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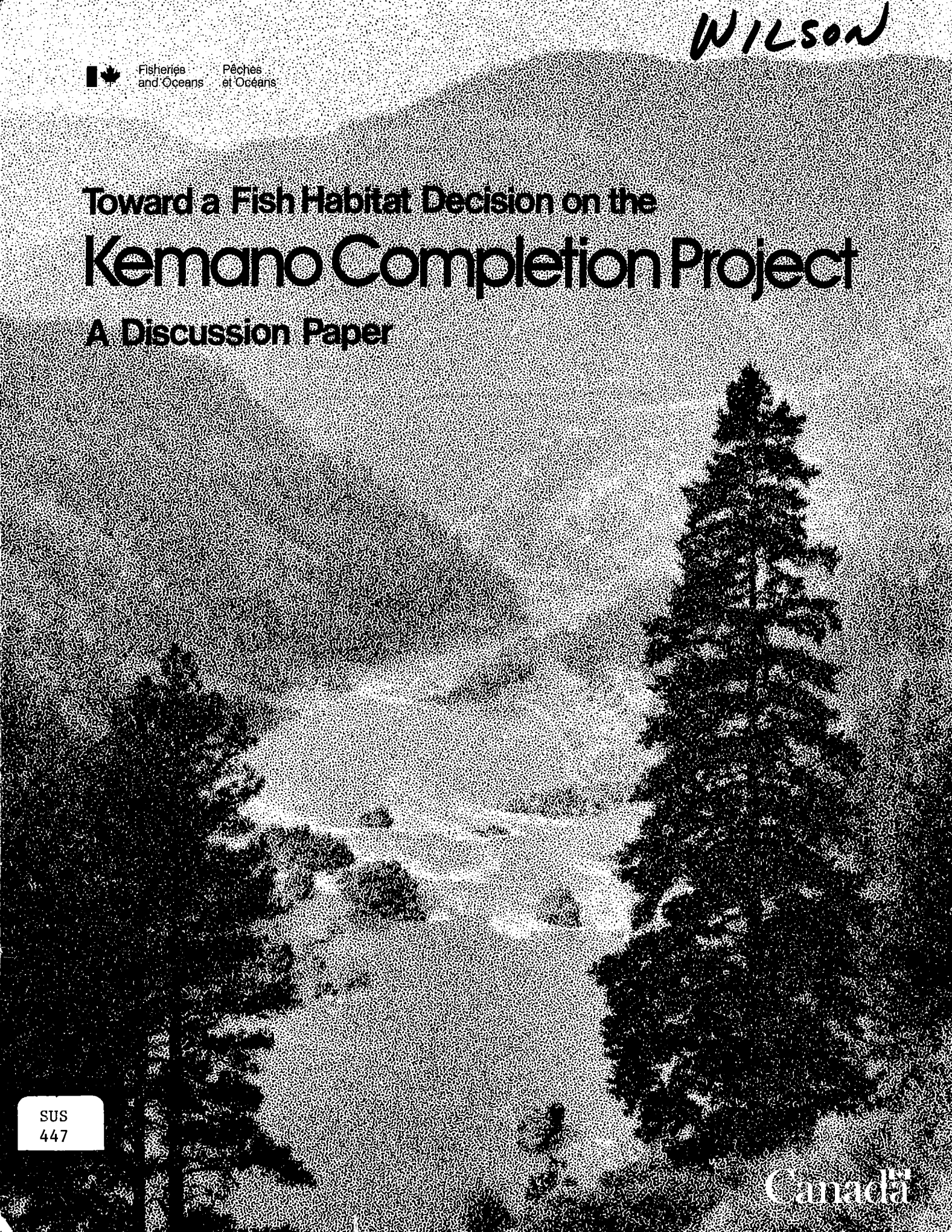
# Toward a Fish Habitat Decision on the Kemano Completion Project

## A Discussion Paper





Canada

# Toward a Fish Habitat Decision on the

# Kemano Completion Project

## A Discussion Paper

VANCOUVER, B.C. JANUARY 1984



Government of Canada
Fisheries and Oceans

Gouvernement du Canada
Pêches et Océans

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SALMONID ENHANCEMENT PROGRAM

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## PREFACE

In ordering his staff to prepare for a series of public meetings on the Kemano Completion project, Director-General of DFO's Pacific Region, Wayne Shinners, stated; "This project proposal contains elements which make it of more vital concern to salmon than any other fish habitat question we are likely to encounter in the rest of this century". In that spirit, the staff of DFO's Habitat Management Division and Communications Branch have afforded the public information and public involvement process the highest working priority.

The reader who wishes to become fully informed on this massive project will be confronted with a bewildering array of biological, economic and engineering data. None of these data are to be withheld from public scrutiny but the great volume of material makes it impossible for inclusion in so small a document as this discussion paper. In producing this discussion paper the Department has one primary objective; to more fully inform the public on the vastness of this project and its likely impact on the fisheries resources for which the Department is responsible.

In presenting this information, the Department of Fisheries and Oceans wishes to point out that its powers and legislative mandate are very clear and quite specific. These extend, as spelled out in the Fisheries Act, to those matters pertaining to the management of five species of salmon and the habitat on which they depend. While the Department is aware of the considerable level of public concern over broadly-based environmental values and are sympathetic to them, the powers of the Department are set out clearly in the Fisheries Act and do not extend to cover overall environmental considerations.

While there has been much media publicity afforded this project, the Department believes that the full magnitude, the enormous extent of the project are not fully appreciated. The Fraser and Skeena River systems drain a significant portion of the land mass of British Columbia. This project will provide a link, a physical connection by which these two great rivers will be joined together. While the extensive studies of this proposal have produced a massive amount of scientific data, there are still a good many unknowns.

Following the release of the Kemano Completion Discussion Paper, Alcan has advised the Department of a number of revisions. The estimate of sidechannel losses in the Morice River has been revised and now ranges from 10 to 35% with the best estimate being 25% (see pages 20 and vi). Alcan has also suggested some minor changes in flow calculations particularly for the Nechako River. These changes are presently being reviewed. They are not, however, expected to significantly alter our analysis in the Discussion Paper.

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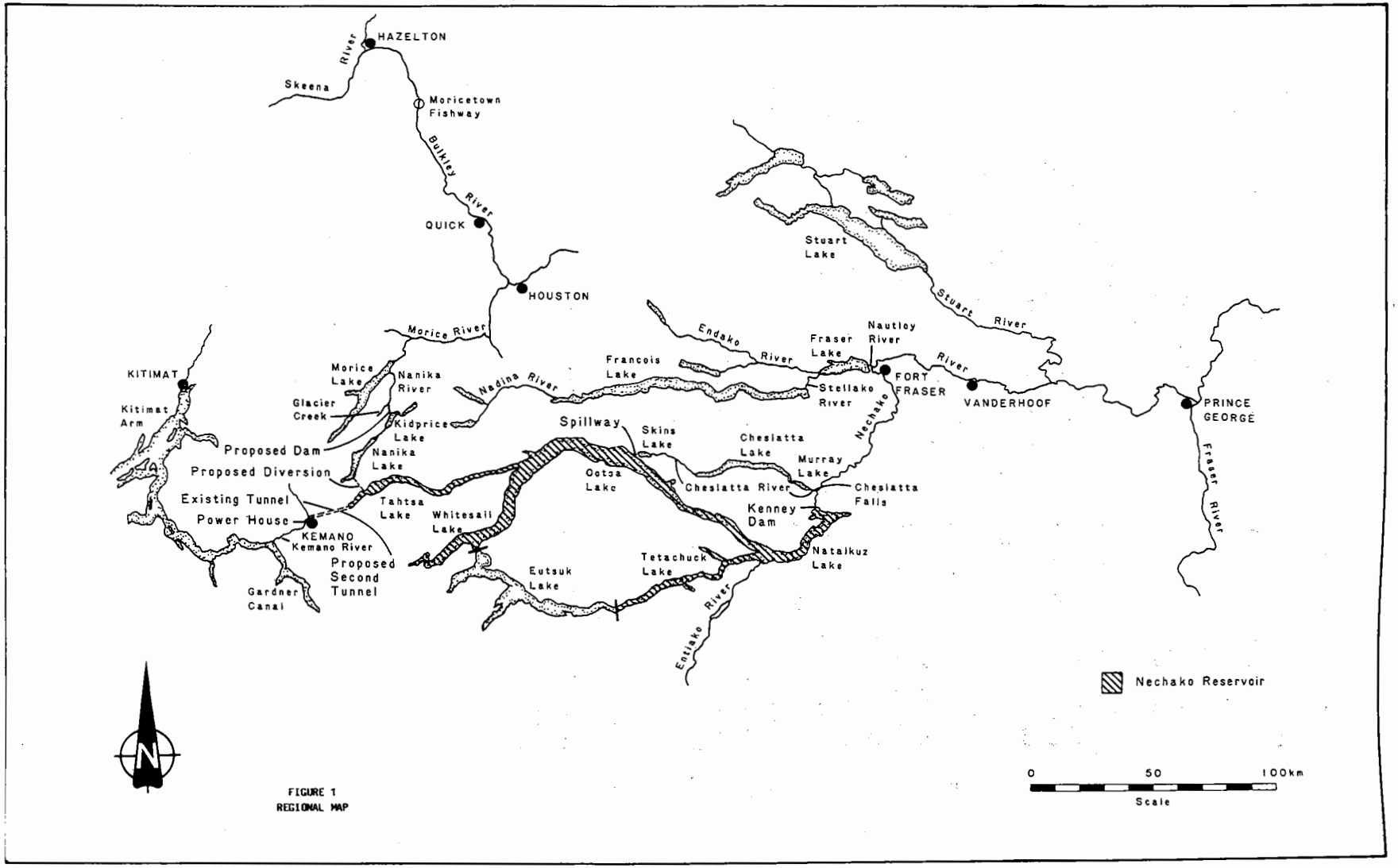


FIGURE 1
REGIONAL MAP

# EXECUTIVE SUMMARY

The Kemano Completion Project is massive. The Aluminum Company of Canada (Alcan) proposes a capital expenditure in excess of ~~$2.2~~ 3.0 billion which could increase aluminum production from its present level of ~~240,000~~ 368,000 metric tonnes per year to 582,000 metric tonnes per year. It will generate 1,500 permanent jobs and several thousand man-years of temporary construction employment.

The project entails the construction of two aluminum smelters of 170,000 and 200,000 metric tonnes capacity, the first of which would be located near Vanderhoof. They are the primary source of permanent employment. The power to operate the smelters would be generated by an additional powerhouse to be built at Kemano and transmitted via new transmission lines to the B.C. Grid System. Water to operate the new powerhouse would be conveyed from the Nechako Reservoir by a new ~~12~~ 16 km long tunnel and penstock system passing through the Coast Range, which parallels the existing water delivery system. The additional water required to generate the power would be obtained by minimizing the spill of water from the existing Nechako Reservoir and augmenting it by diverting water from the Nanika River into the reservoir. This will be accomplished by constructing a ~~22~~ 43 meter high dam on the Nanika River at the outlet of Kidprice Lake. An 8 km long diversion tunnel through the mountain between Nanika Lake and Nechako Reservoir would be constructed thus linking the Skeena and Fraser River drainage. A low-level flow regulation dam on Murray Lake in the Cheslatta system and a cold water release tunnel around the Kenney Dam would be constructed to provide a source of cold water for downstream cooling purposes.

The Kemano Completion project directly threatens the salmon stocks in the Fraser River system (especially the chinook of the Nechako River, as well as the sockeye of the Stuart, Stellako and Nadina rivers). Several species (chinook, sockeye, coho and pink salmon) would be impacted in the Nanika and Morice rivers as a result of the diversion of the Nanika River. All five species of Pacific Salmon and the eulachon populations of the Kemano River would be impacted. The potential exists for significant downstream effects in the Skeena and Fraser River.

The present level of salmon production from these rivers is significant, and the opportunity for increasing production is substantial. Using current catch to escapement ratio and escapement estimates, the current and potential stocks for each river that would be affected by the project are as follows:

TOTAL FISH STOCKS BY SPECIES

| RIVER | CURRENT PRODUCTION | | POTENTIAL PRODUCTION |
|---|---|---|---|
| Nanika | Sockeye | 9,200 | 73,600 |
| | Chinook | 525 ~~750~~ | 1,400 ~~2,000~~ |
| | Coho | 750 | 1,250 |
| | Total | ~~10,700~~ 10,475 | ~~76,850~~ 76,250 |
| Morice | Sockeye | 1,150 | 4,600 |
| | Chinook | 19,250 ~~27,500~~ | 42,000 ~~60,000~~ |
| | Coho | 6,250 | 25,000 |
| | Pink (Even) | 16,800 | 57,500 |
| | (Odd) | 57,500 | 57,500 |
| | Total | ~~109,200~~ 100,950 | ~~204,600~~ 186,600 |
| Nechako | Sockeye * | 2,600,000 ~~3,100,000~~ | 4,450,000 ~~34,700,000~~ |
| | Chinook | 8,400 ~~12,600~~ | 30,000 ~~45,000~~ |
| | Total | ~~3,112,600~~ 2,608,400 | ~~34,745,00~~ 4,480,000 |
| Kemano | Chum | 72,000 | 180,000 |
| | Pink (Even) | 296,800 | 560,000 |
| | (Odd) | 69,000 | 560,000 |
| | Chinook | 7,000 ~~10,000~~ | 7,000 ~~10,000~~ |
| | Coho | 12,500 | 12,500 |
| | Total | ~~460,300~~ 456,500 | ~~1,322,500~~ 1,319,500 |
| GRAND TOTAL (Stocks and Species) | | 3,176,325 ~~3,692,800~~ | 6,062,350 ~~33,348,950~~ |

* Dominant cycle only

The project threatens the fish habitats upon which these stocks depend. The principal impacts stem from the major changes in the flow regimes of the rivers affected by the project. Sixty-two percent of the mean annual flow in the Nanika River will be diverted to the Nechako Reservoir and this will primarily occur in the months of June through August. This diversion of the Nanika will reduce the mean annual outflow from Morice Lake by 25%, essentially in the same time period. The existing, partially regulated flow of the Nechako River will be reduced further by 80%. This represents a 88% reduction in flow from pre-Kemano I conditions. The diverted water from the Nechako and Nanika rivers will be discharged into the Kemano River, where the mean annual flow will increase approximately by a factor of two. A 52 square kilometer (20 sq. mile) new reservoir will be created, flooding 14.6 sq. kilometers (5.6 sq. miles) of land between Nanika and Kidprice Lake.

The Department is reviewing Alcan's proposal and the preliminary results of their detailed bio-engineering impact studies.

For the purposes of the review a fisheries management objective has been defined as follows:

> TO PRESERVE THE NATURAL STOCKS
> AND THE NATURAL SALMON PRODUCING
> POTENTIAL OF ALL RIVERS THAT WOULD
> BE AFFECTED BY THE DEVELOPMENT

In its review the Department has attempted to identify likely impacts, possible solutions and areas of uncertainty and risk. The information has been assembled into this discussion paper which has been prepared to stimulate public input into the decision which the Department must soon make with respect to the project.

The principal impacts of the Nanika diversion relate to the survival of juvenile coho and chinook rearing in the Nanika River and juvenile sockeye rearing in Morice Lake. The reduced flows and altered flow regime would cause major channel changes and losses of sidechannel habitat. Likely significant changes in the river temperature regime would occur. Some opportunity exists for mitigation. When considering compensation in a diminished Nanika River, possible gains would likely not offset the 90% loss of coho rearing habitat and 70% loss of chinook habitat. The loss of nutrients carried by the Nanika River to Morice Lake which threatens sockeye fry may be offset by applying lake enrichment technology.

The proposed Nanika diversion would principally affect chinook and coho rearing in the Morice River. The most utilized reach of the river would suffer up to a 30% loss of sidechannel habitat. The sidechannels in this reach account for 46 and 79% of the total chinook and coho production respectively in the Morice River. Pink salmon which spawn almost exclusively in sidechannels, and to a lessor extent coho salmon would also suffer some loss of spawning habitat. There appears to be an opportunity to improve overwintering survival of juvenile chinook and coho. However, the extent of increased production that can be expected from such activity has not been determined. The full impact of flow reductions in the Morice River salmon populations is difficult to assess because of the uncertainties of predicting long term changes in the physical environment (channel structure, substrate, groundwater, transport of debris ) and the effects of these changes on fish habitat and production.

The Nechako River is already a diminished river. There is no certainty that the river currently has sufficient rearing capacity to meet its potential chinook salmon production targets and there is no belief that Alcan's proposal will permit the maintenance of current production which is substantially less than the target. The opportunities for the application of substantial habitat improvement as compensation appears severely limited although the potential for hatchery production appears to be good.

The opportunity to mitigate against temperature effects on sockeye appears good although more data is required if temperatures in the Upper Nechako River are to be regulated for juvenile chinook as well as migrating adult sockeye.

With regards to other water quality parameters on the Nechako River, more detailed study is required to identify the need for and the method of controlling the supersaturation of dissolved gases. Similarly, there is a need to further study the effects of flow reduction on the concentration of natural and man-made pollutants in the Nechako River and on the need to upgrade existing pollution treatment systems.

The impacts on fish production on the Kemano River are not predictable at this time with any degree of certainty. The expectation is that current fish production can be maintained.

On the general subject of diseases and parasite transfer, there was no substantial concern identified to warrant objection to the Nanika Diversion. Some long term monitoring has been suggested.

To facilitate public discussion and input into the Department's consideration of the project, three possible decision scenarios have been presented. They are:

1. Present Situation: No expansion to existing facilities. Continuation of an inefficient and destructive method of regulating temperature in the Nechako River.

2a. No Nanika Diversion: Provision of Injunction flows with a suitable quality and quantity of cold water release flows. Possibly yields one 200,000 tonne smelter, allows some flexibility for responding to unforeseen impacts. Provides for the maintenance of a reduced number of chinook necessitating limited compensation.

2b. No Nanika Diversion: Provision of Alcan's proposed flow and temperature regime . Yields one 200,000 tonne smelter with considerable surplus power. Anticipate substantial loss of chinook production and continuation of sockeye cooling problems.

3a. Nanika Diversion: Diversion of a pristine river. Provision of Injunction flows with a suitable quality and quantity of cold water release flows. Yields one 200,000 tonne smelter, and substantial surplus power. Impacts to fish are substantial and are spread over three drainages.

3b. Alcan's Proposal: Yields two 170,000 tonne smelters. Presents maximum degree of impact and risk. Provides no flexibility to adjust or respond to unforeseen circumstances or impacts.

The public is invited to express its preferences concerning these or other possible scenarios. The paper concludes with a statement to the effect that regardless of which decision option is finally chosen, it is absolutely clear that in the face of so much uncertainty and risk to the fisheries resources of Canada, the proponent will be expected to engage in considerable post-project assessment and monitoring. The need to retain the flexibility to adequately respond to the inevitable impacts, be they positive or negative, is essential.

# 1. INTRODUCTION

**PROBLEM OF WATER ALLOCATION**

The proposed Kemano Completion Project raises and necessitates consideration of the longstanding problem of water allocation. Again there is competition over the use of water, in this case, for the production of aluminum or for other uses ranging from the preservation of fish habitat to the preservation of natural rivers for the simple pleasure that comes from the sight of them.

**DEPARTMENT ENCOURAGES PUBLIC DISCUSSION AND INPUT**

This discussion paper represents a deliberate attempt by the Department of Fisheries and Oceans to consult with an interested and concerned public on the fisheries management and habitat issues arising from the Aluminum Company of Canada's (Alcan) plan to use the waters of the Nanika and Nechako rivers in central British Columbia for aluminum production. Public consultation is particularly applicable, as decisions arising from consideration of this project will, most certainly, involve complex judgements about environmental risk, alternatives, social and economic costs and benefits and mitigation and compensation action. Upon completion of a public consultation process concerning the matters raised in this paper, it is the Department's intention to develop a position concerning the acceptability of the project. It should be noted that in keeping with its responsibility, the International Pacific Salmon Fisheries Commission has completed an analysis of the potential effects of the Kemano Completion Project on Fraser River sockeye and pink salmon. It is intended that this analysis, contained in a separate report (IPSFC, 1983) also be subject to public review prior to the development of a Departmental position.

**DEPARTMENT DEVELOPS POSITION AFTER PUBLIC CONSULTATION**

To place the present proposal in perspective, it is appropriate to provide some background history.

**ALCAN'S 1950 CONDITIONAL WATER LICENCE FAILED TO ADDRESS SALMON CONCERNS**

In December, 1950 the Government of British Columbia granted a conditional water licence to Alcan authorizing it to store and divert all waters in the Nechako watershed upstream of the Cheslatta River and all waters of the Nanika watershed upstream of Glacier Creek, approximately 4 km below Kidprice Lake. The Department of Fisheries reviewed the licence application and stipulated provisions regarding temperature regulation and flow releases to protect the fisheries resources; however, despite the provisions of the Fisheries Act the spirit of the times dictated that those provisions were, in the main, ignored.

**EFFECT OF RESERVOIR FILLING ON NECHAKO RIVER CHINOOK**

By 1957 the first, or Kemano 1, phase of development was fully operational. Its works consisted of a dam on the Nechako River resulting in the creation of a 890-$km^2$ reservoir with tunnels through Mt. Boise to a power house constructed at Kemano and transmission lines conveying power to an aluminum smelter constructed at Kitimat (Figure 1). Predictably, during the period of reservoir filling (1952 - 1957), when very little water was being released below the dam, the Nechako chinook salmon stocks were decimated. Since 1957, as water became available for release to the Nechako river, the chinook stocks have shown signs of recovery.

**ORIGINAL WATER LICENCE ALLOWED FOR EXPANSION**

In 1978 Alcan announced its intentions to add to the hydroelectric generating capacity at Kemano, and to increase aluminum production capacity. Under the terms and conditions of the original licence granted in 1950 Alcan now propose to divert more water from the Nechako as well as to use water diverted from Nanika Lake. Key components of the project include a second tunnel from West Tahtsa Lake through to Kemano, a tunnel diversion from Nanika Lake to Tahtsa Lake, a dam at the outlet of Kidprice and Murray Lakes, and a new power station at Kemano.

**KEY PROJECT COMPONENTS**

**1980 INJUNCTION FLOWS**

During the winter of 1979, because of a perceived water shortage, Alcan reduced the releases of water from the Nechako reservoir through the Skins Lake spillway. In 1980 the Department of Fisheries and Oceans successfully appealed to the Supreme Court of British Columbia for an injunction ordering Alcan to make specified flow releases into the Nechako River. These injunction flows have been adhered to since August of 1980.

**THREAT TO SALMON STOCKS**

The second, or completion phase of the Kemano development, once again threatens the salmon stocks in the Fraser system (especially the chinook of the Nechako River, as well as the sockeye of the Stuart, Stellako and Nadina Rivers). For the first time, several species (chinook, sockeye, coho and pink salmon) would be impacted in the Nanika,and Morice Rivers as a result of the diversion of the Nanika River. All five species of Pacific salmon and the eulachon populations of the Kemano River would again be impacted.

Once again the Department of Fisheries and Oceans finds itself having to respond to a development proposal. In the context of the present Kemano Completion project review, a fisheries management objective has been defined as follows:

FISHERIES OBJECTIVE

**TO PRESERVE THE NATURAL STOCKS AND THE NATURAL SALMON PRODUCING POTENTIAL OF ALL RIVERS THAT WOULD BE AFFECTED BY THE DEVELOPMENT**

**THREAT TO FISH HABITATS**

The Kemano Completion project threatens the fish habitats upon which the fisheries resources of the Nechako, Nanika, Morice and Kemano Rivers depend. In its review of the project the Department is examining ways to avoid damage to fish habitat that is likely to permanently reduce its productivity, by (a) prohibiting certain proposed activities that could permanently damage highly productive fish habitats; (b) mitigating potential problems through design, construction and operational adjustments, (c) and compensating for unavoidable losses by employing habitat replacement and enhancement techniques.

**ATTEMPT BY ALCAN TO DEFINE FLOW REQUIREMENTS**

At this time, apart from a very general description of the project, Alcan has not provided detailed information concerning the construction and operation of their facilities, and a comprehensive environmental impact statement being prepared by Alcan is not yet available. To date, Alcan and their consultants have attempted to define the fisheries flow requirements

in the rivers downstream of the proposed dam site on the Nanika River and the existing dam on the Nechako River. Alcan wants to know whether the fish protection flows proposed by them are acceptable. To Alcan, the definition of fish protection flows is an essential first step, as the scope, and indeed, the viability of the Kemano Completion Project depend on knowing how much water is available through a diversion for power-generating purposes and how much has to be released for downstream (i.e., fish protection and other) purposes.

**TECHNICAL INFORMATION REVIEWED**

A mass of technical data on the subject has been provided and reviewed. It is not intended to reproduce all of this information here. Rather, this paper is a synopsis of the most important considerations that have arisen from the Department's review of the data. In many cases the data are incomplete, and certainly this paper does not address all facets of the impacts arising from the Kemano Completion Project.

**SCOPE OF PAPER**

The paper begins with a brief review of the applicable legislation by which the Department of Fisheries and Oceans has the authority to conduct its review, then reviews the hydrology of the Nanika, Morice, Nechako and Kemano River systems, and discusses, by life cycle stages, the biology of the salmonid species utilizing the rivers. The implications of the Alcan proposal are discussed by river system, water quality and quantity considerations are presented, comments are offered on diseases and parasites, salmon production targets for each river system are provided, and opportunities for compensation are identified. The paper finishes with a presentation of a number of possible decision options or scenarios designed to stimulate, and to provide a focus for public discussion. A glossary of terms used throughout the paper is provided at the end.

## 2. LEGISLATIVE AUTHORITY

**FISHERIES ARE A FEDERAL RESPONSIBILITY**

The jurisdictional responsibility for the salmon resources of the Nechako, Morice, Nanika and Kemano rivers, as for all freshwater and marine fisheries resources in Canada, was assigned to the Federal Government under Section 91 of the British North America Act. Over the years, the Federal and Provincial governments have developed separate agreements in regard to the administration of the fisheries resources. In British Columbia, the Provincial Government now has responsibility for the management, protection and restoration of all non-anadramous species as well as steelhead and sea-run cutthroat trout. Responsibility for protection, preservation and extension of the Fraser River sockeye and pink salmon resource is vested with the International Pacific Salmon Fisheries Commission under the Sockeye Salmon Fisheries Convention signed in 1930, ratified in 1937 and amended by the Pink Salmon Protocol in 1957.

**FISHERIES ACT RELATIONSHIP TO PROJECT**

Since Confederation the main instrument of the Federal Government in protecting fish habitat has been the Fisheries Act. Amendments to the Fisheries Act have been recently enacted. These amendments have broadened the scope of 'fish' to be protected and included new controls on physical disruption of 'fish habitat'; they have shifted the burden of proof of

whether fish habitat will be altered from the Crown to the proponent; and strengthened other provisions. Particular attention is directed to Sections 20, 31, 33 and 53, which specifically relate to development activities such as those proposed by Alcan.

Section 20 in part states:

**PROVISIONS FOR MAINTAINING ANNUAL RETURN OF FISH**

20.(1) Every slide, dam or other obstruction across or in any stream where the Minister determines it to be necessary for the public interest that a fishpass should exist, shall be provided by the owner or occupier with a durable and efficient fishway, or canal around the slide, dam or other obstruction, which shall be maintained in a good and effective condition by the owner or occupier, in such place and of such form and capacity as will, in the opinion of the Minister, satisfactorily permit the free passage of fish through the same; where it is determined by the Minister in any case that the provision of an efficient fishway or canal around the slide, dam or other obstruction is not feasible, or that the spawning areas above such slide, dam or other obstruction are destroyed, the Minister may require the owner or occupier of such slide, dam or other obstruction to pay to him from time to time such sum or sums of money as he may require to construct, operate and maintain such complete fish hatchery establishment as will, in his opinion, meet the requirements for maintaining the annual return of migratory fish.

**FLOW REGULATION BELOW DAMS FOR SAFETY OF FISH**

and 20.(10) The owner or occupier of any slide, dam or other obstruction shall permit to escape into the riverbed below the said slide, dam or other obstruction, such quantity of water, at all times, as will, in the opinion of the Minister, be sufficient for the safety of fish and for the flooding of the spawning grounds to such depth as will, in the opinion of the Minister, be necessary for the safety of the ova deposited thereon.

Section 31 in part states:

**FISH HABITAT**

31.(1) No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.

