
SAMPLE LOCATIONS

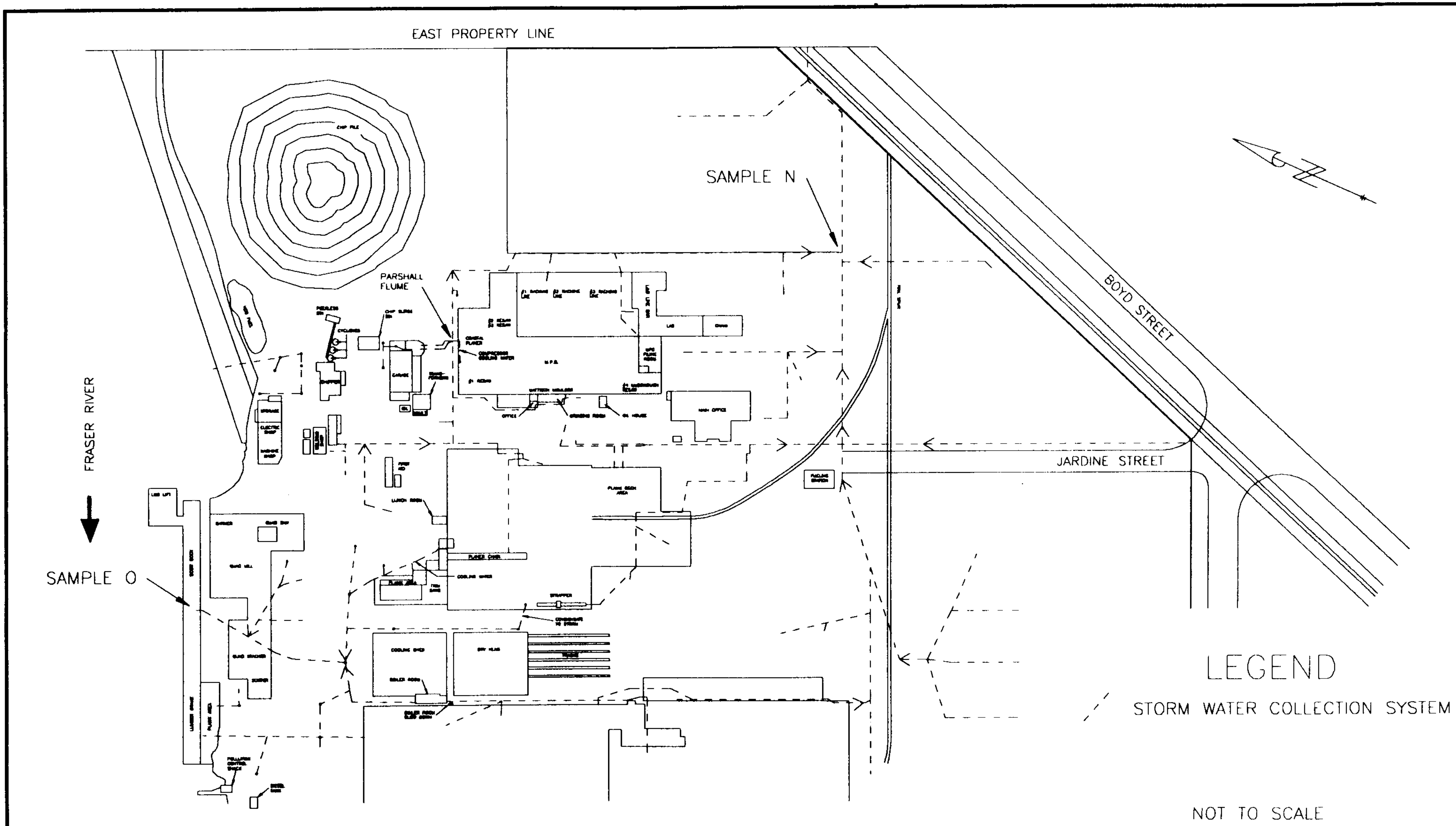
TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
01/10/93	
Drawn By: RB	
Date: 12/02/93	
File: FRASERML.DWG	

FIGURE 3-3
IFP FRASER MILLS
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	

Drawn By: RB

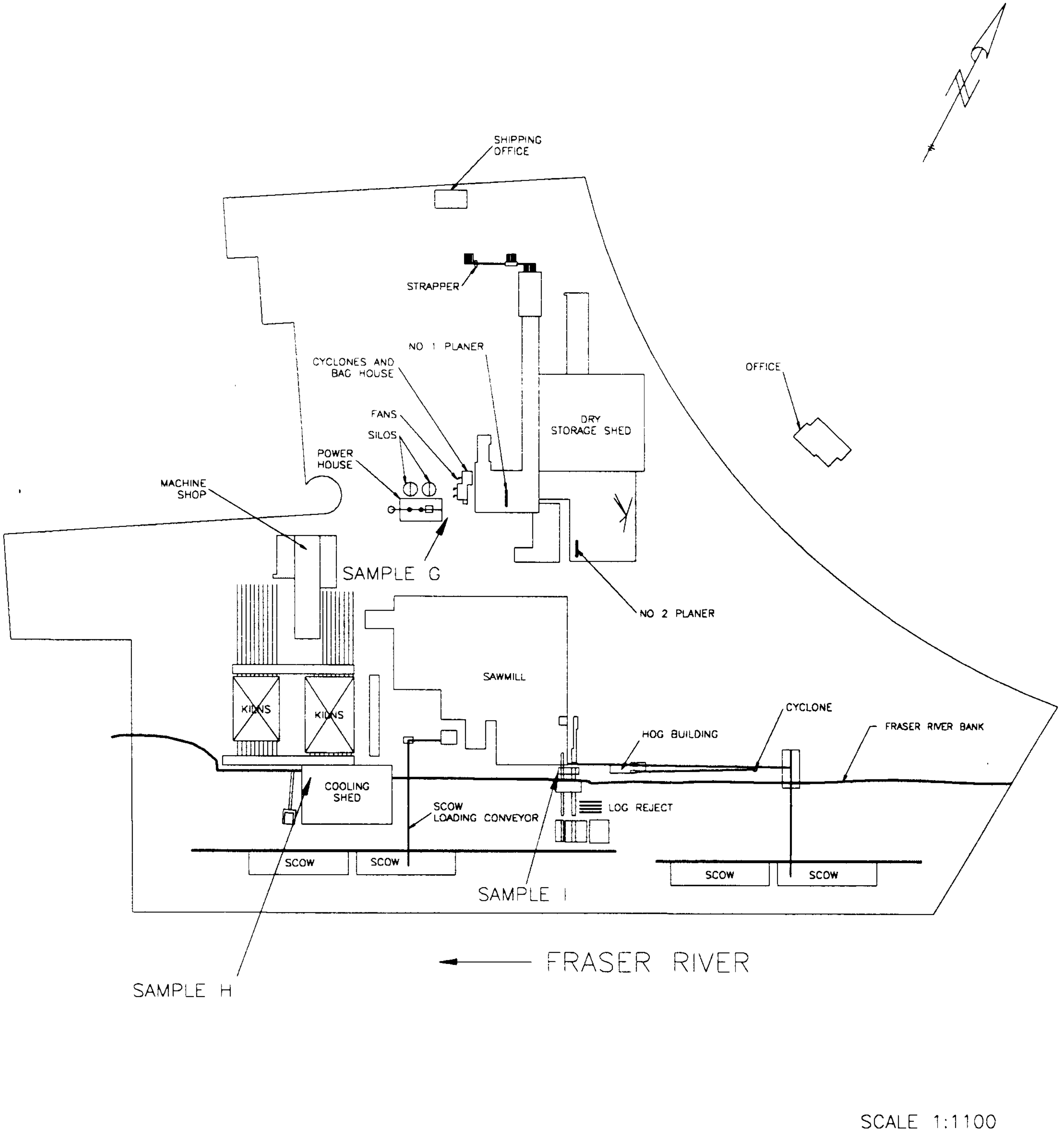
Date: 04/03/93

File: MACBLOST.DWG

FIGURE 3-4
MACMILLAN BLOEDEL
NEW WESTMINSTER
SAMPLE LOCATIONS

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

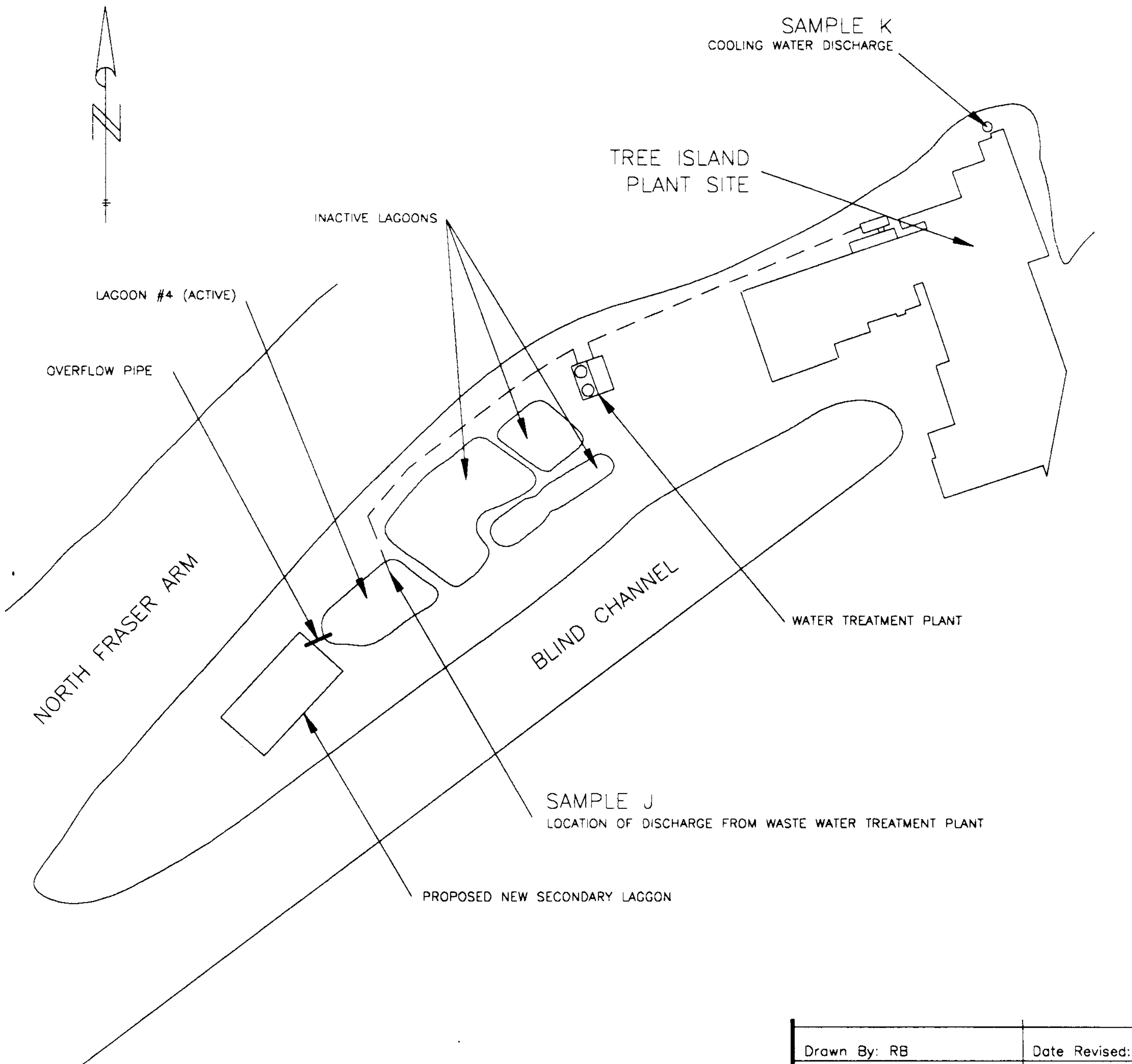
TECHNOLOGY RESOURCE INC.



Date Revised:	
24/06/93	
Drawn By: RB	
Date: 08/04/93	
File: HAMMND.DWG	

FIGURE 3-5
IFP HAMMOND
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



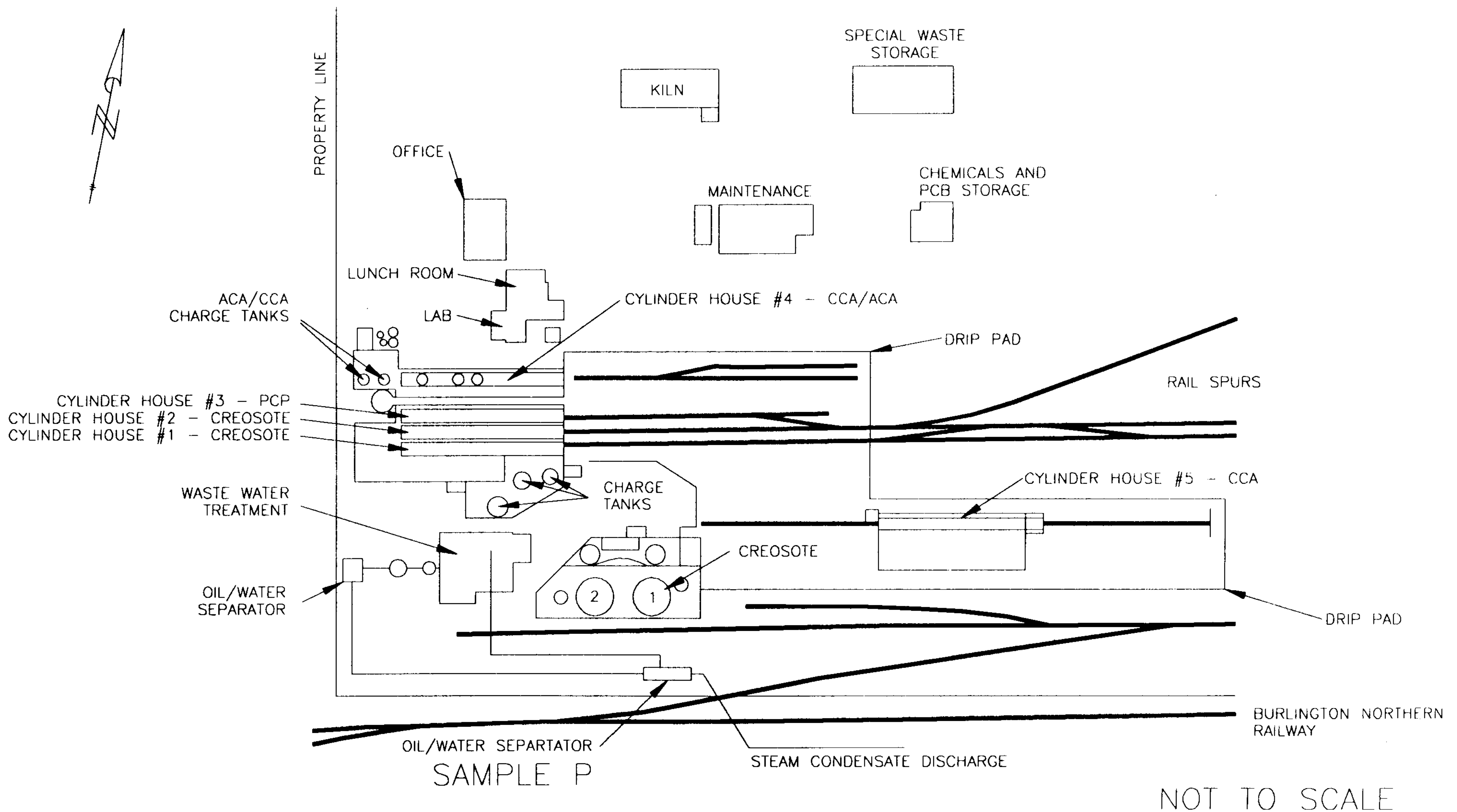
NOT TO SCALE

Drawn By: RB	Date Revised:
Date: 29/03/93	24/06/93
File: TREESITE.DWG	

FIGURE 3-6
TREE ISLAND
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.



Date Revised:	
31/03/93	

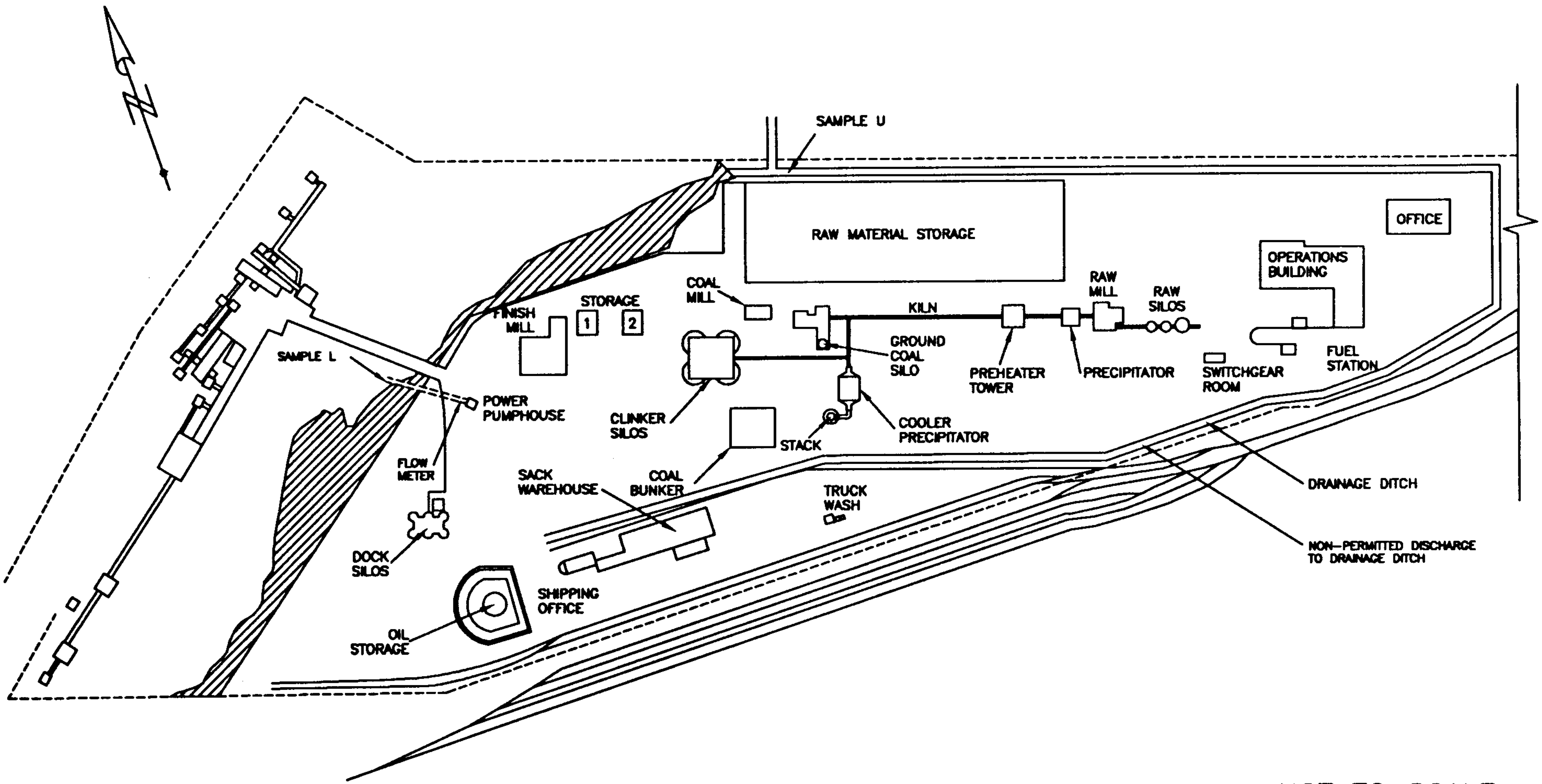
Drawn By: RB

Date: 16/03/93

File: DOMTAR.DWG

FIGURE 3-7
DOMTAR CHEMICALS LTD.
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.

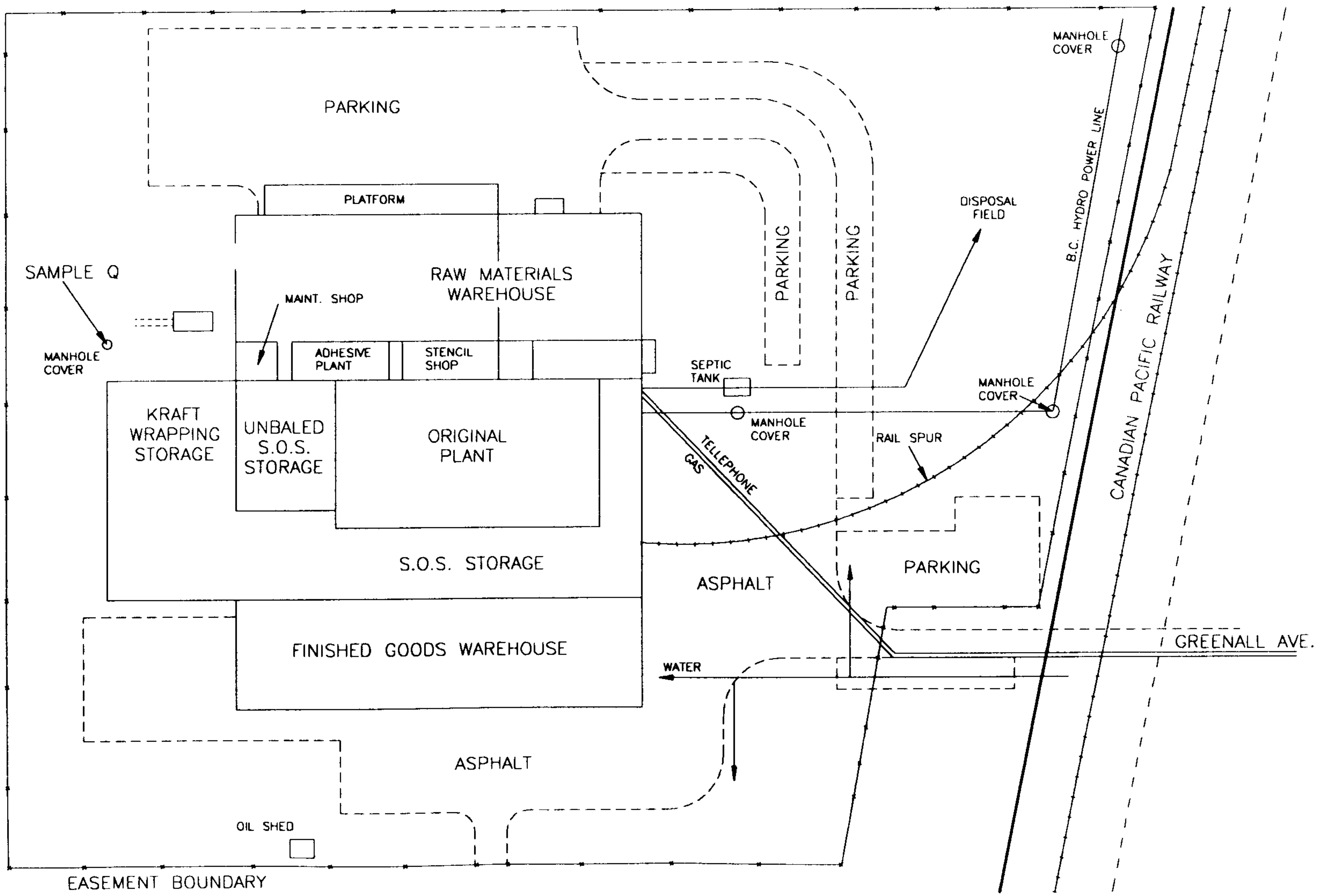


NOT TO SCALE

Date Revised:	
REVISED	
Drawn By: RB	
Date: DATE	
File: FILENAME	

FIGURE 3-8
TILBURY CEMENT LTD.
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



