AN INTERIM REPORT.

THE IMPACT OF HATCHERY EFFLUENT DISCHARGES ON WATER QUALITY, PRIMARY PRODUCTION AND BENTHIC INVERTEBRATES IN SELECTED RIVER SYSTEMS IN B.C.

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I. SUMMARY

On behalf of the Salmonid Enhancement Program, staff of the Water Quality Unit, Habitat Protection Division, started an assessment of the impacts of hatchery effluent, and the feasibility of locating hatcheries on selected river systems in British Columbia, in June 1978. This interim report details some of the preliminary findings.

1. HATCHERY IMPACT STUDIES

a) Continuous Hatcheries (Capilano, Quinsam, Puntledge, Qualicum)

The data indicate that measurable changes in water quality, benthic algae and macro-invertebrates occur downstream from the hatchery outfalls. While the extent of these changes differs between locations, it appears to be restricted to a distance of 500 metres or less from the outfalls.

Based on a very preliminary assessment of some of the data and continuing subjective observations of water quality conditions downstream of the hatchery outfalls, the following conclusions are offered, subject to the gathering of additional data and further statistical analyses:-

i) Nutrients

Elevated nutrient concentrations, particularly total phosphate and ammonia, were frequently measured in the receiving water below the hatchery outfalls.

Total phosphate and ammonia concentrations at distances well downstream of the hatchery outfalls (> 750 m) were usually similar to those of control stations. Only in the Quinsam River were nutrient and periphyton standing crop levels higher at an intermediate downstream site (300 m) than at the first downstream site (60 m). The reasons for this apparent anomaly are currently unknown.

ii) Periphyton

Increases in periphyton standing crop have been documented below the major hatchery outfalls during the late summer and fall sampling periods when dilution of nutrients in rivers was low.

Changes in algal species composition (especially those intolerant of high organic concentration) and growths of the "sewage fungus", *Sphaerotilus* sp., (in the Qualicum River) were documented in the receiving waters below hatchery outfalls. These conditions may be attributed to discharges of nutrients from rearing channel effluents and salmon carcass decomposition.

iii) Macro-invertebrates

An increase in the numbers of oligochaetes and chironomids and a decrease in the number of mayflies occurred downstream of the main Qualicum Hatchery discharge (90 m) possibly as a result of organic enrichment. Data from the furthest downstream site (750 metres) indicate that the benthos at this location is similar in composition to that of the control site.

At the Quinsam Hatchery, an increased abundance of oligochaetes was documented at the first receiving water site, possibly as a result of organic enrichment. Further downstream (350 m), their abundance was similar to that at the control site. The abundance of chironomids and mites increased at the intermediate receiving water sampling site (350 m) and mayfly numbers decreased, perhaps in response to extraneous nutrient input.

Macro-invertebrate samples from the Puntledge and Capilano Rivers have been sorted and identified to the family level. Accordingly, an assessment of the data is not possible at this time.

b) Seasonal Hatcheries

The impact on receiving water of effluents from three seasonal chum hatcheries was monitored at Inches Creek, Snootli Creek and the Conuma River in 1979. Detailed analyses of the monitoring data from these hatcheries have not yet been carried out. However, identification of algal samples, enumeration of diatom cells and the sorting of some benthic invertebrate samples has been completed.

2. FEASIBILITY STUDIES

A predictive assessment of the impact of hatchery effluent upon the Chilliwack and Nicola Rivers and Deadman Creek, started in June, 1978. Water quality and benthic algal data are being assessed for those systems, and techniques for predicting impacts based on background river conditions and projected wastewater concentrations are being developed.

Sampling in the Nicola River and Deadman Creek will be discontinued in late summer, 1979, but will be continued on the Chilliwack River until the freshet period in spring, 1980. The proposed expansion of the provincial Loon Creek Hatchery to accommodate chinook rearing and other proposals for hatchery development on the Bowron, Quesnel, Nechako, Eagle and Chehalis Rivers will be assessed for potential receiving water impacts during 1980/81.

3. 1980/81 PROGRAM

At this time it is not known if adequate data has been collected during the 1979 monitoring program. Extensive monitoring at times of low river flows, maximum waste loadings and high ambient light levels will be required to produce the definitive impact and feasibility data required to achieve program goals.

During 1980/81, the emphasis of the program will be directed toward the statistical analysis of the water quality, benthic algae and macro-invertebrate data. In addition, increased feasibility assessment work will occur where there are enhancement proposals to be located in environmentally sensitive areas.

The recommendations contained in the final report from this project are expected to lead to the promulgation of federal hatchery effluent guidelines.

II. INTRODUCTION

In 1975, the Provincial Pollution Control Branch (PCB) established a set of Objectives for the quality of effluent discharged from "Food-processing, Agriculturally-Oriented, and Other Miscellaneous Industries of British Columbia." Effluent criteria for fish hatchery wastes are included in these Objectives which regulate discharges from all private and government-operated fish-rearing facilities in B.C. The federal government, although not strictly bound to comply with provincial guidelines, has historically pursued a leadership role in the field of pollution control. However, a contradictory situation exists, since compliance with existing provincial objectives may not be technologically feasible at some federal hatchery facilities. Hatcheries which do not recycle water used by rearing fish usually discharge a large volume of extremely dilute "effluent" which would not be amenable to conventional treatment.

The PCB Objectives are designed to regulate the total amount of waste discharged on a daily basis, using the units of kilograms of pollutant per kilogram of product (fish) per day. Units such as these are widely used in the regulation of effluents from feed lots and small industries. However, in the case of single-pass hatcheries, a large variable volume of water comprises most of the effluent and the concentration of pollutants may vary irrespective of the total fish mass. Fish metabolic rate (a function of fish size, environmental and physiological factors, etc.) governs the rate of fish feeding and therefore waste production more so than does fish biomass. Measurement units reflecting effluent concentration, such as milligrams per litre, would be easier to enforce and would relate more effectively to the protection of the receiving environment. In this way the concentration of nutrients permitted in the effluent would not vary with the mass of fish on hand.

The Salmonid Enhancement Program (SEP) is actively developing salmon hatcheries and rearing facilities throughout the province, without federal guidelines for the maintenance of effluent quality. In recognition of this concern, and to provide information on the constituents of hatchery effluents and wastewater treatment technology, the consulting firm of Underwood, MacLellan and Associates undertook a project on behalf of the Salmonid Enhancement Program. This project culminated in 1979 (Underwood, MacLellan and Associates Ltd., 1979 a, b). Another study was initiated by DFO to assess the effects of the discharge of hatchery effluents on receiving waters. Beginning in June, 1978, the Water Quality Unit of the Habitat Protection Division designed and now directs the receiving water study for the Salmonid Enhancement Program. This study includes the regular monitoring of water quality, periphyton standing crop and macro-invertebrates. Four operational, year-round hatcheries (Quinsam Hatchery, Campbell River; Puntledge Hatchery, Courtenay; Big Qualicum Hatchery, Qualicum; and Capilano Hatchery, North Vancouver), and three seasonal rearing facilities (Snootli Creek Hatchery, Bella Coola; Conuma River Hatchery, Tahsis; and Inches Creek Hatchery; Mission) are presently under study.

In addition to providing the necessary monitoring data to permit the site-specific assessment of impact at several operating hatcheries and the need for treatment at some facilities, the study will provide a data base for the development of federal effluent guidelines for hatcheries in B.C.

As an adjunct to the receiving water impact monitoring program, a feasibility study of the potential impact of proposed hatchery effluent discharges was initiated. In this latter study, baseline water quality and primary productivity (periphyton) are monitored, and the results analyzed in conjunction with an examination of data on proposed hatchery feed rates. It is anticipated that the data will be used to predict receiving water impacts. Based upon these predictions, the need for wastewater treatment facilities will be determined. For example, if effluent treatment, such as filtration or sedimentation is required, advice will be provided during the preliminary stages of hatchery project development so that more accurate cost/benefit assessments can be produced and negative environmental impacts avoided. Currently, one proposed coastal (Chilliwack Hatchery, Fraser Valley) and two proposed interior (Deadman Creek Hatchery, Savona; and Nicola River Hatchery, Merritt) year-round hatcheries are under study. The proposal to enlarge the provincial Loon Creek Hatchery near Clinton (Bonaparte River Watershed) for chinook rearing is being assessed with respect to potential receiving water degradation.

This report discusses the progress of the receiving water impact study and feasibility assessment monitoring programs and presents some preliminary results of these studies.

III. MATERIALS AND METHODS

The field sampling program of the impact studies involves monitoring the following:

A) Water quality

B) Periphyton standing crop

C) Benthic invertebrates

In the feasibility studies at the proposed hatcheries, water quality and periphyton standing crop are monitored at one site during those months when salmon rearing would occur.

Sampling details are as follows:

A. Water Quality

1) Sampling Procedures

A control site and three or more sampling sites downstream from hatchery effluent discharges have been established in the receiving streams at four year-round operational hatcheries (Figures 2-5) for monitoring water quality. Hatchery flows, fish feeding rates, and river flows are recorded at specific intervals to relate to hatchery operations and document receiving water responses. Samples of river water and hatchery effluent are taken at the same frequency as the periphyton standing crop samples (every two to four weeks, depending on algal growth rates).

During rearing pond cleaning operations at the Qualicum and Puntledge Hatcheries, grab and composite samples of the effluent were taken in conjunction with benthic invertebrate samples to determine if periodic or "slug" effluent discharges have an added impact on the benthos in the receiving waters.

2) Laboratory Analyses

Some of the water quality analyses are conducted at the Inland Waters Directorate laboratory (IWD) in North Vancouver and the remaining water samples are analyzed at the joint DFO/DOE chemistry laboratory at Cypress Creek, West Vancouver. IWD provides the particulate carbon and nitrogen determinations and, the important, low-detection limit analyses for total and dissolved phosphate. The remaining water quality variables listed below are determined at IWD from the filtrate of water samples used for the particulate carbon/nitrogen analyses:-

total and dissolved phosphate
particulate carbon
particulate nitrogen
nitrate/nitrite
ammonia
total dissolved nitrogen

The following water quality variables are determined at the joint DFO/DOE Chemistry Laboratory in West Vancouver:-

total alkalinity	extractable	calcium
hardness	"	cadmium
conductivity	"	copper
turbidity	"	iron
total residue	"	lead
non-filterable residue	"	magnesium
total organic carbon	"	mercury
total phosphate	"	potassium
nitrite	"	sodium
nitrate	"	zinc
total ammonia		chloride
silicate		fluoride
sulfate		dissolved oxygen

Furthermore, a number of measurements are taken in the field at the time of sample collection:-

pH
air and water temperatures
sampling site depths and river flow rates
incident light at primary productivity monitoring sites (using a Gossen Model 9.69-211, hand-held, surface-operated light meter).

B. Periphyton Standing Crop

Artificial substrate plates mounted above solid 40 kg concrete blocks (Plate 1) are used to monitor the growth rate of periphyton (microfloral growth upon a substrate) in the receiving water, following the technique described by Stockner and Shortreed (1976). The plexiglass plates are colonized by algae during a two to four week growth period (Plate 2). In addition, a qualitative sample of periphyton from natural rock substrates is obtained during each sampling period for comparison with those collected from the artificial substrate plates.

Algal standing crop (i.e. the total biomass of the accumulated periphyton) is calculated using chlorophyll a and phaeopigment concentration measurements during each colonization period. Ash-free dry weight analyses (i.e. samples are dried and weighed, then ashed and weighed: the loss on ignition represents the approximate weight of organic matter accumulated during the colonization period) are performed to substantiate these results. Algae are identified to the species level for information on community succession, species dominance and, in the feasibility assessments, to provide information for predicting the potential impact of future hatchery operations.

Duplicate "pool" sites (flows 10-20 $cm \cdot s^{-1}$) and "riffle" sites (flows 45-60 $cm \cdot s^{-1}$) are used at each sampling location during the study, except in rivers largely devoid of pool habitats. Standardization of flows and depths at sampling sites was established initially using a Model 622 Gurley Current Meter. As flows and depths varied during the study, many sites were relocated (within 20 metres of the original site) so that substrates did not become either exposed or inaccessible. Typically, in winter, the coastal river systems exhibit extremely variable flows and depths due to periods of high runoff. The concrete blocks used to anchor the artificial substrates were often buried or swept downstream during high water flows, resulting in a repeated loss of some data.

C. Benthic Invertebrates

Benthic invertebrates were sampled using the methods described by Mundie (1971) at sites located adjacent to those used for the periphyton sampling program (Plate 3). The benthic invertebrate sampling frequency was reduced from a proposed ten times per year, to twice a year, comprised of: a) "pre-emergence" period (i.e. during March or April at the time when larval invertebrates are usually large and readily identifiable) and b) summer "maximum-loading" period (i.e. at Capilano and Quinsam, when late summer low flows correspond with comparatively high fish feeding rates; and at Puntledge and Qualicum following pond cleaning discharges). However, concurrent with this reduction in sampling frequency, the number of replicate samples taken per site was increased from three to six.

During summer, 1979, the established benthic invertebrate sampling regime in the Capilano River was augmented by the use of benthic invertebrate artificial substrates. Rock-filled metal baskets were attached to the existing periphyton concrete blocks and placed on the river bottom. The sampling of natural substrates for benthic invertebrates in the Capilano River was of limited success in 1978 due to the predominance of boulders and an insufficient number of shallow riffle sites necessary for quantitative benthic invertebrate sampling. It was also not known for what length of time the shallower sampling sites had been under water during periods of fluctuating river levels.

IV. RESULTS AND DISCUSSION

It should be noted that these results have not been subjected to statistical analysis and are presented at this time to outline apparent general trends in the response of receiving waters to hatchery effluent discharges.

A. Impact Assessments at Operational Hatcheries

1) Quinsam River Hatchery

The Quinsam Hatchery, which began operation in 1974, is located on a tributary of the Campbell River on the east coast of Vancouver Island (Figure 2).

During late summer, 1978, a greatly increased level of periphyton standing crop (Figures 16A, B and 17) occurred on the artificial substrates located downstream from the hatchery discharge (sites QI-2, QI-3, and QI-4, Figure 2). Control site QI-1 mean chlorophyll a concentration was 96 $mg \cdot 100\ cm^{-2}$; whereas sites downstream of the hatchery exhibited the following higher mean chlorophyll a concentrations: QI-2: 223 $mg \cdot 100\ cm^{-2}$; QI-3: 349 $mg \cdot 100\ cm^{-2}$; and QI-4: 240 $mg \cdot 100\ cm^{-2}$, n = 4 at each site. Because maximum standing crop occurred at site QI-3, where peaks in ammonia occurred, (mean total ammonia concentrations between August, 1978 and January, 1979 were as follows: QI-1: 0.006 $mg \cdot L^{-1}$; QI-2: 0.005 $mg \cdot L^{-1}$; QI-3: 0.013 $mg \cdot L^{-1}$; and QI-4: 0.008 $mg \cdot L^{-1}$, n = 7 at each site, Figure 14A), it initially appeared that site QI-2 was located outside the effluent plume. However, dye releases indicated that all downstream sites were located adequately within the influence of the hatchery discharge. Therefore, an additional nutrient source such as land drainage or groundwater could be entering the river between sites QI-2 and QI-3. Further water quality sampling is underway to clarify this situation. Peaks in total phosphate concentrations also occurred at site QI-3. (Mean total phosphate concentrations between August, 1978 and January, 1979 were as follows: QI-1: 0.007 $mg \cdot L^{-1}$; QI-2: 0.009 $mg \cdot L^{-1}$; QI-3: 0.017 $mg \cdot L^{-1}$; and QI-4: 0.014 $mg \cdot L^{-1}$, n = 7 at each site, Figure 15A).

Between late fall and early spring, 1978, little quantitative periphyton data were collected due to the intensive scouring, increased dilution and reduced temperature and light conditions that prevailed.

Algal species colonizing the artificial substrates differed between the Quinsam site upstream of the hatchery, and the downstream receiving water sites. For example, during fall, *Draparnaldia plumosa*, a filamentous green algae intolerant of high "organic" concentrations commonly occurred upstream of the hatchery discharge; whereas another filamentous green algae, *Stigeoclonium stagnatile*, frequently occurred further downstream. The genus *Stigeoclonium* is generally considered to be tolerant of comparatively higher levels of "organics."

Within successive sampling intervals, "pool" substrates generally exhibited greater algal biomass than "riffle" substrates. Diatoms were the dominant algal group in the Quinsam River, including the following more abundant species:- *Achnanthes minutissima*, *A. linearis* var. *pusilla*, *Cymbella minuta*, *Nitzschia amphibia*, *Synedra ulna*, *Nitzschia dissipata*, *Oedegonium* spp., *Gomphonema truncatum* (especially at site QI-1); and *Navicula pelliculosa*, (especially at site QI-4). In addition, the blue-green alga, *Plectonema notatum*, sometimes comprised up to 20% of algal biomass on the artificial substrates during fall.

Results of the March 27, 1979, Quinsam River "pre-emergence" benthic invertebrate sampling period have been analyzed for gross numerical differences at sites above and below the hatchery outfall. The upstream control site, QI-1, and the first receiving water site, QI-2, exhibited similar abundances of mayflies, chironomids and mites. Mean oligochaete abundance, however, exhibited a 20-fold increase at site QI-2 (increasing from $500 \cdot m^{-2}$ to $11\ 000 \cdot m^{-2}$, n = 4 at each site), possibly as a result of organic enrichment. Further downstream, at site QI-3, oligochaete numbers were similar to control site levels, while mayfly abundance was reduced to one-half that of the upstream sites (QI-1 and QI-2). Mean chironomid abundance was somewhat greater at site QI-3, and mites exhibited a 50-fold increase at site QI-3 (increasing from $500 \cdot m^{-2}$ at site QI-2 to $27\ 000 \cdot m^{-2}$ at site QI-3, n = 4 at each site).

At site QI-4, mayfly and chironomid numbers were somewhat reduced from those at site QI-3. Mites did not occur in the samples taken at site QI-4.

2) Puntledge River Hatchery

The Puntledge River joins the Tsolum River and the combined watercourse forms the tidal Courtenay River which flows into Comox Harbour. The Puntledge Hatchery was built in 1971 at the site of the existing Fisheries spawning channel near the B.C. Hydro Puntledge diversion dam.

In addition to the provision of land, B.C. Hydro supplies the hatchery with a continuous supply of river water pumped from the lake-like impoundment above the penstock weir to the hatchery spawning and rearing channels. As a result of the impoundment, the upstream control site for the receiving water study was located at the top end of the hatchery spawning channel where water flow and depth are similar to that in the mainstem Puntledge River.

Despite very constant flows, in the spawning channel control site, in contrast to the more variable flow regime in the mainstem Puntledge, it was possible to document an apparent impact of the discharge of hatchery effluent in the river. Distinct peaks in diatom number and photosynthetic pigments concentration (see Figures 20A through 24B) typically occurred below the hatchery at the first receiving water site (PU-2, Figure 3B), while further downstream, periphyton standing crop was similar to "control levels".

In general, more than 50% of the algal growth below the hatchery was comprised of green algae. The commonly recorded species of algae are listed below:

In September, *Spirogyra* spp., and in mid-autumn, *Oedegonium* spp., *Ulothrix zonata*, *U. tennerrima* and *U. aequalis* commonly occurred. The blue-green alga, *Oscillatoria agardhii* also was frequently sampled from below the hatchery during autumn. Numerically dominant amongst diatom species were *Achnanthes minutissima* and *Synedra rumpens* at sites PU-2 through PU-4. The control site generally had a different algal composition from the mainstem river sites, consisting mainly of diatoms. Chlorophyll a concentration and diatom numbers were much lower at the control site than at the downstream sites. The following diatoms were most commonly sampled from the control site: *Tabellaria fenestrata*, *Synedra rumpens* and *Achnanthes minutissima*.

The Puntledge River water quality samples were typically very close to to the detection limits for most variables sampled during fall and winter, and do not appear to warrant extensive interpretation at this time.

During spring and summer of this year, flow and temperature conditions are expected to produce more definitive impact data. (Photographs of the March 21, 1979, cleaning of the Puntledge Hatchery rearing channel are included as Plates 5-8). The potential for receiving water impact through operation of an additional hatchery facility on the lower Puntledge River (below the penstock tailrace, Figure 3A), will also be assessed.

3) Qualicum River Hatchery

The main Qualicum Hatchery is located on land leased from the Qualicum Indian Band, a short distance from the mouth of the Qualicum River (Figures 4A, 4B and 4C). Three kilometers upstream from the hatchery, the Enhancement Research Program (Nanaimo) conducts additional salmon rearing operations on a portion of the Qualicum River which has been diverted into an experimental rearing channel. Between those two rearing facilities, a chum spawning channel is operated on a diverted portion of the Qualicum River.

The water quality data collected for the Qualicum River indicate that during autumn and winter the experimental channel does not measurably affect receiving water quality during day-to-day operation (Figures 12B, 13B, 14B, and 15B). However, below the rearing section, the last 150 metre part of the experimental channel may act as a settling basin, removing silt and suspended organic matter originating upstream.

Below the main Qualicum Hatchery, elevated algal pigment concentrations and diatom numbers were measured during September, 1978. Control site (QA-1) mean chlorophyll a concentration was 3 mg·100 cm^{-2}; whereas sites downstream of the hatchery exhibited the following mean chlorophyll a concentrations: QA-4: 60 mg·100 cm^{-2}; QA-5: 29 mg·100 cm^{-2}; and QA-6: 40 mg·100 cm^{-2}, n = 2 for each site. Mean diatom numbers at the control site were 21 500 cells·cm^{-2}; whereas at downstream sites, mean counts were as follows: QA-4: 541 000 cells·cm^{-2}; QA-5: 649 000 cells·cm^{-2} and; QA-6: 319 000 cells·cm^{-2}, n = 2 for each site (Figures 25 and 26). In addition, extensive growths of the green alga, *Cladophora glomerata*, were evident at the first downstream site (QA-4) during late summer, indicating conditions usually associated with increasing eutrophication. High flows in successive monitoring periods made collection of further quantitative periphyton data on the Qualicum River impossible in 1978.

Generally, diatoms were numerically dominant above the main Qualicum Hatchery discharge, whereas diatoms and green algae commonly occurred below. Diatom composition was similar upstream and downstream of the hatchery, however, *Achnanthes minutissima* was numerically dominant above, whereas *Nitzschia dissipata* and *N. amphibia* were more common below. Green algae species which were most abundant below the hatchery were *Ulothrix zonata* and *U. aequalis*.

The increased nitrite/nitrate, ammonia, total dissolved nitrogen and total phosphate concentrations monitored below the main Qualicum Hatchery during January and February, 1979, are attributed to the decomposition of salmon carcasses in the chum spawning channel and mainstem Qualicum River above the sampling sites.

Mean concentrations of selected nutrients at the control and furthest downstream sites in the Qualicum River between August, 1978 and January, 1979 were as follows:

Mean nitrite/nitrate

QA-1	0.026 $mg \cdot L^{-1}$	(n = 7)
QA-6	0.048 $mg \cdot L^{-1}$	(n = 7)

Mean total dissolved nitrogen

QA-1	0.063 $mg \cdot L^{-1}$	(n = 7)
QA-6	0.115 $mg \cdot L^{-1}$	(n = 7)

Mean total ammonia

QA-1	0.006 $mg \cdot L^{-1}$	(n = 7)
QA-6	0.043 $mg \cdot L^{-1}$	(n = 7)

Mean total phosphate

QA-1	0.006 $mg \cdot L^{-1}$	(n = 7)
QA-6	0.018 $mg \cdot L^{-1}$	(n = 7)

In January and February, 1979, growths of the "sewage fungus", *Sphaerotilus natans*, were sampled from artificial and natural substrates in the Qualicum River, below the hatchery and at the bottom end of the chum spawning channel. *Sphaerotilus* growth is generally indicative of high organic loadings.

