

**SALMON STUDIES ASSOCIATED
WITH THE POTENTIAL
KEMANO II HYDROELECTRIC DEVELOPMENT**

VOLUME I

SUMMARY

FEBRUARY, 1979

VOLUME 1

SUMMARY OF SALMON STUDIES CONDUCTED
ON NECHAKO, MORICE AND NANIKA RIVER
SYSTEMS RELATIVE TO THE PROPOSED
KEMANO II POWER DEVELOPMENT

BY

THE FISHERIES AND MARINE SERVICE AND
THE INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

FEBRUARY, 1979

Although the major part of the funding for these studies was provided by the British Columbia Hydro and Power Authority, the findings and opinions expressed within the report are solely those of the author agency.

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INTRODUCTION

The Kemano II project is in effect the second stage of a hydro-electric development which was constructed in the mid-1950's. In order to place this new development in its proper perspective, it is necessary to have an awareness of the features and limitations of the installed facilities which are central to the expansion proposal.

The existing Kemano development, identified as Kemano I for purposes of this report, is owned and operated by the Aluminum Company of Canada Ltd. (Alcan) to supply the electrical needs of an aluminum smelter at Kitimat. The development consists of Kenney Dam, a 300 foot high rock-fill structure located at Grand Canyon on the Nechako River about 60 miles upstream of Fort Fraser, and the Skins Lake spillway structure containing two 35 foot wide gates plus an ungated 73 foot wide ogee section to permit the release of surface water from the reservoir to the Nechako River via the Cheslatta River (Figure 1). The reservoir created behind these two structures is approximately 350 square miles in area and with a 20 foot drawdown provides 4 million acre feet of live storage. An underground powerhouse containing eight impulse turbines is located on the Kemano River approximately 10 miles upstream from Gardner Canal. Water is conveyed to the powerhouse from the Nechako reservoir by a gated 10 mile long partially lined power tunnel and two steel lined penstocks. These facilities have a generating capacity of 815 megawatts, assuming seven of the eight units are operational.

During the early 1950's when the development was licenced and constructed there was a lack of public and political awareness about multiple resource use concepts and environmental issues. Consequently, these concerns, as expressed