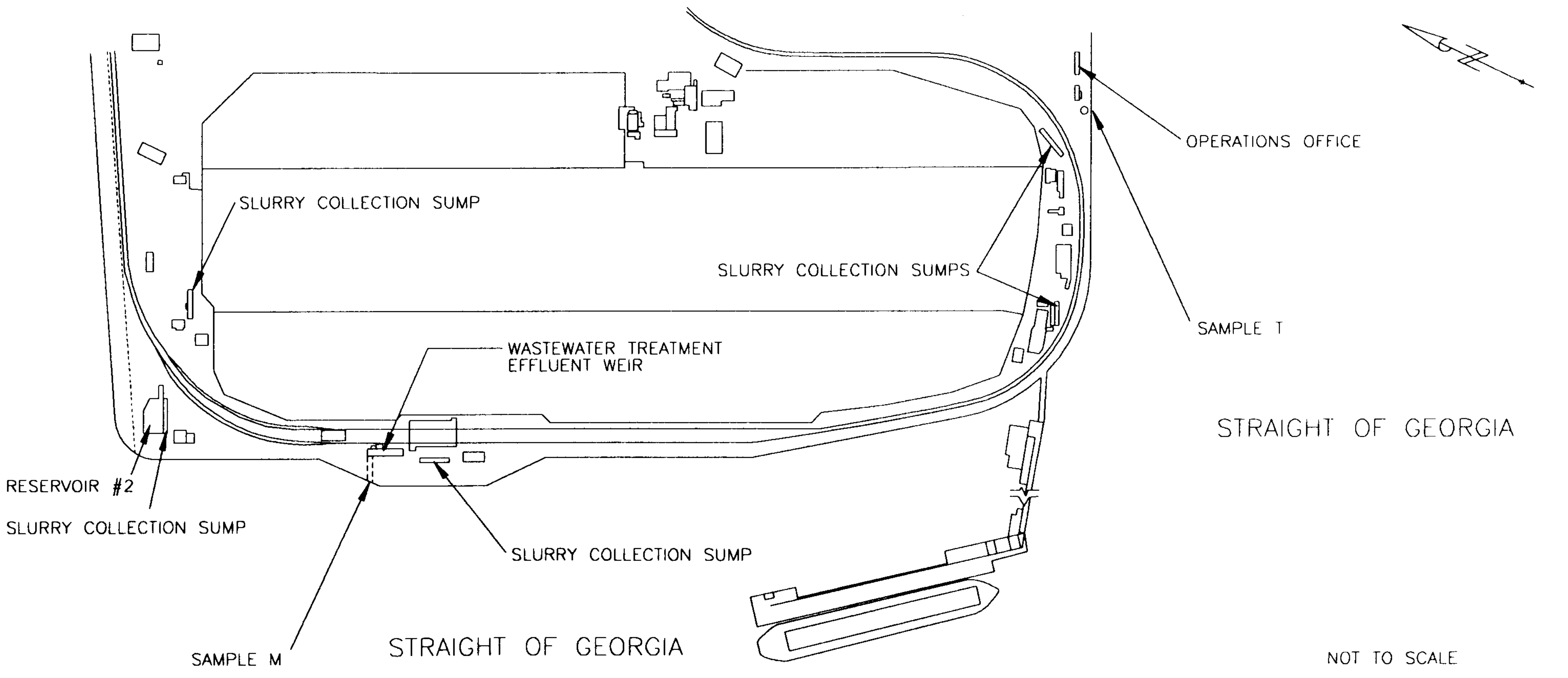
APPROXIMATE SCALE 1:1200

Drawn By: RB	Date Revised:
Date: 25/02/93	01/10/93
File: HILNXSTE.DWG	

FIGURE 3-9
HILINEX PACKAGING
SAMPLE LOCATIONS

502 Kapilano 100
West Vancouver, BC
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.



Date Revised: 01/10/93

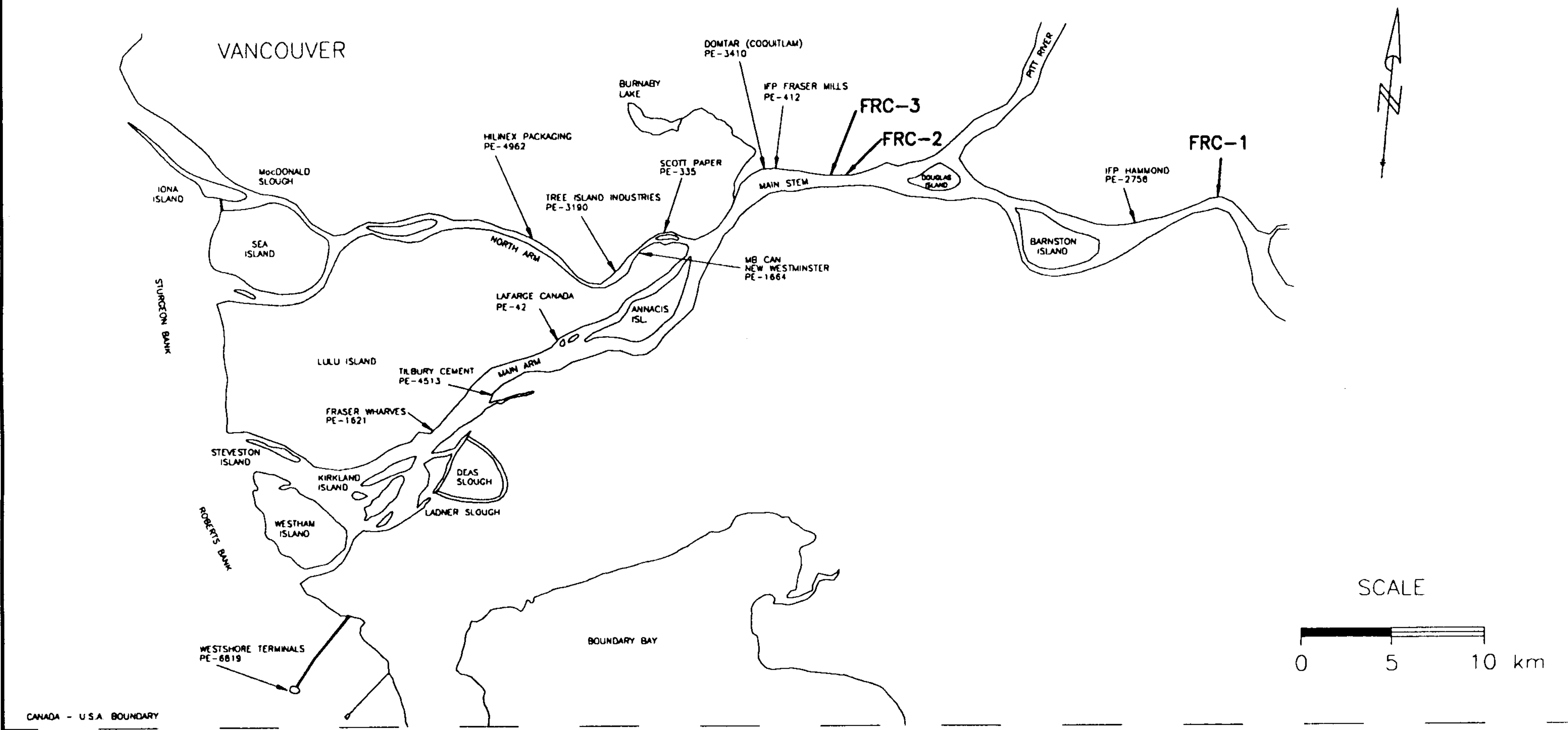
Drawn By: RB

Date: 16/03/93

File: WESTSHR.DWG

FIGURE 3-10
WESTSHORE TERMINALS LTD.
ROBERTS BANK
SAMPLE LOCATIONS

TRI
502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323
TECHNOLOGY RESOURCE INC.



Drawn By: RB

Date: 24/06/93

File: FRASER.DWG

FIGURE 3-11

FRASER RIVER SITES SAMPLE LOCATIONS FEBRUARY 8, 1993

TRI

502 Kapilano 100
West Vancouver, B.C.
V7T 1A2
(604) 925-2323

TECHNOLOGY RESOURCE INC.

4.0 RESULTS AND DISCUSSION

Section 4 presents results of the field work and operational assessments (Section 4.1), the chemical characterization of the 17 effluent streams (Section 4.2), the toxicity tests on the 10 primary effluents (Section 4.3), the bio-uptake study (Section 4.4) and the quality control / quality assurance program (Section 4.6). In Section 4.1, effluent flow measurement is discussed. Section 4.2 deals with the overall results of chemical analysis. A discussion and summary tables are provided. Section 4.3 summarizes the results of the *Daphnia magna*, rainbow trout and *Ceriodaphnia dubia* toxicity tests. A discussion of the effluents from each industry, including the relationship between toxicity and the chemical characteristics, is provided in Section 4.5.

4.1 <u>Field Information</u>

4.1.1 Flow Measurement

A list of the effluent flow rates and temperatures during field sampling is provided in Table 4-1. Field reports can be found in Appendix I. A summary of the flow measurement techniques used by the industries is provided in Table 4-2. As can be seen in this table, only 4 of the 17 discharges have continuous, on-line flow measurement of the effluent. An additional 3 streams are measured with a Parshall flume, while 7 are estimated (with varying degrees of accuracy, as discussed in Section 2) and 1 (Hilinex), has no flow measurement. The discharge flow at Hilinex was estimated by field personnel. There are two non-permitted discharges as part of this study - a combined storm water and kiln condensate discharge at MB New Westminster (recently permitted) and a fugitive effluent at Tilbury. Neither of these flows are measured and the flow rates reported in Table 4-1 were estimated by field staff.

Discharge 02 at Westshore Terminals (sample location M) does not operate continuously. In fact, this discharge may only occur for a few days in a given month, as required by the facility operation. Discharge was not scheduled during the sampling period, but Westshore personnel agreed to discharge as required by the sampling schedule (on Monday, Wednesday and Friday of a given week). The flow rate reported in Table 4-1 is a monthly-average estimate of the flow discharged at Westshore. This estimate is taken from Norecol (1992), and was verified by staff at Westshore. It was decided that a monthly-average flow rate would be more useful and representative of the overall discharge to the environment from this facility, particularly with respect to toxic loadings which are calculated in subsequent sections of this report.

Table 4-1: Summary of Recorded Field Data

Sample	Permitted Flow m³/day	Flow m³/day	Permitted Temp C	Temp. C	Comments
A-1	3,410	196	32	13	one kiln down
A-2	3,410	171	32	11	one kiln down
A-3	3,410	685	32	13	one kiln down
B-1	2,950	3,106	32	12	one kiln down
B-2	2,950	1,540	32	9	one kiln down
B-3	2,950	1,810	32	8	one kiln down
D-1	23,000	16,000	35	27.5	grade change
D-2	23,000	16,000	35	27	
D-3	23,000	16,000	35	30	recycled paper prod.
E-1	60	60	35	34	2 comp. operating
E-2	60	60	35	29	
E-3	60	60	35	32	2 comp. operating
G-1	2,500	6	-	25	
G-2	2,500	6	-	25	
G-3	2,500	6	-	26	slight sharp odour
H-1	50	1	35	11	diesel odour
H-2	50	1	35	9	diesel odour
H-3	50	1	35	9	diesel odour
I-1	40	14.4	35	26	sheen on surface
I-2	40	14.4	35	30	sheen on surface
I-3	40	14.4	35	29	sheen on surface
J-1	2,000	1,225	-	16	
J-2	2,000	1,225	-	18	
J-3	2,000	1,225	-	24	

K-1	2,500	1,730	27	14	

Table 4-1: Summary of Recorded Field Data (cont.)

Sample	Permitted Flow m³/day	Flow m³/day	Permitted Temp C	Temp. C	Comments
K-2	2,500	1,730	27	15	
K-3	2,500	1,730	27	18	
L-1	18,200	95	10	9	
L-2	18,200	330	10	-	
L-3	18,200	55	10	11	
M-1	10,000	283	-	6	coal dust present
M-2	10,000	283	-	8	
M-3	10,000	283	-	8	coal dust present
N-1	91	75	35	9	hydrocarbon sheen
N-2	91	75	35	8	foam
N-3	91	65	35	10	hydrocarbon sheen
O-1	320	60.2	-	11	hydrocarbon sheen
O-2	320	60.2	-	6	
O-3	320	60.2	-	14	
P-1	465	6	35	18.5	cyl. house #5 down
P-2	465	6	35	17	cyl. house #5 down
P-3	465	6	35	30	cyl. house #5 down
Q-1	0.5	2.3	-	13	organic growth
Q-2	0.5	2.3	-	13.5	organic growth
Q-3	0.5	2.3	-	12.5	organic growth
T-1	32	17.6	-	-	septic odour
T-2	32	17.6	-	14	septic odour
T-3	32	17.6	-	6	septic odour
U-1	-	-	-	2	open ditch

U-2	-	-	-	8	open ditch
U-3	-	-	-	10	open ditch

Table 4-2: Flow Measurement Techniques Used by Industries

Industry	Discharge	Flow Measurement	Comments
Lafarge Canada	01	Parshall flume	formula for calculating flow rate may be incorrect and may overestimate flow
	02	Parshall flume	formula for calculating flow rate may be incorrect and may overestimate flow
Scott Paper	02	magnetic flow meter	expected to be accurate
IFP Fraser Mills	03	estimated	estimate
MB New Westminster	02	Parshall flume	water is added to the discharge stream after flow measurement, reported flow is lower than actual
	03	unknown	new discharge since site visit
IFP Hammond	01/02	estimated	estimate
	03	estimated	estimate
	04	estimated	estimate
Tree Island Industries	01	magnetic flow meter	expected to be accurate
	02	estimated	expected to overestimate flow
Domtar (Coquitlam)	01	estimated	estimate, flow meter being installed
Tilbury Cement	01	on-line	expected to be accurate

Hilinex Packaging	01	none	none
Westshore Terminals	01	estimated	based on pump run-time
	02	totalizer	expected to be accurate

Only Lafarge exhibited a flow greater than that permitted under Waste Management Permit. This flow was from Discharge 01 (sample B-1). It should be noted that this flow rate is calculated based on water height in a Parshall Flume. The operational assessment indicated that the measurement may be high. This is discussed in more detail in Section 2.1. Additionally, Lafarge had just begun an unplanned shutdown and the operation and maintenance at the facility was atypical.

None of the samples collected at any of the permitted discharges were above the permitted temperature limit.

4.1.2 Permit Accuracy

A number of instances were found in which information provided in the Waste Management Permit was out-of-date. These discrepancies between the actual operation and that described by the Waste Management Permit are outlined below.

< Scott Paper no longer discharge effluent from the groundwood mill to the Fraser River as outlined in Discharge 01 of Waste Management Permit PE-355. This discharge is now connected to the GVS&DD sewer.

< Fraser Wharves no longer operate their car de-waxing facility and therefore do not discharge to the Fraser River. They have not amended Waste Management Permit PE-1621 to reflect this change because they wish to reserve the right to use the facility, should the need arise.

< At MB New Westminster, the flow measurement device is not located near Discharge 03 as indicated on Waste Management Permit PE-1664.

< There was a continuous discharge to a ditch surrounding the Tilbury Cement facility which is not included in Waste Management Permit PE-4513.

< Discharge 01 at Hilinex does not discharge to a ditch surrounding the property (no ditch exists). Subsequent information from Hilinex indicates that this discharge has been connected to the GVS&DD sewer. Hilinex have applied for amendment of Waste Management Permit PE-4962 to reflect the present operation.

4.2 Chemistry

4.2.1 Calculated Data

A large quantity of data was generated as part of this project. All of the chemical analytical data for the effluent samples are provided in Appendix VI. This data is organized alphabetically by sample letter code. The appendices to this report are provided in a companion volume. Analytical data will be discussed in a summary fashion in this Volume I. Readers are referred to the Appendices for details of analytical results.

Chemical results which have been calculated are provided in Tables 4-3 through 4-5. Table 4-3 provides toxicity equivalency (TEQ) concentration for dioxins and furans. The calculation of TEQ is based on an international standard which expresses the toxicity of dioxins and furans on a common basis. Equivalency factors are assigned by NATO based on the relative toxicity compared with 2,3,7,8-tetrachlorodibenzodioxin, the most toxic dioxin (Health and Welfare, 1990). Un-ionized ammonia concentrations have been calculated for the 10 primary effluents at three different temperatures, based on sample pH. Un-ionized ammonia is shown in Table 4-4. Total resin and fatty acids are given in Table 4-5.

Table 4-3: Dioxin and Furan TEQs, pg/L

Sample	TEQ	Sample	TEQ
D-1	2.18	O-3	0.783
D-2	0.752	P-1	0.469
D-3	0.000	P-2	0.097
I-1	0.122	P-3	8.04
I-2	0.108	Q-1	0.450
I-3	0.079	Q-2	0.187
N-1	5.01	Q-3	0.250
N-2	5.01	R-1	0.787
N-3	2.62	R-2	0.654

O-1	0.127	R-3	0.000
O-2	2.82	S-1	0.000

Table 4-4: Calculated Un-Ionized Ammonia at 15, 20 and 25 C, mg/L

Sample ID	Total Ammonia (as N)	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia
		15 C		**20 C**		**25 C**	
A-1	0.450	7.7	0.006379	7.9	0.014147	7.8	0.015513
A-2	0.440			8.0	0.017110	8.0	0.023133
A-3	0.140	7.1	0.000492	7.4	0.001457	7.3	0.001426
D-1	0.011	6.7	0.000014	6.8	0.000027	6.8	0.000034
D-2	0.008			7.2	0.000052	7.2	0.000073
D-3	0.015	7.0	0.000041	6.4	0.000013	6.7	0.000041
E-1	0.011	5.5	0.000000	6.9	0.000035	6.2	0.000008
E-1 dup.	0.011			8.0	0.000428	8.0	0.000578
E-2	0.000			6.9	0.000000	6.9	0.000000
E-3	0.005	5.9	0.000001	7.4	0.000052	6.7	0.000012
I-1	0.006	9.3	0.002180	9.0	0.001708	9.2	0.002960
I-2	0.250			8.8	0.048687	8.8	0.064375
I-3	0.063	9.2	0.019008	8.6	0.008319	8.9	0.019585
K-1	0.000	6.3	0.000000	7.0	0.000000	6.7	0.000000
K-2	0.005			7.5	0.000065	7.5	0.000090

Table 4-4: Calculated Un-Ionized Ammonia at 15, 20 and 25 C, mg/L

Sample ID	Total Ammonia (as N)	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia
		15 C		20 C		25 C	
K-3	0.011	6.4	0.000007	6.9	0.000035	6.7	0.000027

Table 4-4: Calculated Un-Ionized Ammonia at 15, 20 and 25 C, mg/L

Sample ID	Total Ammonia (as N)	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia	pH	Un-Ionized Ammonia
		15 C		**20 C**		**25 C**	
L-1	0.057	7.3	0.000323	7.5	0.000745	7.4	0.000817
L-2	0.064			7.8	0.001622	7.8	0.002206
L-3	0.066	7.3	0.000374	7.4	0.000687	7.4	0.000845
M-1	0.160	6.6	0.000160	7.2	0.001048	6.9	0.000715
M-2	0.210			6.7	0.000408	6.7	0.000574
M-3	0.120	6.6	0.000120	6.7	0.000233	6.7	0.000290
N-1	0.460	6.1	0.000119	5.9	0.000104	6.0	0.000200
N-2	0.013			5.7	0.000002	5.7	0.000002
N-3	0.013	6.9	0.000028	5.7	0.000002	6.3	0.000013
P-1	0.021	5.8	0.000002	7.0	0.000085	6.4	0.000027
P-2	0.013			7.1	0.000067	7.1	0.000093
P-3	0.025	6.1	0.000006	7.0	0.000102	6.6	0.000047
Q-1	0.017	5.7	0.000001	7.6	0.000278	6.7	0.000041
Q-2	0.013			6.4	0.000012	6.4	0.000017
Q-3	0.000	6.1	0.000000	6.5	0.000000	6.3	0.000000

Table 4-5: Total Resin and Fatty Acids (mg/L)

Sample	Total RA&FA	Sample	Total RA&FA
D-1	0.104	O-3	0.000
D-1	0.115	P-1	0.000
D-2	0.288	P-1	0.000
D-2	0.312	P-2	0.000
D-3	0.256	P-2	0.000
D-3	0.248	P-3	0.000
I-1	0.000	P-3	0.000
I-2	0.000	Q-1	0.000
I-3	0.000	Q-1	0.000
N-1	0.000	Q-2	0.000
N-1	0.000	Q-2	0.000
N-2	0.000	Q-3	0.000
N-2	0.000	Q-3	0.000
N-3	0.000	R-1	0.121
N-3	0.000	R-2	0.585
O-1	0.000	R-3	0.227
O-2	0.000	S-1	0.000

The dioxin/furan TEQs presented in Table 4-3 show that there are only trace quantities of these substances in all of the effluents tested. As shown in Table 4-5, resin and fatty acids were only detected in effluent from Scott Paper (samples D and R). The impact of un-ionized ammonia concentration on sample toxicity is discussed in Section 4.3.

4.2.2 Compliance with Waste Management Permits

There were four instances where discharges exceeded permit limits, as outlined below.

< The flow rate from Discharge 01 at Lafarge Canada was calculated as 3106 m^3/day; the permitted limit for this discharge is 2950 m^3/day.

< Discharges 02 and 03 at MB New Westminster were found to have an oil & grease concentration of 6 and 5 mg/L, respectively; the permitted O&G limit is <5 mg/L. However, based on the analytical detection limits, BCELP does not consider these concentrations to be significantly different from the permitted value.

< The three samples of boiler blowdown at IFP Hammond were found to have pH values of 9.49 (sample I-1), 9.06 (sample I-2), and 9.07 (sample I-3). The boiler blowdown, Discharge 04, is permitted a pH in the range 6.5 to 8.5.

< Discharge 01 at Westshore is permitted a total suspended solids concentration of 130 mg/L. One sample (T-3) exceeded this limit with a TSS of 194 mg/L.

4.3 Toxicity

One sample location at each industrial operation was chosen for a series of toxicity tests. The selected discharges, termed primary effluents, are listed in Table 4-6. Three types of toxicity tests were conducted on the these effluent samples: 48-h LC50s using *Daphnia magna*, 96-h LC50s using rainbow trout and chronic toxicity tests using *Ceriodaphnia dubia*. Toxic effects of a particular effluent can be lethal or sublethal, and acute (occurring rapidly) or chronic (occurring or persisting with prolonged exposures) in nature. The LC50 tests are limited by providing only quantitative measurements of acute lethality together with observations of concentrations that are acutely stressful to the animals. Samples with LC50s >100% could still cause significant sublethal toxic effects. The chronic toxicity test using *Ceriodaphnia dubia*, is appreciably more sensitive than the acute lethality test using *Daphnia magna* or rainbow trout, which enables a more sensitive and reliable comparison of relative toxicity emission rates for various effluents, including those which are not acutely lethal.

4.3.1 Tests with *Daphnia magna*

A separate BCR data sheet reporting the findings for each *D. magna* 48-h LC50 test with a primary effluent sample is provided in Appendix XII. These data sheets include details regarding the sublethal and lethal effects of the individual concentrations of each sample tested, as well as information concerning specific test conditions and the results of reference toxicant tests using the same culture of daphnids. The 48-h LC50s derived for each *D. magna* test are summarized in Table 4-7, together with the 96-h LC50s determined for underyearling rainbow trout using the same samples.

Table 4-6: Discharge Numbering and Sample Collection

Sample	Industry	Discharge Permit		Type of Discharge
		Permit #	Discharge #	
A	Lafarge Canada	42	02	cooling & storm
D	Scott Paper	335	02	paper mill discharge
E	IFP Fraser Mills	412	03	cooling & storm
N	MB New Westminster	1664	02	cooling, boiler, runoff
I	IFP Hammond Cedar	2756	04	boiler blowdown
K	Tree Island Industries	3190	02	cooling water
P	Domtar (Coquitlam)	3410	01	condensate, boiler
L	Tilbury Cement	4513	01	cooling water
Q	Hilinex Packaging	4962	01	cooling water
M	Westshore Terminals	6819	02	surface runoff

According to the 48-h LC50 tests with *D. magna*, each of the three samples from four of the ten primary effluents studied were not acutely lethal to the majority of daphnids exposed. LC50s for these samples (Scott Paper's papermill effluent, IFP Hammond's boiler blowdown discharge, Tree Island Industries' cooling water, and Domtar's effluent) were consistently greater than 100%. One or two of the three samples of primary effluent discharged by Lafarge Canada, Westshore Terminals, and MB New Westminster were also shown to be "not acutely lethal" (48-h LC50s >100%) according to this test; LC50s for the remaining samples of these effluents ranged from a low of 7% (Westshore Terminals) to

71% (MB New Westminster). The samples of primary effluent discharged by IFP Fraser Mills, Hilinex Packaging and Tilbury Cement showed 48-h LC50s ranging from 35 to 71%.