Slightly elevated total phosphate concentrations were measured during winter, upstream of the spawning channel (but below the experimental channel impact site, QA-2) and are attributed to runoff from a temporary land clearing project.

Results of the March 26, 1979, Qualicum River "pre-emergence" benthos sampling period have been analyzed for gross numerical differences at sites above and below the hatchery outfalls. Benthic invertebrate sampling sites are adjacent to the following periphyton sampling sites: QA-1 (upstream control), QA-2 (immediately downstream of the experimental channel), QA-4 (immediately downstream of main Qualicum Hatchery) and QA-6 (furthest downstream site, see Figure 4A for locations).

The control site (QA-1) was characterized by the numerically-dominant mayflies (especially the genus *Cinygmula*, and the second-most numerous group, the chironomids (especially the genera *Corynoneura* and *Eukiefferiella*).

At site QA-2 below the experimental channel, the abundance of mayflies of most genera increased. In addition, the chironomid genera, *Stempellinella* and especially *Micropsectra*, showed large numercial increases (5 to 10 fold) at site QA-2. Less noticeable increases in chironomids of the genera *Eukiefferiella* and *Thiemaniella* also occurred at site QA-2.

Abundance of the following "silt-tolerant" invertebrate taxa increased 4 to 8 fold downstream of the experimental channel: harpacticoid copepods, mites, and ostracods.

At site QA-4, immediately below the main Qualicum Hatchery effluent discharge, the following changes in benthic fauna were documented:

a) All mayfly genera, except *Pseudocleon* sp. and *Epeorus* (*Iron*) *longimanus* were reduced to one-half of their "control site" abundance.

b) The chironomid genus *Micropsectra*, abundant above the hatchery, was absent in samples from below the hatchery.

c) The chironomid genera, *Corynoneura* and *Stempellinella* at site QA-4 were about twice as abundant as at the control site; while the following chironomid genera exhibited about a 10-fold increase over control site abundances:- *Polypedilum*, *Cricotopus*, *Eukiefferiella*, *Thiemaniella* and *Procladius*.

d) Oligochaetes at site QA-4 were more numerous than at upstream sites (QA-1 and QA-2); while blackflies (Simuliidae) were four times more abundant at the "below hatchery" site (QA-4) than at the control site (QA-1).

The data for the furthest downstream site (QA-6) have not been completely analyzed, but the abundance of mayflies, oligochaetes and blackflies appears to be similar to those at the control site. Only numbers of harpacticoid copepods and mites remained high at site QA-6.

4) Capilano River Hatchery

This hatchery is located on the Capilano River 300 metres below the Greater Vancouver Water District's "Cleveland Dam", North Vancouver (Figure 5). Water for the hatchery is drawn from the 50 metre level in Capilano Lake behind the dam. Due to flow control at Cleveland Dam during late summer and early fall, the Capilano River is frequently comprised of only a small amount of dam seepage water, hatchery supply overflow water and the hatchery effluent.

Highly variable flows in the Capilano River during the sampling program during winter, 1978, led to repeated loss of the artificial substrate plates and concrete blocks. The automatic control works on Cleveland Dam were opened manually for maintenance and other reasons, causing sudden rises in river depth and flow. Due to manipulative and natural river fluctuations through runoff, continuous monitoring of periphyton standing crop was not possible during much of 1978 on the Capilano River.

Water quality sampling results showed that slightly elevated total phosphate concentrations usually occurred at site CA-2, immediately below the hatchery discharge into the Capilano River and at the Cable Pool site, CA-3. (Mean total phosphate concentrations between September, 1978 and February, 1979 for the Capilano River were as follows: CA-1: 0.003 $mg \cdot L^{-1}$; CA-2: 0.007 $mg \cdot L^{-1}$; CA-3: 0.008 $mg \cdot L^{-1}$; CA-4: 0.006 $mg \cdot L^{-1}$ (n = 8 for each site).

Elevated nitrite/nitrate levels at site CA-4 (Figure 12C) are largely attributed to the input of Holgate Creek which drains the British Properties in West Vancouver. (Mean nitrite/nitrate concentrations between September, 1978 and February, 1979 were as follows: CA-1: 0.189 $mg \cdot L^{-1}$; CA-2: 0.189 $mg \cdot L^{-1}$; CA-3: 0.190 $mg \cdot L^{-1}$ and; CA-4: 0.253 $mg \cdot L^{-1}$ (n = 8 for each site).

During low flows in October, 1978, extensive mats of the blue-green alga, *Lyngbya aerugineo-caerula,* were evident on natural rock surfaces in the Capilano River below the hatchery outlet. At the control site (CA-1), mixed greens, and diatoms such as *Tabellaria fenestrata* were common. Further downstream, at sites CA-2 and CA-3, diatoms, blue-green algae, and green algae commonly occurred. At site CA-4, near the 401 Highway Bridge, the following green algae were numericall dominant: *Ulothrix zonata, U. tennuissima* and *U. tennerrima*. In November and December, 1978 sharp peaks in diatom numbers occurred on the "pool" substrates at site CA-2, located downstream of the hatchery discharge (mean diatom numbers for the control site, CA-1 were 66 000 $cells \cdot cm^{-2}$; whereas downstream of the hatchery, mean counts were as follows: CA-2: 614 000 $cells \cdot cm^{-2}$; CA-3: 7000 $cells \cdot cm^{-2}$ and CA-4: 53 000 $cells \cdot cm^{-2}$, n = 2 for each site. Light levels and inorganic nitrogen concentrations were much lower at the "canyon" sites (CA-1 through CA-3 than at the "below canyon" site (CA-4).

B. Feasibility Assessments at Proposed Facilities

1) Nicola River

The recently constructed Nicola River rearing facility is located 8 km downstream of Merritt at a groundwater-fed pond adjacent to the Nicola River (Figure 6). In April, 1979, a small number of chinook fry were trapped in the Nicola River and were reared during May and June.

During autumn, 1978, prior to the commencement of fish rearing activities, extensive macrosopic diatom mats (*Navicula* spp.) indicative of a high nutrient supply, were documented in the Nicola River at the monitoring site located downstream of the rearing pond. If year-round rearing were to take place at the Nicola River facility, increased nutrient loading at low flow periods from hatchery operations may cause either an undesirable increase in these diatom mats, or a shift to blue-green or green algal production.

Following the commencement of fry feeding in April, 1979, control and downstream monitoring sites were established in the Nicola River to document the impact of fish rearing on the receiving water. However, because of the Nicola River freshet which occurs between April and July, little periphyton impact data were obtained. Monitoring to determine the feasibility of rear-round rearing was resumed following the release of the chinooks in July, 1979.

2) Deadman Creek

A chinook rearing facility has been proposed for Deadman Creek, a tributary of the Thompson River located west of Kamloops (Figure 7). Water for the facility would be drawn from three sources: a) Deadman Creek; b) Snohoosh Lake (13 metre depth) and; c) groundwater (wells). Problems associated with groundwater quality, approval from other water user groups, and access rights from the local Indian Band, have reduced the likelihood that this project will proceed as planned.

During autumn, 1978, large amounts of the planktonic blue-green alga, *Aphanizomenon flos-aquae*, were sampled from natural substrates in Deadman Creek. These cells, which presumably originate from Snohoosh Lake, the source of Deadman Creek, settle out on the creek bottom and possibly grow there. *A. flos-aquae*, is a bloom-forming alga, some strains of which are toxic, and can cause fish kills and livestock poisonings. Other planktonic algae, originating from Snohoosh Lake, such as the unicellular flagellate, *Ochromonas* spp., exhibited heavy winter growth under ice during 1978, and along with *A. flos-aquae*, may cause clogging of hatchery intake screens.

3) Chilliwack River

A large year-round hatchery is proposed for the Chilliwack River, with construction proposed for 1980/81 (Figure 8). The water for this facility will be drawn from Slesse Creek tributary and a number of groundwater wells.

Small quantities of diatoms and green algae were sampled from the Chilliwack River periodically last fall, but the frequent scouring of the river bottom during high river flows eliminated algal guild-up during early spring. Continued feasibility monitoring in low flow periods should permit a predictive assessment of the potential impact of a year-round hatchery operation on the Chilliwack River.

C. Impact Assessment at Seasonal Hatcheries

1) Bella Coola (Snootli Creek) Hatchery

A Japanese-style chum hatchery with added chinook rearing was operated in spring, 1979, on Snootli Creek, a tributary of the Bella Coola River (see Figure 9). Groundwater and Snootli Creek water are combined in the concrete rearing channels and the discharge is directed into a small surface drainage stream which flows back into Snootli Creek.

Only a water quality monitoring program was carried out at the Snootli Creek hatchery this year. The data, which were useful in assessing initial fry mortalities, (a number of dead fry were found in the pens at the commencement of rearing) will provide information on the characteristics of effluent from chum and chinook fry rearing operations utilizing concrete channels.

The largely inaccessible Bella Coola Hatchery discharge stream flows a distance of 800 metres before entering Snootli Creek, thus nutrient and suspended solids levels should be reduced at the Creek. A mid-June, 1979, inspection of the discharge stream itself showed that it supported heavy growths of the green algae, *Ulothrix* spp. It was also noted that a large number of fry had apparently moved out of the mainstem Snootli Creek and were rearing in the creek receiving the discharge. Flows in this tributary have been augmented by approximately 3 cfs with the addition of the hatchery flows.

2) Conuma River (Tlupana) Hatchery

A Japanese-style chum and chinook hatchery was recently built on the Conuma River on the west coast of Vancouver Island near Tahsis (Figure 10). In 1979, chum fry from both the Conuma and Sucwoa Rivers were reared for a short time during spring.

At the time of rearing, dense mats of filamentous green algae (*Ulothrix* spp.) were observed within the rearing channels and in the release channel leading into Leagh Creek, a tributary of the Conuma River. However, during spring, the Conuma River apparently offered sufficient dilution to minimize any impact from the hatchery discharge. Following fry release in April, 1979, feasibility monitoring for the proposed ninety-day chinook rearing was undertaken (one additional periphyton colonization period).

3) Inches Creek Hatchery

A pilot chum rearing facility on this tributary of Norrish Creek in the Fraser River valley was operated during spring, 1979 (Figure 11). Additional groundwater sources may be utilized, and this facility enlarged in the future.

Inches Creek is almost a completely groundwater-fed stream and as a result, flows remain quite constant. Any benthic algal growth occurring in the stream is not subjected to the periodic scouring typical of surface water drainages. The flooding of Inches Creek by the Fraser River during portions of this spring's rearing period will make interpretation of the monitoring results more difficult.

Acknowledgements

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The chemical analysis of water samples under the direction of Dr. R. Swingle and J. Davidson and the analysis of particulate and dissolved nutrients under the direction of Dr. W. Erlebach and F. Mah are greatly appreciated.

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S. Prothero prepared the figures for the report.

Dr. I.K. Birtwell and M.D. Nassichuk reviewed all edited draft manuscripts.

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3. Underwood, MacLellan and Associates Ltd., 1979a. Salmon rearing facilities wastewater study. Waste characterization.

4. Underwood, MacLellan and Associates Ltd., 1979b. Salmon rearing facilities wastewater study. Treatment technology.

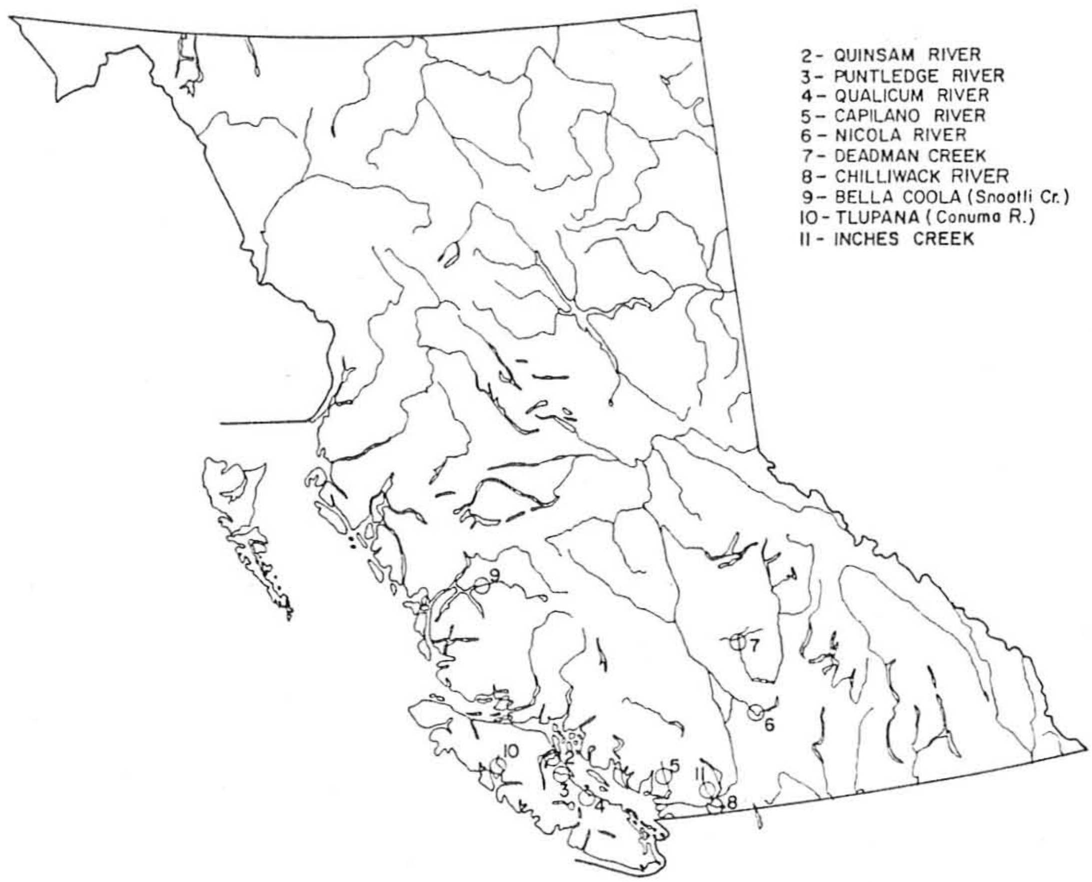

FIGURE 1- MAP OF B.C. SHOWING SAMPLING SITES.
SCALE: 1" = 100 miles.

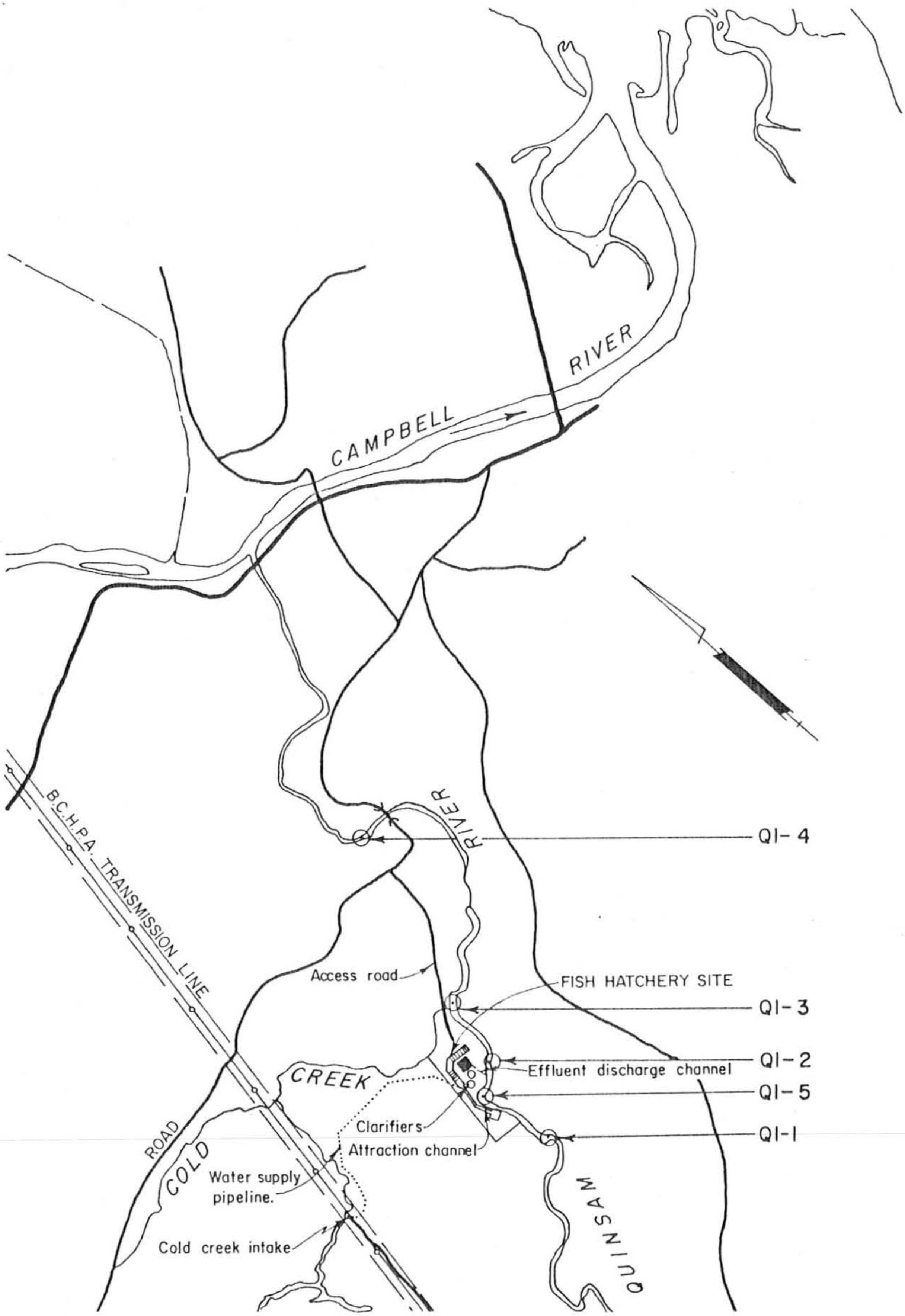

FIGURE 2. QUINSAM RIVER SAMPLING SITES.

SCALE: 1" = 2000'.

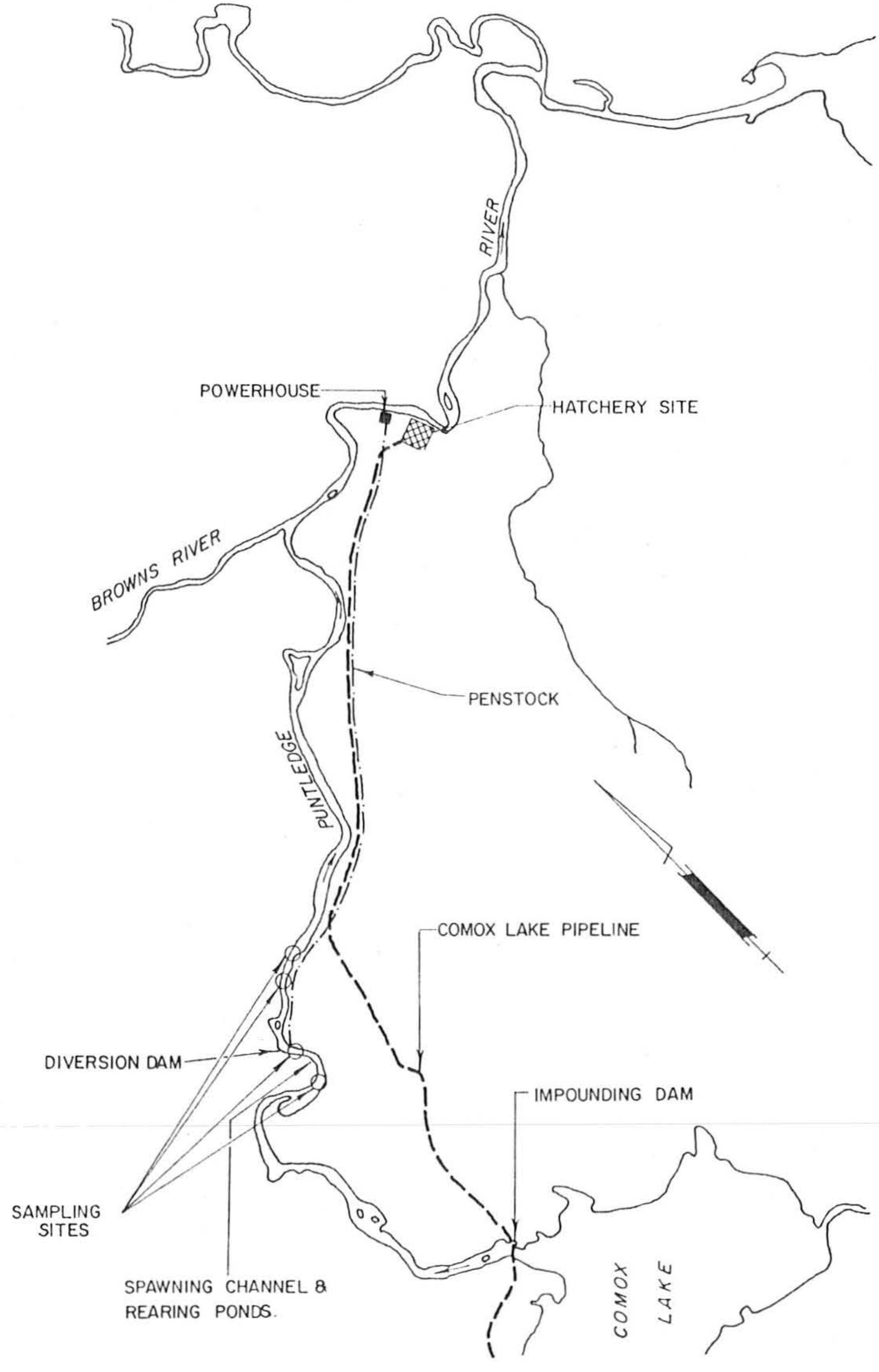

FIGURE 3A. PUNTLEDGE RIVER SITE PLAN

SCALE 1" = 3960' ±

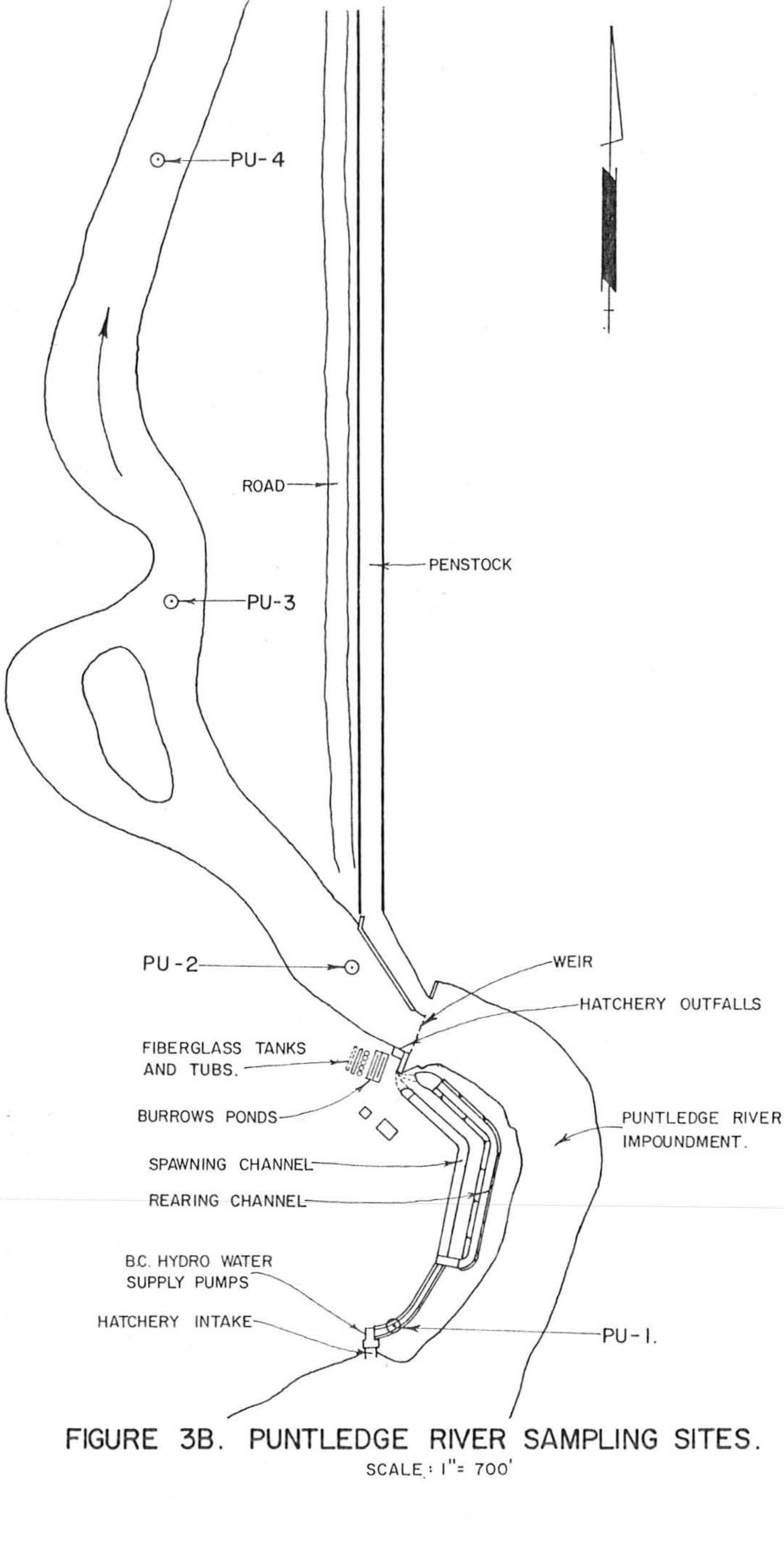

FIGURE 3B. PUNTLEDGE RIVER SAMPLING SITES.

