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ABSTRACT

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The methods used and the wastes produced during the cleaning of various types of rearing containers, commonly used by the Salmonid Enhancement Program, were surveyed in the late spring of 1985. This survey attempted to describe procedures and characterize effluents in relation to provincial pollution control objectives. Results were highly variable and required detailed knowledge of the daily hatchery operations for interpretation. Cleaning procedures were grouped into 'flush', 'baffle', 'vacuum' or 'pressure-hose' methods. When daily dilution factors within the hatchery were considered for cleaning effluents, it appears that the pollution control objectives would not be exceeded by any of these cleaning methods for non-filtrable residues (NFR) or biochemical oxygen demand (BOD), but could be exceeded by vacuum effluents for total nitrogen (TN) and total phosphorus (TP). Sludge sampled from the bottom of fish rearing units had high concentrations of TN and especially TP. 'Control' water samples taken from rearing unit outlets prior to cleaning indicated that the NFR, TN and TP objectives could be exceeded at the hatchery outfall even during normal operations. There were a number of possible reasons for this result, the major ones being the manner of sampling and the way in which the objectives are expressed. The paper concludes with some suggestions how to improve effluent discharge procedures, and calls for the removal of fish biomass from the units of measurement used for the objectives.

RESUME

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Les méthodes utilisées et les déchets produits au cours du nettoyage de divers types d'enceintes d'élevage couramment utilisées dans le cadre du Programme de mise en valeur des salmonidés ont fait l'objet d'un relevé au cours de la fin du printemps de 1985. Ce relevé avait pour but de décrire les procédures utilisées et de caractériser les effluents produits dans le contexte des objectifs de la lutte anti-pollution provinciale. Les résultats obtenus se sont avérés très variables et leur interprétation exigeait une connaissance détaillée des opérations courantes de l'installation piscicole. Les méthodes de nettoyage ont été réparties de la façon suivante: nettoyage à grande eau, par écran, par aspiration et sous pression. On a trouvé, en tenant compte des facteurs quotidiens de dilution au sein de la pisciculture, que les objectifs anti-pollution ne seraient pas dépassés par aucune des méthodes utilisées en ce qui concerne les résidus non filtrables (RNF) et la demande biochimique d'oxygène (DBO), mais qu'ils pourraient l'être par la méthode par aspiration en ce qui concerne l'azote total (NT) et le phosphore total (PT). Les boues prélevées dans le fond des unités d'élevage présentaient des teneurs élevées de NT et, plus particulièrement, de PT. Des échantillons d'eau "témoins" prélevés au niveau du déversoir d'unités d'élevage, avant leur nettoyage, indiquaient que les valeurs précisées par les objectifs pour les teneurs en RNF, NT et PT pouvaient être dépassées au niveau du déversoir de la pisciculture, ceci même au cours d'opérations normales. Diverses raisons pouvaient expliquer ce phénomène. Les principales avaient trait au mode d'échantillonnage et à la façon d'exprimer les objectifs anti-pollution. Les auteurs concluent en faisant quelques suggestions sur la façon d'améliorer les méthodes de rejet des effluents et proposent que la biomasse des poissons soit éliminée des unités de mesure des objectifs.

INTRODUCTION

The Phase I (1976-1984) and Transition (1984-1986) periods of the Salmonid Enhancement Program (SEP) resulted in the relatively rapid expansion in both the number and capacity of fish culture facilities in British Columbia. This expansion also increased concerns as to the impact that hatchery effluents might have on receiving waters in British Columbia, particularly in the environmentally sensitive Central Interior region. In response to these concerns, SEP had a consultant company characterize effluents from existing British Columbia hatcheries, and review effluent treatment technologies (Underwood McLellan Ltd. MS 1979a, MS 1979b). In addition, SEP funded studies done by the Habitat Management Division in 1978-1981 which examined the effects of hatchery effluents on the water chemistry, periphyton and benthic invertebrates of receiving waters (Munro et al. 1985).

While these studies were underway, the SEP Enhancement Operations Division was requested by the Provincial Waste Management Branch (WMB) to apply for Effluent Permits (see Appendix 1 for a sample application form) for some of its facilities, particularly those under construction in the Central Interior. These permits require the applicant to not exceed certain objectives (Table 1). The objectives are expressed in pounds of pollutant per 100 pounds of fish on a composite daily, as well as an average annual basis. Although these objectives are acknowledged to be overdue for revision, they remain in force at the time of writing of this report.

It became obvious during the effluent permit application process that, for predictive purposes, the studies by Underwood McLellan Ltd. (MS 1979a) and Munro et al. (1985) did not deal adequately with certain hatchery activities. In particular, characterization of effluents resulting from pond cleaning activities was not possible. Also, the WMB guidelines recommend a monthly sampling frequency in order to monitor effluent quality. The results of such infrequent monitoring could be quite misleading if such sampling occurred during a peak in cleaning activities.

Characterization of cleaning effluents was additionally important, in that various fish rearing containers (see Shepherd, 1984) and new cleaning techniques are now in use that had not been considered in earlier studies. In most cases, the change to a different container or cleaning technique was done to minimize the costs of construction or operation. The rapid expansion of facilities, together with financial and manpower constraints, have pushed hatchery staff to use labor-saving innovations wherever possible. The impact of these innovations on hatchery effluent quality requires checking.

This study presents the results of a summer student project to describe various cleaning techniques and the resultant effluents, for several types of rearing containers presently in common use at SEP hatcheries.

Table 1. Provincial pollution control objectives for the discharge of effluent to marine and fresh waters from fish hatcheries (Water Resources Service 1975).

Parameter	New/Proposed Discharges	Existing Discharges	Monitoring Frequency
BOD (lb/100 lb of fish/day)	0.40	1.3	Monthly
Suspended solids (lb/100 lb of fish/day)	0.40	1.5	Monthly
Ammonia nitrogen (lb of N/100 lb of fish/day)	0.04	0.14	Monthly
Nitrate nitrogen (lb of N/100 lb of fish/day)	0.12	0.12	Monthly
Total phosphate phosphorus (lb of P/100 lb of fish/day)	0.020	0.035	Monthly
pH range	6.5-8.5	-	Monthly

NOTE - All parameter values are incremental to intake water values.

The study focus was on the levels of suspended solids produced during the cleaning of individual rearing containers. Suspended solids present in the hatchery water supply, uneaten food, and feces settle out as a sludge on the bottom of virtually all rearing containers, due to the generally low water velocities in them. Removal of this sludge is necessary to maintain good fish health. The regularity of removal varies from a daily to an annual event, depending on the type of container and the approach taken by the hatchery manager. The sludge is disposed of in various ways, including into swamps or more formal flow-through settling ponds, into isolated sludge lagoons (with the sludge mechanically removed at intervals), overland into surrounding forest areas or directly into river systems.

In addition to sampling for suspended solids, grab samples of both water and sludge were analysed for nutrients (nitrogen and phosphorus compounds). These were taken because ammonia and total phosphate levels have been found to be significantly higher in and downstream of hatchery discharges, sometimes even after fish release; this has been attributed to the decomposition of hatchery wastes and subsequent release of nutrients over time (Munro et al. 1985). This report also provides an extrapolation technique to predict daily total parameter levels in hatchery effluents.

It is emphasized that further studies are required to properly characterize all types of cleaning effluents. This report has only scratched the surface of that topic. There were a number of problems with the data (see Methods) that made thorough quantitative analyses impossible or unadvisable. Nevertheless, preliminary characterization of cleaning techniques and effluents has been attempted. Although these observations are largely subjective, they should be useful in the planning of more definitive studies. This report is seen as a set of overview 'snapshots' of a wide variety of pond cleaning events; its chief value is in the identification of the highly dynamic and variable nature of a number of factors that must be considered in the design of any follow-up studies.

METHODS

WATER QUALITY PARAMETERS

Effluent samples were collected and analysed for the following parameters: Non-filtrable residue (NFR), filtrable residue (FR), total residue (TR), nitrite (NO_2), nitrate (NO_3), total nitrogen (TN), total phosphate (TP) and five-day biochemical oxygen demand (BOD). TP and TN concentrations also were determined for samples of sludge collected from rearing containers.

Some comments relating the above parameters to those identified in Table 1 are necessary. First, suspended solids were considered to be equivalent to NFR, but this is theoretically incorrect (Dept. Env. and Dept. Fish and Oceans 1979). Depending on the filter paper used, varying amounts of the smaller suspended solids may pass; thus in theory, suspended solids could be slightly greater than NFR. Second, ammonia levels were not measured in this study because the samples could not be delivered to the lab in time to prevent conversion of ammonia to nitrite or nitrate. Third, NO_2 and NO_3 were analyzed separately, but primarily to determine TN. Although the text of this report deals with TN only, the levels of the NO_2 and NO_3 components are given in Appendix 2. Readers wishing more information on ammonia and urea levels in BC federal hatcheries are referred to McLean and Fraser (1974).

FIELD SAMPLING

Two-litre plastic bottles were used to manually collect effluent samples at selected sites and intervals over a cleaning cycle. One-litre plastic bottles were used to collect BOD samples for selected cleaning events; one sample was taken before cleaning began, and a second sample was taken at the apparent peak of turbidity (determined visually). If the accumulation of sludge was heavy enough, samples were collected in 250 ml glass jars prior to cleaning events. All sample bottles were rinsed three times with water from the sample site prior to actually taking the sample. The 2 L bottles took approximately 25 s to fill and 1 L bottles took approximately 15 s. In some cases, this limited the number of samples that could be taken during a cleaning event, making the use of average values questionable. Reported sampling times (eg, 30 s) refer to the start of filling, except for 0 s which was a 'control' sample taken at the container outlet before cleaning began. After collection, the bottles were capped and stored on ice in coolers and delivered within 48 h to the EPS-DFO Water Quality Lab at Cypress Creek in West Vancouver.

Where appropriate, the following information also was collected for each rearing container sampled:

1. Container dimensions (length, width, height, and water depth and volume) taken from as-built documents, or as measured by hatchery staff or the student author

2 Flows in L/min (expressed as LPM in this report in order to shorten notations)

   a) routine - determined by hatchery staff from weir measurements
   b) during cleaning - determined by measuring the volume decrease over time, adding inflow rates where present
   c) during vacuuming or hosing - determined by bucket and stopwatch method

3. Fish culture data, from hatchery staff

   a) species
   b) mean weight of fish
   c) number of fish
   d) type of food
   e) the most recent food conversion ratio
   f) recent prophylactic treatments

TYPES OF REARING CONTAINERS SAMPLED

Several types of rearing containers are used at SEP facilities (Table 2). Key dimensions, loading criteria, and pros/cons of the more common types of units are reviewed in Peel (1982) and Shepherd (1984).

Table 2. Types of freshwater rearing containers in use at SEP Enhancement Operations Division's facilities in 1985 (data taken from Umedaly MS 1985; Rosberg and MacKinlay, MS 1985; MacKinlay MS 1986a,b).

FACILITY	Capilano Troughs	Starter Units	Circular Tubs	Burrows Ponds	Raceways**	Sloping-Sided Channels**	Other
Bella Coola	10		4		8 (C)		Offsite pens(A)
Big Qualicum	6		6	3*	3 (C)*	4 (E)	
Birkenhead	3		5			1 (E)	
Capilano	27*		2	12	31 (C)*		
Chehalis	32				14 (C)*	3 (C)	
Chilliwack	34*				5 (C)*	3 (E)*	
Clearwater	12	8			6 (C),4 (A)		
Devereux	5					1 (E)	
Eagle	8	8			6 (C),4 (A)*		
Inch	20*				14 (C),2 (A)*		
Kitimat	64				14 (C)		
Little Qualicum						1 (E)	
Mathers					2 (V)		
Nitinat	18				12 (C)*		
Pallant					4 (C)		Seapens
Puntledge	44*		5	2	4 (C)*	5 (E)	
Quesnel	32				7 (C)		
Quinsam	40		10	15	6 (B)		Seapens
Robertson	18		9		13 (C)*	10 (E)	Ponding section at top of 2 raceways
Shuswap	4*						
Spius	12	8	3		6 (C),3 (A)		3 California Troughs
Tenderfoot	16*					2 (C)*	6 Atnarko Boxes*
Tlupana	40				4 (C)*	3 (E)	Seapens

* Indicates sampling undertaken in this study.
** C = Concrete; A = Aluminum; E = Earthen; V = Vinyl Liner; B = Converted Burrows pond.

Three sets of effluent and sludge samples for each container type at each facility were collected when possible. In some cases this was not possible (Table 3); the cleaning extended over several days, the hatchery did not have enough containers running, or sludge collection would have severely decreased effluent concentrations (the latter pertains specifically to Capilano troughs).

Two common unit types were not sampled in this study. No circular tubs were in operation at the time any of the facilities were visited, precluding sampling. Also, the Large Starter Units were a new development, and were not yet functional at the time of the study. However, the Atnarko-box raceways sampled at the Tenderfoot facility were similar in dimensions to the Large Starter Units.

SAMPLING LOCATIONS

Effluent was sampled at the outlet of each container or of the discharge hose. In a few cases, sampling was also done at points farther along the discharge route.

ANALYSES

The effluent samples were analysed following standard procedures (Table 5). Two problems arose during analyses. In some of the lab analyses of NFR and TR, NFR values were greater than TR. Theoretically TR = NFR+FR, therefore NFR must be less than TR. An overnight evaporation and drying procedure is used for TR, versus filtration and a shorter drying time procedure for NFR. Lab staff suggested that drying was incomplete for the NFR samples, and that the TR result is probably the more accurate. The samples for which NFR exceeded TR are identified in Appendix 2. The second problem was that only a small number of the samples collected at the Eagle River Hatchery were analyzed. Thus there was only one complete data set from the concrete channels and aluminum raceways sampled at this facility.

STUDY LIMITATIONS

This study began in late May when many of the hatcheries had released their fish. Rearing at all facilities was finished by mid-June. Because only 3 wk were available for sampling, several facilities were not visited and the time available for sampling at each facility visited was limited. In some cases, containers were cleaned sooner than usual, so that they could be fit into the sampling schedule. The scheduling of tagging and release activities led to the sampling of what may be atypical effluent in several cases (Table 4). For instance, cleaning of containers was left longer than usual; the frequency and amounts of food were reduced where the fish had reached the size required for release; and fish densities often were unusually high or low, due to crowding or thinning as part of tagging and release activities.

Effluents resulting from only two stages of juvenile salmonids, early fry and smolts, were sampled. The output of pollutants may change over time

Table 3. List of the cleaning methods sampled at each hatchery. (F = Flush, V = Vacuum, P = Pressure-hose, K = Kitimat 'creeper-sweeper; number refers to number of cleaning events sampled.

Facility	Capilano Troughs	Atnarko Boxes	Burrows Ponds	Earthen Channels	Biofilter Underground Chambers	Aluminum/ Concrete Raceways
Big Qualicum			V-1			P-1
Capilano	F-3				F-3	
Chehalis						V-2 P-1
Chilliwack	F-5			P-5		
Conuma						V-1
Eagle						V-5
Inch	F-3					V-3
Nitinat						P-3
Puntledge	F-3					V-3
Quinsam			V-2			
Robertson						V-2
Shuswap	F-3					
Tenderfoot	F-3 K-2	F-2				V-3

Table 4. 'Normality' of effluent from rearing containers during the sampling program, as estimated by hatchery staff.[a]

Facility	Capilano Troughs	Atnarko Boxes	Burrows Ponds	Earthen Channels	Biofilter Chambers	Aluminum/ Concrete Raceways	Total Effluent Discharge
Big Qualicum			N		N	N	N
Capilano	N				N		N
Chehalis						+	N
Chilliwack	N			N			N
Conuma						+	-
Eagle						-	N
Inch	N					N	-
Nitinat						N	-
Puntledge	+					+	-
Quinsam			+				-
Robertson						N	N
Shuswap	N					N	
Tenderfoot	N	N				N	-

[a] N = Normal
\+ = greater than normal (usually because of high fish densities)
\- = less than normal (usually because of a low number of containers in actual operation).

Table 5. List of analyses carried out on effluent and sludge samples from rearing containers (MacKinlay 1984, Dept. Env. and Dept. Fish. Oceans 1979).

Parameter Name	Abbreviation	Techniques	Units	Precision	Detection Level
WATER SAMPLES:					
Non-Filterable Residue	NFR	Filtration, drying	mg/L	± 10%	5.0
Filterable Residue	FR	TR-NFR	mg/L	± 10%	5.0
Total Residue	TR	Evaporation	mg/L	± 5%	5.0
Nitrite	NO_2	Diazotization-Colormetric	mg/L N	± 0.8%	0.005
Nitrate	NO_3	Cadmium - Copper Reduction, Automated Colorimetric	mg/L N	± 2.3%	0.01
Total Nitrogen	TN	Hydrazine Reduction, Automated Colorimetric	mg/L N	± 2.3%	0.01
Total Phosphate	TP	Acid-Persulfate, Autoclave Digestion	mg/L P	± 1.9%	0.005
Biochemical	BOD	5 day, 20°C, Oxygen	mg/L	± 5-15%	2.0
SLUDGE SAMPLES:					
Nitrogen	TN	Freeze dried-Digestion as for water analysis	Dry Weight mg/kg		
Phosphate	TP	Biota preparation-ICAP analysis	mg/kg		

with fish metabolism and growth rate, and external factors such as temperature and ration level.

Comparisons of data between facilities were complicated further by physical differences between the facilities, including:

1. Influent water chemistry.
2. The method of treatment of effluent.
3. The degree of dilution before discharge (several types of containers and discharges can be combined).
4. The period of operation when rearing is at its maximum.
5. Even similar container types can differ in size and structure, and the degree to which they are self-cleaning.

For instance, there were marked differences in the design of the concrete raceways sampled at Robertson and Tenderfoot compared to other hatcheries (Eagle, Conuma, Puntledge, Inch and Chehalis). The Robertson raceways were deeper through the mid-section, which was supposed to promote self-cleaning. The Tenderfoot raceways have sloped sides and depth increases towards the outlet end. The other hatchery raceways are basically rectangular containers, with the outlet end slightly deeper to facilitate movement of sludge toward that end of the container.

Our analyses were based on the following simplifying assumptions: (1) Input values were assumed to be zero (not detectable), which probably resulted in overestimation of outputs attributable to the facility in some cases. (2) Changes (eg, settling out of NFR) as the cleaning effluent passes along the discharge pathway were ignored. Again, this is likely to overestimate the overall hatchery outputs. (3) Differences in self-cleaning efficencies were noted on a subjective basis only.

RESULTS AND DISCUSSION

CHARACTERIZATION OF CLEANING TECHNIQUES AND NFR CONCENTRATIONS

Fish culture and effluent sampling data are compiled in Appendix 2 for each cleaning event sampled.

Flush Method

Flushing of rearing containers is restricted mainly to smaller-sized rearing containers; Underwood and McLellan (1979b) did provide data on the flushing of a large earthen channel at the Big Qualicum facility, where incremental NFR levels ranged 3-65 mg/L. Water flow and velocity are increased by removal of the standpipes or stoplogs, causing suspension and scouring of the settled material. Manual sweeping of the floor from the head end of the container to the outlet aids in removal of the settled material. The discharge outlet screen collects material between and during cleanings. This is scrubbed clean at the end of the sweeping. The standpipe or stoplogs then are replaced, and the container allowed to refill.

Capilano Troughs: The Capilano trough is the standard early rearing container used at SEP hatcheries (Fig. 1). Some facilities clean these troughs with a siphon (generally the lower third of the trough), or use 3-4 baffles at 1.5 m intervals for continuous cleaning. However, troughs are routinely cleaned on a daily basis using the flush method. The standpipe is pulled, and the accumulated wastes are brushed from the sides and bottom of the trough, down to the outlet screen. Although unusually dirty outlet screens are brushed clean before beginning general trough cleaning (this was not sampled), normally the outlet screen is cleaned last. The operator then waits approximately 30 s for the water level to drop to the shoulders of the trough (seen as the 'limit of comfort' for the fish) and replaces the standpipe. On average, it took less than 2 min overall for the operators to clean a trough to the point of standpipe replacement. At an inflow rate of 240 LPM, the effluent flow then is stopped for about 3-4 min until the trough refills to the point of overtopping the standpipe or the spillway at the rear. By the time that effluent flows resume, the majority of the remaining suspended solids have resettled and NFR levels presumably have returned to background levels (initial sampling showed NFR to be non-detectable unless the effluent was visibly cloudy; thereafter, NFR samples were taken only where cloudiness was noted).

The troughs are generally arranged in lines of two to allow water reuse (Fig. 1). The operator normally cleans all the upper 'A' troughs first, which allows time for the upper troughs to refill and resume spilling flows into the lower 'B' troughs. The 'B' troughs are not cleaned until flow is re-established. Discharge during cleaning is via separate standpipes, so that cleaning wastes from the 'A' trough are not passed to the 'B' trough (flow to the 'B' trough is interrupted during cleaning of the 'A' trough, however). The 'B' troughs might have greater waste accumulations, due to food and wastes being swept downstream from the 'A' trough. Tests done on trough pairs (Table 6) indicated no such difference, so the results from 'A' and 'B' troughs were pooled in analysis.

NFR levels in the grab samples (Table 7A) varied from < 5 mg/L to 185 mg/L, and were 27 mg/L on average (sample n=55, taken during 20 trough cleanings at six facilities). Adjusting the NFR values to reflect the biomass of fish present (Table 7B), the numbers translate to an average of 2.1 and a maximum of 26.0 mg/L per kilogram of fish; note that the maximum comes from a different sample when fish biomass is considered. Most of the troughs sampled were lightly loaded. Biomass averaged 50 kg/trough, which was less than half of the recommended maximum loading of 115 kg/trough (Shepherd 1984), and went as low as 6 kg/trough. However, some troughs sampled also exceeded the recommended biomass by up to 35% (Table 7A).

The general NFR pattern seen in flush cleaning of Capilano troughs is outlined in Fig. 2. When unusually dirty outlet screens are brushed clean at the outset of cleaning, a brief NFR spike may occur. Over the first 45 s of cleaning, NFR levels rise and can achieve maximum levels in some cases; more often, NFR levels continue to rise to a maximum over the first 90 s, normally peaking with the cleaning of the outlet screen at about the 60 s point. Thereafter, NFR levels should decline quickly to the point of standpipe replacement, and probably will be at ambient levels by the time that standpipe flows resume.

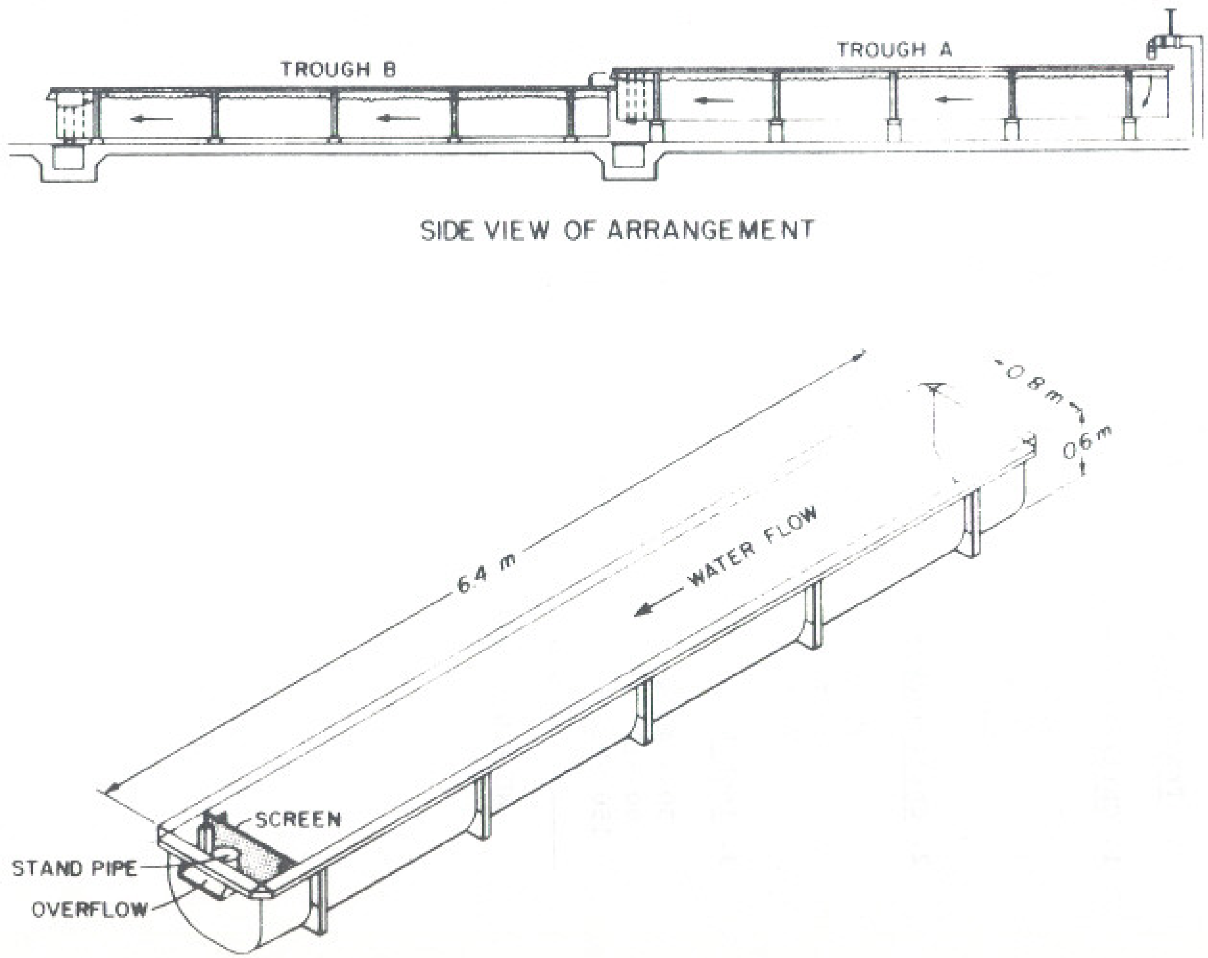

Figure 1 Capilano Style Rearing Trough

Table 6. Comparison of NFR levels generated from 'A' and 'B' Capilano troughs (sample size was too small for statistically-valid conclusions).

Trough Pair	(mg/L/kg) 'A'	'B'
1. Chilliwack #16		
30 s	12.4	4.5
60 s	9.0	2.3
90 s	4.1	0.4
2. Chilliwack #17		
30 s	8.9	ND
60 s	11.2	0.3
90 s	1.0	0.8
3. Inch #5		
30 - 40 s	ND	ND
90 -120 s	0.5	0.4
150 -200 s	ND	0.6

ND = Not Detectable

Table 7. NFR production from Capilano troughs during flush cleaning, at various facilities.