Table 4-7: Summary of Acute Toxicity of Primary Effluent Samples to *Daphnia magna* and Rainbow Trout

Sample Code	Industry	Sample Description	Sample Date	*Daphnia magna* 48-h LC50 (%)*	Rainbow Trout 96-h LC50 (%)+
A-1	Lafarge Canada	cooling water	15/02/93	25 (13, 100)	>100
A-2	Lafarge Canada	cooling water	17/02/93	>100	-
A-3	Lafarge Canada	cooling water	19/02/93	>100	>100
D-1	Scott Paper	papermill effluent	15/02/93	>100	>100
D-2	Scott Paper	papermill effluent	17/02/93	>100	-
D-3	Scott Paper	papermill effluent	19/02/93	>100	>100
E-1	IFP Fraser Mills	cooling water	22/02/93	ND	80 (56, 100)
E-1	IFP Fraser Mills	cooling water^	22/02/93	71 (0, 100)	-
E-2	IFP Fraser Mills	cooling water	24/02/93	ND	-
E-3	IFP Fraser Mills	cooling water	26/02/93	50 (25, 100)	>100
N-1	MB New Westminster	cooling water	01/03/93	71 (50, 100)	>100
N-2	MB New Westminster	cooling water	03/03/93	>100	-
N-3	MB New Westminster	cooling water	05/03/93	>100	>100
I-1	IFP Hammond	boiler blowdown	08/03/93	>100	>100
I-2	IFP Hammond	boiler blowdown	10/03/93	>100	-
I-3	IFP Hammond	boiler blowdown	12/03/93	>100	>100

ND = Not determined (mortality data would not allow calculation of LC50).

* Median lethal concentration for *D. magna*, during a 48-h test period. 95% confidence limits in parentheses.

[+] Median lethal concentration for rainbow trout, during a 96-h test period. 95% confidence limits in parentheses.
[^] The test was repeated starting the next day, using the same sample.

Table 4-7: Summary of Acute Toxicity of Primary Effluent Samples to *Daphnia magna* and Rainbow Trout (cont.)

Sample Code	Industry	Sample Description	Sample Date	*Daphnia magna* 48-h LC50 (%)*	Rainbow Trout 96-h LC50 (%)+
K-1	Tree Island Industries	cooling water	08/03/93	>100	>100
K-2	Tree Island Industries	cooling water	10/03/93	>100	-
K-3	Tree Island Industries	cooling water	12/03/93	>100	>100
P-1	Domtar (Coquitlam)	effluent	08/03/93	>100	>100
P-2	Domtar (Coquitlam)	effluent	10/03/93	>100	-
P-3	Domtar (Coquitlam)	effluent	12/03/93	>100	>100
L-1	Tilbury Cement	cooling water	01/03/93	71 (50, 100)	>100
L-2	Tilbury Cement	cooling water	03/03/93	59 (25, 100)	-
L-3	Tilbury Cement	cooling water	05/03/93	71 (50, 100)	>100
Q-1	Hilinex Packaging	effluent	22/02/93	ND	>100
Q-2	Hilinex Packaging	effluent	24/02/93	35 (25, 50)	-
Q-3	Hilinex Packaging	effluent	26/02/93	59 (6, 100)	88 (56, 100)
M-1	Westshore Terminals	discharge water	03/03/93	>100	>100
M-2	Westshore Terminals	discharge water	03/03/93	59 (25, 100)	-
M-3	Westshore Terminals	discharge water	05/03/93	7 (3, 13)	>100

ND = Not determined (mortality data would not allow calculation of LC50).

* Median lethal concentration for *D. magna*, during a 48-h test period. 95% confidence limits in parentheses.

[+] Median lethal concentration for rainbow trout, during a 96-h test period. 95% confidence limits in parentheses.

Some common terms used in toxicity studies are defined briefly in the section on Terminology; readers not familiar with these terms are referred to that section.

Federal Pulp and Paper Regulations require that pulp and paper mill effluents be monitored weekly using Environment Canada's (1990b) 48-h acute lethality test with *Daphnia magna* (DFO, 1992). Under these regulations, a sample of effluent is considered to have failed the *Daphnia magna* test when, at 100% concentration, it kills more than 50% of the *Daphnia magna* subjected to it during a 48-h period (DFO, 1992). According to this definition, 11 of the 30 samples of primary effluent (i.e., 37% of samples) failed the 48-h acute lethality test with *Daphnia magna*.

4.3.2 Tests with Rainbow Trout

Separate BCR data sheets giving the results of the acute lethality tests using underyearling rainbow trout are provided in Appendix XIII. These data sheets include details regarding the appearance and behaviour of fish during the test, sample appearance, test conditions, and findings for reference toxicant tests with the same fish population. The 96-h LC50s derived for each test are summarized in Table 4-7 together with the *D. magna* 48-h LC50s determined for the same samples.

For eight of the ten primary effluents, the two samples tested with this assay had 96-h LC50s 100% For the remaining effluents (cooling water discharged by IFP Fraser Mills and Hilinex Packaging), one of the two samples was "not acutely lethal" (96-h LC50 >100%) and the other required some dilution to render the sample non-lethal to trout.

The acute lethality test using rainbow trout is the assay used most commonly to determine whether or not an effluent is "acutely lethal". Regulators frequently define an effluent as not acutely lethal if its 96-h LC50 is greater than 100%. Conversely, an effluent may be defined as acutely lethal if, at 100% concentration, it kills more than 50% of the rainbow trout subjected to it during a 96-h period (DFO, 1992). According to this (Environment Canada, 1990d) test, 18 of the 20 samples of primary effluent studied were not acutely lethal, and 2 of the 20 samples were acutely lethal.

A comparison of the summary findings for the rainbow trout acutely lethality test with those of the *Daphnia magna* acute lethality test indicates that, overall, the acute lethality test using *D. magna* was generally more sensitive to the samples examined than the acute lethality test using trout. This is not always the case, and many examples exist in the literature where the converse is true or there is no discernible difference in sensitivity of the two acute lethality tests. The relative sensitivity of these two test methods is influenced by the nature of the toxic constituents to which the organisms are exposed, as well as by the condition of the organisms at the time of the test.

4.3.3 Tests with *Ceriodaphnia dubia*

BCR data sheets, giving the detailed findings for the chronic toxicity tests with *Ceriodaphnia dubia* and each of the ten primary effluents studied, are provided as Appendix XIV. These data sheets include all endpoint data calculated for each test (LC50, IC50, IC25, LOEC, NOEC, TEC), data regarding the total number of neonates produced per replicate (n = 10) in each test concentration including the triplicate control groups, the mean ± standard deviation number of neonates produced per concentration, the percentage of mortalities of first-generation adults in each concentration, the range of pH and dissolved oxygen measurements for each concentration, comments concerning test conditions, and comments concerning the survival, behaviour and appearance of the test organisms. The key endpoint statistics determined for each of these chronic toxicity tests are summarized in Table 4-8.

This chronic toxicity test (Environment Canada, 1992) examines in one assay the effects of three discrete effluent samples from the same source, on the number of young (neonate) daphnids generated by the first-generation daphnids exposed to a range of concentrations of the samples for a period of time adequate (if in uncontaminated water) to produce three broods of young. Test results showed that each of the ten primary effluents caused a significant impairment of reproductive success, at effluent concentrations ranging from 1% to 80% depending on sample source. According to this test, the most toxic primary effluents were those discharged by Westshore Terminals, IFP Hammond, and Domtar: IC25s for these sources were <1% to 2%. The least toxic primary effluents were those discharged by Lafarge Canada, IFP Fraser Mills, MB New Westminster, and Tree Island Industries: IC25s for these four effluent sources ranged from 38% to 80%. The chronic toxicity of the primary effluents discharged by Scott Paper, Hilinex Packaging and Tilbury Cement was similar (IC25s, 15% to 18%) and in the mid-range relative to the other effluent sources.

Comparison of the results for this chronic toxicity test shown in Table 4-8 with those derived for the *D. magna* acute lethality test given in Table 4-7 indicates that the chronic test was appreciably more sensitive than the acute lethality test. This is as anticipated, based on numerous previous studies with effluents involving these tests. Biotreated or other effluents which are not acutely lethal in *D. magna* or rainbow trout tests frequently have IC25 values for the *C. dubia* chronic toxicity test within the range of 1 to 10% Further comparison suggests that the correlation between *D. magna* (or rainbow trout) LC50s and *C. dubia* IC25s is poor, and that the chronic toxicity of effluents cannot be predicted from the acute lethality data. For example, the samples for two of the three effluents found to be most toxic using the *C. dubia* test for chronic toxicity (IFP Hammond and Domtar) were not acutely lethal to *D. magna* or rainbow trout at full strength. Conversely, one of the primary effluent sources causing acute lethal toxicity to both *D. magna* and rainbow trout (IFP Fraser Mills) was amongst the less toxic effluents according to the chronic *C. dubia* test.

Table 4-8: Summary of Chronic Toxicity of Effluent Samples to *Ceriodaphnia dubia*

Sample Code*	Industry	Sample Description	LC50+ (%)	NOEC (%)	LOEC (%)	TEC (%)	IC25 (%)
A	Lafarge Canada	cooling water	>100	25	50	35	51 (39, 57)
D	Scott Paper	papermill effluent	81 (6, >100)	13	25	18	18 (12, 56)
E	IFP Fraser Mills	cooling water	55 (25, 100)	25	50	35	38 (35, 50)
N	MB New Westminster	cooling water	>100	50	100	71	80 (66, 91)
I	IFP Hammond	boiler blowdown	>100	1	3	2	2 (0.8, 28)
K	Tree Island Industries	cooling water	71	25	50	35	42 (27, 57)
P	Domtar (Coquitlam)	effluent	100 (50, >100)	1	3	2	2 (0.8, 4)
L	Tilbury Cement	cooling water	35 (25, 50)	3	6	4	15 (15, 16)
Q	Hilinex Packaging	effluent	59 (0, 100)	13	25	18	16 (1, 23)
M	Westshore Terminals	discharge water	71 (50, 100)	<1	1	<1	1 (0.7, 6)

[*] Three samples, collected on Monday, Wednesday and Friday of a given week, were used in this test. Sample no. 1 was used for Days 1 and 2, sample no. 2 for Days 3 and 4, and sample no. 3 for Days 5, 6 and 7 of the test.

[+] Median lethal concentration for *Ceriodaphnia dubia*, during the 6- to 7-day test period. 95% confidence limits in parentheses.

4.3.4 Acute and Chronic Toxicity Emission Rates

The Toxic Unit (TU) and Toxicity Emission Rate (TER) concepts (McLeay *et al*, 1987) were used to appraise the toxic loadings discharged to the envions of the Fraser River. Both Acute Toxic Units (ATU) and Chronic Toxic Units (CTU) were calculated. These are defined as follows:

1 ATU = 48-h LC50 (*D. magna*)
1 CTU = 7-d IC25 (*C. dubia*)

Therefore: ATU = 100(%) / 48-h LC50 (%)
CTU = 100(%) / 7-d IC25 (%)

Both the ATU and CTU are dimensionless.

Acute Toxicity Emission Rates (ATERs) and Chronic Toxicity Emission Rates (CTERs) were calculated from the ATUs and TCUs, as follows:

ATER = ATU x discharge flow rate (m^3/ d)
CTER = CTU x discharge flow rate (m^3/ d)

Therefore, ATER has the units ATU$\cdot m^3$/ d and CTER has the units CTU$\cdot m^3$/ d.

Estimated ATERs for each of the samples of primary effluent studied are given in Table 4-9. Also included in this table are the *D. magna* LC50, Acute Toxic Unit (ATU), and effluent-flow data used to derive the ATERs for each sample.

Seventeen of the 30 ATERs are expressed as "less-than" ("<") values. For each of these samples, the LC50 was >100%, resulting in an ATU of <1 and a resulting "<" ATER. For these samples, the higher values reflect the relatively high flow rates, and the lower values reflect the relatively low flow rates for the respective discharges. Since each of these samples was demonstrated to be not acutely lethal at full strength, no real significance can be placed on the magnitude of the "less than" value shown.

Table 4-9: Acute Toxicity Emission Rates for Primary Effluent Samples, Based on *D. magna* Results

Sample Code	Industry	Sample Description	Sample Date	LC50* (%)	ATU	Flow (m^3/d)	ATER (ATU•m^3/d)
A-1	Lafarge Canada	cooling water	15/02/93	25	4	196	784
A-2	Lafarge Canada	cooling water	17/02/93	>100	<1	171	<171
A-3	Lafarge Canada	cooling water	19/03/93	>100	<1	685	<685
D-1	Scott Paper	papermill effluent	15/02/93	>100	<1	16,000	<16,000
D-2	Scott Paper	papermill effluent	17/02/93	>100	<1	16,000	<16,000
D-3	Scott Paper	papermill effluent	19/02/93	>100	<1	16,000	<16,000
E-1	IFP Fraser Mills	cooling water	22/02/93	71	1.4	60	84
E-2	IFP Fraser Mills	cooling water	24/02/93	ND[5]	ND	60	ND
E-3	IFP Fraser Mills	cooling water	26/02/93	50	2	60	120

N-1 N-2 N-3	MB New Westminster MB New Westminster MB New Westminster	cooling water cooling water cooling water	01/03/93 03/03/93 05/03/93	71 >100 >100	1.4 <1 <1	75 75 65	105 <75 <65
I-1 I-2 I-3	IFP Hammond IFP Hammond IFP Hammond	boiler blowdown boiler blowdown boiler blowdown	08/03/93 10/03/93 12/03/93	>100 >100 >100	<1 <1 <1	14.4 14.4 14.4	<14.4 <14.4 <14.4

* Median lethal concentration for *Daphnia magna*, during a 48-h test period (see Table 4-7).

ATU = Acute Toxic Units (based on 48-h LC50 for *D. magna*).
ATER = Acute Toxicity Emission Rate (product of ATU times flow).
ND = Not determined (mortality data would not allow calculation).

Table 4-9: Acute Toxicity Emission Rates for Primary Effluent Samples (cont.)

Sample Code	Industry	Sample Description	Sample Date	LC50* (%)	ATU	Flow (m^3/d)	ATER
K-1	Tree Island Industries	cooling water	08/03/93	>100	<1	1,730	<1,730
K-2	Tree Island Industries	cooling water	10/03/93	>100	<1	1,730	<1,730
K-3	Tree Island Industries	cooling water	12/03/93	>100	<1	1,730	<1,730
P-1	Domtar	effluent	08/03/93	>100	<1	6	<6
P-2	Domtar	effluent	10/03/93	>100	<1	6	<6
P-3	Domtar	effluent	12/03/93	>100	<1	6	<6
L-1	Tilbury Cement	cooling water	01/03/93	71	1.4	95	133
L-2	Tilbury Cement	cooling water	03/03/93	59	1.7	330	561
L-3	Tilbury Cement	cooling water	05/03/93	71	1.4	55	77

Q-1	Hilinex Packaging	effluent	22/02/93	ND	ND	2.3	ND
Q-2	Hilinex Packaging	effluent	24/02/93	35	2.9	2.3	7
Q-3	Hilinex Packaging	effluent	26/02/93	59	1.7	2.3	4
M-1	Westshore Terminals	discharge water	03/03/93	>100	<1	283	<283
M-2	Westshore Terminals	discharge water	03/03/93	59	1.7	283	481
M-3	Westshore Terminals	discharge water	05/03/93	7	14.3	283	4,047

* Median lethal concentration for *Daphnia magna*, during a 48-h test period (see Table 4-7).

ATU = Acute Toxic Units (based on 48-h LC50 for *D. magna*).
ATER = Acute Toxicity Emission Rate (product of ATU times flow).
ND = Not determined (mortality data would not allow calculation).

The Chronic Toxicity Emission Rate (CTER) calculated for each of the ten primary effluent sources is given in Table 4-10, together with the data (IC25, CTU, effluent flow) on which the calculations are based. The CTERs, which are a product of Chronic Toxic Units (CTUs) and estimated daily effluent flow (m^3/d) for the respective effluent sources, range from a low of 14 CTU·m^3/d (Hilinex Packaging) to a high of 89,600 CTU·m^3/d (Scott Paper). For purposes of comparison, the following rankings for CTERs have been arbitrarily assigned:

Low CTER:	<100 CTU·m^3/d
Moderately low CTER:	100 to 999 CTU·m^3/d
Moderately high CTER:	1,000 to 9,999 CTU·m^3/d
High CTER:	10,000 to 99,999 CTU·m^3/d
Very high CTER:	≥100,000 CTU·m^3/d

Using this arbitrary ranking scheme, and the present results and calculations associated with the *C. dubia* chronic toxicity tests, the 10 primary effluents studied can be ranked as follows:

Low CTER:	Hilinex Packaging
	MB New Westminster
Moderately low CTER:	Lafarge Canada
	IFP Fraser Mills
	IFP Hammond
	Domtar
Moderately high CTER:	Tilbury Cement
	Tree Island Industries
High CTER:	Scott Paper
	Westshore Terminals

In terms of potential toxic effects in receiving waters, the calculation of CTERs provides a useful tool for ranking and comparing the chronic toxic loading discharged daily by various effluent sources. Effluent flow is an integral component of such an analysis.

Table 4-10: Chronic Toxicity Emission Rates for Primary Effluent Samples

Sample Code	Industry	Sample Description	IC25 (%)	CTU	Flow (m^3/d)	CTER (CTU·m3/d)
A	Lafarge Canada	cooling water	51	2.0	351	702
D	Scott Paper	papermill effluent	18	5.6	16,000	89,600
E	IFP Fraser Mills	cooling water	38	2.6	60	156
N	MB New Westminster	cooling water	80	1.3	72	94
I	IFP Hammond	boiler blowdown	2	50	14.4	720
K	Tree Island Industries	cooling water	42	2.4	1,730	4,152
P	Domtar (Coquitlam)	effluent	2	50	6	300
L	Tilbury Cement	cooling water	15	6.7	160	1,072
Q	Hilinex Packaging	effluent	16	6.3	2.3	14
M	Westshore Terminals	discharge water	1	100	283	28,300

CTU = Chronic Toxic Units (based on IC25s for chronic tests using *Ceriodaphnia dubia*).
CTER = Chronic Toxicity Emission Rate (product of CTU times flow).

4.4 **Bio-Uptake**

The concentrations of heavy metals, PAHs, and chlorophenolic compounds found in the samples of pooled muscle tissue from groups of juvenile rainbow trout held in the ten primary effluents or in control water (two groups) for eight days are presented in Tables 4-11 through 4-13 (wet-tissue values) and 4-14 through 4-16 (dry-tissue values). Both wet-tissue and dry-tissue values are presented to enable comparison with published tissue concentrations which are variously given as wet-weight and / or dry-weight concentrations. Tables 4-11 and 4-14 list heavy metal concentrations, Tables 4-12 and 4-15 provide PAH data and Tables 4-13 and 4-16 give chlorinated phenolic concentrations.

Appendix XIX contains notes on fish survival during the eight-day tests, and on observations of any gross pathologies observed during fish dissections. Also included in this appendix is a list showing the ranges of pH and dissolved oxygen concentrations to which fish were exposed during each bio-uptake test. All pH and dissolved oxygen values were compatible with fish survival.

The findings of muscle-tissue concentrations for each group of fish exposed to a particular primary effluent are summarized below, together with brief comments regarding the relevance of these findings. The findings for the control groups are summarized and discussed in Subsection 4.6.2.4 of this report.

In reviewing these findings, the reader should keep in mind that the effluent concentrations to which fish were exposed were normally 100%, and that this does not reflect the significantly lower exposure concentration in the environment. Additionally, it should be recognized that the period of exposure in this study was eight days only, and that this period was likely too short to result in the maximum concentrations of specific contaminants that could occur in fish muscle if exposures to fresh effluent were prolonged. The reader should also be aware that other tissues (e.g., liver and fatty tissue) commonly accumulate significantly higher concentrations of contaminants than fish muscle. Thus the present findings, which are limited to edible (muscle) tissue, do not reflect the greater extent of accumulation of specific contaminants that might have been found if whole-body or other (*e.g.*, liver) tissue had been analyzed. The data do, however, provide an indication of the relative degree of bio-uptake of the measured contaminants in edible (muscle) fish tissue for the primary effluents studied, under the defined test conditions.

Table 4-11: Wet-Tissue Heavy Metal Concentrations In Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (mg/kg wet weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-5
Total Metals											
Aluminum	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25
Antimony	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Arsenic	0.333	0.262	0.216	0.302	0.275	0.411	0.316	0.291	0.249	0.391	0.332
Cadmium	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Chromium	0.09	0.038	0.028	0.017	<0.015	0.034	0.017	0.018	0.023	0.02	0.03
Copper	0.46	0.49	0.45	0.43	0.37	0.35	0.4	0.35	0.48	0.46	0.3
Iron	4.5	3.6	4.2	4.1	4	3.4	3.7	5.6	4.2	5	3.6
Lead	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	338	334	336	334	335	322	332	324	308	316	321
Manganese	0.135	0.193	0.167	0.126	0.112	0.151	0.208	0.145	0.117	0.157	0.113
Mercury	0.049	0.025	0.036	0.034	0.018	0.074	0.033	0.053	0.056	0.048	0.081
Molybdenum	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	0.027	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Silver	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Zinc	5.42	5.16	5.42	4.72	5.74	5.09	4.96	5.11	5.48	5.65	5.28

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed.

< indicates below detection limit.

Table 4-12: Wet-Tissue Polycyclic Aromatic Hydrocarbon Concentrations In Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (mg/kg wet weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-5
Acenaphthene	-	0.005	-	<0.005	-	-	<0.005	0.008	<0.005	<0.005	<0.005
Acenaphthylene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Anthracene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)anthracene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)pyrene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(b)fluoranthene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(ghi)perylene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(k)fluoranthene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Chrysene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Dibenzo(a,h)anthracene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Fluorene	-	0.01	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(1,2,3-cd)pyrene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Naphthalene	-	0.013	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Phenanthrene	-	0.016	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Pyrene	-	<0.005	-	<0.005	-	-	<0.005	<0.005	<0.005	<0.005	<0.005
Total PAHs	-	0.044	-	<	-	-	<	0.008	<	<	<

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed.

< indicates below detection limit.

Table 4-13: Wet-Tissue Chlorinated Phenolic Concentrations In Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (Fg/kg wet weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-5
2,3,4-Trichlorophenol	-	<0.03	-	<0.04	-	-	<0.03	<0.04	<0.03	<0.03	<0.03
2,3,5-Trichlorophenol	-	<0.03	-	<0.04	-	-	<0.03	<0.03	<0.1	<0.04	<0.06
2,4,5-Trichlorophenol	-	<0.02	-	<0.04	-	-	<0.03	<0.04	<0.03	<0.03	<0.02
2,4,6-Trichlorophenol	-	1.5	-	<0.1	-	-	<0.1	<0.03	<0.1	<0.04	<0.02
2,3,4,5-Tetrachlorophenol	-	<0.05	-	<0.07	-	-	<0.05	<0.07	<0.05	<0.05	<0.05
2,3,4,6-Tetrachlorophenol	-	0.7	-	0.3	-	-	0.9	0.3	<0.2	0.2	0.2
2,3,5,6-Tetrachlorophenol	-	<0.08	-	<0.1	-	-	<0.07	<0.1	<0.08	<0.08	<0.07
Pentachlorophenol	-	0.4	-	0.1	-	-	1.9	0.3	0.2	0.1	0.2
3,4,5-Trichloroguaiacol	-	0.5	-	<0.06	-	-	<0.05	<0.08	<0.05	<0.06	<0.05
Tetrachloroguaiacol	-	0.3	-	<0.04	-	-	<0.03	<0.05	<0.03	<0.04	<0.03
3,4,5-Trichlorocatechol	-	<0.07	-	<0.08	-	-	<0.08	<0.07	<0.09	<0.05	<0.07
Tetrachlorocatechol	-	<0.2	-	<0.2	-	-	<0.1	<0.3	<0.1	<0.2	<0.1
Total Chlorinated Phenolics	-	3.4	-	0.4	-	-	2.8	0.6	0.2	0.3	0.4

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed.

< indicates below detection limit.

Table 4-14: Dry-Tissue Heavy Metal Concentrations
In Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (mg/kg dry weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-4
Total Metals											
Aluminum	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Antimony	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic	1.45	1.12	0.962	1.34	1.23	1.76	1.39	1.53	1.13	1.7	1.49
Cadmium	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Chromium	0.39	0.17	0.12	0.07	0.07	0.14	0.07	0.1	0.11	0.08	0.14
Copper	2	2.12	2.02	1.9	1.66	1.51	1.76	1.81	2.18	2	1.35
Iron	19.6	15.6	18.7	18.2	17.8	14.4	16.1	29.5	18.8	21.9	16.1
Lead	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	1470	1430	1500	1480	1500	1370	1460	1700	1390	1370	1440
Manganese	0.59	0.83	0.74	0.56	0.5	0.65	0.92	0.76	0.53	0.68	0.51
Mercury	0.211	0.109	0.161	0.152	0.08	0.315	0.147	0.277	0.253	0.208	0.362
Molybdenum	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nickel	0.12	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc	23.6	22.1	24.2	20.9	25.7	21.8	21.8	26.8	24.8	24.5	23.7

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed

< indicates below detection limit.