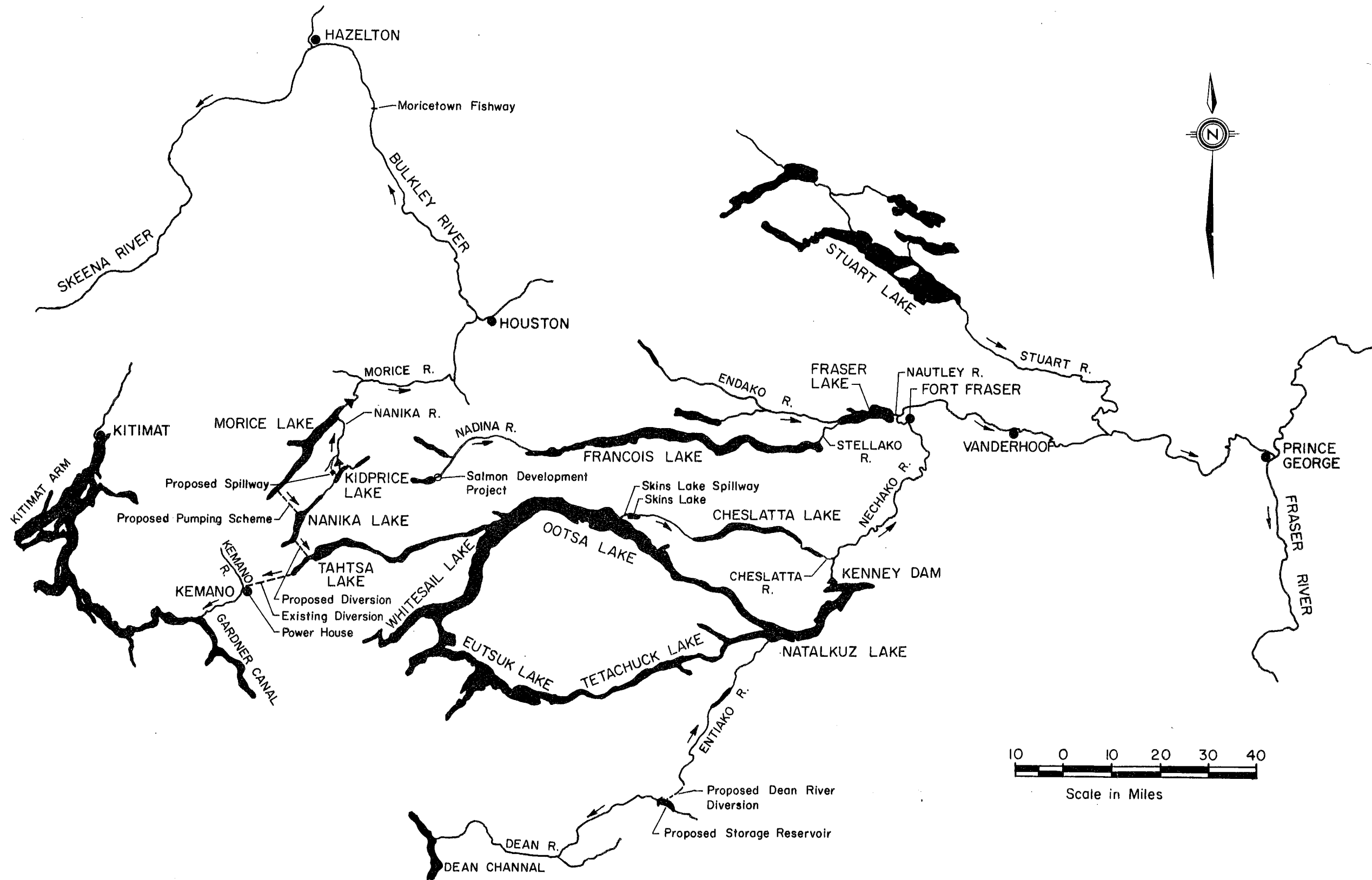


FIGURE I - Location Map of the Kemano II Power Development

by fisheries agencies at that time, were not reflected in the political and administrative decisions which were made to permit the development to proceed. The water licence issued in December, 1950 authorized the developer to store and divert all waters in the Nechako watershed upstream of Cheslatta River and all waters of the Nanika watershed upstream of Glacier Creek, approximately 3 miles below Kidprice Lake. There were no stipulations regarding the provision of minimum fisheries flow releases in either stream or for cooling water releases in the Nechako River despite recommendations by the federal Department of Fisheries and the International Pacific Salmon Fisheries Commission. Studies conducted by these two agencies from 1951 to 1953 led to the recommendations that adequate flows for fish transportation, spawning and rearing be provided for the protection of the Nechako River Salmon populations. Further, it was recommended that adequate quantities of cooling water be discharged from the reservoir to the Nechako River to maintain near normal temperature regimes. These recommendations were considered necessary because:

- a) adult chinook and sockeye salmon migrating to their spawning grounds in the Nechako River could be obstructed or delayed by points of difficult passage or inadequate water depth.
- b) substantial increases in summer water temperatures in the Nechako River would be caused by increased time of exposure to solar radiation thereby imposing a severe threat to Nechako River salmon stocks particularly sockeye.
- c) reduction in discharge would reduce the spawning area available to chinook salmon due to adversely changing velocities and depths. Such

reduction in flow could adversely affect the over winter survival of eggs deposited in shallower areas.

During the period of reservoir filling from October, 1952 to June, 1955, no water was discharged from the reservoir to the Nechako River and only intermittent releases were made between June, 1955 and January, 1957. Before the diversion, flows over the chinook salmon spawning grounds in the upper Nechako River normally ranged between 4,000 and 7,000 cfs during spawning. After diversion and the installation of a temporary storage dam on the Cheslatta River system, flows during the spawning period were reduced to approximately 600 cfs. As a result, much of the spawning area was exposed and this condition persisted until a continuous discharge from the Skins Lake spillway was obtained in January, 1957. Since that date, flow releases via the Skins Lake spillway have seldom been interrupted and discharges as high as 17,000 cfs have been recorded. It should be noted that the Nechako Reservoir is used as a flow control reservoir for the Fraser River system and discharges through the Skins Lake spillway are curtailed during those years when the flood threat is high. The streams draining Skins and Cheslatta Lakes were small in their natural state and when the large flows were released from the Skins Lake spillway, massive erosion of the stream channels occurred and much of the resultant silt and debris was deposited on the chinook salmon spawning grounds in the Nechako River. The combined factors of spawning ground dewatering and silt releases have undoubtedly contributed to an approximate 60 percent decline of the Nechako River chinook stock since 1952. High water temperatures have been recorded in the Nechako River since 1952, but because of fortuitous timing of the salmon runs relative to the periods of high temperature, losses of salmon attributable to the high temperatures appear to have been small.

The Nanika River diversion has not been built and the fish stocks of the Nanika-Morice River systems have therefore not been affected by the Kemano I development.

In 1970 the B.C. Energy Board was instructed to study provincial energy requirements and resources and to identify those energy resources, both public and private, which could best be developed to meet the projected requirements. During the same year, members of the provincial Cabinet began publicly discussing development of the unused Kemano capacity to meet provincial needs. This was identified as the Kemano II development and would require construction of a second power tunnel from Tahtsa Lake to Kemano River and expansion of the Kemano powerhouse to utilize the balance of the Nechako reservoir inflow as well as water from the Nanika River. In accordance with the terms of the original Alcan water licence, a dam would be constructed at the outlet of Kidprice Lake and a tunnel would be provided between Nanika Lake and the Nechako reservoir to allow diversion of most of the Nanika River flow. The Board also considered two possible additions to the original proposal. These additions involved the diversion of that portion of the Dean River extending upstream from the eastern boundary of Tweedsmuir Park into the Nechako reservoir via the Entiako River, and a pumping scheme to divert water from Morice Lake into the Nechako reservoir. A dam would be constructed at the outlet of Morice Lake to provide approximately 20 feet of storage for the pumping system. The scheme as proposed by the Board would increase power production from the Kemano powerhouse by an average of 740 megawatts.

In addition to the Nechako River, all other rivers which would be affected by the proposed development contain populations of Pacific salmon and steelhead trout. Of

primary concern are sockeye stocks in the Nechako and Nanika Rivers and Morice Lake, chinook stocks in the Nechako, Morice and Dean Rivers, pink stocks in the Morice River, and steelhead trout in the Morice and Dean Rivers. Coho salmon are found in all river systems except the Nechako River. The Kemano River, which would be affected by increased flows, contains all five species of Pacific salmon and steelhead trout.