Section 33 in part states:

**POLLUTION**

33.1(1) Every person who carries on or proposes to carry on any work or undertaking that results or is likely to result in

(a) the deposit of a deleterious substance in water frequented by fish or in any place under any conditions where that deleterious substance or any other deleterious substance that results from the deposit of that deleterious substance may enter any such water, or

**HABITAT DEGRADATION**

(b) the alteration, disruption or destruction of fish habitat, shall, on the request of the Minister or without request in the manner and circumstance prescribed by regulations made under paragraph (3)(a), provide the Minister with such plans, specifications, studies, procedures, schedules, analyses, samples or other information relating to the work or undertaking and with such analyses, samples, evaluations, or other information relating to the water, place or fish habitat that is or is likely to be affected by the work or undertaking as will enable the Minister to determine.

**PROVISION OF PLANS FOR REVIEW**

(c) whether there is or is likely to be a deposit of a deleterious substance by reason of such work or undertaking that constitutes or would constitute an offence under Section 33 and what measures, if any, would prevent such a deposit or mitigate the effects thereof; or

(d) whether the work or undertaking results or is likely to result in any alteration, disruption or destruction of fish habitat that constitutes or would constitute an offence under Section 31 and what measures, if any, would prevent such a result or mitigate the effects thereof.

Section 53 in part states:

53.(1) Where the Minister determines that the provision, which he deems necessary for the public interest, of an efficient fishway or canal around any slide, dam or other obstruction is not feasible or that the spawning areas above such slide, dam or other obstruction are destroyed by reason of any such obstruction, the owner or occupier of any such slide, dam or other obstruction shall from time to time pay to the Receiver General such lump sum or annual sum of money as may be assessed against him by the Minister for the purpose of constructing, operating and maintaining such complete hatchery establishment as will, in the opinion of the Minister, meet the requirements for maintaining the annual return of migratory fish.

**COST RECOVERY**

Section 71 states:

71. This Act is binding on Her Majesty in right of Canada or a province and any agent thereof.

**APPLICATION OF ACT TO HER MAJESTY**

**ADMINISTRATION OF ACT AS IT RELATES TO PROJECT**

The Habitat Management Division of the Department of Fisheries and Oceans has the main responsibility for administering the habitat provisions of the Act. This is accomplished in a manner that (a) recognizes the legitimate interests of other levels of government and private sector interests, (b) provides opportunities for public views and concerns to be heard, and (c) makes full use of the results of scientific research in reaching habitat management decisions. The reader is reminded that the Division's responsibilities are limited by the authority of the Fisheries Act and do not concern other environmental matters.

## 3. RIVER ECOLOGY, AND THE IMPLICATIONS OF CHANGE

**RIVERS ARE COMPLEX AND HIGHLY CHANGEABLE**

Rivers are complex and highly changeable systems. To visualize what happens if their patterns of flow are altered it is helpful to have a simple descriptive scheme of the main factors and processes operating in rivers. Figure 2 lists key physical and biological features of a river that go into the making of salmon habitat and to the production of salmon. These features are referred to throughout the report.

**KEY PHYSICAL AND BIOLOGICAL FEATURES LISTED**

The biological processes of a river are the product of an adaptation of plants and animals to their surroundings in various zones of the river; surroundings that are shaped by the physical phenomena of hydrology, hydraulics and local geology. The general shape (or morphology) of a river is characterized by lateral bends (meanders) and pool - riffle series.

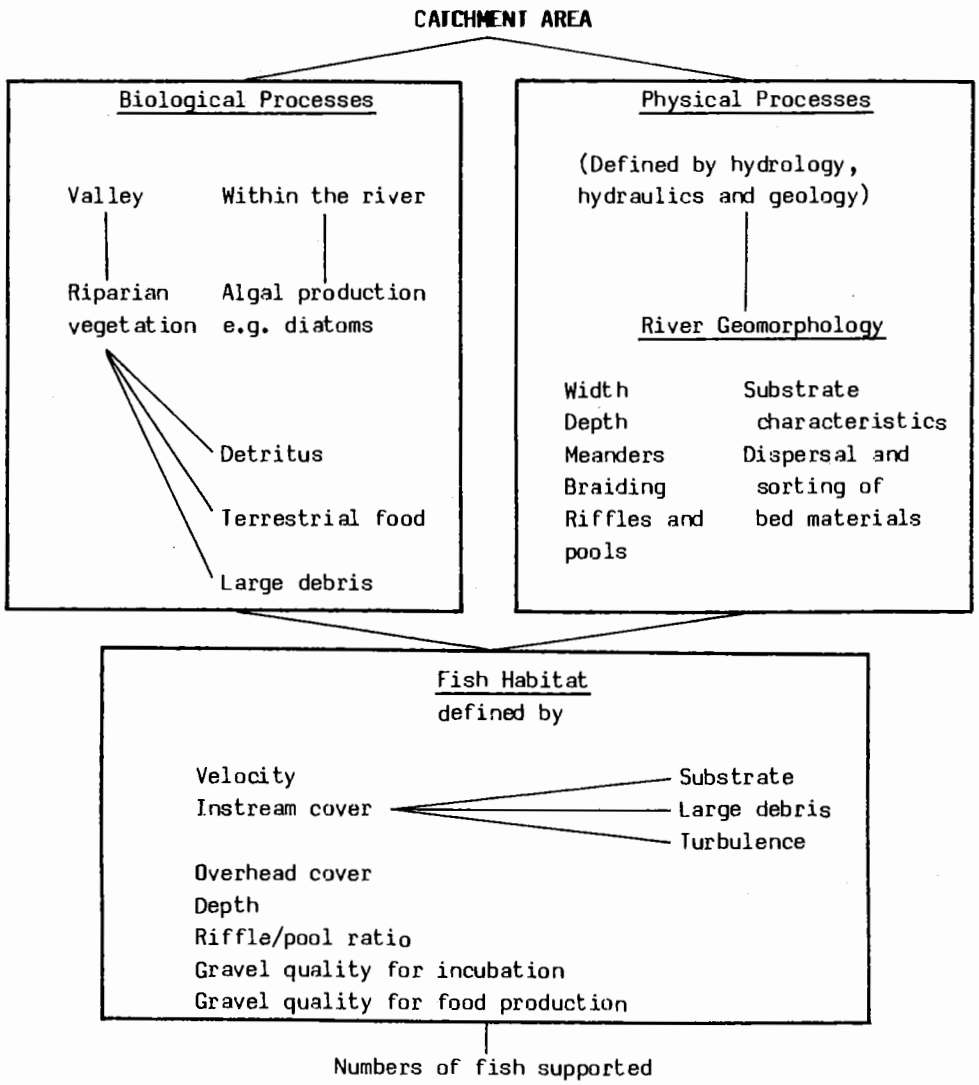


**FIGURE 2 - PHYSICAL & BIOLOGICAL FEATURES**

Both result in the dispersal and sorting of bed materials, with riffles acquiring large gravel and cobble near the surface, and pools acquiring a high sand and silt content. In rivers of highly variable discharge with erodible banks, the stream channel may divide and coalesce repeatedly, thereby producing a braided pattern. The annual flood flow constitutes the dominant discharge. The stress of dominant discharge, which is correlated with velocity and depth, moves bed materials and determines which materials remain in place in various river zones. This stress reconditions the river by suspending and transporting sediment and organic materials that would otherwise build up and clog the spaces within the coarse gravel and cobble material.

**STRESS OF DOMINANT DISCHARGE**

**VARIOUS TYPES OF HABITAT**

The physical features of a river - its riffles, pools and side channels - present various types of habitat to salmon and to the aquatic invertebrates that constitute most of their food.

**RIFFLES ARE PRODUCTIVE AREAS**

The main strands of the food web of salmon streams pass from algae and leaf litter through aquatic insects to fish. The most productive food-producing areas are riffles where thousands of insects per square metre, of a great diversity of species, feed upon algae and detritus.

**AQUATIC INVERTEBRATES FOOD FOR REARING SALMONIDS**

The flow of a river results in a continuous downstream drift of these organisms, which increases several-fold during the hours of darkness. This drift makes up the food of rearing salmonids. The rate of growth of salmonids that feed upon the insects can be limited by high or low temperatures. Thus the temperature regime of a stream strongly affects its productivity. Conspicuous changes in a stream's flow regime result in changes to its temperature regime.

**TERRESTRIAL INSECTS FOOD FOR SALMONIDS**

Terrestrial insects can constitute a significant portion of the food of young salmon during daylight hours. Their abundance as food is influenced by streamside vegetation, wind, and sunshine. Streamside vegetation provides security to fish as cover, retards scouring of river banks and reduces the effect of solar radiation on stream temperatures. In rivers diminished by man, receding water levels isolate streamside vegetation for a period of time.

**FISH PREFER TO SPAWN IN CERTAIN AREAS**

For reasons not entirely understood, salmon prefer to spawn in certain areas of a stream. Each species has different preferences. Spawning chinooks, for example, select relatively deep, fast flowing, coarsely-gravelled areas; pinks favour the slower velocity fine-gravelled bottom areas. Flow alterations can alter the depth and velocity conditions of spawning areas and alter their gravel composition.

**CHANGES DIFFICULT TO FORECAST AND VERY DIFFICULT TO QUANTIFY**

Radical reductions in flows may create points of difficult passage that block or deter the migration of adult salmon. Such flow reductions may also cause river temperatures to rise to levels that stress migrating salmon so that some may die or their migration may be delayed. Rearing habitat and fish food may be permanently lost. The conclusion that emerges, from a review of the elements of stream ecology is that the quantity and quality of habitat presented to salmon in any river are very

closely related to the flows that shape it. To alter flow regime radically is to invite complex biological changes that are difficult to forecast and even more difficult to quantify.

**FURTHER DISCUSSION FOLLOWS**

In the following sections, a review of the hydrology, biology and implications of alcan's proposal on the salmon resource is presented for each river system affected by Kemano completion. Steelhead trout and resident species would also be impacted by the project and these concerns are being addressed by the B.C. Fish and Wildlife Branch.

## 4. NANIKA RIVER

### 4.1 Hydrology and Alcan's Proposal

**DESCRIPTION OF NANIKA RIVER DRAINAGE**

The Nanika River is a tributary of Morice Lake, entering the lake only 3 kilometers from the lake outlet (Figure 1). The Nanika River watershed has a total area of 890 sq.km. yielding a mean annual flow of 36.6 cms (1292 cfs). Eighty-two percent, or 732 sq.km., of the watershed lies above the outlet of Kidprice Lake. The long term mean annual flow at this point (Envirocon, 1983) is 29.65 cms (1047 cfs).*

Glacier Creek, the main tributary to the Nanika, has a mean annual flow of about 3.0 cms (107 cfs) (Envirocon, 1983). It joins the Nanika downstream of the main spawning areas.

**FLOW RECORDS**

The hydrograph of the mean monthly flows at the outlet of Kidprice Lake (gauge 8ED001) is shown in Figure 3. It is based on the historic period 1962 - 1981. As recorded data (WSC) are available only for some of these years (1950 - 1952, 1972 - 1981), flows for other years had to be synthesized (Envirocon, 1983). The high flows in May-August result from snow melt. High flows in October-November result from fall rains.

**PHYSICAL DESCRIPTION OF PROPOSED DIVERSION STRUCTURES**

Alcan proposes the construction of a dam 330 meters downstream of Nanika Falls (Nanika Falls, presently the upper limit of salmon migration, is about 400 meters below the outlet of Kidprice Lake). A 52 sq.km. reservoir would be created consisting of both Kidprice and Nanika lakes, and would flood out Nanika Falls and that reach of the river joining the two lakes. A tunnel approximately 5 meters in diameter would divert 62% of the total annual flow 18.49 cms (653 cfs) from the Nanika reservoir to Tahtsa Lake (Nechako reservoir). It is understood that the tunnel would be so designed and the reservoir so operated that all surplus runoff could be diverted, even in extremely wet years.

**TOTAL REGULATED FLOW PROPOSED**

Alcan has proposed a regulated flow regime, as shown in Figure 3, which would provide an annual average flow of 11.16 cms (394 cfs) (38% of the natural flow) in the Nanika below the dam. Alcan proposes to release flows via a gate at the spillway. Part of this mean annual flow 0.34 cms (12 cfs) would be for flushing purposes. Alcan has suggested a flushing release of 75 cms (2648 cfs) for four days every three years.

* This is Alcan's most recent estimate (Oct. 1983.)

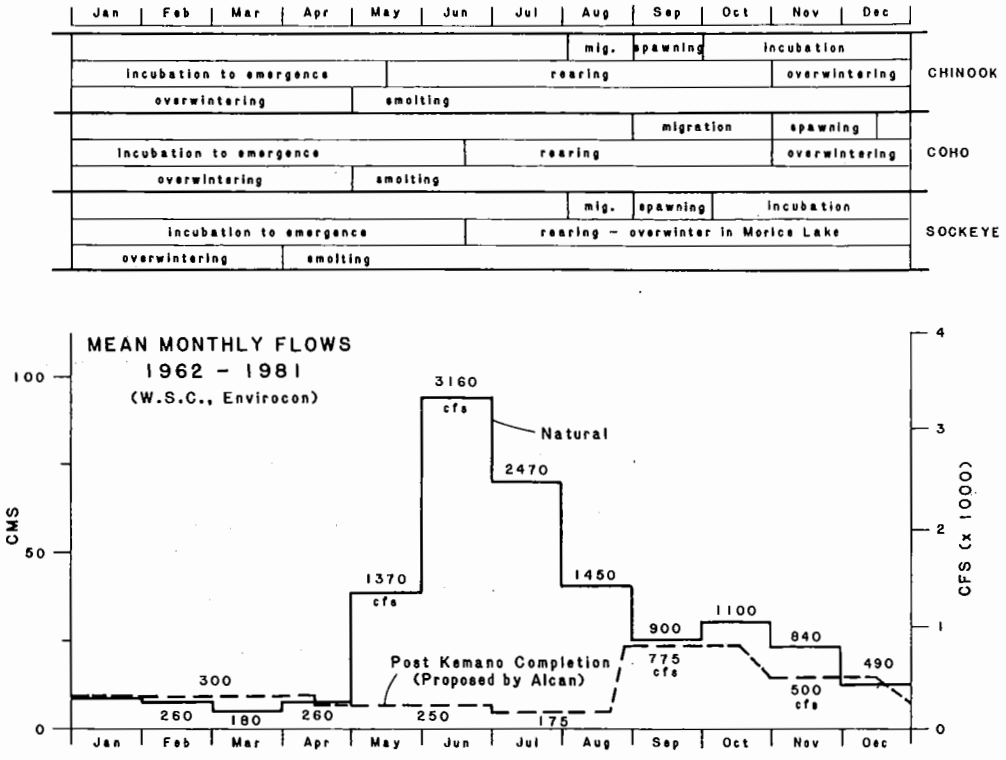


**FIGURE 3 - NANIKA RIVER AT KIDPRICE LAKE**

**DIVERSION OF GLACIER CREEK**

A possible modification, suggested by the B.C. Fish and Wildlife Branch, is the diversion of Glacier Creek into the Nanika-Kidprice reservoir via Des Lake. The approximately 1.7 cms (60 cfs) thus diverted would then be released in addition to the 11.16 cms (394 cfs) proposed by Alcan. The purpose of so diverting Glacier Creek would be to reduce or eliminate the sediment load presently transported by Glacier Creek into the Nanika River, and to increase flow in the Nanika between the dam and Glacier Creek.

## 4.2. Biology

**NANIKA RIVER SUPPORTS SOCKEYE, COHO AND CHINOOK SALMON**

The Nanika River supports a major sockeye run and smaller populations of coho and chinook salmon and steelhead trout. The Nanika River is the principal spawning area for the Morice Lake sockeye population. Other sockeye populations spawn along the lakeshore near Cabin Creek at the southwest end of Morice Lake and in Atna Lake. The Nanika River is also a significant coho producing tributary of the Morice River system.

## Sockeye escapements

**SOCKEYE SPAWNING CAPACITY**

From 1949 to 1954, sockeye numbered in the order of 35,000 to 70,000 fish comprising as much as 10% of the total Skeena River escapement (Shepherd, 1979). These escapements, however, exceeded the total capacity of the spawning grounds which is estimated to be approximately 32,000 fish (Robertson et al, 1979). From 1955 to 1975, an average of over 4,000 sockeye returned to the Nanika River. Numbers then declined to less than 1,000 fish, but increased to 3,000 and 4,000 sockeye in 1982 and 1983 respectively.

**DECLINING SOCKEYE POPULATIONS**

Despite efforts to rehabilitate the Nanika River stock, numbers have not returned to optimal levels. A pilot hatchery operated from 1960 to 1965 was not successful owing to the use of transplant stock from the Babine system. These proved to be poorly suited for Nanika River conditions. The Nanika River sockeye population also has a history of being overfished, because its timing coincides with the larger and more productive Pinkut River sockeye run. Nanika River sockeye presently represent only 0.1% of the total Skeena River sockeye escapement.

## Chinook and coho escapements

**COHO SPAWNING COUNTS UNDERESTIMATED**

For the period of record, chinook salmon spawners averaged about 150 fish ranging from 25 to a maximum of 400. The spawning population of coho salmon averaged 300 fish with a maximum of 500 recorded. It is expected, however, that the coho escapements may be significantly underestimated owing to their extended spawning period, scattered distribution and poor visibility, typical of late fall and winter conditions for observation. In addition, counts are timed to coincide with peak sockeye spawning. This occurs considerably earlier than the peak spawning period for coho and contributes to the underestimates.

## Timing and distribution of sockeye salmon

**SOCKEYE SPAWNING MIGRATION**

Timing of the various life stages of sockeye salmon is shown in Figure 3. A peak migration past the Alcan counting tower near Owen Creek in the Morice River occurs in early to mid-August (Farina, 1982). Sockeye probably hold in Morice Lake until they move into the Nanika River, usually in September. Peak spawning at the Nanika grounds is usually in late September and ends in October. Sockeye salmon spawn in the upper Nanika River in the 3 kilometer reach below Nanika Falls (Figure 4). The two prime spawning areas, designated A and B contain 17,000 $m^2$ (20,000 sq.yds.) and 1600 $m^2$ (2,000 sq.yds.) respectively (Robertson et al, 1979). An additional 8400 $m^2$ (10,000 sq.yds.) are estimated to be available in scattered pockets.

**EXTENT OF SPAWNING AREAS**

**PRIME SPAWNING AREA**

In 1979, approximately 96% of the sockeye spawners utilized area A (Envirocon, 1981). Spawning occurs within a relatively deep channel at this site and is not subject to dewatering or freezing in the winter. High egg to fry survival was reported (R. Palmer in Shepherd, 1979). The smaller spawning area (B), on the other hand, is located near the river margin and, being shallower, is more subject to dewatering with decreasing discharge in the winter incubation period.

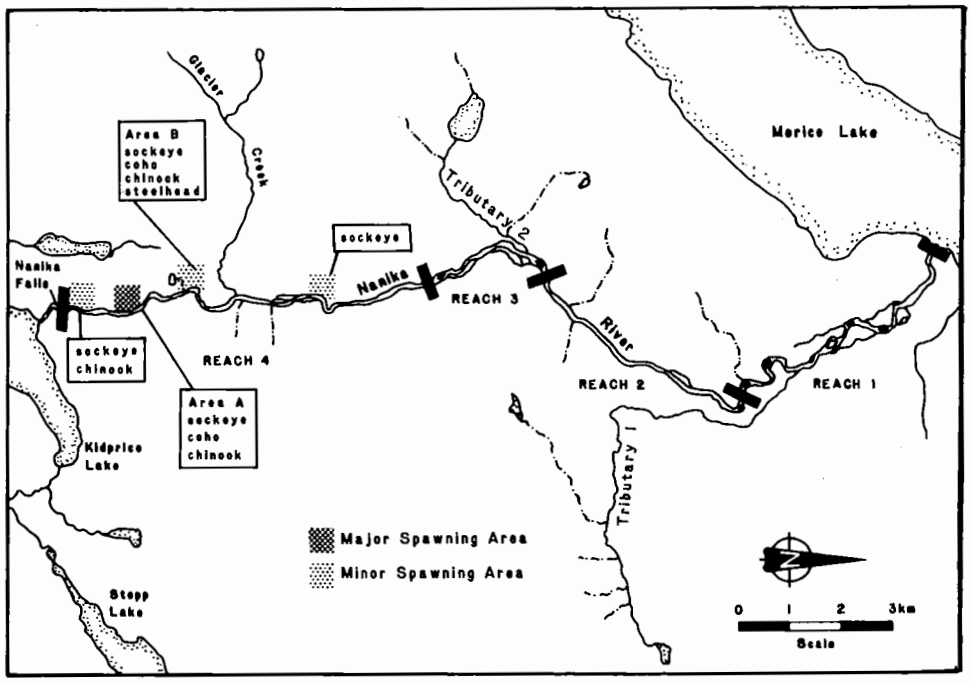


**FIGURE 4 - NANIKA RIVER SALMON SPAWNING AREAS**

**TIMING OF DOWNSTREAM SOCKEYE FRY MIGRATION**

Sockeye fry emerge and migrate downstream to Morice Lake in late May to July, peaking in June and coinciding with peak annual flows (Shepherd, 1975; Zyblut, 1974). Peaks in sockeye fry migration are generally associated with a rise in flow and temperature. In the absence of freshet flows, studies in the Babine system indicated that downstream migration occurred when temperatures reached 4°C (West, 1978).

**SOCKEYE RESIDENCE TIME IN MORICE LAKE**

In contrast to other Skeena sockeye stocks, which spend one year in freshwater, over 85% of Nanika River sockeye spend two years in Morice Lake and 90% return as five-($5_3$) and six-($6_3$) year-olds (Shepherd, 1979). The age distribution of sockeye spawners in 1983 was similar with approximately 84% aged $5_3$ and $6_3$.

**SMOLTIFICATION AFFECTED BY MORICE LAKE PRODUCTIVITY**

Tow netting of sockeye in the early 1960's led to the conclusion that the duration of sockeye residence in Morice Lake was size related (R. Palmer, pers. comm.). Subsequent study by Cleugh (1979) demonstrated the low productivity of Morice Lake, that Shepherd (1979) suggested, resulted in delayed smoltification. Sockeye smolts migrate out of Morice Lake from late April to August with a peak migration in May (Shepherd, 1979, Smith & Berezay, 1983).

## Timing and distribution of chinook and coho salmon

**ADULT CHINOOK MIGRATE IN AUGUST**

**COHO MIGRATE LATER**

Timing of the various life stages of chinook and coho salmon are shown in Figure 3. Chinook salmon that spawn in the Morice and Nanika rivers pass the counting tower near Owen Creek usually in early August and in some years in late July (Farina, 1982). Peak migration of coho salmon past this point is in late August or early September.

**CHINOOK SPAWN IN SEPTEMBER**

**COHO SPAWN IN SEPTEMBER/DECEMBER**

In the Nanika River, chinook salmon spawn in September; coho salmon spawn later. According to the Department's spawning reports, the coho spawning period extends from September through November. This observation is probably the result of the early timing of the surveys, since winter observations in 1979 indicated that peak spawning occurred in November and extended through December (Envirocon, 1981).

**PRINCIPAL SPAWNING AREAS SAME AS SOCKEYE**

Chinook and coho spawners utilize the same areas as sockeye salmon, area A being the major spawning site (Figure 4). A small number of coho may also spawn in a tributary stream (approximately 10 km downstream of the falls) in years when flows permit access.

**JUVENILE CHINOOK AND COHO MIGRATION**

Emergence of chinook was observed in early May in 1979 (Envirocon, 1981) and minor downstream chinook and coho fry migrations from the Nanika River were monitored in June and August (Shepherd, 1979). While some chinook and coho fry move out of the Nanika River and rear in Morice Lake (R. Palmer, pers. comm.), others overwinter in the Nanika River. Chinook smolts move out of the Nanika River in the spring following their first winter, while coho may spend one or two winters in the river. Some chinook smolts also leave the Nanika River in the fall of their first year.

**JUVENILE CHINOOK AND COHO HABITAT REQUIREMENTS**

During their residence in rivers, coho and chinook juveniles have specific habitat requirements and preferences during the rearing period in the summer (May to October) and the inactive overwintering (November to April) phase. The availability of food, cover and suitable space are all important factors that determine the ultimate production of chinook and coho smolts. Based on studies in the Morice River, there is evidence that a limiting constraint to chinook and coho production in the Nanika River may occur in the overwintering period. Significant mortalities were observed in the Morice River associated with dewatering and freezing of sidechannels used by juveniles (Bustard, 1983).

**CHINOOK AND COHO REARING AND OVERWINTERING HABITAT**

Studies of the Nanika River indicate that sidechannel habitat and log jams, which provide cover were the key components of summer rearing and winter habitat for both chinook and coho juveniles (Shepherd, 1979; Envirocon, 1981, 1983). This is reflected in the distribution of juveniles in the Nanika River. The lower reach (Reach 1), with the most abundant sidechannels and log jams and hence rearing capacity, was heavily utilized by both juvenile chinook and coho. In contrast, abundance of coho juveniles was consistently low in Reach 2, a single channelled section with few low velocity areas. In 1979, chinook and coho fry were found in the vicinity of the spawning areas early in the season and became increasingly abundant in the lower reach in the fall where they probably overwintered.

Coho yearlings also favoured this lower reach. In 1982, the distribution of coho fry and yearlings was similar to that reported above, but chinook were found throughout the river in the fall. Chinook juveniles were, however, twice as abundant in sidechannels compared with the mainstem, thus confirming the importance of this type of habitat.

**NANIKA RIVER TRIBUTARIES HAVE LIMITED REARING POTENTIAL**

Nanika River tributaries do not contribute significantly to the overall rearing potential of Nanika River. Some chinook fry were found in tributary '2'. Coho fry were observed in two tributaries (1 and 2) but were estimated to account for less than 10% of the overall rearing capacity in the Nanika River (Envirocon, 1981).

## 4.3 Implications of Alcan's Proposal

**COMPARISON OF NATURAL AND REGULATED FLOWS**

Alcan's proposed regime for the Nanika River substantially alters the natural hydrograph (Figure 3). The Nanika would become a much diminished river. The annual flow below Kidprice Lake would be reduced to 38% of the present mean annual flow. The flow for June, which is the highest flow month, would be reduced to 8% of the present June mean. Not only would flows be greatly reduced but the shape of the hydrograph, that is the relative distribution of flow month by month, would be entirely altered.

**SIDECHANNEL LOSSES FROM FLOW REGULATION**

The river would naturally adapt itself over a long period of time (decades) by a reduction of mainchannel width, vegetation encroachment on banks and bars, redistribution of sediment sizes, and abandonment of sidechannels. It is estimated that most of the sidechannels would eventually be lost because of the severe reduction in June-July flows, which now govern the morphological patterns. The loss of sidechannels would have a major impact on coho and chinook salmon in the Nanika River. Losses of 90% and 70% of the rearing habitat are estimated for coho and chinook respectively (Envirocon, 1983).

**FLUSHING FLOWS AND GRAVEL QUALITY**

The flushing flows required to maintain present channel conditions in the lower Nanika below Glacier Creek would have to be of a magnitude and duration comparable to present annual flood flows. This would require so much water that it would probably make it impractical for Alcan to consider the Nanika project. Diversion of the upper part of Glacier Creek may reduce some of the sediment load but with an acceptance of Alcan's flow proposal one would have to accept the long term channel changes. The consequent effect on fish life in the lower Nanika, whether negative or positive, cannot be predicted.

It is not known what the magnitude or duration of flushing flows should be, or even if they are required at all, in the Nanika above Glacier Creek where the major spawning areas are located. The only contribution of silt to this part of the river would be from the local banks and the limited watershed below the proposed dam.

**SPAWNING AND INCUBATION FLOWS**

Spawning flows from late August to October are comparable to mean monthly flows, and incubation flows though reduced in November would be increased during the late winter period (February to April).

The implications of these changes on Nanika River sockeye, chinook and coho are described for each life stage. The effects of changes in temperature regime on Nanika River salmon populations are discussed in the Water Quality section.

Sockeye salmon

**EFFECTS OF FLOW REGULATION ON ADULT SOCKEYE MIGRATION**

Migration of sockeye adults into the Nanika River would probably not be substantially affected by the proposed regime. While August flows would be significantly reduced (5 cms, 175 cfs), the increase to 22 cms, (775 cfs) in late August to accommodate spawning would likely provide an "attraction" flow for sockeye entering the Nanika River. Time of entry into the Nanika River would therefore not be expected to depart significantly from present "average" conditions. On the basis of spawning records, the adult sockeye generally migrate into the river in September but in some years enter the river earlier. With the proposed schedule of water releases there may be a delay of sockeye at the mouth of the Nanika River until flows are increased in late August. The effects of this delay are difficult to predict.

**FLOW REGIME WOULD MAINTAIN SPAWNING HABITAT**

Alcan's proposed spawning flow is consistent with that estimated by the Department to protect sockeye spawning habitat. At 22.7 and 28.3 cms (800 and 1000 cfs), 95% and 100% of the total suitable gravel in the prime spawning areas (A and B) were estimated to be available (Robertson et al, 1979). This assumes that gravel quality on the spawning grounds would be maintained.