A. NFR LEVELS IN GRAB SAMPLES:

Facility	Trough No.	kg of Fish	Species[c] (g)	NFR in mg/L[a] 0 s	30 s	45 s	60 s	65 s	75 s	90 s	95 s	105 s	115 s	120 s	125 + s[b]	Normal Min to Clean
Capilano	4A	123	CN (2.0)	ND[d]	85	-	ND	-	-	-	-	-	-	ND	-	2.0
	8B	130	CO (1.8)	42	ND	-	-	14	-	-	-	-	-	-	-	1.5
	10A	93	CN (1.5)	ND	ND	-	-	-	-	-	-	-	-	ND	-	2.0
Chilliwack	15B	25	ST (0.5)	ND	22	-	96	-	-	-	-	45	-	-	-	1-3
	16A	15	ST (0.3)	ND	185	-	134	-	-	-	61	-	-	-	-	1-3
	16B	14	ST (0.3)	ND	64	-	32	-	-	6	-	-	14	-	-	1-3
	17A[e]	14	ST (0.3)	24	124	-	157	-	-	-	-	-	-	-	-	1-3
	17B	18	ST (0.5)	ND	ND	-	5	-	-	-	-	15	-	-	-	1-3
Inch	2B	28	CO (1.0)	ND	-	ND	-	-	-	-	-	-	-	22	6 (180 s)	3.0
	5A	48	CO (1.2)	18	ND	-	-	-	-	24	-	-	-	-	ND (150 s)	2.5
	5B	35	CO (0.8)	ND	-	ND	-	-	-	-	-	-	-	13	21 (200 s)	3.5
Puntledge	7	6	ST (0.3)	ND	ND	-	-	-	143	-	-	9	-	-	-	2.0
	9	6	ST (0.3)	ND	-	ND	-	-	9	-	-	-	-	9	-	2.0
	11	6	ST (0.3)	ND	ND	-	-	-	107	-	-	-	-	-	ND (125 s)	2.0
Shuswap	1	155	CN (6.0)	ND	-	-	ND	-	-	-	-	-	-	ND	ND (180,240 s)	3-5
	2	138	CN (5.2)	ND	-	-	-	-	-	-	-	-	-	ND	ND (180,240 s)	3-5
	3	55	CN (3.8)	ND	-	-	79	-	-	-	-	-	-	10	ND (180,300 s)	3-5
Tenderfoot	3A	48	CO (1.1)	ND	ND	-	ND	-	-	-	-	-	-	-	-	1.0
	4A	30	CO (0.7)	ND	8	-	ND	-	-	-	-	-	-	-	-	1.0
	5A	21	CO (0.5)	19	15	-	-	7	-	-	-	-	-	-	-	1.0

[a] See Appendix 2 for sampling details

[b] Actual sampling time given in brackets for 125+ category

[c] CN = Chinook; CO = Coho; ST = Steelhead

[d] ND = Not Detectable (<5 mg/L)

[e] Square trough

(Table 7 cont'd)

B. NFR LEVELS ADJUSTED FOR FISH BIOMASS:

Facility	Trough No.	kg of Fish	Species (g)	NFR in mg/L per kg of fish 0 s	30 s	45 s	60 s	65 s	75 s	90 s	95 s	105 s	115 s	120 s	125+ s	Total L in Flush
Capilano	4A	123	CN (2.0)	ND	0.7	-	ND	-	-	-	-	-	-	ND	-	1108
	8B	130	CO (1.8)	0.3	ND	-	-	-	0.1	-	-	-	-	-	-	956
	10A	93	CN (1.5)	ND	ND	-	-	-	-	-	-	-	-	ND		1472
Chilliwack	15B	25	ST (0.5)	ND	0.9	-	3.9	-	-	-	-	1.8	-	-	-	2976
	16A	15	ST (0.3)	ND	12.4	-	9.0	-	-	-	4.1	-	-	-		2452
	16B	14	ST (0.3)	ND	4.5	-	2.3	-	-	0.4	-	-	-	-		1661
	17A	14	ST (0.3)	1.7	8.9	-	11.2	-	-	-	-	-	1.0	-		2560
	17B	18	ST (0.5)	ND	ND	-	0.3	-	-	-	-	0.8	-	-	-	2710
Inch	2B	28	CO (1.0)	0.4	ND	-	-	-	-	0.5	-	-	-	-	ND	2778
	5A	48	CO (1.2)	ND	-	ND	-	-	-	-	-	-	-	0.4	0.6	2310
	5B	35	CO (0.8)	ND	-	ND	-	-	-	-	-	-	-	0.8	0.2	2635
Puntledge	7	6	ST (0.3)	ND	ND	-	-	-	26.0	-	-	1.6	-	-		1780
	9	6	ST (0.3)	ND	-	ND	-	-	1.6	-	-	-	-	1.6		1716
	11	6	ST (0.3)	ND	ND	-	-	-	19.5	-	-	-	-	-	ND	1812
Shuswap	1	155	CN (6.0)	ND	-	-	ND	-	-	-	-	-	-	ND	ND (2)	2172
	2	138	CN (5.2)	ND	-	-	-	-	-	-	-	-	-	ND	ND (2)	2000
	3	55	CN (3.8)	ND	-	-	1.4	-	-	-	-	-	-	0.2	ND (2)	2935
Tenderfoot	3A	48	CO (1.1)	ND	ND	-	ND	-	-	-	-	-	-	-	-	1500
	4A	30	CO (0.7)	ND	0.3	ND	ND	-	-	-	-	-	-	-	-	1130
	5A	21	CO (0.5)	0.9	0.7	-	-	0.3	-	-	-	-	-	-	-	1180

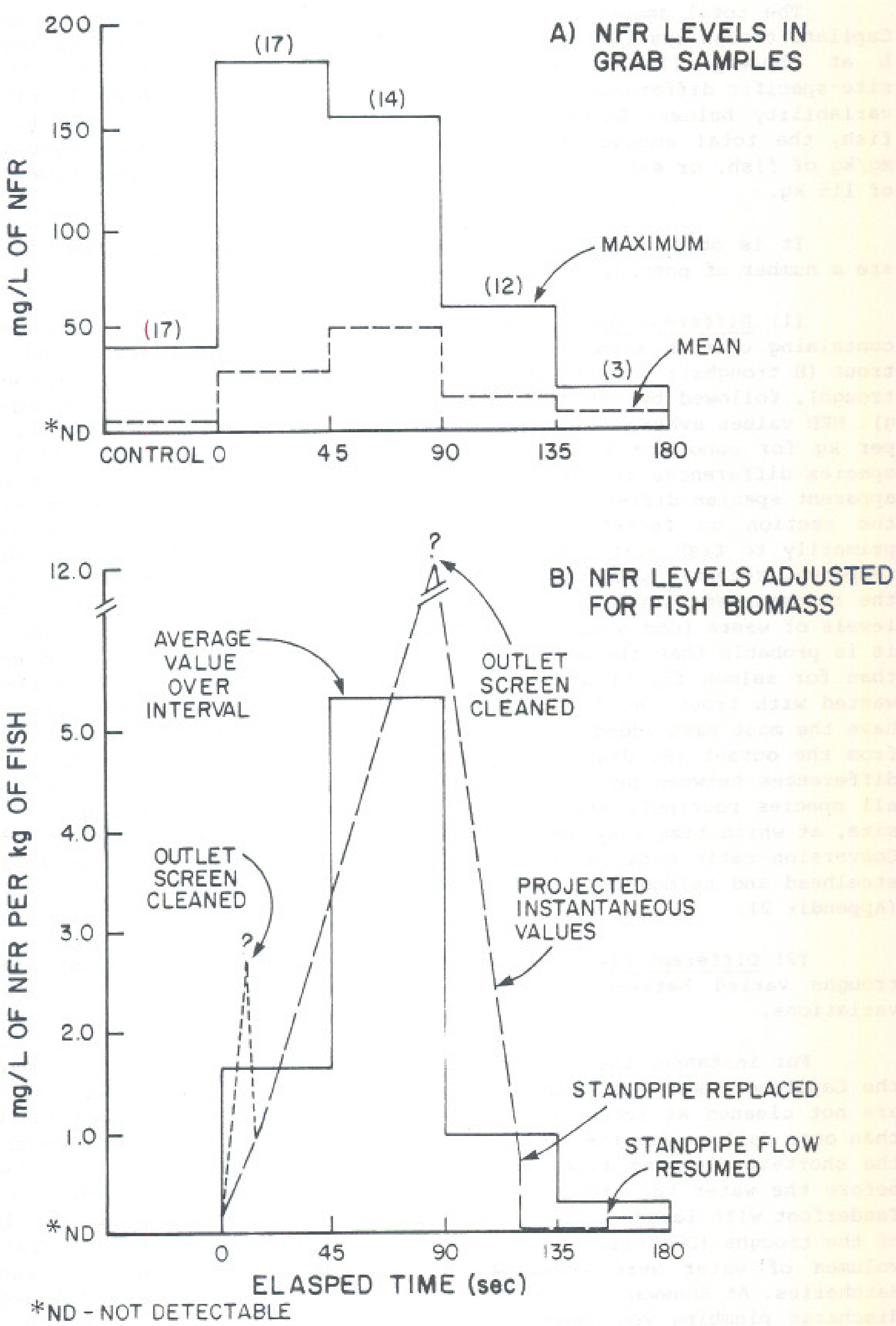

Figure 2 Generalized NFR patterns during flush cleaning of Capilano troughs

The total amount of water involved in the average flush cleaning of a Capilano trough was 1992 L, but the range varied from 956 L at Capilano to 2935 L at Shuswap (Table 7B). Such variation probably is due largely to site-specific differences in cleaning techniques (see the general discussion on variability below). Given an average NFR level of 2.1 mg/L per kilogram of fish, the total amount of NFR generated in cleaning a trough would be 4183 mg/kg of fish, or 481 g from a trough loaded to the recommended biomass maximum of 115 kg.

It is obvious from the above results that variability was high. There are a number of possible reasons for such variability:

(1) Different Species and Size of Fish. Sampling was done on troughs containing chinook salmon (5 troughs), coho salmon (7 troughs) and steelhead trout (8 troughs); chinook were the largest (range 1.5-6.0 g average weight per trough), followed by coho (range 0.5-1.8 g) and then steelhead (range 0.3-0.5 g). NFR values averaged by species were 0.1 mg/L per kg for chinook, 0.2 mg/L per kg for coho and 3.5 mg/L per kg for steelhead. Although there may be species differences in the level of waste generation (it was noted that were apparent species differences in the physical appearance of fecal material; see the section on feces), it is more likely that these differences relate primarily to fish size. To promote the rapid development of a strong feeding response, recently-ponded 0.3-0.5 g fry often are given in excess of 100% of the recommended ration on a continuous basis throughout the day. Thus higher levels of waste food would be expected at this time for all species. However, it is probable that the waste generated by the trout species would be greater than for salmon fry of a similar size. This is because more food tends to be wasted with trout (W. Foye, Inch Creek Hatchery, pers. comm.) and steelhead have the most mash added to the diet, while chinook fry are given 1/32 pellets from the outset (R. Stanton, Capilano River Hatchery, pers. comm.). No major differences between species are projected beyond the start-feeding period, as all species routinely are fed 100% of the recommended ration up to the 1-2 g size, at which time they are transferred to other types of rearing containers. Conversion ratio data collected during sampling reinforce the above argument; steelhead and salmon food conversion ratios averaged 1.9 and 1.1 respectively (Appendix 2).

(2) Different Cleaning Techniques. The techniques for flush cleaning of troughs varied between facilities sufficiently to account for some major variations.

For instance, the volumes of water involved in flushing were smallest at the Capilano River and Tenderfoot Creek Hatcheries. At Capilano, the troughs are not cleaned as intensively each time, but they are cleaned twice rather than once daily; also the troughs are smaller than most others. Tenderfoot had the shortest cleaning times (1 min) because the standpipe was replaced well before the water had dropped to the trough shoulders; this often is done at Tenderfoot with larger coho, as most of the wastes settle out at the lower end of the troughs (D. Celli, Tenderfoot Creek Hatchery, pers. comm.). The greatest volumes of water were measured at the Shuswap River and Chilliwack River Hatcheries. At Shuswap, normal flushing procedures could not be followed as the discharge plumbing was undersized, causing the trough floor area to flood if the standpipe was pulled completely. Therefore, the standpipe was only partially pulled (angled over the outlet) and cleaning took longer. At

Chilliwack, there were no obvious reasons for the high and variable volume; it may be that some of the troughs were unusually dirty compared to others, and thus took longer to clean.

Highest values of NFR were seen at the Chilliwack River and Puntledge River Hatcheries, which had the lowest fish loads; this probably was because both facilities were rearing 0.3 g steelhead trout fry. Conversely, the most heavily loaded troughs, which were at Capilano and Shuswap, had low NFR levels. At Capilano, this probably was the result of the more frequent but less thorough cleaning procedure (lids were not lifted). At Shuswap, cleaning was unusually prolonged, and the fish were much larger than what would be normally held in this type of trough.

Atnarko Incubation Boxes Converted to Raceways: These units (Fig. 3) are unique to the Tenderfoot Hatchery, although they had been used previously at the Inch Hatchery. Each unit was made up from modular fiberglass sections bolted together (four main sections and two shorter end sections) originally used as incubation boxes. The units are larger than Capilano troughs, and would be closer in size and flows to the Large Starter Units now in use at other facilities (Table 8).

Table 8. Dimensions (m) and maximum flows for various rearing units.

Unit Type	Length	Width	Wall Height	Water Depth	Usable Vol (m^3)	Flows (LPM)
Capilano Trough	6.4	0.8	0.6	0.5	2.3	240
Atnarko Box	6.3	1.1	1.7	1.3	8.6	400
Large Starter	13.0	1.2	1.2	0.8	11.5	480
Chamber Raceways	11.0	4.9	0.9	0.7	36.0	1500

The method of cleaning was similar to that used for Capilano troughs, except a dip net was used instead of a broom to gently move the bottom wastes towards the outlet. Total time involved in the cleaning cycle was about 5 min; the screens were scrubbed 1-3 min after the start of cleaning and the standpipe was replaced after 4 min.

NFR levels in the grab samples (Table 9A) ranged from the non-detectable level to 83 mg/L, and averaged 23 mg/L (n=8, taken during two raceway cleanings at the one facility). Adjusted for biomass, these values translate to a respective average and maximum of 0.08 and 0.3 mg/L per kg of fish (Table 9B). These are much lower levels than found for Capilano troughs. Although the Atnarko-box units were loaded to densities in excess of the recommended maximum according to the 'LOAD RATE' program (see Shepherd 1984), they were less heavily loaded than Capilano troughs and had larger fish than normally carried in Capilano troughs (Table 10).

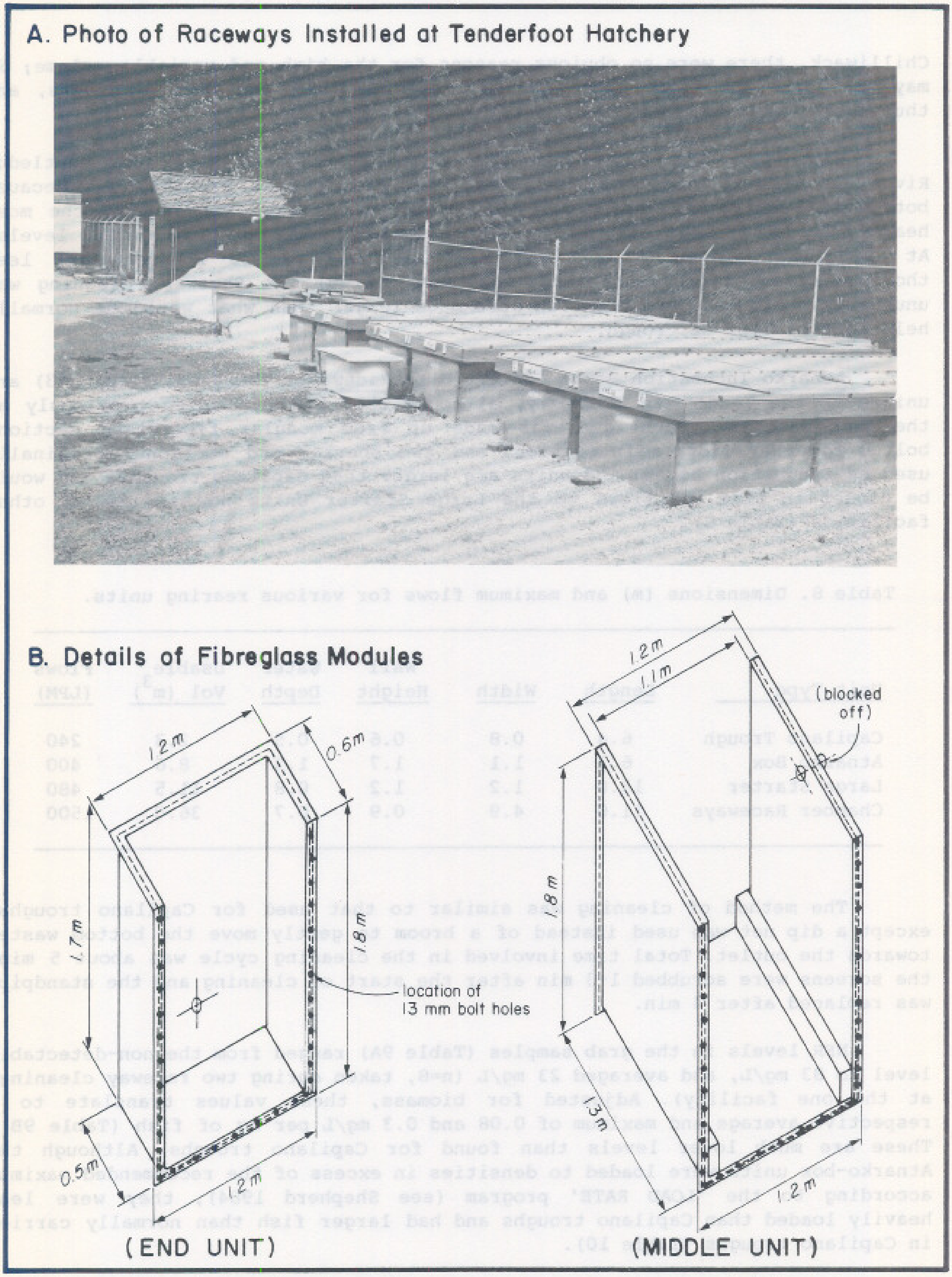

Figure 3 Atnarko-box Raceway (photo taken by A.Moore)

Table 9. NFR production from Atnarko-box raceways at Tenderfoot Hatchery, and from biofilter chamber raceways at Capilano Hatchery.

Facility	Unit No.	kg of Fish	Species (g)	Normal Min to Clean	Total L in Flush	0 s	30 s	60 s	120 s	150 s	180 s	240 s
A. NFR LEVELS IN GRAB SAMPLES:						(NFR in mg/L)[a]						
Tenderfoot	1	303	CN[b] (5.5)	5.0	4744	ND[c]	ND	42	-	ND	-	ND
	3	300	CN (4.9)	5.0	4572	ND	-	ND	56	-	83	ND
Capilano	10B	200	CN (4.1)	1.5	12654	212	10	15	-	-	-	-
	10C	233	CN (4.7)	3.0	NA[c]	ND	-	-	136	-	16	-
	10D	260	CN (5.3)	4.0	NA	NA	-	-	73	-	-	15
B. NFR LEVELS ADJUSTED FOR FISH BIOMASS:						(NFR in mg/L per kg of Fish)						
Tenderfoot	1	(as in Section A)				ND	ND	0.1	-	ND	-	ND
	3					ND	-	ND	0.2	-	0.3	ND
Capilano	10B	(as in Section A)				1.1	0.1	0.1	-	-	-	-
	10C					ND	-	-	0.6	-	0.1	-
	10D					ND	-	-	0.3	-	-	0.1

Table 11. NFR production using a 'creeper-sweeper' baffle in Capilano troughs

Facility	Unit No.	kg of Fish	Species (g)	Min to Clean	Total L in Cycle	0 s	150 s	240 s	360 s	450 s	520 s	540 s	660 s
A. NFR LEVELS IN GRAB SAMPLES:						(NFR in mg/L)							
Tenderfoot	1A	28	CO (0.8)	8.7	2682 (988)[d]	27	ND	8	-	ND	ND	-	-
	2A	32	CO (0.7)	11.0	3546 (1566)	ND	10	-	ND	-	-	ND	ND
B. NFR LEVELS ADJUSTED FOR FISH BIOMASS:						(NFR in mg/L per kg of Fish)							
Tenderfoot	1A	(as in Section A)				1.0	ND	0.3	-	ND	ND	-	-
	2A					ND	0.3	-	ND	-	-	ND	ND

[a] See Appendix 2 for sampling details

[b] CN = Chinook; CO = Coho

[c] ND = Not Detectable (<5 mg/L); NA = Not Available

[d] Volumes in brackets refer to L involved in flush only

Table 10. Actual Atnarko-box biomass loadings compared to recommended levels.

Unit Type	Volume Loading kg/m	Flow Loading kg/LPM
Atnarko-box Unit	35	1.3
General for Raceways ('LOAD RATE')	16	1.1
Capilano Trough	50	2.1
(normally not taken beyond 2 g at this density)		

The general NFR pattern seen in flush cleaning of the Atnarko-box raceways was different from that seen for Capilano troughs. There was little visible cloudiness until the sludge was pushed to the outlet screen. NFR levels rose and fell quickly as the wastes were pushed and brushed through the screen to the drain. As with Capilano troughs, NFR had returned to ambient levels by the time discharge resumed through the standpipe.

The total volume of water involved in flush cleaning of the Atnarko-box raceway was around 4600 L. This was twice the amount for the average Capilano trough, but only half the amount if equivalent volumes are considered (the Atnarko-box raceway volume is almost four times that of a Capilano trough). Given the average NFR level of 0.08 mg/L per kg of fish, the total amount of NFR generated in cleaning these units was only 3.68 mg/kg of fish, almost one-tenth of the amount calculated for Capilano troughs. As only two Atnarko-box units were sampled, the degree of variability cannot be assessed.

Biofilter Chambers Converted to Raceways: When the Capilano Hatchery was constructed in the early 1970s, gravel-filled biofilters were installed below the Burrows ponds, to avoid possible pollution of the Capilano River. These biofilters proved to be unnecessary, and the chambers were converted into rearing containers in 1984. Each chamber contains four small raceways (Table 8). Each raceway can be supplied with up to 1500 LPM of water taken from the Capilano reservoir. In addition, about 250 LPM of heated groundwater exiting the Capilano troughs and Burrows ponds above ground can be re-used[a] in each chamber raceway. At the time of sampling in early June, each chamber raceway probably was receiving about 280 LPM; 180 LPM of this amount would have been re-used water.

Channel cleaning was done weekly by raising the stoplogs about 10 cm off the bottom, sweeping down only the lower one-third of the channel, scrubbing the outlet screen, and replacing the stoplogs. Normally the entire process took 1-2 min, and is seen as a strongly-pulsed event. Because sample bottles could not be filled that rapidly, cleaning was deliberately prolonged to 3-4 min in two of the three samplings.

[a] Cleaning flows from the Capilano trough are plumbed directly to the release chamber.

Perhaps because the effluent exiting these raceways was turbulently aerated by dropping into an open release channel, the discharge had a strong, unpleasant odor. NFR levels in the grab samples (Table 9A) averaged 44 mg/L and went as high as 136 mg/L, (n=6, taken during three raceway cleanings at the one facility). In addition, one control sample was 212 mg/L. The reason for such a high control sample value, followed by relatively low values during cleaning, is unknown; it is possible that a large clump of waste could have been accidentally dislodged and sampled, as it was impossible to see the sampling point within the falling water. Adjusting the NFR values for fish biomass, average and maximum values are 0.2 and 0.6 mg/L per kg of fish. These units were loaded at 5.5-7.2 kg/m^3 and 0.7-0.9 kg/LPM, which was considerably lower than the recommended maximum volume loading of 14.9-15.7 kg/m^3, but slightly exceeded the recommend maximum flow loading of 0.7 kg/LPM (by 'LOAD RATE'; see Shepherd 1984).

Only one cleaning test was run as rapidly as normal. The calculated volume of water involved in that test was 12,654 L. At an average NFR level of 0.2 mg/L, the total amount of NFR discharged was 2531 mg/kg of fish. This is equivalent to 362 mg/kg of fish on a daily basis, which is very similar to the 368 mg/kg daily value calculated for chinook of the same size in Atnarko-box raceways (see the previous section).

Insufficient testing was done to assess the degree of variability between raceways of this type.

Baffle Method

As previously mentioned, some facilities have installed 3-4 fixed baffles in their Capilano troughs to provide a continuous sweeping action. Wastes are concentrated in smaller areas of the troughs, and are brushed or siphoned out at regular intervals. Another method employs a single moving baffle, called a 'creeper-sweeper' (Fig. 4). The creeper-sweeper was developed by Kitimat River Hatchery staff, and is being tried at other facilities such as Eagle River Hatchery. The creeper-sweeper is placed at the top end of the trough, and water pressure pushes it along the trough. Gaps of 1 cm between the creeper-sweeper and the trough bottom create a sweeping velocity along the bottom. Wastes and fish thus are moved slowly downstream. In general, little material has been observed to be lofted into the water column as the baffle travels down the trough. Because of the downstream position of the support arm, the creeper-sweeper stops short of the outlet screen. The standpipe then is pulled and the accumulated waste brushed through the screen. The entire process took 9-11 min, 7-8 min of which was baffle travel time, when it was tested at Tenderfoot Creek Hatchery; this time was longer than actually necessary because of a panic response by the fish, which were not used to the unit. As the creeper-sweeper crowded the fish into the bottom half of the trough, some fish tried to force their way past the unit's neoprene edges and became wedged between the creeper-sweeper and the trough sides, jamming the unit and injuring the fish. This problem has not been observed at Kitimat, where the fish are exposed to the creeper-sweeper early in rearing and where ambient light levels are much lower (troughs are inside a building at Kitimat, outside at Tenderfoot), resulting in less skittish behavior.

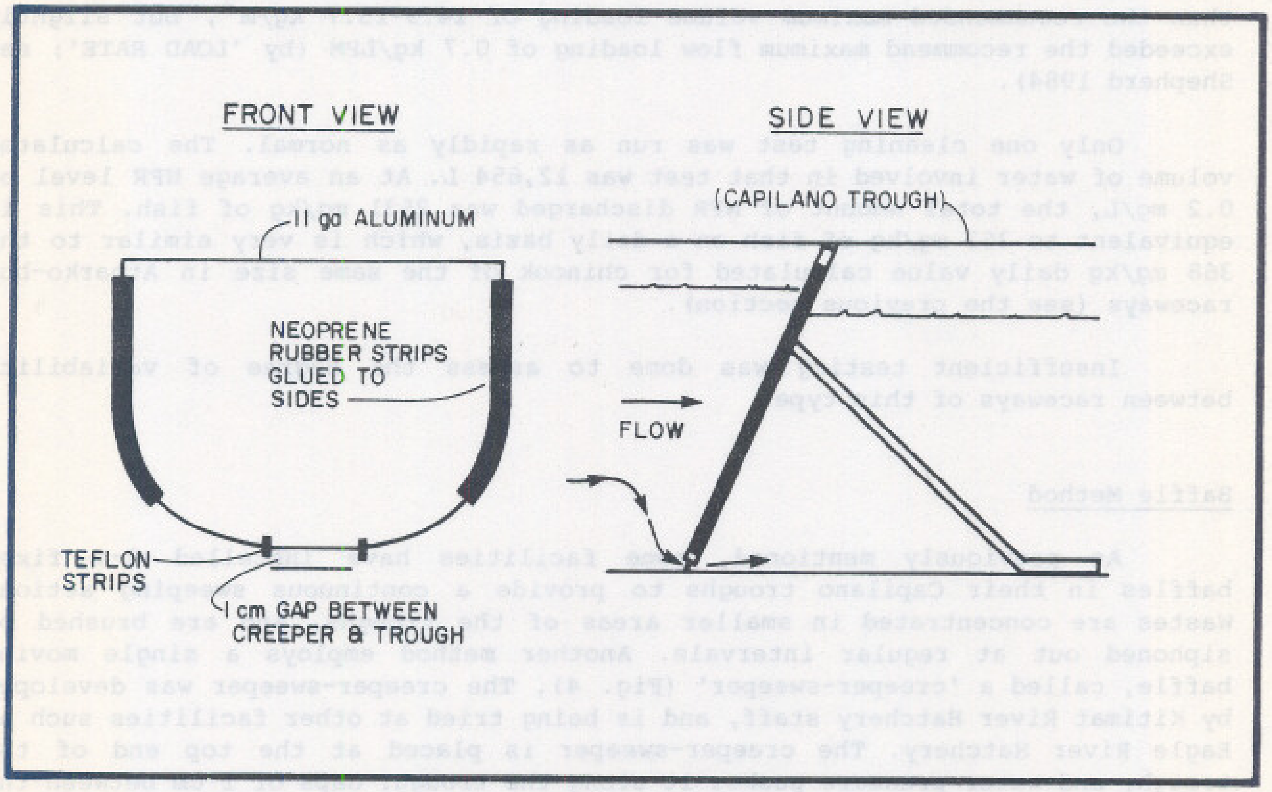

Figure 4 Kitimat Creeper Sweeper (Abraham et al, MS 1985)

NFR levels in most of the grab samples (Table 11A) were below detectable levels; there were two detectable values of 8 and 10 mg/L in samples taken when the creeper-sweeper was only a third of the way down the trough. There is no good explanation for these results, or for the high values of 27 mg/L obtained in one of the control samples; the fish did not panic--which could have stirred up material--until the creeper-sweeper was past the halfway point in the trough. In general, though, the troughs at Tenderfoot were cleaner than at many of the other facilities. Adjusted for fish biomass, the average and maximum values were lower at 0.1 and 0.3 mg/L per kg of fish for the creeper-sweeper method, as compared to the respective values of 0.2 and 0.7 mg/L for the normal flush method at the same facility, with the same species and approximately the same size and biomass of fish (Table 7B). If the total volumes of water involved in the cleaning cycles are considered, the creeper-sweeper method took more water at around 3100 L (the flush at the end accounted for about 1300 L of this) versus respective averages of around 1300 and 2000 L for the flush method at Tenderfoot and at all facilities combined. In terms of the total amounts of NFR generated in cleaning a trough, values for the creeper-sweeper versus the manual flushing method at Tenderfoot and at all facilities combined are calculated to be 310, 260, and 4183 mg/kg of fish respectively. Thus the amount of waste generated at Tenderfoot was similar, or even slightly greater for the creeper-sweeper as compared to manual flushing, but Tenderfoot troughs were in general far cleaner than those at other facilities. Due to the small sample size (creeper-sweeper testing was discontinued to avoid stressing the fish further) the statistical significance of these results was not addressed.

A larger, floating version of the creeper-sweeper was tried on raceways (21.0 m L x 1.8 m W x 1.0 m D) at the Eagle River Hatchery. Because of mortality resulting from fish becoming jammed between the raceway walls and the creeper-sweeper, testing was discontinued. However, the method remains attractive from the manpower perspective, and modified units probably will be tried again in the future. Should such units come into more common use, further water quality sampling should be done.

The Michigan Department of Natural Resources uses fixed baffles in raceways (Boersen and Westers, 1986). There were no units with fixed baffles in operation during sampling at SEP facilities. This type of unit should be tested, but it is anticipated that NFR levels and patterns would be similar to those described above. It seems that wastes are swept into piles, rather than suspended and discharged (Boersen and Westers, 1986).

<u>Vacuum Method</u>

Larger-sized rearing containers normally are vacuumed. Water flows through the container are reduced only slightly by the minor amount of water removed by the pump. There are no major changes in water heights during this procedure. Because of the low water turnover rate in the larger containers, sludge accumulates in thick mats along the bottom. Vacuuming is done twice weekly to monthly, depending on the site. A vacuum head similar to those used in cleaning swimming pools (see Peel, 1982) is connected with hoses to a small water pump. Vacuuming is done end to end or in sections, and the pump discharge can be routed to various locations away from the rearing container (eg, onto surrounding grass or bush, into an infiltration basin, or directly into an outlet channel).

As mentioned previously, some facilities clean their Capilano troughs using a siphon. Unfortunately, no facilities were using this process at the time of this study. However, this process would be akin to the vacuum method, but considerably reduced in volume.

Concrete Raceways: Concrete raceways do not have the same dimensions (Table 12) nor were cleaning methods similar at all sites sampled. This made characterization of their cleaning effluents even more difficult.

NFR levels, taken as near to the vacuum discharge hose exit as possible, varied from non-detectable up to 12,800 mg/L (Table 13A). The average value was 978 mg/L (n=57 taken from 14 units at six facilites). Correcting for fish biomass, values still ranged from non-detectable to 6.6 mg/L per kilogram of fish (Table 13B). The average of 1.1 mg/L per kilogram of fish is slightly less than for Capilano troughs (2.1 mg/L per kilogram of fish), despite the frequency of cleaning being much less (weekly for raceways versus daily for troughs).

The major reason for such variability has to do with the patchy distribution of settled wastes on the container bottoms. The general NFR pattern in the vacuum discharges is one of intermittent slugs of waste, separated by stretches of relatively clear discharge. Even within a 5 min interval, NFR levels varied up to two orders of magnitude.

There are other potential factors contributing to this variability, including the degree to which these differently shaped and sized containers are self-cleaning, pumping rates, and different cleaning and fish culture techniques (Table 14). The values at Robertson are high because they were single samples taken at the visual peak of turbidity. There is some indication that different species or larger fish may generate lower waste levels (Table 15). However, all samples for the large coho came from the Tenderfoot facility, which seemed to be unusually clean (see the Flush Method section).