Reduced flows or inundation of lakes resulting from the Kemano II development would also affect several species of resident fish. Diversion of water also poses a potential problem of parasite and disease transfer between adjacent watersheds. Loss of wildlife habitat is of particular concern in respect to flooding of terrain around Nanika and Kidprice Lakes, and the reservoir area on the Dean River.

In 1971 the Energy Board requested the views of the Fisheries Service concerning the provision of minimum flows on the Nechako, Nanika, Dean and Morice Rivers. Advice as to the minimum flows necessary to maintain fish production in the Dean and Morice Rivers could not be provided at that time due to a lack of biological and physical data. Minimum flow recommendations were provided for the Nechako and Nanika Rivers but these were not accepted by the Board and their proposed fisheries flow releases were below those considered necessary for fish resource maintenance. The minimum flow suggested by the Board for the Morice River was so low that no information was necessary to facilitate an objection to that proposal. These objections were subsequently conveyed to the B.C. Hydro and Power Authority early in 1973.

Early in 1974 discussions were initiated between representatives of B.C. Hydro and Power Authority, the Fisheries and Marine Service, the International Pacific Salmon Fisheries Commission and the Fish and Wildlife Branch. The purpose of these discussions was:

- (1) to identify those aspects of the project which would require resolution if the fish and wildlife resources were to be sustained as well as the means toward resolving these difficulties; and
- (2) to identify the additional information required to assess the implications of development on the fish and wildlife resources.

It was agreed that the fish and wildlife agencies would submit an outline of their environmental concerns and a proposal for future studies which they considered necessary for a sufficient assessment of the environmental problems. At the same time, the B.C. Hydro and Power Authority indicated a willingness to consider financing some of these studies providing they were closely related to the proposed power development.

As a result of these decisions, the Fisheries Service, the Fish and Wildlife Branch and the International Pacific Salmon Fisheries Commission jointly prepared an outline of concerns with respect to the fish and wildlife in the Nanika, Morice and Nechako River basins and a study proposal involving biological, physical and socio-economic aspects of the development. Cost estimates were also prepared on the basis that the studies might be completed in a one year

period. These were forwarded to B.C. Hydro on March 4, 1974. On April 26, 1974, B.C. Hydro indicated that it was prepared to fund the studies to the extent indicated in the cost estimates and the studies commenced immediately.

During initial discussions with B.C. Hydro on the Kemano II development it was recognized that diversion of the upper Dean River could have major impact on steelhead trout in the lower Dean River. Since salmon do not ascend the river as far as steelhead, they would be affected to a lesser degree. The Fish and Wildlife Branch indicated that a major research investigation would be required to assess the impact of the diversion on steelhead. Such investigations would have to span several years and definitely could not be completed within the time frame of the remainder of the studies. It was therefore agreed to exclude the Dean River from the studies, with any future consideration of the diversion being a subject of further discussions between B.C. Hydro and the Fisheries agencies.

While studies were not conducted on the Kemano River as part of the B.C. Hydro funded program, previous investigations by the Fisheries and Marine Service have tentatively concluded that the development would not have a major detrimental impact on the salmon resources of this river.

This report summarizes the results and conclusions of all biological, physical and socio-economic studies conducted on the Kemano II development by the Fisheries and Marine Service and the International Pacific Salmon Fisheries Commission.

CHAPTER ONE

REQUIREMENTS FOR THE PROTECTION OF
SALMON IN THE NECHAKO RIVER

Possible effects of the Kemano II development on sockeye salmon in the Nechako River were analyzed by the International Pacific Salmon Fisheries Commission. Field work was undertaken in 1974 and 1975 to obtain additional information on meteorological conditions and river topography so that changes in water temperature could be predicted over a wide range of flow conditions. Available information on existing and potential numbers of sockeye spawners, time of migration, observed prespawning mortalities, measured river temperatures, etc., was also assembled to provide a fuller understanding of the requirements for sockeye protection and to estimate the maximum daily discharge and maximum annual volume of cooling water required for temperature control.

The effects of flow reduction on chinook salmon in the Nechako River upstream of Fort Fraser were investigated by the Fisheries and Marine Service during 1974. Studies were conducted on two of the principal spawning areas to investigate the physical conditions under which these salmon spawn, and to determine the relationship between discharge and available spawning area. Requirements for incubation discharges were also considered. In addition, juvenile rearing characteristics of the river were investigated. Five rearing areas were selected at which water depth and velocity were measured and rearing populations sampled.

1. Nechako River Salmon Resource

Sockeye salmon migrate up Nechako River from the Fraser River each year in the period July 10 to October 5 (Table 1) en route to spawning grounds in the Stuart and Nautley River tributary systems. Chinook salmon migrate into the Nechako River after August 1 and spawn at various locations between Cheslatta Falls and Vanderhoof during the period September 1 to October 15. Chinook salmon also spawn in the Nautley and Stuart River tributary systems, but the mainstem Nechako River provides most of the spawning area within the system.