**INCUBATION FLOWS INCREASED**

Alcan's proposed increase in late winter incubation flows (February to April) to 8.5 cms (300 cfs) is likely to be an improvement to the present flow regime, which may drop to a minimum of 3.1 cms (109 cfs) during this period. Robertson et al, (1979) estimated that 100% of the smaller spawning area (B), which is more sensitive to dewatering than area A, would remain wetted at 9.9 cms (350 cfs). At 8.5 cms (300 cfs), 95% of the spawned area would remain wetted.

**IMPACTS OF REDUCED FLOWS ON SOCKEYE FRY MIGRATION**

It is during sockeye emergence, fry migration and rearing phases that the implications of Alcan's flow regime on sockeye production in the Nanika River are more difficult to predict and quantify. Even if spawning habitat is maintained and egg to fry survival improved, the ultimate production of the Nanika River sockeye stocks depends also on the fry to smolt survival. Some of the key factors affecting survival are the successful migration of fry to the lake, lake entry, which coincides with food availability and favourable temperatures, and a lake environment that promotes good growth and survival during the entire period of lake residence.

**NUTRIENT INPUT INTO MORICE LAKE REDUCED**

The proposed Nanika River flow regime, by reducing the discharge into Morice Lake, would significantly reduce nutrient input into the lake. Morice Lake is presently an unproductive lake and the two year residence of Nanika River sockeye in the lake has been attributed to their slow growth rate. Further reducing sockeye growth may increase the lake residence period. Smaller smolt size would reduce the survival of seaward migrating smolts.

**TIMING OF FRY ARRIVAL IN MORICE LAKE IS CRITICAL**

The proposal would result in higher water temperatures during the fall incubation period. The timing of fry emergence in the spring is dependent on temperature. Higher temperatures accelerate the rate of development and emergence. The effects of early emergence and migration are difficult to predict. In general, sockeye fry enter the lake just prior to, or at the onset of, an increase in plankton food supply, to rear. Heavy mortalities would be expected to occur if, at the time of lake entry, the appropriate foods were not readily available.

**INCREASED SUSCEPTIBILITY TO PREDATION**

Finally, the large decrease in the volume of water in May/June would likely render sockeye fry more susceptible to predation during the migration to Morice Lake. Foerster (1968) indicated that predation may be a significant limiting factor accounting for the loss of 50 to 75% of the fry emerging and migrating to the rearing lake.

**OVERALL EFFECTS ON SOCKEYE UNCERTAIN**

The Alcan proposal identifies the reduced input of nutrients into Morice Lake and the earlier emergence of fry in the spring as principal impacts on the Nanika River sockeye population. Fry survival at emergence and during downstream migration to the lake are considered as risks to sockeye production that Alcan states will be balanced by the benefits of a more stable flow regime and increased winter flows. While the Department recognizes that there is uncertainty in assessing the effects on sockeye survival during all life phases, these 'risks' nevertheless could have serious implications for achieving our objective of preserving the salmon producing potential of the Nanika River. There is no convincing evidence that the risks identified will be balanced by potential benefits.

Chinook and coho salmon

**SUBSTANTIAL LOSS OF CHINOOK AND COHO REARING AREA EXPECTED**

While sockeye move out of the Nanika River following emergence, chinook and coho rear in the river through summer and winter. It is at this stage of their life cycle that losses would be greatest. Due to a major reduction in peak annual flows, most sidechannels that are heavily utilized by rearing coho and chinook would be lost. Envirocon (1983) estimates that chinook and coho rearing habitat would be reduced by 70 and 90%, respectively, owing to the loss of sidechannels as well as mainstem rearing areas. In addition, the quality of the remaining habitat below Glacier Creek would be expected to decline. The increased proportion of cold Glacier Creek water with its glacial silt would result in a deterioration of gravel quality in the Nanika River affecting both fish and invertebrate habitat. This might, however, be alleviated by the proposal to divert Glacier Creek into Kidprice Lake, which is currently being considered by Alcan.

The proposed changes in flow regime during chinook and coho spawning and incubation are less extreme. Since sockeye and chinook spawn at similar times, the spawning flows and increased incubation flows proposed for sockeye should also maintain chinook habitat.There may however be a delay in adult chinook migration into the Nanika River. Coho spawn later in the season (November-December) when proposed flows are less than present mean monthly flows, and some loss of spawnable area is expected.Some dewatering of redds at emergence and increased predation owing to reduced spring flows may reduce the survival of chinook and coho fry. It is important to note

**MAJOR IMPACT ON CHINOOK AND COHO**

that spawning habitat could be maintained, and increased incubation flows could improve egg to fry survival, the loss of rearing habitat in the Nanika River would threaten chinook and coho populations in the Nanika River.

## 5. MORICE RIVER

### 5.1 Hydrology and Alcan's Proposal

**RELATIVE FLOW CONTRIBUTIONS**

Morice River is considered a tributary of the Bulkley River (Figure 1) but in fact the Bulkley River above the confluence is a very small river, representing only 14% of the flow at the confluence, whereas the Morice, with a mean annual flow of 118.1 cms (4171 cfs), represents 86% of the flow.

The Morice River at the outlet of Morice Lake has a mean annual flow of 76.32 cms (2695 cfs), which is 56% of the mean annual flow of the Bulkley River at Quick. Figure 5 shows the monthly relationship.

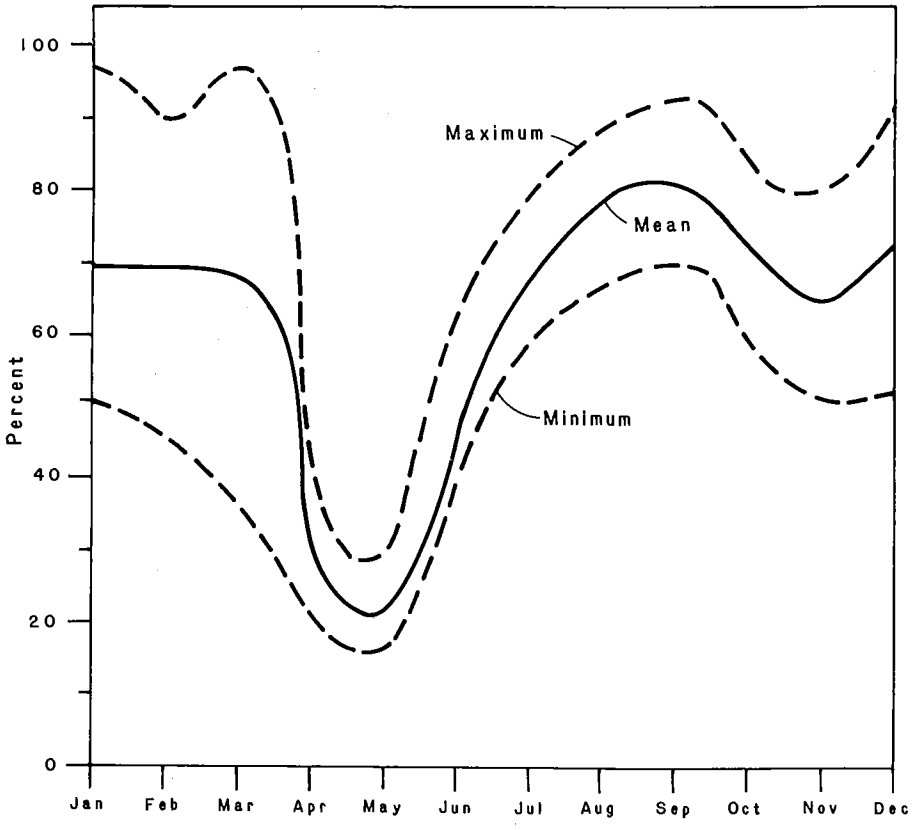


**FIGURE 5 - BULKLEY RIVER**
**PERCENT OF DISCHARGE AT QUICK ORIGINATING FROM MORICE LAKE**

| | | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outlet Morice Lake Reach 1 | Natural | 27.11 | 23.63 | 17.84 | 16.75 | 65.13 | 187.71 | 174.48 | 126.62 | 82.86 | 83.16 | 68.46 | 39.03 |
| | K.C. | 26.24 | 23.53 | 18.94 | 18.39 | 50.12 | 111.59 | 104.49 | 85.65 | 72.22 | 75.43 | 57.38 | 35.67 |
| | Difference | 0.87 | .10 | +1.10 | +1.64 | 15.01 | 76.12 | 70.00 | 40.97 | 10.64 | 7.73 | 11.08 | 3.36 |
| | %Diff. | 3% | 0% | +6% | +10% | 23% | 41% | 40% | 32% | 13% | 9% | 16% | 9% |
| D/S Thautil Reach 2 | Natural | 32.43 | 27.66 | 21.96 | 33.58 | 150.89 | 288.82 | 224.08 | 146.74 | 96.11 | 104.32 | 88.12 | 47.33 |
| | K.C. | 31.56 | 27.57 | 23.06 | 35.23 | 135.89 | 212.70 | 154.08 | 105.76 | 85.48 | 96.59 | 77.05 | 43.89 |
| | Difference | 0.87 | .10 | +1.10 | +1.65 | 15.00 | 76.12 | 70.00 | 40.98 | 10.63 | 7.73 | 11.07 | 3.44 |
| | %Diff. | 3% | 0% | +5% | +5% | 10% | 26% | 31% | 28% | 11% | 7% | 13% | 7% |
| U/S Owen Cr. Reach 3 | Natural | 33.19 | 28.17 | 22.56 | 37.03 | 175.74 | 305.84 | 227.57 | 147.85 | 97.65 | 106.67 | 90.55 | 48.31 |
| | K.C. | 32.32 | 28.07 | 23.66 | 38.67 | 160.73 | 229.71 | 157.57 | 106.88 | 87.01 | 98.93 | 79.47 | 44.87 |
| | Difference | 0.87 | .10 | +1.10 | +1.64 | 15.01 | 76.13 | 70.00 | 40.97 | 10.64 | 7.74 | 11.08 | 3.44 |
| | %Diff. | 3.% | 0% | +5% | +4% | 9% | 25% | 31% | 28% | 11% | 7% | 12% | 7% |
| U/S Peacock Cr. Reach 4 | Natural | 34.51 | 29.36 | 23.80 | 45.32 | 213.25 | 329.31 | 234.00 | 149.69 | 99.36 | 109.95 | 94.28 | 50.12 |
| | K.C. | 33.63 | 29.26 | 24.91 | 46.96 | 198.24 | 253.18 | 164.00 | 108.72 | 88.72 | 102.22 | 83.20 | 46.66 |
| | Difference | .88 | .10 | +1.11 | +1.64 | 15.01 | 76.13 | 70.00 | 40.97 | 10.64 | 7.73 | 11.08 | 3.46 |
| | %Diff | 3% | 0% | +5% | +4% | 7% | 23% | 30% | 27% | 11% | 7% | 12% | 7% |

**TABLE 1**

**MORICE RIVER MEAN MONTHLY FLOWS (1962 - 1981)**

(Differences Between Natural and Kemano Completion Flows(in cms))

(All Differences and % Differences are Negative,Unless Shown Positive)

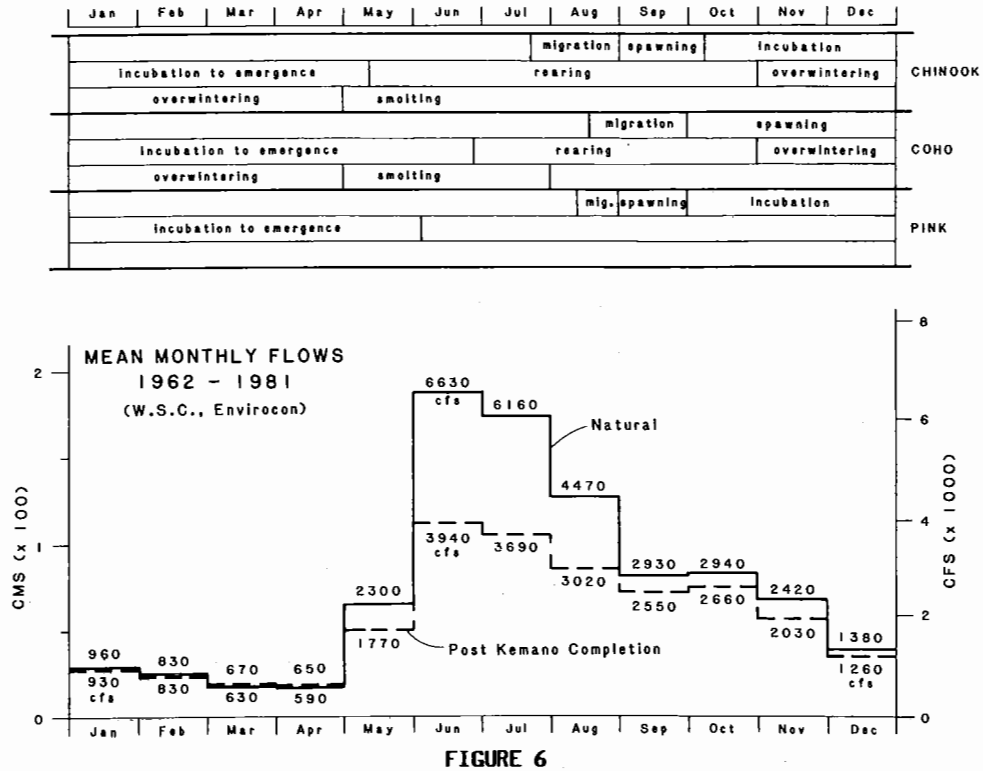


**FIGURE 6**

**MORICE RIVER AT OUTLET OF MORICE LAKE (REACH 1)**

**FLOW RELATIONSHIPS BETWEEN NANIKA RIVER AND MORICE RIVER**

The influence of the Nanika River on the Morice and Bulkley rivers is considerable. It represents 48% of the mean annual flow at the outlet of Morice Lake, 27% of the flow at Quick, and 22% of the flow at Moricetown. Alcan's proposed mean annual diversion of 18.49 cms (653 cfs) from the Nanika River would reduce the flow at the outlet of Morice Lake by 25% and the flow at Moricetown by 11%. During the period of June 1 to September 30, which is the timing of upstream migration at Moricetown, Alcan's diversion would represent up to 20% of the flow.

**FOUR STUDY REACHES DEFINED**

Alcan's consultants divided the Morice River into four reaches as shown in Figure 10. For purposes of reference and uniformity the same division has been adopted in this report.

Table 1 and figures 6 to 9 show the differences in mean monthly flows that would occur in the four reaches of the Morice River with Kemano Completion.

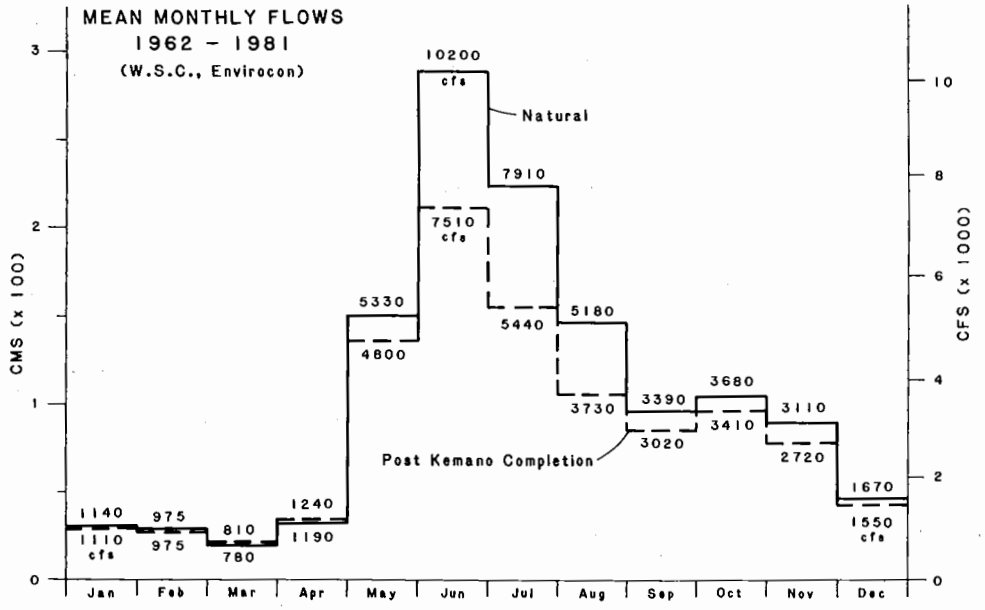


**FIGURE 7**
**MORICE RIVER DOWNSTREAM OF THAUTIL CREEK (REACH 2)**

**FLOW REDUCTIONS IN REACH 2**

In Reach 2, between Thautil and Owen Creeks, which is the braided section of the Morice River, the mean monthly flows would be reduced as follows:

**PREDICTED LOSSES OF SIDECHANNEL AREA**

| May | June | July | August |
|---|---|---|---|
| 10% | 26% | 31% | 28% |

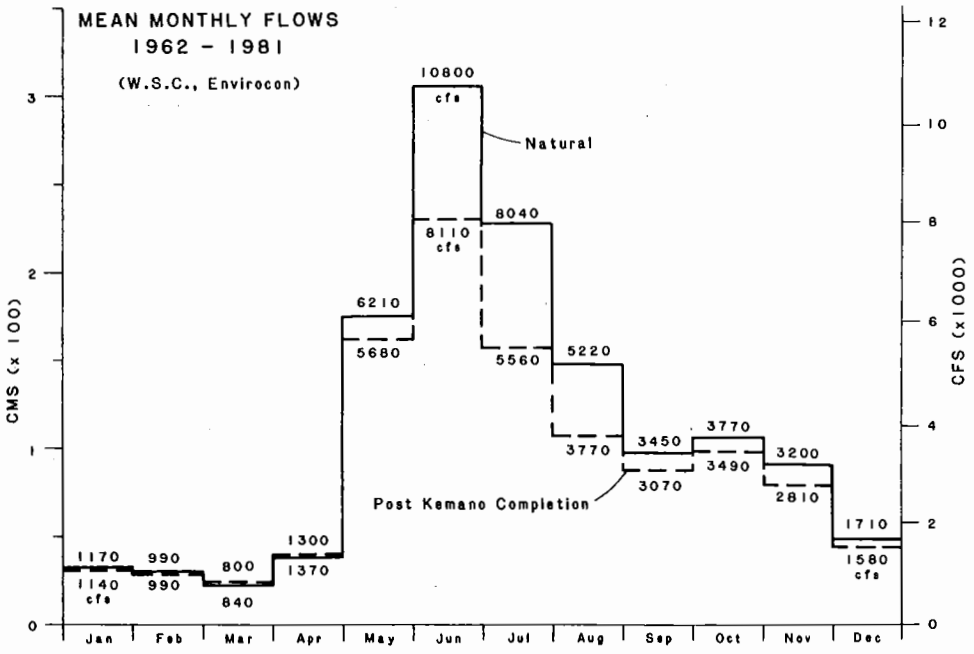


**FIGURE 8**
**MORICE RIVER UPSTREAM OF OWEN CREEK (REACH 3)**

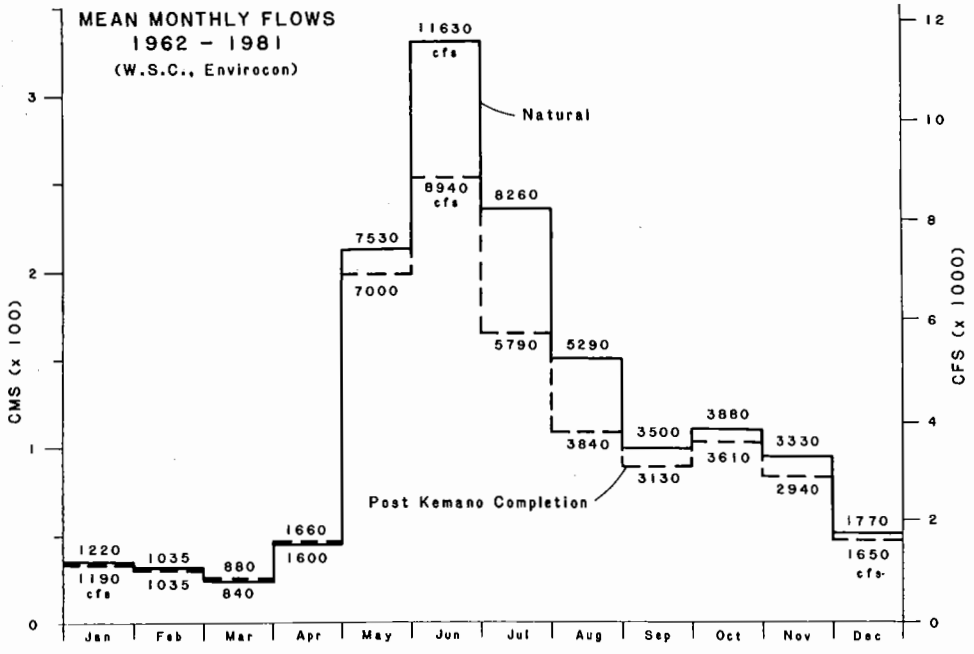


**FIGURE 9**
**MORICE RIVER DOWNSTREAM OF PEACOCK CREEK (REACH 4)**

It is important to recognize that high flows, usually occurring in June, control the channel forming processes. A decrease of 26% in June is therefore very significant. Based on experience with the Peace River Project, it has been estimated (pers. comm. R. Kellerhals) that the long term loss in sidechannel area would be 8 to 30%. This would result from a reduction in the rate of creation of new channels combined with an increase in the rate of blockage and siltation of old channels. The uncertainty in the estimate is due to the lack of data on sidechannel losses in diminished rivers, and the high variability and very sensitive balance inherent in braided systems.

## 5.2 Biology

**MORICE RIVER SALMON PRODUCTION IN RELATION TO SKEENA RIVER**

The Morice River produces three of the five salmon species; chinook, coho and pink salmon, and contains a major steelhead population. Chinook are the most important single salmon stock in the Morice River and represent 20% of the total Skeena river chinook escapement. In the recent past, this stock has constituted as much as 40% of the total Skeena chinook population. The relative contribution of coho and pink salmon to the Skeena as a whole is minor, representing 4 and 2% respectively. Although the percentage contribution of pink salmon is small, the Morice River pink run is significant among the small producers in the Skeena system considering that 80% of the pink production comes from 4 systems (Lakelse, Kitwanga, Kispiox and Babine). Sockeye salmon migrate up the Morice River to spawn in the Nanika River and in Morice and Atna Lakes.

### Chinook escapements

**CHINOOK ESCAPEMENT TRENDS**

An average of 5,500 spawners has returned to the Morice River since 1960, generally ranging between 3,000 and 7,000 fish. In the late 1950's a maximum escapement of 15,000 was recorded. The most recent 5-year average (1978 - 1983) was 3,820 chinook.

It should be noted that a single census of spawning salmon as provided in the spawning records can seriously underestimate actual escapements. Using several aerial counts and the residence time of spawning chinook females, Nielson and Geen (1981) found that a maximum single count in the Morice River yielded only 52% of the total estimated escapement.

### Coho escapements

**ESTIMATES OF COHO SPAWNING INCOMPLETE**

Average escapements from 1957 to 1979 were in the order of 2,500 to 3,000 coho. Prior to 1957, 7,500 to a maximum of 15,000 coho were reported. In recent years the record is incomplete since surveys during coho spawning were not always conducted. Estimates in 1979 and 1981 were only 300 and 500 fish respectively. The 1979 escapement was the second lowest on record.

Pink escapements

**PINK SALMON ESTABLISHMENT IN MORICE RIVER**

The odd-year pink run to the Morice River has been expanding since the Moricetown fishway was built in 1951 and the obstruction at Hagwilget Canyon was removed in 1958. The average of the last 5 cycles has been about 25,000 fish, and 30,000 pink spawners were reported in 1983. Even-year escapements have also increased in recent years from less than 500 fish to over 4,000 in 1980 and 8,000 in 1982 (Farina, 1982).

Timing and distribution of chinook salmon

**UPSTREAM MIGRATION OF CHINOOK BEGINS LATE JULY**

Timing of the various life stages of chinook are shown in Figure 6. Chinook salmon pass the Alcan counting tower near Owen Creek in late July or early August and peak spawning usually occurs in September.

**PRINCIPAL CHINOOK SPAWNING AREA AT OUTLET OF MORICE LAKE**

The major chinook spawning area is in the reach from Morice Lake to Gosnell Creek (greater than 80% of the spawners), particularly in the upper 4 kilometers (Figure 10). A prime spawning area that supports the highest density of chinook spawners in the river is located about 1 km below Morice Lake. Most of the river bed at this site is characterized by a series of large gravel dunes oriented perpendicularly to the direction of flow. Chinook were observed to spawn on the upstream face of the dunes where depths and velocities were suitable. The remainder of the chinook population spawn in areas of suitable gravels downstream to Lamprey Creek.

**HIGH EGG TO FRY SURVIVAL IN PRINCIPAL SPAWNING AREA**

High egg to fry survival rates have been reported in the prime chinook spawning area and are attributed to the moderating effect of Morice Lake on water temperature and discharge rates. In 1979 and 1980, egg to fry survival was estimated to be 12.5 and 23.7%, respectively (Smith and Berezay, 1983). Low winter flows can, however, result in dewatering of some redds. Envirocon (1981) observed that several marginal redds were dewatered at flows less than 28.32 cms (1000 cfs) in November and December 1979. In April, flows less than 14.16 cms (500 cfs) were marginal for the survival of alevins and fry within the gravel.

**LOW WINTER FLOWS AFFECT SURVIVAL**

**PEAK OF CHINOOK FRY EMERGENCE IN LATE APRIL**

Trapping studies in 1979 and 1980 indicated that chinook fry emerge in early April, peak in late April and then decline until June (Smith and Berezay, 1983). Envirocon (1981) observed emergent fry as early as March in 1979. Some chinook migrate to sea in their first year but most rear in fresh water (Morice, Bulkley and Skeena rivers) for one year. This has been determined by scale analysis from four years of chinook returns. In 1974, 1979 and 1980, chinook that had overwintered in fresh water for one year predominated (65%, 76% and 95% respectively). In 1978, however, chinook that had migrated to sea in their first year constituted 52.6% of the adult returns.

**MAJORITY OF CHINOOK SPEND ONE FULL YEAR IN FRESHWATER**

This variability in life history may be a function of prevailing stream conditions during emergence and the early rearing of chinook fry that results either in migration out of, or residence, in the river. It may also be a reflection of the variability in the differential survival of the two groups. For example, if heavy winter mortalities of chinook fry

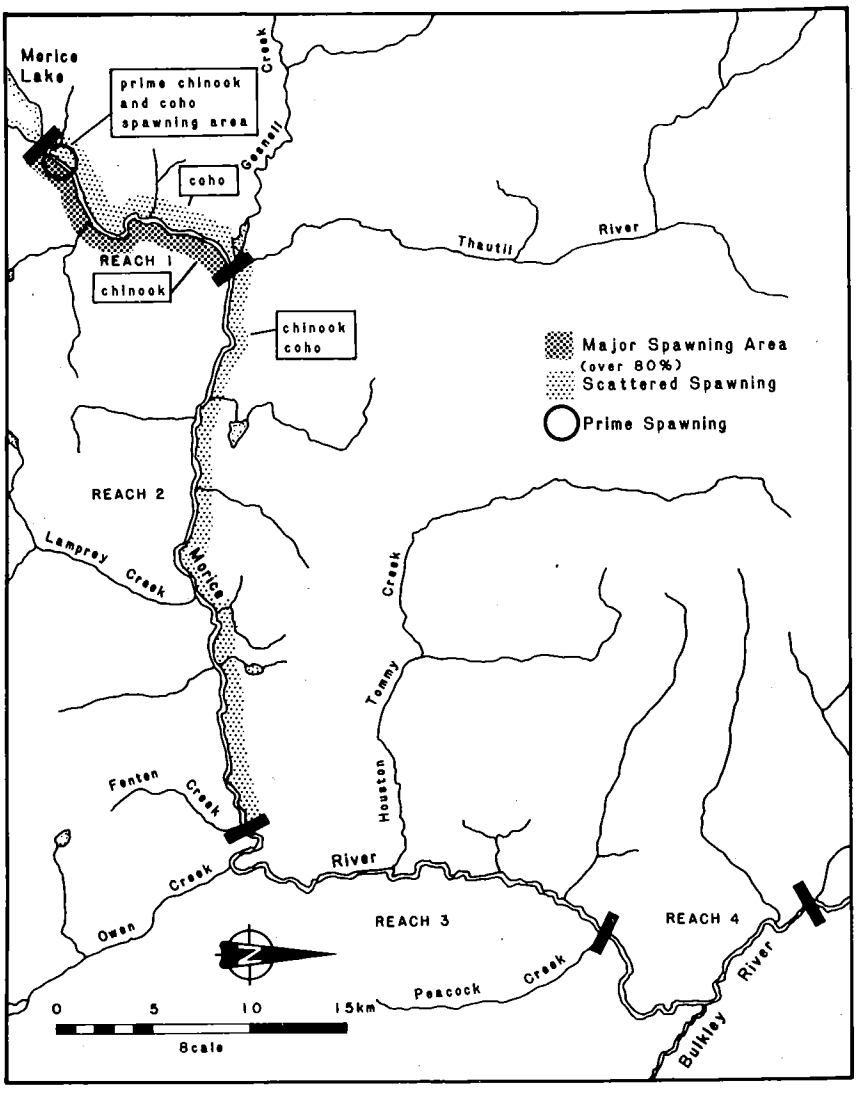


**FIGURE 10**
**MORICE RIVER CHINOOK AND COHO SPAWNING AREAS**

occurred in abnormally dry and cold winters, then the proportion of this 'stream type' would be depressed in the adult returns.