SCALE: 1"= 700'

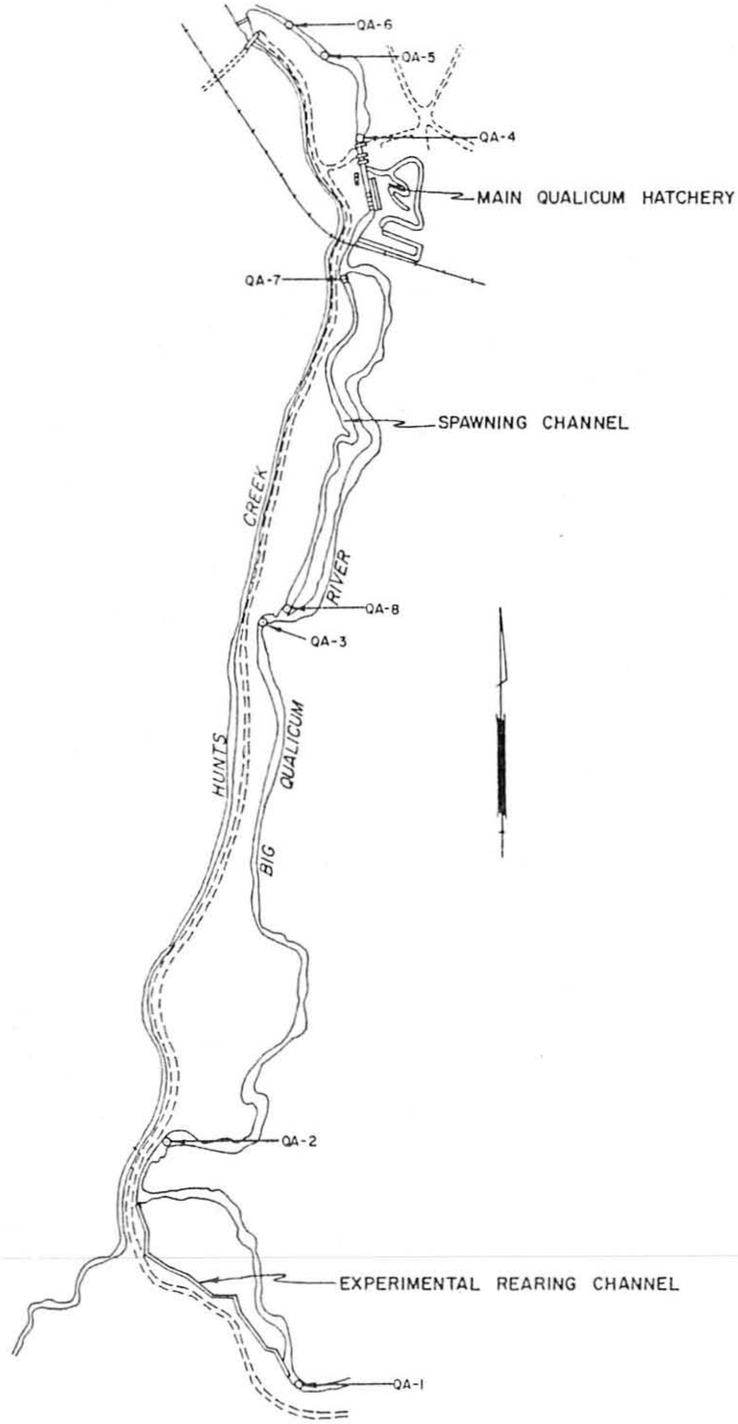

FIGURE 4A. BIG QUALICUM RIVER - OVERALL SITE PLAN.
SCALE: 1" = 2000'. ±

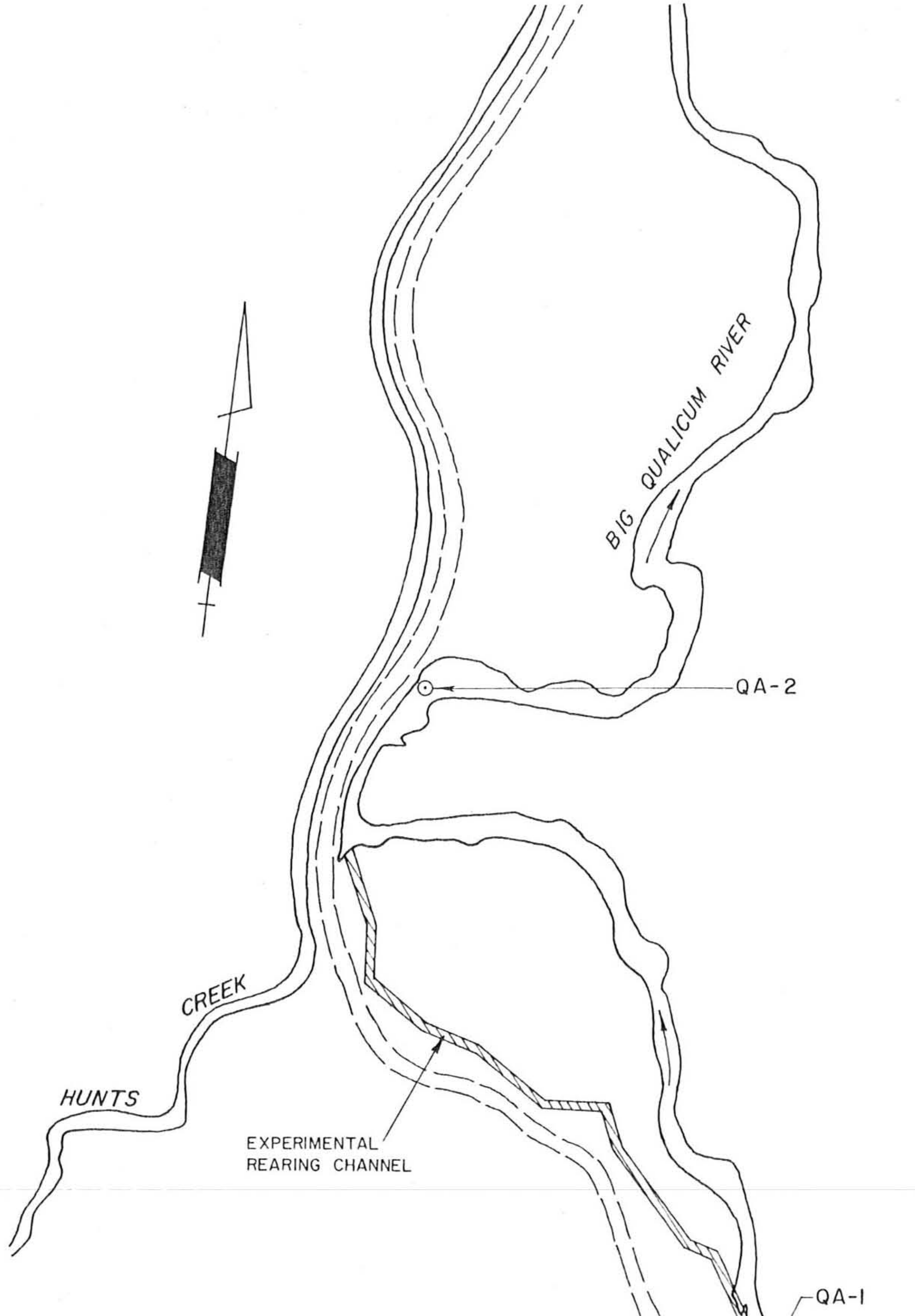

FIGURE 4B. BIG QUALICUM RIVER SAMPLING SITES.
(UPPER PORTION)
SCALE: 1"= 400'.

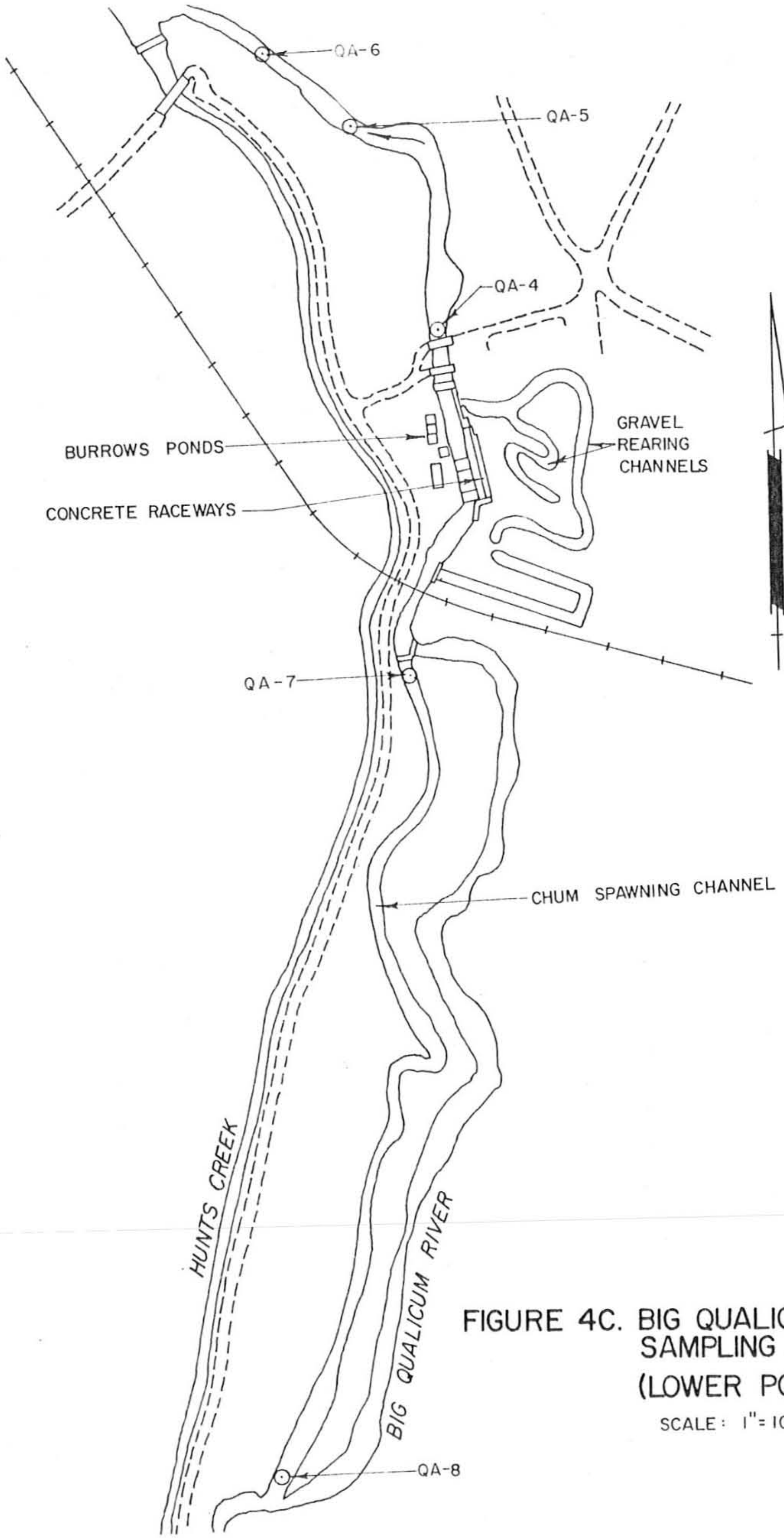

FIGURE 4C. BIG QUALICUM RIVER SAMPLING SITES (LOWER PORTION)

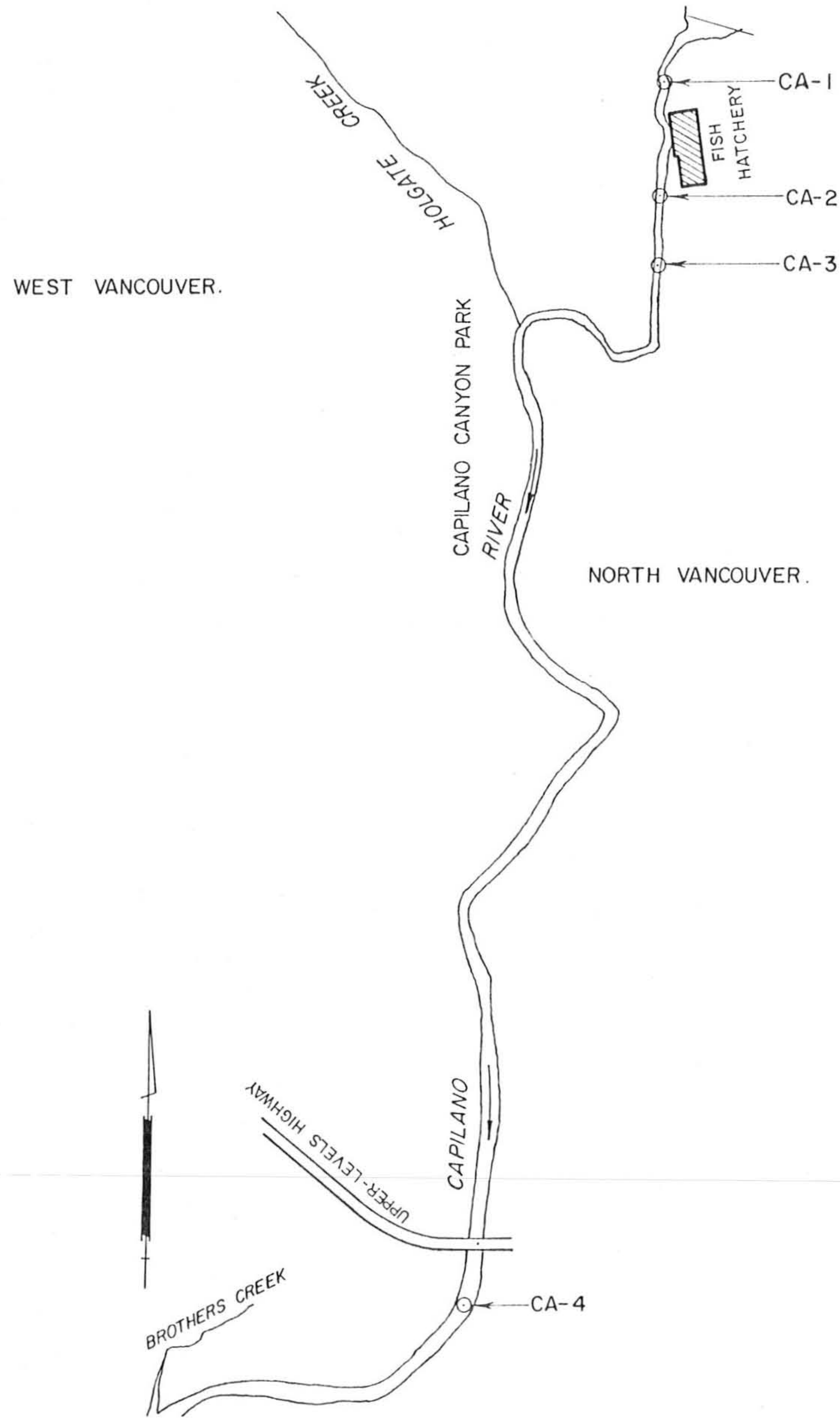

FIGURE 5. CAPILANO RIVER SAMPLING SITES.

SCALE : 1" = 3000' ± .

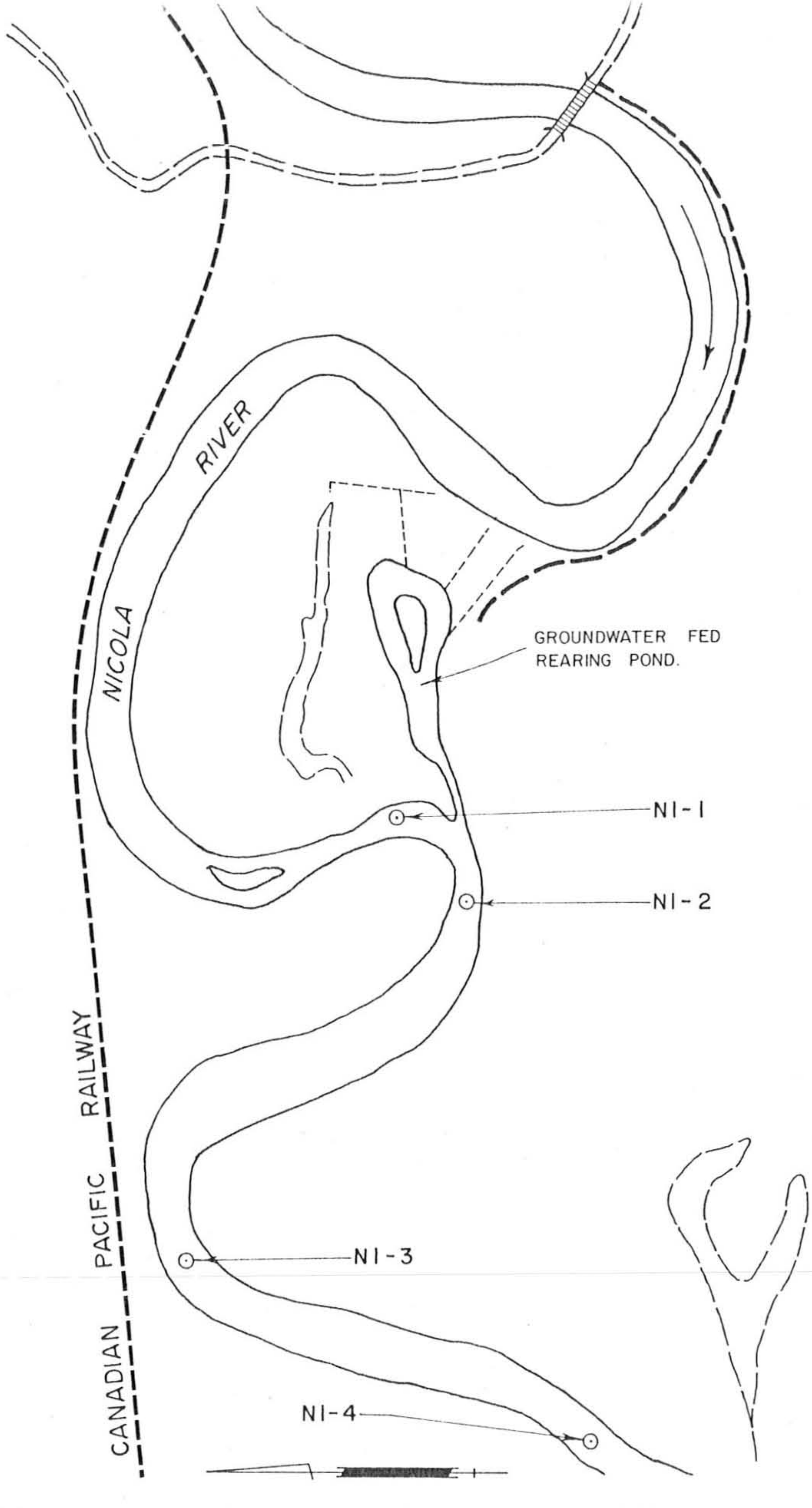

FIGURE 6. NICOLA RIVER SAMPLING SITES.

SCALE: 1"= 325'.