Table 4-15: Dry-Tissue Polyaromatic Hydrocarbon Concentrations Measured in Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (mg/kg dry weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-5
Acenaphthene	-	0.021	-	<0.020	-	-	<0.020	0.033	<0.020	<0.020	<0.020
Acenaphthylene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Anthracene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(a)anthracene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(a)pyrene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(b)fluoranthene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(ghi)perylene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(k)fluoranthene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Chrysene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Dibenzo(a,h)anthracene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Fluoranthene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Fluorene	-	0.042	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Indeno(1,2,3-cd)pyrene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Naphthalene	-	0.059	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Phenanthrene	-	0.07	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
Pyrene	-	<0.020	-	<0.020	-	-	<0.020	<0.020	<0.020	<0.020	<0.020
TOTAL PAHs	**-**	**0.192**	**-**	**<**	**-**	**-**	**<**	**0.033**	**<**	**<**	**<**

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed. "<" indicates below detection limit.

Table 4-16: Dry-Tissue Chlorinated Phenolic Concentrations In Muscle Dissected From Juvenile Rainbow Trout Held in Effluent Samples for Eight Days (mg/kg dry weight)

	A-1, A-3	D-1, D-3	E-1, E-3	I-1, I-3	K-1, K-3	L-1, L-3	N-1, N-3	P-1, P-3	Q-1, Q-3	S-1, S-3	S-4, S-5
2,3,4-Trichlorophenol	-	<0.13	-	<0.18	-	-	<0.13	<0.18	<0.13	<0.13	<0.13
2,3,5-Trichlorophenol	-	<0.13	-	<0.18	-	-	<0.13	<0.13	<0.44	<0.18	<0.26
2,4,5-Trichlorophenol	-	<0.09	-	<0.18	-	-	<0.13	<0.18	<0.13	<0.13	<0.09
2,4,6-Trichlorophenol	-	6.6	-	<0.44	-	-	<0.44	<0.13	<0.44	<0.18	<0.09
2,3,4,5-Tetrachlorophenol	-	<0.22	-	<0.31	-	-	<0.22	<0.31	<0.22	<0.22	<0.22
2,3,4,6-Tetrachlorophenol	-	3	-	1.32	-	-	3.95	1.32	<0.88	0.88	0.88
2,3,5,6-Tetrachlorophenol	-	<0.35	-	<0.44	-	-	<0.31	<0.44	<0.35	<0.35	<0.31
Pentachlorophenol	-	1.75	-	0.44	-	-	8.33	1.32	0.88	0.44	0.88
3,4,5-Trichloroguaiacol	-	2.19	-	<0.26	-	-	<0.22	<0.35	<0.22	<0.26	<0.22
Tetrachloroguaiacol	-	1.32	-	<0.18	-	-	<0.13	<0.22	<0.13	<0.18	<0.13
3,4,5-Trichlorocatechol	-	<0.31	-	<0.35	-	-	<0.35	<0.31	<0.39	<0.22	<0.31
Tetrachlorocatechol	-	<0.88	-	<0.88	-	-	<0.44	<1.32	<0.44	<0.88	<0.44
Total Chlorinated Phenolics	-	14.86	-	1.76	-	-	12.28	2.64	0.88	1.32	1.76

Note: The first sample code (*ie:* A-1) represents the sample to which fish were exposed for Days 1 to 4. The second sample code (*ie:* A-3) represents the sample to which fish were exposed for Days 5 to 8. See Table 3-4 for concentrations of each sample to which fish were exposed.

< indicates below detection limit.

4.5 Discussion of Effluent Characteristics, Toxicity and Bioavailability, by Industry

A detailed assessment of the likely source(s) of toxicity for the effluent samples included in this study is beyond the scope and intent of the investigation. A comprehensive toxicity identification evaluation, including appropriate sample pre-treatments (e.g., pH adjustment, filtration, pre-aeration) and greater numbers of samples, would be necessary to provide insightful information regarding the probable source(s) of effluent toxicity for a specific discharge. However, some indication of specific contaminants in the test effluents which might have contributed to the toxicity of samples found in this study is provided by the analytical data in Appendix VI. The toxic relevance of these analytical data is reviewed briefly here for each primary effluent characterized in the study. Initially, a summary of the toxicity-test findings for each primary effluent is presented.

Table 4-17 gives a summary of the possible sources of toxicity identified in each of the ten primary effluents. Constituents listed are those found in the samples at concentrations sufficient to contribute to the acute or chronic toxic effects noted. Reasons for listing each constituent as a possible source of toxicity are provided in the toxicity appraisal presented here for each primary effluent. Other possible sources of toxicity, due to unmeasured contaminants in the effluent (e.g., residual chlorine) or toxic concentrations below the limits of detection for the analyses employed (e.g., chlorinated phenolics, dissolved copper, dissolved aluminum), are not listed in this table but are discussed in the individual appraisals.
In assessing the possible contribution of various effluent constituents to sample toxicity, consideration should be given to the combined influence of individual contaminants. Their interactive effect on exposed aquatic life could be additive, synergistic, or antagonistic. An additive toxic effect is normally assumed unless evidence for the interaction of specific contaminants provides conclusive evidence that synergistic (greater than additive) or antagonistic (less than additive) toxic effects would be anticipated if both contaminants were present in the effluent.

For the purposes of this study, no in-depth assessment of the combined toxic influence of the various effluent constituents on daphnids (*Ceriodaphnia dubia* and *Daphnia magna*) and rainbow trout is possible. Rather, the appraisal is based on the measured concentrations of individual contaminants in the effluent and a cursory consideration of the concentrations of each reported in the technical literature to be toxic (lethal or sublethal; acute or chronic) to salmonid fish and other sensitive freshwater life. Nonetheless, the reader should be aware that low concentrations of individual contaminants known to be toxic at certain levels can together result in acute or chronic toxic effects due to their additive effect, even if the levels of each of these contaminants is below the threshold-effect concentration reported to be harmful (i.e., below reported LOECs). No attempt is made here to search the literature for reported chronic or acute toxicity values for daphnids (*Ceriodaphnia dubia* and *Daphnia magna*) exposed to the chemical constituents measured in the effluent samples, nor to address the toxic units and overall toxic effects that would be anticipated if the measured concentrations of known toxicants were additive in effect.

Table 4-17: Summary of Possible Sources of the Acute and/or Chronic Toxic Effects Identified for the Samples of Primary Effluent Studied

Industry	Sample Description	Sample Code	Possible Sources of Toxicity Identified in the Samples
Lafarge Canada	cooling water	A-1, A-2, A-3	conductance / salinity, copper, zinc
Scott Paper	papermill effluent	D-1, D-2, D-3	resin and fatty acids, TSS, zinc
IFP Fraser Mills	cooling water	E-1, E-2, E-3	copper, iron, zinc
Hilinex Packaging	effluent	Q-1, Q-2, Q-3	viscosity / starch, copper, iron, zinc, TSS
Tilbury Cement	effluent	L-1, L-2, L-3	conductance / salinity, TSS
Westshore Terminals	discharge water	M-1, M-2, M-3	TSS, zinc, cadmium, benzo(a)pyrene
MB New Westminster	cooling water	N-1, N-2, N-3	TSS, copper, zinc, iron, manganese, naphthalene
IFP Hammond	boiler blowdown	I-1, I-2, I-3	copper, zinc, aluminum, cadmium, iron, TSS, pH
Tree Island Industries	cooling water	K-1, K-2, K-3	zinc
Domtar	effluent	P-1, P-2, P-3	iron, TSS

4.5.1 Lafarge Canada

Samples from Location A (Process Cooling Water)

Chemistry and Toxicity

Results of the acute lethality tests with *Daphnia magna* showed that sample A-1 was acutely lethal (48-h LC50, 25%), whereas 100% concentrations of samples A-2 and A-3 were not (48-h LC50s, >100%). *Daphnia magna* held in sample A-3 for 48 h appeared stressed, but survived. Underyearling trout exposed to samples A-1 and A-3 survived the 96-h test without signs of distress, as did the juvenile trout held in these samples for eight days. In the chronic toxicity test with *Ceriodaphnia dubia*, the survival of these daphnids was unaffected by their exposure to samples A-1, A-2 and A-3, although reproduction was significantly inhibited at concentrations of 51% and higher. The No-Observed-Effect Concentration (NOEC) in the chronic assay was 25%. The present results indicate that little dilution of Lafarge Canada's cooling water is required to render the samples non-toxic according to the acute and chronic toxicity tests employed.

The conductance of samples A-1, A-2 and A-3 was 1,200, 6,040 and 5,610 micromhos/cm, respectively. These conductance values are relatively high for fresh water and reflect some intrusion of seawater in the water drawn from the Main Arm of the Fraser River by Lafarge Canada for use as cooling water. Daphnids are freshwater organisms and do not tolerate appreciable concentrations of seawater. Accordingly, it is very likely that the conductance/salinity of these samples contributed largely to the acute and chronic toxic effects noted in the daphnid assays, and might have been entirely responsible for the results found.

Concentrations of total suspended solids in samples A-1, A-2 and A-3 were low (9, <1 and 8 mg/L, respectively. These low TSS levels did not contribute to sample toxicity.

The concentrations of un-ionized ammonia calculated to be present in samples A-1, A-2 and A-3 at the time of the chronic toxicity test ranged from 0.001 to 0.023 mg NH_3/L. These concentrations are ~0.01 to 0.1 times lower than those concentrations of un-ionized ammonia reported to be acutely lethal to sensitive freshwater organisms, and appreciably below the 0.74 mg NH_3/L demonstrated to reduce the reproductive success of daphnids (EPA, 1985). Thus insufficient ammonia was present in these samples to contribute to sample toxicity. Nitrite concentrations were below detection limits and did not influence the toxicity-test results.

Concentrations of total zinc in samples A-1, A-2 and A-3 were 0.010, 0.025 and 0.034 mg/L, respectively; dissolved zinc levels for these samples were 0.009, 0.025 and 0.033 mg/L. These zinc levels approached or exceeded the provincial (Nagpal and Pommen, 1993) water quality criterion for total zinc recommended as a tentative maximum for the protection of sensitive freshwater life. Based on this criterion, the level of zinc in these samples might have contributed to sample toxicity.

Dissolved copper concentrations were non-detectable in sample A-1, but 0.015 and 0.013 mg/L in samples A-2 and A-3. The high hardness of samples A-2 and A-3 would diminish the toxic effects of these copper loadings, although these results might be spurious due to the presence of seawater in the samples. Dissolved copper in soft water can be harmful to sensitive freshwater life at much lower concentrations; the relatively low hardness of the dilution water used in the chronic toxicity test might have enabled some toxic influence of the concentrations of dissolved copper detected. Concentrations of other metals including arsenic and manganese were below levels of concern.

Since Lafarge Canada uses Fraser River water as its principal supply of cooling water, it is possible that contaminants in this water from sources unrelated to Lafarge Canada's operations may have also contributed to sample toxicity.

Bioavailability

The four fish held in a 100% concentration of Lafarge Canada's cooling water for eight days[12] survived the exposure with no signs of distress. No gross pathologies were evident during the fish dissections.

Contaminant analyses of the pooled muscle homogenate from these fish were restricted to metals. Muscle chromium was approximately three times control values. Muscle nickel was also detected, unlike all other pooled muscle samples (including controls) where nickel was below detection. Concentrations of other metals detected in fish exposed to Lafarge Canada's cooling water were similar to the control values.

The concentration of chromium found in fish exposed to Lafarge Canada's cooling water for eight days is similar to levels reported in the muscle tissue of various species of fish sampled from the lower Fraser River during 1988 (Swain and Walton, 1989). Muscle chromium values ranging from 0.08 to 2.05 mg/kg wet weight were reported for various species of fish taken from the North Arm of the Fraser River, and provincial data report a mean chromium concentration of 0.27 mg/kg (presumably wet weight) in muscle from rainbow trout captured from uncontaminated B.C. lakes (Swain and Walton, 1989). These

[12]Fish were exposed to A-1 for 4 days, then transferred to A-3 for the remaining 4 days. The identical procedure (i.e., sample "_-1" for Days 1 to 4; sample "_-3" for Days 5 to 8) was used for each effluent bio-uptake test.

data indicate that the chromium concentration in the muscle of trout exposed to Lafarge Canada's cooling water is not exceptional. Nor is their muscle nickel concentration. Rieberger (1992) reports a mean muscle nickel concentration of 1.20 mg/kg wet weight (44 times that found in the trout held in Lafarge Canada cooling water) in rainbow trout captured from uncontaminated B.C. lakes. Mean muscle nickel levels in various species of fish captured from the lower Fraser River during 1988 ranged from 0.04 to 2.42 mg/kg wet weight (Swain and Walton, 1989).

The muscle-metal data from the 1988 river survey indicate that the highest values of both nickel and chromium were taken from fish captured from the North Arm, relative to those for fish taken from the Main Arm or Main Stem of the Fraser River (Swain and Walton, 1989). Since Lafarge Canada's cooling water is discharged to the Main Arm, the somewhat higher levels of nickel and chromium in muscle tissue from fish captured from the North Arm is not related to the findings of slightly elevated (relative to other groups in this study) nickel and chromium levels in trout muscle tissue in the present bio-uptake test. Concentrations of total and dissolved nickel and chromium in all three samples of Lafarge Canada's cooling water analyzed were below detection limits.

Samples from Location B (Process Cooling Water)

The chemical data from sample location B are similar to those at location A. This is consistent with information regarding the process, since both discharges are process cooling water. Concentrations of copper, iron and zinc were elevated. Total suspended solids concentrations were quite low in all three samples (3, 12 and 30 mg/L, respectively).

4.5.2 Scott Paper

Samples from Location D (Papermill Effluent)

Chemistry and Toxicity

With the exception of two of ten daphnids in a single (50%) concentration of sample D-1, the three samples of Scott Paper's papermill effluent examined in this study caused no discernible lethal or sublethal toxic effects on *Daphnia magna* during 48-h LC50 tests. Similarly, the populations of underyearling and juvenile rainbow trout exposed to Scott's effluent for periods of four or eight days showed no toxic responses. In the chronic toxicity test with *Ceriodaphnia dubia*, Scott Paper's papermill effluent caused partial (10 to 70% of daphnids) mortalities of the first-generation daphnids at concentrations ranging from 100% to 12.5%, although all daphnids of this species survived the seven-day exposure to 6.3%, 3.2% and 1% effluent. Reproduction of *Ceriodaphnia dubia* was significantly inhibited at concentrations of 18% and higher. The NOEC in the chronic assay was 12.5%. These results indicate no acute toxicity for 100% or lower concentrations of Scott Paper's papermill effluent, and no chronic toxicity unless the concentration of effluent was greater than 12.5%.

The cause(s) of the chronic toxicity of Scott Paper's papermill effluent cannot be determined with any degree of confidence without an in-depth toxicity identification evaluation, including additional *Ceriodaphnia dubia* chronic tests and correlated chemical analyses. Present results rule out ammonia, nitrite, PAHs, and most metals as likely sources of toxicity. No evidence exists that chlorinated phenolics contributed to sample toxicity, and all measured CPs were below detection limits. However, since the limit of detection for 3CP, 4CP and 5CP used in the present analyses was 0.001 mg/L, and since provincial water quality criteria for the protection of sensitive freshwater life (Nagpal and Pommen, 1993) list maximum values for these CPs ranging from 0.00002 mg/L to 0.0009 mg/L (depending on chemical and the pH of water), the present analyses do not rule out the possibility that trace levels of chlorophenolics (below the detection limit for the analyses) might have been present at concentrations that could have contributed to the observed toxicity.

Concentrations of total resin and fatty acids (RA&FA) in samples D-1, D-2 and D-3 were 0.058 mg/L, 0.288 mg/L and 0.256 mg/L, respectively. Resin and fatty acids are well known as wood extractives that can, depending on chemical species and concentration, cause lethal and sublethal toxic effects on sensitive species of freshwater invertebrates and fish at low concentrations. The total RA&FA concentrations in these samples are below concentrations known to be acute lethal to salmonid fish or daphnids; however it is quite possible that they contributed to the chronic toxic effects observed for the higher concentrations of effluent. Provincial water quality criteria (Nagpal and Pommen, 1993) list a maximum total RA&FA concentration of 0.025 mg/L for the protection of freshwater life in water at pH 7.0.

The concentrations of dioxins and furans found in these samples of papermill effluent were trace levels only, and likely did not contribute to sample toxicity. Calculated TEQ concentrations for these samples were 2.18, 0.75 and 0.00 pg/L. To our knowledge, the lowest concentration of 2,3,7,8-tetrachlorodibenzodioxin presently demonstrated to be harmful to freshwater organisms (rainbow trout) is 38 pg/L. This concentration affected growth, survival and behaviour of fish in long-term exposure studies (Mehrle *et al.*, 1988). Insufficient scientific information is available regarding the threshold-effect concentrations of dioxins and furans that are harmful to *Ceriodaphnia dubia* or other sensitive freshwater life in chronic toxicity tests. Without such information, the possible toxic contributions due to the extremely low levels of dioxins and furans measured in Scott Paper's papermill effluent, or in the other samples of primary effluent analyzed for these constituents in this study, cannot be completely dismissed.

Levels of total suspended solids (TSS) in samples D-1, D-2 and D-3 were 139, 27 and 26 mg/L, respectively. Although these levels are well below those that would be anticipated to be acutely lethal to fish, it is possible that suspended solids could have contributed to the effects observed in the chronic toxicity test with *Ceriodaphnia dubia*. Sublethal effects on fish and freshwater invertebrates have been reported in certain studies for TSS concentrations within this range (Singleton, 1985; CCREM, 1987; McLeay *et al.*, 1987; McLeay, 1990).

Concentrations of zinc (total, 0.02, 0.01 and 0.08 mg/L; dissolved, <0.005, 0.008 and 0.056 mg/L; samples D-1, D-2 and D-3, respectively) in Scott Paper's papermill effluent could conceivably have contributed to the chronic toxicity found. The provincial water quality criteria for zinc include a tentative maximum concentrations of 0.03 mg/L total zinc in receiving waters, to assure the protection of sensitive freshwater life (Nagpal and Pommen, 1993). The level of zinc in one of the three samples used in the chronic toxicity test exceeded this criterion for zinc, and might have exerted some chronic toxic effect on *Ceriodaphnia dubia*.

Concentrations of total copper in the samples were 0.012, <0.010 and 0.016 mg/L (samples D-1, D-2 and D-3, respectively). Based on the measured hardness values for these samples, total copper in samples D-1 and D-3 exceeded the provincial water quality criteria for maximum concentrations recommended to protect sensitive freshwater life (Nagpal and Pommen, 1993). The toxicity of copper to aquatic life is caused primarily by ionic copper which is present in the dissolved fraction. Dissolved copper concentrations in samples D-1, D-2 and D-3 were consistently below the detection limit of 0.010 mg/L for the present analyses. However, since dissolved copper concentrations as low as 0.004 mg/L can cause chronic toxic effects if the dilution water is soft (CCREM, 1987), the possibility exists that dissolved copper was present in the samples at strengths that could have contributed to the observed chronic toxic effects. Accordingly, the detection limit for copper in this study was inadequate to ensure that copper was below the threshold level of effect.

Water for Scott Paper's paper mill is primarily that drawn from the Fraser River. It is possible that low levels of contaminants in this water supply might be partially responsible for the chronic toxic effects noted for *C. dubia* held in effluent concentrations of 18% and higher.

Bioavailability

All juvenile rainbow trout held in Scott Paper's papermill effluent for eight days survived and appeared normal during the exposure. No gross pathologies were evident during the fish dissections.

All muscle metal concentrations measured in the pooled homogenate from fish held in Scott Paper's effluent were indistinguishable from respective control values.

Detectable fluorene (0.01 mg/kg wet weight; 0.042 mg/kg dry weight), naphthalene (0.013 mg/kg wet weight; 0.059 mg/kg dry weight), and phenanthrene (0.016 mg/kg wet weight; 0.07 mg/kg dry weight) were found in this sample of muscle tissue. All other polycyclic aromatic hydrocarbons were below the detection limit (<0.005 mg/kg wet weight; <0.02 mg/kg dry weight). The total detectable PAH concentration in the muscle sample from fish exposed to Scott Paper's papermill effluent for eight days was 0.044 mg/kg wet weight, or 0.192 mg/kg dry weight.

Measurable quantities of a number of chlorophenolic compounds were found in the sample of fish muscle, as follows (values for both dry weight and wet weight shown, as dry weight/wet weight): 2,4,6-trichlorophenol, 0.0066/0.0015 mg/kg (Fg/kgx0.001); 2,3,4,6-tetrachlorophenol, 0.003/0.0007 mg/kg; pentachlorophenol, 0.0018/0.0004 mg/kg; 3,4,5-trichloroguaiacol, 0.0022/0.0005 mg/kg; and tetrachloroguaiacol, 0.0013/0.0003 mg/kg. All other chlorophenolics were below detection limits. The total detectable chlorophenolic concentration for this muscle tissue was 0.0149 mg/kg dry weight, or 0.0034 mg/kg wet weight.

Of the five samples of muscle tissue from fish held in the various primary effluents that were analyzed for PAHs, Scott Paper's tissue sample was one of two showing any detectable PAHs. The chemical analytical data for Scott Paper's effluent samples does not explain the presence of the specific PAHs found in muscle tissue of fish held in their effluent for eight days. Fluorene and phenanthrene in effluent samples D-1 and D-3 were below detection limits of 0.0001 mg/L and 0.0002 mg/L respectively, and naphthalene was either non-detectable (0.0002 mg/L) or present in trace quantities (0.0003 mg/L).

Concentrations of fluorene and naphthalene in muscle tissue from various species of fish captured from the lower Fraser River during the 1988 survey were consistently below the detection limit of 0.004 mg/kg wet weight for these PAHs; levels of phenanthrene ranged from non-detectable (<0.004 mg/kg wet weight) to 0.026 mg/kg wet weight (Swain and Walton, 1989). In previous 8-day bio-uptake tests with juvenile rainbow trout, Swain and Walton (1992) reported mean dry-weight concentrations of 0.062 mg/kg naphthalene and 0.011 mg/kg phenanthrene in the control fish, and non-detectable (<0.005 mg/kg dry weight) or trace (0.006 mg/kg dry weight) concentrations of these PAHs in fish held in Paperboard Industries effluent for eight days.

BCELP recently approved water quality criteria for PAHs which include a recommendation that concentrations of benzo(a)pyrene in edible tissue should not exceed 0.001 mg/kg wet weight for heavy consumers of fish or shellfish (200 g/wk), and should not exceed 0.004 mg/kg wet weight for low consumers (50 g/wk) (Nagpal and Pommen, 1993). No benzo(a)pyrene (i.e., <0.005 mg/kg wet weight) was detected in the muscle tissue of fish held in Scott Paper's papermill effluent for eight days. Benzo(a)pyrene was also below detection limits (<0.01 µg/L) in the three samples of Scott Paper's papermill effluent analyzed in this study. The detection limit for benzo(a)pyrene in muscle tissue achieved in this study was not low enough to confirm that the provincial (Nagpal and Pommen, 1993) recommended concentrations of this PAH in edible tissue were not exceeded.

The 1988 survey of contaminants in various fish species captured from the lower Fraser River (Swain and Walton, 1989) showed the following ranges for mean dry-weight concentrations of specific CPs in muscle. The comparative value for Scott Paper's muscle sample is shown in parentheses. These ranges were: trichlorophenol (3CP), 0.011 - 0.038 mg/kg (0.0066 mg/kg); tetrachlorophenol (4CP), <0.001 mg/kg (0.003 mg/kg); and pentachlorophenol (5CP), 0.003 - 0.011 mg/kg (0.0018 mg/kg). This comparison shows that the levels of 3CP and 5CP in muscle of trout exposed to Scott Paper's papermill effluent for eight days were below those in lower Fraser River fish, whereas a trace quantity of 4CP was found in the Scott sample but not in the muscle from Fraser River fish. In the 8-day trout bio-uptake tests reported by Swain and Walton (1992), muscle tissue from fish held in undiluted effluent from Paperboard Industries contained non-detectable (<0.005 mg/kg) 3CP, <0.005 - 0.006 mg/kg 4CP, and 0.038 - 0.066 mg/kg 5CP (dry weight), as well as non-detectable (<0.005 mg/kg) trichloroguaiacol (3CG) and tetrachloroguaiacol (4CG). In the present study, the lower detection limits for 3CG and 4CG enabled the finding of trace quantities of 3CG (0.0022 mg/kg) and 4CG (0.0013 mg/kg) in muscle tissue of trout held in Scott Paper's papermill effluent for eight days.