Boerson and Westers (1986) noted levels of 10-20 mg/L in raceway discharges during vacuuming of wastes from settling areas at the downstream ends of raceways in Michigan. At SEP facilities,, vacuuming began at the upstream ends of containers and care was taken to avoid re-suspension of settled wastes within the container. In the few cases where re-suspension of wastes was noted and sampled,[a] levels in the immediate area of the disturbance were elevated (Table 16); the maximum sample value was 310 mg/L, or 3.2 mg/L per kilogram of fish. NFR levels declined rapidly downstream where hose discharges mixed with outflows from other rearing containers. Vacuuming took

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[a] Eagle hatchery staff noted that sludge was re-suspended more easily during vacuuming of the smaller (21400 mm L x 1820 mm W x 750 mm D) modular aluminum raceways. Also coho tended to aggregate around the vacuum head, possibly seeking the cover offered by the turbidity, which aggravated re-suspension. Unfortunately, most of the samples taken at Eagle were lost, and the few remaining samples were not considered representative of normal cleaning procedures.

Table 12. Dimensions (cm) of the raceways and channels that were sampled at various SEP facilities.

Facility	Length	Width	Water Depth
Big Qualicum	7620	427	122
Chehalis	3310	400	180
Chilliwack (earthen channel)	25298	448	137
Conuma	2680	700	97
Eagle	3240	300	111-122
Inch	3000	300	66
Nitinat	2100	400	910
Puntledge	7315	457	152
Robertson	4420	610	122
Tenderfoot (concrete channel)	5000	400	100

Table 13. NFR levels (mg/L) in vacuum effluents from concrete raceways and channels, as measured at various SEP facilities.

A. NFR LEVELS IN GRAB SAMPLES:

Facility	Unit No.	kg of Fish	Species (g)	Sampling Time in Minutes									Avg	(n)
				0	1-5	6-10	11-15	16-30	31-45	46-60	61-75	76-90+		
				(NFR in mg/L)										
Chehalis	2C	463	CN (2.4)	ND	–	799	–	1200	45	560 778	335	676 508	613	(8)
	2D	226	CN (2.4)	–	–	775	399	572	–	292	326	674	506	(6)
Conuma	1	276	CO (2.3)	–	335 334	239	–	209	ND 308	67	108	246 11	188	(10)
Inch	3	77	CO (2.4)	198[a]	34	11	–	–	–	–	–	–	23	(2)
	4	49	CO (2.1)	–	116 ND	–	–	–	–	–	–	–	58	(2)
	5	98	CO (2.7)	–	75 620		–	–	–	–	–	–	232	(3)
Puntledge	1C	1874	CN (1.9)	ND	428	843 9	–	–	–	–	–	–	427	(3)
	2B	2032	CN (1.7)	–	255 2450 2160	811	1520	1040	–	–	–	–	1373	(6)
	2C	2032	CN (1.7)	ND	–	1620	–	4020	–	–	–	–	2820	(2)
Robertson	5B	1441	CN (2.5)	–	–	–	–	–	–	–	9520	–	9520	(1)
	6B	2898	CN (4.0)	–	12800	–	–	–	–	–	–	–	12800	(1)
Tenderfoot	1A	1935	CI (18.1)	ND	39	70 68	41 254 13	–	–	–	–	–	– 81	– (6)
	2AB	2000	CO (18.3)	ND	5890	–	–	315 235	172	92	–	–	1341	(5)
	2C	912	CO (17.0)	ND	232	–	196	–	–	–	–	–	214	(2)
											GRAND MEAN =		978	(56)

[a]Sample suspect (see Appendix 2).

(Table 13 cont'd).

B. NFR LEVELS ADJUSTED FOR FISH BIOMASS:

Facility	Unit No.	kg of Fish	Species (g)	Sampling Time in Minutes: 0	1-5	6-10	11-15	16-30	31-45	46-60	61-75	76-90+	Avg	(n)
				(NFR in mg/L per kg of Fish)										
Chehalis	2C	463	CN (2.4)	ND	-	1.7	-	2.6	0.1	1.2 1.7	0.7	1.5 1.1	1.3	(8)
	2D	226	CN (2.4)	-	-	3.4	1.8	2.5	-	1.3	1.4	3.0	2.2	(6)
Conuma	1	276	CO (2.3)	-	0.8 1.2	0.9	-	0.8	ND 1.1	0.2	0.4	0.9 0.04	0.6	(10)
Inch	3	77	CO (2.4)	1.2	0.4	0.1	-	-	-	-	-	-	0.3	(2)
	4	49	CO (2.1)	2.5[a]	2.4 ND	-	-	-	-	-	-	-	1.2	(2)
	5	98	CO (2.7)	-	0.8 6.3	ND	-	-	-	-	-	-	2.4	(3)
Puntledge	1C	1874	CN (1.9)	ND	0.3	0.4 0.005	-	-	-	-	-	-	0.2	(3)
	2B	2032	CN (1.7)	-	0.1 1.2 1.1	0.4	0.7	0.5	-	-	-	-	0.7	(6)
Robertson	2C	2032	CN (1.7)	ND	-	0.8	-	2.0	-	-	-	-	1.4	(2)
	5B	1441	CN (2.5)	-	-	-	-	-	-	-	6.6	-	6.6	(1)
	6B	2898	CN (4.0)	-	4.4	-	-	-	-	-	-	-	4.4	(1)
Tenderfoot	1A	1935	CO (18.1)	ND	0.03	0.04 0.04	0.02 0.13 0.01						0.05	(6)
	2AB	2000	CO (18.3)	ND	2.9	-	-	0.2 0.1	0.1	0.1	-	-	0.7	(5)
	2C	912	CO (17.0)	ND	0.3	-	0.2	-	-	-	-	-	0.3	(2)
												GRAND MEAN =	1.1	(56)

[a] Sample suspect (see Appendix 2).

Table 14. Summary of relevant details for vacuum cleaning of raceways and channels at various SEP facilities.

Facility	Pump Discharge (LPM)	Normal Min to Clean	Weekly Cleaning Frequency	Comments
Chehalis	91	90-120	once	-
Conuma	225	90	once	-
Inch	598	5-7	twice	(on 65% ration)
Puntledge	168	60-90	twice	-
Robertson	227	60-90	twice	-
Tenderfoot	340	15-20	once	-

Table 15. NFR levels grouped by species of fish.

Species	Size in g (Range)	Average mg/L/kg of Fish Range	n
Chinook	2.4 (1.7 - 4.0)	1.6 (0.2 - 6.6)	27
Coho	2.4 2.1 - 2.7)	1.0 (0.06 - 2.4)	17
	17.8 (17.0 - 18.3)	0.3 (0.05 - 0.7)	13

Table 16. NFR levels measured at various points within raceways and channels at various SEP facilities.

Facility	Unit No.	Grab Samples mg/L	mg/L per kg of Fish	Time (min)	Location Description/Comments
Conuma	1	12	0.04	7.5	- these samples taken during 90-min cleaning, downstream of hose discharge where effluent appeared completely mixed with the channel water.
		15	0.05	75	
		5	0.02	84	
Eagle	3	51	0.08	2	- during cleaning of outlet screen
		ND	ND	4-12	- total of 4 samples (plus one at 2 min, above) taken at outlet of aluminum raceway.
Inch	3	17	0.22	7	- all 4 samples taken from disturbed area in pond near vacuum head.
		17	0.22	7	
	4	117	2.39	4	
	5	310	3.16	3	
Robertson	5B	ND	ND	2-63	- total of 8 samples, taken from an upwelling section downstream of hose discharge.
	6B	ND	ND	5-55	- total of 8 samples, taken as for 5B. Only 1 sampled had detectable NFR; this came from a section that had little self-cleaning ability, and thus the heaviest accumulation wastes.
		2150	0.74	37	

about 90 min and was done once or twice weekly (Table 14). Pump discharges varied from 90-600 LPM, averaging 285 LPM. With an average value of 1.1 mg/L per kg of fish in the hose discharge and ignoring the minor amount of re-suspended wastes, the 'average' raceway cleaning produced a total of 23.3 g of NFR per kilogram of fish.

Fish loadings during sampling at the various facilities were only one-quarter on average (range 6-100%) of the maxima recommended using the 'LOAD RATE' program (Table 17). The heaviest loadings sampled had the highest NFR production per kilogram of fish; the two Robertson Creek raceways, loaded at 50% and 100% of maximum, produced 6.6 and 4.4 mg/L per kilogram of fish respectively (Table 13B). However, the relationship is not consistent. The next heaviest loadings (Tenderfoot) produced the lowest overall NFR values, and the next highest NFRs came from facilities with the lightest loadings (Chehalis and Inch). Thus it seems unlikely that the increasing fish density increases the rate (ie, per kilogram of fish) of waste generation, but more sampling would be required to confirm this. If these raceways were loaded to the maximum as defined by the 'LOAD RATE' program, and if the rate of NFR production remains constant, the 'average' raceway cleaning could produce around 90 g of NFR per kilogram of fish in the vacuum effluent.

Burrows Ponds: These units are supposed to be largely self-cleaning (see Burrows and Chenoweth 1970, for a detailed description), but wastes do accumulate on the bottom. McLean (MS 1978) estimated that 85% of suspended solids were discharged from the Quinsam ponds during normal operations. Vacuuming of Burrows ponds was monitored in our study at the Big Qualicum and Quinsam Hatcheries. Although the Big Qualicum ponds did not use turning vanes at the corners and were shorter (15 m versus 23 m) than those at Quinsam, channel widths and depths were the same (2.4 and 0.9 m respectively).

Waste accumulations were quite patchy, and the pond ends were cleaner than along the legs. Burrows ponds normally are spot-vacuumed weekly, but this depends on the amount of waste accumulation; vacuuming can take most of the day if accumulations are heavy, but only took around a half-hour in the three cleanings sampled. Vacuuming procedures were similar to those for raceways, save for difficulties in cleaning around the turning vanes.

NFR levels in the grab samples taken from the vacuum hose discharges (Table 18) once again reflected considerable variability, ranging from non-detectable up to 5000 mg/L and averaging 832 mg/L. Adjusting for biomass, values ranged from non-detectable up to 77 mg/L and averaged 12.7 mg/L per kilogram of fish (28 samples taken during three cleanings at two facilities). Even within the same 5 min interval, values could vary by more than an order of magnitude due to the patchiness of the waste accumulations. Highest levels of NFR tended to occur within the first 5 min, probably because the areas of heaviest accumulation were vacuumed first.

NFR levels were far higher at Quinsam (average of 1036 mg/L, or 16.1 mg/L per kilogram of fish) than at Big Qualicum (average of 80 mg/L, or 0.3 mg/L per kilogram of fish) for a number of reasons. First, differences in fish sizes were extreme, ranging from recently-ponded 0.6 - 0.7 g fry at Quinsam to 26 g smolts at Big Qualicum. As mentioned in previous sections, fry tend both to be fed more and to waste more food until they develop a strong feeding

Table 17. Comparison of actual load rates at SEP facilities during sampling, to recommended maximums as determined by the 'LOAD RATE' program.[a]

Facility	Unit	Sp	Size (g)	°C	Actual Flow Loading (kg/LMP)	'LOAD RATE' Maximum (kg/LPM)	Actual As % of Maximum
Chehalis	2C	CN	2.4	8.0	0.09	0.86	10
	2D	CN	2.4	8.0	0.05	0.86	6
Conuma	1	CO	2.3	9.0	0.17	0.74	23
Inch[b]	3	CO	2.4	6.5	0.80	1.21	7
	4	CO	2.1	6.5	0.22	1.17	19
	5	CO	2.7	6.5	0.14	1.24	11
Puntledge	1C	CN	1.9	8.0	0.12	0.82	15
	2B	CN	1.7	8.0	0.20	0.81	25
	2C	CN	1.7	8.0	0.20	0.81	25
Robertson	5B	CN	2.5	16.5	0.15	0.30	15
	6B	CN	4.0	16.5	0.32	0.32	100
Tenderfoot	1A	CO	18.1	7.5	0.53	1.67	32
	2AB	CO	18.3	7.5	0.53	1.67	33
	2C	CO	17.0	7.5	0.25	1.65	15

[a]The following assumptions were used:

input O_2 = 100%

output O_2 = Davis 'B' level (ranges from 5.9-7.0 mg/L D.O.)

ration level = 90% of maximum for CN and small CO
60% of maximum for large CO

metabolic correction rates = 1.35.

[b]65% ration used, both in actual and 'LOAD RATE' calculations.

Table 18. NFR levels in vacuum effluents from Burrows ponds at Big Qualicum and Quinsam Hatcheries. Numbers not bracketed are NFR in mg/L from grab samples; bracketed values are adjusted to mg/L per kilogram of fish.

Facility	Unit No.	kg of Fish	Species (g)	Time in Min from Start of Cleaning 0	1-5	6-10	11-15	16-20	21-25	25-30	31-35	Avg	(n)
Big Qualicum	3	286	CO (26)	ND[b] (ND)	- (-)	ND (ND)	445 (1.56)	ND (ND)	- (-)	11 (0.04)	26 (0.09)	80 (0.28)	(6)
Quinsam	13	63	CO (0.7)	-	1290 (20.5) 2050 (32.5) 950 (15.1)	548 (8.7) 350 (5.6)	316 (5.0) 594 (9.4)	70 (1.1) 222 (3.5)	325 (5.2) 279 (4.4)	-	-	636 (10.1)	(11)
	14	65	CO (0.6)	(-)	2300 (35.4) 5000 (76.9) 1520 (23.4)	475 (7.3) 130 (2.0) 638 (9.8) 2240 (34.5)	2940 (45.2) 315 (4.8)	186 (2.9) 76 (1.2)	-	-	-	1438 (22.1)	(11)
										GRAND MEAN	=	832 (12.7)	(28)

[a]CO = Coho

[b]ND = Not Detectable (< 5 mg/L).

response. Second, the degree to which Burrows ponds are self-cleaning is highly dependent on water velocities. At the time of sampling, the larger Quinsam ponds were being run at one-third the flow at Big Qualicum (681 LPM versus 1818 LPM); this would promote settling of wastes in the Quinsam pond. Third, different-size vacuum pumps could affect the results. The pumping rate at Big Qualicum was not measured directly, but was estimated at 225 LPM; the Quinsam pump ran at 109 LPM, which was smaller than most pumps used at several other facilities (see Table 14). Fourth, the Quinsam ponds had not been cleaned for 10 days, as opposed to the usual weekly pattern.

McLean (MS 1978) also sampled three vacuum cleanings of Burrows ponds at the Quinsam Hatchery during August when fish size was larger, probably 8 g. At that time, NFR samples averaged 0.1-0.2 mg/L per kilogram of fish (incremental values) which is in line with our Big Qualicum results.

Given a cleaning time of 30 min, a pumping rate of 109 LPM, and the highest NFR level measured of 1036 mg/L or 16.1 mg/L per kilogram of fish, the worst-case total NFR generated in vacuuming a Burrows pond is projected to be 3.4 kg, or 53 g per kilogram of fish.

Loading rates in all three cases were less than one-fifth of the recommended maximum using the 'LOAD RATE' program:

Facility	Actual kg/LPM	'LOAD RATE' Maximum kg/LPM	Actual As % of Max
Big Qualicum	0.16	0.84	19
Quinsam	0.09-0.10	0.53	17-19

If these Burrows ponds were loaded to these maximums, the total NFR generated in vacuuming would be projected to be about 18 kg.

NFR levels in vacuum discharges from Burrows ponds were similar to those from raceways. Comparing units containing large coho, NFR levels were 0.3 mg/L per kilogram of fish in both unit types. Comparing units carrying coho fry, NFR levels in fact were higher for Burrows ponds than raceways (16.1 versus 6.1 mg/L per kilogram of fish).

Comparing the estimated total weight of NFR contained in the vacuum effluent to calculated food conversion efficiency for the two Quinsam Burrows pond samplings, it would appear that less than 12-16% of the potential NFR production settled out in the Burrows ponds, indicating a high self-cleaning ability. However, settling rates were calculated to be even lower (7-9%) for raceways sampled at Conuma and Chehalis. Although the NFR results for the Burrows ponds may be atypically high for the various reasons mentioned earlier, they nevertheless call into question the self-cleaning ability of this type of unit.

Pressure-hose Method

Annual cleaning of large rearing containers generally occurs after the juvenile fish are released. The containers are drained, and a firehose with a pressure nozzle is used to clear sludge and periphyton from the container. Cleaning generally begins at the upstream end and works downstream. Containers coated with green algicide paint were more easily cleaned; unpainted containers often required scrubbing to dislodge materials. This method at times produced quite turbid and fetid discharges, diluted with minimal amounts of water. As well as sludge, gravel and algae were major components in the discharge. During hosing, some water flow was maintained through the channels to assist in removal of the wastes; this flow was varied to flush the container. Consequently, flows were too variable over time to quantify properly. Instead, pump discharge rates measured during vacuuming have been used in the calculations. These rates are felt to roughly approximate actual values; the same pumps that are used for vacuuming are usually reversed for pressure-hosing. Although flows would be reduced with the use of a pressure nozzle, this reduction should be more than offset by the additional channel flow.

Concrete Raceways: The highest values of NFR (measured at the raceway outlets) occurred at the start and end of cleaning (Table 19), which generally took 1.5 h. NFR levels rose, going as high as 2680 mg/L (1.36 mg/L per kilogram of fish), in the last half-hour of cleaning at all three facilities. This was because the heavy waste material was pushed out of the channel using the hose during this period. NFR values up to 4370 mg/L (2.3 mg/L per kilogram of fish) were measured within the first 15 min of cleaning, but only at the Nitinat facility. This was due to the use of a different cleaning technique at Nitinat; loose accumulations were hosed out first, then a thorough washing and scrubbing was started at the upstream end.

NFR levels averaged 384 mg/L in the grab samples, or 0.2 mg/L per kilogram of fish at release (n=40 for five cleanings at three facilities). As usual, the variability was high, with the results from Nitinat being 1-2 orders of magnitude greater than from the other two facilities. This was because the Nitinat raceways were vacuumed only once during the entire rearing period, as opposed to more regular cleaning at the other facilities. Thus where raceways have not been cleaned regularly, it would be more realistic to assume higher average NFR levels of 0.5 mg/L per kilogram of fish. Regardless, the levels for all pressure-hosings were much lower than those found during vacuuming of raceways (1.1 mg/L per kilogram of fish). This would seem to be reasonable for those containers that were cleaned during the final stages of rearing, but is puzzling for Nitinat.

The 'average' total NFR discharge during pressure-hosing was projected to be 9.5 kg overall, or 5 g per kilogram of fish, given a 90 min duration, a flow of 275 LPM, and 0.2 mg/L per kilogram of fish for raceways that were cleaned regularly during rearing. For raceways not cleaned regularly, 'worst-case' total NFR values of 24 kg overall, or 12.5 g per kilogram of fish are suggested. These values are still considered to be lower than actual, as the debris often was in large clumps which would not fit through the narrow mouths of the sample bottles.

Table 19. NFR levels in pressure-hosing effluents from concrete raceways at various SEP facilities.

A. NFR LEVELS IN GRAB SAMPLES:

Facility	Unit No.	kg of Fish	Species[a] (g)	Sampling Time in Minutes (NFR in mg/L): 0	1-15	16-30	31-45	46-60	61-75	76-95	Peak[c]	Avg	(n)
Big Qualicum	Rd. side	4075	CN (7.8)	7	8 8 7 19 52	15	16 10	7	10	134 21	-	26	(12)
Chehalis	7	1826	CO (7.7)	9 48	22	-	17	-	124	28 27	112	55	(6)
Nitinat	1	1971	CN (0.9)	78	730	387 40	27	19	2680	618	-	643	(7)
	2	1924	CN (0.9)	8	411 434	ND[b]	12	21	16	1120	-	288	(7)
	4	1906	CN (1.0)	9	4370 1040	45	31	48	1450 1200	23		1026	(8)
											GRAND MEAN =	384	(40)

[a] CN = Chinook; CO = Coho

[b] ND = Not Detectable

[c] Sample taken at visual peak of turbidity

(Table 19 cont'd)

B. NFR LEVELS ADJUSTED FOR FISH BIOMASS: Sampling Time in Minutes

Facility	Unit No.	kg of Fish	Species (g)	0	1-15	16-30	31-45	46-60	61-75	76-95	Peak	Avg	(n)
				(NFR in mg/L kg of Fish)									
Big Qualicum	Rd. side	4075	CN (7.8)	< 0.01	< 0.01 < 0.01 < 0.01 < 0.01 0.01	< 0.01	< 0.01 < 0.01	< 0.01	< 0.01	0.03 < 0.01	-	< 0.01	(12)
Chehalis	7	1826	CO (7.7)	< 0.01 0.03	0.01	-	0.01	-	0.07	0.02 0.02	0.06	0.03	(6)
Nitinat	1	1971	CN (0.9)	0.04	0.37	0.20 0.02	0.01	0.01	1.36	0.31	-	0.33	(7)
	2	1924	CN (0.9)	< 0.01	0.21 0.23	ND	< 0.01	< 0.01	< 0.01	0.58	-	0.15	(7)
	4	1906	CN (1.0)	< 0.01	2.29 0.55	0.02	0.02	0.03	0.76 0.63	0.01	-	0.54	(8)
										GRAND MEAN =		0.19	(40)

Earthen Channels: The earthen channel is normally constructed with a gravel bottom and 2:1 sloped sides made of rip-rap or dirt. Compared to raceways, channels are wider at the water surface, considerably longer and often are provided with much higher flows. The procedure for cleaning these channels was similar to that for concrete channels, although it was much more time consuming and often involved weeding and replacement of rip-rap along the sides. Sediment was spread over the sloping sides of the channel as well as the bottom, requiring careful washing of both. At Chilliwack, the only facility where an earthen channel was sampled during pressure-hosing, the following procedure was used. The 253 m channel is divided into eight sections, each with its own weir. The stoplogs were removed from the top four weirs and those four sections were allowed to flush to a depth of about 15 cm over the period of an hour into the lower sections, which remained ponded. Waste was scoured from the upper sections during this flushing. A 315 LPM pump was used for hosing, starting at the upstream end of Section 1. During hosing, channel inflows were reduced to a minimum. Sludge and some of the weeds on the channel bottom were dislodged by thorough hosing of each section, which took 0.5-3.5 h per section (average 2.5 h, but time per section increased stepwise downstream). One section a day was hosed in this manner, then the weirs were replaced and the sections allowed to refill overnight. The next day, the weirs would be removed and the next downstream section cleaned. After all four sections had been hosed, the channel was weeded by hand and then pressure-hosed a second time. The lower four sections were cleaned in a similar manner.

Because this procedure took weeks to complete, only the first section was sampled at regular intervals during the flushing and subsequent hosing; the next four sections were sampled by the hatchery staff, who were instructed to take a sample at the visual peak of turbidity for each section. These samples generally were taken within an hour after cleaning of each section began. The last three sections were not sampled at all. Also, Section 1 samples were taken at the Section 5 weir during flushing; all other samples were taken at the bottom of the section being cleaned. Because of both the sequential and annual nature of this cleaning, correction of NFR levels for fish biomass was not seen as meaningful.

NFR levels in the various grab samples were (see also Table 20):

	Average in mg/L	Range in mg/L	(n)
Section 5 weir during flushing	64	21 - 131	(4)
End of Section 1 during hosing	274	183 - 365	(2)
All sections during hosing peaks	744	162 - 1360	(5)

NFR levels peaked during the early stages of flushing, and then again towards the end of hosing (when the material was forced out of the section). Also, peak NFR for each section tended to increase as cleaning progressed downstream; this may be the result of both rearing and cleaning wastes from upstream sections being carried into downstream sections before settling. However, NFR levels may be higher in the upstream sections of channels at

Table 20. NFR levels generated during cleaning of earthen channel # 2 at Chilliwack Hatchery.

	Min of Flushing					Min of Hosing			
Section	0	10	20	30	40	0[a]	20	Peak	(Min)
					(mg/L)				
1	-	-	-	-	-	10	83	365	(35)
2	-	-	-	-	-	-	-	162	(55)
3	-	-	-	-	-	-	-	572	(60)
4	-	-	-	-	-	-	-	1360	(35)
5	ND	131	52	53	21	-	-	1260	(60)

[a] Sampling times re-set to zero at start of hosing.

Table 21. Nutrient and solids levels in water samples taken during various container cleanings at SEP facilities.

Container/Method	n	TN (mg/L) ± 95% C.I.	TP (mg/L) ± 95% C.I.	Average NFR (mg/L)
Control	48	1.2 ± 0.8	0.5 ± 0.4	14 (10)[a]
Capilano troughs/ Flush	41	9 ± 10	1.0 ± 0.5	71
Channels, Raceways/ Pressure-hosing	51	7 ± 4	5 ± 4	320
Raceways, Burrows/ Flush, Vacuum	87	54 ± 24	23 ± 11	825

[a] Value in brackets deletes single abnormally high reading of 212 mg/L for Capilano biofilter raceway from average.

Table 22. TN and TP levels in Capilano troughs and biofilter chamber raceways at the Capilano Hatchery.

	Unit Type	TN (mg/L) ± 95% C.I.	TP (mg/L) ± 95% C.I.	(n)
Pre-cleaning (Time 'O')	Trough	0.6 ± 0.4	0.1 ± 0.1	(3)
	Raceway	3.9 ± 4.9	1.6 ± 1.7	(3)
During Cleaning	Trough	0.7 ± 0.2	0.4 ± 0.2	(7)
	Raceway	5.0 ± 3.9	3.1 ± 2.4	(6)

facilities that, unlike Chilliwack, do not have a settling basin for stream-borne sediments. Without such a settling basin, heavier siltation of the upper sections of channels will occur.

Although NFR levels during the flushing period were much lower than during hosing at Chilliwack, the volume of water involved was much higher; given a total volume for all four sections of around 1.5 million L, which drained in about 60 min, flows would have been about 25,000 LPM and total NFR production in the flush would have been about 100 kg. This compares to an estimate of 35 kg per section, presuming only the 315 LPM pump flow (thus minimum dilution) for 2.5 h, and that NFR levels remain at the average peak value of 744 mg/L throughout the period.

Underwood and McLellan (1979b) sampled one of the Robertson earthen rearing channels and found incremental NFR levels of 72-163 mg/L at the channel outlet, which are similar to the levels found in our study.

BOD LEVELS

Of the 46 BOD samples taken at the outlets of containers prior to cleaning at the various facilities, 25 were at non-detectable levels (<2 mg/L); the 21 samples having measurable BOD averaged 6 mg/L. All but two of these samples were $\leq$ 7 mg/L. One sample (20 mg/L BOD) was from the Capilano underground channels, and was associated with the high NFR value of 212 mg/L. This high value may have resulted from accidentally dislodging a clump of material when sampling in the outfall. The second sample (33 mg/L BOD) was taken from a concrete raceway at Puntledge, that was considered overdue for cleaning. Both of these samples, however, were low compared to the BOD value of 315 mg/L seen in the sample from the Conuma effluent channel. At the time of sampling, this channel had low flows and a thick bottom deposit; rotting salmon carcasses were present, along with heavy growths of algae and macrophytes. Effluent ponds and channels at the other facilities looked much less noxious than this one and non-detectable BOD levels in samples taken at the Chilliwack, Eagle, and Inch hatcheries support this observation.

McLean (MS 1978) sampled BOD levels from vacuum and flush cleaning events as well as during normal discharges from Burrows ponds at the Quinsam Hatchery. He also found the incremental (to inflow valves) BOD levels to average 2 mg/L during normal discharge periods, and 41 mg/L during cleaning events. Underwood McLellan Ltd (1979b) found few measurable increases in BOD during the normal operation of concrete raceways and earthen channels at the Robertson and Big Qualicum facilities, and incremental BOD averaged 1.1 mg/L during the normal operation of Burrows ponds at the Quinsam hatchery. During cleaning, average incremental BOD levels ranged 1-25 mg/L at the outlets of these containers.

NUTRIENT CONCENTRATIONS

In Water

Except for Capilano troughs, TN and TP levels in water samples taken from cleaning effluents were significantly higher than for control (pre-cleaning) samples, and samples taken of vacuum or flush effluents from raceways were significantly higher than for the other two methods employed (Fig. 5 and Table 21).

TN levels were consistently lowest for Capilano troughs at most facilities, most likely due to the relatively low levels of NFR involved. There was no statistically significant relationship between either TN or TP and fish size or species. Maximum TN and TP levels, up to 590 and 330 mg/L respectively, were measured during vacuuming of raceways at Robertson, Puntledge and Chehalis. The high values at Puntledge may have to do with the fact that cleaning had been delayed there. Also, there may be a species effect on TN and TP, as values for chinook were significantly higher than for coho (69 ± 35 mg/L versus 15 ± 5 mg/L TN, and 31 ± 18 mg/L versus 9 ± 4 mg/L TP; n = 57 and 51 respectively). However, it still could be a site-specific effect, as the high-value facilities did not carry both species at the time of sampling. At Capilano, water from the Capilano troughs was re-used in the underground chambers, and both TN and TP were higher in the chambers as a result (Table 22).

McLean (MS 1978), in his sampling of five Burrow pond cleanings, found incremental TP levels to average 0.01 and 0.3 mg/L for normal and cleaning discharges respectively. Underwood McLellan Ltd (1979b) reported incremental TN and TP levels to range 0.2-10.5 mg/L and 0.2-1.4 mg/L respectively at the outlets of earthen channels during cleaning. These TP results are considerably lower than those found in our study, possibly because we sampled effluents in less dilute form.

Munro et al. (1985) speculated that hatchery wastes settled out along the discharge route, decomposed, and released nutrients for some time after fish release. This should imply that NFR levels are linked to TN and TP. For the most part, our data confirm this. NFR levels correlated positively and significantly ($p < .01$) with both TN and TP levels for all container types and cleaning methods, despite high variability (R^2 values ranged from 0.34-0.70 for NFR-TN and 0.52-0.57 for NFR-TP). The statistically higher levels of TN and TP in raceway vacuum effluents support their speculation, in that these effluents were the least dilute and thus highest in NFR. One might argue against nutrient release through decomposition because TN and TP levels for Capilano troughs, where wastes were at most a few days old, are similar to the levels found during channel pressure-hosings which are done yearly (Table 21). However, the inclusion of algal growths and settled river silts in the channel wastes probably confounds the results.