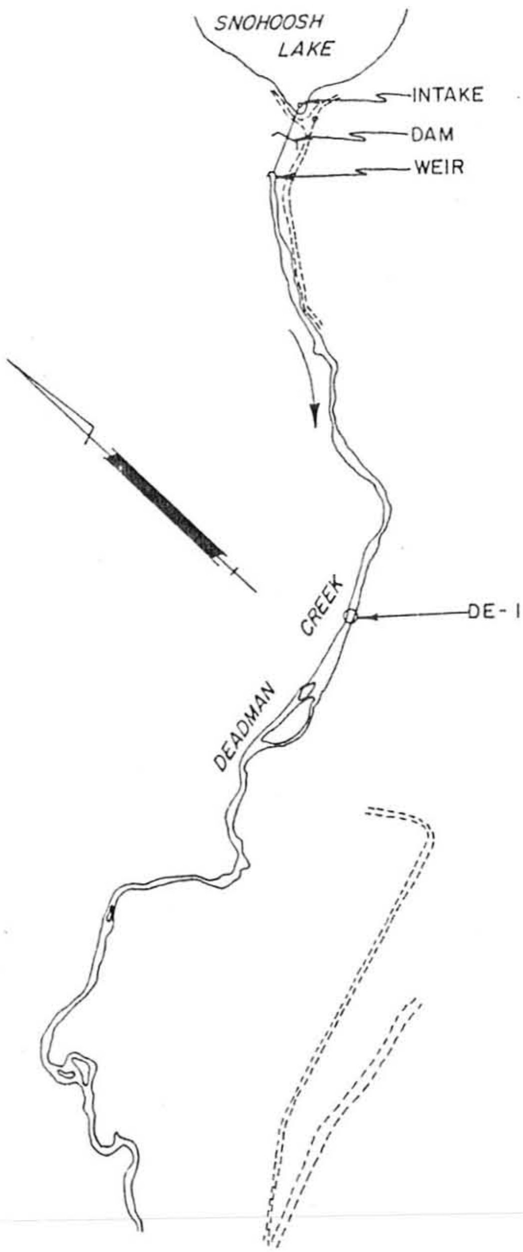

FIGURE 7. DEADMAN CREEK SAMPLING SITE

SCALE: 1" = 300'

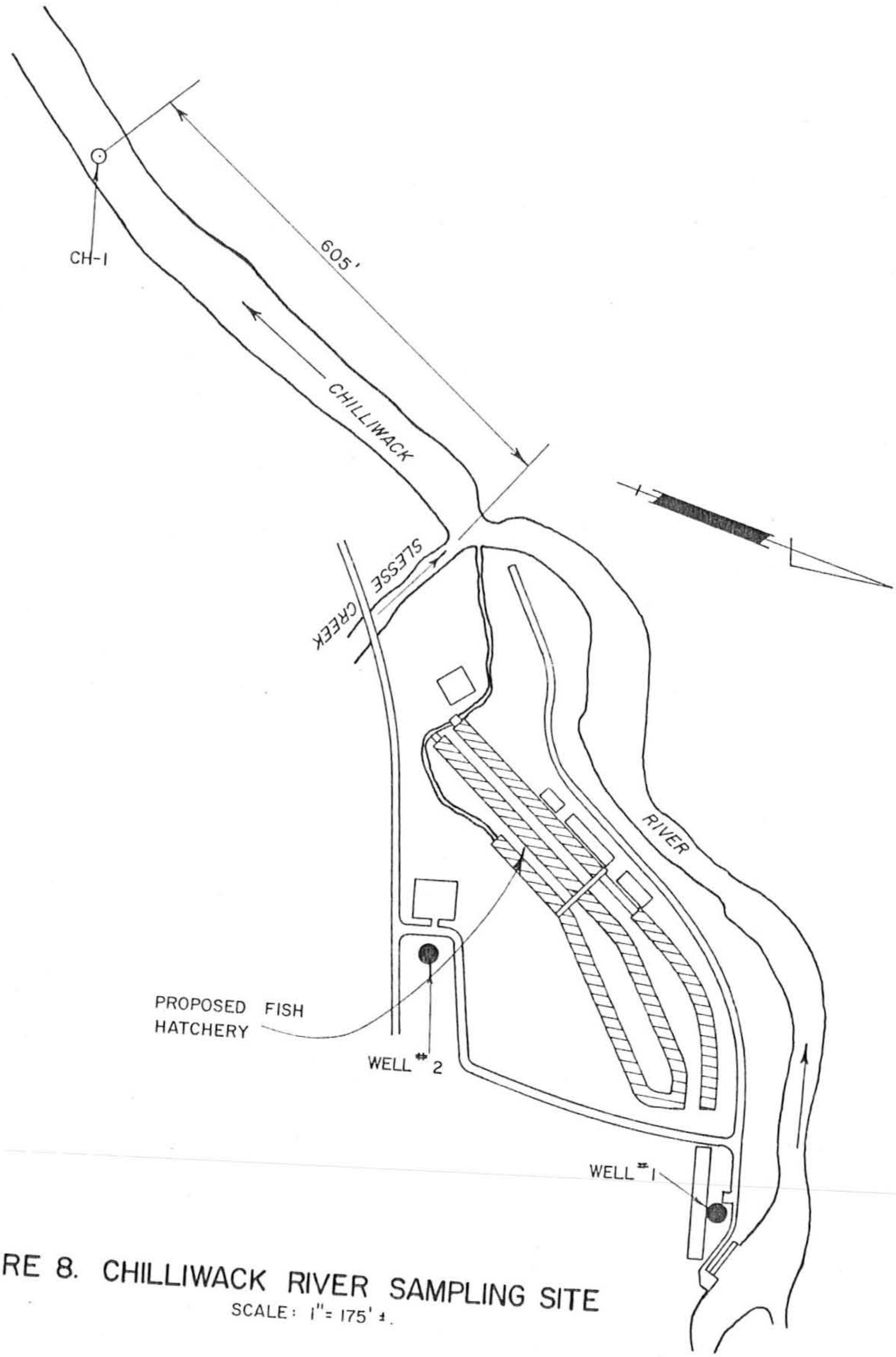

FIGURE 8. CHILLIWACK RIVER SAMPLING SITE

SCALE: 1" = 175' ±.

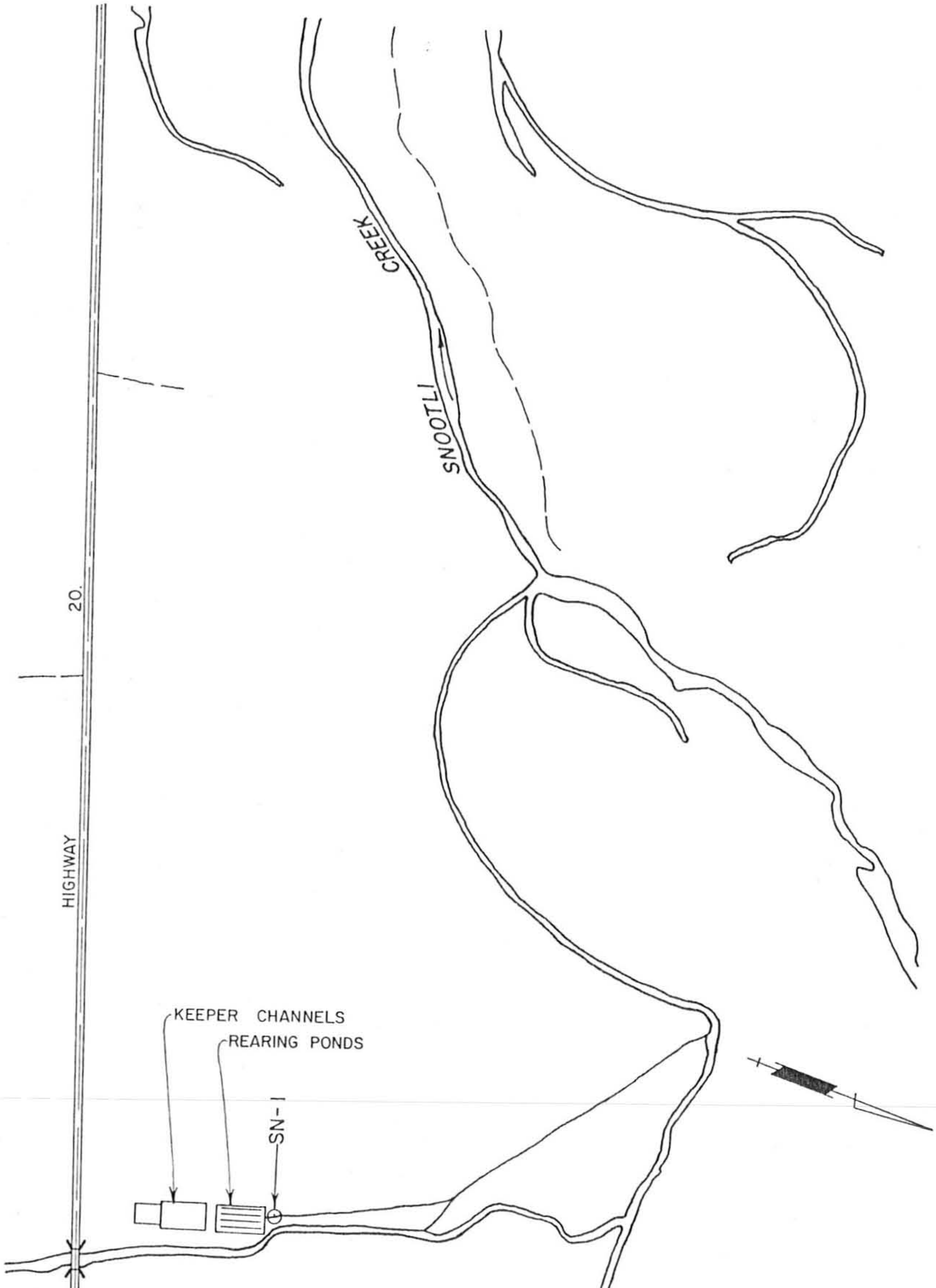

FIGURE 9. BELLA COOLA
(SNOOTLI CREEK) SAMPLING SITE
SCALE : 1" = 500'

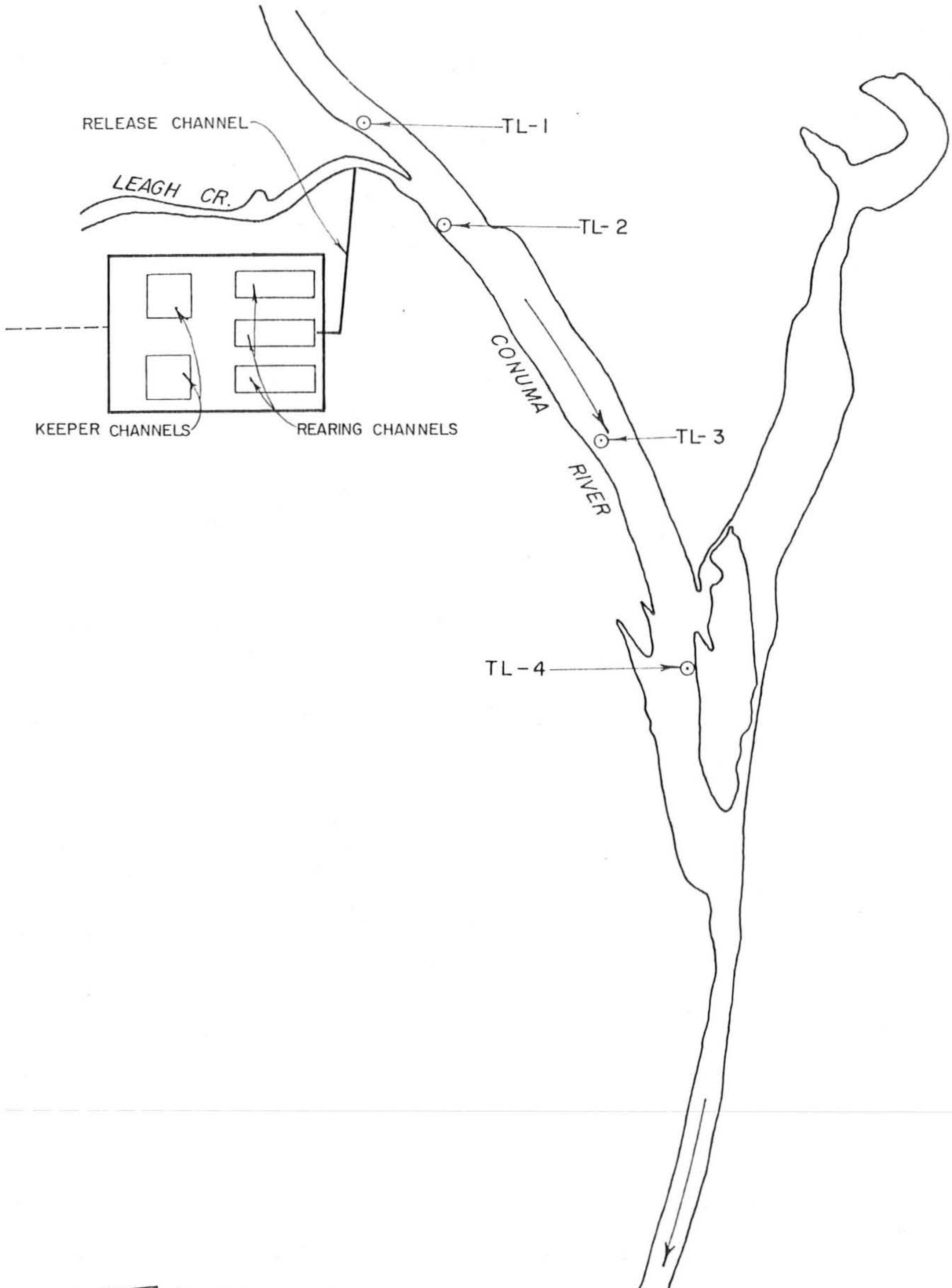

FIGURE 10. CONUMA RIVER SAMPLING SITES.
SCALE: 1"= 250'.

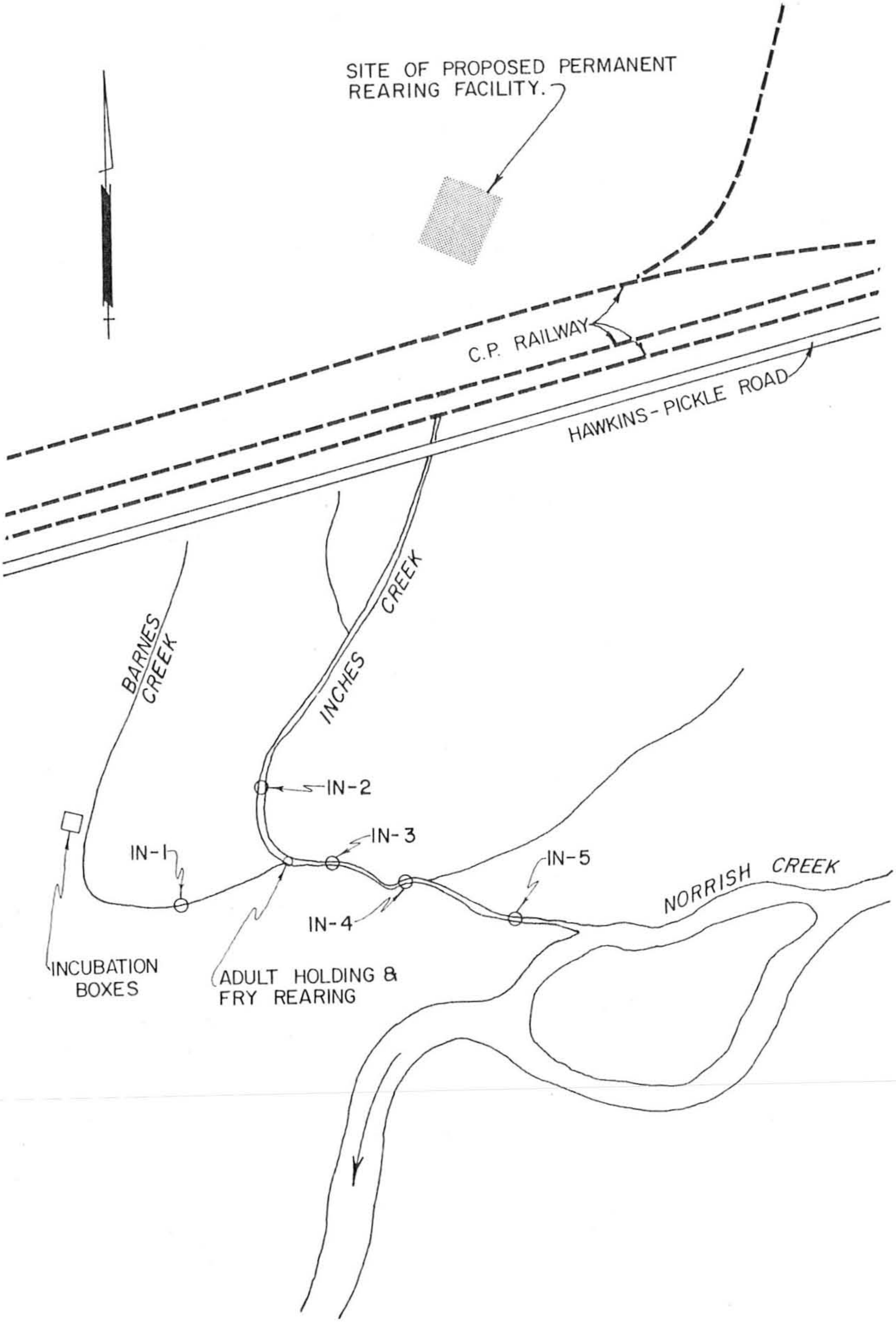

FIGURE 11. INCHES CREEK SAMPLING SITES.
SCALE = 1" = 300' ±

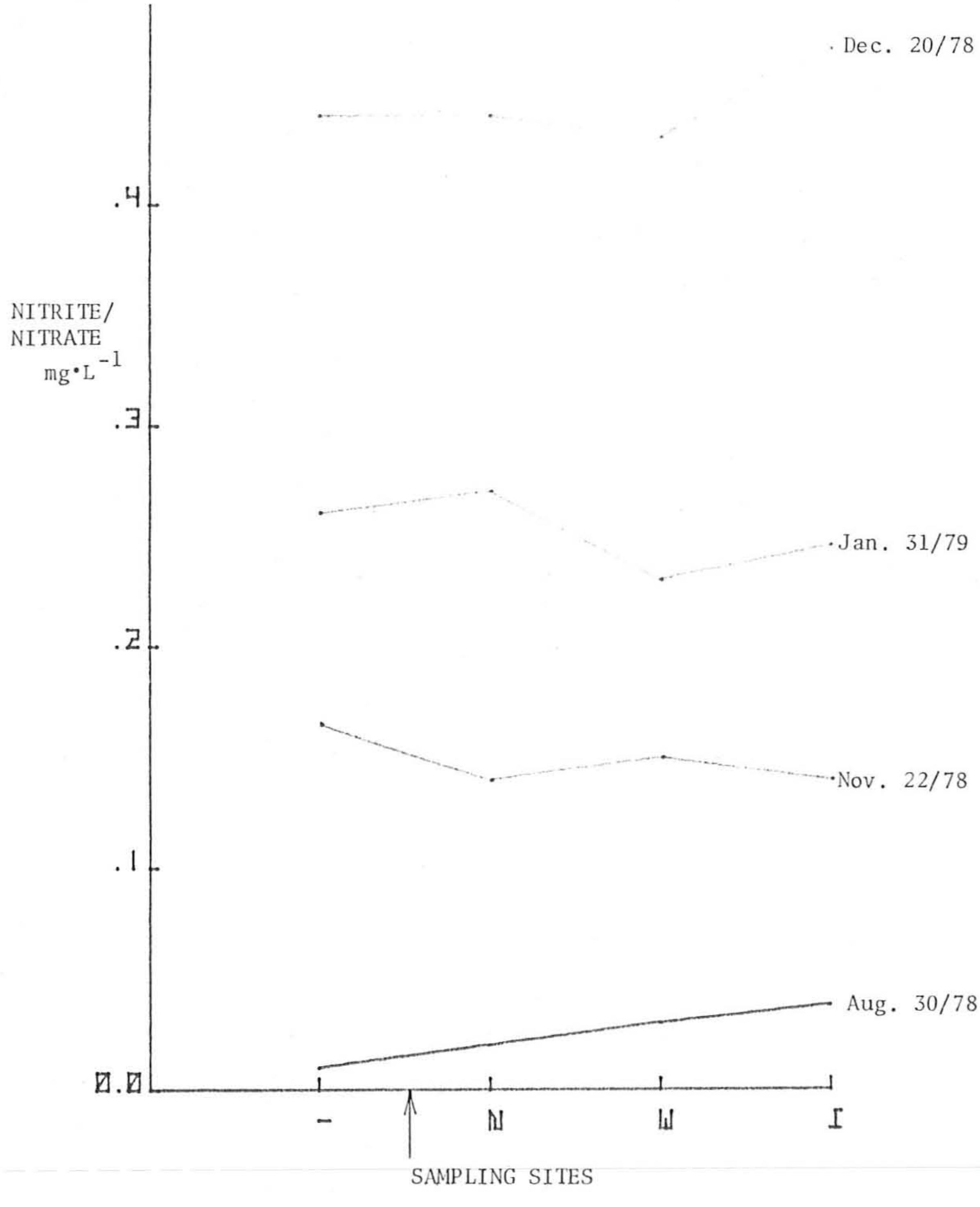

FIGURE 12A

Concentration of filtered nitrite/nitrate ($mg \cdot L^{-1}$) from selected samples taken between August 30, 1978 and January 31, 1979 in the Quinsam River. Arrow indicates the location of the Quinsam Hatchery effluent discharge.

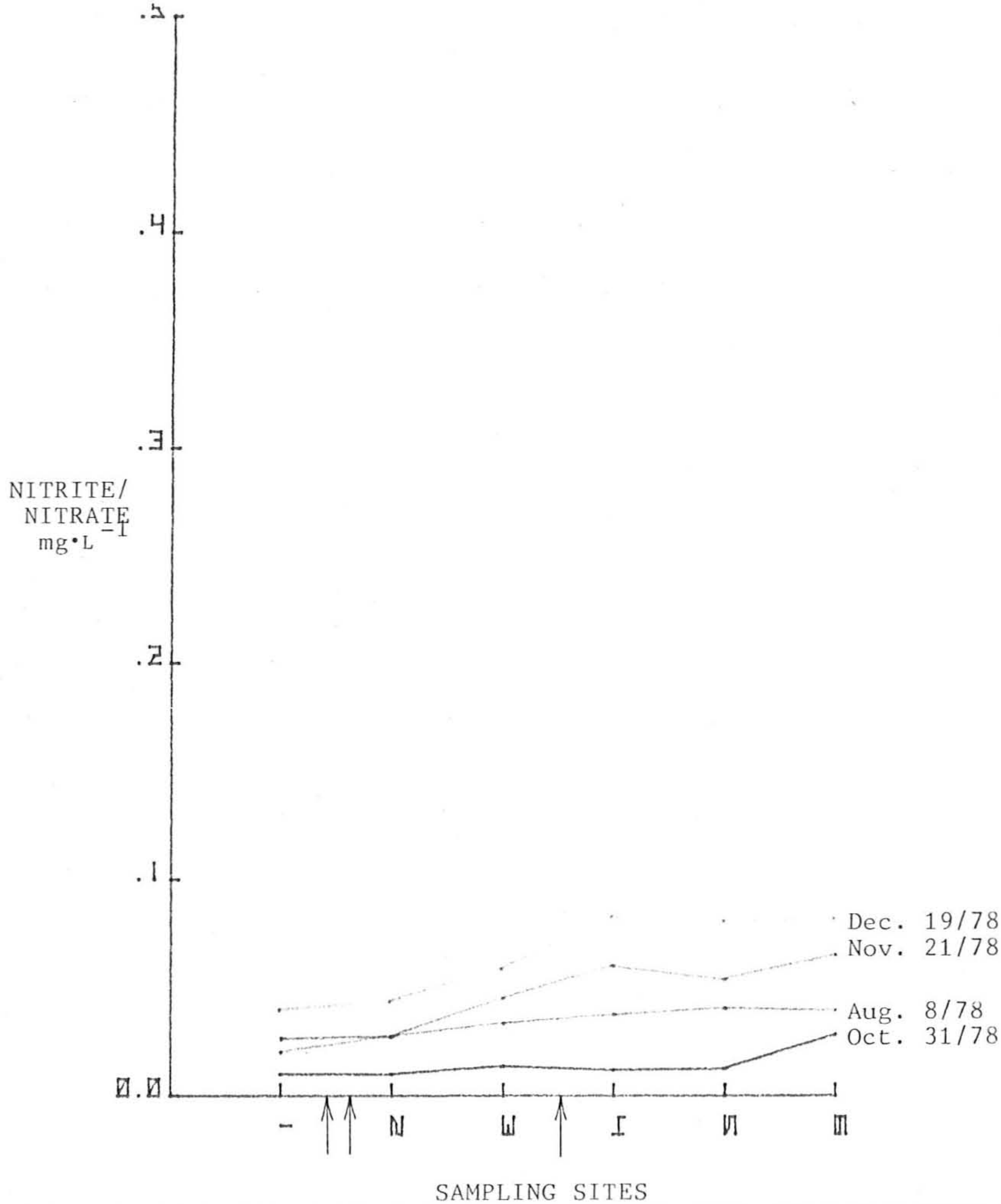

FIGURE 12B

Concentration of filtered nitrite/nitrate ($mg \cdot L^{-1}$) from selected samples taken between August 8, 1978 and December 19, 1978 in the Qualicum River. Arrow indicates the location of the Qualicum Hatchery effluent discharge and the chum spawning channel discharge. Double arrow indicates the location of the experimental channel effluent discharge.