Of the five samples of muscle tissue from fish held in the various primary effluents that were analyzed for chlorophenolic compounds (CPs), Scott Paper's tissue sample contained the highest concentration of total CPs. However, the concentration of total CPs measured in this tissue sample was only 0.0034 mg/kg wet weight. This concentration was appreciably less than the maximum total CP concentration of 0.1 mg/kg wet weight specified in the water quality objectives for fish muscle in this area (Swain and Holms, 1985). The chemical data for Scott Paper's effluent indicates that, as with the other effluent samples analyzed in this study, all CPs measured were below detection limits (Appendix VI).

Provincial water quality criteria for chlorophenols specify maximum concentrations of 1CP, 2CP, 3CP and 5CP in fish muscle, to prevent flavour impairment (Nagpal and Pommen, 1993). Flavour-impairment criteria are not given for 4CP, 3CC, 4CC, 3CG, or 4CG. The trace quantity (0.0015 mg/kg wet weight) of 2,4,6-trichlorophenol found in muscle tissue of trout held in Scott Paper's papermill effluent for eight days was well below the maximum concentration of 50 mg/kg wet weight specified in Nagpal and Pommen (1993) to protect against flavour impairment. Similarly, the trace quantity (0.0004 mg/kg wet weight) of pentachlorophenol in muscle tissue from fish exposed to Scott Paper's effluent was well below the maximum concentration of 20 mg/kg wet weight specified in Nagpal and Pommen (1993) as a criterion for flavour impairment in fish muscle.

4.5.3 IFP Fraser Mills

Samples from Location E (Cooling Water)

Chemistry and Toxicity

In the acute lethality tests with *Daphnia magna*, 60% of daphnids died in 1% cooling water although no deaths occurred at concentrations of 6.3%, 12.5% or 25%. This test was repeated, at which time 20% of daphnids died at 1% and a 48-h LC50 of 71% was calculated. Results for the *Daphnia magna* test with sample E-2 were also unusual, with all daphnids dying in 1% and 100% cooling water and all daphnids surviving in the concentrations ranging from 3.2% to 50%. No 48-h LC50 could be calculated for this test. In the *D. magna* test with sample E-3, survival data were straightforward (0% survival at 100% concentration, 50% survival at 50% concentration, 100% survival at all lower concentrations including 1%) and a 48-h LC50 of 50% was calculated. The acute lethality tests with underyearling rainbow trout showed that sample E-1 was lethal to fish without dilution, but all fish exposed to 56% and lower concentrations survived without signs of distress. Ten percent of underyearling trout held in a 100% concentration of sample E-3 for four days died; all other fish exposed to this and lower concentrations survived with no signs of distress. All juvenile rainbow trout held in a 50% concentration of samples E-1 and E-3 for eight days survived, and no signs of distress were observed. In the chronic toxicity test with *Ceriodaphnia dubia*, all first-generation daphnids died in 100% cooling water as did 40% of daphnids exposed to 50% cooling water. Reproduction of *C. dubia* was significantly inhibited at concentrations of 38% and higher. The NOEC in the chronic assay was 25%.

The findings of mortalities of *Daphnia magna* in 1% cooling water are odd (samples E-1 and E-2 only); further acute lethality tests with this species exposed to IFP Fraser Mills cooling water at concentrations ranging from 100% to #1% would be appropriate to confirm that these results are typical of this discharge.

The results of the acute toxicity tests with underyearling and juvenile rainbow trout indicate that little if any dilution of the cooling water is required to prevent overt toxic effects on this species. The results of the chronic toxicity test with *C. dubia* indicate no evidence of toxic effects if the cooling water is diluted to concentrations of 25% or lower.

IFP Fraser Mills cooling water is primarily "non-contact" chlorinated municipal water provided by GVWD (see Section 2.0). The observed toxicity of this discharge is not attributable to total suspended solids (#2 mg/L), un-ionized ammonia (#0.0006 mg/L).

Any direct effect of water hardness on the toxicity of this cooling water to *Daphnia magna* or *Ceriodaphnia dubia* is also unlikely. Although the water was extremely soft, sample hardness was adjusted to ~25 mg/L before commencing the 48-h LC50s with *Daphnia magna* (Environment Canada, 1990b); separate tests demonstrated that this daphnid species could tolerate this hardness without any adverse responses (see Subsection 4.6.2.3). Similarly, it was demonstrated that *Ceriodaphnia dubia* could tolerate very soft (5 mg/L) water without any adverse effects on reproductive success or survival (Subsection 4.6.2.3).

Concentrations of iron in IFP Fraser Mills cooling water might have contributed to the toxic effects found. Values for total iron in samples E-1, E-2 and E-3 were 0.15, 0.18 and 0.2 mg/L, respectively; dissolved iron concentrations for these samples were 0.1, 0.09 and 0.1 mg/L, respectively. Provincial water quality criteria recommend a maximum concentration of 0.3 mg/L total iron in receiving waters for the protection of freshwater life (Nagpal and Pommen, 1993).

Zinc levels in cooling-water sample E-3 might also have contributed to the observed toxic effects. Concentrations of total zinc were 0.008, <0.005 and 0.02 mg/L for samples E-1, E-2 and E-3, respectively. Dissolved zinc levels for these samples were 0.005, <0.005 and 0.02 mg/L, respectively. Provincial water quality criteria recommend a maximum concentration of 0.03 mg/L total zinc in receiving waters for the protection of freshwater life (Nagpal and Pommen, 1993).

Dissolved copper in this cooling water is perhaps the most likely single cause of the observed toxic effects. Dissolved copper values reported for samples E-1, E-2 and E-3 were <0.01, 0.027 and 0.028 mg/L, respectively; total copper values determined for these samples were 0.024, 0.029 and 0.028 mg/L. Since the preponderance of the total copper in samples E-2 and E-3 was dissolved, and since sample E-1 had a total copper value similar to the other two samples, the finding of non-detectable dissolved copper in sample E-1 is suspect. In soft water, dissolved copper can be acutely lethal to young salmonid fish at concentrations as low as 0.02 mg/L (Chapman, 1978). Dissolved copper can also cause chronic toxic effects on fish and freshwater invertebrates at concentrations as low as 0.004 mg/L (CCREM, 1987). Nagpal and Pommen (1993) recommend a maximum concentration of 0.0025 mg/L total copper in receiving waters with a hardness of only 5 mg $CaC0_3$/L (i.e., the hardness of IFP Fraser Mills cooling water), for the protection of sensitive freshwater life.

Sample E had the highest concentration of molybdenum detected in this study. However this concentration of 0.032 mg/L is well below the BC freshwater aquatic life guideline of 2 mg/L.

Concentrations of total residual chlorine were not measured in these samples. However, free chlorine can cause acute and chronic toxic effects on fish and freshwater invertebrates at extremely low levels which challenge the analytical detection limits. Provincial water quality criteria for chlorine recommend that the average concentration of total residual chlorine in freshwater should not exceed 0.002 mg/L (continuous exposure) to assure the protection of sensitive freshwater life (Nagpal and Pommen, 1993). Since IFP Fraser Mills uses chlorinated municipal water as cooling water, it is possible that trace levels of total residual chlorine, as free chlorine, were present in the samples at time of testing, and contributed to the toxic effects observed.

Bioavailability

Due to the indications of fish toxicity in concurrent LC50s with samples E-1 and E-3, juvenile rainbow trout were exposed to only 50% concentrations of these samples during the eight-day bio-uptake test. All juvenile trout survived this exposure with no signs of distress. No fish pathologies were apparent during the dissections for muscle tissue.

All muscle metal concentrations measured in the pooled homogenate from fish held for eight days in 50% IFP Fraser Mills effluent were indistinguishable from respective control values. Muscle PAHs and CPs were not measured.

4.5.4 MB New Westminster

Samples from Location N (Cooling Water and Boiler Blowdown)

Chemistry and Toxicity

A 100% concentration of sample N-1 killed all *Daphnia magna* within 48 h; daphnids of this species survived exposure to 50% and lower concentrations without signs of distress. All but one *D. magna* survived the two-day exposure to sample N-2, and no signs of distress were evident for any of the survivors. Sample N-3 caused 30% and 10% mortalities of *Daphnia magna* in 100% and 50% concentrations, respectively; all survivors in these and lower concentrations appeared normal during the test. In the acute toxicity tests with underyearling rainbow trout, 90% of fish exposed to undiluted N-1 survived, and all fish held in lower concentrations survived. No signs of distress for survivors held in this sample for four days were observed. In the 96-h LC50 with sample N-3, 80% of underyearling trout exposed to 100% and 56% concentrations survived whereas all fish died in 32% cooling water. All underyearling trout held in 18% and 10% concentrations of N-3 (and in the control water) survived. Technicians reporting results for this test stated "Concentration 32% was suspect, possibly contaminated". In the eight-day bio-uptake test with juvenile rainbow trout, all fish exposed to 50% concentrations of samples N-1 and N-3 survived without signs of distress.

All first-generation *Ceriodaphnia dubia* exposed to 100% and lower concentrations of N-1, N-2 and N-3 for seven days survived and appeared normal throughout the test. Reproduction of these daphnids was significantly impaired at 80% concentration. The NOEC in this test was 50%. According to this chronic toxicity test, MacMillan Bloedel's discharge water was the least toxic of the ten primary effluents evaluated in the study.

Concentrations of un-ionized ammonia (0.000002 to 0.0002 mg/L) and nitrite (<0.001 to 0.004 mg/L) estimated to be present in the three samples of MB New Westminster's cooling water were below levels that would have contributed to the minimal toxicity of the samples.
Concentrations of total suspended solids in samples N-1, N-2 and N-3 were 17, 21 and 14 mg/L, respectively. These levels were below threshold-effect concentrations known to be harmful to sensitive freshwater fish or invertebrate species (Singleton, 1985; CCREM, 1987; McLeay *et al.*, 1987; McLeay, 1990). However, it is possible that this low level of suspended solids could have contributed to the toxic effects observed in the chronic toxicity test with *Ceriodaphnia dubia.* Information regarding NOECs, LOECs and IC25s for *C. dubia* exposed to a range of concentrations of suspended solids during chronic toxicity tests (Environment Canada, 1992) is required to further evaluate this possibility.

Levels of total lead (0.008, 0.013, 0.011 mg/L; samples N-1, N-2, N-3, respectively) in the three samples of MB New Westminster cooling water were higher than those found in most of the primary effluents studied. Concentrations of dissolved lead (0.002, <0.001, 0.003 mg/L) were low. The provincial water quality criteria for lead (Nagpal and Pommen, 1993) include a recommendation that the maximum concentration of total lead should not exceed 0.025 mg/L (at a water hardness of 40 mg/L) to protect freshwater life. Lead levels in these cooling water samples were well within this criterion, and likely did not contribute to sample toxicity.

Concentrations of iron in the samples (total, 6.33, 3.06, 4.28 mg/L; dissolved, 4.36, 1.81, 2.17 mg/L; samples N-1, N-2, N-3, respectively) were high and exceeded the provincial water quality criterion of 0.3 mg/L total iron recommended as a maximum for the protection of freshwater life (Nagpal and Pommen, 1993). Concentrations of manganese (total, 0.51, 0.30, 0.41 mg/L; dissolved, 0.48, 0.28, 0.41 mg/L) in these samples were the highest found for any of the samples studied. A provincial water quality criterion of 0.1

to 1.0 mg/L total manganese is cited for the protection of freshwater life (Nagpal and Pommen, 1993). Based on these values, it is possible that the concentrations of iron and/or manganese in the samples participated in the toxic effects observed.

These samples contained the highest concentrations of dissolved zinc (0.18, 0.20, 0.24 mg/L) found for the samples of primary effluent included in the study. Total zinc concentrations (0.21, 0.24 and 0.24 mg/L; samples N-1, N-2 and N-3, respectively) were high and substantially greater than the maximum concentration of 0.03 mg/L total zinc recommended as a tentative provincial water quality criterion for the protection of sensitive freshwater life (Nagpal and Pommen, 1993). The levels of dissolved zinc found in these samples are a potential contributor to the toxic effects noted.

Concentrations of total aluminum in the samples (0.75, 0.65, 0.89 mg/L) were the second highest of those levels measured in the ten primary effluents included in the study. Dissolved aluminum concentrations in these three samples were consistently below the detection limit of 0.2 mg/L. This detection limit was inadequate to confirm that dissolved aluminum was below the provincial water quality criterion of 0.1 mg/L recommended as a maximum (at pH $\geq$6.5) for the protection of freshwater life (Nagpal and Pommen, 1993). Conceivably, dissolved aluminum could have been present in the samples at concentrations sufficient to contribute to the observed toxic effects.

Concentrations of copper in the samples (total, 0.029, 0.026, 0.022 mg/L; dissolved, 0.019, 0.011, 0.012 mg/L) exceeded the provincial water quality criterion of 0.006 mg/L total copper (based on a hardness of 40 mg/L) recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993). Based on the dissolved copper concentrations for these samples and the known acute and chronic toxicity of dissolved copper to fish and freshwater invertebrates (e.g., Chapman, 1978; CCREM, 1987), it is possible that copper in these samples was partly or completely responsible for sample toxicity.

Most concentrations of polycyclic aromatic hydrocarbons measured in the samples were below detection limits. Levels of naphthalene were 0.0002, <0.0002 and 0.0012 mg/L. The provincial water quality criteria include a criterion that naphthalene should not exceed 0.001 mg/L to prevent chronic toxic effects on freshwater life (Nagpal and Pommen, 1993). The concentration of naphthalene in sample N-3 just exceeded this criterion. A trace quantity of fluorene (0.0002 mg/L) was found in sample N-2; this concentration was below the provincial water quality criterion of 0.012 mg/L fluorene recommended for the protection of sensitive freshwater life from chronic toxic effects (Nagpal and Pommen, 1993).

Concentrations of all chlorophenolic compounds were below detection limits. Levels of 3CP, 4CP and 5CP were <0.001 mg/L. Since provincial water quality criteria for the protection of sensitive freshwater life (Nagpal and Pommen, 1993) list maximum values for these CPs ranging from 0.00002 mg/L to 0.0009 mg/L (depending on chemical and the pH of water), the present analyses do not rule out the possibility that trace levels of chlorophenolics (below the detection limit for the analyses) might have been present at concentrations that could have contributed to the observed toxic effects.

All resin and fatty acids measured in the samples of MB New Westminster's cooling water were below detection limits (<0.010 mg/L). The provincial water quality criteria (Nagpal and Pommen, 1993) include a recommendation that maximum concentrations of total resin and fatty acids not exceed 0.025 mg/L (at pH 7.0) for the protection of sensitive freshwater life. Within the limitations of the limit of detection for resin and fatty acids in this study, no evidence is provided indicating that resin or fatty acids contributed to sample toxicity.

Calculated TEQ concentrations for the trace levels of dioxins and furans in these three samples were 1.47, 5.01 and 2.62 pg/L. In light of the lowest concentration of 2,3,7,8-tetrachlorodibenzodioxin demonstrated to be harmful to fish or freshwater invertebrates in the technical literature reviewed (i.e., 38 pg/L; Mehrle *et al.*, 1988), no evidence exists indicating that these trace quantities of dioxins and furans would have contributed to the toxic effects observed.

Since the source of water comprising MB New Westminster's cooling water is chlorinated municipal water, the possibility exists that low levels of residual chlorine in this water supply were present in the cooling water and contributed to sample toxicity. Since concentrations of residual chlorine were not measured, this is speculative. However, due to the extremely toxic nature of very low levels (e.g., $0.003 mg/L) of both free chlorine and combined chlorine (CCREM, 1987; McLeay, 1992), the contribution of trace levels of residual chlorine in the mill's cooling water to sample toxicity cannot be ruled out.

Bioavailability

Due to the indications of fish toxicity in concurrent LC50s with underyearling rainbow trout held in samples N-1 and N-3 for four days[13], juvenile rainbow trout were exposed to only 50% concentrations of these samples during the eight-day bio-uptake test. All juvenile trout survived this exposure with no signs of distress. No gross abnormalities were detected during their dissection.

[13]One or two of the ten fish held in each of these samples of undiluted effluent appeared stressed during the initial 24 hours of the 4-day test. The other fish appeared normal.

All muscle metal concentrations measured in the pooled homogenate from fish held for eight days in effluent from MacMillan Bloedel's sawmill operation were indistinguishable from respective control values. All polycyclic aromatic hydrocarbons were below detection limits. With the exception of 2,3,4,6-tetrachlorophenol (4CP) and pentachlorophenol (5CP), all chlorinated phenolics measured were also below detection limits.

A concentration of 2,3,4,6-tetrachlorophenol measuring 0.00395 mg/kg dry weight, or 0.0009 mg/kg wet weight, was found in this pooled-muscle sample. This trace quantity of 4CP, which was approximately four times the trace level found in both control groups (0.00088 mg/kg dry weight), is similar to the maximum concentration (0.006 mg/kg dry weight) of 2,3,4,6-tetrachlorophenol reported for juvenile rainbow trout held in 100% effluent from Paperboard Industries for eight days (Swain and Walton, 1992). Concentrations of 4CP in muscle from various fish species sampled from the lower Fraser River during the 1988 survey by Swain and Walton (1989) were consistently below the limit of detection (<0.001 mg/kg dry weight).

The trace quantity (0.0083 mg/kg dry weight; 0.0019 mg/kg wet weight) of pentachlorophenol in muscle tissue from fish exposed to MacMillan Bloedel's New Westminster sawmill effluent for eight days was well below the maximum concentration of 20 mg/kg wet weight specified in Nagpal and Pommen (1993) as a provincial (BCELP) criterion for flavour impairment in fish muscle. Trichlorophenol in fish muscle was below the limit of detection (<0.0001 mg/kg wet weight) for this CP compound and thus well below the provincial maximum concentration of 50 mg/kg wet weight 5CP specified in Nagpal and Pommen (1993) to prevent tainting of fish flesh.

Muscle tissue from fish held in MB New Westminster's cooling water for eight days contained 0.0028 mg/kg wet weight total CPs. This concentration was appreciably less than the maximum total CP concentration of 0.1 mg/kg wet weight specified as a Fraser River Estuary water quality objective for fish muscle (Swain and Holms, 1985). The chemical analytical data for MB New Westminster's cooling water indicates that, as with the other effluent samples analyzed in this study, all CPs measured were below detection limits.

Samples from Location O (Storm Water and Kiln Condensate)

Chemical data for samples collected at location O are similar in character to those collected at location N. Concentrations of copper, iron, zinc and benzo(a)pyrene were elevated, although concentrations of copper and iron were much lower in sample O than sample N. Sample O showed the highest zinc concentration of all samples analyzed as part of this study (0.696 mg/L). No chlorinated phenolics, resin or fatty acids were found. BOD_5 and oil & grease concentrations were also low.

4.5.5 IFP Hammond

Samples from Location G (Compressor Cooling Water)

Sample G is cooling water from a compressor. Since this cooling water does not come into contact with any process chemicals, the chemical character of this water is expected to be consistent with intake water. Chemical analysis indicates that this is, in fact, the case. The only contaminant in this discharge which was found to be elevated was copper (sample G3 only). Copper piping in the facility could account for this slightly elevated copper concentration. Sample G-3 was found to have the lowest pH recorded in all samples analyzed during this study.

Samples from Location H (Kiln Condensate)

No elevated concentrations of any contaminants were noted.

Samples from Location I (Boiler Blowdown)

Chemistry and Toxicity

All but one *Daphnia magna* survived the 48-h exposure to 100% and lower concentrations of sample I-1; all surviving daphnids appeared normal throughout the test. Sample I-2 caused no toxic effects on this species at any concentration. Sample I-3 was also non-toxic to *D. magna* at 100% and lower concentrations. All underyearling rainbow trout exposed to 100% or lower concentrations of IFP Hammond's boiler blowdown water for four days survived with no signs of distress. Similarly, all juvenile rainbow trout held in 100% concentrations of I-1 and I-3 survived the eight-day test period without signs of distress.

All first-generation *Ceriodaphnia dubia* exposed to 100% concentrations of I-1, I-2 and I-3 for seven days survived and appeared normal throughout the test; similar results were found for all dilutions of this boiler blowdown water tested. However, significant reductions in reproductive success of this daphnid species occurred at concentrations of 2% and higher. The NOEC found in this chronic toxicity test was 1%. IFP Hammond's boiler blowdown water was one of the three primary effluents found to be most toxic according to the *Ceriodaphnia dubia* chronic toxicity test.

The initial pH values for the three samples of IFP Hammond's boiler blowdown water were 9.49, 9.06 and 9.07 (I-1, I-2 and I-3, respectively). Fresh water with pH values $9.0 is frequently harmful to sensitive aquatic life (CCREM, 1987). During the chronic toxicity test with *Ceriodaphnia dubia*, the pH of the undiluted (100%) samples ranged from 7.2 to 9.1, and that for the 50% concentration ranged from 7.0 to 8.6. The pH values for test concentrations #25% did not exceed 8.1. These data indicate that, while the high pH of the undiluted samples might have contributed to adverse effects on *C. dubia* exposed to a 100% concentration, the pH of the other concentrations to which this daphnid species was exposed in the chronic assay were not particularly adverse. The 9.49 pH of sample I-1 was the highest recorded in this study.

Concentrations of total suspended solids in samples I-1, I-2 and I-3 were 28, 1 and 30 mg/L, respectively. These levels were below threshold-effect concentrations reported to be harmful to sensitive freshwater fish or invertebrate species (Singleton, 1985; CCREM, 1987; McLeay et al., 1987; McLeay, 1990). It is possible that this low level of suspended solids could have caused some adverse effects in the chronic toxicity test with *Ceriodaphnia dubia*. However, given the degree of dilution of the samples required to reach the 1% NOEC in this test, it is unlikely that total suspended solids contributed much if at all to the observed toxic effects found in this assay.

Concentrations of un-ionized ammonia calculated to be present in the samples of IFP Hammond's boiler blowdown water during the chronic toxicity test were 0.003, 0064 and 0.020 mg/L for I-1, I-2 and I-3, respectively. Total ammonia-nitrogen levels in these samples were 0.006, 0.250 and 0.063 mg/L. These concentrations were below the provincial maximum concentration of 0.8 mg/L total ammonia-nitrogen for protection of freshwater life (Nagpal and Pommen, 1993). The lowest concentration of un-ionized ammonia reported to inhibit reproduction of daphnids is 0.7 mg/L (EPA, 1985). Based on this information, neither un-ionized ammonia nor nitrite contributed to sample toxicity.

Unlike the other primary effluents studied, detectable concentrations of dissolved aluminum (0.25, 0.21, 0.23 mg/L; samples I-1, I-2, I-3, respectively) were found in the samples. These concentrations exceeded the provincial maximum of 0.1 mg/L dissolved aluminum recommended for the protection of freshwater life in waters with pH values $6.5 (Nagpal and Pommen, 1993). Dissolved aluminum might have contributed to the chronic toxicity of these samples.

Concentrations of copper in the samples (total, 0.139, 0.011, 0.085 mg/L; dissolved, 0.031, <0.010, 0.019 mg/L; samples I-1, I-2, I-3, respectively) exceeded the provincial water quality criterion of 0.0025 mg/L total copper (based on a hardness of 5 mg/L) recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993). Given the dissolved copper concentrations for these samples and the known acute and chronic toxicity of dissolved Cu to fish and freshwater invertebrates (e.g., Chapman, 1978; CCREM, 1987), it is quite possible that copper in these samples contributed to sample toxicity.

Concentrations of total and dissolved cadmium in samples I-1 and I-2 were below the detection limit of 0.0002 mg/L, although 0.0002 mg/L cadmium (both total and dissolved) was found in sample I-3. The trace quantity of cadmium in sample I-3 was at the provincial water quality criterion of 0.0002 mg/L recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993). Since 0.0002 mg/L has been reported as a threshold-effect concentration for dissolved cadmium in chronic toxicity tests with daphnids (CCREM, 1987), it is possible that cadmium may have contributed to the chronic toxicity of IFP Hammond's boiler blowdown water.