**CHINOOK REARING HABITAT**

During their freshwater residency, chinook fry disperse throughout the mainstem of the Morice and Bulkley rivers (Envirocon, 1981). Habitat preferences in spring, summer and fall are fairly typical for the species (Shepherd, 1979; Envirocon, 1981; Smith and Berezay 1983). In general, chinook reared along river margins and were often associated with slow water velocities and cover in the form of log jams, cobble and debris. Shepherd (1979) found that, in spring, chinook were concentrated in side-channels; in summer, in mainstream log jams and flats. The reach between Gosnell and Owen creeks (Reach 2), with abundant sidechannels and log debris, was considered the most productive rearing area.

**MAINSTEM VERSUS SIDECHANNEL DISTRIBUTION OF CHINOOK FRY**

Envirocon (1981) reported that chinook fry use the mainchannel (74%) more than sidechannels (26%) in May, moved into sidechannels at high flows which normally occur in June and July and were equally distributed between both types of habitat in September and November. It was estimated that 63.9% of the juvenile chinook in the Morice River reared in Reach 2 (Envirocon, 1983).

**LATE FALL DISTRIBUTION OF CHINOOK**

As temperatures decline in the fall, chinook become inactive, hiding under cobbles or log jams where they will remain over the winter. The late fall distribution of chinook is therefore indicative of their overwintering habitat. In the fall, Envirocon (1981) found that chinook fry were most abundant in Reach 1 (above Gosnell Creek) and below Owen Creek (reaches 3 and 5). Smith and Berezay (1983), on the other hand, reported highest catches in Reach 2 between Gosnell and Owen creeks and the area just above the confluence of the Bulkley and Morice rivers. The differences in relative distribution between the two studies are likely attributable to different sampling techniques (electroshocking vs. minnow trapping) and locations since both sampling programs were conducted in 1979. The results indicate, however, that chinook fry overwinter throughout most of the Morice River.

**NO DATA ON RELATIVE CONTRIBUTION OF MORICE RIVER OR BULKLEY REARED CHINOOK**

Although Shepherd (1979) suggested that the majority of chinook fry move out of the Morice River to overwinter in the Bulkley River, sampling by Envirocon (1981, 1983) showed that a significant number of chinook overwinter in the Morice. There is no estimate, however, of the proportion of the population that remains in the Morice River. The seasonal distribution (spring to fall) indicates that there is a progressive downstream dispersal of chinook fry. The number of fry remaining in the Morice River is probably determined by the amount of suitable rearing habitat. Requirements for space, food and cover, and the territorial behaviour of chinook fry as they grow, probably determines their summer distribution. A key component of overwintering habitat is the availability of cover, primarily cobbles and log jams in channels that do not dewater, freeze or stagnate.

**HEAVY OVERWINTERING LOSSES NOTED**

Studies of Morice River sidechannels indicated that chinook and other overwintering salmonids are subject to heavy mortalities as flows decrease in winter. Bustard (1983) concluded that the overwintering phase may be a major constraint to chinook smolt production in the Morice river.

Timing and distribution of coho salmon

**COHO SPAWNING EXTENDED OVER FALL AND EARLY WINTER PERIOD**

Timing of coho salmon life stages is shown in Figure 6. Peak migration of adults past the Owen Creek counting tower occurs in late August and early September (Farina, 1982) and coho salmon spawn over an extended period from late September to December (Hancock et al, 1983). Peak spawning occurs in mid-to-late November (Envirocon, 1981).

**COHO SPAWNING DISTRIBUTION IS FLOW DEPENDENT**

Coho spawn in the mainstem of the Morice and in several tributaries (Figure 10). The distribution of spawners is dependent on water flow conditions. In 1979, a year with below average stream flows, most spawners (85%) were observed in the prime spawning areas below Morice Lake that had been utilized by chinook salmon. Scattered spawning was also noted in sidechannels

between Fenton and Gosnell Creeks (Envirocon, 1981). In that year the only tributaries with adequate flow for coho access and spawning were the Gosnell and Houston Tommy creeks and the Thautil River. In 1975, on the other hand, Shepherd (1979) observed that coho held in the mainstem or in Morice Lake and moved with the fall freshet into the tributaries to spawn. Owen, McBride and Gosnell creeks, and Thautil River were identified as the preferred coho spawning areas.

**COHO FRY EMERGENCE AND DISPERSAL**

Coho fry emergence extends from April to July, and downstream movements have been monitored from April to October (Shepherd, 1979), and in May and June in the upper Morice River (Smith and Berezay, 1983). Peaks in migration were not identifiable owing to the small numbers of fry and smolts that it was possible to trap. Dispersal upstream has also been observed from spring through fall (Shepherd, 1979).

**AGE COMPOSITION OF MORICE COHO STOCKS**

Coho juveniles rear for one or two years in the river. In 1975, 75% of Morice River coho had overwintered in freshwater and returned in their third year ($3_2$'s). The remainder were four years old and spent two winters in freshwater ($4_3$'s).

**TRIBUTARY REARING OF COHO**

Coho fry are distributed throughout the Morice River and many tributaries, and in McBride and Morice lakes. Envirocon (1981) estimated that 67% of coho fry reared in the tributaries, particularly Gosnell, Houston Tommy and McBride creeks. Shepherd (1979) also indicated that Gosnell and McBride creeks were the most productive tributaries. Mainstem rearing (33%), may however, be underestimated owing to differences in sampling efficiency between the mainstem and tributaries. Coho may move out of the tributaries into the Morice in the fall (Smith and Berezay, 1981).

**DISTRIBUTION AND HABITAT PREFERENCES OF MAINSTEM COHO**

In the mainstem Morice River an estimated 95% (Envirocon, 1983) and 85% (Smith and Berezay, 1982) of rearing coho were found between Morice Lake and Owen Creek (reaches 1 and 2). Habitat preferences of coho juveniles were well defined. Sidechannels, sidepools, ponds and sloughs were heavily utilized by rearing coho with instream cover providing a key habitat component (Envirocon, 1981). These habitats are typical of the braided section of the Morice River between Gosnell and Owen Creek (Reach 2). Over 80% of the coho fry and 65% of coho yearlings occupied sidechannels in July and September (Envirocon, 1981). Shepherd (1979) also found that coho were concentrated in sidechannels in summer and that Reach 2 was potentially the most productive rearing habitat for coho juveniles in the Morice River.

**UTILIZATION OF SIDECHANNELS BY OVERWINTERING COHO**

Overwintering studies showed that coho utilize sidechannels extensively, and found cover under log jams and debris. Coho juveniles were the most abundant species in sidechannels sampled in late fall constituting 52% of the total, while chinook fry made up about 9%. The preference of coho for sidechannels makes them susceptible to reduced winter flows and temperatures that may result in dewatering and freezing of their winter habitat. This is likely a major constraint for coho smolt production in the Morice River, as significant mortalities during this period were documented (Bustard, 1983). Groundwater inflows reduced the amount of dewatering and resulted in greater juvenile survival. Sidechannels with groundwater input, therefore, provide very important overwintering habitat.

**SIGNIFICANCE OF PONDS AND SLOUGHS**

Ponds and sloughs adjacent to the main channel and relatively common in Reach 2, also provided important wintering habitat for coho. Fall migrations into ponds were observed, and densities of coho juveniles were an order of magnitude higher than in the river. Studies in Carnation Creek and in Washington creeks have documented good survival and high smolt output from overwintering ponds (Bustard and Narver, 1975; Peterson, 1982).

Timing and distribution of pink salmon

**PINK SALMON MIGRATION AND SPAWNING**

Migration of adult pink salmon past the Owen Creek counting tower is usually in late August or early September. Peak spawning is reported to occur in early September, ending before the end of the month.

**PINK SALMON DISTRIBUTION**

Over 90% of the total escapement spawns in Reach 2 of the Morice River between Gosnell and Owen creeks (Figure 11) (Envirocon, 1983). Approximately 80% of the total pink population spawned in sidechannels. Small numbers of pink spawners have also been observed at the chinook spawning grounds below Morice Lake and in Gosnell Creek.

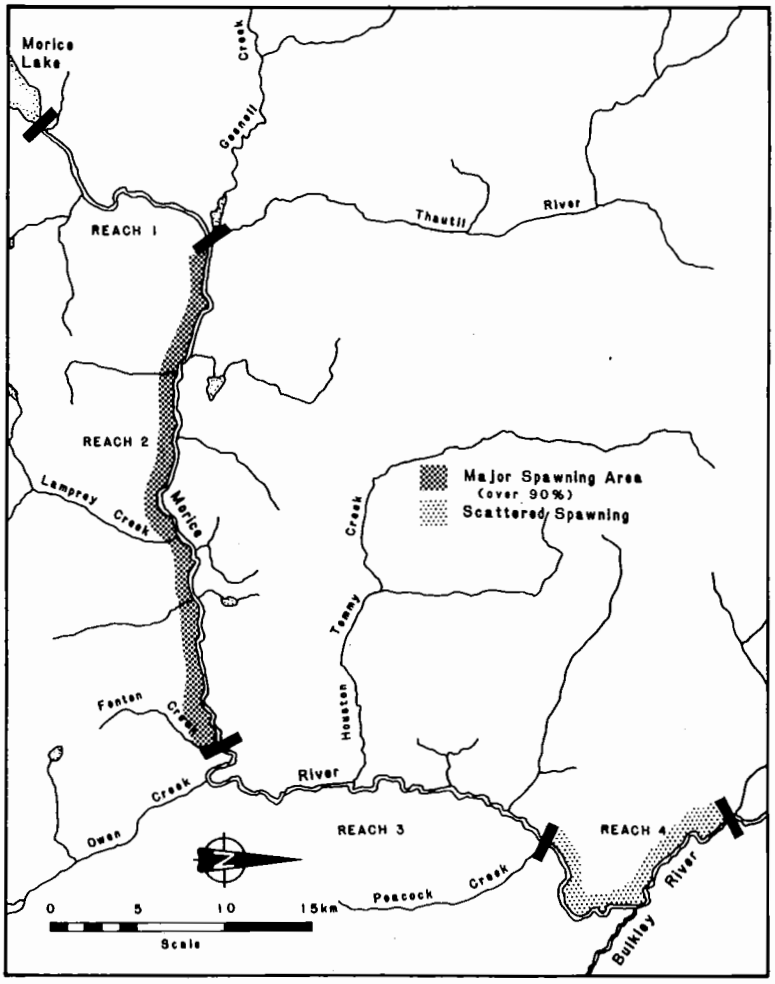


FIGURE 11
MORICE RIVER PINK SPAWNING AREAS

**PINK SALMON INCUBATION LOSSES NOTED**

Winter observations in 1979 of pink redds in a heavily utilized sidechannel indicated that dewatering of redds and probable losses of eggs and alevins occur with reduced flows to a greater extent than in the more stable main-channel spawning areas (Envirocon, 1981).

Pink fry probably emerge in April and migrate directly to the ocean, returning to spawn as two-year-old fish.

5.3 Implications of Alcan's Proposal

**PRE AND POST FLOW REGULATION COMPARISONS**

The projected post Kemano Completion mean monthly flows at Morice Lake outlet are shown in contrast to existing mean monthly flows in Figure 6. Since flow would be controlled from the Nanika River dam, the Morice River hydrograph would reflect that control, but it would also be influenced by natural inflows and the buffering effect of Morice Lake.

**PEAK SUMMER FLOWS REDUCED BY 40%**

**SIGNIFICANT REDUCTION IN CHINOOK AND COHO REARING AREA**

The most significant change would be in the spring and summer period when flows would be reduced in the order of 30 to 40%. This reduction in peak flows would result in an estimated loss of up to 30% of the sidechannels in Reach 2 between Gosnell and Owen Creeks (Envirocon, 1983). This represents a major loss of chinook and coho rearing habitat and would affect pink and coho salmon that spawn in this reach. Although the river would stabilize into a new morphological pattern, it may not be as productive as it is at the present time.

**MAJOR SPAWNING GROUNDS NOT IMPACTED AND POTENTIAL IMPROVEMENT OF INCUBATION AND REARING CONDITIONS OVER WINTER**

The changes in flow regime during the remainder of the year are of smaller magnitude with a decrease in existing mean flows during the fall spawning and early incubation periods and a proposed increase in flows in the late winter incubation period (February to April). It is expected that flows at spawning time, which would not differ substantially from natural mean flows, would not reduce the capacity of the major spawning grounds below Morice Lake and that increased winter flows might have potential benefits for incubation of eggs and alevins and overwintering of juveniles.

**CHANGES IN PHYSICAL CONDITION OF RIVER DIFFICULT TO PREDICT AND RELATE TO FISH PRODUCTION**

The overall impact of flow regulation upon river morphology is difficult to predict, and it is even more difficult to predict how such physical changes would affect salmon habitat.

The implications of the proposed flow regime for the various species and life stages are discussed in the following section. The section focuses on the impacts specific to the Morice River and the Moricetown fishway. It should be recognized that there would be downstream effects on the Bulkley and Skeena Rivers owing to the reduction in flow regime. The reduced flows would improve the effectiveness of the river fishery since exploitation rates generally increase with reduced flows. Due to the absence of data, detailed consideration of the downstream effects is not presented.

**DOWNSTREAM EFFECTS**

Migration flows

Salmon that spawn in the Morice, Nanika and Bulkley systems pass the Moricetown fishway on the Bulkley River on their upstream migration from

**FLOWS REDUCED AT MORICETOWN FISHWAY DURING FISH MIGRATION**

June to September. The reduction of the mean monthly flows at the fishway during this time would be 15 to 21% for the months of June, July and August and 8% in September.

**REVIEW OF HYDRAULIC CONDITIONS AT FISHWAY REQUIRED**

The effect on migration of all species would depend on how these percentages may vary in dry and wet years. A detailed review of hydraulic conditions at the fishways is necessary to determine the effect of reduced flows, and structural alterations could be required.

**NO OBSTRUCTIONS TO MIGRATION EXPECTED**

No obstructions to migration in the Morice River would be expected at the proposed flows. Whether flows reduced by 30 to 40% would affect the migration timing of Morice River salmon and Nanika River sockeye salmon cannot be determined beforehand.

Spawning flows

**MAJOR CHANNEL CHANGES IN REACH TWO EXPECTED**

The effect of the proposed flows on spawning habitat in the prime chinook spawning areas below Morice Lake can be estimated with some confidence assuming that gravel quality would be maintained. Because this reach is single-channelled and relatively stable, relationships between discharge and suitable spawning habitat can be analyzed. Reach 2, on the other hand is multichannelled and would be expected to experience significant changes in channel morphology that cannot be predicted with accuracy. The effects on salmon that spawn in this reach are more difficult to quantify.

**MINOR IMPACTS ON PRIME CHINOOK AND COHO SPAWNING AREA BELOW MORICE LAKE**

The proposed September flow for chinook spawning requirements would not be expected to reduce chinook spawning habitat capacity appreciably. Proposed flows would average about 13% less than natural flows. On the basis of measurements in the prime spawning area below Morice Lake, Robertson et al (1979) estimated that 100% of the suitable spawning gravel were available at 79 cms (2800 cfs). The mean post Kemano flow of 2550 cfs in September would represent an approximate reduction of 7% in available spawning area.

Mean monthly flows during coho spawning would be reduced by 9% in October and December and 16% in November when fall freshets occur. Envirocon (1983) estimated that maximum suitable coho habitat occurs between 35 and 40 cms (1235 and 1412 cfs). Flows would not drop below 35 cms until the end of coho spawning in December.

**LOSS OF REACH TWO COHO SPAWNING EXPECTED BUT DIFFICULT TO QUANTIFY**

While this assessment may be valid for Reach 1, the changes in spawning habitat below Gosnell Creek (Reach 2) are more difficult to evaluate. Approximately 15% of the coho spawned in this reach in 1979, utilizing both the mainstem and sidechannels.This percentage may be underestimated since spawning flows in 1979 were below average and the coho escapement was the second lowest on record. Loss of spawning habitat in this reach would be dependent on the extent of sidechannel losses, changes in gravel quality and other morphological changes resulting from the reduction in peak annual flows.

**IMPACT ON PINK SPAWNING NOT PREDICTABLE**

The impact on pink salmon spawning habitat would also result from changes in Reach 2 where over 90% of the pink escapement spawns, primarily in sidechannels. The loss of sidechannels would result in a significant loss of pink spawning habitat. Pink salmon may, however, find alternative sites in the mainstem, since they have fairly broad spawning requirements as indicated by expanding populations in other river systems. The net impact on pink salmon cannot therefore be predicted with any accuracy.

Incubation and overwintering flows

**WINTER FLOW INCREASED EXCEPT IN WET YEARS**

Alcan has proposed to increase flows in the late winter incubation period. A review of the hydrology for Reach 1, year by year, shows that the median increase for the lowest month in the February to April period would be 8% over natural conditions. In dry years it would be 20% to 30% more, and in wet years as much as 8% less. Incubation flows would, however, be reduced 1-17% from October through December.

**INCREASED WINTER FLOWS MAY IMPROVE EGG TO FRY AND OVERWINTERING SURVIVAL**

The intent of these increased flows would be to improve egg to fry survival by reducing the risk of dewatering and freezing redds and by reducing the spawning to incubation flow ratio. This could potentially benefit all salmon species. In addition, overwinter survival of juvenile chinook and coho is expected to increase since heavy losses during this period have been documented. Mortalities have been attributed to stranding and freezing of fish, low dissolved oxygen and predation in sidechannels that dewater. According to Alcan, the improvement in winter flows is expected to balance negative impacts resulting from slightly decreased spawning and early incubation flows, and the large reduction in early summer flows.

**DEPARTMENT DOES NOT ACCEPT ALCAN'S ASSUMPTION OF BENEFITS AND LOSSES BEING EQUAL**

While the Department recognizes the potential benefits of these extra flows for incubation and overwintering there is no assurance that they would be realized. There are many uncertainties and two key assumptions made by Alcan must be questioned; that the winter flows proposed would increase overwinter survival sufficiently to compensate for potential losses and risks that have been identified at other life stages and that decreasing summer flows by 30 to 40% would not diminish juvenile production.

**IMPORTANCE OF GROUNDWATER INFLOWS FOR INCUBATION AND OVERWINTERING**

Slightly increased winter flows may not produce the benefits expected. Groundwater inflows may be a critical factor in determining the quality of the incubation environment and overwintering habitat (Hartman 1983). Groundwater includes subsurface water affected directly by river levels, seepage from minor tributaries or slopes, and springs from deep groundwater sources. There is evidence that sidechannels with groundwater inputs were selected by some pink and coho spawners and that the overwinter survival of juvenile salmonids in these areas was substantially increased. The impact of major changes in hydrology and morphology on these areas is unknown.

Rearing flows

**ALCAN ASSUMES LATE SUMMER AND LATE WINTER FLOWS MOST CRITICAL FOR FISH**

Alcan's flow regime for rearing salmonids is based on their assumption that both late summer (September to October) and late winter flows (January to April) limit salmon production in the Morice River. While a small reduction in the historic median flows is projected for the September/October

period, a substantial reduction (30-40%) in early summer flows (June to August) is proposed.

**MAJOR LOSS OF SIDECHANNEL REARING HABITAT**

The major impact on coho and chinook rearing habitat is the permanent loss of sidechannels (up to 30%) in Reach 2 between Gosnell and Owen creeks. This reach accounts for 64 to 89% of juvenile production of chinook and coho, respectively. Over the short term, Envirocon (1983) has estimated losses of early summer rearing habitat of up to 50% in June and July when peak flows occur. These losses represent a significant threat to coho and chinook production in the Morice River.

**VALUE OF EARLY SUMMER REARING IN DISPUTE**

While Alcan recognizes the loss of sidechannels as a major impact, other potential effects of the project are considered as risks to fish production. These include the substantial loss of early summer rearing habitat, and smaller reduction of late summer and early winter habitat. As discussed earlier, Alcan's proposed flow regime assumes that these risks will be balanced by the benefits of increased winter flows. The Department does not accept this assumption.

**LOWER SUMMER FLOWS MEAN REDUCTION OF DISPERSAL OPTIONS**

In the Morice River Envirocon (1981) found that rearing habitat generally increased with increasing discharge. As channels were flooded additional low velocity water and more suitable cover for juvenile salmonids was provided. Reduced summer flows would affect the dispersal of newly emerged chinook and coho and their options to use a diverse range of habitats that provide them with a favourable feeding environment, favourable temperatures and protection from predators. Migrations into smaller sidechannels and off-channel rearing ponds occur during early summer in the Morice River concurrent with high flows. The reduction in summer habitat and the increase in density of fry and yearlings could well have an impact on their overwinter survival. (Hartman 1963) In Carnation Creek, for example, high densities resulted in smaller sized coho fry that experienced lower winter survival rates (Holtby and Hartman, 1982).

**SUMMER FLOW REDUCTIONS YIELD LOSS OF TERRESTRIAL INSECT AND COVER PROVIDED BY BANK VEGETATION**

Alcan's proposal assumes that losses of summer rearing habitat are proportional to losses in area. Reduction in summer flows would, however, result in the loss of river margins close to riparian vegetation with disproportionately high negative impacts due to loss of terrestrial insects and cover afforded by the vegetation. Both aquatic and terrestrial prey were consumed by chinook and coho juveniles in the Morice River (Shepherd, 1979).

**EFFECTS OF FLOW REDUCTIONS ON SUMMER REARING HABITAT NOT WELL UNDERSTOOD**

There are many uncertainties in evaluating the effects of substantially reduced flows on the rearing capacity of the Morice River. There is uncertainty in predicting both physical and biological changes. The long term physical effects of flow regulation on channel structure, gravel quality, groundwater flows and the transport and deposition of larger debris are not well understood, yet these changes have a profound influence on rearing habitat. There are considerable data on the distribution of juvenile chinook and coho and their utilization of different habitat types, however, the complex interrelationships between juvenile salmon and their environment (including food, cover, suitable space and other needs) are not well enough understood to allow for accurate prediction of the full effects of flow reduction.

## 6. NECHAKO RIVER

### 6.1 Hydrology and Alcan's Proposal

**DESCRIPTION OF REGULATED WATERSHED**

The Kenney Dam, completed in October 1952 as part of the Kemano I project, created the Nechako Reservoir (Figure 1). The reservoir has a surface area of 890 sq.km. and a contributory watershed of 13,900 sq.km. The mean annual flow stopped by the dam is 205 cms (7239 cfs)*. During reservoir filling, from October 1952 to January 1957 (see Figures 12 to 14 for historic monthly flows, 1930 - 1942 and 1952 - 1982), there were no significant releases from the reservoir into the Nechako River. However, there was some local inflow, primarily from the Cheslatta River system which has an average annual flow of 5 cms (175 cfs),on which Alcan operated a temporary timber dam to regulate the flow seasonally. Since 1957 all releases to the Nechako from the reservoir have been made through the spillway at Skins Lake. These releases must pass down approximately 68 kms of the Cheslatta River through Skins Lake, Cheslatta Lake and Murray Lake (Figure 1), before entering Nechako River, via Cheslatta Falls below Kenney Dam. Approximately 80 kms. downstream from Cheslatta Falls, the Nautley River, with a mean annual flow of 35 cms (1,236 cfs) joins the Nechako.

**COMPARISON OF PRE AND POST NECHAKO RIVER FLOWS**

Figure 15 shows the average pre-Kemano I flows (1930 - 1952) in the Upper Nechako River (above Nautley River) and Figure 16 shows the average post-Kemano I flows (1957 - 1979). These two figures show the change that has occurred since Kemano I in both the mean flows and the range between the minimum and maximum flows. This change was caused in part by the way releases were made from Skins Lake, such as for flood control, and in part by the diversion to Kemano (which increased gradually from a mean annual value of 24.9 cms (879 cfs) in 1955 to 124 cms (4380 cfs) in 1979, as aluminum production was increased and power was sold to B.C. Hydro.

**DESCRIPTION OF CHESLATTA RIVER AND CHANGES SINCE KEMANO I**

Releases to Nechako River via Skins Lake and Cheslatta River have averaged about 130 cms (4600 cfs) since 1956, with peak flows occasionally exceeding 425 cms (15000 cfs). Prior to Kemano I, the Cheslatta was a very small system with a mean annual flow of about 5 cms (175 cfs). Consequently, a great deal of erosion,flooding, and channel change has occurred along the Cheslatta. Most of the sediment so created settled out in the string of intervening lakes, but in 1961 during high flows, the Cheslatta River broke through a gravel hillside just upstream of Cheslatta falls, bypassed the falls and washed out a large volume of material that in part settled in the Nechako River in the vicinity of the falls and in part was carried further down river affecting fish productivity for some years. This material has stabilized and all Cheslatta flow, confined by a saddle dam, now goes over the falls.