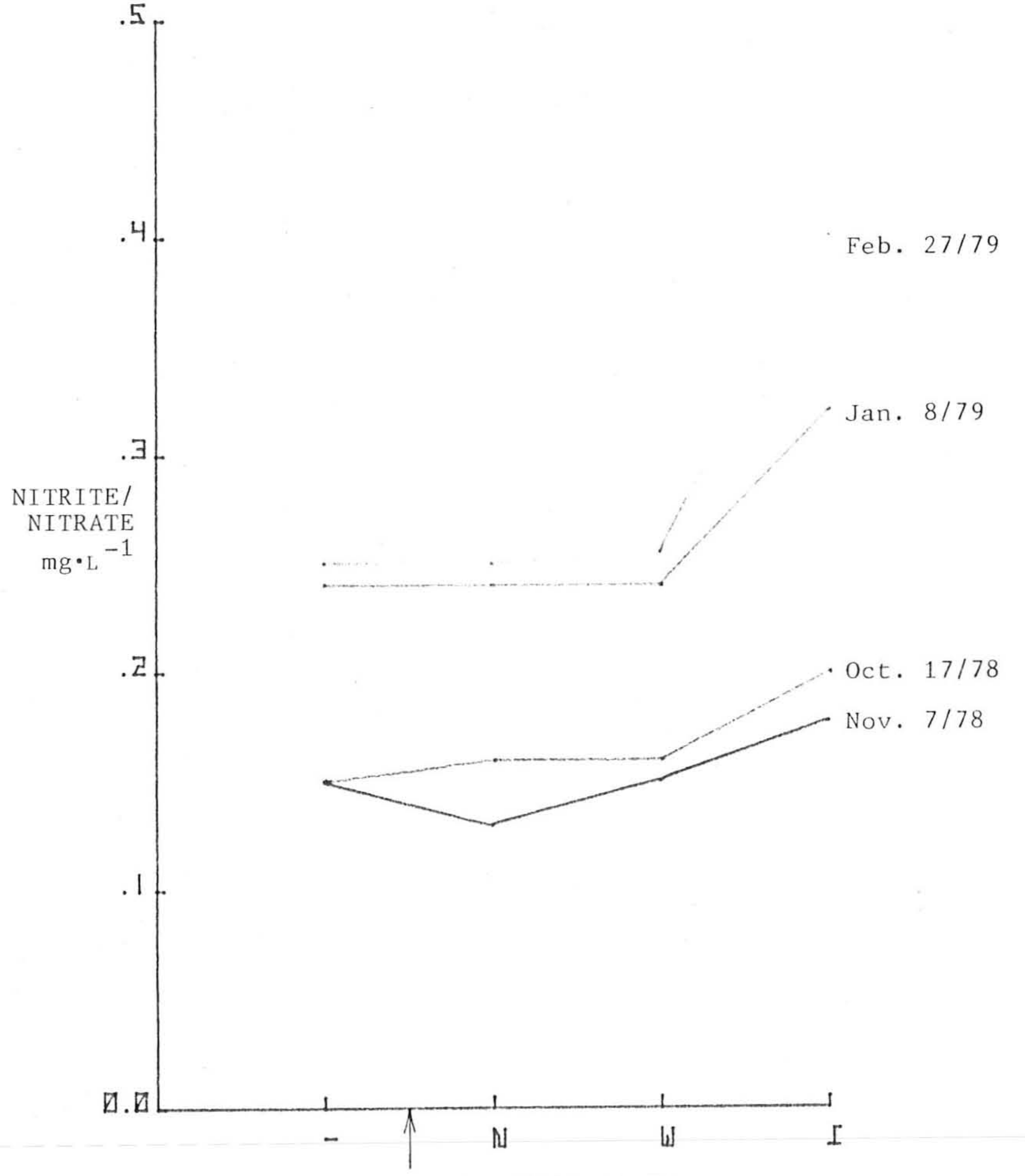

FIGURE 12C

Concentration of filtered nitrite/nitrate ($mg \cdot L^{-1}$) from selected samples taken between October 17, 1978 and February 27, 1979 in the Capilano River. Arrow indicates the location of the Capilano Hatchery effluent discharge.

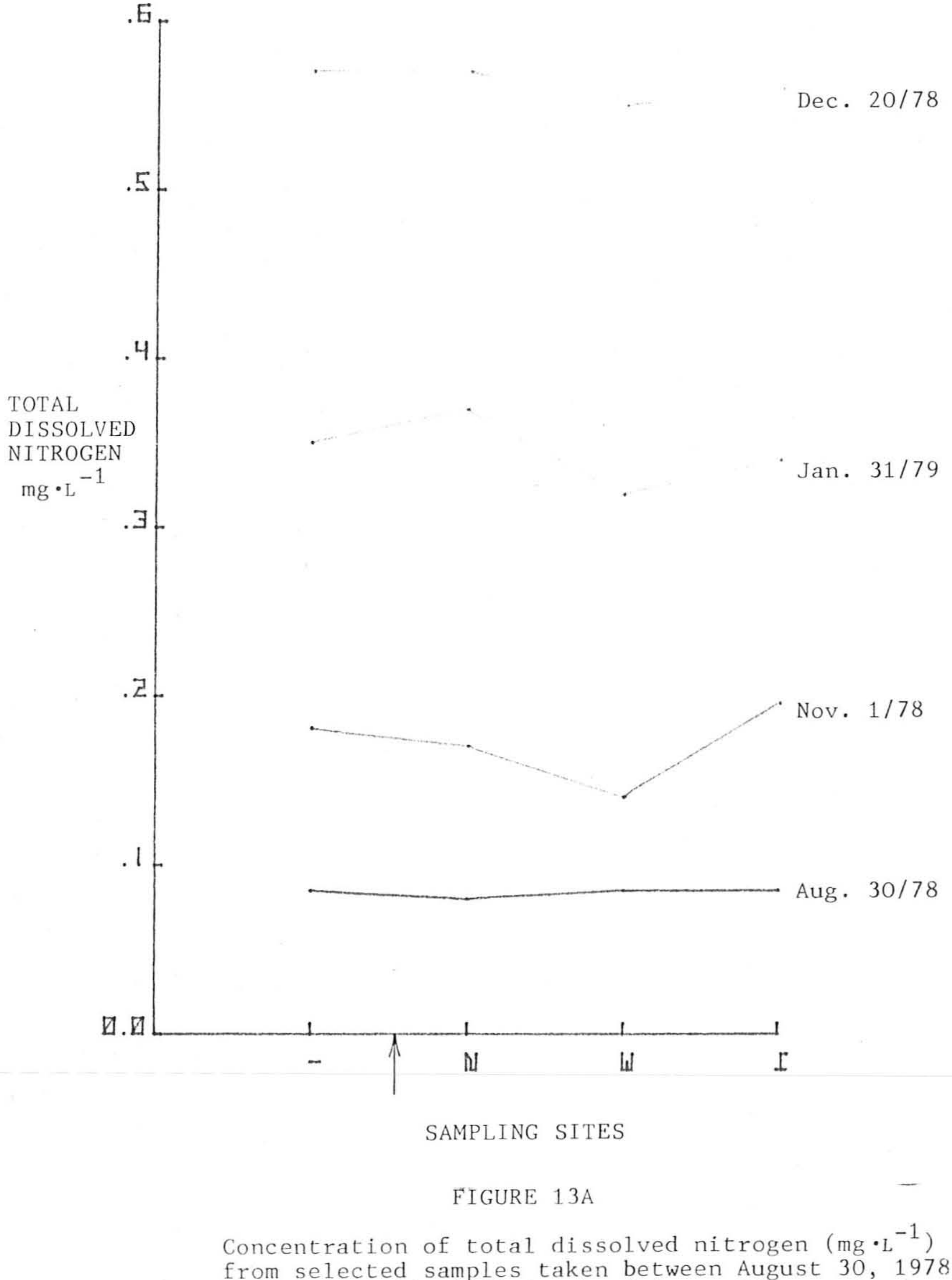

FIGURE 13A

Concentration of total dissolved nitrogen ($mg \cdot L^{-1}$) from selected samples taken between August 30, 1978 and January 31, 1979 in the Quinsam River. Arrow indicates the location of the Quinsam Hatchery effluent discharge.

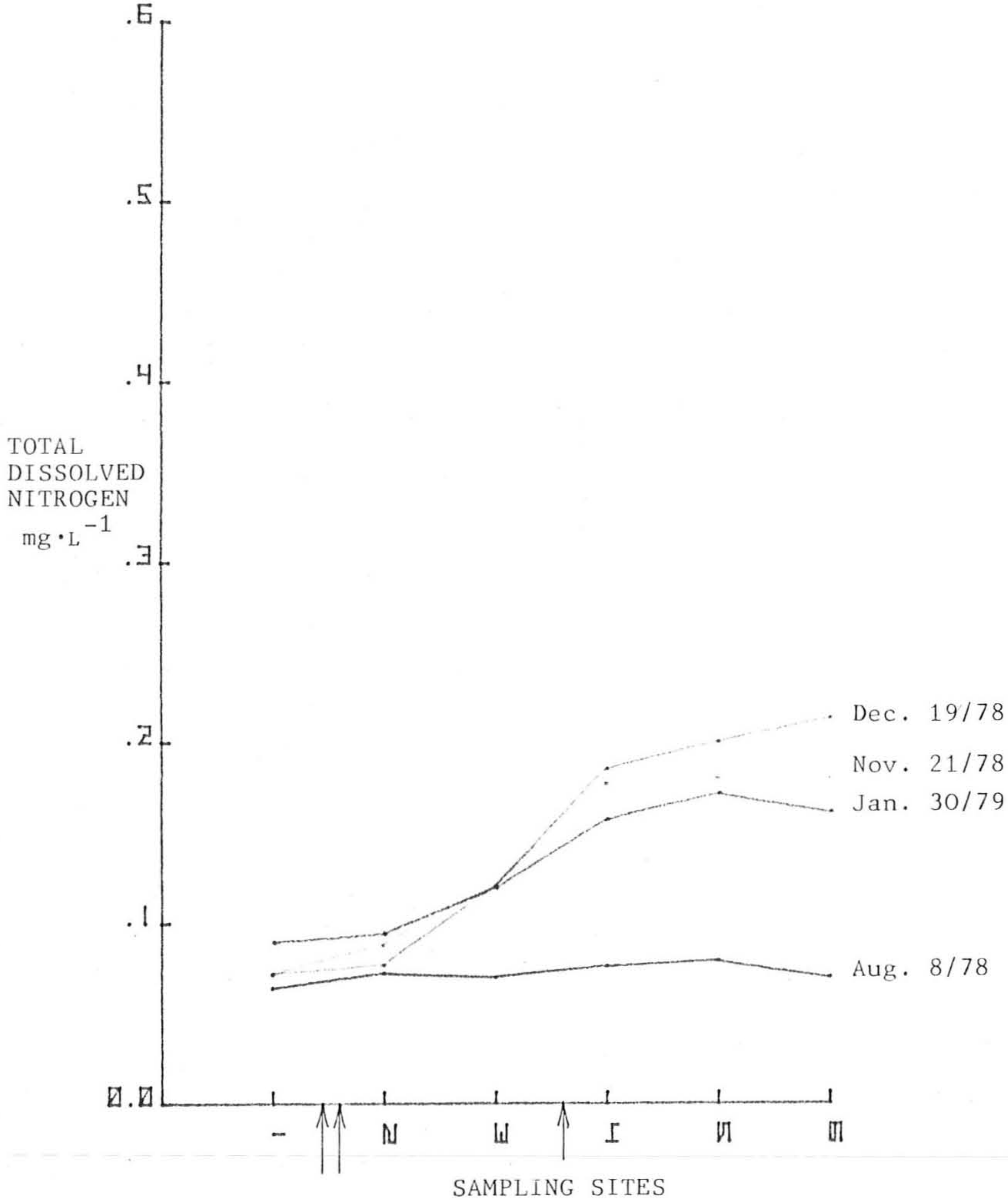

FIGURE 13B

Concentration of total dissolved nitrogen from selected samples taken between August 8, 1978 and January 30, 1979 in the Qualicum River. Arrow indicates the location of the Qualicum Hatchery effluent discharge and the chum spawning channel discharge. Double arrow indicates the location of the experimental channel effluent discharge.

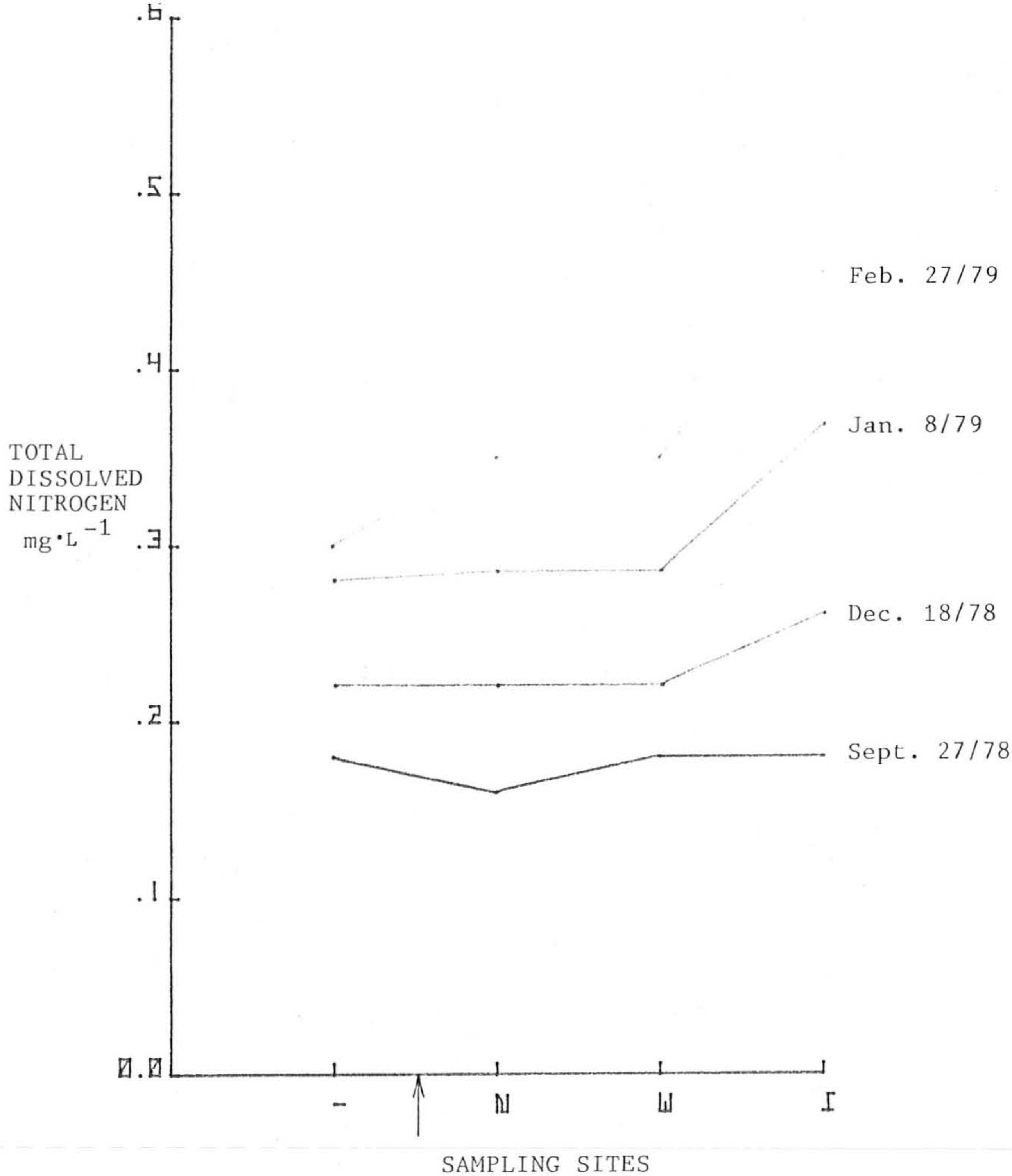

FIGURE 13C

Concentration of total dissolved nitrogen (mg·L^{-1}) from selected samples taken between September 27, 1978 and February 27, 1979 in the Capilano River. Arrow indicates the location of the Capilano Hatchery effluent discharge.

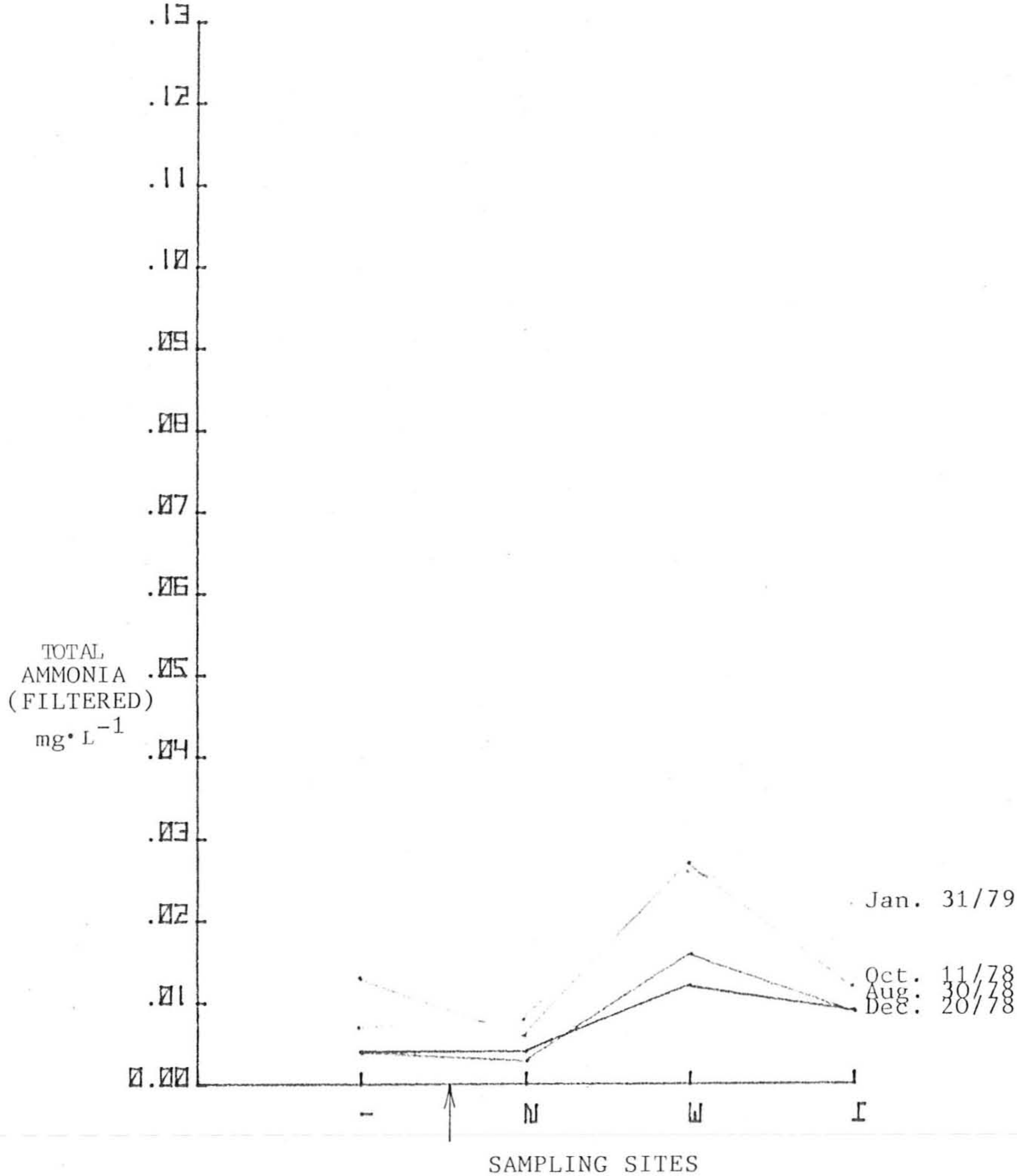

FIGURE 14A

Concentration of total ammonia (filtered) (mg · L^{-1}) from selected samples taken between August 30, 1978 and January 31, 1979 in the Quinsam River. Arrow indicates the location of the Quinsam Hatchery effluent discharge.

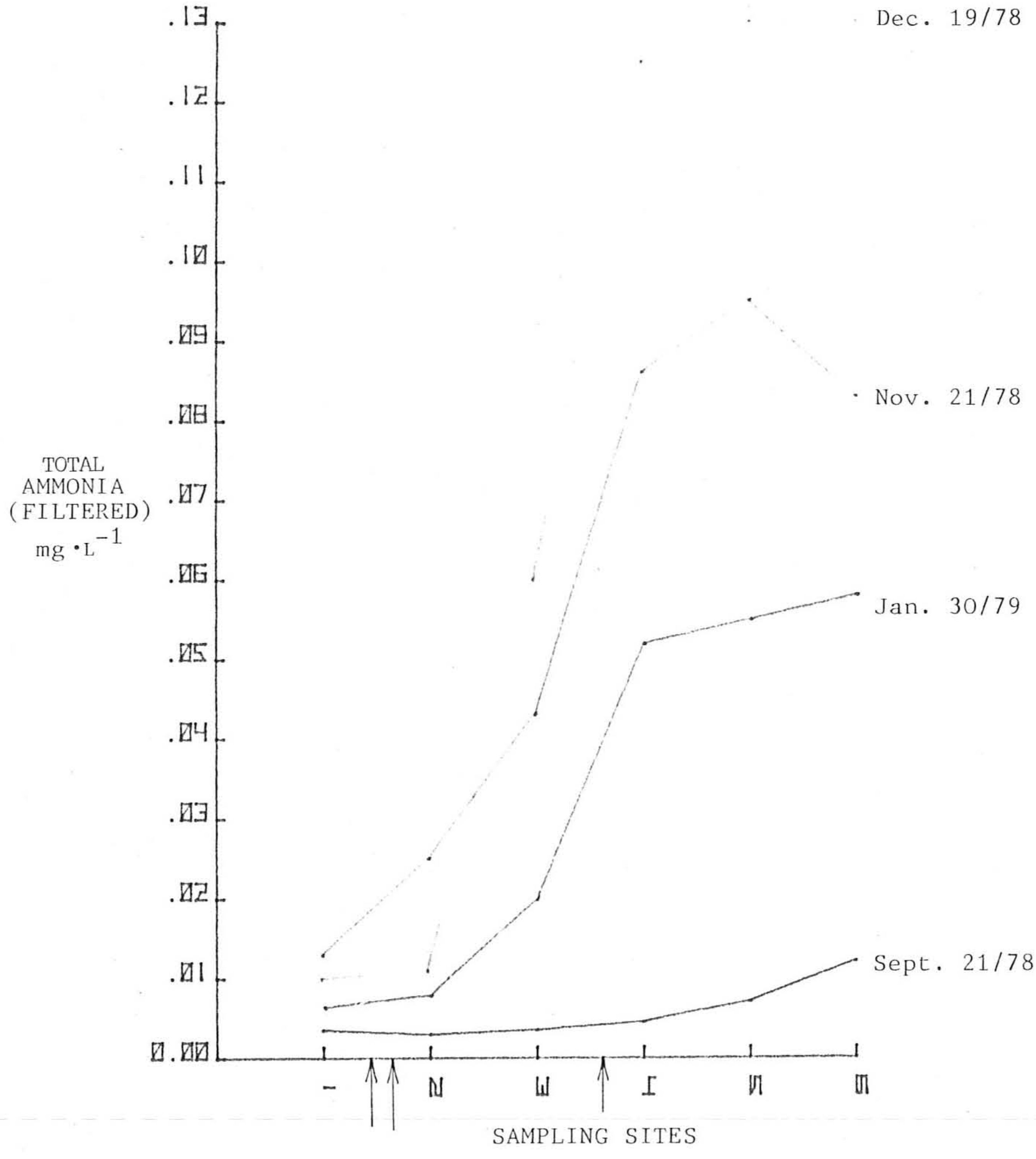

FIGURE 14B

Concentration of total ammonia (filtered) (mg$\cdot$L^{-1}) from selected samples taken between September 21, 1978 and January 30, 1979 in the Qualicum River. Arrow indicates the location of the Qualicum Hatchery effluent discharge. Double arrow indicates the location of the experimental channel effluent discharge.