In the period 1938 to 1975 the annual number of sockeye spawners in the Nechako River tributaries has ranged from 3,600 to 866,000 with an average of 194,190 (Table 2). These stocks have produced a commercial catch averaging 798,000 sockeye annually in the period 1952 to 1972 (Table 3), which is 20 percent of the average catch produced by all Fraser River sockeye stocks in the same period. In addition, these sockeye runs are the source of a substantial Indian subsistence food fishery in the Fraser River system upstream from Mission. The average annual catch from the Nechako stocks has been 36,000 sockeye (Table 4), which is 31 percent of the total Indian food fishery catch for all Fraser River runs. Approximately 40 percent of the catch from the Nechako stocks is made from the early Nadina and early Stuart runs. These early runs are the first to move up the Fraser River each year and are of particular interest to the Indians.

Estimated annual chinook spawning populations in the Nechako River are presented in Table 5 for the period 1935 to 1977. Drastic declines in the run occurred following the Kemano 1 development. This was largely the result of the

TABLE 1. Timing of Adult Sockeye Migrations in Nechako River

Nechako River Location	NADINA RUN				STELLAKO RUN		STUART RUN			
	EARLY		LATE		Earliest Date	Latest Date	EARLY		LATE	
	Earliest Date	Latest Date	Earliest Date	Latest Date			Earliest Date	Latest Date	Earliest Date	Latest Date
Prince George	July 18	Aug. 14	July 25	Aug. 21	Aug. 12	Sept. 29	July 10	Aug. 9	Aug. 1	Sept. 6
Stuart	July 20	Aug. 16	July 27	Aug. 23	Aug. 15	Oct. 2	July 12	Aug. 11	Aug. 3	Sept. 8
Nautley	July 22	Aug. 18	July 29	Aug. 25	Aug. 18	Oct. 5				

TABLE 2. Sockeye Salmon Spawning Populations in Nechako River Tributaries

Year	Nadina River		Stellako River	Stuart System		Total All Runs
	Early	Late		Early	Late	
1938	272	-	6,943	7,671	62	14,948
1939	23	p	2,585	979	-	3,587
1940	70	-	3,276	335	279	3,960
1941	525	45	8,566	6,535	10,231	25,902
1942	686	-	91,840	8,474	p	101,000
1943	83	-	14,897	2,738	-	17,718
1944	29	-	5,768	717	46	6,560
1945	1,405	205	20,826	31,913	67,964	122,313
1946	1,401	-	245,172	9,243	2,116	257,932
1947	589	-	59,904	13,849	52	74,394
1948	291	-	16,213	20,960	1,049	38,513
1949	25,168	-	104,835	582,228	107,752	819,983
1950	4,325	774	145,108	59,443	5,843	215,493
1951	1,005	175	96,208	61,041	4,402	162,831
1952	2,829	38	40,466	33,582	1,975	78,890
1953	27,114	14,438	43,688	154,312	369,023	608,575
1954	2,032	770	141,882	35,058	5,470	185,212
1955	798	108	51,746	2,170	7,618	62,440
1956	1,613	83	38,459	25,157	1,454	66,766
1957	31,744	29,146	38,921	235,033	531,130	865,974
1958	854	718	112,273	38,812	23,638	176,295
1959	2,106	1,013	79,355	2,670	8,225	93,369
1960	1,755	157	38,884	14,572	2,961	58,329
1961	18,578	17,544	47,241	199,136	411,105	693,604
1962	758	1,683	124,495	26,716	18,689	172,341
1963	4,363	7,304	138,805	4,628	3,237	158,337
1964	1,597	232	31,047	2,421	1,900	37,197
1965	3,920	11,293	39,418	23,045	214,958	292,634
1966	93	1,784	101,684	10,859	9,032	123,452
1967	4,232	7,790	91,525	21,069	1,642	126,258
1968	1,021	1,496	30,420	1,587	470	34,994
1969	8,681	27,898	49,341	109,818	207,057	402,795
1970	78	3,939	45,876	32,747	15,055	97,695
1971	3,302	14,525	39,726	95,942	1,535	155,030
1972	966	2,702	36,771	5,086	8,704	54,229
1973	2,759	16,737	30,755	300,653	214,343	565,247
1974	34	3,825	41,473	51,536	14,627	111,495
1975	1,817	15,319	176,079	85,499	14,229	292,943

Uncha, Nithi, Ormonde, Endako included with Early Nadina.

Tagetochlain included with Late Nadina.

P = Some spawners were present but not counted.

- = No observations were made.

TABLE 3. Annual Commercial Catch of Sockeye Produced from Nechako River Tributaries

Year	Nadina River		Stellako River	Stuart System		Total All Runs
	Early	Late		Early	Late	
*1952	8,097	108	146,128	151,461	1,300	307,094
**1953	168,747	89,858	151,599	867,057	1,133,915	2,411,176
**1954	11,167	4,232	750,794	198,094	30,427	994,714
**1955	6,745	558	319,944	137,985	48,557	513,789
**1956	5,759	296	150,257	65,289	9,939	231,540
**1957	141,239	129,680	132,839	289,625	997,608	1,690,991
**1958	4,806	4,173	1,036,135	114,399	111,932	1,271,445
**1959	6,201	2,982	583,055	23,336	44,212	659,786
**1960	6,880	616	200,200	63,891	12,116	283,703
**1961	106,605	96,352	115,973	996,570	904,414	2,219,914
**1962	1,359	3,067	187,543	75,185	31,570	298,724
**1963	5,067	8,593	370,408	8,648	3,432	396,148
**1964	11,018	619	119,599	33,482	6,046	170,764
**1965	27,772	80,768	110,352	225,473	525,558	969,923
**1966	549	10,272	464,550	55,923	40,786	572,080
**1967	21,173	42,578	624,427	75,337	11,953	775,468
**1968	12,035	11,327	139,413	13,803	1,542	178,120
**1969	20,388	65,955	172,315	270,449	843,947	1,373,054
1970	265	25,155	287,624	27,526	76,204	416,774
1971	24,121	110,059	504,875	180,549	6,138	825,742
1972	7,466	56,622	98,641	12,126	27,472	202,327

* Does not include Johnstone Strait catches or non-Convention troll catches.