N:P ratios have been used by other researchers to indicate nutrient limitations for algal growth; a N:P ratio much higher than 12:1 suggests phosphorus limitation, while a much lower ratio suggests nitrogen limitation (Munro et al. 1985). The average N:P ratios seen during our sampling (Fig. 6) were only slightly higher at 13:1-14:1 for control (pre-cleaning) and raceway vacuum/flush cleanings, which would suggest near-optimal conditions for algal growth. Note, however, the extremely high variability associated with the raceway data. Mean Capilano trough flushing and pressure-hosing ratios were significantly lower, at 4:1 and 2:1 respectively, than control and raceway ratios. This suggests that effluents resulting from these cleaning techniques are nitgrogen-limited.

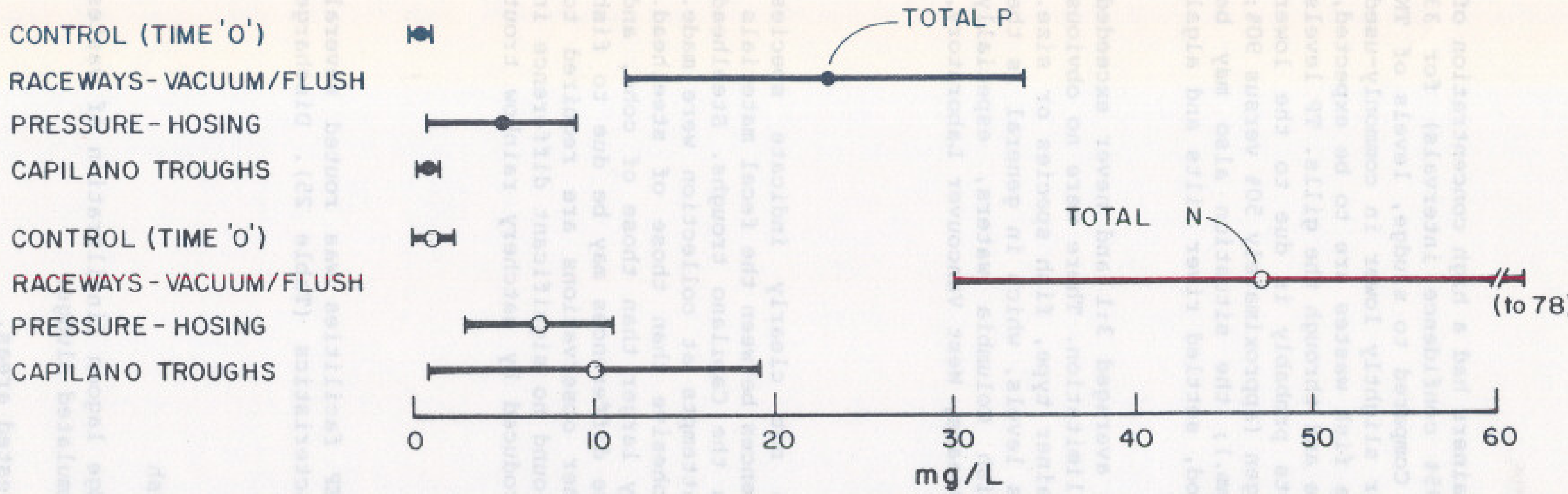

Figure 5 Total N and total P levels (± 95% confidence intervals) in water samples taken at various SEP facilities

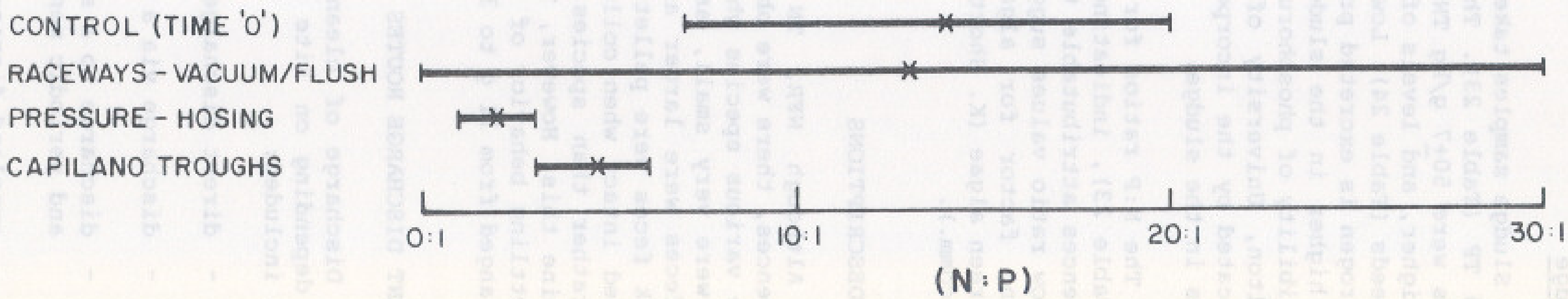

Figure 6 N:P ratios (± 95% confidence intervals) from water samples taken at various SEP facilities

In Sludge

Sludge samples taken from various containers had a high concentration of TN and TP (Table 23). The mean levels ($\pm$ 95% confidence intervals) for 33 samples were 50 ± 7 g/kg TN and 21 ± 3 g/kg TP. Compared to sludge, levels of TN were higher, and levels of TP were the same or slightly lower in commonly-used fish feeds (Table 24). Lower TN levels in the fish wastes are to be expected, as nitrogen is excreted primarily in the urine and through the gills. TP levels being higher in the sludge than in the diets probably is due to the lower digestibility of phosphorus compared to nitrogen (approximately 50% versus 90%; J. Hilton, University of Guelph, pers. comm.); the situation also may be complicated by the incorporation of waste food, settled river silts and algal growths in the sludge.

The N:P ratios for all sludge samples averaged 3:1 and never exceeded 8:1 (Table 23), indicating general nitrogen limitation. There were no obvious differences attributable to facilities, container type, fish species or size. Such low ratio values suggest high phosphorus levels, which in general is the limiting factor for algal growth in British Columbia waters, especially blue-green algae (K. Shortreed, Dept. Fish. Oceans, West Vancouver Laboratory, pers. comm.).

FECES DESCRIPTIONS

Although NFR, TN and TP data do not clearly indicate species differences, there were obvious visual differences between the fecal materials of the various species while being reared in the Capilano troughs. Steelhead feces were very small, and dissolved when attempts at collection were made. Coho feces were larger and slightly more cohesive than those of steelhead. Chinook feces were pellet-shaped and slightly larger than those of coho, and remained intact when collected. Some of these differences may be due to fish size rather than species differences. Further observations are required to determine this. However, Thomson (MS 1986) found no significant difference in the settling behavior of the waste solids produced by hatchery rainbow trout that ranged from 11 g to 311 g.

EFFLUENT DISCHARGE ROUTES

Discharge of cleaning wastes from SEP facilities was routed several ways, depending on site and facility characteristics (Table 25). Discharge routes included:

- direct discharge into the stream
- discharge via a natural pond or marsh
- discharge to a separate formal sludge lagoon (infiltration of wastes and periodic manual removal of accumulated sludge)
- overland disposal into adjacent forested areas.

Table 23. Levels of TN and TP, and N:P ratios found in sludge samples taken at various SEP facilities (some containers could not be sampled due to insufficient sludge accumulations--eg, Atnarko-box raceways).

Facility	Unit Type	Unit No.	g/kg Sludge TN	g/kg Sludge TP	N:P	Species[a] (g)	Comments
Big Qualicum	Raceway	Rd side	32.0	16.5	1.9(:1)	CN (7.8)	-
Capilano	Capilano Trough	4A	40.0	25.3	1.6	CN (2.0)	Antibiotic trt.[b]
		8B	40.0	29.8	1.3	CO (1.8)	Hormone trt.
		10A	45.0	24.5	1.8	CN (1.5)	Hormone trt.
	Underground Channel	10B	54.0	24.3	2.2	CN (4.1)	-
		10C	53.0	28.6	1.9	CN (4.7)	-
		10D	44.0	26.6	1.7	CN (5.3)	-
Chehalis	Raceway	2D	52.0	11.1	4.7	CN (2.4)	-
Chilliwack	Capilano Trough	15B	32.0	13.3	2.4	ST (0.5)	-
		16A	42.0	12.8	3.3	ST (0.3)	-
		16B	65.0	11.8	5.5	ST (0.3)	-
		17A	53.0	6.5	8.2	ST (0.3)	Square trough
		17B	51.0	11.7	4.4	ST (0.4)	-
	Earthen Channel	2	28.0	4.9	5.7	CO (16.8)	Section 1
Conuma	Raceway	1	93.0	14.9	6.2	CO (2.3)	-
Eagle	Raceway	5	27.0	14.2	1.9	CN (3.5)	-
Inch	Capilano Trough	2B	25.0	4.9	5.0	CO (1.0)	-
		5A	52.0	30.4	1.7	CO (1.2)	-
		5B	58.0	25.4	2.3	CO (0.8)	-
	Raceway	4	118.0	14.2	8.3	CO (2.1)	-
Nitinat	Raceway	1	30.0	12.0	2.5	CN (0.9)	-
		2	42.0	17.4	2.4	CN (0.9)	-
		4	37.0	23.7	1.6	CN (1.0)	-
Puntledge	Raceway	2	34.0	31.4	1.1	CN (1.7)	-
Shuswap	Capilano Trough	1	42.0	29.8	1.4	CN (6.0)	-
		2	38.0	49.2	0.8	CN (5.2)	-
		4	50.0	35.3	1.4	CN (3.8)	-
Tenderfoot	Capilano Trough	1A	59.0	30.7	1.9	CO (0.8)	-
		2A	61.0	24.0	2.5	CO (0.7)	-
		3A	57.0	30.2	1.9	CO (1.1)	-
		4A	70.0	21.5	3.3	CO (0.7)	-
		5A	65.0	21.9	3.0	CO (0.5)	-
	Channel	2AB	75.0	18.0	4.2	CO (18.3)	-
	AVERAGE	(n=33)	50.4	21.1	3.0		

[a] CO = Coho; CN = Chinook; ST = Steelhead [b] trt = treatment

Table 24. TN and TP levels in fish diets used in SEP facilities compared to levels in sludge taken from various rearing containers (dry weights).

	BioDiet[a]	OMP[b]	Sludge
TN	87 (min)	86 (avg)	50 ± 7 g/kg
TP	15 (avg)	18 (avg)	21 ± 3 g/kg

[a]Calculated from data given in BioDiet commercial pamphlet: 43% crude protein ÷ 0.79 (moisture content) ÷ 6.25 (N:protein ratio) X 10 (conversion from % to g/kg basis) = TN in g/kg; 1.2% P ÷ 0.79 (moisture content) X 10 (conversion from % to g/kg basis) = TP in g/kg.

[b]Calculated from OMP feed analyses (C. Cross, unpub.): 39.3% protein ÷ 0.73 (moisture content) ÷ 6.25 (N:protein ratio) X 10 (conversion from % to g/kg basis) = TN in g/kg; 13112 mg/kg P ÷ 0.73 (moisture content) ÷ 1000 (conversion from mg/kg to g/kg basis) = TP in g/kg.

Table 25. Effluent discharge routes for major container types at SEP facilities visited in study (see also site layout figures in Appendix 2).

Facility	Unit Type	Description of Discharge Route
Big Qualicum	Earthen Channels	- annual pressure hosing effluent discharged from each channel into common confluence pond approx. 15 m diameter, then drained via 60 m channel to river.
	Raceways	- regular vacuuming, and pressure-hosing twice yearly; effluent discharged directly to river or via fishway for two channels; third (road-side) channel effluent sent via pipe to confluence pond for earthen channels (see above) or piped to bridge area.
	Burrows Ponds	- regular vacuuming and annual pressure-hosing; effluent from each pond discharged separately into river via pipe.
Capilano	Capilano Troughs	- cleaning effluent discharged to concrete release channel into fishway and out to river (sometimes directly into river).
	Burrows Ponds	- vacuumed regularly, pressure-hosed annually; effluents discharged as for Capilano troughs.
	Chamber Raceways	- normal rearing water from Burrows pond and Capilano troughs can be re-used in chambers (cleaning discharges diverted to release channel).

cont'd ...

(Table 25 cont'd)

Chehalis	Capilano Troughs	- cleaning effluent discharged via common pipe with normal trough flows into concrete release channel, which drains into 275 m earthen outfall channel to the river.
	Raceways	- vacuum effluent sent via pipe and sump-pump system to formal infiltration lagoon. - annual cleaning employs some pressure-hosing of walls and lighter materials, discharged into river via release channel and outfall channel. - annual sand removal done by either pumping material into release channel, or drying up raceway, shovelling out and disposing on land.
	Channels (Asphalt-lined)	- cleaning similar to that of raceways, except less vacuuming and more sand removal required. 'Super-sucker' used to transport sand to sludge lagoon initially (over-sized); backhoe probably will be used in future to remove sand for overland disposal.
Chilliwack	Capilano Troughs	- cleaning effluent discharged to the river via a separate pipe through the dyke, combined with the routine flows from other troughs and from the incubation room. Pipe discharges into 30 m open channel and shallow basin.
	Raceways	- vacuum and annual pressure-hose effluents discharged directly into release channel at base of raceways, pass down fishway into 400 m outfall channel, which exits into Slesse Cr 500 m above confluence with river.
	Channels	- annual pressure-hose effluents discharged directly into release channel as for raceways.

cont'd ...

(Table 25 cont'd)

Conuma	Capilano Troughs	- cleaning effluent combined with normal trough flows and piped to outfall channel between earthen channel and raceway outlets.
	Raceways	- all cleaning effluents washed out into release channel, which drains into earthen outfall channel, 20 m below rearing channel exit, and then to river.
	Channels	- same as for raceway, save that exit is at start of outfall channel (50 m to river).
Eagle	Capilano Troughs	- cleaning effluent combined with normal trough flows and piped to a continuous settling pond prior to discharge via an outfall channel into a marsh area draining to the river.
	Raceways	- vacuum effluent discharged into ditches at edges of site; overflow drains into the marsh area.
		- normal flows discharged continuously through settling pond.
Inch	Capilano Troughs	- cleaning effluent combined with normal trough flows and piped to a continuous settling pond (30x30 m) prior to discharge via a short outfall channel into the creek's headwaters.
	Raceways	- vacuum effluent discharged by hose directly into settling pond; normal flows discharge continuously into settling pond.
Nitinat	Capilano Troughs	- cleaning effluent combined with normal trough flows and discharged into transport channel at base of raceways, then sent down fishway.
	Raceways	- monthly vacuum effluent discharged overland in surrounding forested areas.
		- annual pressure-hosing effluent washed into release channel, down fishway and into river via 100 m outfall channel.

cont'd ...

(Table 25 cont'd)

Puntledge	Capilano Troughs	- cleaning effluent combined with normal trough flows and piped directly to the river.
	Raceways	- vacuum and pressure-hose effluents discharged into release channel, draining to river through a fishway.
Quinsam	Capilano Troughs	- all these units normally combine cleaning and regular flows, and are piped to two 23 m diameter clarifiers (total of 1300 m^3 settling capacity) before discharge to river
		- during sampling for this study, fish were being reared in the clarifers, and vacuum effluent from the Burrows Ponds was being discharged overland into adjacent forested areas.
	Channels	- discharge directly into river; cleaning consists only of drying channels up (little waste accumulates).
Robertson	Capilano Troughs	- cleaning effluents combined with regular trough and tub flows and piped into Stamp Lagoon.
	Raceways	- weekly vacuum effluents discharged directly into creek (1B and 2B) or via release channel and fishway at mouth of creek (3B-6B).
		- annual cleaning done using scrub brooms with 15 cm of water flowing through.
	Trout Ponds	- daily flush by lifting stoplogs, piped to creek.
		- annual scrubbing as for raceways.
	Channels	- annual cleaning using hose and barn brooms, discharge to creek.
	'Test Flume'	- vacuum effluent discharged overland into surrounding bush (flume 180 m upstream of 1B and 2B).

cont'd ...

(Table 25 cont'd)

Shuswap (Pilot only)	Capilano Troughs	- all effluent discharged directly into river sidechannel.
Tenderfoot	Capilano Troughs	- effluents from each unit are combined with flows from other units of the same type and piped to separate discharge points along the small lake at the top of Tenderfoot Creek.

In most cases, cleaning effluents were diluted by flows from other containers and areas of the hatchery before discharge into receiving waters. However, there are instances where the degree of dilution of cleaning wastes is often considerably less than the total hatchery discharge might indicate. For instance, it is common for the Capilano trough areas to have separate plumbing. Thus the cleaning flows could be diluted only by the routine flows from the other troughs (generally there will be no more than 32 troughs at any one hatchery). The degree of dilution also is reduced considerably during both the early and late phases of rearing, when only a few containers might be running. Similarly, annual pressure-hosing of raceways and channels often will be done at a time when the other containers are empty. Because this study was done at the end of rearing, the degree of dilution during sampling was less than during the rearing period. Even with the relatively small amounts of diluting flow seen during this study, the calculated daily dilution rate was never less than 25:1 within the hatcheries (Table 26). Where two or more container types are cleaned on the same day, the dilution rate would be effectively reduced, however (this was not considered in the calculations contained in Table 26).

In this study, there was only limited sampling (n=7, spread over the Chilliwack, Conuma, Eagle, Inch and Shuswap facilities) done at points downstream along the effluent pathways. Most of these samples indicated rapid improvement of water quality parameters prior to reaching the outfalls. With the exception of the one high BOD value of 315 mg/L at Conuma, NFR and BOD were never detectable, and TN and TP levels averaged 0.3 ± 0.4 and 0.1 ± 0.1 mg/L respectively. In comparison, pre-cleaning samples averaged 0.4 ± 0.1 mg/L TN and 0.3 ± 0.2 mg/L TP at these same facilities. It was also noted that the productivity of the effluent channels often seemed to be enhanced rather than degraded; wild juvenile salmonids seemed to be attracted to and rearing in the effluent channels and lagoons at the Chilliwack, Eagle and Inch facilities.

CONCLUSIONS

CHARACTERIZATION OF CLEANING EFFLUENTS

Previous researchers have emphasized the complexity and high variability inherent in the sampling of hatchery discharges, and this study has had to struggle with these same problems. Rather than just call for more sampling--which obviously is required--we have attempted to provide at least an interim perspective on the nature of hatchery effluents. This required a number of simplifying assumptions; their acceptability is left to the reader's judgement. On the basis of the results presented in earlier sections, effluents from various cleaning methods and container types are characterized and extrapolated for the worst-case daily situation in Tables 27 (NFR) and 28 (TN and TP).

Table 26. Calculated daily dilutions of cleaning effluent by other hatchery flows.

Facility	Container Type	Cleaning Method	Daily Total L[a]	Daily Cleaning	Cleaning/ Total
(Generalized Case)	Capilano Troughs (32)	Flush	11.7M	64K	0.005
Big Qualicum	Raceway	Pressure-hose	183.0M	99K	0.0005
	Burrows Pond (1)	Vacuum	2.6M	81K	0.003
Capilano	Chamber Raceway	Flush	21.2M	785K	0.04
Chehalis	Raceway	Vacuum	7.2M	33K	0.005
	Raceway	Pressure-hose	47.4M	99K	0.002
Conuma	Raceway	Vacuum	17.3M	99K	0.006
	Raceway	Vacuum	12.8M	273K	0.02
Inch	Raceway	Vacuum	5.2M	215K	0.04
Puntledge	Raceway	Vacuum	5.5M	240K	0.04
Quinsam	Burrows Pond (1)	Vacuum	981K	39K	0.04
Robertson	Raceway	Vacuum	69.7K	82K	0.001
Tenderfoot	Atnarko-box	Flush	3.5M	28K	0.008
	Channel	Vacuum	10.5M	122K	0.01

[a]At time of sampling.

Table 27. Characterization of effluents: NFR and cleaning flows, durations and volumes. Expanded to worst-case situation (maximum numbers and time spent cleaning containers of each type in any one day), and as proportion of total daily hatchery flows (as estimated on sampling days).

Cleaning Method	Container Type	NFR mg/L	NFR mg/L/kg	Flow (LPM)	x Duration (min)	= Volume L	mg/kg Fish	x Maximum No Cleaned/ Day	= Total Daily g/kg of Fish	Prop'n of Daily Flow	Average Daily mg/kg
Controls	All Types	15 (6)[a]	0.02 (0.009)	2755 (2874)	1440	3967200 (4138560)	79344 (37247)	N/A	79 (37)	1.00	79344 (37247)
Flush	Capilano Troughs	27	2.1	996	2	1992	4183	32	134	0.04	5
	Atnarko-box Raceways	23	0.1	1150	4	4600	368	6	2	100.0 (separate outlet)	2
	Chamber Raceways	44	0.2	6327	2	12654	2531	31	78	0.25	20
Baffle	Capilano Troughs	2	0.2	310	10	3100	620	32	20	0.04	1
Vacuum	Raceways	978	1.1	285	90	25650+	90000	4	360	0.25	90
	Burrows Ponds	832	12.7	109+	30+	3270+	53000	12	636	0.25	159
Pressure-hose	Raceways	384	0.2	275+	90	79750+	12500	4	50	0.25	13
	Channels	274	N/A	7368	210	1547250+	N/A	N/A	N/A	N/A	N/A

[Versus Pollution Control Objective = 4000-15000]

[a]Numbers in brackets are after deletion of abnormally high control values (212 mg/L at Capilano, 198 mg/L at Inch).

Table 28. Characterization of effluents: TN and TP expanded per Table 24 to worst-case situation for container group, and as proportion of total hatchery flows.

Parameter	Containers (Method)	Average mg/L	Average kg of Fish	Daily Vol (L)	Prop'n of Daily Flow	Average Daily mg/kg
TN	Controls	1.2	638	3967200	1.00	7642
	Capilano Troughs (Flush)	9.0	416	64000	0.005	7
	Raceways (Pressure-hose)	7.0	1920	99000	0.25	90
	Raceways/Burrows/ Channels (Flush/Vacuum)	54.0	706	182000	0.25	3480
	Pollution Control Objective (Nitrate + Ammonia)					1600-2600
TP	Controls	0.5	638	3967200	1.00	3109
	Capilano Troughs (Flush)	1.0	416	64000	0.005	<1
	Raceways (Pressure-hose)	5.0	1920	99000	0.25	64
	Raceways/Burrows/ Channels (Flush/Vacuum)	23.0	706	182000	0.25	1482
	Pollution Control Objective					200-350
BOD	Controls	<3	638	3967200	1.00	<18655
	Pollution Control Objective					4000-13000

When calculated in this manner, the daily Pollution Control NFR objective would be exceeded at the point of exit from the individual container when using vacuum and pressure-hose cleaning methods, but not when using the flush cleaning method (Table 27). Considering the diluting effects of flows from other containers of the same type and from other areas at the hatcheries over the day, NFR levels should be well below the objective level at the hatchery outfall in the majority of cases. It is emphasized that this result presumes nil NFR levels in routine flows for the rest of the day, which is not the case. Expansion of the 'control' values (samples taken at the outlet of the container just prior to cleaning) to a daily basis per kg of fish results in the NFR objective being exceeded by 2-3 times. This is likely more a result of the ways in which the guidelines are expressed and how the sampling was done, rather than a true indication of environmental problems; this is discussed further below.

TN and TP calculations indicate that the daily Pollution Control TN and TP objectives would be exceeded by vacuum effluents even when dilution by total hatchery flows is considered; flush and pressure-hose cleaning results fall below the objectives when considered in isolation (Table 28). As with NFR, using 'control' values as indicative of routine TN, TP and BOD levels resulted in the daily objectives being exceeded by up to an order of magnitude. This result probably is not due to the inclusion of TN and TP levels present in the water supply before it reaches the fish; previous samplings of the various hatchery supplies (Table 29) indicated that subtraction of ambient TN and TP levels would reduce the outflow values only by 5-10%. Rather, the problem again is seen as mainly to do with the way in which the objectives are formulated and how the sampling was done. Downstream sampling of effluents done earlier by Munro et al. (1985) at four SEP hatcheries resulted in average TP values of only 35-96 mg/kg/day.

These extrapolations were from single grab samples, taken during daylight when fish were active and feeding. Composite sampling over 24 h, as called for in the Pollution Control objectives (Water Resources Service 1975) would be likely to show lower levels of pollutants.

One thing becomes obvious from the above extrapolation exercises, and that is current cleaning procedures potentially account only for a minor portion of the NFR, TN and TP being released to the receiving waters. Barely detectable levels of NFR in routine hatchery discharges result in the Pollution Control objectives being grossly exceeded, due to the large volumes of water involved. McLean (MS 1978) also concluded that cleaning effluents accounted for a relatively small proportion of the total waste materials (15% of NFR, 4% of BOD and TP) discharged over the study period from Burrows ponds.

POLLUTANT DISCHARGE PREDICTION METHODS

SEP began to apply for provincial Effluent Discharge Permits for new facilities in 1984. The applications were made with little knowledge of the nature of hatchery effluents and their impacts on receiving waters. Accordingly, the approach taken in the applications was to request the maximum levels of pollutant discharge allowable under the current Pollution Control objectives. Although these objectives are expressed as pounds of pollutant per

Table 29. Summary of TN and TP levels averaged from previous samplings of SEP facility water supplies (taken from Miller et al. 1986).

Facility	Source	TN (mg/L)	TP (mg/L)
Big Qualicum	river	0.06	0.01
Capilano	river	0.12	0.002
	well	0.11	0.02
	overall	0.12	0.01
Chehalis	river	0.12	0.01
	mixed wells	0.11	0.03
	overall	0.12	0.02
Chilliwack	river	0.12	0.004
	well #1	0.13	0.18
	well #2	0.02	0.14
	well #3	0.03	0.24
	overall	0.08	0.14
Conuma	creek	0.04	0.001
	well #1	0.16	0.002
	well #2	0.09	0.001
	well #3	0.21	0.001
	well #4	0.16	0.002
	well #5	0.13	0.001
	well #6	0.10	0.03
	overall	0.13	0.005
Inch	mixed wells	0.19	0.002
Nitinat	mixed wells	0.09	0.003
Puntledge	river	0.05	0.0004
Quinsam	river	0.09	0.01
Robertson	river/well	0.04	0.003
Shuswap	mixed wells	0.12	0.007
Tenderfoot	mixed wells	0.10	0.008
	OVERALL AVERAGE:	0.10	0.02

100 pounds of fish per day, the application form requests that effluent characteristics be committed to in terms of mg/L. This required both conversion to metric values, and translation of hatchery biomass into water usage. The procedure used is outlined in Table 30. This procedure did not take dilution past the outfall point into account. The Pollution Control objectives (Water Resources Service 1975) are for samples taken 91 m (300 ft) downstream of the outfall, and assume a dilution rate of 20:1. If this dilution rate was incorporated and perfect mixing within the 91-m zone was assumed, it is doubtful that any of the NFR, TN or TP values found in this study would exceed the objectives.

SUGGESTED IMPROVEMENTS

To Effluent Discharge Procedures

The use of baffles, the flushing of smaller rearing containers and the pressure-hosing of larger containers are not seen as methods that normally will significantly boost levels of pollutant discharge. Vacuum effluents, on the other hand, are significant sources of pollutants; they also probably are the most amenable to treatment. Vacuum discharges can be easily pumped onto overland disposal sites or into holding tanks or infiltration ponds. One potential problem requiring some further thought is that of freezing of such intermittent discharges during winter weather, and their subsequent build-up. The Environmental Protection Service (1985) has issued a report compiling information on sewage lagoons in cold climates, which provides some guidance on the design and operation of hatchery sludge lagoons. These wastes are often used by the local communities as fertilizer; the Michigan Department of Natural Resources uses a tank truck to dispose of vacuum effluents on land as fertilizer (Boersen and Westers 1986).

Should routine hatchery effluents exceed Pollution Control objectives even when sampling is done according to their specifications, the provision of a continuous settling pond before the outfall may be a low-cost way to meet objectives. Kramer, Chin and Mayo (1970) suggested that a 2 hr detention time would remove gross solids and minimize the effects of pond cleaning, but that one day of detention would remove only 30-50% of BOD, nitrates or phosphates.

McLean (MS 1978) suggested that another practical approach to pollution abatement would be to concentrate on in-house control methods, such as more accurate pond inventory techniques, closer control of feeding rates, and more frequent cleanings. Use of some of these techniques may cause additional stress for the fish, so they must be approached with caution.

Mechanical filtration of effluent water could be done, but should be avoided if possible. There are commercially-available units, such as the Skretting 'Trianglefilter', capable of handling up to 1500-4800 LPM (30-80 u filter opening sizes respectively). Much larger units would be required for most federal facilities, which would have to be custom-designed and would be very expensive to construct and operate.

Table 30. Conversion of Pollution Control objectives (see Table 1) to values more useful for federal SEP facilities. Lower value is for new or proposed discharges; higher value is for existing discharges.

Parameter	Objectives (lb/100 lb fish/day)	Metric Conversion (mg/kg fish/min)	'Translation' to mg/L[a] 0-2g	3-5g	6-25g
BOD	0.40 - 1.30	2.8 - 9.0	2-6	3-9	6-18
NFR	0.40 - 1.50	2.8 -10.4	2-7	3-10	6-20
NH_3 - N	0.04 - 0.14	0.3 - 1.0	0.2-0.7	0.3-1.0	0.6-2.0
NO_3 - N	0.12	0.8	0.5	0.8	1.6
PO_4 - P	0.02 - 0.035	0.1 - 0.2	<0.1	0.1-0.2	0.2-0.4
(factor used)	(x 6.94)	(÷ 0.5-1.5)			

[a] 'Translation' made using values generated by LOAD RATE computer program (see Shepherd, 1984). In general, LOAD RATE predictions are considered to be the maximum safe loading rate for SEP facilities; actual load rates will be lower in most cases. Use of LOAD RATE values allowed the following rough conversions for the purposes of the above table:

Fish Size	LPM/kg fish
2 g	1.5
5 g	1.0
25 g	0.5

Site-specific values for ration and temperature normally would be used when applying for effluent permits.