Concentrations of iron in the samples (total, 10.2, 0.35, 6.91 mg/L; dissolved, 0.30, 0.17, 0.19 mg/L; samples I-1, I-2, I-3, respectively) exceeded the provincial water quality criterion of 0.3 mg/L total iron recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993). Iron in these samples might have contributed to their chronic toxicity. The concentration of total iron in sample I-1 was the highest recorded in this study.

Concentrations of zinc in the samples (total, 0.29, 0.06, 0.17 mg/L; dissolved, 0.12, 0.05, 0.06 mg/L; samples I-1, I-2, I-3, respectively) exceeded the provincial water quality criterion of 0.03 mg/L total zinc recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993). The zinc concentrations found in these samples might have contributed to their chronic toxicity.

Concentrations of total chromium in samples I-1, I-2 and I-3 were 0.048, <0.015 and 0.026 mg/L, respectively. Dissolved chromium concentrations were below the detection limit of 0.015 mg/L in all samples. Provincial water quality criteria recommend 0.002 mg/L total chromium as a maximum concentration for the protection of zooplankton (*e.g.*, daphnids) and phytoplankton in fresh water (Nagpal and Pommen, 1993). Laboratory studies have shown that chromium can cause chronic toxic effects on daphnids at concentrations as low as 0.003 mg/L (CCREM, 1987). Based on this information, it is possible that chromium contributed to the toxicity of IFP Hammond's boiler blowdown water. However, the detectable chromium was not soluble, and therefore perhaps not in a form that could cause toxic effects. The limit of detection for chromium by ICAP scan (0.015 mg/L) is not adequately low to ensure that concentrations of this metal in these or the other samples studied are below levels that could contribute to chronic toxic effects on daphnids.

Concentrations of total nickel in samples I-1, I-2 and I-3 were 0.048, <0.020 and 0.020 mg/L, respectively. Dissolved nickel concentrations were below the detection limit of 0.020 mg/L in all samples. Nagpal and Pommen (1993) recommend that total nickel not exceed a maximum concentration of 0.025 mg/L in soft fresh water, to protect sensitive aquatic life. Chronic toxicity tests with *Daphnia magna* have shown that nickel concentrations in soft water as low as 0.015 mg/L can cause harmful effects (CCREM, 1987). Accordingly, the present data indicate that the dissolved nickel concentrations in IFP Hammond's boiler blowdown water, although below detection limits, might have been present at concentrations sufficient to contribute to the chronic toxic effects observed. This is also true of the other primary effluents studied, since the limit of detection for nickel by ICAP scan (0.020 mg/L) is not sufficiently low to ensure that nickel concentrations are below the threshold level of 0.015 mg/L reported to cause chronic toxic effects on daphnids.

No detectable PAHs were found in the samples of IFP Hammond's boiler blowdown water. Concentrations of all chlorinated phenolics were also consistently below detection limits, as were all resin and fatty acids. The detection limits for chlorinated phenolics, resin acids and fatty acids were not sufficiently low to assure that they were below levels that could be harmful to freshwater life (Nagpal and Pommen, 1993), although no evidence is provided here indicating any contribution of these chemicals (or PAHs) to the chronic toxicity of the boiler blowdown water.

Calculated TEQ concentrations for the trace levels of dioxins and furans in these three samples were 0.12, 0.11 and 0.08 pg/L (samples I-1, I-2 and I-3, respectively). Given the lowest concentration of 2,3,7,8-tetrachlorodibenzodioxin demonstrated to be harmful to fish or freshwater invertebrates in the technical literature reviewed (i.e., 38 pg/L; Mehrle *et al.*, 1988), no evidence exists indicating that these trace quantities of dioxins and furans would have contributed to the chronic toxicity observed for IFP Hammond's boiler blowdown water.

The source of water in IFP Hammond's boiler blowdown discharge is chlorinated municipal water. Although concentrations of residual chlorine were not measured in the concentrations of boiler blowdown water to which daphnids were exposed in the chronic toxicity tests, it is conceivable that trace levels (i.e., $0.003 mg/L) of residual chlorine could have been present in the samples and contributed to the chronic toxic effects observed.

Bioavailability

All juvenile rainbow trout held in IFP Hammond's boiler blowdown water for eight days survived and appeared normal during the exposure. No gross pathologies were evident during the dissection of these fish.

All muscle metal concentrations measured in the pooled homogenate from fish held for eight days in a 100% concentration of IFP Hammond's boiler blowdown water were indistinguishable from respective control values. All polycyclic aromatic hydrocarbons were below detection limits.

Trace concentrations of 2,3,4,6-tetrachlorophenol (0.00132 mg/kg dry weight; 0.0003 mg/kg wet weight) and pentachlorophenol (0.00044 mg/kg dry weight; 0.0001 wet weight) were found in this muscle sample. All other chlorophenolics analyzed for were below detection limits.

The trace quantity of 2,3,4,6-tetrachlorophenol found in this sample was only 1.5 times that in the two control groups. The trace quantity of pentachlorophenol in the sample was identical to that in one of the control samples, and 0.5 times that in the other control. No environmental significance should be given to these trace quantities of 4CP or 5CP.

4.5.6 Tree Island Industries

Samples from Location J (Process Effluent)

Samples J-1, J-2 and J-3 had elevated concentrations of iron, lead, zinc, total ammonia and nitrite, as indicated below (samples J-1, J-2 and J-3, respectively):

< Iron: 0.97, 0.627 and 0.937 mg/L
< Lead: 0.035, 0.011 and 0.020 mg/L
< Zinc: 0.371, 0.229 and 0.217 mg/L
< Total Ammonia: 7.68, 29.4, 7.30 mg/L
< Nitrite: 0.683, 0.667, 0.646 mg/L

Samples from Location K (Cooling Water)

Chemistry and Toxicity

All *Daphnia magna* exposed to 100% and lower concentrations of samples K-1, K-2 and K-3 survived the 48-h test period, and showed no signs of distress. Similarly, underyearling trout exposed to samples K-1 and K-3 for four days survived and appeared normal throughout the tests. The four juvenile rainbow trout held in 100% concentrations of samples K-1 and K-3 during the eight-day bio-uptake test also survived without signs of distress.

In the chronic toxicity test with *Ceriodaphnia dubia*, 90% and 10% mortalities of first-generation daphnids occurred in 100% and 50% concentrations (respectively) of Tree Island Industries's cooling water; all daphnids held in lower concentrations survived and appeared normal throughout the test. Reproductive success of *Ceriodaphnia dubia* was significantly impaired at concentrations of 42% and higher. The NOEC was 25%; i.e., no evidence of lethal or chronic sublethal toxic effects were found when this cooling water was diluted to concentrations of 25% or lower.

Tree Island Industries's cooling water is "non-contact" chlorinated municipal water provided by GVWD (see Section 2.0). The chronic toxic effects found for this discharge are not attributable to total suspended solids (#1 , 1 and 3 mg/L; samples K-1, K-2, K-3), un-ionized ammonia (#0.00003 mg/L in the chronic toxicity test) or nitrite (#0.001 mg/L).

It was demonstrated (see Subsection 4.6.2.3) in this study that *Ceriodaphnia dubia* could tolerate very soft (5 mg/L) water without any adverse effects on reproductive success or survival, thus the low hardness (5 - 7 mg $CaCO_3$/L) measured for these samples of cooling water likely was not stressful to *C. dubia*. However, since soft water can enhance the toxicity of certain dissolved metals including copper and zinc (e.g., CCREM, 1987), the low hardness of Tree Island Industries's cooling water might have contributed indirectly to the chronic toxicity of samples K-1, K-2 and K-3. Total and dissolved copper concentrations in these samples were consistently below the detection limit of 0.010 mg/L. This finding does not ensure that trace levels of dissolved copper (e.g., from copper or brass contacting the cooling water) were not present at strengths sufficient to cause chronic toxic effects. Nagpal and Pommen (1993) recommend a maximum concentration of 0.0025 mg/L total copper in receiving waters with a hardness of only 5 mg $CaCO_3$/L (i.e., the hardness of Tree Island Industries's cooling water) to protect sensitive freshwater life. The detection limit for copper in this study was inadequate to ensure that copper was below the level that could cause chronic toxic effects.

Concentrations of zinc (total, 0.12, 0.08, 0.09 mg/L; dissolved, 0.08, 0.08, 0.08 mg/L; samples K-1, K-2, K-3 respectively) in the cooling water were adequate to cause chronic toxic effects on *C. dubia*, given the very low hardness of this water. Both total and dissolved zinc levels in these samples exceeded the provincial water quality criterion of 0.03 mg/L total zinc recommended as a tentative criterion for the protection of sensitive freshwater life (Nagpal and Pommen, 1993). The levels of zinc found in these samples might have been partially or solely responsible for the chronic toxic effects observed.

Concentrations of iron in the samples (total, 0.22, 0.17, 0.09 mg/L; dissolved, 0.10, 0.07, 0.08 mg/L; samples K-1, K-2, K-3 respectively) were consistently below the maximum concentration of 0.3 mg/L total iron recommended as a provincial water quality criterion for the protection of freshwater life (Nagpal and Pommen, 1993). The concentrations of iron in these samples likely did not contribute to chronic toxicity.

Concentrations of PAHs, chlorinated phenolics, resin and fatty acids, and dioxins and furans were not anticipated to be present in this cooling water, and the samples were not analyzed for these chemicals.

As with the other primary effluents studied, the samples of Tree Island Industries's cooling water were not analyzed for concentrations of total residual chlorine. However, the possibility should not be ignored that trace (i.e., $0.003 mg/L) levels of residual chlorine were present in the sample(s) of cooling water at the time of the chronic toxicity tests, and contributed to the toxic effects found.

Bioavailability

All juvenile rainbow trout held in 100% concentrations of Tree Island Steel's cooling water for eight days survived and appeared normal during the exposure. No gross pathologies were evident during the dissection of these fish.

All muscle metal concentrations (including iron, lead and zinc) measured in the pooled homogenate from fish held for eight days in 100% Tree Island Steel cooling water, were indistinguishable from respective control values. Muscle PAHs and CPs were not measured.

4.5.7 Domtar

Samples from Location P (Steam Condensate and Boiler Blowdown)

Chemistry and Toxicity

All *Daphnia magna* exposed to 100% and lower concentrations of samples P-1 and P-3 survived the 48-h test period, and showed no signs of distress. Those held in 100%, 50% and 25% concentrations of P-2 showed mortalities of 40%, 20% and 10% respectively; all daphnids surviving in these and lower concentrations appeared normal during the test. All underyearling rainbow trout exposed to 100% and lower concentrations of Domtar's effluent (samples P-1 and P-3) for four days survived and showed no signs of distress. Similarly, the four juvenile rainbow trout held in 100% concentrations of samples P-1 and P-3 survived and appeared normal during the eight-day exposure.

In the chronic toxicity test with *Ceriodaphnia dubia*, 50% of the first-generation daphnids died in 100% effluent and 10% died in concentrations of 25% and 3.2% effluent. All survivors appeared normal throughout the seven-day test. Reproductive success of *Ceriodaphnia dubia* was inhibited significantly by effluent concentrations of 2% and higher.

The NOEC found for this test was 1%. Domtar's effluent was one of the three primary effluents found to be most toxic (IC25s, 1 - 2%) according to this test.

Concentrations of total suspended solids in samples P-1, P-2 and P-3 were 48, 1 and <1 mg/L, respectively. It is possible that the TSS concentration in sample P-1 contributed to the chronic toxicity of Domtar's effluent; however, further experimentation would be required to ascertain this.

Concentrations of un-ionized ammonia calculated for the three effluent samples were #0.00009 mg/L, and concentrations of nitrite were #0.006 mg/L. These values are below levels of toxic concern.

Concentrations of total iron in these samples (0.41, 0.28, 0.30 mg/L) approached or exceeded the provincial water quality criterion of 0.3 mg/L total iron recommended as a maximum for the protection of freshwater life (Nagpal and Pommen, 1993). Dissolved iron concentrations were 0.26, 0.17 and 0.21 mg/L, thus the majority of the iron was classified as dissolved. The iron concentrations in these samples of Domtar's effluent might have been sufficiently high to contribute to sample toxicity.

Concentrations of both total and dissolved copper in samples P-1, P-2 and P-3 were consistently less than the detection limit of 0.010 mg/L. Dissolved copper concentrations as low as 0.004 mg/L can cause chronic toxic effects if the dilution water is soft (CCREM, 1987). Nagpal and Pommen (1993) recommend a maximum concentration of 0.0025 mg/L total copper in receiving waters with a hardness of only 5 mg $CaCO_3$/L (the hardness of Domtar's effluent) to protect sensitive freshwater life. Accordingly, the detection limit for copper in this study was inadequate to ensure that copper was below a level that could have contributed to the chronic toxicity of Domtar's effluent samples found in the test with *Ceriodaphnia dubia*.

Concentrations of total zinc in samples P-1, P-2 and P-3 were 0.011, 0.008 and 0.009 mg/L, respectively. Values for dissolved zinc were 0.010, 0.008 and 0.009 mg/L. These zinc concentrations were below the provincial water quality criterion of 0.03 mg/L total zinc specified as a tentative maximum concentration for the protection of sensitive freshwater life. The zinc concentrations found in these samples likely did not contribute to the toxic effects observed.

Most PAHs measured in P-1, P-2 and P-3 were below detection limits. Trace amounts of benzo(a)anthracene (0.00002 or 0.00003 mg/L) were found in samples P-2 and P-3; 0.0001 mg/L fluoranthene and 0.0003 mg/L naphthalene were detected in sample P-3 only. These trace quantities are below the provincial water quality criteria for benzo(a)anthracene (0.0001 mg/L), fluoranthene (0.004 mg/L) and naphthalene (0.001

mg/L) specified for the protection of freshwater life from chronic toxicity (Nagpal and Pommen, 1993), and thus are likely of no consequence.

Concentrations of all chlorinated phenolics measured in these samples were below detection limits (i.e., <0.001 mg/L 3CP, 4CP, 5CP, 3CG and 4CG; and <0.010 3CC and 4CC). Concentrations of all resin and fatty acids measured were also below the detection limit of 0.010 mg/L. These detection limits were not sufficiently low to assure that the concentrations of these contaminants were below levels that could cause chronic toxic effects on sensitive freshwater life (Nagpal and Pommen, 1993). Notwithstanding, no evidence is provided here which suggests any contribution of chlorinated phenolics, resin acids or fatty acids to sample toxicity.

Calculated TEQ concentrations for the trace levels of dioxins and furans in these three samples were 0.0.469, 0.097 and 8.045 pg/L (samples P-1, P-2 and P-3, respectively). The value of 8.045 pg/L for sample P-3 was the highest TEQ concentration calculated for any of the samples of primary effluent analyzed for dioxins and furans. Nonetheless, since our understanding is that the lowest concentration of 2,3,7,8-tetrachlorodibenzodioxin presently reported to be harmful to fish or freshwater invertebrates is 38 pg/L (Mehrle *et al.*, 1988), we are unaware of any evidence indicating that the trace quantities of dioxins and furans in Domtar's effluent would have contributed to the chronic toxicity observed in the test with *C. dubia.*

The source of the water in Domtar's effluent is chlorinated municipal water. Due to the reported chronic toxicity of residual chlorine to daphnids at residual chlorine concentrations as low as 0.001 mg/L (McLeay, 1992), the possibility exists that trace quantities of residual chlorine in the GVWD water supply used by Domtar might have contributed to the chronic toxic effects observed.

Bioavailability

All juvenile rainbow trout held in 100% concentrations of Domtar's effluent for eight days survived and appeared normal during the exposure. No gross pathologies were evident during the dissection of these fish.

All muscle metal concentrations (including arsenic and copper) measured in the pooled homogenate from fish held for eight days in 100% Domtar effluent, were indistinguishable from respective control values. Trace quantities of PAHs were detected in this sample.

Trace concentrations of 2,3,4,6-tetrachlorophenol (0.00132 mg/kg dry weight; 0.0003 mg/kg wet weight) and pentachlorophenol (0.00132 mg/kg dry weight; 0.0003 wet weight) were found in this muscle sample. All other chlorophenolics were below detection limits.

The trace quantity of 2,3,4,6-tetrachlorophenol found in this sample was only 1.5 times that in the two control groups. The trace quantity of pentachlorophenol in the sample was twice the mean 5CP concentration for the two control groups. No environmental significance should be given to these trace quantities of 4CP or 5CP without further investigation.

4.5.8 Tilbury Cement

Samples from Location L (Cooling Water)

Chemistry and Toxicity

Undiluted (100%) concentrations of the three samples of Tilbury Cement's cooling water were consistently toxic to *Daphnia magna*, and partial mortalities occurred in a 50% concentration of sample L-2. All other *D. magna* exposed to this cooling water at concentrations ranging from 1% to 50%, survived the 48-h test with no signs of distress. The 48-h LC50s for *D. magna* ranged from 59% to 71%. In the acute toxicity tests with underyearling and juvenile rainbow trout, all fish exposed to 100% or lower concentrations of the cooling water survived with no signs of distress. In the chronic toxicity test with *Ceriodaphnia dubia*, all first-generation daphnids held in 100% and 50% concentrations of the cooling water died, whereas those held in all lower concentrations (1% to 25%) survived. Reproduction of *C. dubia* was inhibited significantly by concentrations of 15% and higher. The NOEC in this test was 3.2%.

The conductance of samples L-1, L-2 and L-3 was 16,500, 17,800 and 12,400 micromhos/cm, respectively. These high conductance values presumably reflect seawater intrusion in the Fraser River water used by Tilbury Cement as source water. The daphnids *Daphnia magna* and *Ceriodaphnia dubia* are freshwater organisms and are not tolerant of high concentrations of salt. The mortalities of each of these species in 50% and/or 100% concentrations of samples L-1, L-2 and L-3 was likely influenced if not caused altogether by the high conductance and high salinity of these samples. Sample conductance/salinity likely also contributed significantly to the observed inhibition of reproduction for *Ceriodaphnia dubia* at concentrations of 15% and higher.

Concentrations of total suspended solids were relatively low (13, 19 and 9 mg/L for samples L-1, L-2 and L-3 respectively), and below threshold-effect levels shown to be harmful to sensitive freshwater fish or invertebrate species (Singleton, 1985; CCREM, 1987;

McLeay *et al.*, 1987; McLeay, 1990). However, it is possible that this low level of suspended solids could cause some adverse effects in chronic toxicity tests with *Ceriodaphnia dubia*.

Concentrations of un-ionized ammonia (0.0002 to 0.0008 mg/L) in these samples at the time of the toxicity tests were low and below levels of concern. Nitrite concentrations (<0.001 to 0.007 mg/L) were also low and below levels of concern.

Concentrations of both total and dissolved copper in samples L-1, L-2 and L-3 were <0.04, <0.05 and <0.02 mg/L, respectively. Depending on water hardness, dissolved copper can be acutely toxic to salmonid fish and freshwater invertebrates at strengths as low as 0.02 mg/L (Chapman, 1978). Dissolved copper concentrations as low as 0.004 mg/L have been reported to cause chronic toxic effects (CCREM, 1987). Accordingly, the limits of detection for dissolved copper in samples L-1, L-2 and L-3 were not sufficiently low to ensure that this metal did not contribute to sample toxicity.

Concentrations of iron and zinc in these samples were likely too low to have contributed to toxicity. Values for total iron in samples L-1, L-2 and L-3 were <0.12, <0.15 and 0.30 mg/L, respectively; dissolved iron concentrations were <0.12, <0.15 and <0.06 mg/L. Concentrations of both total and dissolved zinc in samples L-1, L-2 and L-3 were <0.02, <0.02 and <0.01 mg/L. Nagpal and Pommen (1993) recommend that maximum concentrations of these metals in fresh water not exceed 0.3 mg/L total iron or 0.03 mg/L total zinc, for the protection of sensitive freshwater life.

No chlorophenolics, polycyclic aromatic hydrocarbons, resin and fatty acids, or dioxins and furans were measured in these samples, as such chemicals were unlikely to be present in the samples at concentrations sufficient to exert toxic effects.

Since the source of Tilbury Cement's cooling water is water drawn at depth from the Main Arm of the Fraser River, it is possible that low levels of contaminants in the river water could have contributed to the toxic effects noted in this study for samples L-1, L-2 and L-3.

Bioavailability

The four fish held in a 100% concentration of Tilbury Cement's cooling water for eight days survived the exposure with no signs of distress. Upon dissection, it was observed that three of the fish had swollen, orange-coloured gall bladders. Otherwise, there were no apparent pathologies. It is possible that the relatively high conductivity of L-1 (9500 micromhos/cm) and L-3 (7400 micromhos/cm) caused osmoregulatory adaptations in the fish which resulted in the changes in appearance of their gall bladders.

All muscle metal concentrations measured in the pooled homogenate from fish held for eight days in Tilbury Cement cooling water were indistinguishable from respective control values. No polycyclic aromatic hydrocarbons or chlorinated phenolics were measured for this sample.

Samples from Location U (Non-Permitted Discharge)

Samples were collected from the ditch which surrounds Tilbury Cement, and into which a continuous discharge was noted. These samples had iron concentrations of 0.888 (U-1), 0.433 (U-2) and 0.531 (U-3) mg/L. These concentrations are elevated and further investigation of this discharge is recommended.

Storm Water Sample

One sample of standing water was collected from the Tilbury site. This sample is labelled Tilbury Storm in the data tables in Appendix VI (Volume 2). It should be noted that this sample is not a discharge; the sample was collected from a series of standing pools or puddles noted on the site. Because of the unusual nature of the chemical character of this sample, some of the results are detailed below in Table 4-18. As indicated in this table, high concentrations of total chromium, copper, iron, mercury, selenium, zinc, nitrite and dissolved aluminum were measured. If this water were discharged to the Fraser River, there would be some concern regarding environmental impact. However, as indicated above, this water was not a discharge to the Fraser River.

Table 4-18: Chemical Characteristics of the Sample Tilbury Storm, mg/L

Parameter	Tilbury Storm	Parameter	Tilbury Storm
dissolved Aluminum	0.33	total Mercury	0.00048
total Chromium	0.251	total Selenium	0.0063
total Copper	0.069	total Zinc	0.081

total Iron	5.81	Nitrite	0.473

4.5.9 Hilinex Packaging

Samples from Location Q (Effluent)

Chemistry and Toxicity

Sample Q-1 caused partial mortalities to *Daphnia magna* at both 100% and 1% concentrations, with no discernible adverse effects at concentrations ranging from 3.2% to 50%. The deaths at 1% prevented calculation of a 48-h LC50 for this sample. Sample Q-2 killed all *D. magna* at 100% and 50% concentrations, whereas all daphnids exposed to concentrations ranging from 1% to 25% survived and appeared normal throughout the test. Sample Q-3 killed all *D. magna* at 100% concentration, and killed 30% of daphnids at 50% and 12.5% concentrations. Some of the *D. magna* surviving exposure to lower concentrations of sample Q-3 also appeared distressed during the test. In the acute lethality tests with underyearling rainbow trout, 10% of the fish exposed to a 100% concentration of sample Q-1 died; all others held in this and lower concentrations of the sample survived the test without signs of distress (96-h LC50, >100%). The 100% concentration of sample Q-3 killed 70% of underyearling trout, and survivors in this concentration appeared stressed. All other underyearling trout exposed to lower concentrations of this sample survived and appeared normal throughout the test. Two of the four juvenile rainbow trout exposed to samples Q-1 (100%) and Q-3 (30%) for eight days died; the surviving fish appeared normal.

During the chronic toxicity test with *Ceriodaphnia dubia*, all first-generation daphnids died in 100% effluent. Partial mortalities were also evident in the following concentrations: 50%, 25%, 6.3%, and 1%. Reproduction of *C. dubia* was inhibited at effluent concentrations of 16% and higher. The NOEC for this test was 13%.

These samples were described by the bioassay technicians as clear, yet viscous, gelatinous and/or slimy, even when diluted to 1%. Some of the adverse lethal and sublethal effects observed for the exposed daphnids or fish might have been caused by the viscosity of this effluent. The source of this viscosity is unclear, but is possible that wash water from the glue mixing area is connected to this effluent discharge; wash water contains corn starch and caustic, which would add to sample viscosity.

The observed toxicity of Hilinex Packaging effluent is not attributable to un-ionized ammonia (#0.003 mg/L) or nitrite (<0.001 mg/L). Concentrations of all polycyclic aromatic hydrocarbons, chlorinated phenolics, resin and fatty acids measured in the three samples of Hilinex Packaging effluent were consistently below detection limits; thus no toxicity can be attributed to these chemicals. Water hardness *per se* was not likely responsible for sample toxicity, even though the hardness of these samples was only 5-7 mg $CaCO_3$/L (see Subsection 4.6.2.3 and the discussion regarding the toxicity of IFP Fraser Mills cooling water in Section 4.5.3).