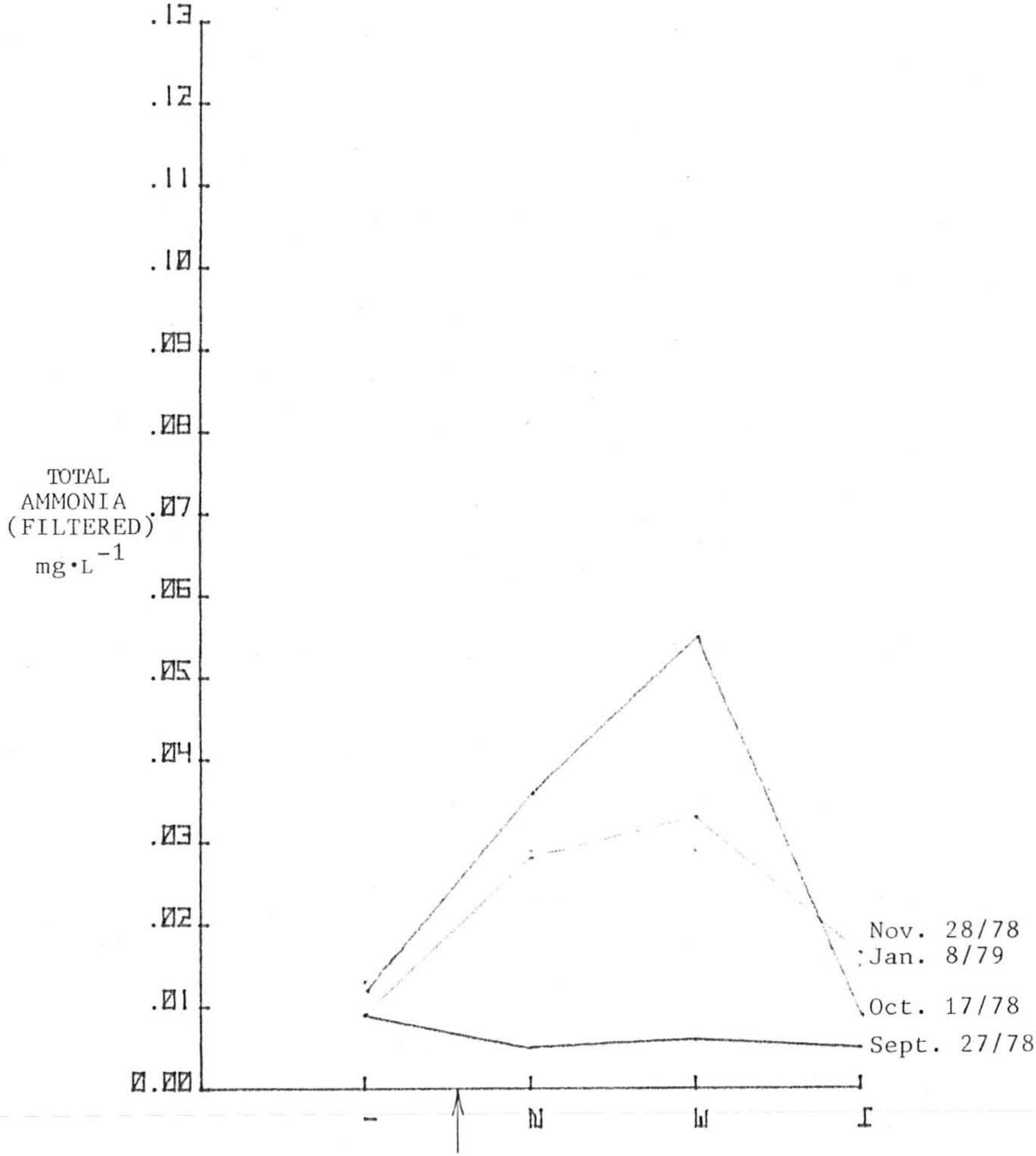

FIGURE 14C

Concentration of total ammonia (filtered) (mg·L^{-1}) from selected samples taken between September 27, 1978 and January 8, 1979 in the Capilano River. Arrow indicates the location of the Capilano Hatchery effluent discharge.

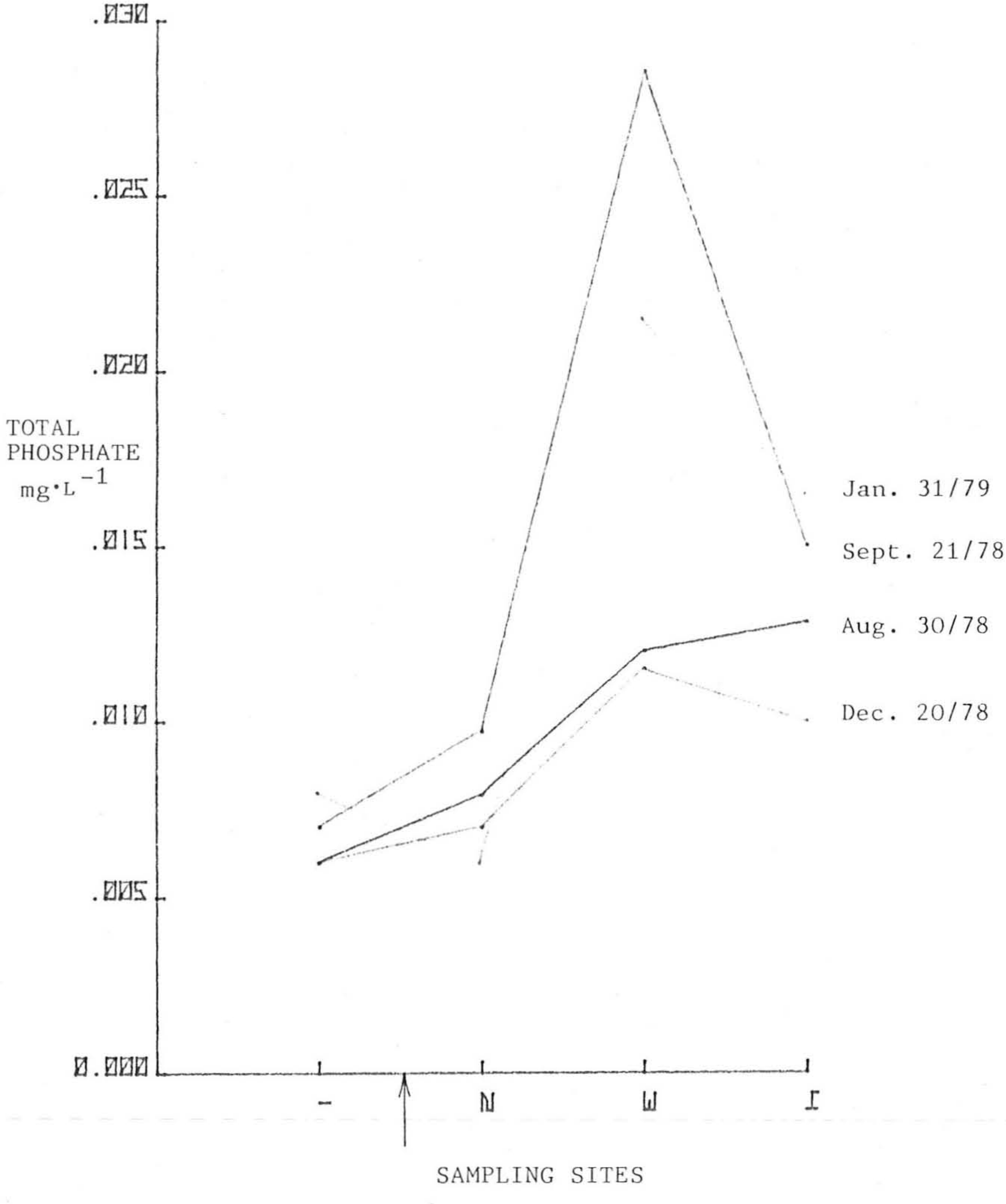

FIGURE 15A

Concentration of total phosphate ($mg \cdot L^{-1}$) from selected samples taken between August 30, 1978 and January 31, 1979 in the Quinsam River. Arrow indicates the location of the Quinsam Hatchery effluent discharge.

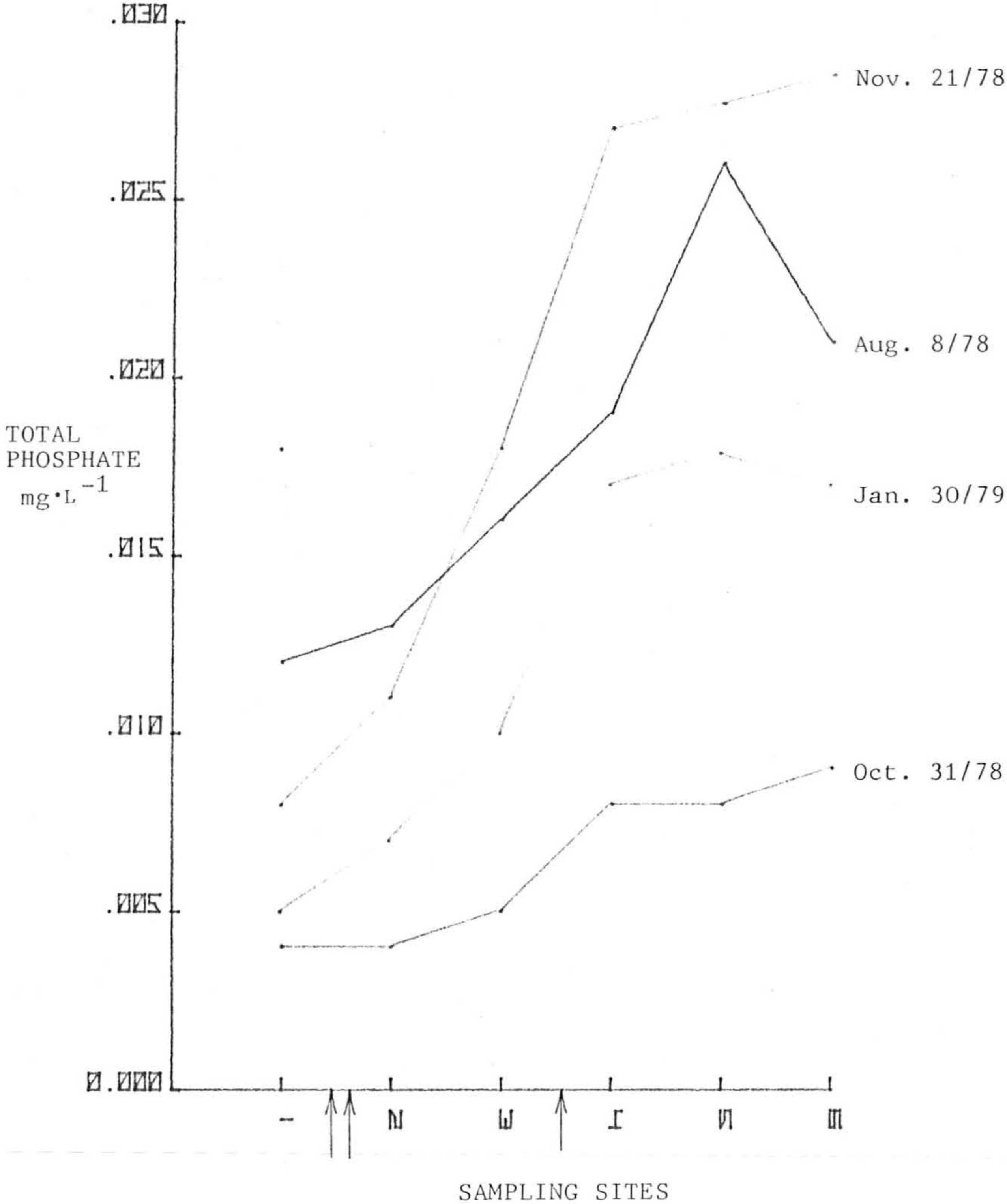

FIGURE 15B

Concentration of total phosphate (mg·L^{-1}) from selected samples taken between August 8, 1978 and January 30, 1979 in the Qualicum River. Arrow indicates the location of the Qualicum Hatchery effluent discharge and chum spawning channel discharge. Double arrow indicates the location of the experimental channel discharge.

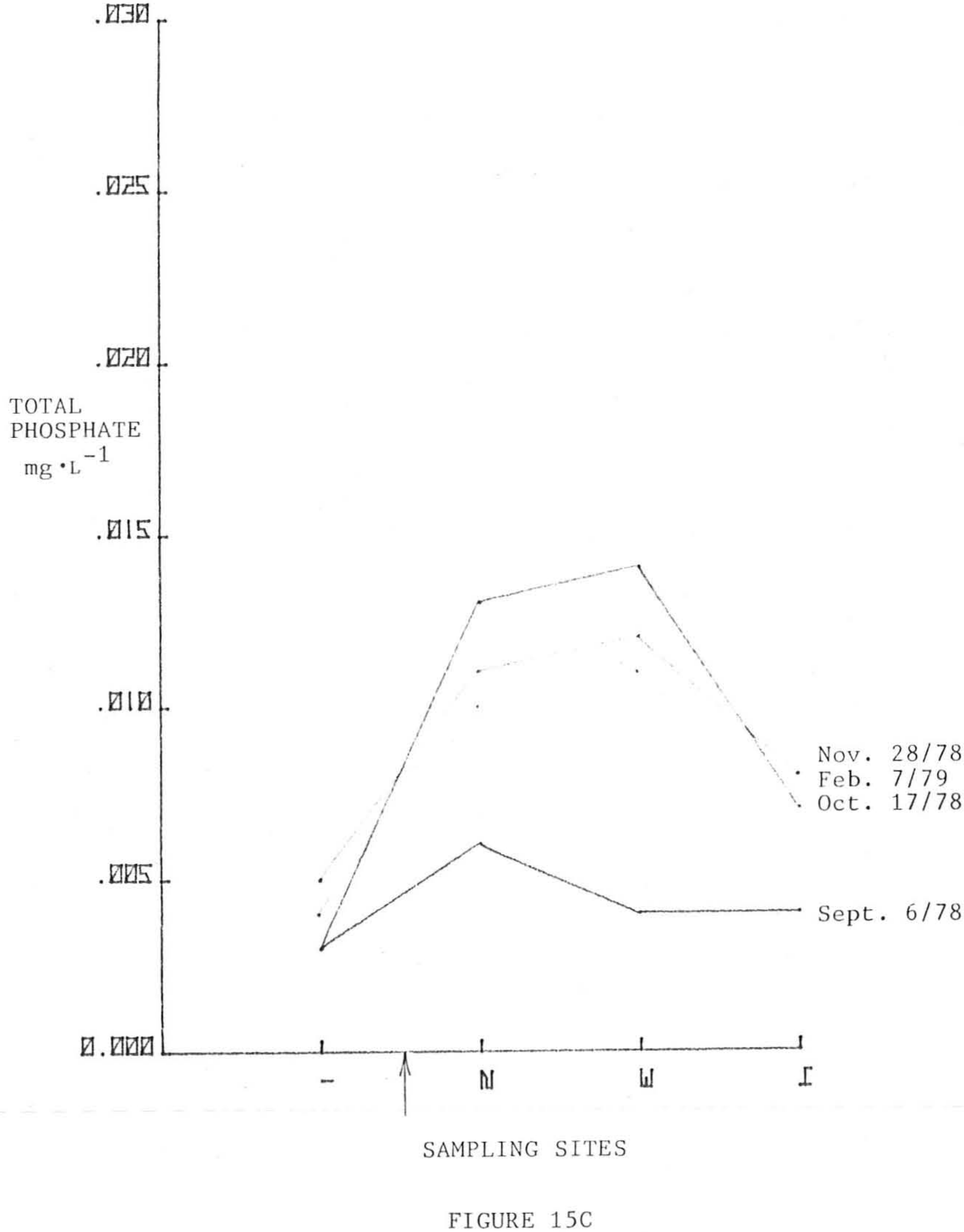

FIGURE 15C

Concentration of total phosphate ($mg \cdot L^{-1}$) from selected samples taken between September 6, 1978 and February 7, 1979 in the Capilano River. Arrow indicates the location of the Capilano Hatchery effluent discharge.

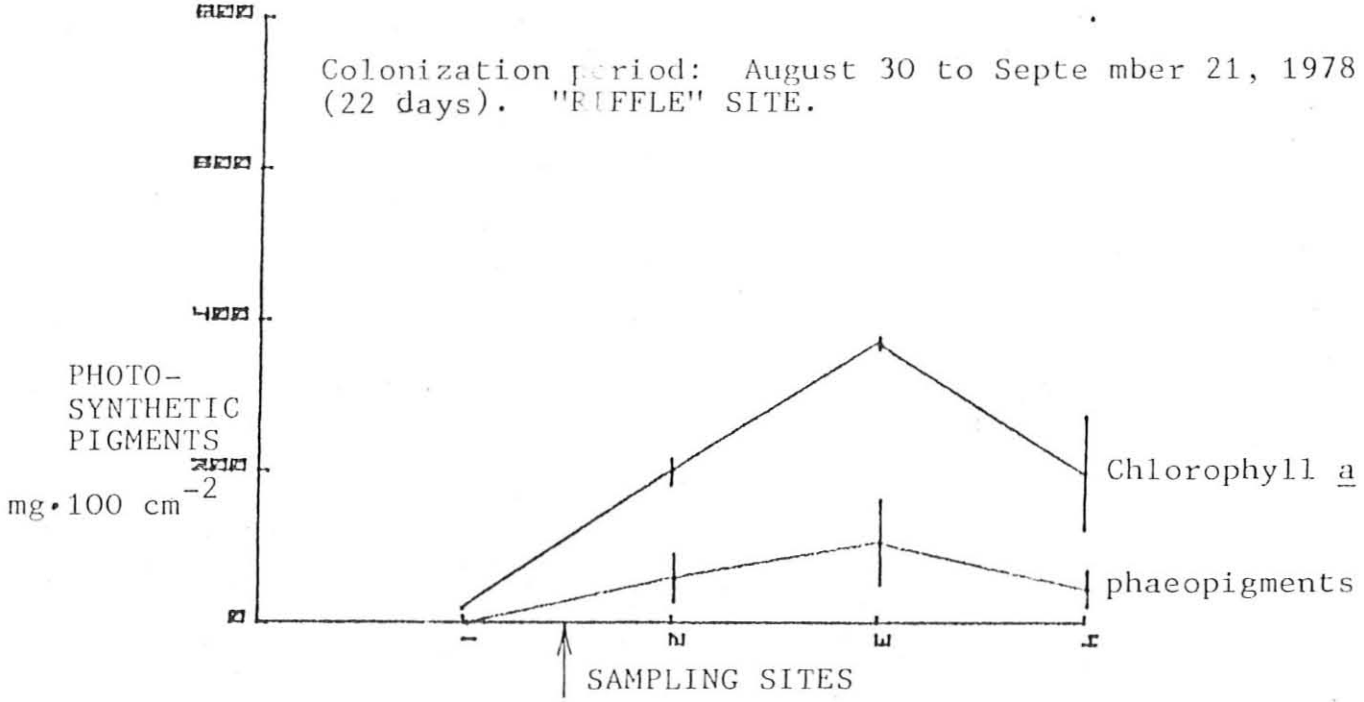

FIGURE 16A

Concentration of photosynthetic pigments (chlorophyll *a* and phaeopigments mg·100 cm^{-2}) from selected colonization periods on the Quinsam River. Arrow indicates location of the Quinsam Hatchery effluent discharge.