To Pollution Control Objectives

Expressing objectives in terms of pounds of pollutant per 100 pounds of fish per day, when water quality measurements are normally given in mg/L, adds unnecessary complexity to the situation. The incorporation of biomass muddies interpretation for a number of reasons. First, estimation of hatchery biomass is subject to up to 20% error (T. Perry, DFO-SEP, pers. comm.). Second, because biomass changes constantly, there is a question as to which biomass value one should use: the annual maximum, the estimate closest in time to the date of sampling, or a special estimate on the day of sampling (the stress of which probably would affect water quality results)? Third, the apparent reason for using biomass was so that the objectives could be applied to all hatcheries regardless of water usage (Pommen MS 1974). This seems a strange rationale, in that discharge volume in relation to receiving water volume is probably much more important in assessing impacts than is biomass. In fact, the existing application form requests information on effluent quantities, but not biomass. Fourth, water quality criteria for salmonid hatchery intake water supplies have been expressed in normal units of measurement, such as mg/L (Sigma Environmental Consultants Ltd MS 1983). Fifth, how much fish is raised on the applicant's property should not be the concern, but rather whether receiving water quality is impaired. With regards to this last point the federal Environmental Protection Agency (EPA) developed hatchery effluent regulations in the late 1970s, which sought to impose pollution abatement systems on all facilities regardless of whether water quality standards already were being met. The Washington Department of Fisheries (WDF) initiated legal action against the EPA, and part of the out-of-court settlement was that the EPA would not attempt to dictate on-site treatment technologies, but instead would concentrate on effluent water quality standards (D. Wood, WDF, pers. comm.).

We therefore suggest that the Pollution Control objectives be restated in the standard units of measurement normally used in water sampling. Such an approach would simplify calculation and interpretation of results. Also, guidelines that incorporate consideration as to the sensitivities of receiving waters are badly needed.

Finally, it should be recognized that the hatchery environment is quite dynamic on the annual, monthly and even daily levels. Both sampling and interpretation can be done properly only if the operating history of the hatchery is known in considerable detail.

ACKNOWLEDGEMENTS

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Appendix 1. Sample application for permit under the Waste Management Act.

Province of British Columbia | Ministry of Environment | WASTE MANAGEMENT BRANCH

Waste Management File No. ....

APPLICATION FOR A PERMIT UNDER THE WASTE MANAGEMENT ACT (Effluent)

THIS APPLICATION is to be filed with the .... (Street address)

.... (City Town), British Columbia, ... (Postal Code).

Any person who may be affected by the discharge of the waste described below may, within 30 days from the last date of posting, publication, service or display, state in writing to the Manager how he is affected.

PREAMBLE—The purpose of this application is ....

....

1. I/We, ... (Full name—if a company, British Columbia registered name)

 of .... (Address—if a company, British Columbia registered address)

 hereby apply for a permit to discharge effluent from ....

 .... (Type of operation causing effluent)

 located .... (General location) into

 .... (Name of creek, river, lake, bay, inlet, etc.)

 which flows .... (Direction) and discharges into ....

 and give notice of application to all persons affected.

2. The land upon which the works are located is ....

 ....

 .... (Give legal description)

3. The discharge shall be located at ....

 .... (Define relative to some surveyed or commonly known point)

4. The quantity of effluent to be discharged is as follows:

 Average daily discharge (based on operating period) .... (Litres, cubic metres)

 Maximum daily discharge .... (Litres, cubic metres)

 The operating period during which the effluent will be discharged is

 .... (Continuous, hours per week, or date to date, etc.)

5. The characteristics of the effluent discharged shall be equivalent to or better than (insert values after completion of column (3) of table (*a*) on reverse side) ....

 ....

6. The type of treatment to be applied to the effluent before discharge is as follows:

 ....

 ....

This application, dated on ...., 19 ...., was posted on the ground in accordance with the Waste Management Regulations.

.... (PRINT name of applicant or agent) .... (Signature of applicant or agent)

ADDITIONAL INFORMATION

In support of the application the following information is submitted:

(*a*) The characteristics of the effluent before and after treatment are as follows:

	(1) Before Treatment Average (Annual)	(2) After Treatment Average (Annual)	(3) After Treatment Maximum
Total suspended solids (mg/L)	....	....	.... *
Total solids (mg/L)	....	....	.... *
Biochemical oxygen demand (mg/L)†	....	....	.... *
pH range	....	....	....
Temperature range (degrees C)	....	....	....
Faecal coliform bacteria (mpn per 100 mL)			.... (Log. mean)

Toxic constituents:

	Units			
....	( )	....	....	....
....	( )	....	....	....
....	( )	....	....	....
....	( )	....	....	....

Other relevant constituents:

	Units			
....	( )	....	....	....
....	( )	....	....	....
....	( )	....	....	....
....	( )	....	....	....

(*b*) Miscellaneous information:

....

....

....

....

....

* These values pertain to a composite sample collected over any operating day during the year.
† Five day 20°C (BOD).

Province of British Columbia

Ministry of Environment

WASTE MANAGEMENT BRANCH

SITE PLAN

LOCATION MAP

(Name of applicant(s))

(Date) (Signature of applicant(s) or agent)

(FOR OFFICE USE ONLY)

Date Issued

Date Amended

Appendix to Permit No.

Approval No.

Appendix 2. Fish culture information and water quality sampling (arranged alphabetically by facility).

For all facilities except Capilano the two tables containing fish culture data ('A' tables) and water quality results ('B' tables) for each cleaning event are preceded by a site layout sketch.

To facilitate reference, the following breakout is provided:

Faciliity	Figure No.	Table Nos.
Big Qualicum	1	1-3
Capilano	-	4-8
Chehalis	2	9-12
Chilliwack	3	13-20
Conuma	4	21
Eagle	5	22-27
Inch	6	28-34
Nitinat	7	35-37
Puntledge	8	38-43
Quinsam	9	44-45
Robertson	10	46-47
Shuswap	11	48-51
Tenderfoot	12	52-61

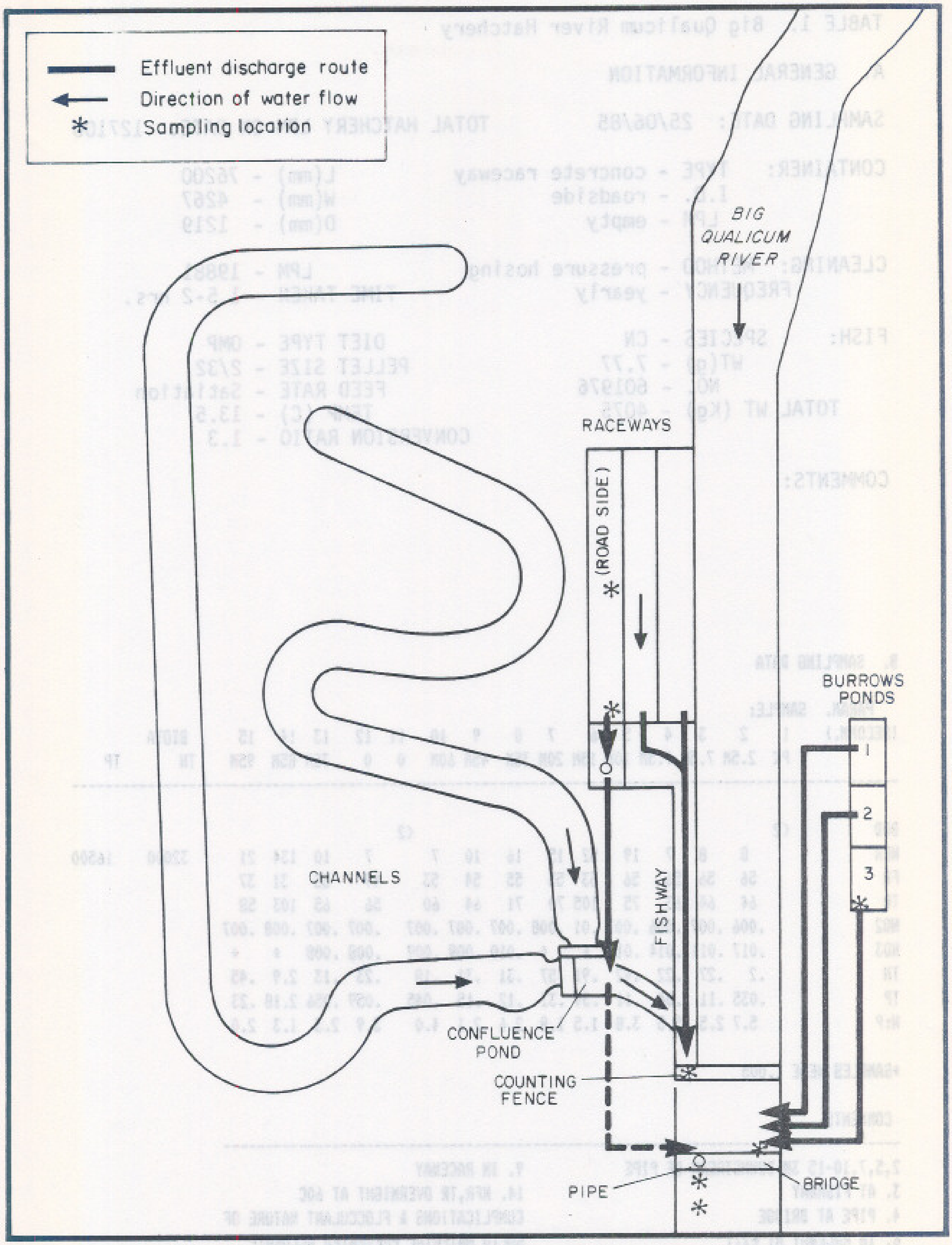

Figure 1 Big Qualicum River Hatchery effluent routes and sampling sites (not to scale)

TABLE 1. Big Qualicum River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 25/06/85 TOTAL HATCHERY LPM ON DATE: 127100

CONTAINER: TYPE - concrete raceway L(mm) - 76200
I.D. - roadside W(mm) - 4267
LPM - empty D(mm) - 1219

CLEANING: METHOD - pressure hosing LPM - 19881
FREQUENCY - yearly TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 7.77 PELLET SIZE - 2/32
NO. - 601976 FEED RATE - Satiation
TOTAL WT (Kg) - 4075 TEMP (C) - 13.5
CONVERSION RATIO - 1.3

COMMENTS:

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1 PK	2 2.5M	3 7.5M	4 7.5M	5 10M	6 15M	7 20M	8 35M	9 45M	10 60M	11 0	12 0	13 75M	14 85M	15 95M	BIOTA TN	TP
BOD	<2										<2						
NFR		8	8	7	19	52	15	16	10	7		7	10	134	21	32000	16500
FR		56	56	56	56	53	55	55	54	53		49	55	31	37		
TR		64	64	63	75	105	70	71	64	60		56	65	103	58		
NO2		.006	.007	.006	.007	.01	.008	.007	.007	.007		.007	.007	.008	.007		
NO3		.017	.011	.014	.012	*	*	.010	.009	.009		.008	.008	*	*		
TN		.2	.27	.22	.42	.91	.57	.31	.31	.18		.23	.13	2.9	.45		
TP		.035	.11	.04	.11	.59	.32	.12	.15	.045		.059	.056	2.18	.23		
N:P		5.7	2.5	5.5	3.8	1.5	1.8	2.6	2.1	4.0		3.9	2.3	1.3	2.0		

*SAMPLES WERE <.005

COMMENTS

2,5,7,10-15 3M DOWNSTREAM OF PIPE
3. AT FISHWAY
4. PIPE AT BRIDGE
6. IN RACEWAY AT EXIT
8. IN RACEWAY NEAR HOSING
9. IN RACEWAY
14. NFR,TR OVERNIGHT AT 60C
COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS

TABLE 2. Big Qualicum River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 25/06/85 TOTAL HATCHERY LPM ON DATE: 127100

CONTAINER: TYPE - Burrows Pond L(mm) - 15240
I.D. - 3 W(mm) - 4877
LPM - 1818 D(mm) - 914

CLEANING: METHOD - vacuum LPM - 225
FREQUENCY - weekly TIME TAKEN - 20-30 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 26 PELLET SIZE - 0
NO. - 10994 FEED RATE - 0
TOTAL WT (Kg) - 285.8 TEMP (C) - 13.506
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1 0	2 0	3 10M	4 15M	5 20	6 30M	7 35M	8	9	COMMENTS
BOD	<2									1-3,5-7. AT PIPE EXIT NEAR BRIDGE
NFR		<5	<5	445	<5	11	26			4. AT VACUUM DIS-CHARGE INTO PIPE
FR		54	59	107	51	63	58			
TR		59	64	552	56	74	84			
NO2		.006	*	*	.007	*	*			
NO3		.012	*	*	.008	*	*			
TN		.19	.7	.25	.21	.7	.71			
TP		.25	.23	3.1	.028	.81	.21			
N:P		.76	3.04	.08	7.5	.86	3.38			

*SAMPLES WERE <.005

TABLE 3. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Capilano Trough L(mm) - 6401
I.D. - 4A W(mm) - 813
LPM - 240 D(mm) - 464

CLEANING: METHOD - flush/sweep LPM - 314
FREQUENCY - daily TIME TAKEN - 2 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 2.0 PELLET SIZE - 3/64
NO. - 61662 FEED RATE - <50% ration
TOTAL WT (Kg) - 123 TEMP (C) - 8
CONVERSION RATIO - 1.04

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 60S	5 120S	BIOTA	COMMENTS
							TREATED WITH TER-
BOD	<2						RAMYCIN 10 DAYS
NFR		<5	85	<5	<5		AGO
FR		30	45	36	27		3. NFR,TR OVER-
TR		35	40	41	32		NIGHT DRYING AT
NO2		<.005	<.005	<.005	<.005		60C
NO3		.101	.104	.105	.105		COMPLICATIONS &
TN		.18	.83	.77	.30	40000	FLOCCULANT NATURE
TP		.03	.97	.45	.08	25300	OF SOLID MATERIAL
N:P		6	.86	1.71	3.75		PREVENTED ACCURATE
							ANALYSIS

TABLE 4. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Capilano Trough
I.D. - 8B
LPM - 240

L(mm) - 6401
W(mm) - 813
D(mm) - 381

CLEANING: METHOD - flush/sweep
FREQUENCY - daily

LPM - 397
TIME TAKEN - 1.5 min.

FISH: SPECIES - CN
WT(g) - 1.75
NO. - 74435
TOTAL WT (Kg) - 130

DIET TYPE - OMP
PELLET SIZE - 3/64
FEED RATE - <50% ration
TEMP (C) - 8
CONVERSION RATIO - 1.0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	BIOTA	COMMENTS
	0	0	30S	75S		
BOD	3					EXPERMENT GROUP
NFR		42	<5	14		GIVEN HORMONE TO
FR		11	38	64		STERILIZE
TR		53	43	65		
NO2		<.005	<.005	<.005		
NO3		.108	.107	.108		
TN		1.04	.92	.96	40000	
TP		.125	.52	.33	29800	
N:P		8.32	1.77	2.91		

TABLE 5. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Capilano Trough L(mm) - 6401
I.D. - 10A W(mm) - 813
LPM - 240 D(mm) - 457

CLEANING: METHOD - flush/sweep LPM - 397
FREQUENCY - daily TIME TAKEN - 1.5 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 1.5 PELLET SIZE - 1/16
NO. - 62004 FEED RATE - <50% ration
TOTAL WT (Kg) - 93 TEMP (C) - 8
CONVERSION RATIO - 1.14

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 / 0	2 / 0	3 / 30S	4 / 120S	BIOTA	COMMENTS
BOD	2					EXPERIMENTAL GROUP
NFR		<5	<5	<5		GIVEN HORMONE TO
FR		33	33	31		MASCULINIZE
TR		38	38	36		
NO2		<.005	<.005	<.005		
NO3		.108	.107	.106		
TN		.69	.47	.53	45000	
TP		.24	.28	.23	24500	
N:P		2.88	1.68	2.3		

TABLE 6. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Chamber 10 Raceway
I.D. - 10B
LPM -

L(mm) - 10973
W(mm) - 4877
D(mm) - 648

CLEANING: METHOD - flush
FREQUENCY - weekly

LPM
TIME TAKEN - 1.5 min.

FISH: SPECIES - CN
WT(g) - 4.1
NO. - 48545
TOTAL WT (Kg) - 200

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.45

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 60S	BIOTA	COMMENTS
BOD	20					
NFR		212	10	15		
FR		90	191	17		
TF		303	201	32		
NO2		.006	<.005	<.005		
NO3		.083	.099	.108		
TN		10	3	.93	54000	
TP		3.7	.95	.54	24300	
N:P		2.7	3.16	1.72		

TABLE 7. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Chamber 10 Raceway
I.D. - 10C
LPM -
L(mm) - 10973
W(mm) - 4877
D(mm) - 648

CLEANING: METHOD - flush
FREQUENCY - weekly
LPM -
TIME TAKEN - 3.0 min.

FISH: SPECIES - CN
WT(g) - 4.7
NO. - 49496
TOTAL WT (Kg) - 233
DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.11

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 120S	4 180S	BIOTA	COMMENTS
BOD	7					
NFR		<5	136	16		
FR		44	81	26		
TF		49	217	42		
NO2		<.005	.007	.005		
NO3		.103	.086	.103		
TN		.87	14	1.1	53000	
TP		.983	8.02	1.71	28600	
N:P		.89	1.75	.64		

TABLE 8. Capilano River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 06/06/85 TOTAL HATCHERY LPM ON DATE:

CONTAINER: TYPE - Chamber 10 Raceway L(mm) - 10973
I.D. - 10D W(mm) - 4877
LPM - D(mm) - 648

CLEANING: METHOD - flush LPM -
FREQUENCY - weekly TIME TAKEN - 4.0 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 5.25 PELLET SIZE -
NO. - 49479 FEED RATE -
TOTAL WT (Kg) - 260 TEMP (C) - 7.5
CONVERSION RATIO - 0.97

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 120S	4 240S	BIOTA	COMMENTS
BOD	4					
NFR		<5	73	15		
FR		16	72	27		
TF		21	145	42		
NO2		<.005	<.005	<.005		
NO3		.014	.109	.111		
TN		.72	9	1.7	44000	
TP		.114	6.46	.917	26600	
N:P		6.32	1.39	1.85		

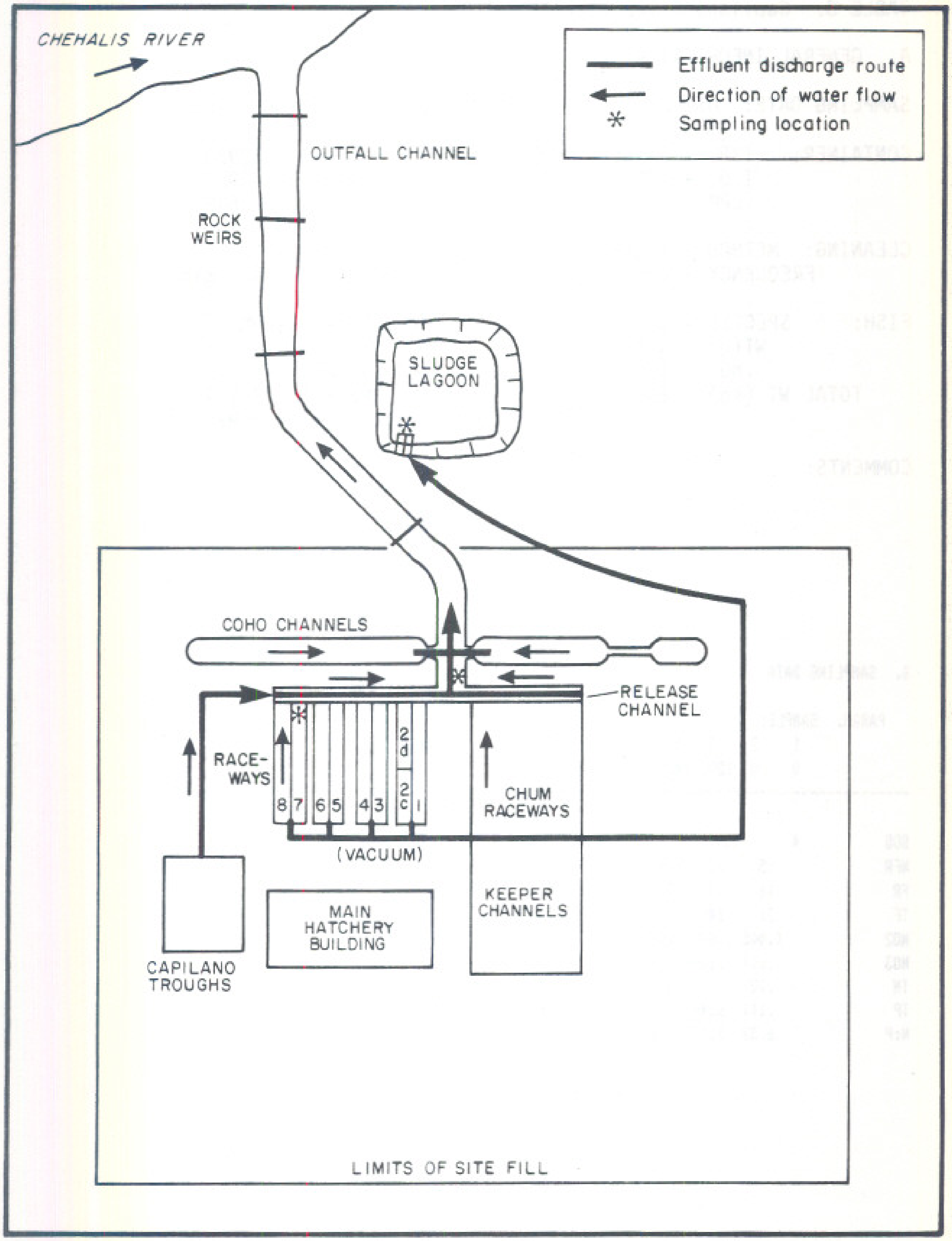

Figure 2 Chehalis River Hatchery effluent routes and sampling sites (not to scale)

TABLE 9. Chehalis River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 10/06/85 TOTAL HATCHERY LPM ON DATE: 32890

CONTAINER: TYPE - Concrete raceway L(mm) - 33100
I.D. - 2C W(mm) - 4000
LPM - 4980 D(mm) - 1800

CLEANING: METHOD - vacuum LPM - 91
FREQUENCY - weekly TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 2.4 PELLET SIZE - 25% 3/64, 75% 1/16
NO. - 193000 FEED RATE -
TOTAL WT (Kg) - 463 TEMP (C) - 8
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	11
	0	0	0	8M	16M	43M	52M	60M	73M	83.5M	95M
BOD	<2										
NFR		<5	<5	799	1200	45	560	778	335	676	508
FR		0	15	-94	180	59	61	312	183	40	95
TR		<5	20	705	1380	104	621	1090	518	716	603
NO2		*	*	.005	.009	.005	.008	*	*	*	*
NO3		.083	.087	.002	.013	.072	*	*	*	*	*
TN		.28	.25	14	91	2.1	32	90	46	52	37
TP		.017	.021	5.9	13	.3	7.1	13.6	6.7	10.9	8.2
N:P		16.47	11.9	2.37	7	7	4.51	6.62	6.87	4.77	4.51

* SAMPLES <.005

COMMENTS

3. BRUSHING DOWN THE SCREENS(DONE DAILY) AT THE REARING CHANNEL
4. SLIGHTLY DISCOLORED
NFR,TR OVERNIGHT AT 60C. COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS
5,8. SHUT DOWN TO FEED FISH

TABLE 10. Chehalis River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 10/06/85 TOTAL HATCHERY LPM ON DATE: 32890

CONTAINER: TYPE - Concrete raceway
I.D. - 2D
LPM - 4980

L(mm) - 33100
W(mm) - 4000
D(mm) - 1800

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM - 91
TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN
WT(g) - 2.4
NO. - 94000
TOTAL WT (Kg) - 226

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 8
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 10M	2 15M	3 30M	4 50M	5 70M	6 90M	BIOTA	COMMENTS
BOD								1. DURING PEAK
NFR	775	399	572	292	326	674		3. FLOW RATE SLOW
FR	149	-137	-41	178	385	107		AFTER 3,4,5 STOP
TR	924	262	531	470	711	781		TO FEED FISH
NO2	*	*	*	*	*	*		6. END
NO3	*	*	*	*	*	*		2,3. NFR,TR OVER-
TN	45	34	50	34	62	56	52000	NIGHT AT 60C
TP	8.8	10.4	9.2	5.2	9.2	9.5	11100	COMPLICATIONS &
N:P	5.11	3.27	5.43	6.54	6.74	5.89		FLOCCULANT NATURE
								OF SOLID MATERIAL
								PREVENTED ACCURATE
								ANALYSIS

*SAMPLES WERE <.005

TABLE 11. Chehalis River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 10/06/85 TOTAL HATCHERY LPM ON DATE: 32890

CONTAINER: TYPE - Concrete raceway L(mm) - 33100
I.D. - 7 W(mm) - 4000
LPM - D(mm) - 1800

CLEANING: METHOD - pressure hosing LPM -
FREQUENCY - yearly TIME TAKEN - entire day

FISH: SPECIES - CO DIET TYPE -
WT(g) - 15.5 PELLET SIZE -
NO. - 117,810 FEED RATE -
TOTAL WT (Kg) - 1826 TEMP (C) - 8
CONVERSION RATIO -

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	COMMENTS
			PEAK CLEANING
BOD			1. CONTROL
NFR	9	112	2. DURING CLEANING
FR	17	18	AT END OF RACEWAY
TR	26	130	
NO2	<.005	.007	
NO3	.072	.076	
TN	2.2	1.1	
TP	.3	1.4	
N:P	7.33	.79	

TABLE 12. Chehalis River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 10/06/85 TOTAL HATCHERY LPM ON DATE: 32890

CONTAINER: TYPE - Outflow channel
I.D. - 7
LPM - 32890

L(mm) - 0
W(mm) - 0
D(mm) - 0

CLEANING: METHOD - *
FREQUENCY - yearly

LPM -
TIME TAKEN - entire day

FISH: SPECIES - 0
WT(g) - 0
NO. - 0
TOTAL WT (Kg) - 0

DIET TYPE - 0
PELLET SIZE - 0
FEED RATE - 0
TEMP (C) - 8
CONVERSION RATIO - 0

COMMENTS:

* During cleaning of concrete raceway 7.

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 10M	4 40M	5 70M	6 80M	7 90M	COMMENTS
BOD	>2							TAKEN AT EXIT OF
NFR		48	22	17	124	28	27	RELEASE CHANNEL
FR		35	11	21	44	10	23	
TR		83	33	38	168	38	50	
NO2		*	*	*	*	*	*	
NO3		.086	.091	.091	.09	.092	.091	
TN		.32	.31	.25	.73	.36	.43	
TP		.092	.058	.034	.24	.11	.078	
N:P		3.48	5.34	7.35	3.04	6.64	5.51	

*SAMPLES WERE <.005

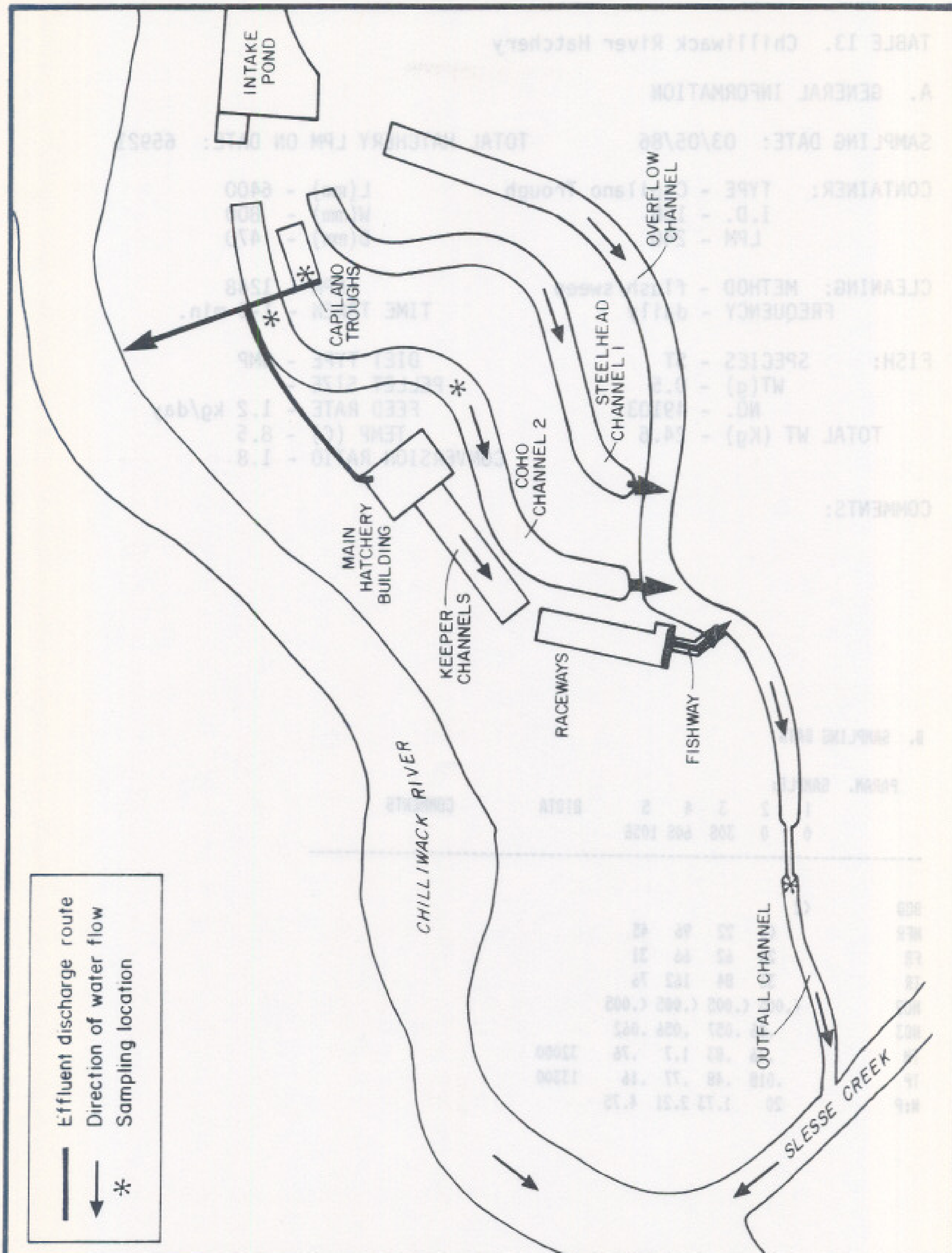

Figure 3 Chilliwack Hatchery effluent routes and sampling sites (not to scale)

TABLE 13. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/86 TOTAL HATCHERY LPM ON DATE: 65921

CONTAINER: TYPE - Capilano Trough
I.D. - 15B
LPM - 240

L(mm) - 6400
W(mm) - 800
D(mm) - 470

CLEANING: METHOD - flush/sweep
FREQUENCY - daily

LPM - 1248
TIME TAKEN - 1-3 min.