Concentrations of total suspended solids were relatively low (15, 14 and 19 mg/L for samples Q-1, Q-2 and Q-3 respectively), and below levels known to cause acute or chronic toxic effects on freshwater fish or invertebrates (Singleton, 1985; CCREM, 1987; McLeay *et al.*, 1987; McLeay, 1990). It is conceivable that this low level of suspended solids could cause some adverse effects in chronic toxicity tests with *Ceriodaphnia dubia*. We are unaware of test results which demonstrate the threshold concentrations of total suspended solids causing adverse effects on the survival or reproductive success of *C. dubia* in chronic toxicity tests.

Trace amounts of 1234678-H7CDD and 08CDD were found in each of the three samples of Hilinex Packaging effluent. Calculated TEQ concentrations for these samples were 0.45, 0.19 and 0.25 pg/L. These trace concentrations are below levels that would be anticipated to cause acute or chronic toxic effects on sensitive freshwater organisms.

Concentrations of dissolved copper in the samples of Hilinex Packaging effluent likely contributed to the observed toxicity. Dissolved copper values reported for samples Q-1, Q-2 and Q-3 were 0.03, 0.03 and <0.015 mg/L, respectively; total copper values were 0.1, 0.08 and 0.08 mg/L. The finding of non-detectable dissolved copper in sample Q-3 is suspect since all three samples had similar total copper values. Regardless, the level of dissolved copper found in samples Q-1 and Q-3 (0.03 mg/L) has been reported to kill young salmonid fish (Chapman, 1978), and dissolved copper concentrations as low as 0.004 mg/L can cause chronic toxic effects on fish or freshwater invertebrates (CCREM, 1987). All total copper concentrations in these three samples were well in excess of the maximum concentration of 0.0025 mg/L total copper recommended as a water quality criterion by Nagpal and Pommen (1993) for the protection of freshwater life.

Iron concentrations in these samples may have contributed to sample toxicity. Average values for total iron in samples Q-1, Q-2 and Q-3 were 1.0, 0.6 and 0.6 mg/L, respectively; dissolved iron concentrations for these samples were 0.1, 0.1 and 0.03 mg/L, respectively. Provincial water quality criteria recommend a maximum concentration of 0.3 mg/L total iron in receiving waters for the protection of freshwater life (Nagpal and Pommen, 1993).

Zinc levels in samples Q-1, Q-2 and Q-3 might also have contributed to the observed toxic effects. Average concentrations of total zinc were 0.06, 0.10 and 0.03 mg/L for samples Q-1, Q-2 and Q-3, respectively. Dissolved zinc levels for these samples were 0.03, 0.08 and 0.02 mg/L, respectively. Provincial water quality criteria recommend a maximum concentration of 0.03 mg/L total zinc in receiving waters for the protection of freshwater life (Nagpal and Pommen, 1993).

Since the water source for Hilinex Packaging effluent is chlorinated municipal water, it is possible that trace levels of residual chlorine contributed to sample toxicity. Chlorine has been reported to cause chronic toxic effects on daphnids at concentrations as low as 0.003 mg/L (CCREM, 1987; McLeay, 1992). Provincial water quality criteria for chlorine recommend that the average concentration (continuous exposure) of total residual chlorine in freshwater should not exceed 0.002 mg/L to assure the protection of sensitive freshwater life (Nagpal and Pommen, 1993). The contribution of residual chlorine to the observed toxicity is speculative, since the samples were not analyzed for total residual chlorine.

Bioavailability

Based on the findings of the concurrent LC50s with underyearling trout exposed to samples Q-1 and Q-3, juvenile trout were exposed to 100% effluent (Q-1) for the initial four days, and only 30% effluent (Q-3) for the remaining four days. During this eight-day exposure, one fish died and one was moribund on Day 5. The remaining two juvenile trout appeared normal and showed no signs of distress during the eight-day period. These two surviving fish showed no evidence of gross pathologies when dissected for muscle-tissue analyses. Tissues from the dead or moribund fish were not included in the pooled homogenate analyzed.

All muscle metal concentrations measured in the pooled homogenate from fish held for eight days in Hilinex Packaging effluent were indistinguishable from respective control values. Concentrations of all PAHs were below detection limits. The only chlorophenolic compound detected was pentachlorophenol. The trace concentration of 5CP in this sample (0.00088 mg/kg dry weight; 0.0002 mg/kg wet weight) was also found in the control samples, thus no significance should be attached to this finding.

4.5.10 Westshore Terminals

Samples from Location M (Surface Runoff Discharge)

Chemistry and Toxicity

In the acute toxicity tests with *Daphnia magna*, a 100% concentration of sample M-1 killed 40% of the daphnids and the survivors appeared stressed. All those in 50% and lower concentrations of M-1 survived without signs of distress. Sample M-2 killed all *D. magna* in 100% concentration, and killed 30% of daphnids in 50% discharge water; surviving daphnids in 50% and 25% concentrations were stressed. Sample M-3 killed all *Daphnia magna* exposed to 100%, 50%, 25% and 12.5% concentrations, and killed 40% of daphnids in 6.3% discharge water; surviving daphnids in 6.3% and 3.2% effluent were stressed. All underyearling trout survived a 96-h exposure to undiluted (100%) M-1 and M-3, and showed no signs of distress during the test. Unlike these findings for underyearling trout, all juvenile rainbow trout held in M-1 (30%) and M-3 (100%) during the eight-day bio-uptake test died.

During the chronic toxicity test with *Ceriodaphnia dubia*, all first-generation daphnids died in 100% effluent. All first-generation daphnids exposed to lower concentrations (#50%) of M-1, M-2 and M-3 for seven days survived. Reproduction of *C. dubia* was inhibited at effluent concentrations of 1% and higher. The NOEC for this test was less than 1% (less than the lowest concentration tested). Of the ten primary effluents studied, Westshore Terminals' discharge water proved the most toxic in this test.

The finding of survival of all underyearling trout exposed to 100% concentrations of M-1 and M-3 for four days is somewhat inconsistent with the finding of deaths of juvenile rainbow trout exposed to the same samples. Differences in duration of exposure (four versus eight days), differing tolerance of the underyearling and juvenile fish may have contributed to the different response found. The behaviour of the effluent contacting the vessels used in these tests might also have contributed to the differing findings of fish survival. In the 96-h LC50 tests, glass aquaria were used and it was noted that black, tarry solids adhered to the sides and bottom of the aquaria. In the eight-day bio-uptake tests, fibreglass tanks were used and no adherence of black, tarry solids to the surface of the fibreglass was noted. Perhaps the differing properties of fibreglass allowed the black, tarry material which coated glass surfaces to remain in suspension within the fibreglass tank and exert a toxic effect on the fish.

Concentrations of total suspended solids in samples M-1, M-2 and M-3 were not particularly high (17, 21 and 12 mg/L, respectively). These levels were below threshold-effect concentrations reported to be harmful to sensitive freshwater fish or invertebrate species (Singleton, 1985; CCREM, 1987; McLeay *et al.*, 1987; McLeay, 1990). However, it is possible that this low level of suspended solids could cause some adverse effects in chronic toxicity tests with *Ceriodaphnia dubia*. Given the nature of the suspended solids (fine coal particulates) and the observations of black, tarry material coating the surfaces of toxicity-test vessels, the suspended solids in these samples might have contributed to the toxic effects found.

Concentrations of un-ionized ammonia (0.0001 to 0.001 mg/L) in samples M-1, M-2 and M-3 at the time of the toxicity tests were low and below levels contributing to toxic effects.

Nitrite concentrations (<0.001 to 0.004 mg/L) in these samples were also low and inconsequential.

Most PAHs were below detection limits. Two of the three samples had detectable concentrations of benzo(a)anthracene (0.00001 and 0.00002 mg/L; M-2 and M-3, respectively); however, these levels were well below the maximum provincial water quality criterion of 0.0001 mg/L for this PAH, recommended to protect freshwater life from chronic toxic effects (Nagpal and Pommen, 1993). One sample (M-3) had a just-detectable concentration of benzo(a)pyrene (0.00001 mg/L); this concentration was identical to the maximum concentration of benzo(a)pyrene recommended for the protection of freshwater life from chronic toxic effects (Nagpal and Pommen, 1993). Accordingly, the trace level of benzo(a)pyrene detected in sample M-3 might have contributed to the chronic toxicity of Westshore Terminals' discharge water found in the *Ceriodaphnia dubia* test using samples M-1, M-2 and M-3.

Concentrations of iron in these samples (total, 0.19, 0.22 and 0.19 mg/L; dissolved, <0.030, <0.030, <0.030 mg/L) were low and below the maximum concentration of 0.3 mg/L total iron recommended as a water quality criterion for the protection of freshwater life (Nagpal and Pommen, 1993). Thus iron likely did not contribute to the observed toxic effects.

Concentrations of zinc in Westshore Terminals' discharge water (total, 0.035, 0.038, 0.069 mg/L; dissolved, 0.028, 0.026, 0.038 mg/L) exceeded the provincial maximum of 0.03 mg/L total zinc proposed as a tentative water quality criterion for the protection of freshwater life (Nagpal and Pommen, 1993). Although the concentrations of zinc in these samples were below levels that by themselves would have resulted in the observed acute lethal effects on fish (juvenile rainbow trout) and daphnids, they might have contributed to these and to the chronic toxicity of this discharge water.

Concentrations of total aluminum in Westshore Terminals' discharge water (1.52, 1.56, 1.08 mg/L; samples M-1, M-2, M-3, respectively) were the highest of any of the ten primary effluents studied. However, for each sample, dissolved aluminum in these samples was below the detection limit of 0.20 mg/L. Nagpal and Pommen (1993) recommend a maximum concentration of 0.1 mg/L dissolved aluminum in fresh water at pH ≥6.5, for the protection of sensitive aquatic life. Since in this study the detection limit for dissolved aluminum was higher than this criterion, it is possible that dissolved aluminum was present at concentrations that contributed to the observed toxic effects.

Copper concentrations in the three samples of this discharge water were as follows: total, <0.010, 0.011, <0.010 mg/L; dissolved, <0.010, <0.010, <0.010 mg/L. Based on the hardness of this water (20 to 25 mg $CaCO_3$/L), the maximum concentration of total copper in fresh water should not exceed 0.0039 mg/L for the protection of sensitive aquatic life (Nagpal and Pommen, 1993). The concentration of total copper in sample M-2 exceeded this provincial water quality criterion; the limits of detection for copper used in this study were not sufficiently low to assure that samples M-1 and M-3 did not exceed this criterion. Dissolved copper in soft water can be acutely lethal to freshwater daphnids at concentrations below this detection limit and chronic toxic effects can occur at appreciably lower levels (CCREM, 1987). Concentrations of dissolved copper in soft water as low as 0.02 mg/L can also, by themselves, be acutely lethal to salmonid fish (Chapman, 1978). Thus, although dissolved copper was below the detection limit for these analyses, the contribution of dissolved copper to sample toxicity cannot be ruled out.

Concentrations of cadmium in these samples were: total, <0.0002, 0.0003, 0.0002 mg/L; dissolved, <0.0002, 0.0003, <0.0002 mg/L. The trace quantity of cadmium in sample M-2 exceeded the provincial water quality criterion of 0.0002 mg/L recommended as a maximum concentration for the protection of freshwater life (Nagpal and Pommen, 1993), and that in sample M-3 was found to be at this limit. Since 0.0002 mg/L has been reported as a threshold-effect concentration for dissolved cadmium in chronic toxicity tests with daphnids (CCREM, 1987), it is possible that cadmium may have contributed to the chronic toxicity noted for the samples of Westshore Terminals' discharge water.

The water source for Westshore Terminals' discharge water is chlorinated municipal water, thus it is possible that trace levels of residual chlorine contributed to sample toxicity. Chlorine has been reported to cause chronic toxic effects on daphnids at concentrations as low as 0.003 mg/L (CCREM, 1987; McLeay, 1992). Provincial water quality criteria for chlorine recommend that the average concentration (continuous exposure) of total residual chlorine in freshwater should not exceed 0.002 mg/L to assure the protection of sensitive freshwater life (Nagpal and Pommen, 1993). The contribution of residual chlorine to the observed toxicity is speculative, since the samples were not analyzed for total residual chlorine.

Bioavailability

All four juvenile rainbow trout exposed to Westshore Terminals effluent died some time following their transfer to M-3 on Day 5 of the test. Fish were undetected until Day 8, due to a brown sludge which formed on the surface of the water in the exposure tank. Due to the advanced state of decay of these fish, they were not dissected and no tissues were taken for analysis.

Samples from Location T (Septic Discharge)

All three samples collected from location T had elevated concentrations of copper, iron, lead, zinc and total ammonia. Elevated concentrations of ammonia are consistent with a septic discharge. Elevated concentrations of copper, iron, lead and zinc might be attributed to septic piping and equipment. These metals are not used as process chemicals at Westshore. Sample T recorded the highest concentrations of TSS, BOD_5, total cadmium, copper and mercury of any sample in this study.

4.6 Non-Contact Cooling

Non-contact cooling water does not, by definition, come into contact with process chemicals. The chemical characteristics of these discharges would be expected to be similar and consistent.

Six non-contact cooling water discharges were sampled as part of this study. These discharges are from the following sample locations: A and B (Lafarge Canada), E (IFP Fraser Mills), G (IFP Hammond), K (Tree Island Steel) and L (Tilbury Cement).

Of these discharges, four were tested for toxicity, bio-availability and chemical characteristics. The other two were tested for chemical characteristics only.

Two samples were found to be acutely lethal to the micro-organism *Daphnia magna* (IFP Fraser Mills and Tilbury Cement). One of the samples from Fraser Mills was also found to be acutely lethal to rainbow trout. Samples from both Tree Island Industries and Tilbury Cement were found to have moderately high chronic toxicity emission rates. However, samples from both Lafarge Canada and Tilbury Cement draw water from the Fraser River. Analytical results indicate that at the time the samples were collected both of these industries were drawing significant amounts of salt water - salt water is toxic to both of the test organisms, and the presence of salt water may explain the toxicity results for these two industries.

Most of these discharges showed elevated concentrations of some heavy metals, notably copper, iron and zinc. It is probable that these contaminants are present as a result of process piping, which is often made of copper and / or steel (iron) and may be galvanized (zinc). None of these discharges were inconsistent with non-contact cooling water.

4.7 Quality Control

4.7.1 Field Quality Control

In the first week of sampling, a series of field blanks were prepared. Samples S-1, S-2 and S-3 were prepared with dechlorinated Vancouver City water. Samples S-1 and S-3 were collected in 4 x 200-L barrels lined with plastic in a manner similar to all other 800-L samples. Sample S-2 was collected in a 20-L jerrican, consistent with all other Wednesday samples. Samples S-4 and S-5, prepared like S-1 and S-3, were collected at the end of the series of experiments.

While samples S-1, S-2 and S-3 were neutral in pH, samples S-4 and S-5 were below the CCREM guidelines (with pH values of 6.30 and 5.93). The GVWD indicate that this is within their normal working range.

No oil & grease, DDAC, TCMTB, PAHs, dioxins or furans were detected.

Traces of calcium, iron, magnesium and zinc were detected. This is not inconsistent with city drinking water.

In the third week of sample collection, some rust was noted to have formed on the inside of the sample barrels. Sample barrels were not in direct contact with samples; however, the plastic liners which were used to contain the sample were previously soaked in Capilano River water. Therefore, barrels were in contact with wet plastic liners which could contribute to rust formation. In order to ensure that no rust (iron) from the barrels was transferred to the sample, three additional samples were collected in glass bottles at the same time as the regular sample was obtained. They are labelled L-3 Barrel Check, M-3 Barrel Check and N-3 Barrel Check in the data provided in Appendix VI. The iron results are presented below in Table 4-19.

As can be seen from the data in Table 4-19, iron concentrations in the barrel check samples (collected in glass bottles and not contacted with metal barrels) are similar to or higher than those collected in the regular 200-L drums. Therefore, none of the rust in these barrels was transferred to the samples.

One series of field duplicates was prepared. Sample R is a duplicate of sample D. Samples R-1, R-2 and R-3 were collected in 4-L glass bottles, while samples S-1, S-2 and S-3 were collected as described in Section 3.2. The purpose of these duplicate samples was to determine if the unusual sample collection vessels in these series of experiments had an effect on analytical parameters. Of particular concern were those parameters which require glass sample bottles, such as oil & grease.

Table 4-19: Barrel Check Iron Results (mg/L)

Sample Identification	Total Iron
L-3	0.345

L-3 Barrel Check	0.253
M-3	0.193
M-3 Barrel Check	0.135
N-3	4.28
N-3 (duplicate)	4.28
N-3 Barrel Check	6.98

Comparison of analytical results between samples D and R show some sample variability. Since there is no consistent trend, *ie:* R is not always either higher or lower than D, this variability is most likely due to actual variances in the samples. Oil & grease results were as follows:

< D-1 = 9 mg/L, D-1 (dup) = 9 mg/L, R-1 = 5 mg/L
< D-2 = 12 mg/L, D-2 (dup) = 17 mg/L, R-2 = 13 mg/L
< D-3 = <5 mg/L, D-3 (dup) = <5 mg/L, R-3 = 12 mg/L

Samples D-1 and R-1 were collected over a period of five hours and samples D-2, R-2, D-3 and R-3 were collected over a period of one hour.

The results for the check standards were part of internal method performance records only. The results for the blanks, spikes, and standard reference materials are reported in Appendices VIII, IX and X, while the results for the duplicates are included with the sample results. The use of such QA samples for this project was extensive.

4.7.2 Control and Blank Tests

4.7.2.1 Controls for Toxicity Tests

FRASER RIVER WATER

The preliminary 48-h LC50 tests with *Daphnia magna* and the three samples of Fraser River water collected February 8, 1993 (see Subsection 3.6.2.1) showed some toxic effects for each of the three samples. Results for the triplicate tests with each sample are given in Appendix XV. With each of these samples, one or two of the three replicates showed lethal or sublethal toxic effects toward the test organisms. Mortalities of 40 to 60% occurred in one of each of the three replicates of each sample, whereas for the other replicates all daphnids survived the 48-h exposure.

Unlike the above findings, all *Ceriodaphnia dubia* exposed to each of these riverwater samples survived the test period (7± 1 days) with no signs of distress. Mean numbers of neonate daphnids produced during the test period in each replicate solution of Fraser River water were high. Statistical analyses (Environment Canada, 1992) revealed no significant differences in reproduction or survival between each riverwater sample and the laboratory culture/control water.

The reason for the toxicity of the three riverwater samples to *Daphnia magna* is not apparent, and is inconsistent with the findings of no toxic effects using *Ceriodaphnia dubia*. Differences in water hardness between the samples of Fraser River water (40 - 50 mg/L) and the culture/control water to which *D. magna* were acclimated do not account for the toxic effects observed, since separate tests for the tolerance of this species to water softer than the culture water (*i.e.*, water with hardness of 24 or 46 mg/L) showed no adverse lethal or sublethal effects (see Subsection 4.7.2.3). Leaching of toxic plasticizers from the jerricans used to transport the riverwater samples is also an unlikely explanation (see Subsection 4.7.2.2). It is conceivable that *D. magna* could be more sensitive than *C. dubia* to contaminants in the samples of Fraser River water, although the chronic toxicity test with *C. dubia*, including effects on reproduction, is normally a much more sensitive test than the 48-h assay with *D. magna*. The lack of any signs of toxic effects in Fraser River water using the *C. dubia* chronic toxicity test suggests that contamination of certain test vessels might have caused the toxic effects noted for one or more of the replicate tests with Fraser River water and *D. magna*. However, the findings of no adverse effects in the triplicate control solutions used for these *D. magna* tests provide no evidence that allows us to completely dismiss attributing the findings of toxic effects to the samples of Fraser River water.

Based on the findings of toxic effects for *Daphnia magna*, it was decided to use laboratory culture/control water as the control and dilution water for all daphnid toxicity tests with effluent samples. The *C. dubia* results for the riverwater samples indicated that "upstream" samples of river water could also be suitable for use as control / dilution water in the tests with this species. However, concerns raised by the findings with *D. magna* about possible toxic contaminants in the upstream water, and of changing riverwater quality during the duration of the study, supported the decision to use laboratory culture / control water for all toxicity tests with *Ceriodaphnia dubia*.

CONTROLS

All controls for the toxicity tests with the effluent samples behaved normally and indicated that the test results were valid. For the 48-h LC50s with *Daphnia magna*, all control daphnids held in laboratory culture water for two days survived and showed no signs of distress (Appendix XII). Similarly, all underyearling rainbow trout held in control (dechlorinated municipal) water for 96 hours during the 96-h LC50s with the effluent samples survived and appeared normal throughout these tests (Appendix XIII). The triplicate controls for the *Ceriodaphnia dubia* chronic toxicity tests with effluent samples showed good survival of the first-generation adults, and high (25 to 44) mean numbers of neonates produced per first-generation adults[14] (Appendix XIV).

REFERENCE TOXICANT

Results for the reference toxicant tests performed by B.C. Research before and during the toxicity tests with *Daphnia magna*, rainbow trout or *Ceriodaphnia dubia* are presented in Appendix XVI. For the reference toxicant tests with *D. magna* using zinc, the 48-h LC50s derived at the time of the tests with effluent samples examined in this study were well within the warning limits of the laboratory's Control Chart. The tolerance to phenol for the population of rainbow trout used in the 96-h LC50s with effluent samples exceeded the laboratory's upper warning limit for this reference toxicant, but was within the upper control limit (Appendix XVI). This finding suggests that the acute tolerance of the population of trout used in the tests with these effluents was somewhat higher than normal. Appendix XVI includes the findings for a reference toxicant test performed by the laboratory at the time of the series of tests with the effluent sample, using sodium chloride. The laboratory's database of past reference toxicant tests with sodium chloride and *C. dubia* was not sufficient to enable the generation of a Control Chart for this species and test. Also included in Appendix XVI are analytical results for a sample of the water used for culturing *C. dubia* and as control / dilution water in chronic assays with this species.

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[14]A minimum mean of 15 live young produced per surviving adult is required for a valid chronic toxicity test with *Ceriodaphnia dubia* (Environment Canada, 1992).

4.7.2.2 Toxicity of Leached Plasticizers to Daphnids

Laboratory data sheets showing the findings of the toxicity tests which evaluated the potential toxicity of plasticizers or other contaminants leached from barrel liners or plastic jerricans during the transport of effluent samples, are presented in Appendix XVII. These tests examined the toxicity of daphnid culture water that was previously exposed to portions of plastic barrel liners or held in plastic jerricans for a few hours (see Subsections 3.6.2.2 and 3.6.2.4).

The triplicate 48-h LC50 assays with *Daphnia magna* showed that all daphnids survived in the barrel-liner leachate water and in the jerrican leachate water. During these tests, the appearance and behaviour of all survivors was normal and indistinguishable from that of the triplicate control groups held concurrently in *D. magna* culture water which was not subjected to plastic (Appendix XVII).

The triplicate chronic assays with *Ceriodaphnia dubia* also found no harmful effects attributable to the samples of *C. dubia* culture water which had previously contacted barrel-liner plastic or jerrican plastic for several hours. The survival of first-generation daphnids exposed to plastic leachate water throughout the test period did not differ from the triplicate control groups, and no differences in the appearance or behaviour of the survivors was apparent. The mean numbers of neonates produced in the triplicate groups exposed to plastic leachate water were consistently higher than the corresponding control groups, suggesting some enhancement of reproduction. However, statistical analyses revealed no significant differences in reproduction or survival between the leachate-exposed and control groups (Appendix XVII).

The results of these blank tests demonstrate that the temporary (few hours) transport and storage of water or wastewater in barrels lined with plastic, or in plastic jerricans, caused no detectable toxic effects in either the 48-h assay with *Daphnia magna* or the chronic (7 ± 1 day) assay with *Ceriodaphnia dubia*. Thus no leaching of toxic plasticizer was evident from these tests, and no concern with respect to transporting effluent samples in plastic-lined vessels was apparent. It is conceivable that the characteristics of certain effluent samples (*e.g.*, acidic pH) might enhance the leaching of plasticizer from plastic-lined transport vessels, or that the use of plastic (rather than glass or other inert material) might adsorb toxic substances and reduce sample toxicity. However, given the experimental design and the large volumes of sample required for this study, the transport of effluent samples in glass containers was impractical. Effluent samples to be tested for toxicity to daphnids or fish are commonly transported and stored in plastic containers, and such practice is considered acceptable by Environment Canada (1990a, 1990c, 1992).