** Does not include non-Convention troll catches.

Tagetochlain Creek included with Late Nadina.

Nithi, Endako, Uncha and Ormonde included with Early Nadina.

TABLE 4. Annual Indian Food Fishery Catch of Sockeye Produced from Nechako River Tributaries

Year	Nadina River		Stellako River	Stuart System		Total All Runs
	Early	Late		Early	Late	
1952	424	6	6,770	6,671	485	14,356
1953	3,008	1,602	4,747	27,427	24,207	60,991
1954	246	93	17,459	8,673	783	27,254
1955	208	17	13,101	1,357	2,415	17,098
1956	274	14	6,590	3,077	1,020	10,975
1957	3,574	3,282	4,361	23,954	22,544	57,715
1958	73	63	9,562	4,467	3,262	17,427
1959	189	91	8,142	519	463	9,404
1960	362	32	8,415	4,134	389	13,332
1961	3,281	2,948	8,020	30,181	44,877	89,307
1962	106	239	19,068	6,631	4,768	30,812
1963	688	1,155	21,939	1,669	411	25,862
1964	866	49	14,008	10,805	708	26,436
1965	849	2,446	8,531	7,807	32,846	52,479
1966	15	292	16,840	4,300	1,264	22,711
1967	462	1,653	15,105	3,142	295	20,657
1968	988	401	14,482	12,807	135	28,813
1969	916	2,946	10,448	52,816	37,895	105,021
1970	88	4,377	15,476	22,897	2,762	45,600
1971	1,483	5,823	10,127	49,662	472	67,567
1972	1,346	4,908	8,969	6,976	4,011	26,210

TABLE 5. Estimated Chinook Salmon Spawning Populations in the Nechako River.

Year	No.	Year	No.
1935	1000-2000	1956	100-300
1936	500-1000	1957	- 2
1937	2000-5000	1958	- 2
1938	500-1000	1959	- 2
1939	1000-2000	1960	50-100
1940	2000-5000	1961	300-400
1941	1000-2000	1962	300-500
1942	300-500	1963	300-500
1943	100-300	1964	600-800
1944	100-300	1965	300-500
1945	500-1000	1966	400-500
1946	500-1000	1967	500-1000
1947	-	1968	300-500
1948	MEDIUM	1969	300-500
1949	2000-5000	1970	500-1000
1950	1000-2000	1971	300-500
1951	2000-5000	1972	300-500
1952	2000-5000*	1973	500-1000
1953	300-500 *	1974	500-1500
1954	1000-2000*	1975	1000-2000
1955	300-500 *	1976	1000-2000
		1977	2000-3000

1 Egg mortality estimated at 95%.

2 1957 to 1959 - Heavy silting of river resulting from high discharge from Skins Lake Spillway, made it almost impossible to observe fish.

large reduction in flows following closure of the Kenney Dam and the high levels of siltation which occurred throughout the upper Nechako River during the initial years of the Skins Lake spillway operation. The escapements have gradually increased in recent years and are now in the order of 2,000 to 3,000 adults. On the basis of escapements to the Nechako River relative to total Fraser River escapements, it is estimated that the average annual commercial catch during the period 1965 to 1974 attributed to the Nechako River stocks was 4,300 adults. An additional number of chinooks are also taken by sports fishermen in Georgia Strait and in the Fraser River as well as by the Indian subsistence food fishery.

Special restrictions were placed on the commercial and Indian Food fisheries during 1977 to conserve chinook salmon populations in the Fraser River system. It is believed that continuation of these restrictions in conjunction with the improved flow regimes which have been experienced in recent years in the upper Nechako River will result in substantial increases in the size of the Nechako chinook run.

It is estimated that the major lakes of the Stuart and Nautley River systems in which sockeye are reared are capable of producing an average catch of 5,500,000 sockeye annually. Approximately 42 percent of the expansion of existing Nechako system stocks to reach this level of production involves the early Nadina and early Stuart stocks. The remainder involves the late Stuart stock. Two-thirds of the unutilized lake rearing capacity for sockeye in the entire Fraser River system is in the lakes of the Nautley and Stuart River systems. It is expected that this salmon production potential will be developed in the near future. Large spawning channel developments in the lower Nadina River (Francois Lake), Ankwil Creek (Takla Lake), Kazchek Creek (Trembleur Lake) and Tachie River (Stuart Lake)

have been recommended by the Commission. At present the Commission operates a spawning channel on the Nadina River at the outlet of Nadina Lake to increase production of the late Nadina run.

The early Stuart run has shown dramatic improvement in recent years, primarily as a result of conservation measures implemented annually since 1967. The 1973 early Stuart total run, estimated at 1,360,000 sockeye, was the largest since 1900 and very likely the largest ever to the system. This run grew in two cycles from an escapement of only 23,000 spawners in 1965 and illustrates the tremendous production capability of the race under favourable conditions.