FISH: SPECIES - ST
WT(g) - 0.5
NO. - 49103
TOTAL WT (Kg) - 24.6

DIET TYPE - OMP
PELLET SIZE -
FEED RATE - 1.2 kg/day
TEMP (C) - 8.5
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 60S	5 105S	BIOTA	COMMENTS
BOD	<2						
NFR		<5	22	96	45		
FR		28	62	66	31		
TR		33	84	162	76		
NO2		<.005	<.005	<.005	<.005		
NO3		.06	.057	.056	.062		
TN		.36	.83	1.7	.76	32000	
TP		.018	.48	.77	.16	13300	
N:P		20	1.73	2.21	4.75		

TABLE 14. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/86 TOTAL HATCHERY LPM ON DATE: 65921

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 16A W(mm) - 800
LPM - 240 D(mm) - 470

CLEANING: METHOD - flush/sweep LPM - 986
FREQUENCY - daily TIME TAKEN - 1-3 min.

FISH: SPECIES - ST DIET TYPE - OMP
WT(g) - 0.3 PELLET SIZE -
NO. - 49668 FEED RATE - 1.4 kg/day
TOTAL WT (Kg) - 14.9 TEMP (C) - 8.5
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 60S	5 95S	BIOTA	COMMENTS
BOD	3						
NFR		<5	185	134	61		
FR		34	320	179	186		
TR		39	505	313	247		
NO2		<.005	<.005	<.005	<.005		
NO3		.067	.057	.055	.058		
TN		.47	1.7	4.2	6.7	42000	
TP		.033	3.7	5.16	3.4	12800	
N:P		14.24	.46	.81	1.97		

TABLE 15. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/86 TOTAL HATCHERY LPM ON DATE: 65921

CONTAINER: TYPE - Capilano Trough
I.D. - 16B
LPM - 240
L(mm) - 6400
W(mm) - 800
D(mm) - 470

CLEANING: METHOD - flush/sweep
FREQUENCY - daily
LPM - 867
TIME TAKEN - 1-3 min.

FISH: SPECIES - ST
WT(g) - 0.3
NO. - 47375
TOTAL WT (Kg) - 14.2
DIET TYPE - OMP
PELLET SIZE -
FEED RATE - 1.2 kg/day
TEMP (C) - 8.5
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 60S	5 90S	BIOTA	COMMENTS
BOD	2						
NFR		<5	64	32	6		
FR		22	18	31	25		
TR		27	82	63	37		
NO2		<.005	<.005	<.005	<.005		
NO3		.065	.06	.079	.062		
TN		.61	2	1.1	.48	65000	
TP		.095	1.15	.69	.14	11800	
N:P		6.42	1.74	1.59	3.43		

TABLE 16. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/86 TOTAL HATCHERY LPM ON DATE: 65921

CONTAINER: TYPE - Square Capilano Trough L(mm) - 6400
I.D. - 17A W(mm) - 800
LPM - 240 D(mm) - 470

CLEANING: METHOD - flush/sweep LPM - 1040
FREQUENCY - daily TIME TAKEN - 1-3 min.

FISH: SPECIES - ST DIET TYPE - OMP
WT(g) - 46662 PELLET SIZE -
NO. - 0.3 FEED RATE - 1.2 kg/day
TOTAL WT (Kg) - 14.0 TEMP (C) - 8.5
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	BIOTA	COMMENTS
	0	0	30S	75S	115S		
BOD	3						
NFR		24	124	157	14		
FR		41	49	54	34		
TR		65	173	211	48		
NO2		<.005	<.005	<.005	<.005		
NO3		.068	.062	.059	.063		
TN		.3	8	8	1.2	53000	
TP		.043	1.1	.24	.71	6500	
N:P		6.98	7.27	33.33	1.69		

TABLE 17. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/86 TOTAL HATCHERY LPM ON DATE: 65921

CONTAINER: TYPE - Capilano Trough
I.D. - 17B
LPM - 240

L(mm) - 6400
W(mm) - 800
D(mm) - 470

CLEANING: METHOD - flush/sweep
FREQUENCY - daily

LPM - 1115
TIME TAKEN - 1-3 min.

FISH: SPECIES - ST
WT(g) - 0.4
NO. - 45958
TOTAL WT (Kg) - 18.4

DIET TYPE - OMP
PELLET SIZE -
FEED RATE - 0.9 kg/day
TEMP (C) - 8.5
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1 0	2 0	3 30S	4 60S	5 105S	BIOTA	COMMENTS
BOD	<2						
NFR		<5	<5	5	15		
FR		23	25	37	27		
TR		28	30	42	42		
NO2		<.005	<.005	<.005	<.005		
NO3		.069	.068	.067	.065		
TN		.35	.55	1.1	.85	51000	
TP		.036	.074	.43	.41	11700	
N:P		9.72	7.43	2.56	2.07		

TABLE 18. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/85 TOTAL HATCHERY LPM ON DATE: 39077

CONTAINER: TYPE - Earthen Channel L(mm) - 252984
I.D. - 2 (section 1) W(mm) - 4481
LPM - 10195 D(mm) - 1372

CLEANING: METHOD - pressure hosing/ weeding LPM - 12111
FREQUENCY - yearly TIME TAKEN - 75 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 16.8 PELLET SIZE -
NO. - 1059316 FEED RATE -
TOTAL WT (Kg) - 40856.7 TEMP (C) - 8
CONVERSION RATIO -

COMMENTS:

B. SAMPLING DATA

PARAM. SAMPLE:	1 0	2 10M	3 20M	4 30M	5 40M	6 0	7 20M	8 35M	BIOTA	COMMENTS
										ALL SAMPLES FOR
BOD										SECTION 1
NFR	<5	131	52	53	21	10	183	365		2-5 DURING DRAIN-
FR	26	29	28	26	33	28	167	45		ING OF SECTIONS 1-
TR	31	160	80	79	54	38	350	410		4
NO2	*	*	*	*	*	*	.011	.014		6 PRIOR TO HOSING
NO3	.011	.017	.133	.199	.122	.105	.089	.089		7-8 DURING HOSING
TN	.21	.96	.53	.79	.54	.33	8.0	9.5	28000	
TP	.011	.305	.15	.248	.110	.07	2.8	3.6	4920	
N:P	19.1	3.15	3.53	3.19	4.9	4.71	2.86	2.64		

*SAMPLES WERE <.005

TABLE 19. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 03/05/85 TOTAL HATCHERY LPM ON DATE: 39077

CONTAINER: TYPE - Earthen Channel L(mm) - 252984
I.D. - 2 (sections 2 - 5) W(mm) - 4481
LPM - 10195 D(mm) - 1372

CLEANING: METHOD - pressure hosing/weeding LPM - 12111
FREQUENCY - yearly TIME TAKEN - 120 - 210 min per section

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 16.8 PELLET SIZE -
NO. - 1059316 FEED RATE -
TOTAL WT (Kg) - 40856.7 TEMP (C) - 8
CONVERSION RATIO -

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	COMMENTS
SECTIONS	2	3	4	5	5	
BOD					<2	SECTIONAL DIMENSIONS ATTACHED
NFR	162	572	1360	1260		
FR	21	209	B0	710		2,3. NFR,FR OVERNIGHT DRY ING AT 60C. COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS
TR	183	363	1280	1970		

*SAMPLES WERE COLLECTED BY STAFF AND DID NOT REACH THE LAB WITHIN THE SPECIFIED 48HRS
TN AND TP WERE NOT RUN

SAMPLES FOR EACH SECTION TAKEN AT VISUAL PEAK OF TURBIDITY.
TAKEN AT SECTION 5 WEIR.

TABLE 20. Chilliwack River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 21/05/85 TOTAL HATCHERY LPM ON DATE:

CONTAINER:	TYPE - Outfall Channel		L(mm) - 0
	I.D. - 0		W(mm) - 0
	LPM - 0		D(mm) - 0
CLEANING:	METHOD - 0		LPM - 0
	FREQUENCY - 0		TIME TAKEN - 0
FISH:	SPECIES - 0		DIET TYPE - 0
	WT(g) - 0		PELLET SIZE - 0
	NO. - 0		FEED RATE - 0
	TOTAL WT (Kg) - 0		TEMP (C) - 0
			CONVERSION RATIO - 0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	COMMENTS
BOD	<2			2. CONTROL
NFR		<5	<5	3. DURING VISUAL PEAK OF
FR		82	83	TURBIDITY
TR		87	88	
NO2		<.005	<.005	
NO3		.112	.112	
TN		.24	.38	
TP		.013	.033	
N:P		18.46	11.52	

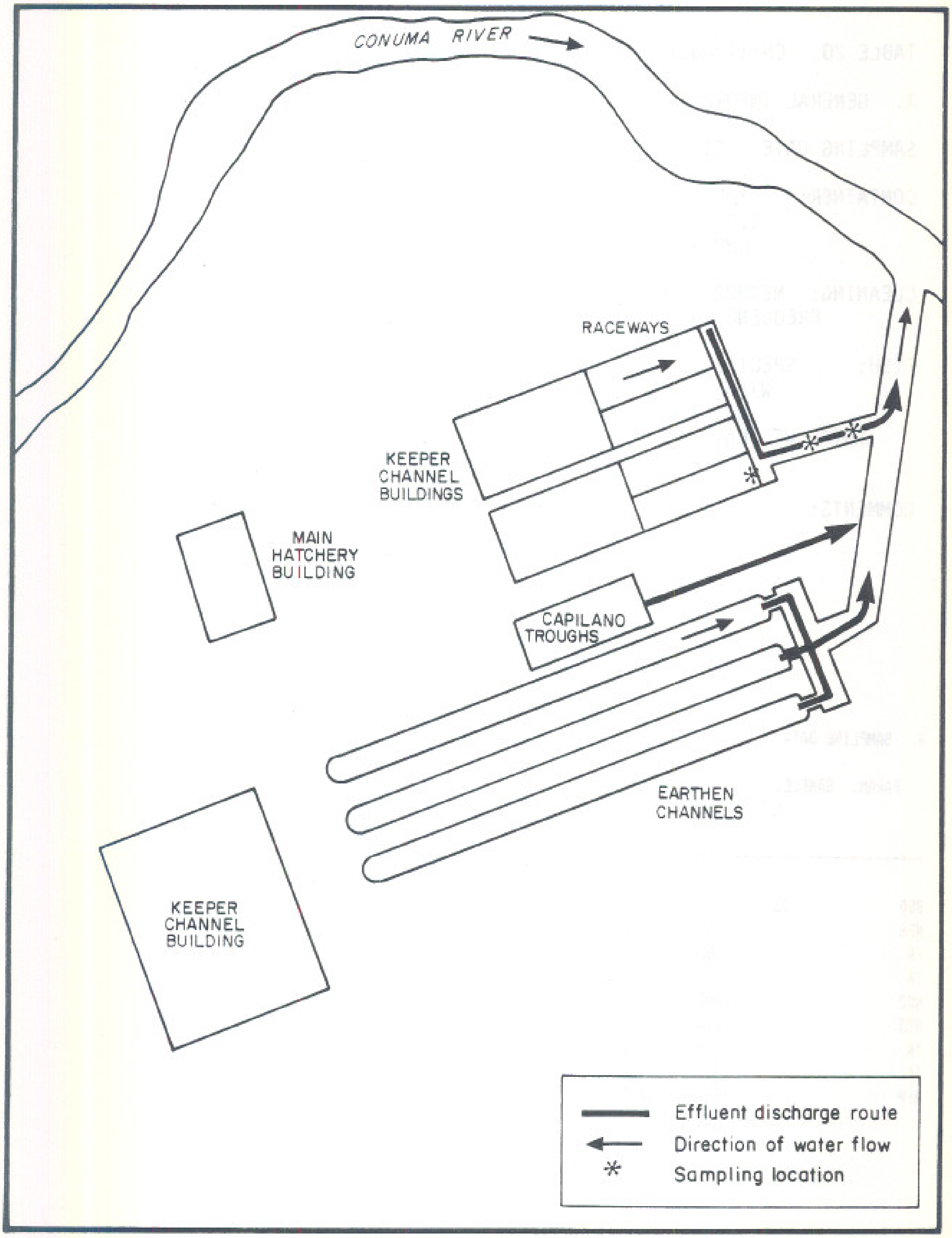

Figure 4 Conuma Hatchery effluent routes and sampling sites (not to scale)

TABLE 21. Conuma River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 30/05/85 TOTAL HATCHERY LPM ON DATE: 12000*

CONTAINER: TYPE - Concrete Raceway
I.D. - 1
LPM - 1600

L(mm) - 26800
W(mm) - 7600
D(mm) - 970

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM -
TIME TAKEN - 1.5 hrs.

FISH: SPECIES - CO
WT(g) - 2.3
NO. - 120000
TOTAL WT (Kg) - 276

DIET TYPE - OMP
PELLET SIZE -
FEED RATE - 10 kg/day 3.5%
TEMP (C) - 9
CONVERSION RATIO - 1.2

COMMENTS:

*Flow rate system: 4100 LPM originally + approx. 20m downstream 8000 LPM equalling 12000 LPM.

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0M	2 .5M	3 5M	4 7.5M	5 10M	6 20M	7 35M	8 45M	9 55M	10 70M	11 75M	12 80M	13 84M	14 84.5M	BIOTA
BOD	315														
NFR		355	334	12	239	209	<5	308	67	108	15	246	11	5	
FR		105	120	123	81	40	33	108	59	70	98	53	33	27	
TR		105	454	135	320	249	38	416	126	178	113	299	44	32	
TN															93000
TP															14900

COMMENTS

4,11,14. TAKEN 12M DOWNSTREAM WHERE EFFLUENT COMPLETELY MIXED IN CHANNEL WATER
THE REMAINING SAMPLES WERE TAKEN NEAR THE HOSE IN THE SURROUNDING WATER

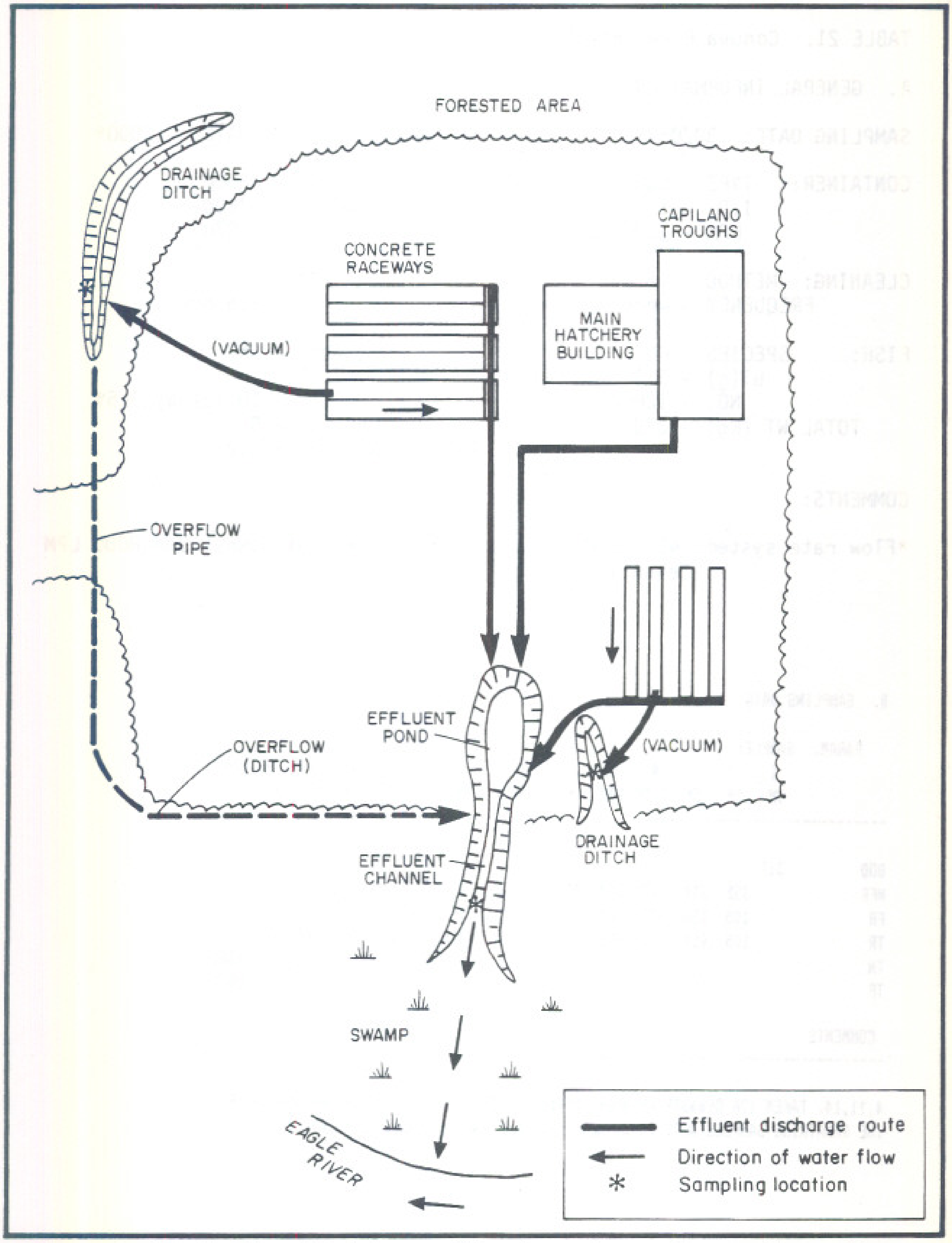

Figure 5 Eagle River Hatchery effluent routes and sampling sites (not to scale)

TABLE 22. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 8868

CONTAINER: TYPE - Concrete Raceway
I.D. - 1
LPM - 1050

L(mm) - 32400
W(mm) - 3000
D(mm) - TD = 1110 BD = 1220

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM - 757
TIME TAKEN - 15-20 min.

FISH: SPECIES - CO
WT(g) - 2
NO. - 340000
TOTAL WT (Kg) - 680

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.55

COMMENTS:

B. SAMPLING DATA

PARAM. SAMPLE:	1 0	2 2M	3 5M	4 10M	5 15M	6 18M	7 0	COMMENTS
BOD							<2	THIS RACEWAY HAD
NFR	<5	<5	<5	<5	<5	<5		JUST BEEN VACUUMED
FR	80	86	90	93	87	82		-VALUES NOT REPRE-
TR	85	91	95	98	92	87		SENTATIVE AND DEL-
NO2	*	*	*	*	*	*		ETED FROM ANALYSIS
NO3	.088	.09	.09	.089	.089	.089		
TN	.53	.62	.58	.59	.63	.64		
TP	.036	.058	.055	.051	.061	.065		
N:P	14.72	10.69	10.55	11.57	10.32	9.85		

*SAMPLES <.005

TABLE 23. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 8868

CONTAINER: TYPE - Concrete Raceway
I.D. - 4
LPM - 1250
L(mm) - 32400
W(mm) - 3000
D(mm) - TD = 1110 BD = 1220

CLEANING: METHOD - vacuum
FREQUENCY - weekly
LPM - 757
TIME TAKEN - 15-20 min.

FISH: SPECIES - CN
WT(g) - 3.5
NO. - 175000
TOTAL WT (Kg) - 612.5
DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 2.4

COMMENTS:

PARAM.	SAMPLE: 1	2	3	4	5	6	7	COMMENTS
	0	5M	10M	15M	16M	0		
BOD								2. 1/4 WAY DONE
NFR								3. 1/2 WAY DONE
FR								4. 3/4 WAY DONE
TR								5. END
NO2	<.005	<.005	<.005	<.005	<.005			SAMPLE 5 ANALYSIS
NO3	.085	.088	.088	.088	.088			INCOMPLETE. LOST
TN	.32	.36	.33	.3	0			IN LAB.
TP	.032	.032	.025	.3	0			
N:P	10	11.25	13.2	1	0			

TABLE 24. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 8868

CONTAINER: TYPE - Concrete Raceway
I.D. - 5
LPM - 1100

L(mm) - 32400
W(mm) - 3000
D(mm) - TD = 1110 BD = 1220

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM - 757
TIME TAKEN - 15-20 min.

FISH: SPECIES - CN
WT(g) - 3.5
NO. - 175000
TOTAL WT (Kg) - 612.5

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.94

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 2.5M	3 4.5M	4 6M	5 10M	6 0	BIOTA	COMMENTS
BOD								2. 1/3 WAY DONE
NFR								3. 1/2 WAY DONE
FR								4. 2/3 WAY DONE
TR								5. END
NO2	<.005	<.005	<.005	<.005	<.005			NFR,FR,TN,TP COULD
NO3	.086	.091	.093	.092	.092			NOT BE RUN. SAMP-
TN							27000	LES LOST IN LAB
TP							14200	BEFORE COMPLETION

TABLE 25. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 8868

CONTAINER: TYPE - Aluminum Raceway
I.D. - 3
LPM - 817

L(mm) - 21400
W(mm) - 1820
D(mm) - 750

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly

LPM - 757
TIME TAKEN - 10 min.

FISH: SPECIES - CO
WT(g) - 3.5
NO. - 175000
TOTAL WT (Kg) - 612.5

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.22

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	COMMENTS
	0	2M	4M	7M	9M	12M	0		
									2. FILTER CLEANED
BOD							<2		4. 1/2 WAY DONE
NFR	<5	51	<5	<5	<5	<5			6. END
FR	82	98	86	88	91	88			
TR	87	149	91	93	96	93			
NO2	<.005	<.005	<.005	<.005	<.005	<.005			
NO3	.097	.085	.091	.091	.092	.092			
TN	.3	4.1	.56	.46	.48	.44			
TP	.01	.996	.061	.051	.042	.038			
N:P	30	4.11	9.18	9.02	11.43	11.58			

TABLE 26. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 8868

CONTAINER: TYPE - Aluminum Raceway
I.D. - 4
LPM - 817
L(mm) 21400
W(mm) - 1820
D(mm) - 750

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly
LPM - 757
TIME TAKEN - 10 min.

FISH: SPECIES - CO
WT(g) - 3.5
NO. - 175000
TOTAL WT (Kg) - 612.5
DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.22

COMMENTS:

B. SAMPLING DATA

PARAM. SAMPLE:	1 0	2 1M	3 3M	4 5M	5 7M	6 0	COMMENTS
BOD						<2	NFR,FR,TN,TP COULD NOT BE
NFR					<5		RUN. SAMPLES LOST IN LAB
FR					90		FORE COMPLETION.
TR					95		
NO2	<.005	<.005	<.005	<.005	<.005		
NO3	.092	.092	.094	.102	.096		
TN							
TP							
N:P							

TABLE 27. Eagle River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE:

CONTAINER: TYPE - Effluent Channel
I.D. - 0
LPM - 0

L(mm) - 0
W(mm) - 0
D(mm) - 0

CLEANING: METHOD - 0
FREQUENCY - 0

LPM - 0
TIME TAKEN - 0

FISH: SPECIES - 0
WT(g) - 0
NO. - 0
TOTAL WT (Kg) - 0

DIET TYPE - 0
PELLET SIZE - 0
FEED RATE - 0
TEMP (C) - 0
CONVERSION RATIO - 0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	COMMENTS
				1,2. CONTROL
BOD	<2			3. DURING PEAK CLEANING OF
NFR		<5	<5	CHANNEL 5
FR		82	83	
TR		87	88	
NO2		<.005	<.005	
NO3		.095	.095	
TN		.26	.29	
TP		.018	.015	
N:P		14.44	19.33	

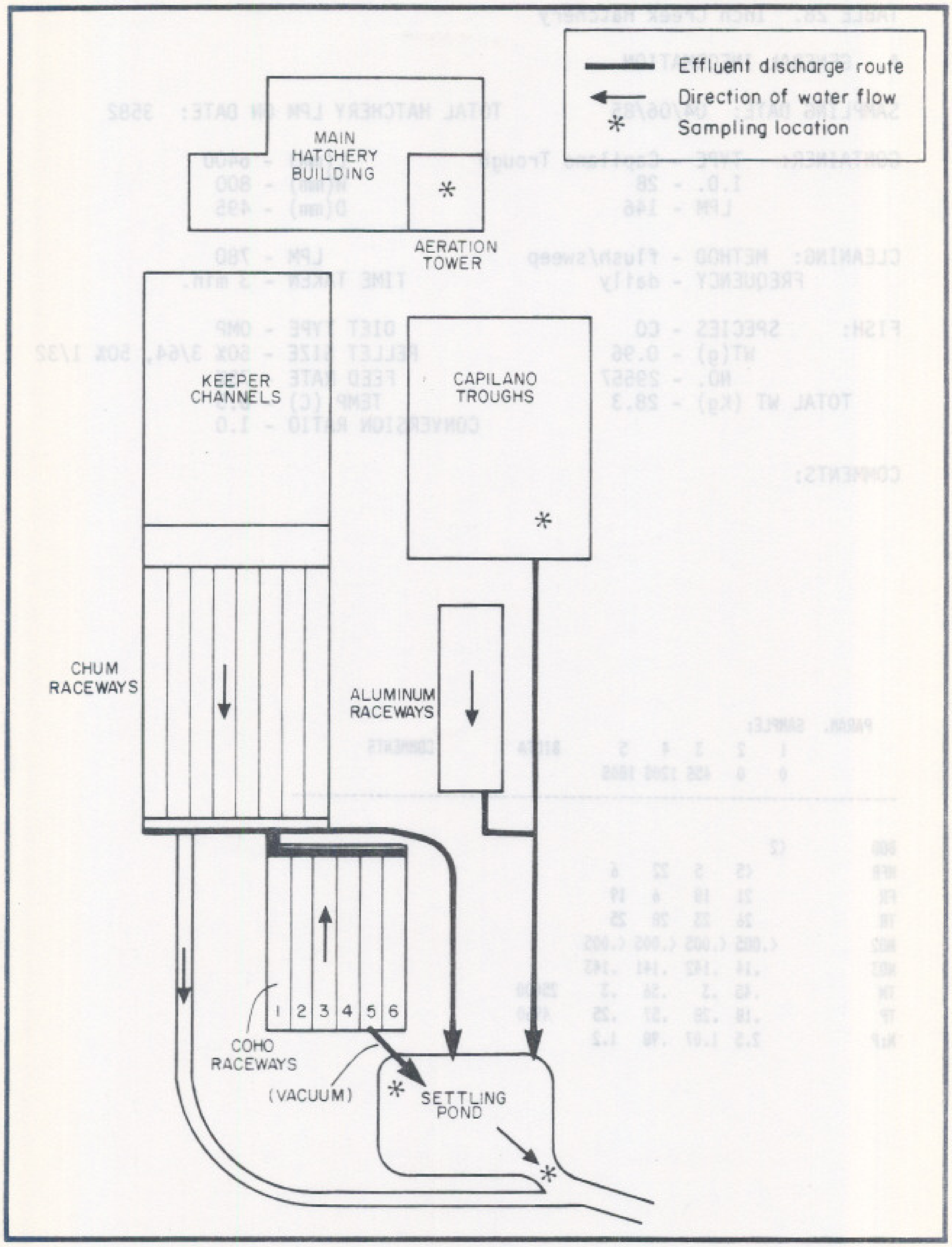

Figure 6 Inch Hatchery effluent routes and sampling sites (not to scale)

TABLE 28. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 04/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Capilano Trough
I.D. - 2B
LPM - 146

L(mm) - 6400
W(mm) - 800
D(mm) - 495

CLEANING: METHOD - flush/sweep
FREQUENCY - daily

LPM - 780
TIME TAKEN - 3 min.

FISH: SPECIES - CO
WT(g) - 0.96
NO. - 29557
TOTAL WT (Kg) - 28.3

DIET TYPE - OMP
PELLET SIZE - 50% 3/64, 50% 1/32
FEED RATE - 75%
TEMP (C) - 6.5
CONVERSION RATIO - 1.0

COMMENTS:

PARAM.	SAMPLE: 1	2	3	4	5	BIOTA	COMMENTS
	0	0	45S	120S	180S		
BOD	<2						
NFR		<5	5	22	6		
FR		21	18	6	19		
TR		26	23	28	25		
NO2		<.005	<.005	<.005	<.005		
NO3		.14	.142	.141	.143		
TN		.45	.3	.56	.3	25000	
TP		.18	.28	.57	.25	4960	
N:P		2.5	1.07	.98	1.2		

TABLE 29. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 04/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 5A W(mm) - 800
LPM - 120 D(mm) - 495

CLEANING: METHOD - flush/sweep LPM - 780
FREQUENCY - daily TIME TAKEN - 2.5 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 1.2 PELLET SIZE - 50% 3/64, 50% 1/32
NO. 39928 FEED RATE - 75%
TOTAL WT (Kg) - 48.28 TEMP (C) - 6.5
CONVERSION RATIO - 1.0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	BIOTA	COMMENTS
	0	0	30S	90S	150S		
BOD	5						
NFR		18	<5	24	<5		
FR		29	26	38	17		
TR		47	31	62	22		
NO2		<.005	<.005	<.005	<.005		
NO3		.128	.136	.141	.143		
TN		.65	.74	1.2	.4	52000	
TP		.92	.60	1.61	.18	30400	
N:P		.71	1.23	.75	2.22		

TABLE 30. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 04/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 5B W(mm) - 800
LPM - 120 D(mm) - 495

CLEANING: METHOD - flush/sweep LPM - 650
FREQUENCY - daily TIME TAKEN - 3.5 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.79 PELLET SIZE - 1/32
NO. - 43840 FEED RATE - 75%
TOTAL WT (Kg) - 34.63 TEMP (C) - 6.5
CONVERSION RATIO - 1.4

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 45S	4 120S	5 200S	BIOTA	COMMENTS
BOD	2						
NFR		<5	<5	13	21		
FR		169	24	82	90		
TR		174	79	95	111		
NO2		<.005	<.005	<.005	<.005		
NO3		.147	.144	.139	.135		
TN		.2	2.1	2.4	4	58000	
TP		.11	.42	1.70	1.82	25400	
N:P		1.82	5	1.41	2.2		

TABLE 31. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 05/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Concrete Raceway
I.D. - 4
LPM - 95.7*
L(mm) - 30000
W(mm) - 3000
D(mm) - 660

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly
LPM - 598
TIME TAKEN - 7 min.