4.7.2.3 Effect of Water Hardness on Daphnids

Laboratory data sheets showing the findings of the "blank" daphnid toxicity tests that evaluated the responses of *Daphnia magna* or *Ceriodaphnia dubia* in water softer than that of the culture/control water are presented in Appendix XVIII. These tests were performed to assess the extent to which the hardness of effluent samples may have contributed to sample toxicity in instances where effluent hardness was lower than that of the culture/control water to which the daphnids were adapted (see Subsections 3.6.2.3 and 3.6.2.5).

Results for the triplicate 48-h LC50s with *Daphnia magna* exposed to deionized water reconstituted to hardness values of ~25, ~50, ~75 and ~100 mg/L indicated that none of these waters, which were softer than the culture/control water (hardness, 125 mg/L), caused any adverse effects with this daphnid species. All *D. magna* held in these softer waters for two days survived the test period without signs of distress (Appendix XVIII).

The performance (survival and number of neonates produced) of the triplicate groups of *Ceriodaphnia dubia* exposed to deionized water reconstituted to hardness values of ~5, ~10, and ~25 mg/L did not differ from that for the triplicate control groups held in culture/control water with a hardness of 45 mg/L. Statistical analyses revealed no significant differences in reproduction or survival data for groups of daphnids exposed to each hardness-adjusted water versus those daphnids held in the culture/control throughout the test period.

Effluents coded E, Q, L, I, K, and P had very low hardness values (2 to 7 mg/L). As per Environment Canada's (1990a, 1990b) test method, the hardness of these samples and two of the three samples of effluent M with hardness values <25 mg/L was adjusted to ~25 mg/L before commencing the 48-h LC50s with *Daphnia magna*. Since *Daphnia magna* is naturally found only in hard water, and since these organisms are cultured in water with a hardness of ~120 mg/L in preparation for the 48-h LC50s, concern that the test performance of this species might be impaired by their exposure to effluents with hardness values lower than that to which they were acclimated was noted. The findings from the present hardness "blank" tests with this daphnid species demonstrate that the survival, appearance and behaviour of *Daphnia magna* was not affected by water hardness within the range 25 to 125 mg/L. Accordingly, no toxic responses observed for daphnids exposed to the test effluents can be attributed to "low" sample hardness. Nor was low effluent "hardness" responsible for the toxic effects found in the chronic assays with *Ceriodaphnia dubia*.

The hardness of water can modify the chemical speciation and resulting toxicity of many aquatic contaminants, including heavy metals and resin acids. In many instances, contaminants within soft waters are less toxic than the same concentrations in harder waters. Thus the hardness of the industrial effluents investigated in this study, and that of the dilution water used in toxicity tests, might have influenced sample toxicity. The effect of water hardness on sample toxicity was not investigated as part of this study.

4.7.2.4 Control/Blank Tests for Bio-Uptake Study

The numbers of juvenile trout surviving the 8-day test period in control water only are indicated in Appendix XIX together with notes regarding their condition during dissection. Only two of the four fish in the initial control group (sample codes S-1 and S-3) survived to test end. One fish jumped from the tank and was discarded from analyses; one fish died a few hours before the end of the test and its muscle was included in the analyses. Surviving fish appeared normal during the test, and no gross pathologies were evident at dissection. For the second control group, exposed to dechlorinated municipal water coded as samples S-4 and S-5, all four fish survived to test end. These fish appeared normal during the 8-day period, and no gross pathologies were found upon dissection (Appendix XIX).

The concentrations of measured contaminants found in the pooled muscle tissue from the two groups of juvenile rainbow trout held in dechlorinated municipal water for eight days are given in Tables 4-11 to 4-13 (wet-weight values) and 4-14 to 4-16 (dry-weight values), together with the corresponding values for groups exposed to effluent samples. Respective contaminant concentrations for the two control/blank groups were similar.

Metal values for the control groups were compared to "baseline" metal concentrations determined by BC Environment in muscle tissue of rainbow trout sampled from uncontaminated B.C. lakes (Table 2b; Rieberger, 1992). Concentrations of Al, Cd, Cu, Fe, Hg, Mn, Ni, Pb and Zn were typical of those for rainbow trout from uncontaminated lakes. Levels of arsenic in the control groups (0.39 and 0.33 mg/kg wet weight) were approximately twice the mean value reported for rainbow trout from B.C. lakes, although SD for this mean was high. The concentrations of arsenic in muscle from the control groups were also somewhat higher than mean muscle concentrations for arsenic found in various species of fish sampled from the lower Fraser River during 1980 (Singleton, 1983) and 1988 (Swain and Walton, 1989) surveys. Other muscle-metal concentrations in the control groups were non-detectable or appeared to be within normal ranges.

No polycyclic aromatic hydrocarbons were detected in the pooled muscle tissue from either control group. Concentrations of most chlorophenolic compounds were below detection limits. Exceptions were 2,3,4,6-tetrachlorophenol (0.00088 and 0.00088 mg/kg dry weight) and pentachlorophenol (0.00044 and 0.00088 mg/kg dry weight). These values are considered low and below the detection limits of 0.005 mg/kg dry weight or

0.001 mg/kg dry weight reported for these contaminants in fish muscle tissue by Swain and Walton (1989; 1992). Previous 8-day bio-uptake tests with juvenile rainbow trout found that concentrations of tetrachlorophenol and pentachlorophenol in muscle tissue from controls were <0.005 mg/kg dry weight (Swain and Walton, 1992). The (lower) values of these contaminants measured in control groups from the present bio-uptake tests might simply reflect trace levels of these chlorophenolics previously undetected in "uncontaminated" fish-muscle tissue due to higher limits of detection.

Duplicate analyses of a single (split) sample of muscle tissue from control fish held in dechlorinated municipal water (samples coded S-4 and S-5) for eight days showed similar values for the contaminants measured. These results for a split sample provide confidence in the analytical values obtained.

5.0 CONCLUSIONS

1. In general, most discharges are in compliance with their Waste Management Permit. Excursions were noted in a few instances for flow, pH and TSS.

2. A number of Waste Management Permits were found to be out of date. It was concluded that permits are usually updated to account for increased flows or changes in discharge characteristics. Communication between BCELP and the permittee regarding other changes such as reduction or cessation of flow does not occur as frequently.

3. While toxicity evaluation was outside the scope of this study, an attempt was made to highlight the contaminants which might contribute to sample toxicity. The limits of detection for dissolved aluminum, cadmium, chromium, copper, nickel, silver, chlorinated phenolics and resin and fatty acids were not sufficiently low to ensure that these chemicals were not present at concentrations that could contribute to sample toxicity.

4. Concentrations of total phenols were found in each discharge, including samples of dechlorinated Vancouver City water. We conclude that there are likely background concentrations of total phenols in Fraser River water and in Vancouver City Water.

5. Some heavy metals, particularly copper, iron, lead and zinc were found in effluents at concentrations which might have an adverse environmental impact. These metals are recommended for future study.

6. The bio-uptake test revealed some specific chlorinated phenolic compounds, PAHs and chromium and nickel in the muscle tissue of certain fish. Provincial water quality objectives and criteria for maximum recommended concentrations in edible tissue of fish were not exceeded.

7. Very low or non-detectable concentrations of anti-sapstain chemicals (including chlorophenolics), resin and fatty acids, PAHs, dioxins and furans were found. These chemicals are not expected to be harmful to aquatic life at the concentrations measured.

8. Present data indicate that the acute lethality test using *Daphnia magna* was in several instances somewhat more sensitive to the effluent samples studied than the acute lethality test using rainbow trout.

9. For the effluent samples studied, the chronic toxicity test using the freshwater invertebrate daphnid *Ceriodaphnia dubia* was more sensitive than the acute lethality tests with *Daphnia magna* or rainbow trout. Undiluted effluents that are not acutely lethal to trout or *D. magna* were shown to inhibit the reproductive success of *C. dubia* at concentrations as low as 1%.

10. No demonstrable leaching of toxic plasticizers was observed from the exposure of daphnid culture water to plastic sample collection containers. It is concluded that, for the purpose of this study, the transport of effluent samples in plastic-lined vessels was suitable and did not contribute to sample toxicity.

11. "Blank" studies of water-hardness effects using each daphnid species indicated that the performance of either species in the acute or chronic toxicity tests was unaffected by the range of hardness values to which they were exposed. Accordingly, it is concluded that any toxic effects towards daphnids noted for certain effluent samples were not caused by sample hardness *per se*.

12. Operational assessments at the seventeen discharges sampled in this study indicated that flow measurement is generally estimated by facility personnel. Only 3 of the discharges had on-line flow measurement, while another 3 measured flow with a Parshall flume and one discharge used a flow totalizer. It can be concluded that reported discharge flow rates do not necessarily reflect actual rates, although estimating techniques were generally determined, in our opinion, to be reasonable.

6.0 RECOMMENDATIONS

1. Future chemical characterization of effluent discharges in the FREMP area should focus on heavy metal concentrations. Concentrations of anti-sapstain chemicals, resin and fatty acids, PAHs, dioxins and furans were found only at trace levels.

2. Chronic toxicity tests with effluent samples derived from processes using chlorinated municipal water should include analysis for total residual chlorine with a detection limit of 0.001 mg/L.

3. To assist in the interpretation of data for chronic toxicity tests, information should be compiled regarding the influence of total suspended solids, salinity, pH, and water hardness on test results. A compendium of reported chronic toxicity data for *Ceriodaphnia dubia* tests with the specific chemicals of concern in effluent samples would also be very useful in interpreting chronic toxicity data for effluents.

4. Because of the detectable concentrations of total phenols in all samples, further study of total phenol concentration in the Fraser River is recommended.

5. Any comparison of the potential toxic loadings of multiple point-source discharges to the lower Fraser River should take into account data regarding daily effluent flow for each discharge (i.e., calculate ATERs and/or CTERs), rather than restricting the appraisal to a simple comparison of sample toxicity.

6. For future effluent characterization studies, the limits of detection for all chemical constituents analyzed should be adequately low to ensure that measured concentrations are below those known to cause chronic toxic effects on sensitive freshwater life. Detection limits for the following are recommended: chlorinated phenolics - 0.00002 mg/L to 0.0009 mg/L; resin and fatty acids - 0.025 mg/L; aluminum - 0.005 mg/L; cadmium - 0.0002 mg/L; chromium - 0.001 mg/L, copper - 0.001 mg/L; nickel - 0.001 mg/L; silver - 0.0001 mg/L.

7. The *C. dubia* chronic toxicity test should be employed routinely (e.g., monthly) for monitoring the toxicity of all toxic (according to this test) effluents that discharge with appreciable flow to the Fraser River.

8. The hardness of all effluent samples used in acute or chronic toxicity tests with daphnids should be routinely measured and reported.

9. A careful consideration of test objectives, study options and associated costs is recommended before future effluent-related bio-uptake studies are performed. The approach selected should be cost-effective and standardized sufficiently to ensure

that comparable results can be obtained for various effluent sources or receiving-water locales.

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LIST OF ABBREVIATIONS AND CHEMICAL FORMULAE

AAS	atomic absorption spectrophotometric
ACA	Ammoniacal Copper Arsenate
ASTM	American Society for Testing Materials
ATER	Acute Toxicity Emission Rate
ATU	Acute Toxic Units
BCELP	British Columbia Ministry of Environment, Lands and Parks
BOD_5	5-day biochemical oxygen demand
C	Celsius
CCA	Chromated Copper Arsenate
CCREM	Canadian Council of Resource and Environment Ministers
CRM	certified reference material
CSA	Canadian Standards Association
CTER	chronic toxicity emission rate
CTU	chronic toxic units
$CaCO_3$	calcium carbonate
Cu-8	or PQ-8, copper-8-quinolinolate; an antisapstain chemical
DDAC	didecyl dimethyl ammonium chloride
DO	dissolved oxygen
Dup.	duplicate sample
FREMP	Fraser River Estuary Management Program
FRHC	Fraser River Harbour Commission
GVRD	Greater Vancouver Regional District
GVWD	Greater Vancouver Water District
GVS&DD	Greater Vancouver Sewerage and Drainage District
IC25	inhibiting concentration for a 25% effect
ICAP	inductively-coupled argon plasma
ICP	inductively-coupled plasma
IFP	International Forest Products
IPBC	3-iodo-2-propynyl butyl carbamate
L	litre(s)
LC50	median lethal concentration
LOEC	lowest-observed-effect concentration
MB	MacMillan Bloedel
Mbfm	Thousand Board Foot Measure
m^3/d	cubic metres per day
mg/L	milligrams per litre (ppm)
NFHC	North Fraser Harbour Commission
NH_3	un-ionized ammonia
NOEC	no-observed-effect concentration
NO_2	nitrite

NO_3	nitrate
NP-1	mixture of DDAC and IPBC; an antisapstain chemical
O&G	oil and grease
PAH	polycyclic aromatic hydrocarbons
pg/L	picogram/L (ppb)
PCP	Pentachlorophenol Wood Treatment Chemical, usually containing 86% 5 CP and 10% other chlorophenols and related products
PQ-8	or Cu-8, copper-8-quinolinolate; an antisapstain chemical
QA	quality assurance
QC	quality control
RA&FA	Resin Acids and Fatty Acids
SD	standard deviation
SPE	solid phase extraction
SRM	standard reference material
TBDMS	N-methyl-N(t-butyldimethylsilyl)-trifluoroacetimide
TCMTB	2-(thiocyanomethylthio) benzothiazole; an antisapstain chemical
TEC	threshold-effect concentration
TEQ	toxic equivalent
TRC	total residual chlorine
TSS	total suspended solids
TU	Toxic Units
µg/L	microgram/litre (ppm)
3 CP	Trichlorophenol
4 CP	Tetrachlorophenol
5 CP	Pentachlorophenol

All units are reported in metric, using the standard abbreviations and prefixes.

TERMINOLOGY

Acclimation means to become physiologically adjusted to a particular level of one or more environmental factors such as temperature. The term usually refers to controlled laboratory conditions.

Acute means within a short period in relation to the life span of the organism, and would be of the order of some minutes for bacteria, #2 days (#48 h) for daphnids, and usually #4 days (#96 h) for fish.

Acute lethality, acutely lethal mean causing the death of the test organisms within a short period of exposure to a test substance, usually 48 h for daphnids and 96 h for fish.

Aliquot means a representative subsample of a larger sample (see "*Subsample*").

Bio-Uptake means the uptake and storage in tissues of an aquatic organism of a chemical or chemicals from the diet and/or the surrounding water. The term "*bioaccumulation*" is synonymous. Since, in this study, fish were not fed during the exposure to samples of effluent, the term "*bioconcentration*" (*ie:* the accumulation in an aquatic organism of a chemical taken up directly from the water) is also synonymous.

Brood means a group or cohort of sibling offspring daphnids, released from the female during an inter-molt period; *ie:* before the carapace is shed by that female during molting.

Chronic means occurring during a relatively long-term period of exposure, usually a significant portion of the life span of the organism such as 10% or more. For tests with cladocerans, chronic is typically defined as continuing until three broods are produced.

Chronic toxicity implies long-term effects that are related to changes in metabolism, growth, reproduction, survival, or ability to survive.

Chronic value is the geometric mean of the NOEC and LOEC in tests which have a chronic exposure. See also *TEC* as the recommended term used in this report.

City water means municipal drinking water distributed by the GVWD. This water is chlorinated, unless otherwise specified.

Clinker is the sintered product from a cement kiln.

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the concentrations of ions in solution, their valence and mobility, and on the solution's temperature. Conductivity is normally reported in the SI unit of milliSiemens / metre, or as micromhos / cm (1 mS / m = 10 Fmhos / cm).

Control means a treatment in an investigation or study that duplicates all the conditions and factors that might affect the results of the investigation, except the specific condition that is being studied. In an aquatic toxicity test, the control must duplicate all the conditions of the exposure treatment(s), but must contain no test substance. The control is used to determine the absence of measurable toxicity due to basic test conditions (e.g., quality of the dilution water, health of test organisms, or effects due to their handling).

Control/dilution water is the water used for diluting the test substance, or for the control test, or both.

Culture, as a noun, means the stock of animals or plants that is raised under defined and controlled conditions in order to produce healthy test organisms. As a verb, it means to carry out this procedure of raising organisms.

Culture medium is the water used for culturing *D. magna* or *C. dubia.*

Daphnid is a freshwater microcrustacean invertebrate (*ie:* cladocerans from the family Daphniidae), commonly known as a water flea. Species of daphnids include *Ceriodaphnia dubia*, *Daphnia magna* and *Daphnia pulex*.

Dechlorinated water is chlorinated municipal drinking water that has been treated by filtering through activated charcoal to remove chlorine and chlorinated compounds from solution.

Deionized water means water that has been passed through resin columns to remove ions from solution and thereby purify it.

Dilution water means the water used to dilute a test substance (e.g., effluent) in order to prepare different concentrations for the various toxicity test treatments.

Distilled water is water that has been passed through a distillation apparatus of borosilicate glass or other material, to remove impurities.

Endpoint means the variables (*ie:* time, reaction of the organisms, etc.) that indicate the termination of a test, and also means the measurement(s) or value(s) derived, that characterize the results of the test (NOEC, LC50, etc.).

Effluent means any liquid waste (e.g., industrial, municipal) discharged to the aquatic environment.

Ephippium is an egg case that develops under the postero-dorsal part of the carapace of a female adult daphnid in response to adverse conditions (e.g., overcrowding, infrequent exchange of culture water, inadequate diet, low temperature, reduced photoperiod). The eggs within are normally fertilized.

Fingerling is a young (underyearling), actively feeding salmonid fish.

First-generation daphnids mean those organisms placed in solutions at the start of the test.

Fork length is the length of a fish, measured from the tip of the nose to the fork of the tail.

Hardness is the concentration of cations in water that will react with a sodium soap to precipitate an insoluble residue. In general, hardness is a measure of the concentration of calcium and magnesium ions in water, and is expressed as mg/L calcium carbonate or equivalent.

IC25 is the inhibiting concentration for a 25% effect. In this study it represents the concentration estimated to cause a 25% reduction in mean number of young *C. dubia* produced, relative to the number produced by control animals.

Immobility is the inability to swim. Daphnids are defined as immobile if swimming activity is not evident or does not resume during the 15 seconds which follow gentle agitation of the test solution.

LC50 is the median lethal concentration, *ie:* the concentration of effluent in water that is estimated to be lethal to 50% of the test organisms exposed to that concentration. The LC50 and its 95% confidence limits are usually derived by statistical analysis of mortalities in several test concentrations, after a fixed period of exposure. The duration of exposure must be specified (e.g., 48-h LC50 or 96-h LC50). This endpoint is appropriate for acute lethality tests with daphnids or rainbow trout.

Lethal means causing death by direct action. Death is usually defined as the cessation of all visible signs of movement or other activity.

LOEC is the lowest-observed-effect concentration. This is the lowest concentration of test material to which organisms are exposed, that causes adverse effects on the organism which are detected by the observer. (For example, LOEC might be the lowest concentration at which the number of live young produced per adult daphnid differed significantly from that in the control).

Neonate is a newly-born or newly-hatched individual daphnid (i.e., first-instar daphnid, <24-h old).

Non-contacting refers to heat transfer equipment in which cooling water passes on one side of a metal surface and a hot fluid passes on the other side. There is no contact between the fluids.

NOEC is the no-observed-effect concentration. This is the highest concentration of a test material to which organisms are exposed, that does not cause any observed adverse effects on the organism (e.g., value of an observed variable such as number of live young produced per adult daphnid does not differ significantly from that in the control). NOEC customarily refers to sublethal effects, and to the most sensitive effect unless otherwise specified.

Overt means obviously discernible under the test conditions employed.

Parshall Flume is an open-channel flow measuring device.

Percentage (%) is a concentration expressed in parts per hundred parts. One percent represents one unit or part of test substance (e.g., Newstech's final mill effluent) diluted with fresh water to a total of 100 parts. Concentrations of effluent are prepared on a volume-to-volume basis, and are expressed as the percentage of undiluted effluent in the final solution.

pH is the negative logarithm of the activity of hydrogen ions in gram equivalents per litre. The pH value expresses the degree or intensity of both acidic and alkaline reactions on a scale from 0 to 14, with 7 representing neutrality, numbers less than 7 signifying increasingly greater acidic reactions, and numbers greater than 7 indicating increasingly basic or alkaline reactions.

Photoperiod is the duration of illumination and darkness within a 24-h day.

Pre-treatment means the treatment of a wastewater sample or dilution thereof (e.g., by pH adjustment or filtration), prior to the exposure of fish.

Quality Assurance refers to the management and technical practices (e.g., planning, control, assessment, reporting, remedial action) designed to ensure an end product of known or reliable quality.

Quality Control refers to the techniques and procedures used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized.

Receiving water means surface water (e.g., in a stream, river or lake) that has received a discharged waste, or else is about to receive such a waste (e.g., it is just upstream from the discharge point). Further descriptive information must be provided to indicate which meaning is intended.

Reconstituted water means deionized or glass-distilled water to which reagent-grade chemicals have been added. The resultant synthetic fresh water is free from contaminants and has the desired pH and hardness characteristics.

Reference toxicant means a standard chemical used to measure the sensitivity of the test organisms in order to establish confidence in the toxicity data obtained for a test material. In most instances a toxicity test with a reference toxicant is performed to assess the sensitivity of the organisms at the time the test material is evaluated, and the precision of results for that chemical obtained by the laboratory.

Stock solution means a concentrated aqueous solution of the material to be tested. Measured volumes of a stock solution are added to dilution water in order to prepare the required strengths of test solutions.

Static describes toxicity tests in which test solutions are not renewed during the test.

Static renewal describes a toxicity test in which test solutions are renewed (replaced) periodically during the test, usually at the beginning of each 24-h period of testing. Synonymous terms are "semi-static", static replacement, and "batch replacement".

Sublethal means detrimental to the organism, but below the level which directly causes death within the test period.

Subsample is a representative portion (aliquot) of a larger sample, taken after the sample is composited and/or mixed thoroughly.

Swimup fry is a young, post-alevin salmonid fish that has commenced active feeding.

TEC is the threshold-effect concentration. It is calculated as the geometric mean of NOEC and LOEC. *Chronic value* or *subchronic value* are alternative terms that may be appropriate depending on the duration of exposure in the test.

Toxicity means the inherent potential or capacity of a test substance to cause adverse effects on living organisms. The effect could be lethal or sublethal.

Toxicity Emission Rate (TER) represents the calculated amount of toxicity discharged daily in an effluent. In this report, both Acute Toxicity Emission Rates (ATER) and Chronic Toxicity Emission Rates (CTER) are calculated. ATER represents the product of the effluent's Acute Toxic Units (ATU) and the daily volume (m^3/ d) of the effluent released. CTER represents the product of the effluent's Chronic Toxic Units (ATU) and the daily volume (m^3/ d) of the effluent released.

Toxicity Identification Evaluation describes a systematic sample pre-treatment (e.g., pH adjustment, filtration, aeration) followed by tests for toxicity. This evaluation is used to identify the causative agent(s) that are primarily responsible for toxicity in a complex mixture. The toxicity test can be lethal or sublethal.

Toxicity test means a determination of the effect of a test substance on a group of selected organisms, under defined conditions. An aquatic toxicity test usually measures either (a) the proportions of organisms affected *(quantal)*, or (b) the degree of effect shown *(graded or quantitative)*, after exposure to specific concentrations of effluent or other test substance. Acute lethality tests with daphnids or rainbow trout are considered as quantal assays. Chronic toxicity tests with *Ceriodaphnia dubia* should be considered as graded (quantitative) assays, since they include measurements of the degrees of reduction in a physiological function (i.e., reproductive success).

Toxic Unit (TU) is a concept for expressing the toxic strength or concentration of an effluent (or chemical) in a term that is related directly to the concentration of toxicants. In this report, both Acute Toxic Units (ATU) and Chronic Toxic Units (CTU) are calculated, as follows:

1 ATU = 48-h LC50 (*D. magna*). Accordingly, ATU=100%÷48-h LC50(%).

1 CTU = IC25 (*C. dubia*). Accordingly, CTU=100%÷IC25(%).

For example, an effluent with a 48-h LC50 (*D. magna*) of 100% contains 1 ATU, and an effluent with a 48-h LC50 of 50% contains 2 ATU. Similarly, an effluent with an IC25 (*C. dubia*) of 20% contains 5 CTU, and effluent with an IC25 of 5% contains 20 CTU.

Upstream water means surface water (e.g., in a stream, river or lake), that is not influenced by the effluent (or other test material, by virtue of being removed from it in a direction against the current or sufficiently far across the current.

Wastewater refers to effluent.

White Water refers to water containing wood fibre.