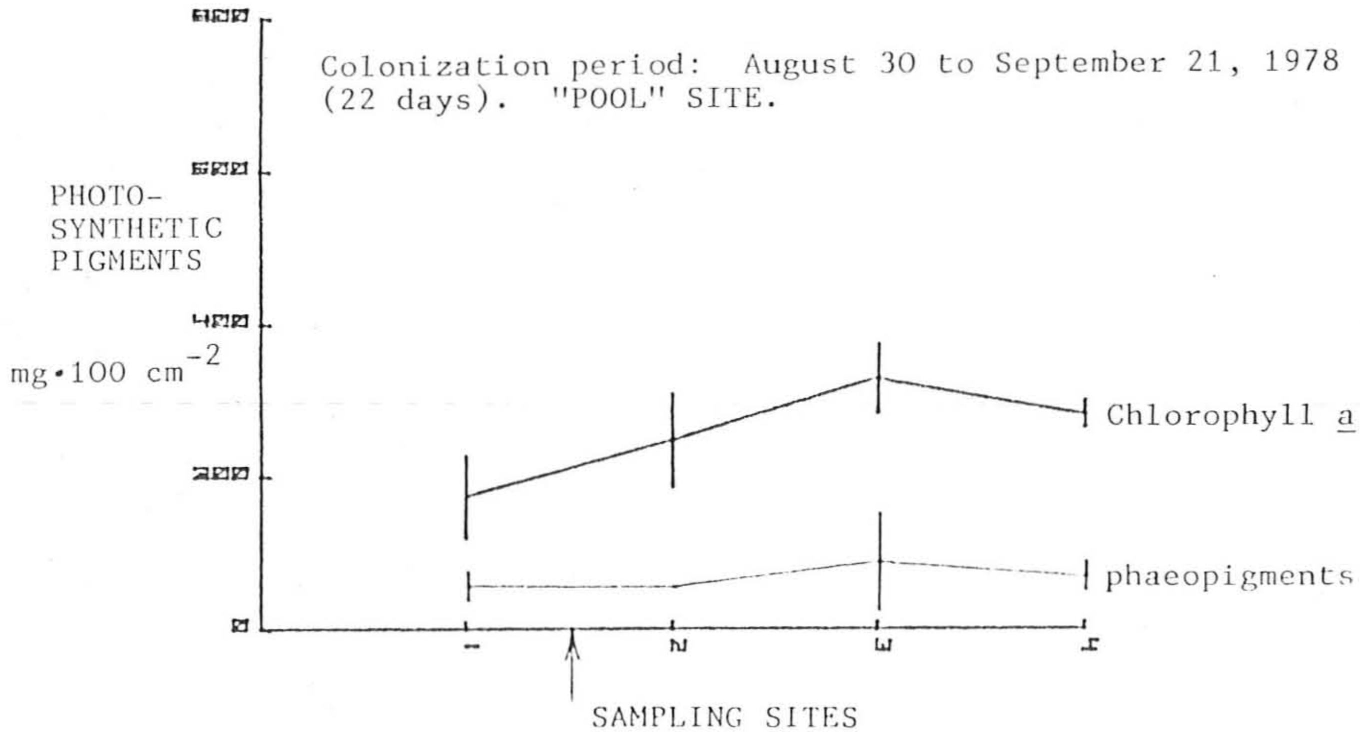

FIGURE 16B

Colonization period: September 21 to October 11, 1978 (20 days). "POOL" SITE

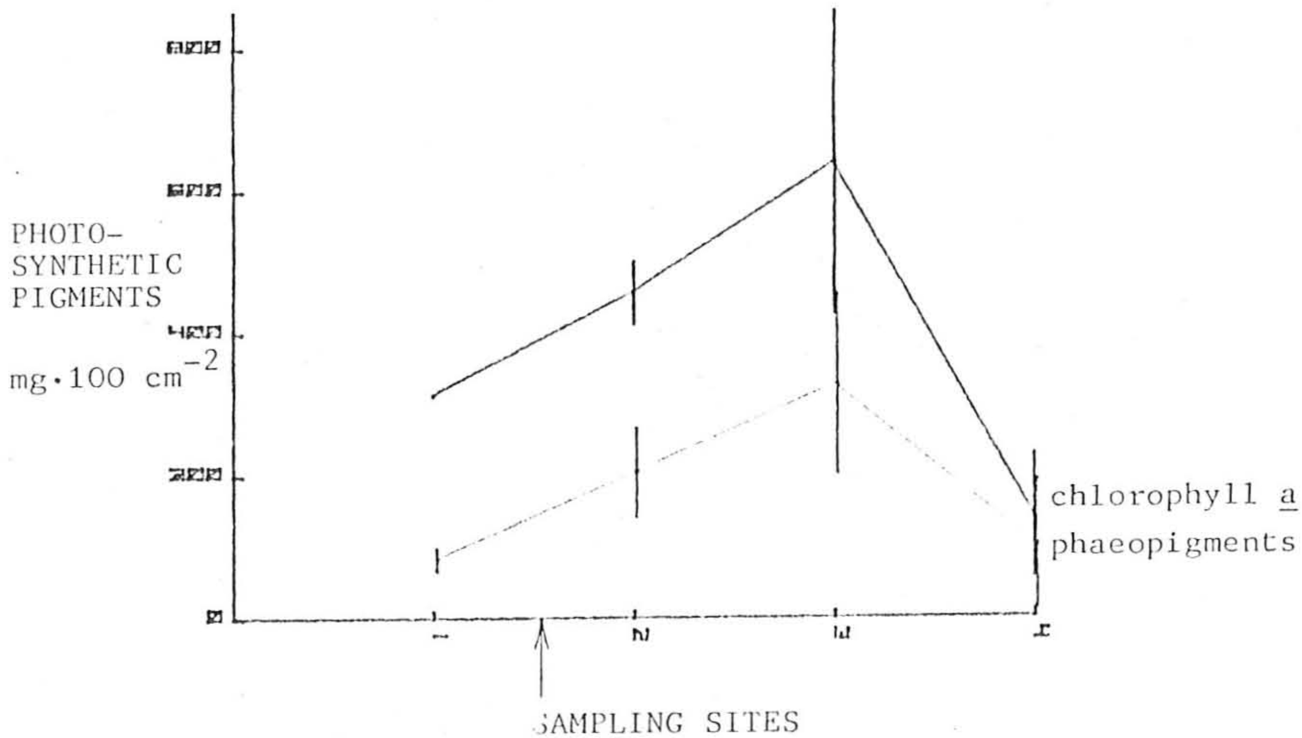

FIGURE 17

Concentration of photosynthetic pigments (chlorophyll a and phaeopigments $mg \cdot 100\ cm^{-2}$) on artificial substrates from selected colonization periods on the Quinsam River. Arrow indicates location of the Quinsam Hatchery effluent discharge.

Colonization period: August 30 to September 21, 1978 (21 days).

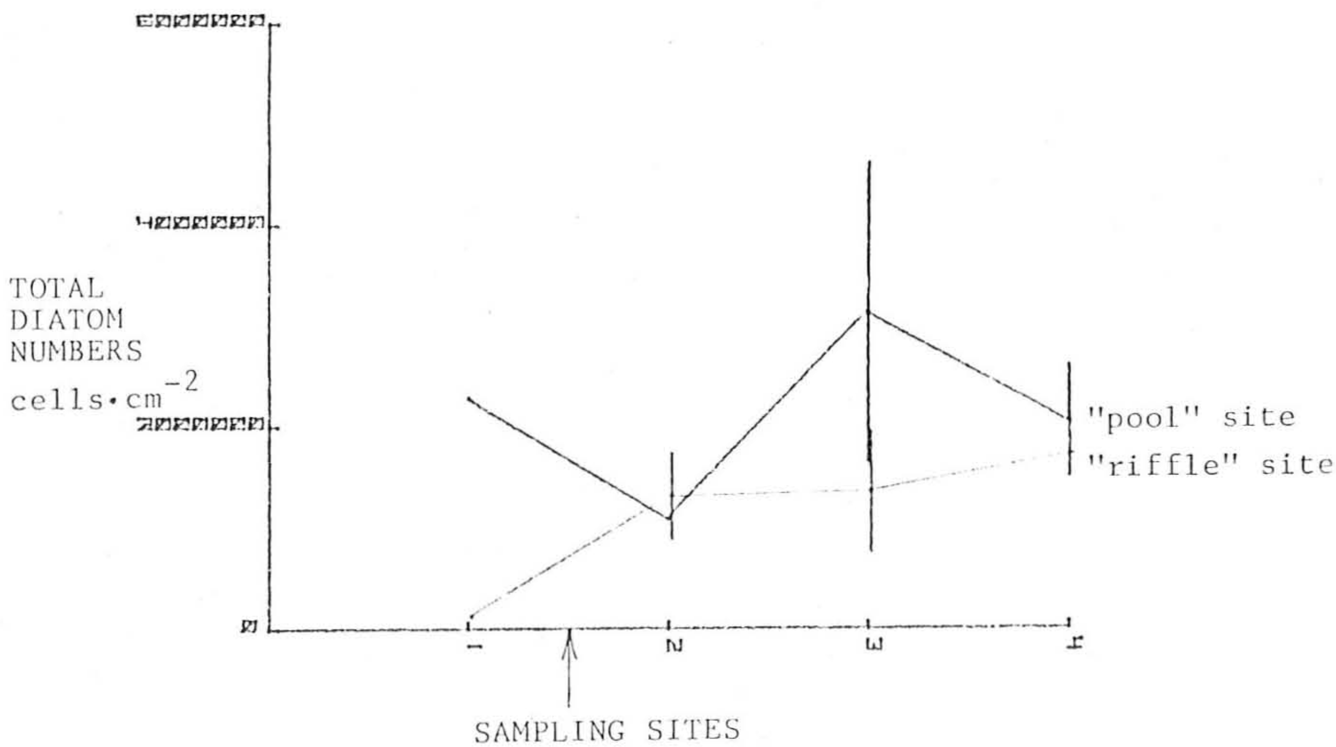

FIGURE 18

Total diatom numbers (cells·cm^{-2}) from selected colonization periods on the Quinsam River. Arrow indicates location of the Quinsam Hatchery effluent discharge.

Colonization period: September 21, 1978 to October 11, 1978 (20 days).

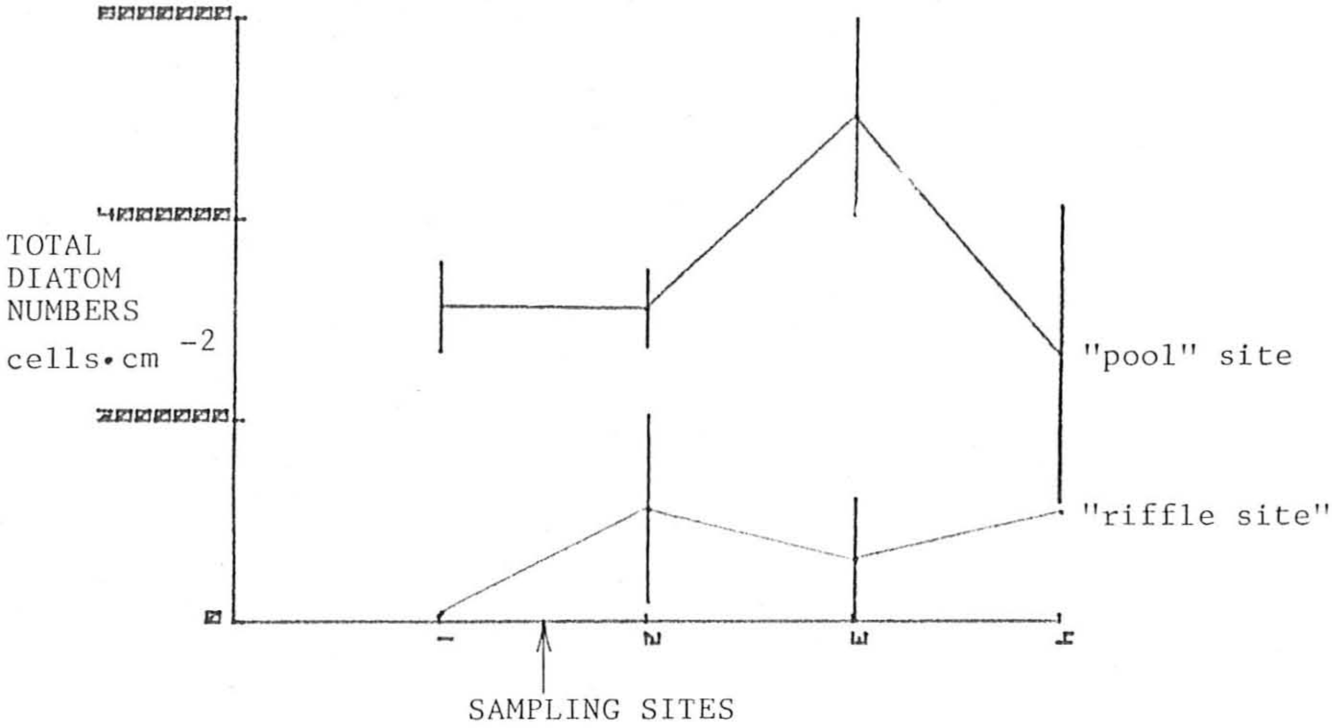

FIGURE 19A

Total diatom numbers (cells•cm^{-2}) from selected colonization periods on the Quinsam River. Arrow indicates location of the Quinsam Hathcery effluent discharge.

Colonization period: October 11 to November 1, 1978 (21 days).

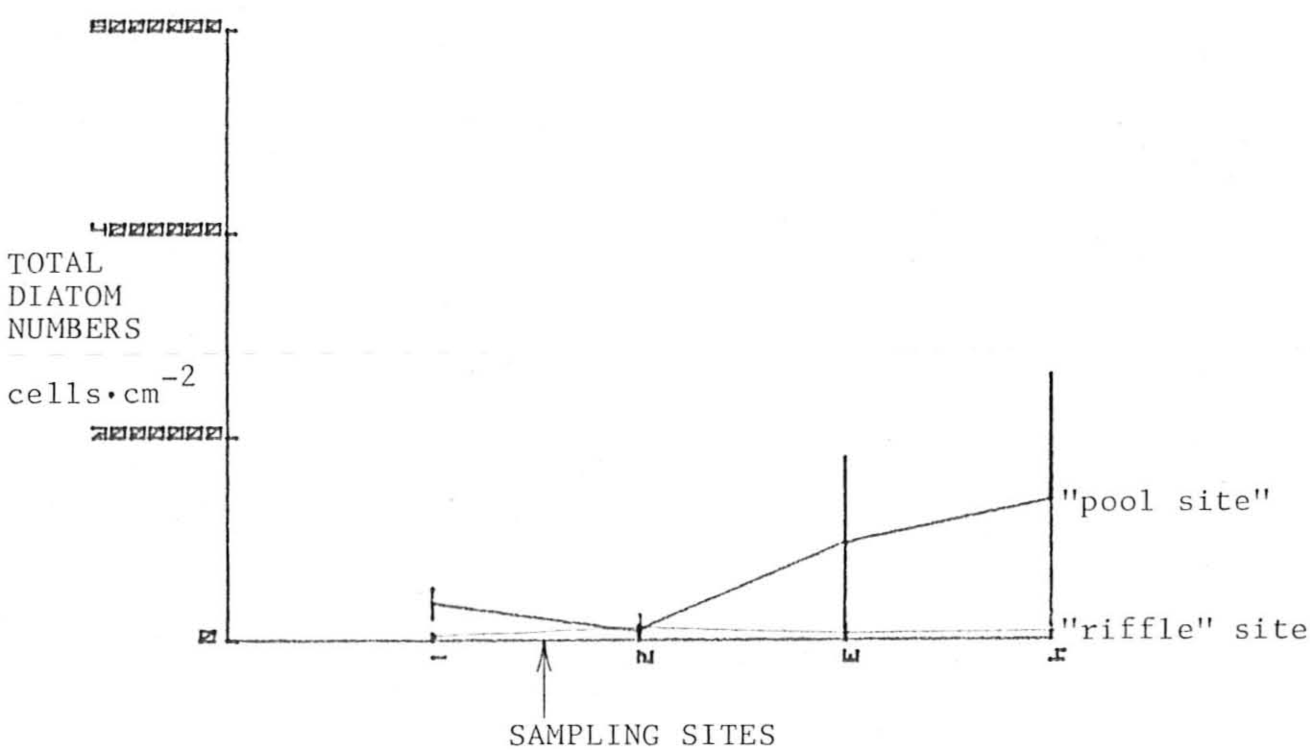

FIGURE 19B

Colonization period: August 29 to September 22, 1978
(24 days). "POOL" SITE.

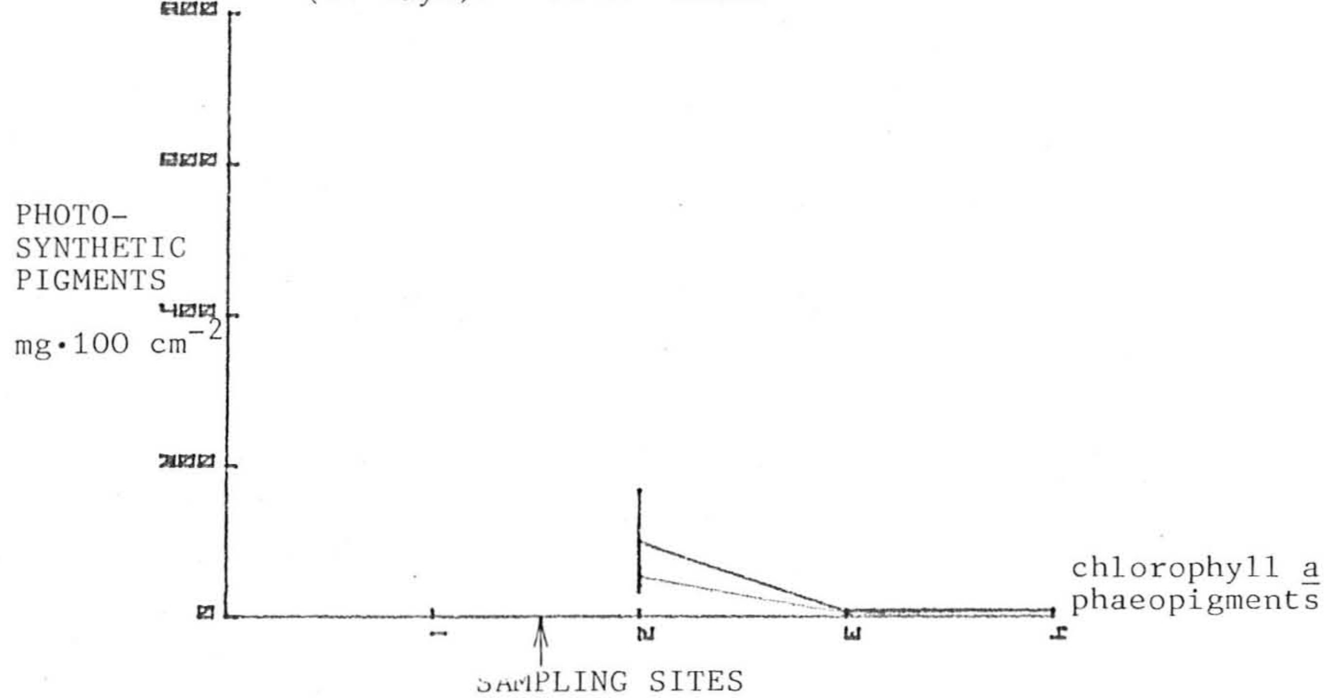

FIGURE 20A

Concentration of photosynthetic pigments (chlorophyll *a* and phaeopigments mg·100 cm^{-2}) on artificial substrates from selected colonization periods on the Puntledge River. Arrow indicates location of the Puntledge Hatchery discharge.

Colonization period: September 22 to October 12, 1978
(20 days). "RIFFLE" SITE.

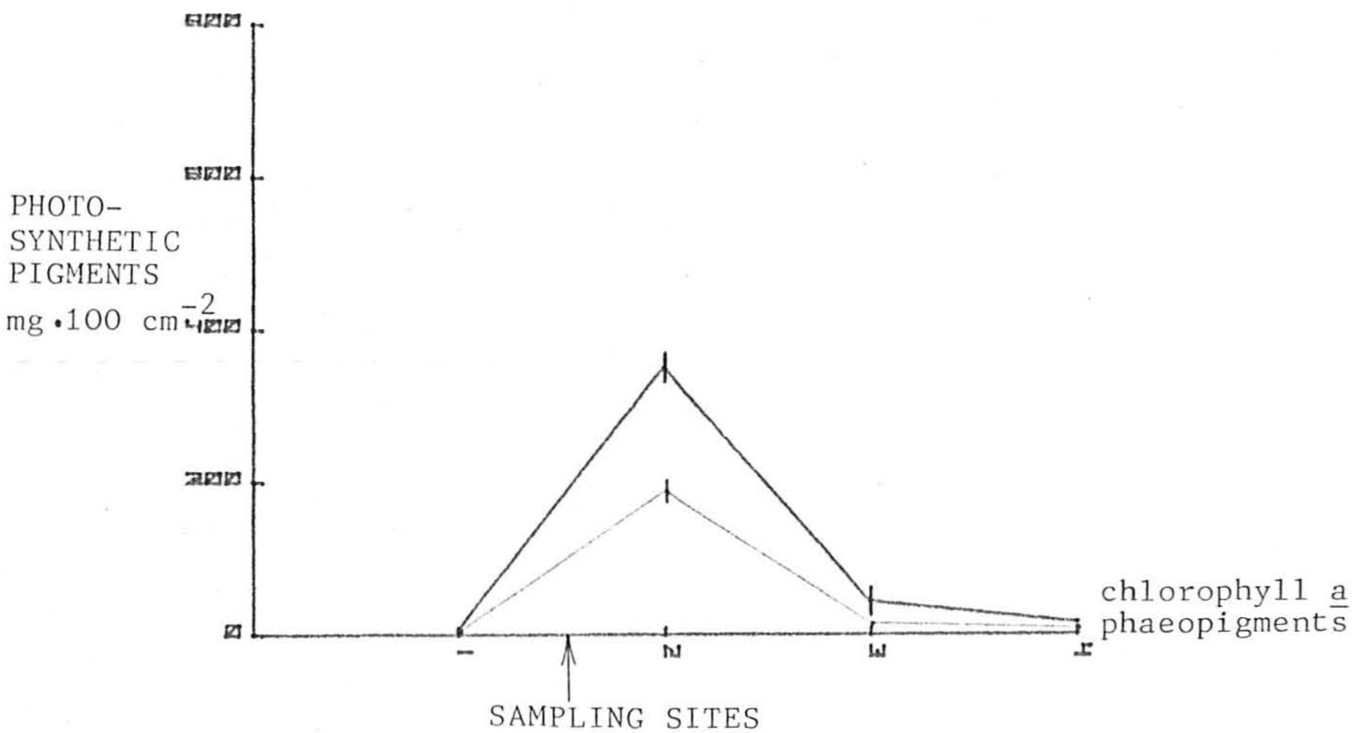

FIGURE 20B

Colonization period: November 23 to December 21, 1978 (28 days). "POOL SITE".

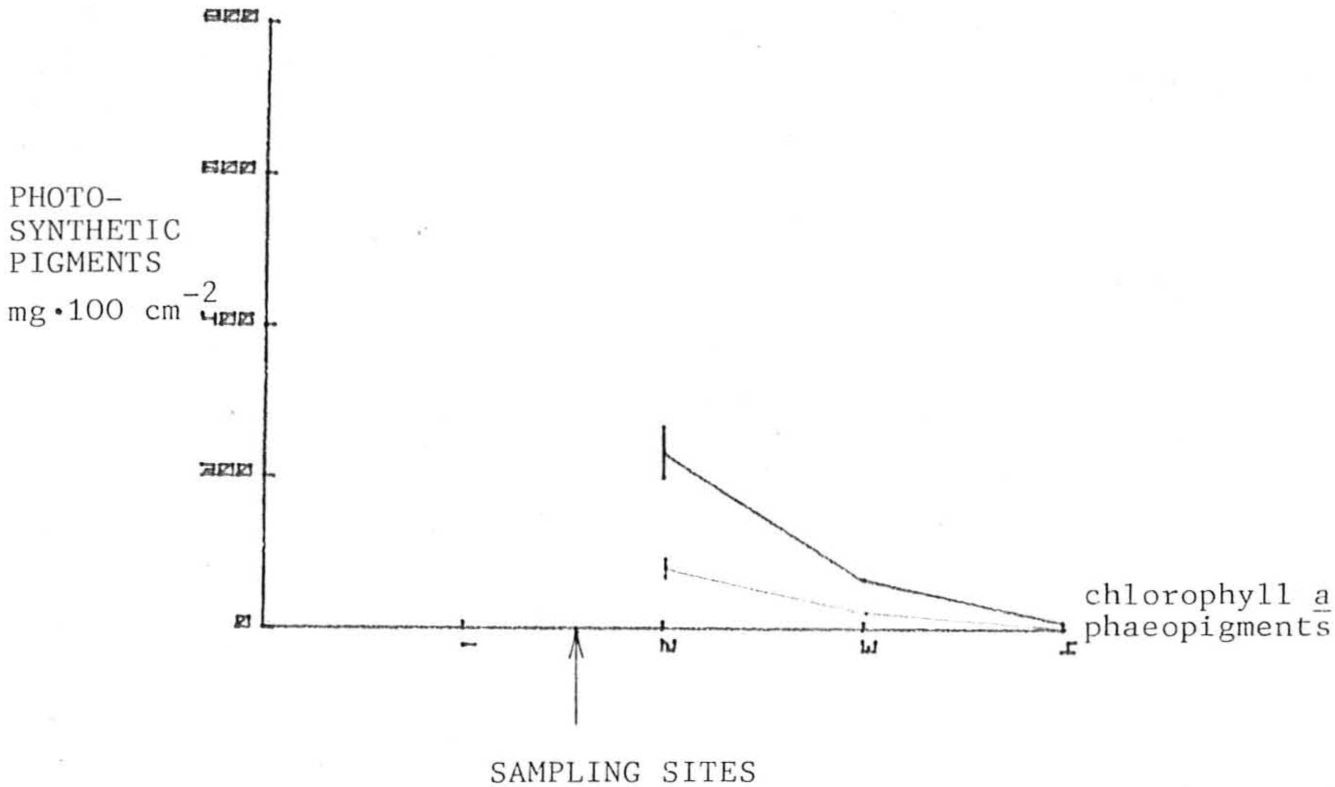

FIGURE 21

Concentration of photosynthetic pigments (chlorophyll a and phaeopigments mg·100 cm^{-2}) on artificial substrates from selected colonization periods on the Puntledge River. Arrow indicates location of the Puntledge Hatchery discharge.