2. Flow Requirements for Preservation of Nechako River Salmon Stocks

2.1 Transportation Requirements:

With the existing Nechako diversion, flow in Nechako River downstream of its confluence with the Nautley has been considerably higher than the estimated minimum requirement of 1,000 cfs for migration of adult salmon. This transportation flow was considered to be necessary on the basis of studies made prior to the Kemano I diversion. Observations since that time have confirmed the need for this minimum transportation flow. Therefore, one requirement for protection of salmon is that there should be sufficient flow from the Nechako reservoir to provide a transportation discharge of not less than 1,000 cfs in the Nechako River between the Nautley and Stuart Rivers from July 10, when the sockeye begin their migration, until October 5, when the sockeye migration is completed. A discharge of not less than 1,000 cfs should also be provided in the Nechako River between the Cheslatta and Nautley Rivers during the month of August for migration of chinook salmon.

2.2 Spawning Requirements:

Sufficient flows are also required to provide spawning habitat for chinook salmon. To determine these requirements, studies were conducted during 1974 on two major spawning sites located approximately 5 to 6 miles downstream from Chelatta Falls. Water depth and velocity preferences of chinook spawners were obtained within each of these areas during the spawning period and are summarized in Table 6. These depth and velocity criteria were programmed in a simulation model together with topographical data for each site, and spawnable area was computed for various discharges. Since small pockets of unsuitable spawning gravel occurred throughout the spawning areas, the computed data cannot be interpreted as the actual areas available for spawning and therefore should not be used to determine the absolute number of spawners that can be accommodated at any particular discharge. The results, however, allow a relative comparison of spawning habitat available at various discharges.

TABLE 6. Redd Depth and Velocity Preferences of Nechako River Chinook Salmon, 1974

Spawning Site	No. Redds	Mean Depth (Ft)	Mean Velocity (fps)
Upper	67	2.53	1.85
Lower	34	2.75	2.15
Upper & Lower combined	101	2.61	1.95

The computer model yielded the gross spawnable area within each site for flows ranging between 100 and 6000 cfs (Figure 2). This indicated that the maximum available spawning area in both sites occurred at approximately 4000 cfs, which is representative of historic spawning discharge prior to the Alcan development. However, in an attempt to establish a more feasible flow regime for the Kemano II project, attention was focused on discharges ranging from 400 to 2000 cfs in increments of 100 cfs (Figure 2). In this range the maximum amount of spawnable area in the upper site occurred with flows between 900 and 1500 cfs and was equivalent to about 80 percent of the area which existed in this site at 4000 cfs. Similarly, the maximum spawning area in the lower site occurred with discharges between 1300 and 1400 cfs and was equivalent to about 75 percent of the spawning area available at 4000 cfs. Gravel availability is not considered to be a limiting factor in this river and it is believed that historic population levels could be accommodated within this discharge range of 900 to 1500 cfs. However, it is possible that the study sites were not entirely representative of other spawning areas in the river and to provide a small margin of safety, it is therefore considered that spawning flows in the Nechako River between Cheslatta and Nautley Rivers should not be less than 1000 cfs during the period September 1 to October 15.

2.3 Incubation Requirements

River discharge must be at a sufficient level subsequent to spawning to provide eggs or alevins with an adequate supply of oxygen and enough water cover to prevent freezing during winter months. The Nechako River can be exposed to extremely low atmospheric temperatures throughout most of the incubation period