**DESCRIPTION OF KEMANO COMPLETION PROPOSALS FOR NECHAKO AND PROPOSED FLOWS**

Kemano Completion, as proposed by Alcan, would consist of another tunnel from the Nechako Reservoir to Kemano to divert additional water to provide power for two new smelters, a new deep water outlet works at Kenney Dam (designed to pass about 130 cms at minimum pond level) for cold water

* This is Alcan's most recent estimate (Oct. 1983)

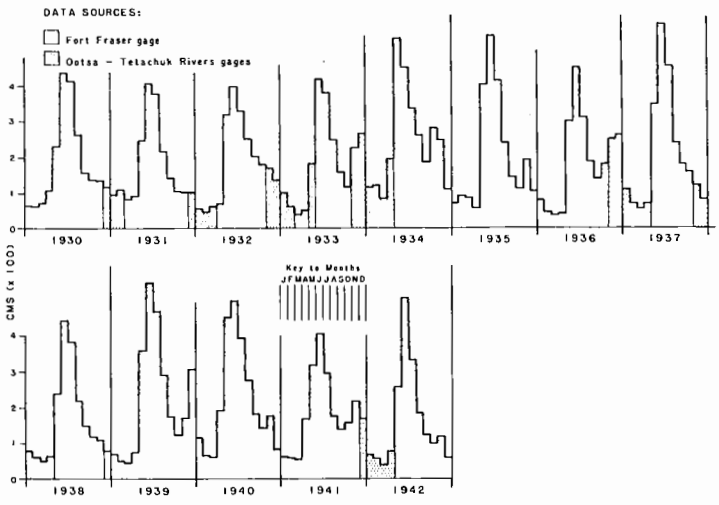


**FIGURE 12 NECHAKO RIVER - MONTHLY FLOWS (1930 - 1942)**

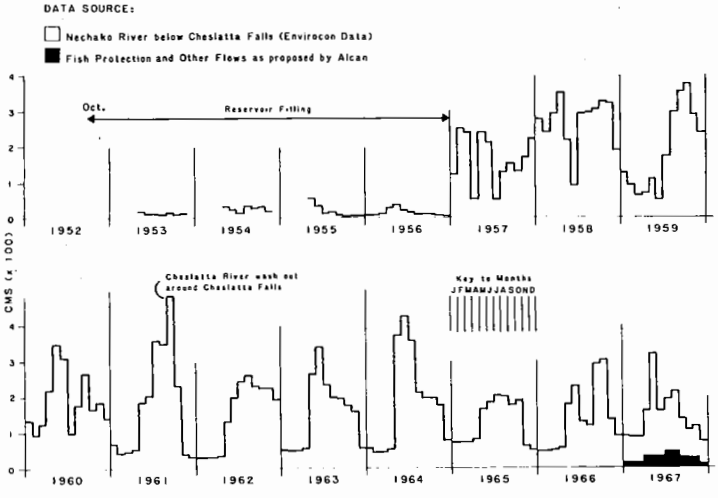


**FIGURE 13 NECHAKO RIVER - MONTHLY FLOWS (1952 - 1967)**

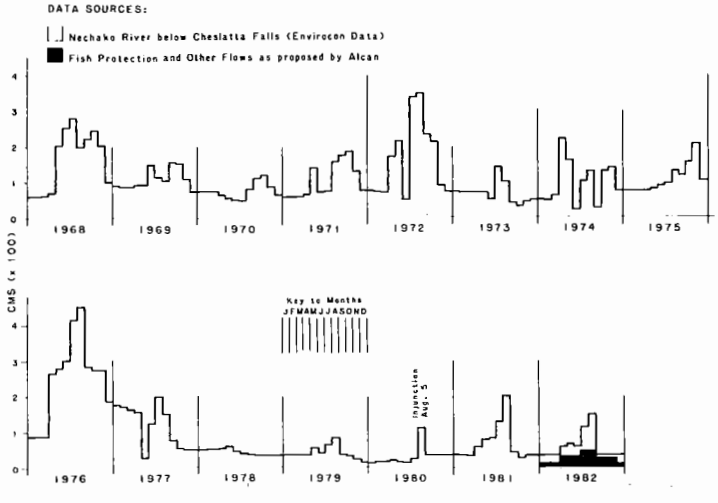


**FIGURE 14 NECHAKO RIVER - MONTHLY FLOWS (1968 - 1982)**

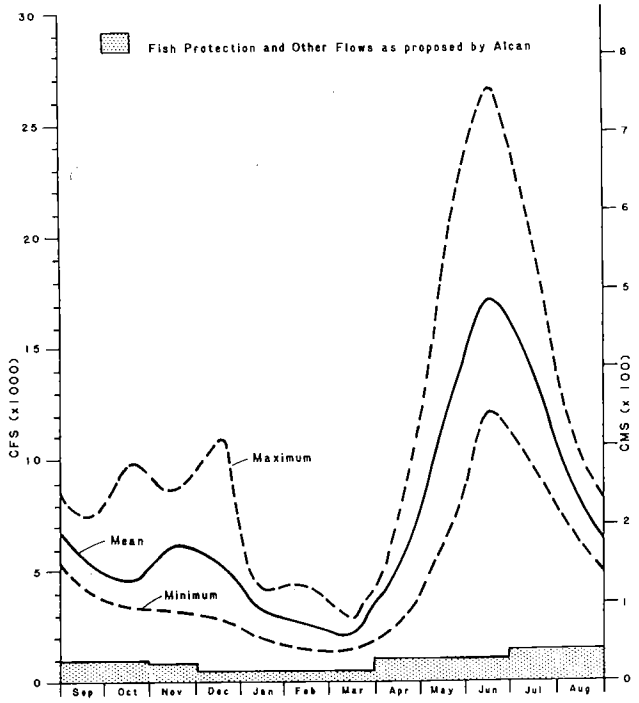


**FIGURE 15**
**NECHAKO RIVER AT CHESLATTA FALLS -**
**NATURAL FLOWS PRIOR TO CONSTRUCTION OF KENNEY DAM**
**(1930 - 1952)**

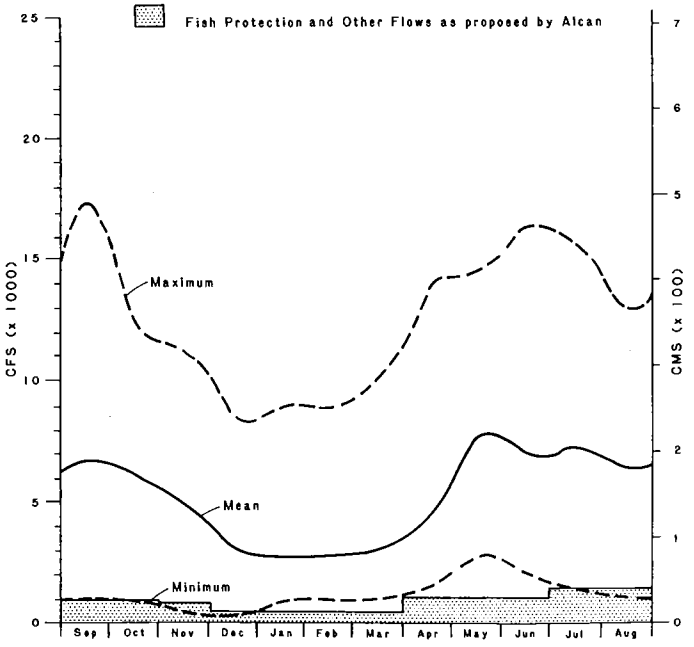


**FIGURE 16**
**NECHAKO RIVER AT CHESLATTA FALLS**
**(1957 - 1979)**

release, and a dam at the outlet of Murray Lake above Cheslatta Falls to better control flows out of the Cheslatta System. Alcan has proposed two possible flow schedules for the Nechako River below Cheslatta Falls as shown in Figure 17. The mean annual flow would be 21.41 cms (756 cfs) for "fishery" flows or 26.14 cms (923 cfs) for "fishery plus other" flows. Although Alcan have not specified the purpose of the "other" flows, it is understood that they would be for instream use, rather than for diversion and offstream consumption. The 26.14 cms (923 cfs) represents a reduction of 80% in the mean annual flow of 131.74 cms (4652 cfs) for the 1957 - 1981 period (Envirocon, 1983).

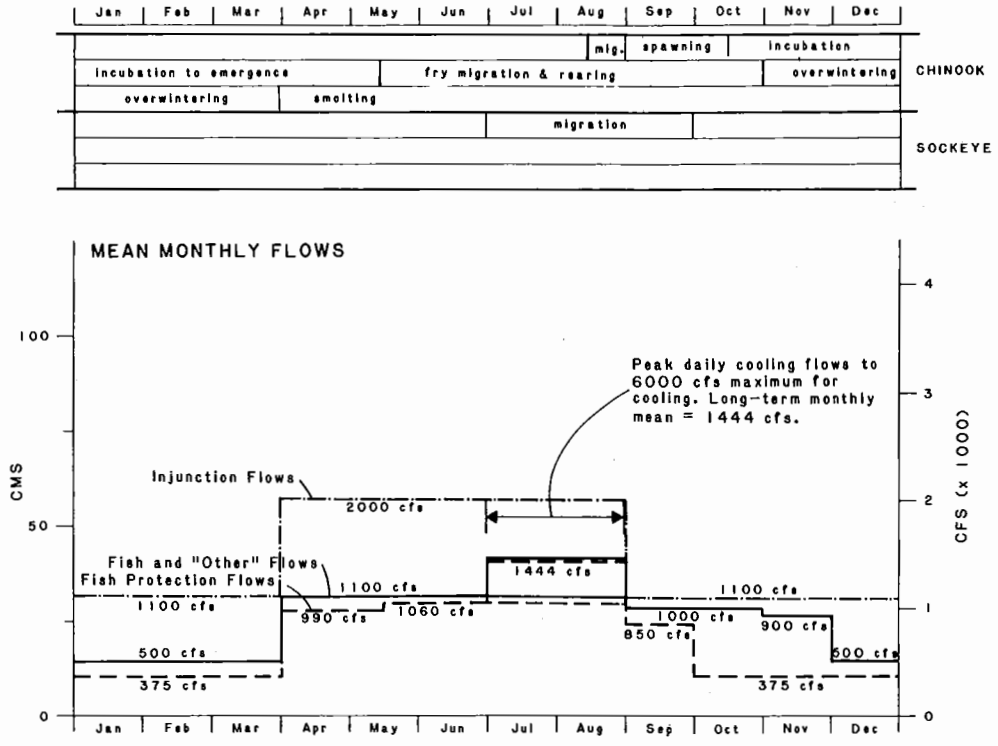


**FIGURE 17**
**NECHAKO RIVER AT CHESLATTA FALLS -**
**FLOW ALTERNATIVE PROPOSED BY ALCAN AND INJUNCTION FLOWS**

**TEMPERATURE REGULATION FOR SOCKEYE**

To overcome the problem of increased water temperatures that would result from reduced flows, Alcan propose to release cold water from the Kenney Dam and to mix it with water from Murray Lake to provide water of suitable temperature (not colder than 10°C) and volume to meet the requirements for sockeye migration in July-August (see Figure 17). In the long term (as calculated by Alcan) this would amount to mean monthly flows of 40.89 cms (1444 cfs) for July and August. Maximum short term flow releases in this period would be unlikely to exceed 170 cms (6000 cfs), even in hot years.

**IMPACTS OF INJUNCTION FLOW RELEASES**

Since 1980, daily discharges as high as 538 cms (19,000 cfs) have been released at Skins Lake to provide cooling flows for sockeye migration. Corresponding flows in the Nechako River at Cheslatta Falls have also been high, although delayed and attenuated by the effect of Cheslatta and Murray Lakes. The discharge of 538 cms (19,000 cfs) at Skins Lake on July 21, 1981 resulted in a maximum flow of 350 cms (12,360 cfs) at Cheslatta Falls on August 11. Flows of this magnitude would not be compatible with a Post Kemano Completion diminished river in which the average flow would be only 26.14 cms (923 cfs). Such high flows would be disruptive to the fish rearing in the river, to their invertebrate food supply, and would be physically damaging to the channel. It would be more appropriate if lower flows of cooler water could be released from the Nechako Reservoir at Kenney Dam.

## 6.2 Biology

**NECHAKO RIVER SUPPORTS CHINOOK POPULATION AND SERVES AS MIGRATION ROUTE FOR SOCKEYE**

The Nechako River supports a significant chinook salmon population and also serves as a migration route for the Stuart River chinook population. Substantial sockeye runs also migrate up the Nechako River to the Stuart and Nautley Rivers and spawn in the Stuart, Nadina and Stellako rivers.

### Chinook salmon escapements

**PRE-DEVELOPMENT ESCAPEMENTS**

In 1951 and 1952, prior to Kemano I, maximum escapements of chinook salmon in the Nechako River averaged 3500. This was the mid point of the recording range (2500 - 5000) in the Department's spawning records. Following the closure of Kenney Dam in 1952, until the operation of the Skins Lake Spillway in 1957, the Nechako River was dewatered. Chinook runs were almost decimated. In response to heavy siltation following large spill releases through the Cheslatta system from 1957 to 1961, chinook moved out of the Nechako River and spawned in the Stellako River. This was reflected in the Stellako River escapements that increased from an average of 50 fish to 1500 spawners in 1958. In the 1960's the average escapement to the Nechako River was about 500 fish. In the last decade, the chinook run has improved, averaging about 1,400 fish.

**1979 - 1980 POOR EGG TO FRY SURVIVAL**

The 1983 estimate of 800 to 900 chinook, however, is low when compared to the brood years in 1978 and 1979 (escapement of 2600 and 1800). It is possible that low flows (400 cfs) in the winter of 1979/80 and freezing conditions may have resulted in poor egg to fry survival and poor survival of overwintering chinook juveniles. The spawning escapement in 1983 was considerably less than expected, particularly for returns to the major spawning areas in the upper Nechako River. Chinook escapements to other upper Fraser River systems increased significantly.

### Timing and distribution of chinook salmon

**CHINOOK MIGRATE IN LATE AUGUST AND SPAWN IN SEPTEMBER**

Adult chinook usually arrive in the Nechako River in late August or early September and spawning occurs in September, peaking in mid-month (Marshall and Manzon, 1980). Chinook spawn from Cheslatta Falls as far downstream as Vanderhoof (Figure 18). Historically, the majority of the run has spawned above Fraser Lake, the major spawning areas being above Greer Creek in

Reach 2. Two prime spawning areas in this reach include an upper site located about 6 km. below Cheslatta Falls and a lower site at Irvine's Lodge about 8 km. below Cheslatta Falls (DFE, 1979).

**VARIATION IN USE OF SPAWNING AREAS**

In 1979 and 1980, Envirocon (1981) estimated that 86 and 72% of the run spawned between Cheslatta and Greer Creek. In 1983, distribution of spawners changed significantly with 44% occurring below Fraser Lake and 56% occurring above Greer Creek. The major spawning area at Irvine's had only 6% of the spawners. A similar change in distribution was also noted in 1974 when only 40 to 50% of the run spawned above Fort Fraser.

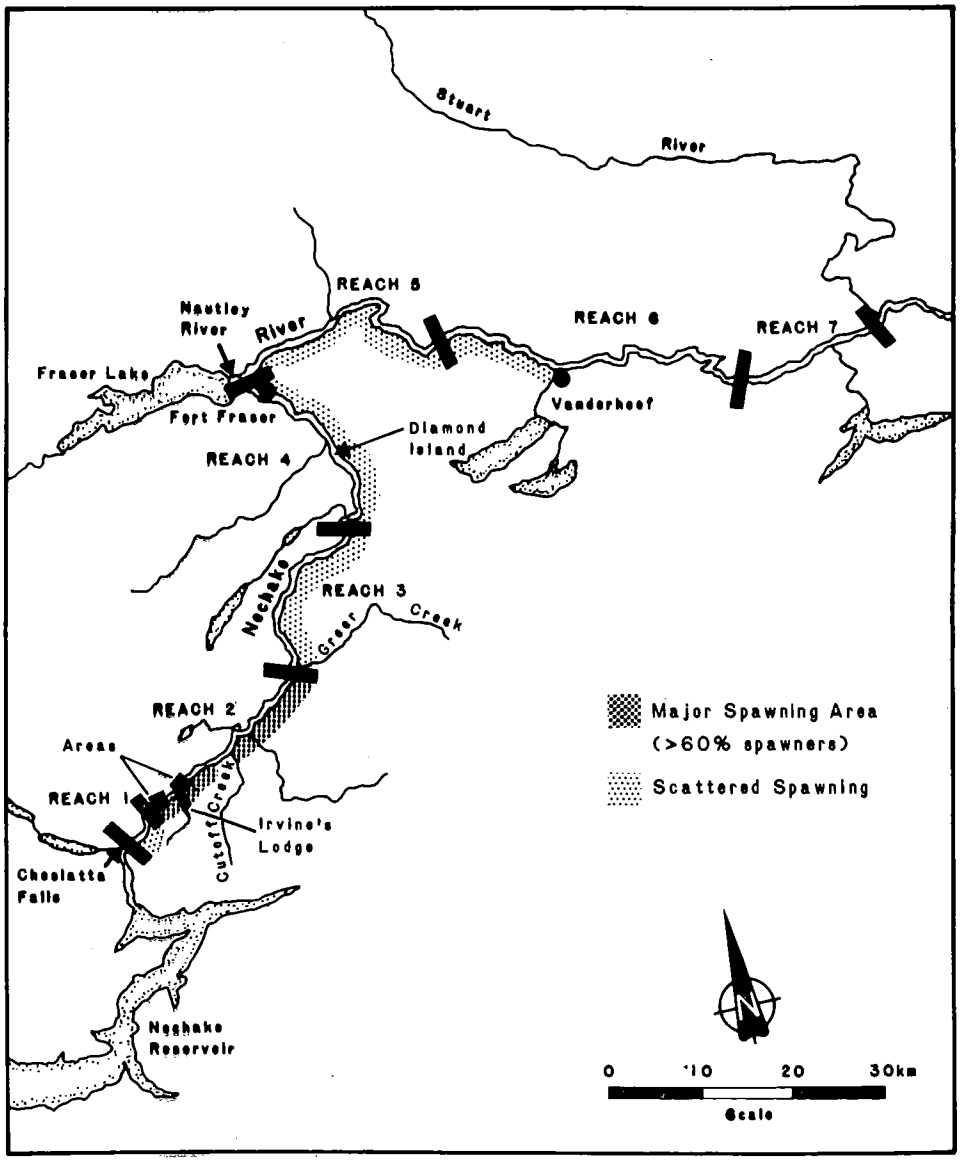


FIGURE 18
CHINOOK SPAWNING AREA

**TIMING OF FRY EMERGENCE**

Incubation studies in 1981 and 1982 indicated that eggs were hatched by mid-November (Russell et al, 1983). Hatching time may vary from year to year depending on temperature. In colder years, eggs may hatch later than November. In 1981, fry emerged in March, peaked in the third week of April and declined through May (Envirocon, 1982). Timing of emergence may vary from year to year and in 1982 emergence was approximately three weeks later than in 1981 (Envirocon, 1982).

**FRY DISTRIBUTION**

Chinook fry were found to rear in the Nechako mainstem and in tributary streams. After emergence, chinook fry were abundant throughout the upper Nechako but declined as the season progressed (Olmsted et al, 1980; Envirocon, 1981; Russell et al, 1983). Fry utilized the shallow river margins after emergence but were found in deeper, faster waters in close proximity to the substrate by June (Russell et al, 1983).

**TRIBUTARY REARING**

Tributaries provide good rearing habitat for chinook fry (Olmsted et al, 1980; Envirocon, 1981; Russell et al, 1983). Rearing capability is, however, limited by the small number and small size of the tributary streams. Utilization of tributaries has varied from year to year (Envirocon, 1982). In 1979, fry were abundant in tributaries and numbers remained relatively constant throughout the summer rearing period. In 1980 and 1981, abundance declined in the summer. Russell et al (1983) reported an outmigration of fry from Greer Creek in the fall.

**AGE COMPOSITION AND FRESHWATER RESIDENCE TIME**

Scale analysis of adult chinook returns in 1980, 1981 and 1982 indicated that the majority were five-year-old (69 to 89%) and four-year-old fish (10 to 27%). Over 88% of the spawners had spent one full year in fresh water. The abundance of chinook fry in the Upper Nechako River, however, declines substantially in the summer. This has been attributed to downstream migration, natural mortalities and the inefficiency of sampling gear to capture larger fry.

**MAGNITUDE OF OVERWINTERING POPULATION UNCERTAIN**

Studies were undertaken to document the downstream migration of fry from the upper Nechako (at Diamond Island) and into the Fraser River (at Prince George) (Envirocon, 1982; Russell et al, 1983). The results regarding the relative proportion of fry that overwinter in the Nechako River and those that move into the Fraser River prior to their first winter were inconclusive. Envirocon (1982) estimated that 30% of the emergent population migrated past Diamond Island with peak migration occurring at the end of June. It is difficult, however, to estimate with accuracy the magnitude of the migration owing to errors associated with sampling efficiency, mark recovery techniques and year to year variations. Nevertheless, it appears that a large number of fry may move out of the upper Nechako to rear in the lower Nechako and/or the Fraser River. A similar pattern, for example, is reported for the Stuart River where an estimated 97% of the fry migrated out of their natal river to rear in downstream areas (Lister et al. 1981). The movement of Nechako fry to the Fraser was confirmed by the recovery of marked fish at Prince George. Numbers were too small, however, to estimate population size.

**FRY OUTMIGRATION FROM UPPER NECHAKO**

**LITTLE INFORMATION AVAILABLE ON OVERWINTERING REQUIREMENTS**

Very little information is available on the size of the overwintering population and on their habitat requirements. Envirocon (1981) has suggested that the upper reach below Cheslatta and the canyons below Greer Creek and Nautley may provide overwintering habitat for chinook fry, but fish utilization data are not available. Trapping and marking studies have indicated dispersal of fry upstream in the Nechako mainstem and into tributaries, and fry have been sampled in the upper Nechako as late as November (Russell et al, 1983). Small numbers of chinook smolts have been sampled in the spring in both the mainstream and in tributaries (DFE, 1979; Olmsted et al, 1980; Envirocon, 1981).

## 6.3 Implications of Alcan's Proposal

**FLOW REGIME COMPARISONS**

Alcan's proposed flows for "fish protection" and "fish and other uses" in the Nechako River and the injunction flows are shown on Figure 17. A mean annual flow of 26.14 cms (923 cfs) as proposed by Alcan for "Fish and Other Uses", would result in an 80% reduction in the mean annual Nechako River flow at Cheslatta Falls, resulting in a much diminished river down to the Nautley River confluence. Below the Nautley the mean annual flow of the Nechako River would be reduced by 60%, still a very substantial amount. During the critical warm weather months of July and August, flows in the Upper Nechako (i.e., above Nautley) could be reduced by as much as 83%.

**PROPOSED FLOW REGIME WILL AFFECT CHINOOK PRODUCTION**

Alcan does not acknowledge any impacts or risks to chinook salmon associated with their proposal. The Department, however, cannot accept that such a significant reduction in flow regime would impose no risks to the chinook salmon population. Flows would be reduced to levels that would threaten their survival, and there is considerable uncertainty in predicting gross river changes and consequent habitat changes that may affect the long term productivity of the Nechako River.

The following analysis of the effects of Alcan's flow regime on chinook salmon generally refers to the proposed "fish and other uses" flows. These flows are higher than the "fish protection" flows that Envirocon (1983) suggests would protect the chinook resource.

The review focuses on the effects of Alcan's proposal on chinook salmon of the Nechako River. Flow reductions and changes in temperature regime would also have downstream effects in the Fraser River that may impact Nechako River chinook as well as other salmon populations. These concerns have not been addressed to date but are discussed with reference to pink and sockeye salmon by the IPSFC (1983).

### Spawning flows

**SPAWNING FLOWS REDUCED 84% FROM NATURAL REGIME**

Mean September flow (chinook spawning time) would be reduced 84% to 28.32 cms (1000 cfs) which is less than the minimum ever recorded (except when the water was cut off during reservoir filling between October 1952 and January 1957 (see Figures 12 to 14). Beginning in 1980, and in accordance with the injunction (issued August 5, 1980), spawning flows have been maintained at about 34 cms (1200 cfs) (somewhat more than the 1100 cfs required by the injunction).

**ALCAN'S DEFINITION OF SPAWNING REQUIREMENTS**

The basis of Alcan's proposed "fish protection" flow of 24.07 cms (850 cfs) is to provide spawning habitat for 3,000 chinook, the "existing stock" as defined by Alcan. By assigning an area per spawning pair (20 $m^2$) the habitat required was calculated. At 24.07 cms (850 cfs), a maximum of 70% of the spawners could be accommodated ~~either~~ both in the prime spawning area of the Upper Nechako River ~~or~~ and in the rest of the river above Vanderhoof. This takes into account variations in the spawning distribution of chinook salmon.

**DEPARTMENT'S OBJECTIVE FOR MAXIMUM SPAWNING AREA**

The Department's objective, however, is to maintain maximum spawnable habitat. With this objective, discharges from 25.49 to 42.48 cms (900 to 1500 cfs) were estimated to provide maximum spawning habitat within the discharge range up to 56.64 cms (2000 cfs) (DFE, 1979). Based on this analysis, the Department recommended a spawning flow of 31.15 cms (1100 cfs) in 1980. Envirocon's (1983) analysis of discharge versus habitat curves also indicated maximum spawnable habitat at 39.65 cms (1400 cfs) which is within the range reported by DFE (1979).

To further define spawning requirements, depth of water and nose velocities at 39 active redds were measured in 1980 at a discharge of 33.7 cms (1190 cfs) (Russell et al, 1983). At 28.32 cms (1000 cfs), Alcan's proposed flow, approximately 20% of the active redds measured in the above study would have water depths of 24 cm or less. This depth (24 cm) was the minimum observed for spawning.

**GRAVEL QUALITY AND FLUSHING FLOWS**

In general, the river substrate of spawning areas would remain highly stable at the reduced flows because of the armouring effect which has already occurred at higher flows. Flushing flows to move gravel at depth in the river bed as required for proper cleansing in spawning areas would not be practical as they would have to be of magnitudes and durations comparable to annual pre-Kemano I flood flows (in the order of 18000 cfs). Flushing flows of lesser magnitude would be necessary to sweep surficial silts and sands through the system but observations would have to be made on the sources of such fines and if they are deposited in crital areas. It is probable that cleansing of spawning gravels would depend almost entirely on the digging action of the spawning fish themselves but this alone would not likely maintain gravel quality throughout the spawning area.

Incubation and overwintering flows

Incubation flows as proposed would be 25.49 cms (900 cfs) in November and 14.16 cms (500 cfs) from December to April. For the three month low flow period (January to March) 500 cfs represents a reduction of 82% from the mean and would be lower than ever recorded except during the reservoir filling period and in January 1980. Since January 1981 flows for these three months have been about 36.82 cms (1300 cfs).

**PROPOSED WINTER FLOWS THREATEN SURVIVAL OF EGGS AND ALEVINS**

Alcan maintains that their proposed flow would be sufficient to protect eggs and alevins from dessication and freezing. It is highly probable, however, that a flow of 500 cfs would subject some redds to dessication and freezing, because water levels would be significantly less than water levels at spawning time. For example, a change from 28.32 cms (1000 cfs)

to 14.16 cms (500 cfs )represents a drop of 0.6 feet (18 cm), from 31.15 to 14.16 cms (1100 to 500 cfs), a drop of 0.72 feet (22 cm), and from 33.98 to 14.16 cms (1200 to 500 cfs), a drop of 0.8 feet (24 cm).

**EFFECTS OF ICE FORMATION ON EGGS AND ALEVINS UNCERTAIN**

The Department has conducted studies over the last few years to assess the effect of ice formation on natural and artificial chinook redds in the prime chinook spawning area. Owing to mild weather conditions these studies did not provide the data required to justify a decrease in flow from spawning to incubation. Until further information is obtained, the Department maintains that decreasing the depth of water over the redds would increase the risk of icing and in some years reduce the survival of eggs and alevins.

**INCREASED RISK OF ICING**

Envirocon (1983) analyzed eight years of meteorological data (1974-1981) to determine the effects of Kemano Completion on the ice regime of the Nechako River. The calculated frequency of 0°C water occurring above Cutoff Creek from December through February was 31% under present conditions (31.15 cms (1100 cfs)) and 65% at the proposed flow (14.16 cms (500 cfs)). These data indicate that the probability of ice formation indeed would be increased by reducing flows to 500 cfs during the incubation period.

In addition to the risks of dessication and freezing of eggs and alevins, increase in the frequency of cooler temperatures could delay the rate of development and timing of fry emergence and possibly reduce their survival.

**REDUCTION IN FLOW WOULD AFFECT OVERWINTERING CHINOOK**

Reduction in flows and increased risk of freezing could also impact overwintering juvenile chinook in the Upper Nechako River. Overwintering habitat was not considered limiting to chinook production by Envirocon (1983). There are, however, significant data limitations regarding the overwintering period. It is not known what percentage of the chinook population overwinter in the Nechako River, what their habitat requirements are, or if there is a differential survival between chinook that remain in the Nechako River compared with those that migrate to the Fraser River.

Rearing flows

**COMPARISON OF CURRENT AND PROPOSED SUMMER FLOW REGIMES**

The proposed flow of 31.15 cms (1100 cfs) departs significantly from historical (post Kemano I) mean flows of 198.2 cms (7000 cfs) and a loss or change in rearing conditions must be assumed. The injunction flow of 56.64 cms (2000 cfs) is already a substantial decrease from previous flows. The proposed regime, initially, would result in loss of sidechannels and bank cover as the diminished flows would be confined to the center of the main channel. Over time, say 20 years, there would be a natural encroachment of vegetation onto exposed gravel bars and up to the stream edges.

**ENVIROCON'S DISCHARGE AND HABITAT RELATIONSHIPS**

The rearing flows proposed by Alcan were based on an analysis of habitat discharge curves developed for chinook fry and also for benthic invertebrates (Envirocon, 1983). This analysis is based on defining habitat preferences (depth and velocity) and quantifying the usable area which provides those conditions as a function of streamflow. The proposed flow for the rearing period from April to September was a compromise between the lowest

flow that provided maximum habitat for fry and the maximum habitat available for invertebrates. Envirocon's discharge versus habitat curves indicate little change in rearing habitat even with a 10-fold increase in discharge (10 to 90 cms; 353 to 3178 cfs).

**LIMITATIONS TO ENVIROCON'S APPROACH**

The foregoing analysis has serious limitations since it does not consider the changes in the quality of the rearing environment and the overall productivity of the system. Shirvell (1983) has provided in detail many limitations of this approach. Along with other instream flow methods, some of its assumptions are debatable. It frequently offers only broad guidelines that cannot accurately predict the effect of flow alteration on fish numbers. Moreover, it does not address gradual but cumulative changes that may occur in the system as a consequence of changes in flow. Specifically, it does not address the discharges that are required to maintain morphometric features and substrate characteristics upon which fish habitat depends. Accordingly, a less theoretical and more empirical approach is called for.

Early in the growing season (April to June) Nechako River chinook fry disperse along the shore margins utilizing shallow backwaters and sidechannels where they occur. These habitats provide the fry with warmer temperatures, favourable feeding conditions, and protection from predators. These shallow marginal areas are often the most productive areas in large rivers.