FISH: SPECIES - CO
WT(g) - 2.44
NO. - 31348
TOTAL WT (Kg) - 76.5
DIET TYPE - OMP
PELLET SIZE - 1/16
FEED RATE - 65%
TEMP (C) - 6.5
CONVERSION RATIO - 1.2

COMMENTS:

* Flow found using Leeds & Northrup O_2 meter and calculated on Apple IIe Computer.

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1 0	2 0	3 6M	4 4M	5 7M	6 7M
BOD	2					
NFR		198	11	34	17	17
FR		-15	79	48	35	27
TR		183	90	82	52	44
NO2		<.005	.007	.012	<.005	.007
NO3		.173	.17	.15	.169	.158
TN		.94	2	4.97	.82	2.1
TP		.524	.49	3.8	.27	1.47
N:P		1.79	4.08	2.9	3.04	1.42

COMMENTS

3,4. AT EFFLUENCE
5. DISTURBED WATER IN POND AROUND HOSE
6. DIRTY END OF CONTAINER
2. NFR,TR OVER-NIGHT DRYING AT 60C
COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS

TABLE 32. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 05/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Concrete Raceway
I.D. - 4
LPM - 219.6

L(mm) - 30000
W(mm) - 3000
D(mm) - 660

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly

LPM - 598
TIME TAKEN - 5 min.

FISH: SPECIES - CO
WT(g) - 2.14
NO. - 22989
TOTAL WT (Kg) - 49.2

DIET TYPE - OMP
PELLET SIZE - 50% 3/64, 50% 1/16
FEED RATE - 65%
TEMP (C) - 6.5
CONVERSION RATIO - 1.3

COMMENTS:

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1	2 2M	3 4M	4 5M	BIOTA	COMMENTS
						2. AT HOSE
BOD						3. DISTURBED WATER
NFR		116	117	<5		IN POND
FR		71	48	25		5. END
TR		187	69	30		3. NFR,TR OVER-
NO2		.012	.006	<.005		NIGHT DRYING AT
NO3		.16	.173	.192		60C
TN		16	2.4	.69	118000	COMPLICATIONS &
TP		7.32	1.07	.15	14200	FLOCCULANT NATURE
N:P		2.19	2.24	4.6		OF SOLID MATERIAL
						PREVENTED ACCURATE
						ANALYSIS

TABLE 33. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 05/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Concrete Raceway
I.D. - 6
LPM - 697.5

L(mm) - 30000
W(mm) - 3000
D(mm) - 660

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly

LPM - 598
TIME TAKEN - 6 min.

FISH: SPECIES - CO
WT(g) - 2.66
NO. - 36975
TOTAL WT (Kg) - 98.4

DIET TYPE - OMP
PELLET SIZE - 1/16
FEED RATE - 65%
TEMP (C) - 6.5
CONVERSION RATIO - 1.5

COMMENTS:

B. SAMPLING DATA

PARAM. (RECOMM.)	SAMPLE: 1	2 2M	3 3M	4 4M	5	6 6M	7	8	9	COMMENTS
										3. DISTURBED WATER
BOD										IN POND
NFR		75	310	620		<5				4. AT HOSE
FR		94	64	73		16				
TR		169	374	693		21				
NO2		.012	.01	<.005		.005				
NO3		.167	.169	.058		.178				
TN		21	15	30		36				
TP		6.54	5.7	18		.043				
N:P		3.28	2.63	1.67		837.2				

TABLE 34. Inch Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 04/06/85 TOTAL HATCHERY LPM ON DATE: 3582

CONTAINER: TYPE - Effluent Pond/ Aeration Tower
I.D. - 0
LPM - 0
L(mm) - 0
W(mm) - 0
D(mm) - 0

CLEANING: METHOD - 0
FREQUENCY - 0
LPM - 0
TIME TAKEN - 0

FISH: SPECIES - 0
WT(g) - 0
NO. - 0
TOTAL WT (Kg) - 0
DIET TYPE - 0
PELLET SIZE - 0
FEED RATE - 0
TEMP (C) - 0
CONVERSION RATIO - 0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	COMMENTS
BOD	<2		<2		1,2. POND EFFLUENT
NFR		<5		<5	DURING CLEANING
FR		14		14	3,4. AERATION
TR		19		19	TOWER
NO2		<.005		<.005	
NO3		.142		<.005	
TN		.3		.2	
TP		.28		.002	
N:P		1.07		100	

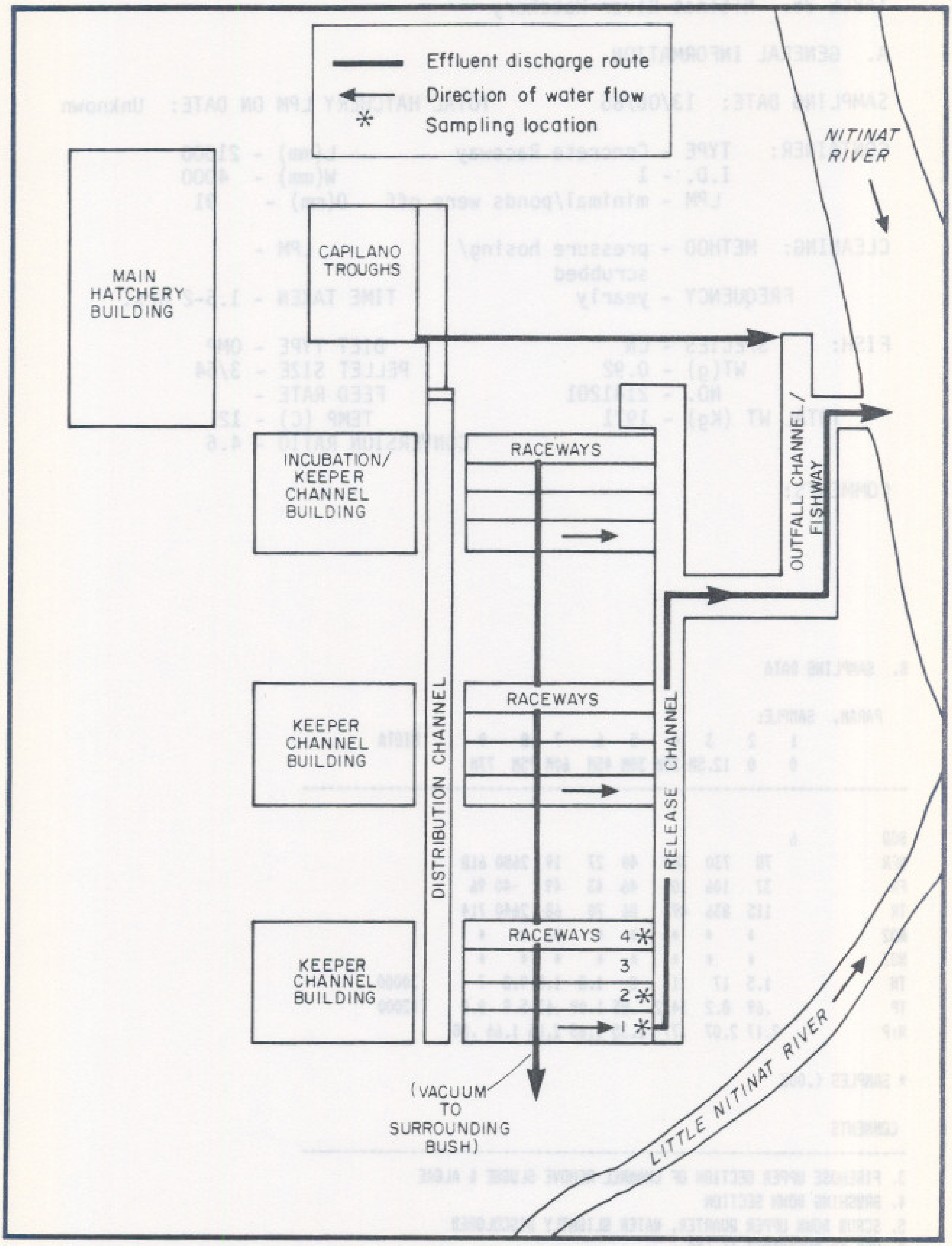

Figure 7 Nitinat Hatchery effluent routes and sampling sites (not to scale)

TABLE 35. Nitinat River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 13/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Concrete Raceway L(mm) - 21000
I.D. - 1 W(mm) - 4000
LPM - minimal/ponds were off D(mm) - 91

CLEANING: METHOD - pressure hosing/ scrubbed LPM -
FREQUENCY - yearly TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 0.92 PELLET SIZE - 3/64
NO. - 2141201 FEED RATE -
TOTAL WT (Kg) - 1971 TEMP (C) - 12
CONVERSION RATIO - 4.6

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 12.5M	4 20M	5 30M	6 45M	7 60M	8 75M	9 77M	BIOTA
BOD	6									
NFR		78	730	387	40	27	19	2680	618	
FR		37	106	108	46	43	49	-40	96	
TR		115	836	495	86	70	68	2640	714	
NO2		*	*	*	*	*	*	*	*	
NO3		*	*	*	*	*	*	*	*	
TN		1.5	17	11	2	1.8	1.8	9.8	7	30000
TP		.69	8.2	14.2	.85	1.09	.63	5.9	8.8	12000
N:P		2.17	2.07	.77	2.35	1.65	2.86	1.66	.80	

* SAMPLES <.005

COMMENTS

3. FIREHOSE UPPER SECTION OF CHANNEL REMOVE SLUDGE & ALGAE
4. BRUSHING DOWN SECTION
5. SCRUB DOWN UPPER QUARTER, WATER SLIGHTLY DISCOLORED
8. NFR,TR OVERNIGHT AT 60C
FOR 90C OVERNIGHT THEN 104C FOR 1HR NFR=841, TR=267
9. INCREASE FLOW FOR 30S THEN SHUT OFF

TABLE 36. Nitinat River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 13/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Concrete Raceway L(mm) - 21000
I.D. - 2 W(mm) - 4000
LPM - minimal/ponds were off D(mm) - 91

CLEANING: METHOD - pressure hosing/scrubbed LPM -
FREQUENCY - yearly TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 0.92 PELLET SIZE - 3/64
NO. - 2820238 FEED RATE -
TOTAL WT (Kg) - 1924 TEMP (C) - 12
CONVERSION RATIO - 4.6

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	BIOTA
	0	0	5M	15M	30M	45M	60M	75M	90M	
BOD	3									
NFR		8	411	434	<5	12	21	16	1120	
FR		47	111	3103	42	49	82	45	-109	
TR		55	522	3537	47	61	103	61	1011	
NO2		*	*	*	*	*	*	*	*	
NO3		*	*	*	*	*	*	*	*	
TN		10	13	36	.5	.9	12	1.3	15	42000
TP		.37	7.8	5.15	.17	.57	2.9	1.64	22	17400
N:P		27.02	1.67	7	2.94	1.58	4.14	.79	.68	

* SAMPLES WERE <.005

COMMENTS

1. PEAK HOSING
2. BRUSHING AT CHANNEL MOUTH
4. NFR,TR OVERNIGHT DRYING AT 60C
FOR 90C OVERNIGHT THEN 104C FOR 1HR NFR=1905, TR=1400
9. AS ABOVE NFR=1030, TR=431
SCRUB & SHUT OFF WATER

TABLE 37. Nitinat River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 13/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Concrete Raceway L(mm) - 21000
I.D. - 4 W(mm) - 4000
LPM - minimal/ponds were off D(mm) - 91

CLEANING: METHOD - pressure hosing/scrubbed LPM -
FREQUENCY - yearly TIME TAKEN - 1.5-2 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 0.96 PELLET SIZE - 3/64
NO. - 1980384 FEED RATE - 0
TOTAL WT (Kg) - 1906 TEMP (C) - 12
CONVERSION RATIO - 4.6

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	BIOTA
	0	0	5M	15M	30M	45M	60M	63M	74M	85M	
BOD	2										
NFR		9	4370	1040	45	31	48	1450	1200	23	
FR		46	-3848	360	2	30	55	-3848	-769	42	
TR		55	522	1400	47	61	103	61	431	65	
NO2		*	*	*	*	*	*	*	*	*	
NO3		.016	*	*	*	*	*	*	.014	*	
TN		.4	78	30	1.5	1.3	3.1	37	13	.6	37000
TP		.3	77.1	76	.79	1.1	2.9	19.6	6.5	1.94	23700
N:P		1.33	1.01	.39	1.9	1.14	1.07	1.89	2	.31	

COMMENTS

1. PEAK HOSING
4. BRUSHING AT FRONT, STRONG ODOR
10. TURN WATER ON FULL BLAST THEN SHUT OFF
3,8,9. NFR,TR OVERNIGHT DRYING AT 60C
COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS

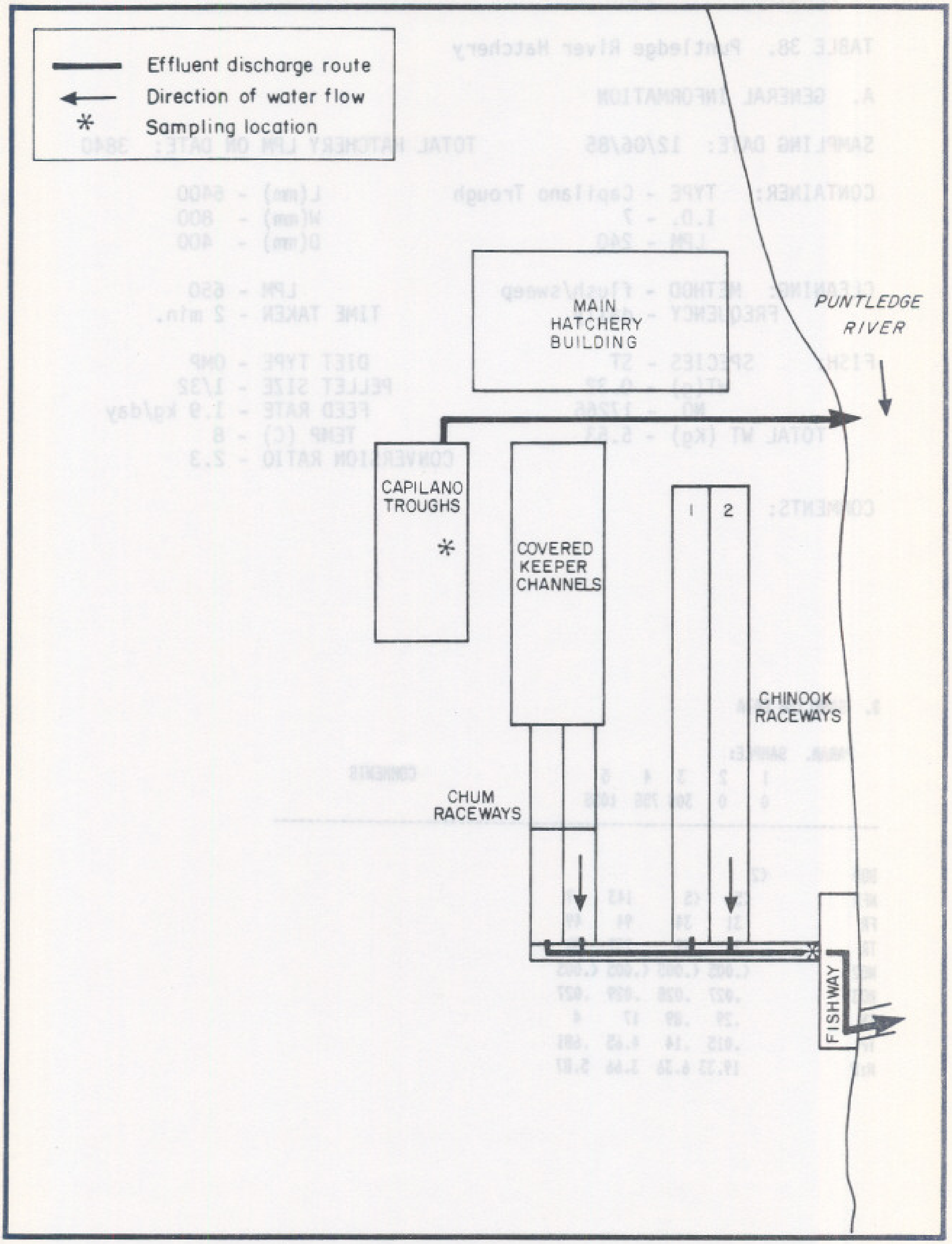

Figure 8 Puntledge Hatchery effluent routes and sampling sites (not to scale)

TABLE 38. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 12/06/85 TOTAL HATCHERY LPM ON DATE: 3840

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 7 W(mm) - 800
LPM - 240 D(mm) - 400

CLEANING: METHOD - flush/sweep LPM - 650
FREQUENCY - daily TIME TAKEN - 2 min.

FISH: SPECIES - ST DIET TYPE - OMP
WT(g) - 0.32 PELLET SIZE - 1/32
NO. - 17266 FEED RATE - 1.9 kg/day
TOTAL WT (Kg) - 5.53 TEMP (C) - 8
CONVERSION RATIO - 2.3

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	COMMENTS
	0	0	30S	75S	105S	
BOD	<2					
NFR		<5	<5	143	9	
FR		31	34	94	49	
TR		36	39	237	58	
NO2		<.005	<.005	<.005	<.005	
NO3		.027	.028	.029	.027	
TN		.29	.89	17	4	
TP		.015	.14	4.65	.681	
N:P		19.33	6.36	3.66	5.87	

TABLE 39. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 12/06/85 TOTAL HATCHERY LPM ON DATE: 3840

CONTAINER: TYPE - Capilano Trough
I.D. - 9
LPM - 240
L(mm) - 6400
W(mm) - 800
D(mm) - 400

CLEANING: METHOD - flush/sweep
FREQUENCY - daily
LPM - 618
TIME TAKEN - 2 min.

FISH: SPECIES - ST
WT(g) - 0.32
NO. - 17266
TOTAL WT (Kg) - 5.53
DIET TYPE - OMP
PELLET SIZE - 1/32
FEED RATE - 1.9 kg/day
TEMP (C) - 8
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 45S	4 75S	5 120S	COMMENTS
BOD	<2					
NFR		<5	<5	9	9	
FR		23	20	48	43	
TR		27	25	57	52	
NO2		<.005	<.005	<.005	<.005	
NO3		.028	.031	.028	.027	
TN		.34	.25	15	3.2	
TP		.036	.025	2.3	.58	
N:P		9.44	10	6.52	5.51	

TABLE 40. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 12/06/85 TOTAL HATCHERY LPM ON DATE: 3840

CONTAINER: TYPE - Capilano Trough
I.D. - 11
LPM - 240
L(mm) - 6400
W(mm) - 800
D(mm) - 400

CLEANING: METHOD - flush/sweep
FREQUENCY - daily
LPM - 666
TIME TAKEN - 2 min.

FISH: SPECIES - ST
WT(g) - 0.32
NO. - 17266
TOTAL WT (Kg) - 5.53
DIET TYPE - OMP
PELLET SIZE - 1/32
FEED RATE - 1.9 kg/day
TEMP (C) - 8
CONVERSION RATIO - 1.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30S	4 75S	5 125S	COMMENTS
BOD	<2					
NFR		<5	<5	107	<5	
FR		19	21	52	27	
TR		24	26	159	32	
NO2		<.005	<.005	<.005	<.005	
NO3		.033	.032	.031	.031	
TN		.21	.16	15	1.6	
TP		.018	.012	3.21	.21	
N:P		11.67	13.33	4.67	7.62	

TABLE 41. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: TOTAL HATCHERY LPM ON DATE: 31620

CONTAINER: TYPE - Concrete Raceway L(mm) - 73152
I.D. - 1C W(mm) - 4572
LPM - 15291 D(mm) - 1524

CLEANING: METHOD - vacuum LPM - 168
FREQUENCY - twice weekly TIME TAKEN - 1-1.5 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 1.9 PELLET SIZE - 3/64, 1/16
NO. 986539 FEED RATE - 52 kg, 48.4 kg
TOTAL WT (Kg) - 1874.4 TEMP (C) - 8
CONVERSION RATIO - 3.8

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 3M	4 6M	5 9M	COMMENTS
BOD	2					
NFR		<5	428	843	9	
FR		35	1072	197	62	
TR		40	1500	1040	71	
NO2		<.005	.049	.016	<.005	
NO3		.025	.032	.017	.009	
TN		.52	200	46	3.3	
TP		.31	74.2	34	1.7	
N:P		1.68	2.7	1.35	1.94	

TABLE 42. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: TOTAL HATCHERY LPM ON DATE: 31620

CONTAINER: TYPE - Concrete Raceway L(mm) - 73152
I.D. - 2B W(mm) - 4572
LPM - 10194 D(mm) - 1524

CLEANING: METHOD - vacuum LPM - 168
FREQUENCY - twice weekly TIME TAKEN - 1-1.5 hrs.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 1.65 PELLET SIZE - 1/2, 3/64, 1/16
NO. - 1231344 FEED RATE - 15 kg, 103 kg, 5.2 kg
TOTAL WT (Kg) - 2031.7 TEMP (C) - 8
CONVERSION RATIO - 1.5

COMMENTS:

B. SAMPLING DATA

PARAM. SAMPLE:	1 0	2 1M	3 2M	4 5M	5 10M	6 15M	7 16M	8	9	COMMENTS
										2. DARK COLORATION
BOD										3. BY SCREEN THICK
NFR		255	2450	2160	811	1520	1040			ACCUMULATION
FR		139	20	1350	145	1020	1140			4. LIGHT COLOR-
TR		394	2470	3510	956	2540	2180			ATION
NO2		*	*	*	*	*	*			5. DARK
NO3		*	*	*	*	*	*			6. END
TN		16	140	490	69	250	501			
TP		.4	126	279	55	120	120			
N:P		40	1.11	1.76	1.25	2.08	4.18			

*SAMPLES WERE <.005

TABLE 43. Puntledge River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: TOTAL HATCHERY LPM ON DATE: 31620

CONTAINER: TYPE - Concrete Raceway
I.D. - 2C
LPM - 10194
L(mm) - 73152
W(mm) - 4572
D(mm) - 1524

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly
LPM - 168
TIME TAKEN - 1-1.5 hrs.

FISH: SPECIES - CN
WT(g) - 1.65
NO. - 1231344
TOTAL WT (Kg) - 2031.7
DIET TYPE - OMP
PELLET SIZE - 1/2, 3/64, 1/16
FEED RATE - 15 kg, 103 kg, 5.2 kg
TEMP (C) - 8
CONVERSION RATIO - 1.5

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 10M	4 18M	BIOTA	COMMENTS
BOD	33					
NFR		<5	1620	4020		
FR		35	320	100		
TR		40	1940	4120		
NO2		*	*	*		
NO3		.025	*	*		
TN		.52	98.3	260	34000	
TP		.31	47	123	31400	
N:P		1.68	2.09	2.11		

*SAMPLES WERE <.005

TABLE 44. Quinsam River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 12/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Burrows Pond L(mm) - 22860
I.D. - 13 W(mm) - 4877
LPM - 681 D(mm) - 914

CLEANING: METHOD - vacuum LPM - 109
FREQUENCY - every 10 days TIME TAKEN - 30 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.65 PELLET SIZE - 1/32
NO. - 97335 FEED RATE - 1.92 kg/day; 5.95% body wt
TOTAL WT (Kg) - 63.27 TEMP (C) - 10.5
CONVERSION RATIO - 2.4

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	11
	1M	3M	5M	7.5M	10M	12M	15M	17.5M	20M	22.5M	25M
BOD											
NFR	1290	2050	950	548	350	316	594	70	222	325	279
FR	500	-1010	160	60	312	88	128	58	83	82	29
TR	1790	1040	1110	608	662	404	722	128	305	407	308
NO2	*	*	*	*	*	*	*	*	*	*	*
NO3	*	*	*	*	*	*	*	*	*	*	*
TN	30	40	20	11	8	9	15	1.6	4	7.5	5
TO	19	24	33	8.5	3.5	3.2	12	.56	3.9	5.8	1.4
N:P	1.58	1.67	.61	1.29	2.29	2.8	1.24	2.9	1.03	1.29	3.57

*SAMPLES WERE <.005

COMMENTS

11. NFR,TR. OVERNIGHT DRYING AT 60C.
FOR 90C OVERNIGHT THEN 104C FOR 1HR NFR=224, TR=121

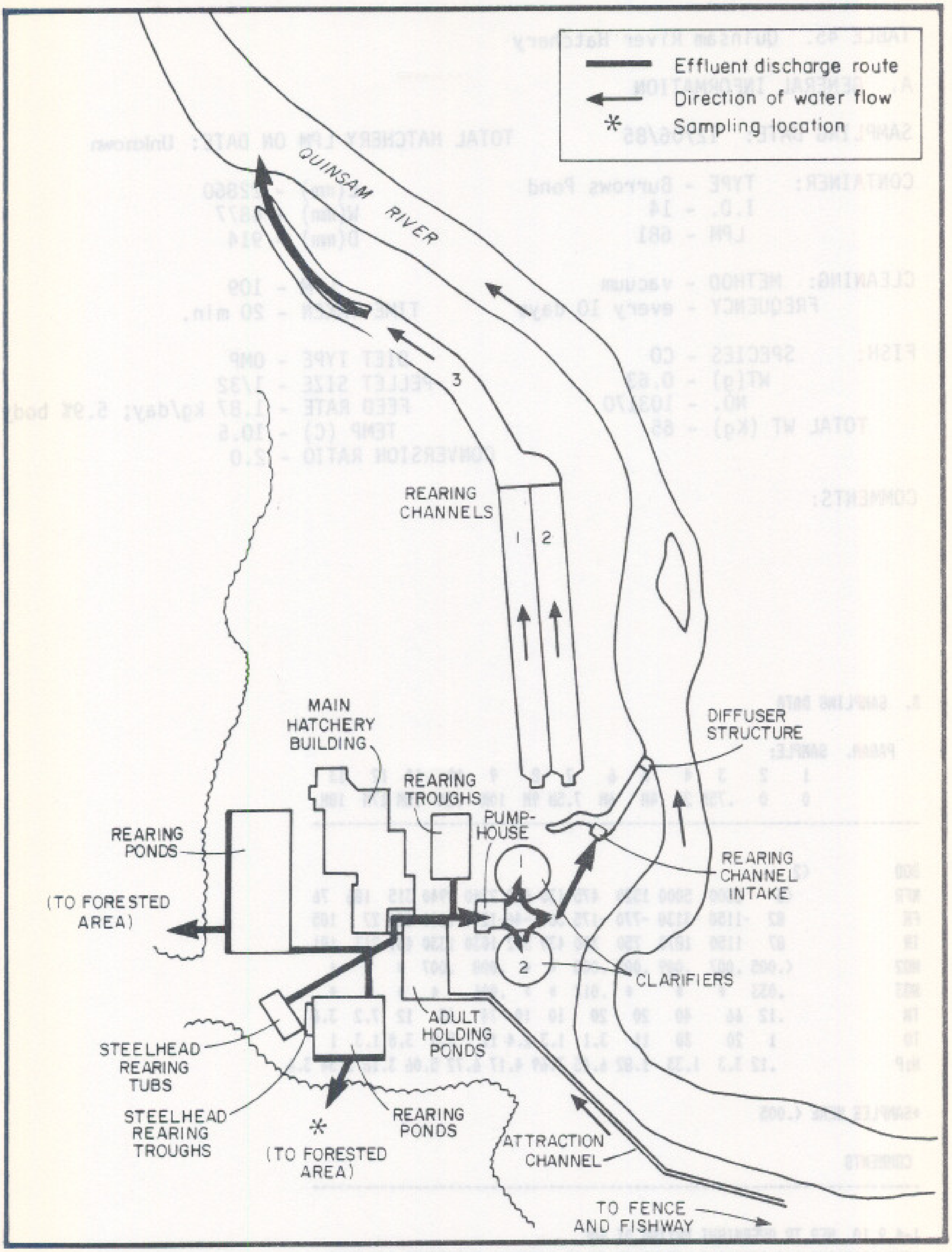

Figure 9 Quinsam Hatchery effluent routes and sampling sites

TABLE 45. Quinsam River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 12/06/85 TOTAL HATCHERY LPM ON DATE: Unknown

CONTAINER: TYPE - Burrows Pond L(mm) - 22860
I.D. - 14 W(mm) - 4877
LPM - 681 D(mm) - 914

CLEANING: METHOD - vacuum LPM - 109
FREQUENCY - every 10 days TIME TAKEN - 20 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.63 PELLET SIZE - 1/32
NO. - 103170 FEED RATE - 1.87 kg/day; 5.9% body wt
TOTAL WT (Kg) - 65 TEMP (C) - 10.5
CONVERSION RATIO - 2.0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	11	12	13
	0	0	.75M	2M	4M	6M	7.5M	9M	10M	12M	15M	17M	18M
BOD	<2												
NFR		<5	2300	5000	1520	475	130	638	2240	2940	315	186	76
FR		82	-1150	-3130	-770	-175	309	-46	-1210	-1610	124	27	105
TR		87	1150	1870	750	300	439	592	1030	1330	439	213	181
NO2		<.005	.007	.009	.005	.005	*	*	.008	.007	*	*	*
NO3		.033	*	*	*	.017	*	*	.006	*	*	*	*
TN		.12	66	40	20	20	10	10	74	43	12	7.2	3.6
TO		1	20	30	11	3.1	1.3	2.4	11	8.5	3.8	1.3	1
N:P		.12	3.3	1.33	1.82	6.45	7.69	4.17	6.72	5.06	3.16	5.54	3.6

*SAMPLES WERE <.005

COMMENTS

1-4,9,10. NFR,TR OVERNIGHT DRYING AT 60C
COMPLICATIONS & FLOCCULANT NATURE OF SOLID MATERIAL PREVENTED ACCURATE ANALYSIS

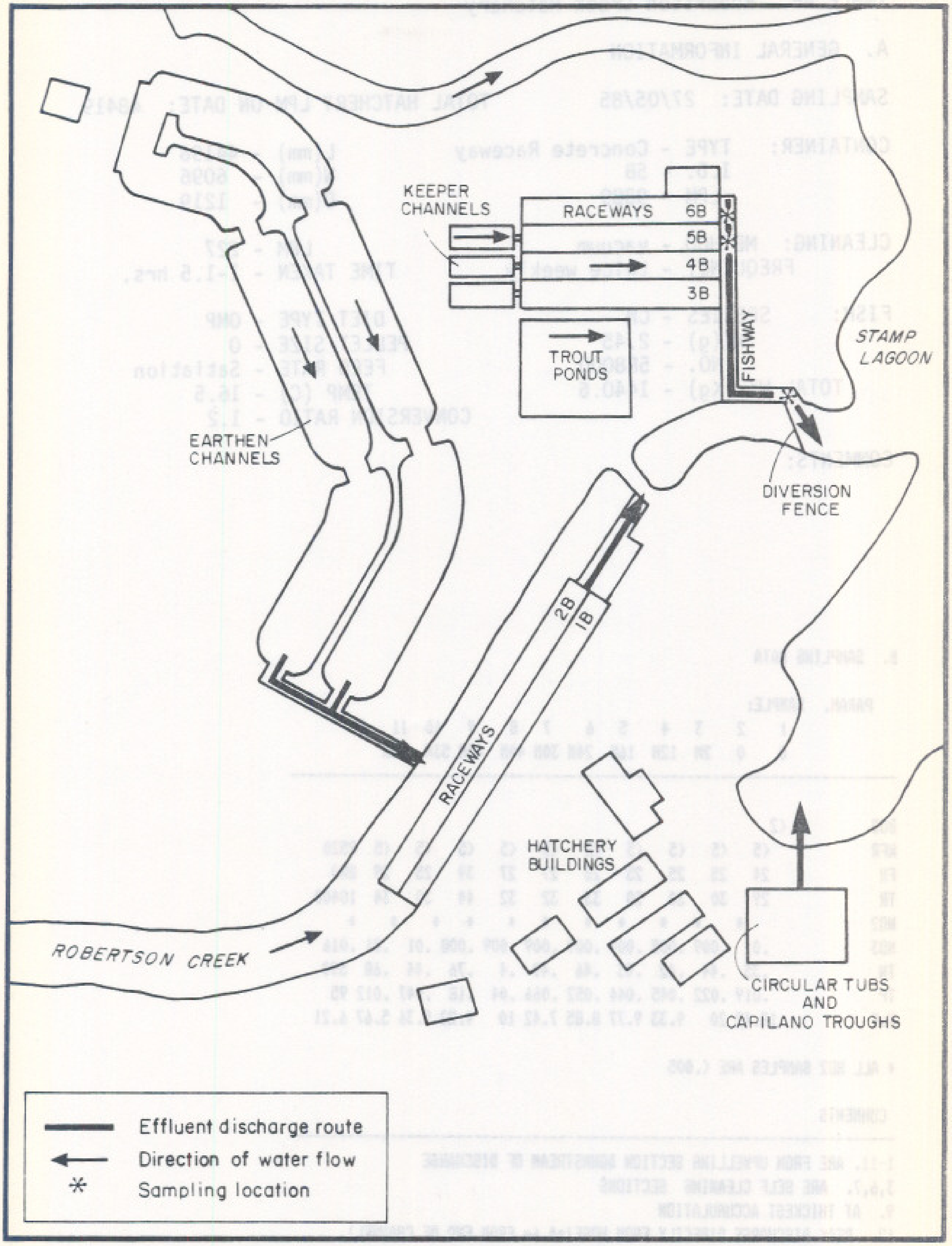

Figure 10 Robertson Hatchery effluent routes and sampling sites (not to scale)

TABLE 46. Robertson Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 27/05/85 TOTAL HATCHERY LPM ON DATE: 48419

CONTAINER: TYPE - Concrete Raceway
I.D. - 5B
LPM - 9389

L(mm) - 44196
W(mm) - 6096
D(mm) - 1219

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly

LPM - 227
TIME TAKEN - 1-1.5 hrs.