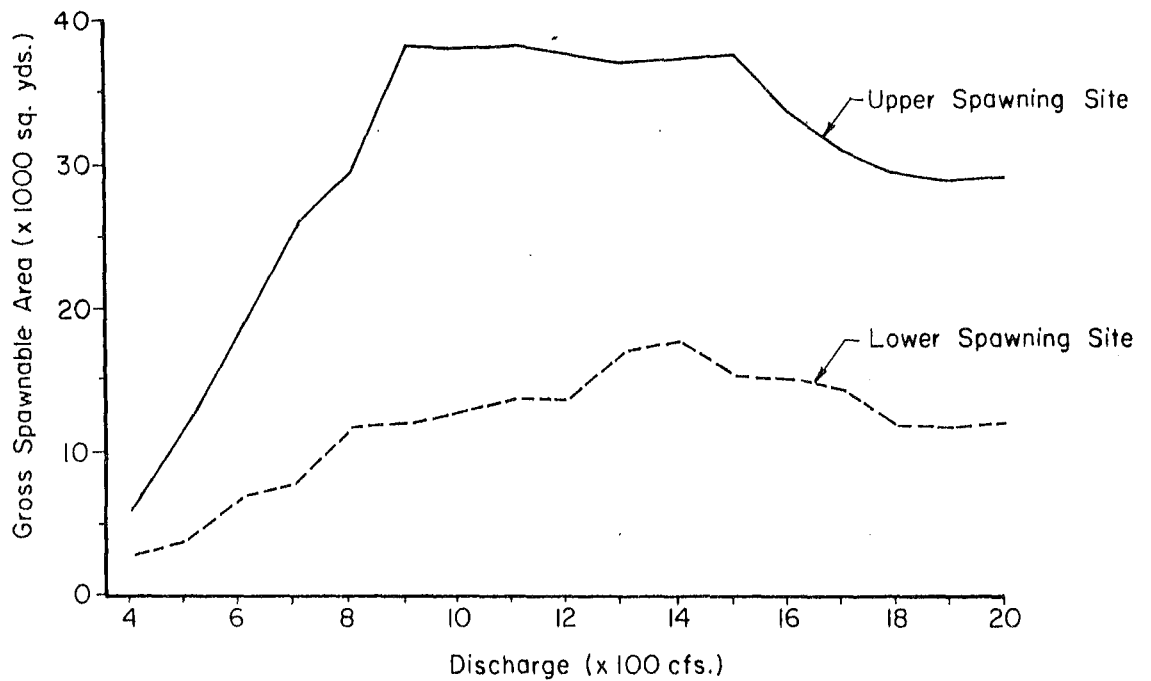
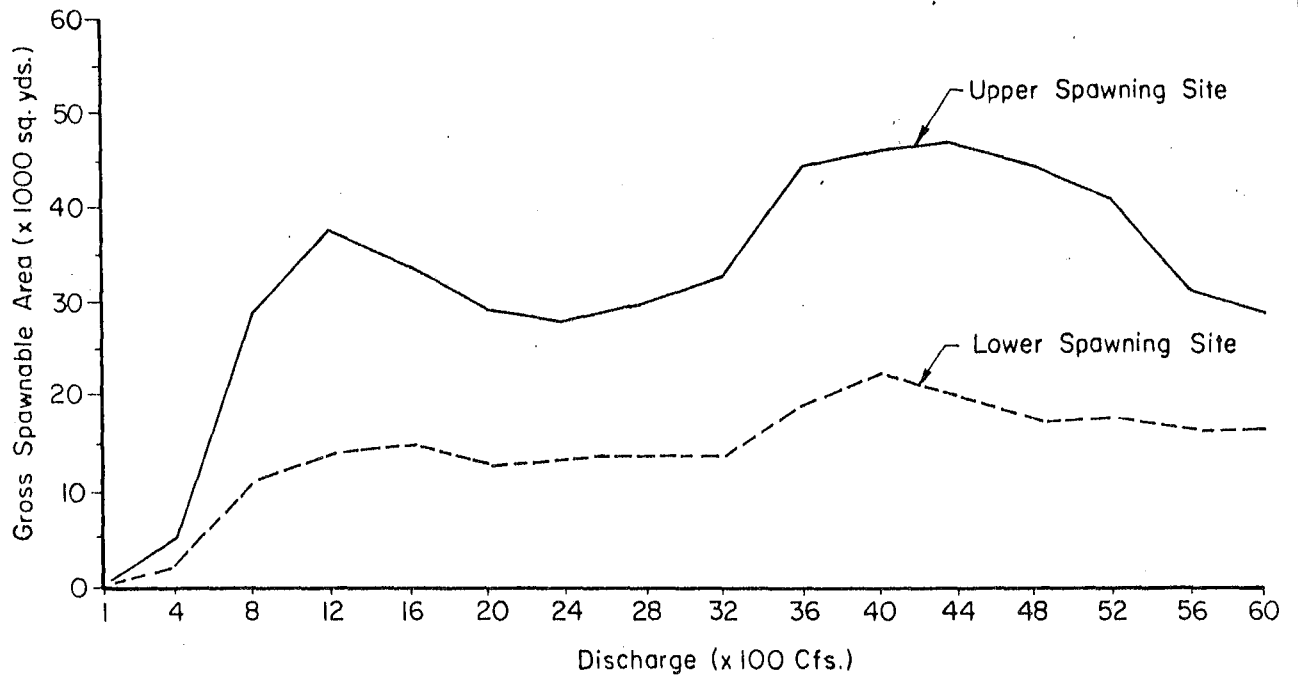


FIGURE 2 - Gross Spawnable Area in the Upper and Lower Spawning Sites of the Nechako River.

and large flow reductions during this time could lead to extensive egg mortalities through freezing of redds. The most critical period during incubation is in the egg stage prior to hatching. Alevins are capable of moving short distances through the gravel and it is therefore believed that they can escape areas of frost penetration brought on by a small and gradual reduction in discharge. Although actual hatching times are not available for the Nechako River, it is probable that most eggs have hatched by the end of January.

Prior to the Alcan development, winter flows in the upper Nechako River were only recorded during the winter of 1929/30. At that time the mean January flow was 43 percent of the mean September spawning flow. From 1957 to 1972 the mean January flow through the Skins Lake spillway averaged 36 percent of the mean September flow. On the basis of water level data obtained within the upper spawning site in 1974, this would represent a reduction in water level of approximately 2 feet from levels occurring with a normal spawning discharge of 5000 cfs. A considerable number of eggs were probably dewatered or exposed to frost under these natural circumstances.

Since 1972, the January incubation flow has averaged 92 percent of spawning discharge. In 1973 and 1974, incubation flows throughout each winter were in fact higher than at any time during the spawning periods. It is interesting to note that the 1977 chinook escapement, the largest since 1952, is comprised primarily of progeny from 1973 to 1974. Although special closures and gear restrictions were placed on the commercial and Indian food fisheries during 1977, it is possible that the favourable incubation conditions which existed in these years is an important factor in the expansion of this salmon run.