**FISH FOOD AVAILABILITY**

Studies indicate that the supply of fish food organisms in the Nechako River is low and drift rates of invertebrates are also low (Russell et al, 1983). There is evidence that available food can be limiting to the growth of chinook fry in the river (Brett et al, 1982). It is desirable, therefore, to maintain as much benthic production as possible during the rearing period. This is so, even after July, as the remaining chinook population has to compete for food with non-salmonid species. The proposed rearing flows would decrease wetted river width and shallow marginal areas, reducing benthic production and juvenile chinook habitat. Benthic studies at two locations in the Nechako River indicated that all habitats across the stream channel contributed significantly to benthic production at one site, while biomass was higher in the nearshore habitats at another. Based on a limited number of transects in the Nechako River the reduction in wetted width from 56.64 cms (2000 cfs) to 31.15 cms (1100 cfs) was in the order of 11 to 17% (Russell et al, 1983).

**MAINTENANCE OF GRAVEL QUALITY**

It is also vital that gravel quality be maintained with the proposed flows. For example, filamentous algae may develop across the river channel and sediments may accumulate that would have a negative effect on invertebrates and fry habitat.

**RESIDUAL CHINOOK REARING IN UPPER NECHAKO**

The impact of reduced rearing flows on the Nechako River chinook is dependent on the importance of the Nechako for overwintering chinook. The size of the population that remains in the river, however, is not known and there are no data to indicate whether or not there is a survival advantage for chinook to remain in the Nechako River over winter. Until the proportion of chinook fry that remain in the Nechako River is known, the proposed flow reduction must be considered a risk to production.

**REARING DATA LIMITATIONS**

Although studies have provided some information on the distribution, migration and habitat utilization of chinook fry in the Upper Nechako River, we do not know whether the population is currently limited by underseeding of the river (resulting from fishing pressure), by available suitable habitat (defined by water depth, velocity and cover, with contrasting requirements in summer and winter), by water quality (e.g., temperature), by available food, or by predators. It is difficult, therefore, to estimate how rearing capacity would change with changes in stream flow.

The effects of water quality changes on rearing chinook, in particular temperature and total gas pressure, are discussed in the Water Quality section. These are key considerations in assessing the proposed rearing flows and have implication for other life stages as well.

## 7. KEMANO RIVER

### 7.1 Hydrology and Alcan's Proposal

**DESCRIPTION OF KEMANO WATERSHED**

The Kemano River flows into Gardner Canal, which is part of Kitimat Arm of Douglas Channel (Figure 1). The Kemano powerhouse is 16 km. upstream from the estuary. Its discharge goes directly into the Kemano River via a tailrace.

The total Kemano watershed area above the Butedale gage (8FE001), located a short distance up from the river mouth, is 780 sq.km. The watershed area above gage 8FE003, located just upstream of the tailrace at Kemano, is about 380 sq.km. This means that about 49% of the natural river flow is contributed by the watershed above the tailrace at Kemano. The remaining 51% is contributed by various tributaries that enter the lower Kemano River (below the tailrace).

**PRE KEMANO FLOW REGIME**

The natural (i.e., pre Kemano I) average monthly flows, shown in Figure 19, for the lower Kemano River were determined from data published by the Water Survey of Canada (Envirocon, 1983). The post Kemano I flows, also shown in Figure 19, were calculated by adding on the monthly tailrace discharge, averaged over the period 1956 - 1978. During this period the tailrace discharge increased gradually from about 47 cms (1660 cfs) in 1956 to about 110 cms (3880 cfs) in 1978.

**POST KEMANO FLOW REGIME**

The mean monthly flows for the two high runoff months of June and July have increased 80% in the last 15 years (see Figure 19). The peak daily flood flows during the same period have increased about 20%. These changes in the high flow hydrology have resulted in some straightening of the mainchannel, an increase in mainchannel width of about 60%, and an increase in total sidechannel length of about 250%. The river ~~appears now to have more or less~~ has not yet stabilized to the post Kemano 1 flow regime. The sidechannels, which have water in them part or all of the time, support a large proportion of the fish population of the lower river.

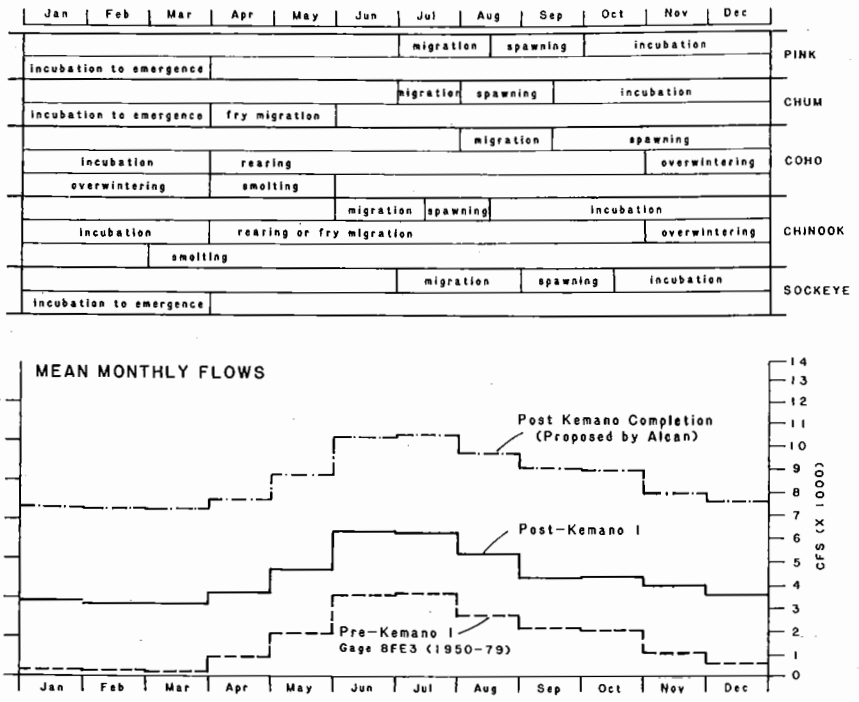


**FIGURE 19**
**KEMANO RIVER MEAN MONTHLY FLOWS**

## 7.2 Biology

**SUPPORTS MAJOR SALMON RUNS AND EULACHONS**

The Kemano River supports all five species of Pacific salmon and a major eulachon population. In order of abundance, eulachons, pink salmon and chum salmon predominate, followed by coho and chinook. The Kemano River supports a small sockeye and steelhead population.

### Salmon escapements

**PINK ESCAPEMENTS HAVE INCREASED**

The even-year pink salmon cycle is dominant in the Kemano River, and the average escapement has increased significantly during the period of record. From 1934 to 1960, the even-year run averaged 37,000 spawners but since the 1960's has increased to an average of 106,000 and a maximum of 200,000 fish. The odd-year escapement varies considerably but, on average, is less than 30,000 fish. Recently, numbers have increased and in 1983, 120,000 spawners were reported.

**CHUM ESCAPEMENTS HAVE INCREASED**

Chum salmon escapements have shown a similar increasing trend to the even-year pink salmon run. Since 1960, chum spawners averaged 40,000 fish (maximum of 100,000). Escapements prior to 1960, were less than 20,000. It is speculated that the increased flows that have resulted from the Kemano I diversion have improved the spawning and incubation environment for pink and chum salmon. The influence of the diversion would have begun to take effect in the late 1950's.

**COHO AND CHINOOK ESCAPEMENTS HAVE DECLINED**

Coho salmon, on the other hand, may not have benefited from Kemano I. Coho escapements averaged 12,000 from 1934 to 1960, and have declined to 5,000 in the last two decades. The maximum escapement recorded was 35,000, which occurred prior to 1950. The trend in chinook escapements is less clear. Spawners averaged approximately 1,500 pre Kemano I, and 2,000 since 1960. In the last decade, escapements have averaged only about 700 chinook. The maximum chinook escapement recorded was 3,500.

**MINOR SOCKEYE RUN**

Six sockeye spawners were first recorded in 1957 and the maximum recorded was 400 in 1971. Sockeye returns to the Kemano River were not consistent until 1977. Since then, sockeye have returned every year, averaging less than 100 fish. It is likely that the sockeye observed are either native stream-reared populations or strays from the Kitlope River. ThE IPSFC (1983) has suggested that there is a possibility that the Kemano River sockeye may be strays from the Fraser River system. These fish spawn immediately below the tailrace and may be attracted to the water from the

Nechako Reservoir that is discharged into the Kemano River. Stream-type sockeye do however commonly occur in central coast streams.

As it relates to the Kemano Completion Project, apart from escapement records and a eulachon spawning survey, the Department has not conducted studies in the Kemano River. The information on salmon distribution and habitat utilization presented in the following sections has been summarized from baseline studies conducted in 1979 by Envirocon (1981).

Timing and distribution of pink and chum salmon

**AUGUST/SEPTEMBER MIGRATION AND SPAWNING**

Pink and chum salmon enter the Kemano River in late July. The spawning periods of both species overlap although chum spawn slightly earlier. Peak spawning of chum and pink salmon occurs in late August and early September, respectively (Figure 19).

**SPAWN IN LOWER KEMANO RIVER**

The majority of the chum and pink salmon populations spawn throughout the lower Kemano River (below the Kemano tailrace) mainly in sidechannels (Figure 20). In 1979, it was estimated that 81 and 62 percent of the total chum and pink escapement respectively, spawned in the lower river. Both species were most abundant in Reach 2 which is characterized by an extensive network of sidechannels. The major spawning tributary is Horetsky Creek and limited spawning also occurs in other tributaries. Only small numbers of pink and chum salmon spawn in the upper river.

Pink and chum salmon fry do not rear in freshwater. Shortly after emergence, likely in February or March, fry migrate to sea. In 1979, the distribution of chum fry reflected the adult spawning distribution. Chum fry were most abundant in April and declined in May. Pink fry were not sampled in April and had likely migrated out of the river by that time.

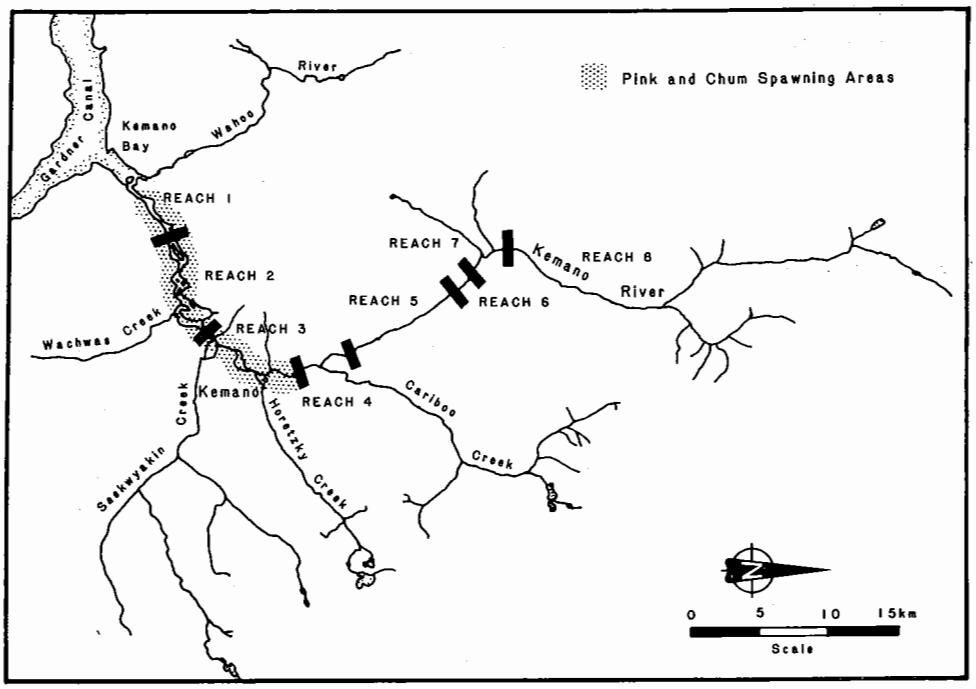


**FIGURE 20**
**KEMANO RIVER PINK AND CHUM SPAWNING AREAS**

Timing and distribution of coho salmon

**SPAWN LATE FALL AND WINTER**

Based on the Department's spawning records, adult coho salmon migrate into the Kemano River in August and spawn in October, Figure 21. In 1979, spawning was first observed in late October but probably peaked in late November. The early spawning time noted in the Department's records may reflect the early timing of the escapement surveys.

**SPAWN IN TRIBUTARIES AND KEMANO RIVER**

Coho salmon spawn in the lower and upper Kemano River and in tributary streams and are roughly equally distributed among these three locations. The greatest concentration of spawners noted in 1979 in the Kemano River occurred in a 4 km braided section below Cariboo Creek in the upper river and below Seekwyakin Creek in the lower river (Figure 21). In the upper river, coho spawners utilized the mainchannel, while, below the tailrace, where flows are augmented and velocities in the mainchannel are high, side-channels rather than the mainchannel were used. Tributaries where coho spawn include the Wahoo River and Wachwas, Seekwyakin, Horetsky and Cariboo Creeks.

**REAR IN LOWER KEMANO**

Based on scale analysis of adult returns, it can be stated that coho fry generally spend one full year in freshwater. Shortly after emergence, coho fry move downstream to rear in the lower Kemano River. It was estimated that about 65% of the coho fry reared in the lower river during late summer and fall (in 1979). Coho fry also reared in tributary streams, particularly in Horetsky Creek, Steelhead creek (Reach 5), and an unnamed tributary in Reach 4.

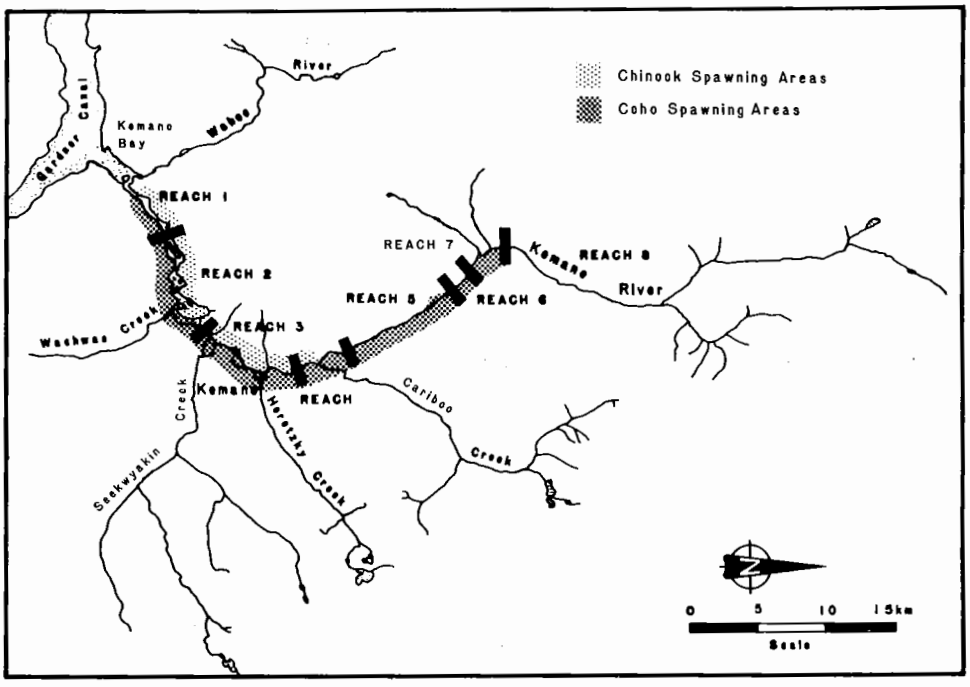


**FIGURE 21**
**KEMANO RIVER CHINOOK AND COHO SPAWNING AREAS**

**FRY HABITAT UTILIZATION**

In the Kemano River, coho fry preferred the low velocity habitats and selected stable and intermittent sidechannels over the mainchannel and larger sidechannels. Cover was very important and fry were associated with log jams, aquatic vegetation, debris, root wads, and overhanging vegetation during the spring, summer and fall. Beaver ponds found in the lower four reaches were also heavily utilized in the fall and likely provide important overwintering habitat.

Timing and distribution of chinook salmon

**JUNE MIGRATION AUGUST SPAWNING**

Adult chinook salmon arrive in the Kemano River in June and spawn in the Kemano River in late July or August, (Figure 19). Chinook spawn throughout the lower 20 kilometers of the Kemano River (Figure 21). They utilize deeper and faster waters than the other salmon species, selecting sites in the mainchannel and larger sidechannels of the Kemano River. In 1979, the major proportion of the escapement (90%) spawned in the Wahoo River and in Seekwyakin and Wachwas creeks. The visibility in the tributary streams was, however, much better than in the Kemano River and the relative distribution may not be representative.

**PROPORTION REARING IN FRESHWATER UNKNOWN**

Juvenile chinook salmon spend a few months to a full year in freshwater prior to sea migration. Little data is, however, available on the proportion of "ocean type" versus "stream type" chinook in the Kemano river and their survival rate to adults. A large decline in catches from May to July

suggested an outmigration of chinook fry, however, scale analysis of a small number of adult spawners indicated one year freshwater residence.

**WIDE DISTRIBUTION OF FRY**

Juvenile chinook fry were found throughout the seven reaches of the Kemano River, in the Wahoo River and in Seekwyakin and Cariboo creeks. Their habitat preferences have not been well documented since catches of chinook fry between spring and fall were low, probably owing to poor sampling conditions during high water. The distribution of chinook fry in the fall suggested that the upper Kemano River and the larger tributaries provide overwintering habitat. Cover in the form of boulders and cobbles and logjams appeared to be a major component of winter habitat and chinook fry were found in a variety of sidechannels that offered this type of cover.

Eulachons

**SPRING SPAWNING**

The eulachon run in the Kemano River numbers several million fish. Eulachon spawn in the lower Kemano River and Wahoo River within tidal limits. They spawn in the spring, usually at the end of March to mid-April. Eulachon are relatively weak swimmers and their upstream migration and spawning generally coincides with low river discharges and high spring tides. River and estuarine water temperatures may also influence the timing of migration. Most adult eulachons die after spawning and after a short incubation period (probably 30 to 40 days), eulachon larvae hatch and are swept with the current to the sea.

## 7.3 Implications of Alcan's proposal

**PREDICTED CHANNEL CHANGES**

Kemano Completion would increase mean June and July flows 70% over present values, or triple the original natural June and July flows (see Figure 19). Peak daily flows would be about 17% greater than present peak flows and 40% greater than natural (pre Kemano I) peak flows. The effect of these increased flows on the lower Kemano River cannot be accurately predicted but gross changes in the morphology would be likely. It is quite possible that the river could take on a wide, single channel configuration that would result in considerable erosion and incising (cutting down) of the channel. If this were to happen, many, or perhaps most, of the sidechannels could be lost. If the channel were to incise, fish access to some of the tributaries and remaining sidechannels could be cut off or made difficult. It would take some years after Kemano Completion before the nature of the morphological changes would be known, and it would take decades before the river would stabilize.

**THREAT TO SALMON PRODUCTION**

The effect of the increased discharge on the Kemano River and the salmon resource would depend on the extent of morphological changes. Should the river become single channelled, salmon production in the Kemano River would be seriously threatened. The sidechannels of the lower Kemano River are heavily utilized by pink, chum and coho spawners. Selected sidechannels in the lower river were found to be the prime rearing and overwintering areas for coho fry. These habitats would be lost.

IMPACT ON SALMON DEPENDENT ON CHANNEL CHANGES

The river may, on the other hand, maintain its wandering, braided nature. The Kemano I diversion, by increasing sidechannel development and increasing winter flows, appears to have considerably improved the pink and chum populations in the Kemano River. Increasing the flows further, as proposed by Alcan, would not necessarily continue this trend. It is not possible to predict what the net impact of Kemano Completion on spawning and rearing habitat would be with the information available.

CHANGES IN TEMPERATURE REGIME EXPECTED

In addition to these major stream flow changes, alteration in temperature regime and potential increases in total dissolved gas would also occur. Since Kemano I, water temperatures have been warmer in the fall and cooler in the spring and summer compared with the natural temperature regime. How these changes have affected fish production, however, is not known. Kemano Completion would further change the temperature regime with potential impacts on migration and spawning of adult salmon, timing of emergence, entry of chum and pink fry into the estuary and the growth rate of rearing coho and chinook. These concerns would have to be addressed.

POSSIBLE MAJOR IMPACT ON EULACHONS

POSSIBLE MAJOR IMPACT ON EULACHONS

The valuable eulachon run in the Kemano River is also a major concern. Although the Department has surveyed eulachon spawning areas to document spawning distribution and conditions, it is not possible to predict how these conditions would change. Increased velocities and changes in temperature may, however, impede migration or reduce the spawning success of eulachons.

## 8. WATER QUALITY

GOOD WATER QUALITY ESSENTIAL FOR THRIVING SALMON POPULATIONS

Good water quality must be preserved for salmon to thrive. Salmon have adapted to cool rivers and streams, and the aquatic organisms that salmon require for food have similarly adapted. As a generality, reductions in flow can be expected to result in warmer summer water temperatures and cooler water temperatures during the winter. Flow reductions also cause the concentrations of man-made and naturally-occurring pollutants to increase.

### 8.1 Temperature

#### 8.1.1 Effects of Temperature on Salmon

ALL SALMON LIFE STAGES SUSCEPTIBLE TO ALTERED TEMPERATURE CONDITIONS

All life cycle stages of salmon are susceptible to impacts from exposure to altered temperature conditions. Reduced water flows to rivers could alter temperature regimes and have significant implications for survival of salmon. Salmon eggs have critical temperature requirements. Lower temperatures during incubation lead to retardation of development rate. Low temperatures during rearing reduce metabolism and feeding success which in turn could markedly reduce the success of salmon survival. Temperature increases may increase the susceptibility of salmon to diseases. Higher temperatures increase metabolic rates and result in greater requirements for energy. Salmon encountering dramatic changes in water temperature may undergo "thermal stress" which renders them less able to survive. Temperature may have other important effects on survival of salmon. The

preferred temperature for most salmon species is close to the optimum temperature for growth, swimming performance and maximal ability to extract oxygen from the water during activity.

### 8.1.2 Nanika and Morice Rivers

**TEMPERATURE OF NANIKA RIVER MAY INCREASE AND AFFECT MIGRATING SOCKEYE AND REARING CHINOOK FRY**

Mathematical temperature modelling was conducted for the Nanika and Morice Rivers (Dept. of Environment, Fish and Oceans, Vol. 9, 1979). On the assumption that water would be discharged at a temperature of 15.5°C (60°F) from Kidprice Lake, it was computed that at a flow of 184 cfs in the Nanika River during sockeye migration (August 1 to August 18) the temperature would rise to 19.7°C (67.5°F) and cooling water may be required. During this period some rearing chinook and coho fry would also be present in the Nanika River, as would trout. It will be noted from Figure 3, that Alcan's proposed flow would only be 4.96 cms (175 cfs) in August; thus under warm weather conditions high temperatures could affect migrating sockeye and rearing chinook and coho.

**GLACIER CREEK DIVERSION TEMPERATURE MODELLING REQUIRED**

If Glacier Creek were diverted, which would be a means of reducing the deposition of silt in the Nanika River, it would be necessary to base calculations of temperature increases upon a higher temperature at Kidprice Lake than 15.5°C (60°F). If this diversion proceeds, further temperature calculations and data are needed. It may be found that it would be necessary to install a cold water intake at the Kidprice Lake Dam.

**TEMPERATURE NOT EXPECTED TO BE A PROBLEM IN MORICE RIVER**

Similar temperature modelling was conducted (Dept. of Environment, Vol. 9, 1979) for the Morice River for the month of August. At a modelled flow of only 2000 cfs the maximum temperature of the Morice River (above the Bulkley confluence) was calculated to be 18.6°C (65.5°F). From this modelling it would appear that at proposed flows in the order of 3000 cfs, excessively high temperatures are not likely to occur. This should be confirmed by comparison with actual stream temperatures.

### 8.1.3 Nechako River

At present, because approximately 54% of the reservoir's flow has been diverted, it is necessary to release very large volumes of water from Skins Lake in July and August into the Nechako River to provide cooling for sockeye migrating to the Stuart and Nautley rivers. These large flows have resulted in erosion of the banks of the Cheslatta River, and silting and flooding of the Nechako River. The release of such large volumes of water could have been avoided by the provision of smaller releases of cold water from Kenney Dam. Alcan now proposes to provide a cold water intake at Kenney Dam.

**PROPOSED TEMP. REGULATION SCHEME AIMED FOR SOCKEYE**

The release of cold water into the Upper Nechako River is intended to reduce the frequency of exposure of sockeye salmon to high temperatures during adult migration through the Nechako River. For a fuller discussion of the adverse effects of high temperatures during sockeye migration, the reader is referred to the IPSFC (1983) report.

Under Alcan's scheme for the provision of sockeye cooling water, releases into the Upper Nechako would be made in the following manner:

**MANNER OF PROPOSED NECHAKO RIVER TEMPERATURE REGULATION**

1. Water would be released only from Murray Lake from September 1 to June 30.

2. On July 1 releases of cold water from the Kenney Dam would be started. Water temperature in the Upper Nechako River would be reduced gradually by reducing the amount of warm water released from Murray Lake and by increasing the amount of cold water released from the Kenney Dam. By July 10, the temperature of the river just below Cheslatta would have stabilized at 10°C (50°F), and the latter temperature would be maintained until August 19.

3. After August 20, by decreasing the release of water from Kenney Dam and increasing the release from Murray Lake, temperatures just below Cheslatta would gradually be raised. By August 31, all water released into the Upper Nechako River would again originate from Murray Lake.

**INCREASED FLOW REQUIRED TO ACHIEVE TEMPERATURE REGULATION**

Alcan proposes to maintain a base flow of 31.2 cms (1100 cfs) during the period of April 1 to August 31 to provide rearing area for chinook fry in the Upper Nechako above its confluence with the Nautley River. Alcan's calculations show, with water released at 10°C (50°F) just below Cheslatta, that it would not be possible to maintain low enough temperatures to safeguard sockeye migration at the base flow. Their calculations show that it would be necessary to maintain a long term mean flow of 40.9 cms (1444 cfs) during July and August. This would result in the maintenance of a long-term average temaperature of 17.9°C (64.2°F) in the Nechako River just above its confluence with the Stuart River. The increase from 31.2 cms (1100 cfs) to 40.9 cms (1444 cfs) is equivalent to a mean annual flow of 1.64 cms (58 cfs).

For adequate protection of migrating sockeye salmon, the IPSFC is recommending that a long-term average temperature of 17.0°C (62.6°F) should be maintained above Stuart. To maintain this lower average temperature in July and August would require additional cooling water equivalent to a mean annual flow of approximately 3.06 cms (108 cfs) above the base flow.

**CONFLICTING REQUIREMENTS OF CHINOOK AND SOCKEYE SALMON**

Based upon data on growth of chinook (Brett, 1982), Alcan deduced that 80% of maximum growth of chinook fry would take place within a temperature range of 11.2°C (52.2°F) to 17.8°C (64.0°F). Unfortunately, if a constant temperature of 10°C (50°F) is maintained below Cheslatta, it would often be impossible to maintain sufficiently high temperatures in the Upper Nechako River to provide maximum capacity for chinook growth (Figure 22).

In cool weather as much as two thirds of the length of the Upper Nechako would be exposed to lower temperatures than those within the range required. It would seem appropriate for Alcan to be prepared to regulate water temperatures just below Cheslatta to meet chinook rearing as well as sockeye cooling temperature requirements. Lower temperatures in the Upper Nechako could not only reduce the capacity for growth of chinook fry, but

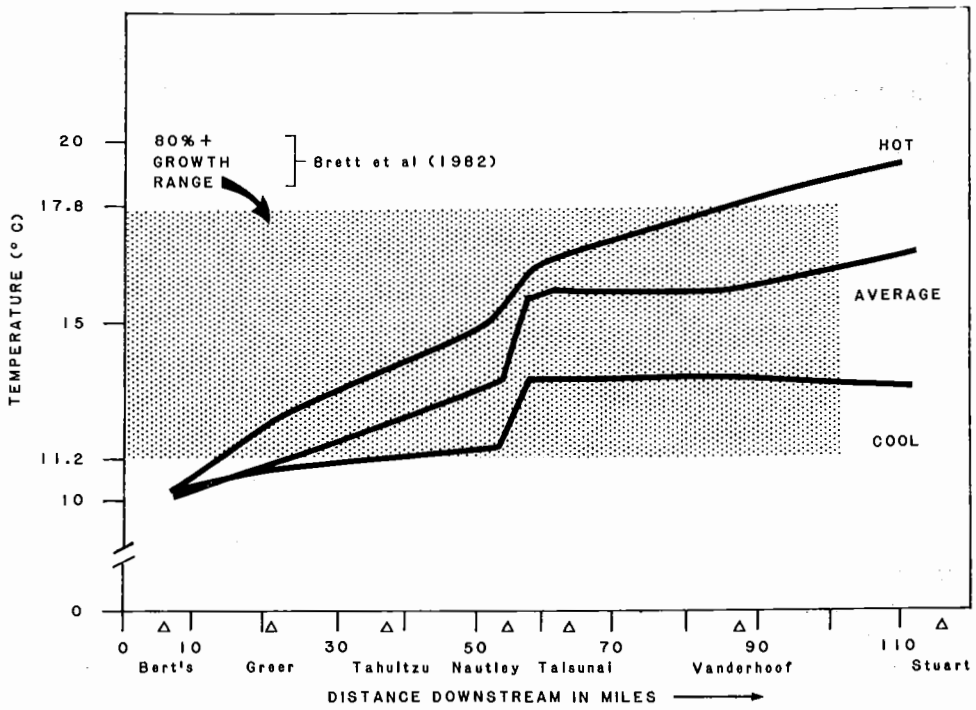


**FIGURE 22**
**TEMPERATURE PROFILES FOR THE NECHAKO RIVER**

also their main food source as Mundie (1983) notes that the effect of cooler and more constant temperatures would likely lead to a reduction in abundance and species diversity of benthic invertebrates. Alcan's temperature modelling studies have focussed upon sockeye migration. Further studies may be required to determine the optimum temperature regime for chinook at all life stages.