FISH: SPECIES - CN
WT(g) - 2.45
NO. - 588000
TOTAL WT (Kg) - 1440.6

DIET TYPE - OMP
PELLET SIZE - 0
FEED RATE - Satiation
TEMP (C) - 16.5
CONVERSION RATIO - 1.2

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	11	12
	0	0	2M	12M	16M	24M	30M	40M	45M	53M	63M	
BOD	<2											
NFR		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	9520
FR		24	25	25	25	28	27	27	39	25	29	880
TR		29	30	30	30	33	32	32	44	30	34	10400
NO2		*	*	*	*	*	*	*	*	*	*	*
NO3		.01	.009	.008	.009	.009	.009	.009	.008	.01	.01	.016
TN		.35	.44	.42	.43	.46	.49	.4	.76	.44	.68	590
TP		.019	.022	.045	.044	.052	.066	.04	.18	.047	.012	95
N:P		18.42	20	9.33	9.77	8.85	7.42	10	4.22	9.36	5.67	6.21

* ALL NO2 SAMPLES ARE <.005

COMMENTS

1-11. ARE FROM UPWELLING SECTION DOWNSTREAM OF DISCHARGE
3,6,7. ARE SELF CLEANING SECTIONS
9. AT THICKEST ACCUMULATION
12. PEAK DISCHARGE DIRECTLY FROM HOSE(=4.6m FROM END OF CHANNEL).

TABLE 47. Robertson Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 27/05/85 TOTAL HATCHERY LPM ON DATE: 48419

CONTAINER: TYPE - Concrete Raceway
I.D. - 6B
LPM - 8971
L(mm) - 44196
W(mm) - 6096
D(mm) - 1219

CLEANING: METHOD - vacuum
FREQUENCY - twice weekly
LPM - 227
TIME TAKEN - 1-1.5 hrs.

FISH: SPECIES - CN
WT(g) - 4.03
NO. - 719000
TOTAL WT (Kg) - 2897.6
DIET TYPE - Bio-diet
PELLET SIZE -
FEED RATE -
TEMP (C) - 16.5
CONVERSION RATIO - 1.2

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	10	11	COMMENTS
	0	5M	13M	4M	20M	34M	40M	37M	48M	55M	0	
BOD											<2	2,3. ARE SELF
NFR	<5	<5	<5	12800	<5	<5	<5	2150	<5	<5		CLEANING SECTIONS
FR	26	26	26	1400	28	30	27	340	39	31		4. CLEANING FROM
TR	31	31	31	14200	33	35	32	2490	44	36		HOSE
NO2	*	*	*	.011	*	*	*	*	*	*		8. INTO HEAVIEST
NO3	.01	.01	.01	.02	.011	*	.011	.014	*	.011		SECTION. LITTLE
TN	.34	.46	.38	470	.47	.72	.55	120	2.2	.77		SELF CLEANING
TP	.005	.119	.008	330	.11	.18	.06	21	1.11	.32		9. END
N:P	68	3.87	47.5	4.27	4	9.17	1.98	2.4	1.98			10. 7 MIN PAST END
												TIME

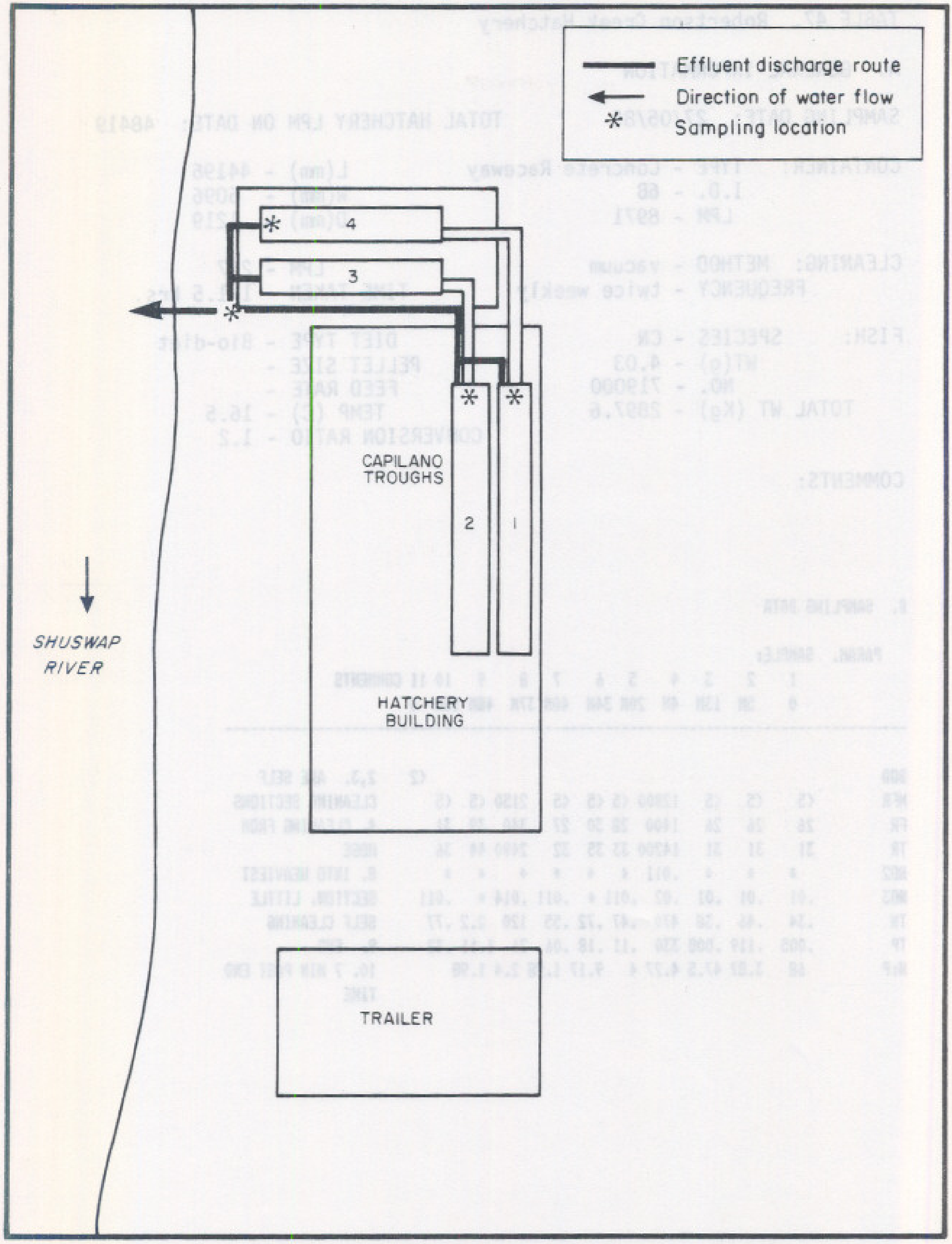

Figure 11 Shuswap Pilot Hatchery effluent routes and sampling sites (not to scale)

TABLE 48. Shuswap River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 480

CONTAINER: TYPE - Capilano Trough
I.D. - 1
LPM - 240
L(mm) - 6400
W(mm) - 800
D(mm) - 470

CLEANING: METHOD - flush/sweep
FREQUENCY - daily
LPM - 303*
TIME TAKEN - 3-5 min.

FISH: SPECIES - CN
WT(g) - 5.98
NO. - 25924
TOTAL WT (Kg) - 155
DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 8.5
CONVERSION RATIO -

COMMENTS:

* This flow was unusually low, as standpipes could only be partially pulled, or floor would be flooded due to plumbing back-up.

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 60S	3 120S	4 180S	5 240S	6 0	BIOTA	COMMENTS
BOD						<2		
NFR	<5	<5	<5	<5	<5			
FR	185	180	178	177	186			
TR	190	185	183	182	191			
NO2	<.005	<.005	<.005	<.005	<.005			
NO3	.014	.014	.013	.012	.02			
TN	.37	.45	.33	.31	.45		42000	
TP	.026	.055	.037	.037	.067		29800	
N:P	14.23	8.18	8.92	8.38	6.72			

* THIS FLOW WAS NOT THE USUAL CAUSED BY GRAVITATIONAL FORCE.
BECAUSE THE TROUGHS ARE INSIDE AND THE PIPING OUT WOULD OVERFLOW
THE STAND PIPE WAS ONLY REMOVED PART WAY.

TABLE 49. Shuswap River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 480

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 2 W(mm) - 800
LPM - 240 D(mm) - 470

CLEANING: METHOD - flush/sweep LPM - 260*
FREQUENCY - daily TIME TAKEN - 3-5 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 5.22 PELLET SIZE -
NO. - 26431 FEED RATE -
TOTAL WT (Kg) - 138 TEMP (C) - 8.5
CONVERSION RATIO -

COMMENTS:

* per Table 48

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	BIOTA	COMMENTS
	0	120S	180S	240S	0		
BOD					<2		
NFR	<5	<5	<5	<5			
FR	182	186	185	177			
TR	186	191	190	192			
NO2	<.005	<.005	<.005	<.005			
NO3	.011	.013	.013	.013			
TN	.06	.13	.19	.15		38000	
TP	.004	.022	.042	.031		49200	
N:P	15	5.91	4.52	4.84			

TABLE 50. Shuswap River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 480

CONTAINER:	TYPE - Capilano Trough	L(mm) - 6400	
	I.D. - 4	W(mm) - 800	
	LPM - 240	D(mm) - 470	
CLEANING:	METHOD - flush/sweep	LPM - 347*	
	FREQUENCY - daily	TIME TAKEN - 3-5 min.	
FISH:	SPECIES - CN	DIET TYPE - OMP	
	WT(g) - 3.80	PELLET SIZE -	
	NO. - 14524	FEED RATE -	
	TOTAL WT (Kg) - 55.2	TEMP (C) - 8.5	
		CONVERSION RATIO -	

COMMENTS:

* per Table 48

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 60S	3 120S	4 180S	5 300S	6 0	BIOTA	COMMENTS
BOD						<2		
NFR	<5	79	10	<5	<5			
FR	184	245	196	194	189			
TR	189	324	206	199	194			
NO2	.059	.007	.112	.228	.139			
NO3	.019	.001	.03	.051	.037			
TN	.39	9.3	1.5	1.03	.86		50000	
TP	.038	6.68	.28	.126	.122		35300	
N:P	10.26	1.39	5.36	8.17	7.05			

TABLE 51. Shuswap River Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 23/05/85 TOTAL HATCHERY LPM ON DATE: 480

CONTAINER: TYPE - Effluent L(mm) - 0
I.D. - 0 W(mm) - 0
LPM - 0 D(mm) - 0

CLEANING: METHOD - 0 LPM - 0
FREQUENCY - 0 TIME TAKEN - 0

FISH: SPECIES - 0 DIET TYPE - 0
WT(g) - 0 PELLET SIZE - 0
NO. - 0 FEED RATE - 0
TOTAL WT (Kg) - 0 TEMP (C) - 0
CONVERSION RATIO - 0

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	COMMENTS
		DURING CLEANING
BOD		
NFR	<5	
FR	184	
TR	189	
NO2	<.005	
NO3	.009	
TN	.33	
TP	.132	
N:P	2.5	

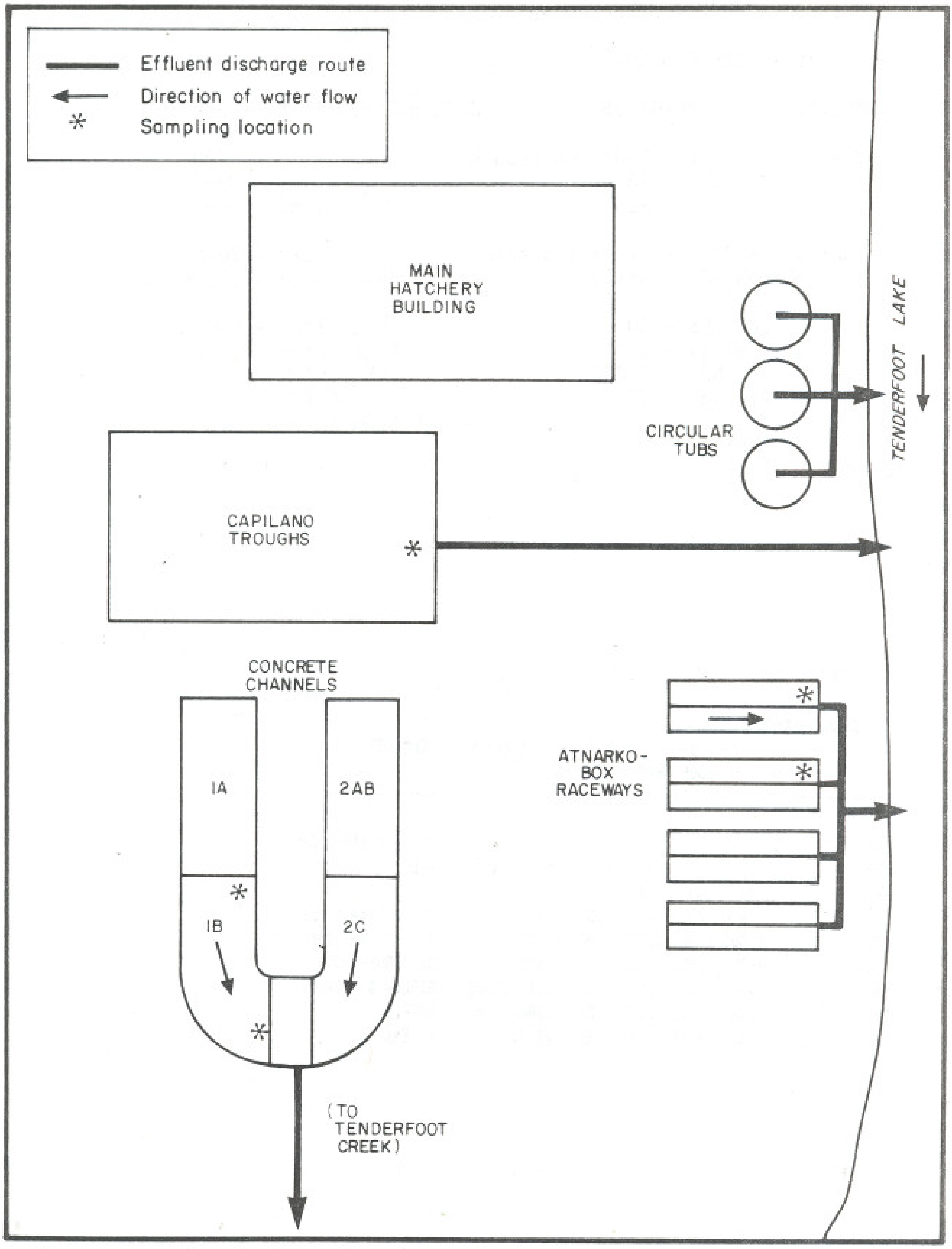

Figure 12 Tenderfoot Hatchery effluent routes and sampling sites (not to scale)

TABLE 52. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 — TOTAL HATCHERY LPM ON DATE: 2200

CONTAINER: TYPE - Capilano Trough
I.D. - 1A
LPM - 220

L(mm) - 6400
W(mm) - 800
D(mm) - 508

CLEANING: METHOD - Kitimat baffle
FREQUENCY - daily

LPM - 768
TIME TAKEN - 8.5 min.

FISH: SPECIES - CO
WT(g) - 0.81
NO. - 34200
TOTAL WT (Kg) - 27.7

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 2.5
CONVERSION RATIO - 1.7

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 150S	4 240S	5 450S	6 520S	7 BIOTA	COMMENTS
BOD	5							USING KITIMAT BAF-
NFR		27	<5	8	<5	<5		FLE.
FR		49	60	68	70	70		
TR		76	70	76	75	75		3. 1/3 WAY DONE
NO2		<.005	<.005	<.005	<.005	<.005		4. 1/2 WAY DONE
NO3		.053	.054	.056	.055	.058		5. BRUSH DOWN
TN		.48	.26	.63	.58	.14	59000	SCREEN & REMOVE
TP		.16	.042	.17	.37	.006	30700	BAFFLE.
N:P		3	6.19	3.71	1.57	23.33		6. END.

TABLE 53. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 2200

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 2A W(mm) - 800
LPM - 220 D(mm) - 508

CLEANING: METHOD - Kitimat baffle LPM - 1126
FREQUENCY - daily TIME TAKEN - 12 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.68 PELLET SIZE -
NO. - 46537 FEED RATE -
TOTAL WT (Kg) - 31.6 TEMP (C) - 7.5
CONVERSION RATIO - 1.4

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 150S	4 360S	5 540S	6 660S	7	BIOTA	COMMENTS
BOD	7								USING KITIMAT BAF-
NFR		<5	10	<5	<5	<5			FLE
FR		110	115	68	71	66			
TR		115	125	73	76	71			3. 1/3 WAY DONE
NO2		<.005	<.005	<.005	<.005	<.005			4. 1/2 WAY DONE
NO3		.057	.056	.062	.064	.064			5. SCRUB SCREENS
TN		2	2	.55	.65	.44		61000	6. END
TP		1.14	1.76	.91	.47	.33		24000	
N:P		1.75	1.14	.60	1.38	1.33			

TABLE 54. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 2200

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 3A W(mm) - 800
LPM - 220 D(mm) - 508

CLEANING: METHOD - Kitimat baffle LPM - 780
FREQUENCY - daily TIME TAKEN - 12 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 1.09 PELLET SIZE -
NO. - 43941 FEED RATE -
TOTAL WT (Kg) - 47.9 TEMP (C) - 7.5
CONVERSION RATIO - 1.3

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 30s	4 60s	BIOTA	COMMENTS
BOD	<2					MANUALLY
NFR		<5	<5	<5		
FR		59	62	52		
TR		64	67	57		
NO2		<.005	<.005	<.005		
NO3		.064	.065	.067		
TN		.28	.7	.24	57000	
TP		.077	.529	.14	30200	
N:P		3.64	1.32	1.71		

TABLE 55. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 2200

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 4A W(mm) - 800
LPM - 220 D(mm) - 508

CLEANING: METHOD - flush/sweep LPM - 910
FREQUENCY - daily TIME TAKEN - 1 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.68 PELLET SIZE -
NO. - 43374 FEED RATE -
TOTAL WT (Kg) - 29.5 TEMP (C) - 7.5
CONVERSION RATIO - 1.05

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 (0)	2 (0)	3 (30s)	4 (60S)	BIOTA	COMMENTS
BOD	3					MANUALLY
NFR		<5	8	<5		
FR		61	62	82		4. CLEAN SCREEN
TR		66	70	87		
NO2		<.005	<.005	<.005		
NO3		.069	.068	.068		
TN		.31	.61	.41	70000	
TP		.178	.46	.27	21500	
N:P		1.74	1.33	1.52		

TABLE 56. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 2200

CONTAINER: TYPE - Capilano Trough L(mm) - 6400
I.D. - 5A W(mm) - 800
LPM - 220 D(mm) - 508

CLEANING: METHOD - flush/sweep LPM - 960
FREQUENCY - daily TIME TAKEN - 1 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 0.48 PELLET SIZE -
NO. - 42751 FEED RATE -
TOTAL WT (Kg) - 20.5 TEMP (C) - 7.5
CONVERSION RATIO - 1.34

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	BIOTA	COMMENTS
	0	0	30s	65s		
BOD	4					MANUALLY
NFR		19	15	7		
FR		66	56	88		
TR		85	71	95		
NO2		<.005	<.005	<.005		
NO3		.065	.066	.066		
TN		1.8	1.5	1	65000	
TP		1.1	.893	.69	21900	
N:P		1.64	1.68	1.45		

TABLE 57. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 800

CONTAINER: TYPE - Atnarko Box (mm) - 6299
I.D. - 1 W(mm) - 1092
LPM - 240 - 400 D(mm) - 1346

CLEANING: METHOD - flush/sweep LPM - 786
FREQUENCY - daily TIME TAKEN - 5 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 5.49 PELLET SIZE -
NO. - 55194 FEED RATE -
TOTAL WT (Kg) - 303 TEMP (C) - 7.5
CONVERSION RATIO - 1.3

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	8	9	COMMENTS
	0	0	30S	60S	150	240S				
BOD	<2									4. SCRUB SCREEN
NFR		<5	<5	42	<5	<5				
FT		77	74	120	79	69				
TR		82	79	162	84	74				
NO2		<.005	<.005	<.005	<.005	<.005				
NO3		.084	.085	.067	.071	.071				
TN		.25	.36	1.2	.4	.28				
TP		.015	.16	.6	.08	.01				
N:P		16.67	2.25	2	5	28				

TABLE 58. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 800

CONTAINER: TYPE - Atnarko Box L(mm) - 6299
I.D. - 3 W(mm) - 1092
LPM - 240 - 400 D(mm) - 1346

CLEANING: METHOD - flush/sweep LPM - 743
FREQUENCY - daily TIME TAKEN - 5 min.

FISH: SPECIES - CN DIET TYPE - OMP
WT(g) - 4.87 PELLET SIZE -
NO. - 61544 FEED RATE -
TOTAL WT (Kg) - 300 TEMP (C) - 7.5
CONVERSION RATIO - 1.6

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 60S	4 120S	5 180S	6 240S	COMMENTS
BOD	6						
NFR		<5	<5	56	83	<5	
FT		67	78	40	15	66	
TR		72	83	96	98	71	
NO2		<.005	<.005	<.005	<.005	<.005	
NO3		.073	.075	.072	.071	.072	
TN		1.4	2.5	2.3	2.2	.7	
TP		.186	.98	.82	.99	.06	
N:P		7.53	2.55	2.80	2.22	11.67	

TABLE 59. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85

TOTAL HATCHERY LPM ON DATE: 7268

CONTAINER: TYPE - Concrete Channel
I.D. - 1A
LPM - 3634

L(mm) - 19500
W(mm) - 4588 = Area in m^2
D(mm) - 89.5 = vol in m^3

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM - 340
TIME TAKEN - 15 min.

FISH: SPECIES - CO
WT(g) - 18.31
NO. - 105700
TOTAL WT (Kg) - 1935.4

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 2.97

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 5M	4 7.5M	5 10M	6 12.5M	7 13M	8 15M
BOD		<2						
NFR		<5	39	70	68	41	254	13
FR		62	93	84	95	84	106	75
TR		67	132	154	163	125	360	88
NO2		<.005	<.005	<.005	<.005	<.005	<.005	<.005
NO3		61	.014	.016	.012	.042	.027	.05
TN		.16	6.7	8.5	8.8	2.4	17	2.7
TP		8.45	2.9	4.3	4.3	2.7	10.4	.67
N:P		.02	2.31	1.98	2. 05	.89	1.63	4.03

COMMENTS

ALL SAMPLES EXCEPT 3 AT HOSE DISCHARGE
3. ENTIRE CHANNEL FILLED WITH EFFLUENT, 6M DOWNSTREAM OF HOSE
7. COMES FROM THICKEST ACCUMULATION
8. END WATER IMMEDIATELY CLEARS
UNDERGOING MALICHITE TREATMENT FOR FUNGUS

TABLE 60. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 7268

CONTAINER: TYPE - Concrete Channel
I.D. - 2AB
LPM - 3634

L(mm) - 19500
W(mm) - 4588 = Area in m^2
D(mm) - 89.5 = vol in m^3

CLEANING: METHOD - vacuum
FREQUENCY - weekly

LPM - 340
TIME TAKEN - 20 min.

FISH: SPECIES - CO
WT(g) - 18.31
NO. - 109225
TOTAL WT (Kg) - 2000

DIET TYPE - OMP
PELLET SIZE -
FEED RATE -
TEMP (C) - 7.5
CONVERSION RATIO - 1.16

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1	2	3	4	5	6	7	BIOTA
	0	0	20M	30M	37.5M	47M	3M	
BOD	<2							
NFR		<5	315	235	172	92	5890	
FR		57	121	121	120	86	1890	
TR		62	436	356	292	178	7780	
NO2		<.005	.005	.006	<.005	<.005	<.005	
NO3		.071	.005	.01	.033	.01	.011	
TN		.21	8.8	2.4	2.4	9.5	64	75000
TP		<.002	16.5	11.2	9.3	4.5	93	18000
N:P		105	.53	.21	.23	2.11	.69	

COMMENTS

ALL SAMPLES TAKEN AT HOSE DISCHARGE (IN 1B)
3. START CLEANING THIS SECTION
5. 3/4 WAY DONE
6. END.
7. PEAK EFFLUENT AT HOSE

TABLE 61. Tenderfoot Creek Hatchery

A. GENERAL INFORMATION

SAMPLING DATE: 28/05/85 TOTAL HATCHERY LPM ON DATE: 7268

CONTAINER: TYPE - Concrete Channel L(mm) - 19500
I.D. - 2C W(mm) - 4588 = Area in m^2
LPM - 3634 D(mm) - 89.5 = vol in m^3

CLEANING: METHOD - vacuum LPM - 340
FREQUENCY - weekly TIME TAKEN - 20 min.

FISH: SPECIES - CO DIET TYPE - OMP
WT(g) - 17.04 PELLET SIZE -
NO. - 535005 FEED RATE -
TOTAL WT (Kg) - 911.6 TEMP (C) - 7.5
CONVERSION RATIO - 1.16

COMMENTS:

B. SAMPLING DATA

PARAM.	SAMPLE: 1 0	2 0	3 5M	4 12.5M	5
BOD	<2				
NFR		<5	232	196	
FR		57	112	117	
TR		62	344	313	
NO2		<.005	<.005	<.005	
NO3		.071	.03	.033	
TN		.21	18	8.5	
TP		<.002	15.2	12.9	
N:P		105	1.18	.66	

COMMENTS

3. PUMP BREAKS DOWN.
4. FLOW IS LIGHT

*IMMEDIATELY CONTINUES ON IN SECTION AB

SAME SAMPLE SITE AS FOR 2AB