Colonization period: October 12 to November 2, 1978 (21 days).

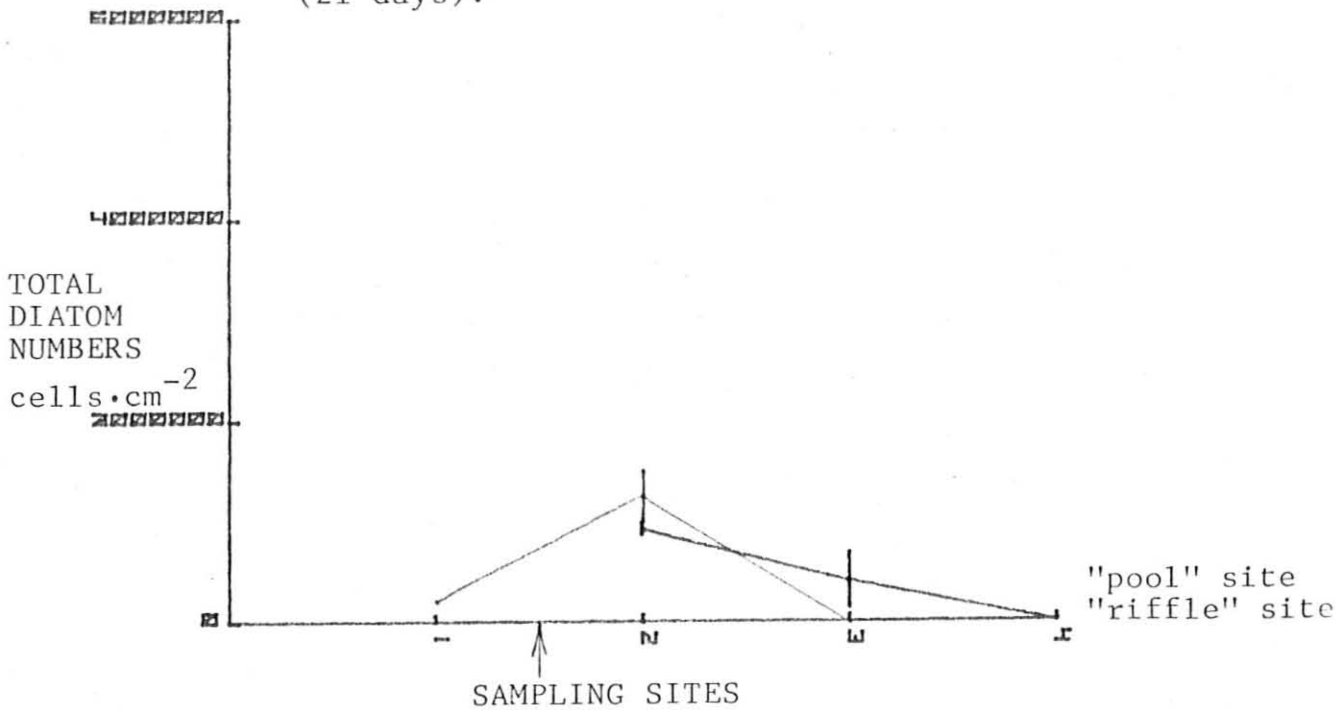

FIGURE 22A

Total diatom numbers (cells·cm^{-2}) from selected colonization periods on the Puntledge River. Arrow indicates location of the Puntledge Hatchery effluent discharge.

Colonization period: November 2 to November 23, 1978 (21 days).

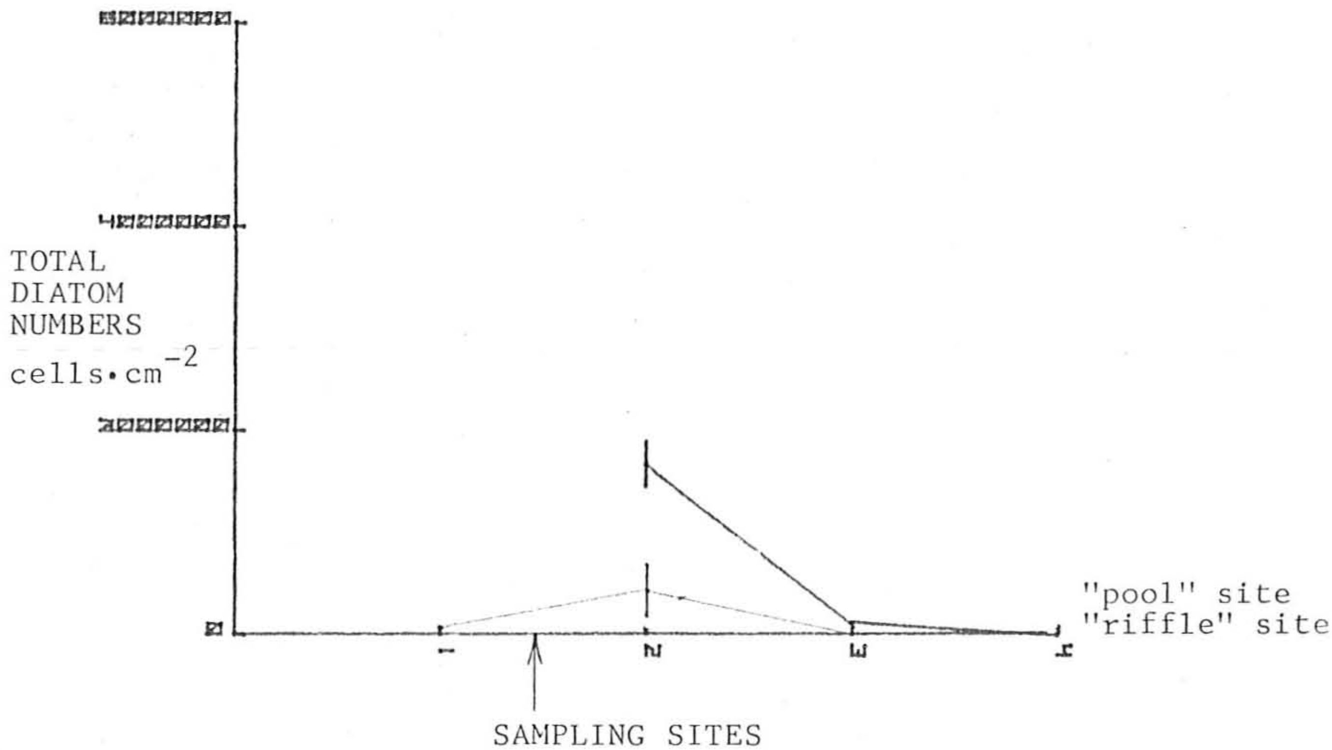

FIGURE 22B

Colonization period: September 22 to October 12, 1978 (20 days).

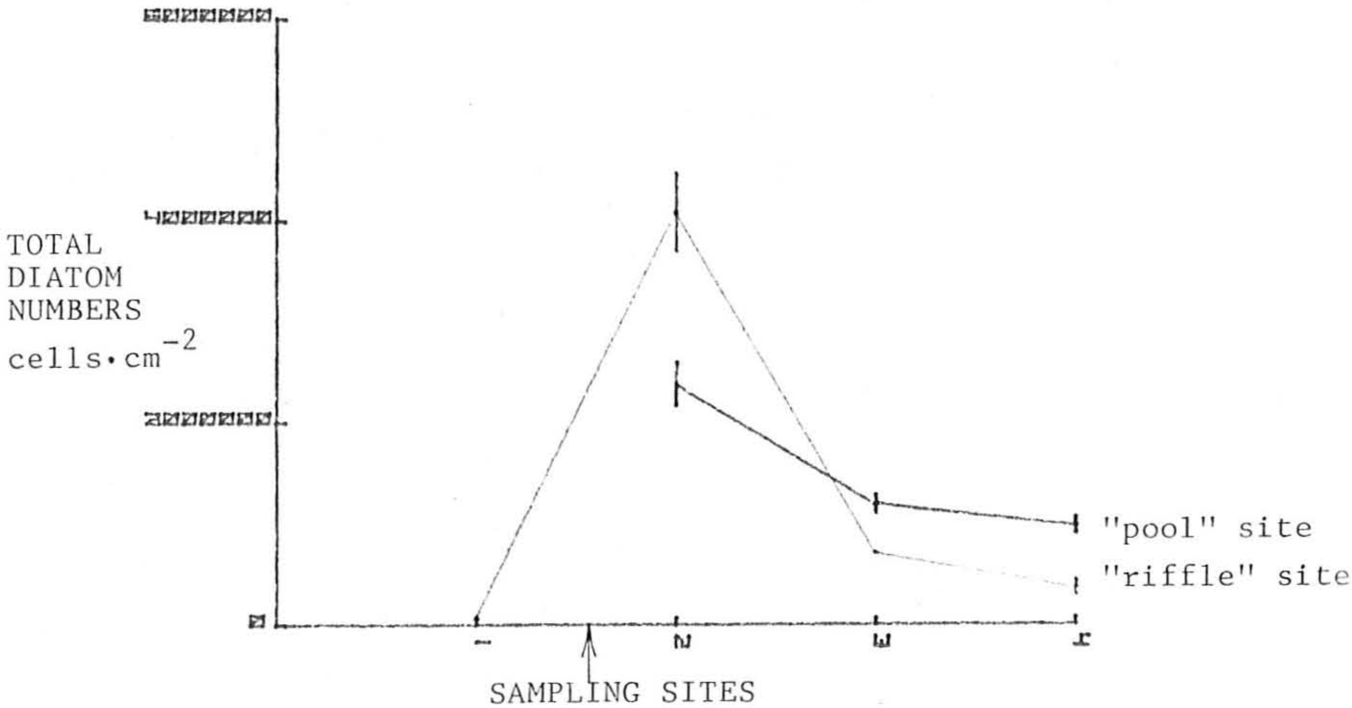

FIGURE 23

Total diatom number (cells·cm^{-2}) from selected colonization periods on the Puntledge River. Arrow indicates location of the Puntledge Hatchery effluent discharge.

Colonization period: September 22 to October 12, 1978
(20 days). "POOL" SITE.

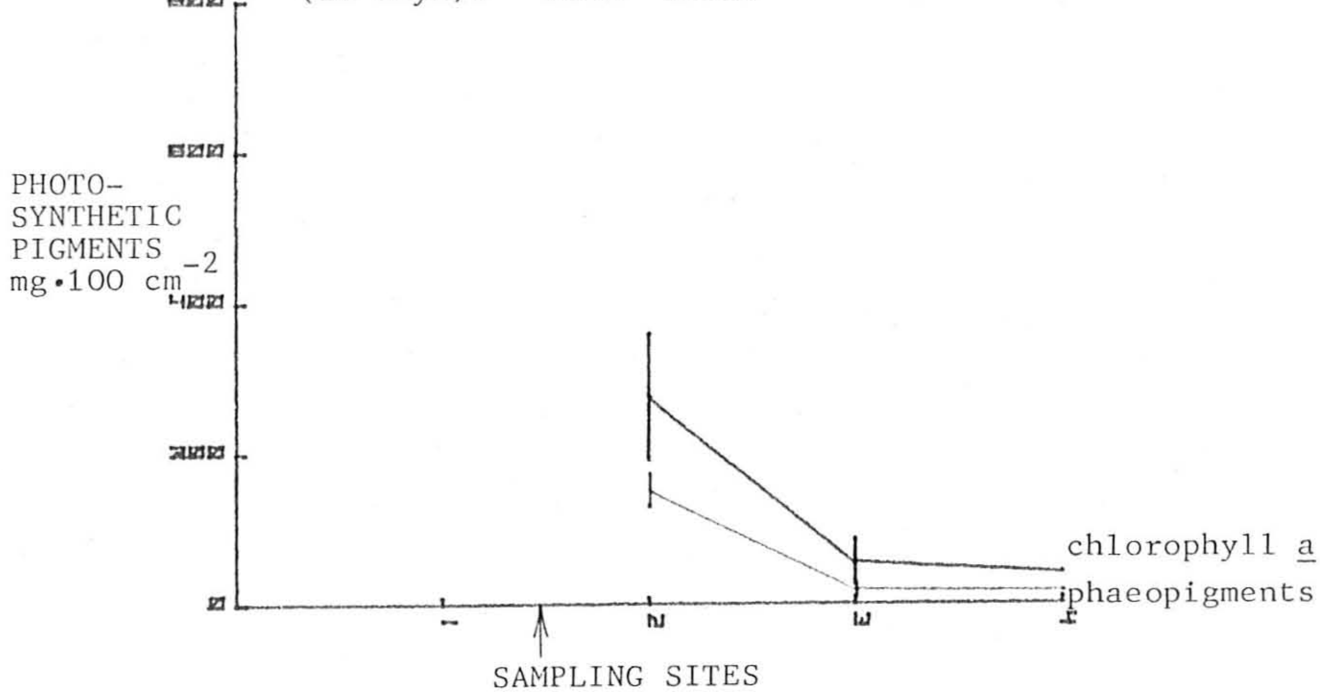

FIGURE 24A

Concentration of photosynthetic pigments (chlorophyll *a* and phaeopigments mg·100 cm^{-2}) on artificial substrates from selected colonization periods on the Puntledge River. Arrow indicates location of the Puntledge Hatchery discharge.

Colonization period: November 23 to December 21, 1978
(28 days). "RIFFLE" SITES.

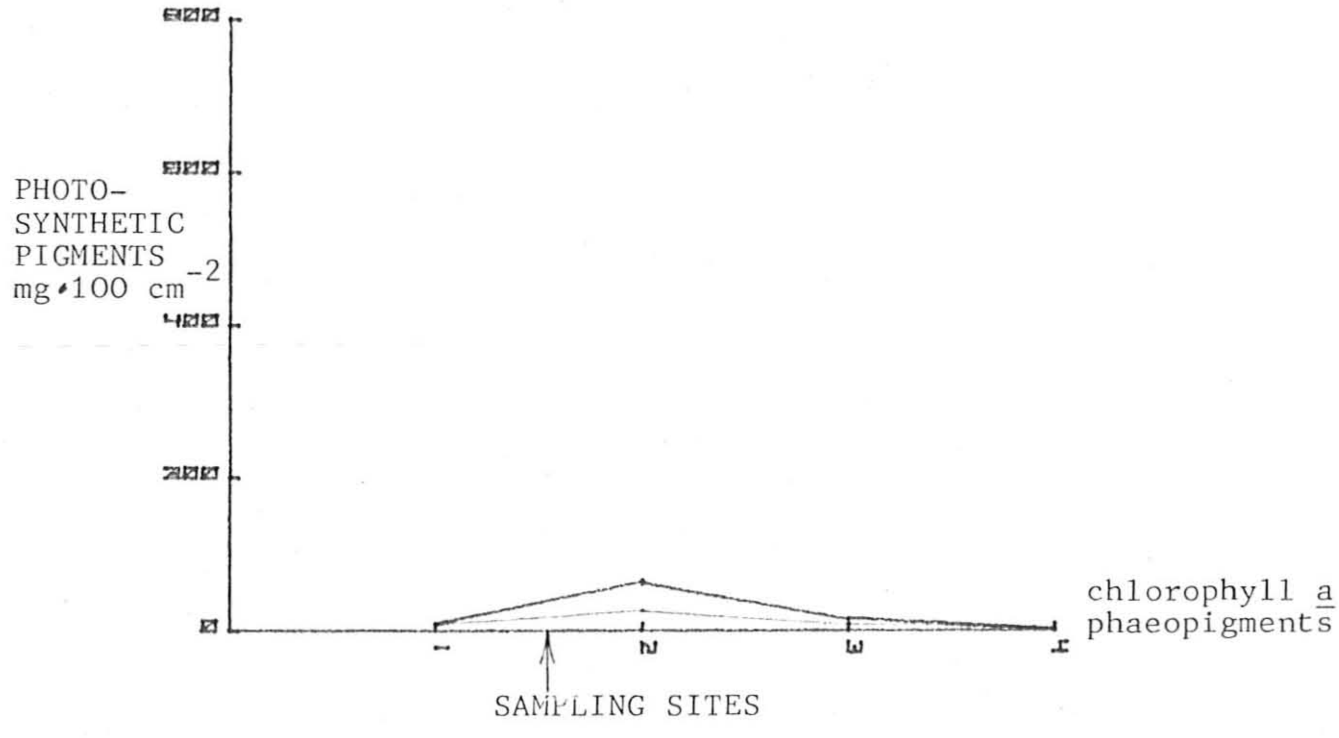

FIGURE 24B

Colonization period: August 31 to September 20, 1978 (20 days).

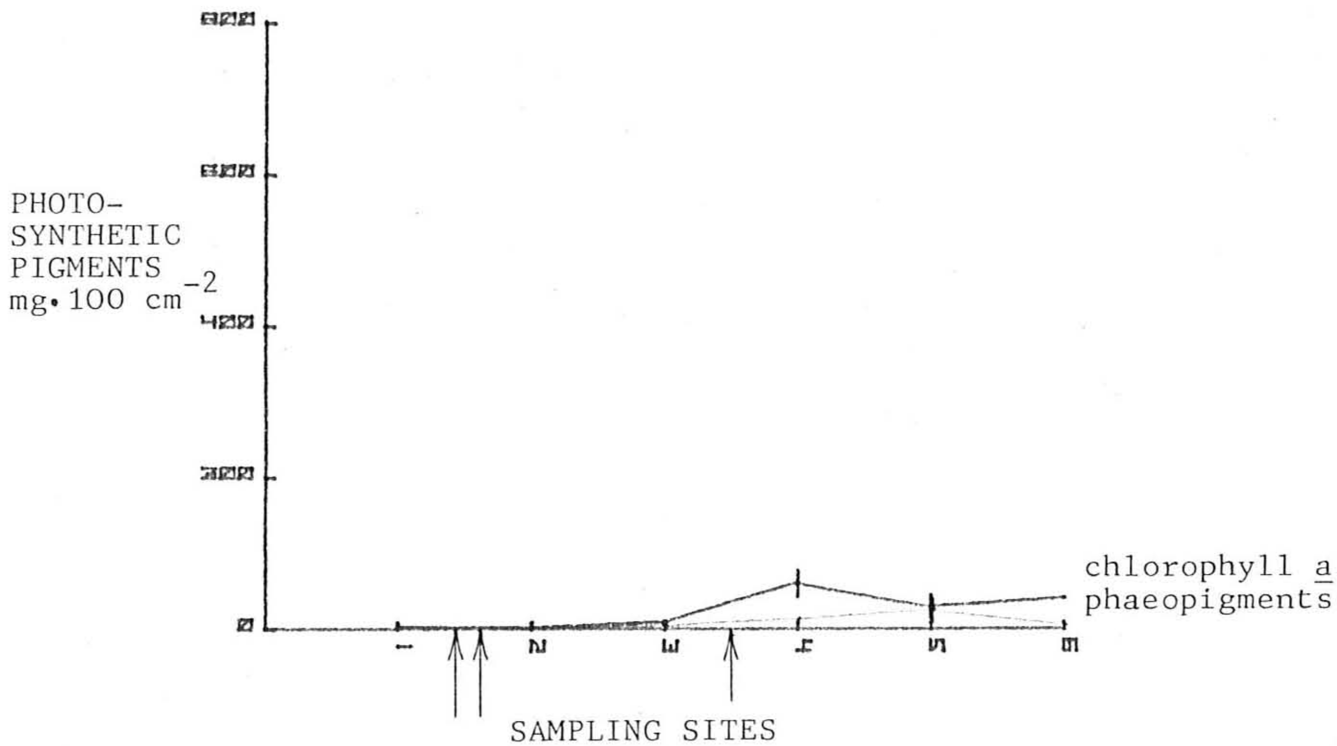

FIGURE 25

Concentration of photosynthetic pigments (chlorophyll *a* and phaeopigments mg·100 cm^{-2}) on artificial substrates from selected colonization periods on the Qualicum River. Arrow indicates location of the Qualicum Hatchery effluent discharge and the chum spawning channel discharge. Double arrow indicates location of the experimental channel discharge.

Colonization period: August 31 to September 20, 1978 (20 days).

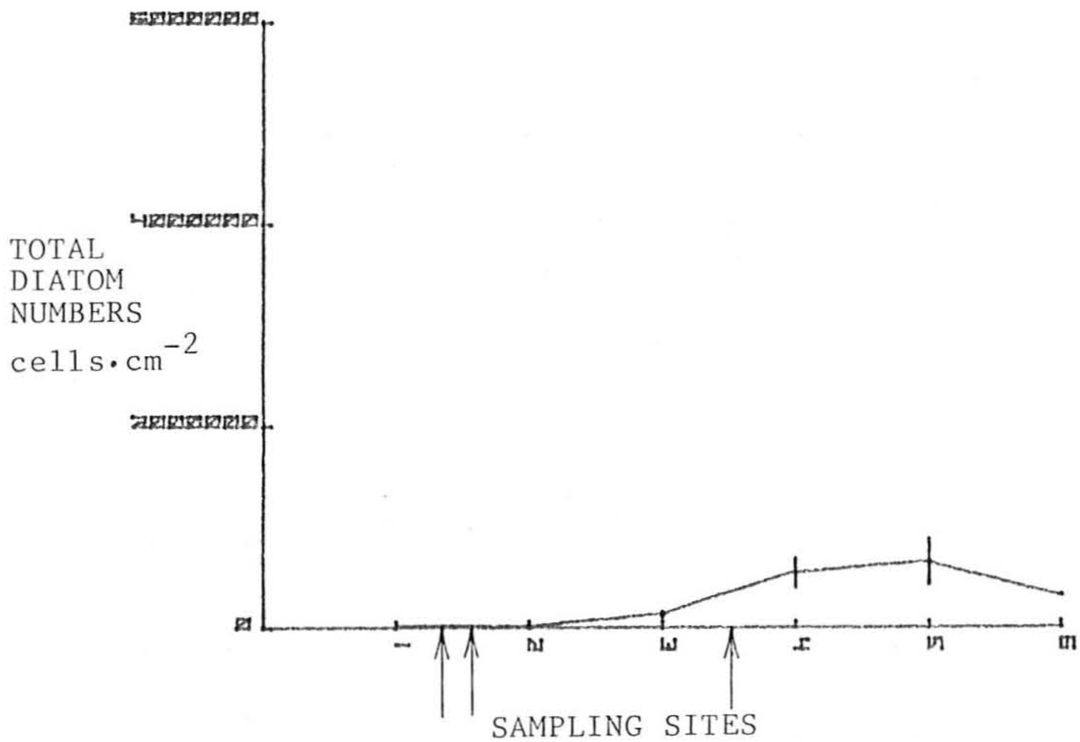

FIGURE 26

Total diatom numbers (cells·cm^{-2}) from selected colonization periods on the Qualicum River. Arrow indicates location of the Qualicum Hatchery effluent discharge and the chum spawning channel discharge. Double arrow indicates the location of the experimental channel discharge.

Plate 1. Periphyton artificial substrate plates mounted on concrete blocks.

a. periphyton artificial substrate plate
b. concrete block

Plate 2. Plexiglass plate following 3-week colonization period.

Plate 3. "Mundie" benthic invertebrate sampler in use in stream riffle.

Plate 4. Periphyton growth in Qualicum experimental channel. July 13, 1978.

Plate 5. Periphyton growth in Puntledge rearing channel. March 21, 1979.

Plate 6. Cleaning procedure at Puntledge channel. Note section of chain link fencing is dragged across channel. March 21, 1979.

PLATES 7 - 8

PUNTLEDGE CHANNEL CLEANING
MARCH 21, 1979