## 8.2 Total Gas Pressure

**HOW SUPERSATURATED DISSOLVED GASES CONDITION OCCURS**

Water, at given depth, temperature and atmospheric pressure, dissolves nitrogen and oxygen until it becomes saturated. Water becomes supersaturated when air bubbles are entrained and subjected to hydrostatic pressure, e.g., as happens at the deep plunge pool at the base of Cheslatta Falls. The solubilities of nitrogen and oxygen decrease as water temperatures rise. Turbulence reaerates water and allows supersaturated gases to escape from solution.

**EFFECTS OF SUPERSATURATION ON FISH**

Gas bubbles may form in the blood and tissues of fish and invertebrates exposed to supersaturated solutions of nitrogen and oxygen, blocking blood circulation, damaging tissues and causing behavioral anomalies. The effects can be lethal. Both supersaturated gases are involved, hence the effects of their combined concentrations are expressed by the term - Total Gas Pressure (TGP). Among salmonids, alevins and early fry are most susceptible to damage from TGP. Invertebrates are less susceptible than

fish. Hydrostatic pressure compensates for TGP at a rate of about one percent per 10 cm increase in depth, but there is no conclusive evidence to show that salmonids can detect gas overpressures and compensate by moving to deeper water.

**DEFINITION OF SAFE LIMIT**

Alderdice (1983) recommended that "with some risk" TGP in the Nechako River should not exceed 102 to 108% for more than 24 hours and should never exceed 108%. Alcan (1983), quoting Ebel and Raymond (1976), cited a concentration of 110% as "usually considered an upper safe limit", but did not identify any relationship between exposure time and concentration.

**CALCULATIONS OF TGP ARE SUSPECT**

Alcan (1983) mathematically modelled TGP for the period July 15 to August 18, 1981 (assuming flow release from the existing Skins Lake spillway). At 10 of 12 stations in the Upper Nechako River, the duration of exposure to TGP exceeding 110% was more than 203 hours, at two, more than 838 hours. If either Alderdice's or Alcan's TGP limits are valid, it is difficult to conceive how chinook in the Upper Nechako could survive under such conditions. It would appear that the accuracies of the model and the TGP limits must be checked.

Alcan's studies appear to have been focussed upon the sockeye migration period (summer) and route. Both the Department and Alcan have acknowledged the need to maintain chinook habitat in the Upper Nechako, but TGP modelling has not been carried out for the period of mid-April to mid-July. Late April to early May is a period when young chinook salmon in the Upper Nechako River would be very vulnerable to TGP because they occupy the shallows where the mitigating effect of compensatory depth is minimal.

**TEMP. MODELLING FOR SPRING SUMMER PERIOD TO DETERMINE NEED FOR MITIGATION**

Low water temperatures will also cause gases to go into solution readily in the spring and summer. Therefore, more TGP modelling is required to predict what supersaturation levels are likely to be encountered during that period. Such calculations may show that it would be necessary to bypass the Cheslatta plunge pool and indicate whether reaeration structures would also be required in the Upper Nechako River.

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## 8.3 Further Water Quality Considerations

**WATER QUALITY STUDIES VERY LIMITED**

Fisheries and Oceans has not conducted water quality investigations, specific to Kemano Completion. Limited water quality studies were carried out by Alcan's consultants. Whether the increased nutrient concentrations that would occur as a result of reduced flows under Kemano Completion would result in excessive plant growths and algae has not been adequately investigated. The impacts of excessive plant growth upon the habitat fish food organisms, habitats of rearing and spawning fish, and upon water quality (e.g., dissolved oxygen) may pose risks that are unacceptable.

**EFFECTS OF FLOW REDUCTION ON EXISTING POLLUTION SOURCES NEEDS TO BE ADDRESSED**

At reduced flows, the dispersion of existing sewage and industrial effluents will be altered and probably retarded. Effects such as reduced dissolved oxygen, algal blooms, and toxicity in the receiving waters have not been adequately investigated.

**NEED TO UPGRADE EXISTING TREATMENT FACILITIES NOT EXAMINED**

Alcan have stated that the Provincial Pollution Control Board objectives concerning effluent quality and dilution could be met. It has been assumed by Alcan that the water quality requirements of fish will also be satisfied. There are not enough data available to substantiate this claim. Consideration has not been given to whether site-specific upgrading of treatment would be needed (e.g., nutrient or heavy metals removal) or whether outfalls would need relocation or upgrading (e.g., diffuser installation).

**MORE STUDY OF DISSOLVED HEAVY METALS REQUIRED**

According to Alcan's projections, concentrations of total and dissolved heavy metals will increase owing to reduced flows following Kemano Completion. However, the fraction of metals that would be reactive with aquatic life has not been estimated, either on the basis of existing levels or at levels based upon projections of metals that would be contributed in future by increased sewage discharges. Because some projected metals concentrations exceed criteria for protection of aquatic life, it is evident that further work must be done.

## 9. DISEASES AND PARASITES

**OVERVIEW OF MECHANISMS OF DISEASE AND PARASITE TRANSFER**

The Kemano Completion Project involves the diversion of Nanika and Kidprice Lake waters (source waters) to the Nechako Reservoir and to the Kemano and Nechako rivers (receiving waters). Linking watersheds can pose a hazard to the health of fishes in the receiving waters by introducing alien disease agents (including parasites) by degrading water quality, and by introducing animals that may transmit or harbour significant numbers of resident disease agents. The effects of these introductions may not become apparent for many years.

**NECHAKO TO KEMANO TRANSFER ALREADY A FACT**

Any transfers of disease agents from the Fraser River (Nechako Reservoir) to the Kemano River are assumed to have already occurred following the completion of the Kemano I diversion.

Bell (1983) and McDonald (1983) have reviewed the implications of transferring diseases and parasites from the Skeena watershed to the Fraser and Kemano systems. These are summarized as follows.

### 9.1 Diseases

**BASIC CONCERNS OF DISEASE AND HEALTH**

It is useful to outline briefly some basic concepts of health and disease in order to put discussion of impact in perspective. Like most animals, fishes usually live in harmony with potential disease agents (pathogens): disease is the exception, not the rule. Disease caused by an indigenous living agent (i.e., infectious disease) is conceived of as resulting from a disturbance of the complex interaction between the fish (host), environment and potential pathogen. For example, debilitation of the host by environ-

mental degradation can so stress the fish that "background" organisms gain the upper hand. Such degradation might consist of chemical or thermal pollution, low oxygen, or gas supersaturation. On the other hand, devastating disease outbreaks can occur from the introduction of even low numbers of an exotic disease agent because the fish are defensively naive. An exotic or alien disease agent is a species or strain of micro-organism or parasite, new to an area. Maintaining the disjunct distribution known for many disease agents is therefore of major consequence to the fisheries resource, and linking watersheds poses a hazard of introducing new disease agents. Also, although larger fish, possibly carrying disease agents, can be prevented from passing into new receiving waters, the microscopic disease agents, cannot be screened out, nor can the seeds of pest plants (e.g., Milfoil) or eggs and larval stages of animals (e.g., snails, leeches, fishes). Some of these animals may act as reservoirs or vectors of disease agents.

**NO AMOUNT OF STUDY PROVIDES ASSURANCE OF PATHOGEN ABSENCE**

Although Alcan have met the sampling requirements suggested by the Department to detect diseases or disease agents, it must be recognized that no amount of sampling and examination can give complete assurance of the absence of a given pathogen. By agreement, Envirocon (1981, 1983) looked primarily for the common threatening diseases or pathogens of salmonids, and they did not examine for strain differences that might be significant. Another limitation that should be noted is that there is the possibility of introducing as yet unrecognized disease agents. There is no way of avoiding this possibility except to maintain the present separation of watersheds.

**RESULTS OF DISEASE STUDY**

According to the results of the disease surveys no important disease agent was found in the source waters that was not also present in the receiving waters. Some important disease agents such as those of furunculosis and bacterial kidney disease were not found in fish from either system, a rather surprising finding considering their wide distribution in B.C. Some agents (Ceratomyxa shasta and Dermocystidium sp.) were detected in the receiving waters only and hence appear to pose no problem.

The finding of infectious pancreatic n ecrosis virus (IPNV) in the study area has serious implications for fisheries management because this is the first report of its occurrence in B.C. (It has been found on the Alberta/B.C. border). However, the finding would not argue against proceeding with the watershed diversion because similar IPNV was reported in both source and receiving waters.

**NO DISEASE TRANSFER PROBLEM EXPECTED**

Kemano Completion does not appear to present a hazard to downstream fishes from the introduction of alien microbial disease agents. On the other hand, because of the threat of introducing exotic pathogens, steps should be taken to ensure that the movement of fish or waters from the Fraser to Skeena systems cannot occur.

### 9.2 Parasites

**PARASITE STUDIES**

The determination of the species composition of the parasite faunas of fish in the source and receiving waters has been reasonably well documented from

a qualitative perspective, although some species, particularly ectoparasites, may have been missed. From a quantitative perspective sampling has been insufficient to provide statistically reliable data on prevalence and intensity of infection, when factors such as age of fish, season collected, sex of fish, and location of fish within a large reservoir system are considered. Likely influences of environmental alterations (e.g., creation of a reservoir, changes in water flows) on the parasite fauna, and their potential consequences for the fisheries resources, have not been addressed.

**NANIKA HAS PARASITES NOT FOUND IN NECHAKO RESERVOIR**

Some parasites from Nanika-Kidprice that have not been found in the Nechako Reservoir could be transferred, with potentially detrimental consequences to the salmonid fishery resource. There is also the possibility of transferring new strains of parasites to the Nechako Reservoir, with additional unknown consequences. Theoretically, there is a potential for the reverse transfer of parasites from the Fraser to the Skeena system, but as long as barriers are maintained against this transfer it can be dismissed from further consideration.

**TRANSFER PROBLEMS DIFFICULT TO PREDICT**

While there is always a risk associated with such a development, the consequences of the completion of the project on the parasite populations and subsequently on their fish hosts are difficult to predict. Should Kemano Completion proceed, monitoring would be required.

## 10. POTENTIAL SALMON PRODUCTION FROM RIVERS AFFECTED BY KEMANO COMPLETION

**NEED FOR DEFINITION OF FISH PRODUCTION OBJECTIVES**

The proposal by Alcan to undertake completion of its giant Kemano hydroelectric project, because of its tremendous social and economic significance to the region and its inherent requirement for large volumes of water, will bring the conflicting demands of water for fish production and water for hydro power generation into sharp focus. Before these conflicting demands can be properly addressed, it is incumbent upon the Department to define and enunciate publicly its fish production objectives for the Nanika, Morice, Nechako and Kemano rivers. These objectives must be realistic and attainable because the fish production objectives will largely determine the quantity of water which must be released by Alcan to permit natural fish production and maintain viable enhancement opportunities. This will provide the Department with the necessary yardsticks against which to measure the merits of Alcan's proposals for ensuring that no net loss of present and potential fish production results from development of the project. The viability of the project may well depend upon the volume of water made available for fish production.

**SIGNIFICANCE OF POTENTIAL FISH PRODUCTION**

When considering the implications of the Kemano Completion Project on the salmon stocks of the four rivers involved, one must rapidly come to grips with the definition of "potential production". This will determine the degree to which the project's impacts must be mitigated and if necessary the extent and nature of compensation to which the developer must be committed in order to ensure that no net loss of potential fish production will ensue as a consequence of project development. It is now generally recognized that current production levels are the result of a long history of overfishing and are not a reflection of the production attainable from

available habitat given changes in the management of the fishery (Pearse, 1981; 1982). However, it must also be recognized that in certain instances, proper management of the fishery does not mean that potential biological production levels could be attained in all areas by all stocks.

**FACTORS AFFECTING POTENTIAL**

The potential of a salmon stock is dependent upon the capacity of the natal stream, its productivity and its manageability. The relative productivity of the stocks within a management unit are determined by the rates of return of adults produced per spawning pair of each stock. The higher the rate of return, the greater is the productivity. Manageability is the term applied to the ability to manage a given fishery with minimal or no detrimental impacts on non-target stocks. For example, if a given stock is mixed with stocks known to have the same relative productivity, they can all be harvested at the same rate to optimize escapement without endangering any of the stocks, and all are considered manageable. On the other hand, if a fishery is conducted on a large productive stock which is mixed in with many stocks of lesser productivity, the fishery is not considered manageable since the fishery targetting of the most productive stock would overexploit all the other less productive stocks in the fishery. A similar and compounding problem may occur when stocks are taken incidentally in a series of sequential fisheries over a wide geographic area. Stocks such as these are on the route to extinction unless their exploitation rates can be reduced through better fishery regulation or their productivity can be improved through application of enhancement technology. All salmon stocks, except the sockeye migrating through the Nechako, implicated in the Kemano Completion Project have one thing in common; all are harvested in mixed stock fisheries of which they are a minor component. Consequently, all stocks are subject to manageability problems and this reality is recognized when the potential of these stocks is identified.

**ALL STOCKS HARVESTED IN MIXED STOCK FISHERY**

Nanika River

**SOCKEYE CAPACITY**

The Nanika River provides the principal spawning ground for what is known as the Morice Lake sockeye population. The Nanika River spawning areas are estimated to have a total capacity of 32,000. The Morice sockeye population has a history of being overfished because its timing coincides with the larger and more productive Pinkut River sockeye run to Babine Lake. The problem has been compounded since increased returns from the Pinkut River spawning channel have entered the Skeena River fishery.

**IMPORTANCE OF NANIKA NUTRIENTS**

The proposal by Alcan does not significantly threaten the sockeye spawning areas on the Nanika. The principal threat is that the prime source of nutrients to Morice Lake is the Nanika River, and its annual flow contribution will be reduced by 62%. In limnological terms, Morice Lake is one of the least productive lakes in North America, and a reduction of nutrients of such magnitude would significantly affect the survival of Morice sockeye. If Alcan were to provide for fertilization of Morice Lake as compensation for the loss of the Nanika River nutrient input, the Morice Lake system may sustain the Nanika potential escapement of 32,000 sockeye plus increases to the 2,000 lake spawners in Morice and Atna Lakes.

**NANIKA RIVER CHINOOK AND COHO POPULATIONS**

The Nanika River supports minor populations of chinook and coho salmon. Historically, escapements of 400 - 500 for each species have been recorded. Mitigation in the form of flow releases to sustain these populations would preclude the diversion of the Nanika as a component of Kemano completion. If this is not the case, Alcan should be prepared to compensate for these stocks to historic escapement levels.

Morice River

**CHINOOK POPULATION DATA AND POTENTIAL**

The Morice River chinook escapements currently represent 20% of the total chinook salmon escapements to the Skeena River. In the recent past, this stock has constituted as much as 40% of the total Skeena chinook population. Recent escapements have been in the 5-7,000 range and consequently it is the most important single salmon stock in the Morice system. Escapements on six occasions since 1950 approximated 15,000 but these have never produced escapements exceeding 50% of the brood year population. That is not surprising since the measured capacity of the chinook spawning grounds is 12,000.

**ASPECTS OF CHINOOK FISHERY**

The Skeena River chinook stocks are all markedly depressed as a consequence of over-fishing. There has not been a directed commercial fishery for Skeena chinook for at least a decade and in some years, constraints have been placed on the recreational fishery. In 1982 The Indian food fishery on the Skeena River is estimated to have caught approximately 9,200 chinook salmon. Of this number 3,000 were attributed to the Moricetown Fishery. All Skeena chinook harvested in the commercial fishery are taken incidentally in the major pink and sockeye fisheries. The prospects for further curtailment of these fisheries are being pursued. In recognition of these circumstances, the Department's North Coast Division is implementing a blend of management and enhancement strategies for all major chinook stocks on the Skeena system to mitigate against the consequences of the major fisheries. It is anticipated that current populations of natural stocks can be sustained. The balance of the natural capacity would have to be filled by enhanced production. The enhancement strategy resulting from the blending of the sources of production is dependent upon the optimal use of currently underutilized habitat. Returns from such efforts would be permitted to spawn naturally until the 12,000 capacity is reached.

**IMPACT OF FLOW REDUCTION ON REARING**

Kemano completion is not expected to reduce the capacity of the chinook spawning areas. However, the reduction of flow in the Morice River will result in a reduction of its natural rearing capacity and as such, represents a threat to the potential production of the system. It would also represent an increase in the capital and operating costs of any chinook enhancement effort because such enhancement would necessitate 1+ years of hatchery rearing. If Alcan diverts the Nanika it must then be prepared to optimize the remaining natural habitat (in the Morice). Losses accruing from reduced rearing habitat that remain would have to be replaced by artificial means.

**COHO POTENTIAL**

Morice River coho constitute 4% of the total Skeena River escapement. Like coho everywhere on the B.C. coast, they are not the subject of a broad management strategy. The proposed reductions in flow will, as for chinook,

manifest itself by reducing the rearing capacity for juvenile coho. Currently, the potential escapement goal is 10,000 fish which the river historically has produced. The proponent should be prepared to provide mitigative and compensatory measures necessary to sustain this potential if the project proceeds.

**PINK SALMON POPULATION EXPANDING**

Morice River pink salmon are in the process of extending their distribution throughout the Bulkley-Morice system as made possible by the construction of the Moricetown fishway and by obstacle removal in the Hagwilget Canyon. In the absence of adequate data, it is not possible to establish realistic estimates of potential pink production. The 1983 escapement was 30,000 spawners. At this level their numbers are not significant in terms of the total Skeena pink escapement or contribution to the pink fishery.

Nechako River

The Nechako River system is utilized by chinook and sockeye salmon. Numerically, the sockeye populations are far more substantial than the chinook, a factor that has always made management of the latter more complex and difficult.

The sockeye salmon stocks of the Nechako system do not spawn in the Nechako River but use it as a migration route to spawning and rearing areas in the Stuart and Nautley River systems. Like all Fraser River salmon stocks above Lytton, sockeye salmon populations native to the Nechako River systems were severely impacted by the Hell's Gate slide of 1913 which was not corrected until 1945.

**SOCKEYE SALMON POTENTIAL**

Since completion of the Hell's Gate fishways, the International Pacific Salmon Fisheries Commission has, through regulation of the commercial fishery and modest enhancement effort, managed to substantially rebuild the sockeye populations native to the Nechako River watershed. However, the potential rearing capacity of the five lakes involved (Takla, Trembleur, Stuart, Francois and Fraser), has scarcely been tapped. Presently, in dominant years, the five lakes are being utilized by the progeny of 310,000 female spawners while they could theoretically handle the progeny from 3,170,000 females (Vernon, 1982)(*). This represents over half of the unused sockeye production potential of the Fraser River system. Consequently, the maintenance of the Nechako River as a migration route is of paramount importance.

**CHINOOK POPULATION DATA**

The period of numerical record for chinook salmon escapements commences in 1934. The escapements up to and including those of 1952 represent the pre-development returns to the river. The maximum estimated chinook escapements to the Nechako was 4,000 (unpublished, McLaren, 1952: Tuyttens, 1952). In the 18 - 20 year period following dam closure, escapements dropped from a pre-development average of approximately 1,150 to as low as 75. Observations were not possible in two years. In the period 1971 - 1980, escapements averaged 1,354.

(*) This could only be achieved through application of enhancement technology.

**MANAGEMENT ACTIONS TAKEN**

The improved escapements in the latter period are considered to be the product of less extreme fluctuations in flow regime and regulatory efforts to reduce the exploitation rate of the various fisheries on Fraser chinook. It was during the latter period that the chinook gillnet fishery of the lower Fraser was virtually eliminated along with the very early sockeye openings in which many early up-river chinook stocks - Nechako included - were incidentally harvested. There is no commercial fishery remaining which targets exclusively on Fraser River chinook salmon. Since 1980 the sport fishery at the mouth of the Fraser has been closed as a conservation measure. Negotiations have been held with various Fraser River Indian Bands for the purpose of securing a reduced exploitation on certain stocks, although the total Indian Fraser River chinook catch has averaged about 18,000 per year for the period 1970 - 1983. Since the precarious state of the Fraser River chinook stocks has been recognized, all targeted fisheries on chinooks have been closed and other regulations have been passed to reduce the incidental catch of chinook. All this indicates that many management options, particularly those applied to the Fraser River fishery itself, have been exhausted and that opportunities for restoration of this stock by management action are limited to those affecting very wide geographic areas.

**CHINOOK POTENTIAL**

It is apparent from a comparison of Departmental and Alcan habitat data with escapement data that the capacity of the spawning grounds has never been reached within the period of record. In the past 10 - 12 years (1983 excepted), there has been a modest trend towards increased escapements. If this modest rate of recovery can be sustained and further augmented by the benefits accruing from wide ranging restrictions on various coastal fisheries, it is possible that escapements of 5,000 could realistically be attained in three cycles. This then is the fish potential to which Alcan must gear its mitigative and compensatory considerations.

Kemano River

**KEMANO RIVER ESCAPEMENT RECORD**

The Kemano powerhouse became operational in 1954 and the low flow regime of the river was gradually expanded, while the mean monthly flows for the two high runoff months increased 80% in the last 15 years. As a consequence, the available habitat for salmon has expanded markedly. Assuming the impact of this increased habitat area and stability began to be demonstrated in 1959, a comparison of pre-and post-development escapement averages (1934 - 1982) is presented. Average coho escapements declined from 12,313 to 4,881. This apparently has been the only Kemano stock which appears to have been negatively affected by the increased flows. The chinook escapement average increased from 1,500 to 2,000. Average chum escapements have increased from 18,700 to 42,000 while average pink escapements have increased from 34,000 to 60,750.

**POTENTIAL APPROXIMATED**

It can be expected that the potential of the Kemano River could be expanded beyond the 200,000 pinks and 100,000 chums which occupied the habitat in 1972. The extent of this growth in potential cannot be predicted at this time because it will depend upon the quality and extent of the habitat that may be created by the expanded flow regime, and the degree of success achieved in the management of the Area 6 mixed stock fishery, which more

than any other factor, dictates the health of Kemano River pink and chum stocks. It also seems reasonable that the potential for coho will decrease because coho micro habitats may be lost as the river assumes larger physical proportions. Chinook potentials may increase.

## 11. TOWARD NO NET LOSS OF FISH PRODUCTION

**COMPENSATION LAST RESORT**

If Kemano Completion proceeds an exhaustive examination of all possible approaches to mitigation will be vigorously pursued by the Department. Notwithstanding that, it should be apparent to the reader that in many instances there will be no way found to mitigate some of the impacts and losses to the fisheries resource suggested by the development of this project. Compensation for the remaining losses must then be considered. Consideration of compensation in return for losses and impacts to the resource must be viewed as a last resort for it should be obvious that there is no perfect substitute for lost natural salmon production and habitat.

**NATURAL PRODUCTION**

The Department's approach to compensation for fish losses stems from its' developing habitat management policy. Compensation is sought firstly as natural production, secondly as some form of semi-natural production and lastly as artificial production. Techniques that provide the least interference with the genetic integrity of the natural stocks and have the greatest chance of success are considered first. In recognition of the Department's approach, Alcan has developed some preliminary views on opportunities for compensation. As the requirement for compensation would most probably constitute a major component of any decision on the acceptability of the project a discussion of possible opportunities is presented for consideration. At this point in time no discussion of compensation in the Kemano River is presented.

Nanika River

Alcan proposes to divert 62% of the mean annual flow of the Nanika River to the Kemano Reservoir. The bulk of this flow would be drawn off in the four month period - May through August - which is the normal high flow period in the river. This diversion would have three principal consequences. It would:

**CONSEQUENCES OF DIVERSION**

1) Greatly reduce the nutrient input into Morice Lake;
2) Greatly reduce the capacity of the Nanika River to produce chinook and coho salmon, and;
3) Substantially reduce the discharge of the Morice River during the high flow months of June, July and August.

**ESTIMATES OF IMPACT**

Alcan has estimated that reductions of rearing area of 90% for coho and 70% for chinook would occur as a consequence of the Nanika Diversion. Using their escapement estimates of 275 chinook and 350 coho, they have translated losses of rearing habitat into total stock losses of 250 chinook and 1,200 coho. The Department considers that the catch to escapement ratios used to derive total stock losses are erroneous. This has led to substantial overestimation of coho losses and underestimation of the chinook

losses. Furthermore, the Department regards the potentials of the Nanika River to be in the order of 400 chinook and 500 coho. Consequently, the re-adjusted potential total stock losses become 1,000 chinook and 900 coho adults. On the positive side, it is possible that flow stabilization could benefit those chinook and coho populations remaining by increasing their rate of survival as long as good water quality conditions can be assured. The extent of this benefit is subject to speculation but it is unlikely to adequately offset losses of rearing habitat.

**EXPECTED FISH LOSSES**

**GLACIER CREEK DIVERSION**

Alcan is considering diverting the cold and silt-laden Glacier Creek water into the Nanika Reservoir. This could improve some characteristics of the Nanika River which now is extremely turbid, naturally silted and cold for two-thirds of its length owing to the Glacier Creek inflow. Temperature regulation might be required to provide suitable temperature conditions. The actual benefits of such a consideration could only be identified after the fact.

**CONTROLLED REARING ENVIRONMENTS**

If the project proceeds, the disruption of natural rearing environments by extreme flood discharges would not occur. This may present an opportunity to develop controlled but natural rearing environments in the Nanika. The feasibility or benefits of any such opportunity cannot be determined beforehand, especially in the absence of detailed proposals. These opportunities would probably be more successful if the Glacier Creek diversion were implemented.

**NANIKA RIVER IS SOURCE OF NUTRIENTS FOR MORICE LAKE**

The Nanika River is the principal source of nutrients into extremely nutrient-poor Morice Lake. It is in Morice Lake where the Nanika juvenile sockeye rear for two or three years. Their length of residency is largely dependent upon their rate of growth which is dependent upon zooplankton availability. The loss of nutrient input associated with the diversion of 62% of the annual Nanika River discharge is expected to exceed 62% because nutrient input is higher during the spring freshet and virtually all of the flows will be diverted at that time. Sockeye populations would not be sustained at their present level let alone potential levels with this magnitude of nutrient loss. Alcan has suggested lake enrichment technology to offset this loss.

Morice River

**NANIKA DIVERSION WOULD IMPROVE WINTER CONDITIONS IN MORICE RIVER**

The Nanika Diversion and the flow regime proposed for Nanika has negative consequences for the Morice River flow regime. There would be reductions ranging between 41 and 32% in the peak mean monthly discharges in the months of June, July and August. Alcan has suggested that the Nanika reservoir be operated in such a way as to release more water than is now naturally available in the Morice River during the months of March and April. These increases expressed as percentages will range from 6 to 10%.

**LOSSES OF SUMMER REARING HABITAT**

Alcan has estimated that the summer flow reductions in the high discharge months will reduce the sidechannel habitat by 8 to 30%. On the basis of their original data, sidechannels of the Morice account for 28% of the chinook production and 37% of the coho production. Assuming incorrect catch to escapement ratios, and escapement potentials of 8,000 chinook and

4,000 coho, they have calculated that the losses resulting from the diversion would be 1,300 chinook adults and 1,650 coho adults. Alcan subsequently increased their estimation of sidechannel production to 46% for chinook and approximately 40% for coho.

**EXPECTED FISH LOSSES**

The Department views the realistic potential escapement as being 12,000 chinook and 10,000 coho. Consequently, the potential losses to fish production would translate to 8,300 chinook and 3,000 coho. It is very uncertain that the benefits of improved winter flow conditions would increase the smolt output to the extent required to offset losses to current populations, let alone the potentials to which the Department proposes to manage the system.

**WINTER CONDITIONS FOR REARING COHO AND CHINOOK IMPROVED**

Alcan has indicated an acceptance of the need to compensate for fish losses with a preference for reliance on habitat improvement or artificial incubation and subsequent natural rearing. Clearly, the approach of improving winter flow conditions proposed by Alcan is a very good recommendation supported by good data that indicate that natural winter flow conditions are the direct cause of substantive mortalities to overwintering salmonids. However, there is no comparison available to show how much habitat will be improved to enable estimates of production gains to be calculated for different increments of flow release. For the Morice River, Alcan has suggested a three-pronged approach to compensation. They are considering various approaches to habitat development to compensate for lost rearing areas and they are considering wild fry rearing and smolt replacement as ways to further compensate for lost habitat and salmon production. Included in habitat development are:

**ENVIROCON'S APPROACH TO COMPENSATION**

1) Maintenance of selected back and side channels;
2) Creation of coho rearing ponds;
3) Instream improvements;
4) Stream fertilization;
5) Tributary access improvement, barrier removal;
6) Tributary flow control.

**SPECIFIC COMPENSATION PROPOSALS NOT ADVANCED**

With the exception of stream fertilization, all of the above are proven methods for improving the productivity of the habitat, although they have not been applied in any system on the scale that would be required here. Stream fertilization technology is still experimental. However, Alcan has not made specific proposals regarding any of these approaches. This may be due to the many uncertainties about the scale of losses likely to accrue and the lack of information needed to design such proposals. However, it would appear that Alcan has considerable biological information on hand that could be employed to identify opportunities for pilot scale investigations.

**FRY PLANTING PROPOSALS**

Wild fry rearing by Alcan's definition involves planting artificially incubated fry from native donor stock into under-utilized areas. This becomes feasible if spawning escapements are considerably less than optimal or if substantial stream lengths above obstructions to salmonid migration

are suitable. Only in the latter case might it be considered a reasonable long term option. With the prospect of diminished flows, fry planting might well compound a habitat shortage problem unless it were undertaken to optimize any habitat development activities.

**SMOLT REPLACEMENT**

Smolt replacement is a viable but costly alternative to natural smolt production since chinook as well as coho production would involve rearing for 12-14 month periods.

**PROPOSAL FOR CHANNEL MAINTENANCE**

Alcan has proposed a temporary dam structure at the outlet of Morice Lake as means for providing an artificial flood surge to maintain the existing channel configuration. This approach is of uncertain merit. It may be more appropriate to consider more direct means of channel maintenance.

**POSSIBILITY TO AUGMENT WINTER FLOW CONDITIONS**

There is, however, merit in considering a control of the outflow from Morice Lake to augment the low winter flows which the consultants have shown is affecting chinook, coho and trout survival. It is possible that a few feet of storage could be developed on Morice Lake that would appreciably increase the low winter flows in Morice River.

Nechako River

Alcan proposes to divert 80% of the mean annual flow (1957-1981) now remaining in the Nechako River through the Kemano Reservoir and into new powerhouse facilities at Kemano. This diversion has four principal consequences which must be addressed to protect the existing and potential chinook and sockeye salmon stocks of the Nechako system. These are the maintenance of:

**PRINCIPAL CONSEQUENCES OF NECHAKO DIVERSION**

1) Satisfactory water quality regimes, such as temperature and total dissolved gases, in the Nechako River between the Nautley River and Prince George to ensure safe migratory conditions for adult sockeye salmon on their way to their respective spawning grounds and to provide suitable conditions for rearing chinook, particularly in the Upper Nechako;

2) Adequate spawning capacity for chinook salmon utilizing the upper Nechako River;

3) The maintenance of adequate rearing capacity for juvenile chinook salmon native to the upper Nechako River; and

4) Assessment and amelioration of potential impediments to migration at points of difficult passage downstream of Prince George.

**WATER QUALITY PROBLEMS MUST EMPLOY MITIGATION**

Alcan proposes to mitigate rather than compensate for the first three problems through controlled flow releases affecting both volume and water quality. It has not addressed the fourth.

**WATER QUALITY PROBLEMS MUST EMPLOY MITIGATION**

The resolution of the water quality problems is dependent upon mitigative and not compensative approaches. While approaches have been discussed previously, solutions remain to be found.

**FLOW REGIME FOR 3,000 CHINOOK**

With reference to the chinook populations, Alcan has proposed a flow regime they believe will sustain an escapement of 3,000 fish which is considerably short of the Department's target.

**DEPARTMENT'S VIEW OF ADEQUACY OF FLOW PROPOSALS**

As has previously been discussed, the proposed flow regime for the September spawning period would probably accommodate 5,000 spawners. However, the Department holds the view that the overwintering flows proposed would place incubating eggs at great risk, because there is no margin of safety for severe winter conditions or ice-generated localized fluctuations in water levels. These flows also serve to provide rearing for overwintering chinook in the Upper Nechako River.

There has been no study done on overwintering chinook to establish their abundance, significance or rearing requirements. The summer rearing requirements for chinook cannot be established for the progeny of 5,000 potential spawners because all the information necessary to make such an assessment has not been obtained or is in dispute. The problem of establishing summer rearing flows is compounded by the possibility that the need to control and depress temperatures in the Upper Nechako River for sockeye cooling purposes may preclude the optimization of chinook rearing there. If the project is to be completed, and on the assumption that long-term monitoring would reveal that rearing conditions are limiting chinook production, it would be necessary to identify approaches to compensation for those losses. As has been stated, the preference would be to use a semi-natural approach to resolve the problem. It may be difficult to obtain acceptable mitigation by using the remaining river channel in view of the 94% reduction from the original natural peak flow regime. Given this reality, a solution for offsetting the impacts of the Nechako River Diversion may be the mitigation of the sockeye requirements by regulating the temperature of their migration route and the maintenance of chinook production by full artificial hatchery enhancement. To date, this possibility has not been considered by Alcan and its consultants because they have held to the conviction that the chinook salmon potential would not be diminished by the proposed reductions in flow.

**HATCHERY MUST BE REQUIRED TO SUSTAIN CHINOOK POTENTIAL**

## 12. DISCUSSION

**SCOPE OF KEMANO COMPLETION PROJECT**

The scope of the Kemano Completion Project is enormous. Its overall cost has been estimated to be $2.2 billion. A glance at Figure 1 shows that a chain of lakes 200 km. (124 miles) long has already been impounded to form the Nechako Reservoir. Just less than half of the reservoir's capacity is now being used to power the Kitimat smelter which has a production capacity of 240,000 tonnes per year. Alcan now proposes to divert even more water from the Nechako Reservoir (a 88% reduction of the pre-Kemano I flow regime) and in addition would like to divert 62% of the mean annual flow of the Nanika River in order to generate the power that would be needed for

two new smelters. To achieve this goal would require the diversion to Kemano of 86% of the combined mean annual flows of the Nechako and Nanika watersheds.

**ALCAN CAUSES HABITAT PROBLEM NOW IN NECHAKO**

The Nechako in its diminished state has already presented the Department with salmon habitat maintenance problems. One, for example, has been to maintain sufficiently cool water temperatures in the Nechako River to prevent large runs of migrating sockeye from being destroyed. Now the Department is faced with a proposal that would impact upon the habitat of salmon (and steelhead and resident trout) in two hitherto pristine rivers; the Nanika and the Morice.

**DEPARTMENT HAS A POLICY OF "NO NET LOSS"**

In all cases, the Department does not insist that the waters of all salmon rivers be reserved for the sole purpose of producing salmon, but it does adhere firmly to the more reasonable position of "no net loss". In other words, potential users of salmon waters must plan to avoid as many losses to salmon production as reasonably possible, and "after the fact" they must stand ready to fully compensate for all damage. For the Department to require less would be to abandon its mandate which is to protect and preserve the fisheries resources of Canada.

**NATURAL HABITAT HARD TO REPLACE**

There is no perfect substitution for natural salmon habitat. If habitat is lost, the loss is likely to be irretrievable. One can partially compensate by producing salmon by alternative methods, but the substitution can only be regarded as second best: for one thing, in the case of hatchery production, the fish may not have the genetic characteristics of the wild stocks, and for another they are costly to produce. Moreover, it is a cost that must be borne in perpetuity.

**RETAIN AS MUCH NATURAL HABITAT AS POSSIBLE**

When other water uses are seen to be important to the public interest, the Department strives first to reduce the severity of impacts; i.e., mitigate as much as possible. If that is insufficient, the Department accepts compensation (in fish production, not monies). Moreover, and most importantly, the compensation is sought firstly as natural production, secondly, as some form of semi-natural production, lastly as artificial production. This distinction arises from the recognition that wild fish are the essential base of all our fisheries. We are, therefore, committed to the maintenance of natural habitat which has the capacity to yield salmon at no cost (except that of its safekeeping) for many years to come.

**THREE SCENARIOS FOR PUBLIC DISCUSSION**

To provide a focus for public discussion of issues embodied in the Kemano Completion proposal three possible decision options or scenarios are presented, together with a summary of the key fish production and habitat impacts anticipated with each scenario. The present situation (status quo) is discussed first. In the second scenario it is assumed that the Nanika River would not be diverted, and in the third which incorporates Alcan's proposal, it is assumed that the Nanika River would be diverted.

Scenario 1 The Present Situation

In this scenario it is assumed, based on the period 1978-1982, that the existing mean annual flow that is now being used to generate power for

aluminum production would continue to be used for that purpose, but that the remainder of the reservoir's mean annual flow, augmented by the mean annual flow of the Cheslatta River, would be used for fisheries purposes.

**LARGE FLOWS PRESENTLY REQUIRED FOR SOCKEYE COOLING CAUSE HARMFUL EFFECTS**

Because water that is now released from the reservoir via the Skins Lake spillway is subjected to considerable warming during its passage through the Cheslatta and Murray Lake system, it has been necessary to release very large flows from Skins Lake for sockeye cooling purposes. Despite large flow releases, it has not always been possible to depress temperatures sufficiently. The very large flows have eroded the banks of the Cheslatta River and have caused siltation of the Cheslatta and Nechako rivers.
The present method of providing sockeye cooling flows is considered to be a continuing threat to the chinook stocks of the Nechako River. The threat could be mitigated by providing a deep intake at Kenney Dam which would enable cold water to be mixed with warm water from the Cheslatta River so that such large flows would not be required. (This was recommended by the Department in 1950 when Alcan originally applied for the water licence.) Assuming that all water surplus to the needs of the Kitimat smelter would be used for fisheries purposes, a flow of 113.6 cms (4010 cfs) would be available for maintenance of fish habitat. Sufficient flow could be provided for cooling during sockeye migration and for chinook spawning, incubation, rearing and overwintering in the Upper Nechako River.

Scenario 2 No diversion of the Nanika River

In this scenario it is assumed that a deep intake at the Kenney Dam would provide a source of very cold water that would permit a constant temperature of 50°F to be maintained just below Cheslatta in the Upper Nechako River.

**MAINTENANCE INJUNCTION BASE FLOWS WITH IPSFC TEMPERATURE REGIME**

Scenario 2a. It is assumed that a base (Injunction) flow of 56.6 cms (2000 cfs) would be maintained in the Upper Nechako River to provide rearing area for chinook from April 1 to August 31. Flows would have to be raised by varying amounts (depending upon weather conditions) to provide for cooling during sockeye migration in July and August.

To target for maintenance of the IPSFC's long term average temperature during sockeye migration with maintenance of the Injunction Flow regime would require the provision of 43.8 cms (1546 cfs) or 21% of the water available from the reservoir and the Cheslatta River for fisheries purposes. The remaining 79% or 166.18 cms (5868 cfs) would be available for generation of power.

**MAINTENANCE OF ALCAN'S FLOW AND TEMPERATURE REGIME**

Scenario 2b. Under Alcan's proposed regime a base flow of 31.15 cms (1100 cfs) would be maintained in the Upper Nechako from April 1 to August 31. Flow adjustments in July and August would be required during sockeye migration.

To target for maintenance of Alcan's long term average temperature and their proposed flow regime for fish and other uses would result in 26.14 cms (923 cfs) being provided for fish. The percentage of water allocated to fish would be 12%; for power, 88%.

Water for maintenance of chinook would originate from the Cheslatta system and would reflect the influence of meteorological conditions upon that system (except during July and August). The temperature regime would not be the same in the Nechako River as it was prior to Kemano I. The effects upon chinook habitat that would result from the changed regime have not been fully addressed.

**IMPACTS OF INJUNCTION FLOW REGIME AND ALCAN'S COMPARED**

The impacts of Alcan's proposed flow regime have been discussed at length in Section 6.3. To summarize, negative effects upon incubating eggs and alevins could take place due to freezing during cold winters under Alcan's proposed flow regime. A loss of rearing area or at least a change in conditions of chinook rearing has probably occurred as a result of Kemano I. Reductions from the Injunction flow of 56.6 cms (2000 cfs) to 31.15 cms (1100 cfs) would probably result in further reductions in quality as well as quantity of rearing area. Further reductions in the quantity of available food could take place under the Alcan regime. Pre-Kemano flushing flows in the order of 509.8 cms (18000 cfs) used to take place in the spring. These flows would be eliminated with provision of either the Injunction Flow regime or Alcan's proposed flow regime.

**OTHER WATER QUALITY FACTORS REQUIRE EVALUATION**

With cool spring water temperatures, the solubility of gases increases, and may cause serious supersaturation problems to occur at a time of maximum susceptibility of chinook fry.

Increased concentrations of nutrients could cause algae and aquatic weeds to proliferate in the Nechako River, and the effects of increased concentrations of heavy metals cannot be predicted at this time.

Scenario 3 (With diversion of the Nanika River)

**MANY ADDED IMPACTS ANTICIPATED WITH NANIKA DIVERSION**

The negative impacts, risks and uncertainties that can be anticipated in the Nechako River under both Alcan's proposed regime and the Injunction flow regime were presented in Scenario 2. They would remain the same under this scenario, but there would be additional impacts upon the Nanika, Morice and Bulkley rivers.

Scenario 3a. In this scenario, it is assumed that the Nanika River would be diverted as proposed by Alcan. In the Nechako River, the injunction flows for chinook salmon and the IPSFC recommended temperature regime for sockeye would be maintained.

**SPECIFIC IMPACTS UPON NANIKA RIVER**

Scenario 3b. Scenario 3b is Alcan's proposed Kemano Completion project which includes the Nanika diversion and Alcan's Nechako River flows for fish and other uses and their recommended temperature regime for sockeye migration.

Nanika River Impacts

The implications of diversion of 62% of the mean annual flow of the Nanika River have been discussed at length in Section 4.3. Briefly, nutrient input into Morice Lake would be greatly reduced and would probably result in

the production of fewer and less viable sockeye smolts, unless the lake were artificially fertilized. Radical reductions in chinook and coho rearing area would occur. Unless chinook and coho fry were able to find sufficient opportunities for rearing in Morice Lake or the Morice River, the Nanika River chinook and coho populations would decline. Excessively high temperatures could occur in the Nanika River as a result of major reductions in flow during June, July and early August. Sockeye and chinook migration from Morice Lake to the Nanika River spawning grounds could be delayed. Greatly reduced spring flows could expose sockeye fry migrating to Morice Lake to increased predation. Reduced flushing flows could lead to a gradual deterioration of substrate quality that could affect spawning success and food production.

Maintenance of generally higher than average winter flows could have beneficial effects upon sockeye, chinook and coho during their incubation period.

Morice River

A full discussion of the impacts upon the Morice River that would result from diversion of the Nanika River has been presented in Section 5.3.

**SPECIFIC IMPACTS ON MORICE RIVER**

Losses of chinook and coho rearing habitat are expected during spring and summer in the Morice River. Major losses of habitat could reduce chinook and coho production. Major losses of presently utilized pink salmon spawning area could occur. Reduced November flows are expected to reduce coho spawning area, and access to some tributaries utilized by spawning coho may be impeded.

Maintenance of generally increased winter flows is expected to benefit the survival of all species during incubation. Overwintering losses of chinook and coho juveniles may be substantially reduced also by increased winter flows.

Bulkley River

**BULKLEY IMPACT**

Reductions in flow of up to 20% are expected in August during the upstream migration period of all species. Alteration of the fishways at Moricetown may be required.

One can see that diversion of two thirds of the mean annual flow of the Nanika River will cause impacts not only upon the Nanika River but also upon the salmon (steelhead and resident trout) habitats of the Morice and Bulkley rivers. It is impossible to predict with accuracy what changes in river morphology would occur as a result of the altered flow regimes and how the salmon populations would respond to the altered habitats that would be presented to them.

**SCENARIO 3 PRESENTS MOST RISKS**

Because the Nanika, Morice and Bulkley rivers as well as the Nechako River would be impacted, Scenario 3 carries with it the greatest risks and highest levels of uncertainty of all three scenarios.

In order to give the reader a sense of perspective relative to the amounts

of water that would be allocated under each scenario for generation of power for aluminum production as opposed to production of fish, Table 2 is presented.

| Scenario | Percent Flow for Fish | Percent Flow for Power |
|---|---|---|
| 1. Present Situation (Kitimat only) (No power sales) | 54 | 46 |
| 2a. No Nanika Diversion, Nechako Injunction Flows, IPSFC Recommended Temperature Regime. | 21 | 79 |
| 2b. No Nanika Diversion, Alcan's Proposed Flow and Temperature Regime. | 12 | 88 |
| 3a. Nanika Diversion Nechako Injunction Flows, IPSFC Recommended Temperature Regime. | 23 | 77 |
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**TABLE 2**

In general terms Alcan have indicated the amount of water required to generate power for two additional smelters. Further to this they have indicated that the minimum economic size for a new smelter would be 171,000 tonnes per year and that an optimum size is 200,000 tonnes per year. They have also indicated that the overall project is not economically viable unless two smelters are built.

**THE STATUS QUO CAUSES SERIOUS PROBLEMS**

Scenario 1 (the status quo) is an undesirable one from the Department's viewpoint, because it causes serious problems now. At the other extreme is Alcan's proposal (Scenario 3b) which would allow two smelters to be built, but two pristine rivers, the Nanika and Morice River would be severely impacted, and there would be no additional water left to maintain fish if it were required. The Department does not know whether the public would wish to support the status quo or Alcan's proposal, but it is obvious that the intervening scenarios (or variants of them) would allow a single large smelter to be built and at the same time provide flexibility, i.e., a surplus of water that could be used to maintain fish or to generate power.

**ALCAN'S PROPOSAL LEAVES NO FLEXIBILITY**

**FULL IMPACTS UNKNOWN UNTIL AFTER KEMANO COMPLETION**

As the reader will have perceived, it is one thing to identify and describe a possible impact upon salmon habitat, but a very different matter to predetermine its effects with accuracy. Regardless of which scenario, or variant thereof, is finally chosen, its impacts cannot be fully understood until after Kemano Completion. It is abundantly clear to the Department that, in the face of so much uncertainty and risk to the fisheries resources of Canada, the proponent will be expected to engage in considerable post-project assessment and monitoring. The need to retain the flexibility to adequately respond to the inevitable impacts, be they positive or negative, is essential.

# GLOSSARY OF TECHNICAL TERMS

## A

**Alevin:** stage of development of the salmonid embryo from hatching to absorption of the yolk sac. The yolk sac is generally the sole source of energy at this stage.

**Algae:** a grouping of primarily aquatic plants that lack true leaves, roots or stems.

**Anadromous:** going up river from sea to spawn.

**Aquatic:** pertaining to water; of the water (freshwwater, estuarine or marine).

## B

**Bedload:** particulates which are transported along the channel bottom in the lower layers of streamflow by rolling and bouncing.

**Benthic:** living in direct relation with the bottom.

**Benthos:** organisms, both plant and animal, living in direct association with the substrate of a water body (freshwater, estuarine and marine).

**Biomass:** the total particulate organic matter present beneath a unit surface area in a body of water.

**Biota:** the plant and animal life of an area or region.

## B (Cont'd)

**Brood year(s):** the calender year or years from which a particular adult salmon population originated.

## C

**Catch:** that part of the total population which is harvested by fishermen.

**cfs:** cubic foot per second.

**Channel:** a water way of discernable extent which continuously or periodically contains moving water, and has a defined bed and banks.

**cms:** cubic meter per second. 1 cms = 35.31 cfs.

**Compensation for loss:** the replacement of natural habitat or the maintenance of fish production by artificial means in circumstances dictated by socio-economic factors and where mitigation techniques are not adequate to maintain fish production.

**Cover:** an area of shelter in a stream that provides aquatic organisms with protection from predators and/or a place to rest and conserve energy (instream cover). Overhead cover is provided by overhanging banks, trees and shrubs and may provide a food source.

**Cycle:** the time interval required to complete all life stages from fertilization to death.

## D

**Debris (Organic):** logs, trees, limbs, branches, bark, and other woody material that accumulates in streams or other water bodies. May be naturally occuring or the result of man's activity.

**Detritus:** organic debris from decomposing plants and animals.

**Diminished river:** a river whose hydrology has been radically changed by a major permanent flow reduction.

**Discharge:** the rate of water movement past a given location in a stream; usually expressed as cubic metres per second (formerly cubic feet per second).

**Disjunct Distribution:** found in one location and not another.

**Dominant discharge:** the cycle of rising and falling flows in the vicinity of bank-full flows, sustained over a significant period so that it reconditions a natural channel by dislodging, transporting and distributing bed materials.

**Drainage area:** see Watershed.

**Drift:** voluntary or accidental dislodgement of aquatic insects from the stream or river bottom into the water column where they become more available as food items for fish.

## E

**Ecosystem:** an ecological system or unit that includes living organisms and nonliving substances which interact to produce an exchange or cycling of materials.

## E (Cont'd)

**Egg:** a germ cell produced by a female organism. A fertilized egg is a zygote.

**Emergence:** the act of or period when alevins leave the gravel and become free-swimming fry.

**Enhancement:** application of bioengineering technology to improve the survival rates of fish populations.

**Epilimnion:** the turbulent superficial layer of a lake lying above the thermocline which does not have a permanent thermal stratification.

**Escapement:** that part of a fish population that escapes the fishery - in the case of salmon to spawn.

**Estuary:** a semi-enclosed body of water which has a free connection with the open ocean and within which sea water is measurably diluted with freshwater derived from land drainage.

## F

**Fishery:** act, occupation, or season of taking fish or other sea products; fishing. A place for catching fish or taking other sea products. The right to take fish at a certain place, or in particular waters, especially by drawing a seine or net.

**Fishway:** a man-made structure installed at points of difficult passage or blockages in a stream to enable the fish to swim upstream under their own effort.

F (Cont'd)

**Flood plain:** flat land bordering a stream or river and subject to flooding; underlying materials consist mainly of unconsolidated material derived from sediments transported by the stream.

**Flow:** see discharge

**Food chain (food web):** series of organisms interrelated in their feeding habits, the smallest being fed upon by a larger one, and so on. Typically consisting of producers (plants), and consumers (animals) including herbivores (plant-eaters) and carnivores (animal-eaters).

**Freshet:** a rapid rise in river discharge and level caused by heavy rains or melting snow.

**Fry:** the young stage of fishes, particularly after the yolk sac has been absorbed.

G

**Gauging station:** a point on a river where water levels are measured either manually or by an automatic recorder from which discharge can be calculated.

**Geomorphology:** science dealing with the form of the earth, the general configuration of its surface, the distribution of land and water, and the changes that take place in the evolution of land forms.

**Gradient (stream):** the general slope, or rate of vertical drop per unit of lengh, of a flowing stream.

H

**Habitat:** generally, the place where an organism lives. Pertains to the conditions found at such locations, including the physical, chemical, and biological featrues such as substrate, cover, water and food.

**Historic flow:** those flows recorded at a given gauging station within a specified time span.

**Hydraulics:** the science which deals with the laws governing the behavior of water and other liquids in states of rest and motion. Hydraulics addresses special properties, such as velocity, depth, density, temperature, viscosity and pressure at specific points in a fluid.

**Hydrograph:** the graph of discharge versus time, usually daily discharge or monthly discharge over a period of one year.

**Hydrology:** the science that deals with the occurance, circulation, and distribution of water on a watershed, or larger area, and includes the relationship to the environment and living things.

**Hypolimnion:** the deep layer of a lake lying below the thermocline and removed from surface influences.

I

**Incubation period:** the life stage of fish extending from egg fertilization to hatching.

L

**Limnology:** the study of inland waters.

L (Cont'd)

**Littoral:** of or pertaining to the shoreward region of a body of water.

M

**Manageability:** the ability to regulate the fisheries on a stock or groups of stocks of fish to optimize fish production without over-harvesting other stocks which may occur in the fisheries at the same time.

**Mean:** arithmetic mean. The sum of all values divided by the number of values.

**Mean flow:** the flow obtained by taking the arithmetic mean of all the daily flows for the year.

**Mean monthly flow:** the arithmetic mean of the monthly flow for a particular month, for a specified historic period.

**Migration:** deliberate movement from one habitat to another. Includes the downstream movement of young salmonids from streams to sea and upstream movement of adult spawners to spawning streams.

**Minimum daily flow:** the lowest daily flow for a specified period, usually a calender year.

**Minimum mean monthly flow:** the lowest mean monthly flow.

**Mitigation:** actions taken during the development, design, construction and operation of works or undertakings to alleviate adverse effects on fish habitat and fish.

M (Cont'd)

**Monitoring:** part of field surveillance, involving the assessment of environmental protection performance and the measurement of environmental impacts.

**Monthly flow:** the flow obtained by taking the arithmetic mean of all the daily flows for a particular month for a particular year.

**Morphology:** study of configuration or form.

**Morphometry:** the form or shape of a lake or stream, including the contour of the bottom.

N

**Natural flow:** the flow in a natural river.

**Natural river:** a pristine river undeveloped and uncontrolled.

**Non-anadromous** fish: see resident fish.

**Nutrient:** chemical element (or compound) essential to the growth and survival of an organism. In aquatic systems, derived from land runoff and decomposition of plant and animal matter within the water body itself, and, in marine waters, from deep water upwelling.

O

**Obstructions (blockages):** any natural or man-made formation, object or formation of debris which impedes or blocks water flow and/or fish migration.

O (Cont'd)

**Oligotrophic:** waters with a small supply of nutrients and hence a small organic production.

**Overwintering period:** the rearing period for juvenile fish extending from December through March.

P

**Plankton:** aquatic, free floating, small living plants (phytoplankton) and animals (zooplankton).

**Pool:** that portion of a stream where the water is relatively deep and slow moving.

**Population:** a group of individuals of any species in a location or area.

**Potential production:** the maximum productive capability of a river given that the habitat available is fully utilized. In fisheries management terms would take manageability factors into account.

R

**Reach:** the length of river between two defined points.

**Rearing (fish):** Adj. growing; usually pertaining to younger stages- fry and juveniles.

**Redd(s):** the nest in the streambed into which eggs are deposited and subsequently buried.

**Regime:** with reference to a river, means the prevailing state of the river during some time interval or historic period.

R (Cont'd)

**Regulated river:** a river in which the flow or water level is artificially manipulated.

**Resident fish:** fish which remain in freshwater throughout their life cycle (non-anadromous).

**Riffle:** a shallow, rapid section of stream where the water surface is broken into waves by obstructions wholly or partly submerged.

**Riparian zone:** the zone immediately adjacent to streams or water bodies, with particular reference to the vegetation.

**Run:** a stream section of varying depth with moderate velocity and surface turbulence. Intermediate in character between a pool and a riffle.

S

**Salmonid:** refers to a member of the fish family classed as Salmonidae, including the salmons, trouts, chars, whitefishes and grayling.

**Sedimentation:** the process of subsidence and deposition of suspended matter carried in water by gravity; usually the result of the reduction of water velocity below the point at which it can transport the material in suspended form.

S (Cont'd)

**Smolt:** a seaward migrating juvenile salmonid which is silvery in color, has become thinner in body form and is physiologically prepared for the transition from fresh- to saltwater. The term is normally applied to the migrants of species such as coho, chinook, sockeye and steelhead which rear in freshwater for a period before migrating to sea.

**Solar radiation:** direct heating by the sun's rays.

**Spawning:** the act of deposition, fertilizing and burying eggs.

**Spawning grounds or areas:** those sections of a streambed known to be utilized by fish as a location for spawning activity.

**Species:** the smallest unit of plant or animal classification commonly used. Members of a species share certain characteristics which differ from those of other species, and they tend not to interbreed with other species.

**Stock:** a population of one species of fish which inhabits a particular stream, tends to spawn at a place or time separate from the other stocks.

**Substrate:** the materials making up the streambed; usually described as bedrock, boulders, cobbles, gravels, sands, and silts.

T

**Terrestrial:** Adj. pertaining to the land.

I (Cont'd)

**Thermocline:** the layer of water in a lake between the epilimnion and hypolimnion in which the temperature exhibits the greatest difference over a vertical direction.

W

**Watershed:** the total area contributing runoff to a river as measured above a gauging station or other fixed point. Generally synonomous with drainage area or basin.

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