On September 5, 1977 the Skins Lake spillway flow was reduced from 3070 cfs to 1880 cfs. With the lag time required to deplete storage in Cheslatta Lake, it is estimated that flows in the upper Nechako River would have been reduced to approximately 2400 cfs by September 15 and continued to drop to approximately 2000 cfs by September 30. Inspections of the Nechako River by boat on September 13 and by helicopter on September 23 indicated that the peak of spawning occurred during the latter two weeks of September. Most of the spawning would therefore have taken place with a discharge range of 2000 to 2400 cfs.

Spillway flows have been maintained at approximately 1800 cfs since spawning ended in 1977. Inspections of the spawning areas upstream of Greer Creek during the latter part of October and mid-November revealed several redds in which the tailspill (gravel mound downstream of area excavated for egg deposition) was exposed to the atmosphere. Although it is unknown if this has resulted in actual egg mortalities, there is a definite possibility that the exposed gravel could allow frost to penetrate the redd. It is hoped that additional investigations can be undertaken this winter to determine the extent of frost damage, if any, and a number of redds have been marked for this purpose. In the interim, it is considered that incubation flows in the Nechako River between Cheslatta and Nautley Rivers should be at least as high as the flows provided during the spawning period. These should be continued throughout the winter until ice breakup occurs in the spring.

2.4 Rearing Requirements

Data obtained between 1974 and 1977 have indicated that the upper Nechako River is utilized by juvenile chinook salmon on a year-round basis. To adequately evaluate rearing re-

quirements for these juveniles, the interrelationships of many environmental factors such as water temperature and velocity, space, cover, behavior patterns, food predation, and competition must be considered. While some of these factors were investigated in 1974, the studies were by no means complete enough to fully assess rearing flow requirements. Additional studies, with more emphasis on food production and its relationship to discharge, would be required to determine these needs.

The amount of wetted riffle area in the Nechako River appeared to decline sharply when discharges were reduced below 1000 cfs. Since riffle areas are normally an important habitat for production of fish food organisms, it is considered that rearing flows in the Nechako River between Cheslatta and Nautley Rivers should never be less than 1000 cfs. Additional flows may be necessary during certain periods of the year to satisfy some of the requirements discussed above.

2.5 Flushing Requirements

Clean gravel beds are needed to ensure successful egg-to-fry survival. If flows are reduced in the Nechako River, it may therefore be necessary to provide high flows over the chinook spawning areas for a short period of time to flush out accumulated silt and debris. These flows should be released prior to spawning in years when they are considered necessary and may be timed to coincide with fry emigration, if subsequent studies indicate this to be desirable. Additional studies will be necessary to determine the magnitude of these flushing flows.

2.6 Temperature Control Requirements

Investigation of water temperature changes that could be expected as a result of the reduction in summer flow in Nechako River showed that the minimum flows required for transportation of salmon would have to be augmented by cooling water discharges in warm years. Available information indicated that the mean daily water temperature should not exceed 68°F for sockeye protection. This temperature limit was established by analysis of field observations and experimental data. Temperatures higher than 68°F have occurred following the initial diversion of Nechako water for power generation but because of fortuitous timing of the sockeye runs in relation to the periods of high temperature, losses of sockeye attributable to the high water temperatures appear to have been small.

River cross sections were surveyed at approximately 1 mile intervals in the 56 miles of Nechako River between Chelatta and Nautley Rivers and a computer program was developed to calculate water temperatures that would occur at the Nechako-Nautley junction at discharges of 500, 1,000, 1,500, 2,000, 3,000 and 4,000 cfs in the upper Nechako River with near-maximum heating conditions. Cross sections measured between the Nautley and Stuart Rivers for Kemano I studies and collection of additional data in this 60-mile reach of Nechako River were used to calculate temperatures immediately upstream from the Stuart confluence for discharges up to 5,000 cfs, in 1,000 cfs increments.

Previous studies concluded that temperature in Nechako River could be controlled by release of cold water from Nechako reservoir. This is still the only apparent means to control temperature if flows in the Nechako are reduced because of the Kemano II development.

The volume of cooling water required for limiting the mean daily temperature of 68°F was calculated for periods of near-maximum weather conditions based on maximum hourly air temperatures recorded in the region and estimated maximum solar radiation which could be expected in a hot year. This near-maximum weather condition was combined with actual Nautley River flow conditions to estimate the maximum amount of cooling water required. In 26 years of record from 1950 to 1975, maximum heating conditions occurred on July 31, 1960 and July 31, 1971. As shown in Figure, 3, about 3,950 cfs of 45°F cooling water would have been required for obtaining a mean temperature of 68°F in the Nechako River above Stuart River on July 31, 1960. For July 31, 1971 (Figure 4) the required 45°F cooling water discharge was indicated by extrapolation to be about 4,400 cfs. On the basis of these data, it was assumed that a maximum cooling water discharge of 4,500 cfs would be required. Colder water could be obtained from the Nechako reservoir but temperatures lower than 45°F at this time of year could have a detrimental effect on the chinook salmon population. Water with temperatures of 50° or higher would not provide the desired control temperature within the range of cooling water discharges studied.

Temperature records for Nechako River above Stuart in 1971 were used to estimate the total volume of 45°F cooling water required in a similar hot year. On the basis of the degree-days above 68°F, using 4,500 cfs for the maximum day, a volume of 107,000 acre-feet would be needed. Since the maximum flow required would take about 3 days to reach the Stuart confluence, it would be necessary to provide an additional 27,000 acre-feet of cooling water, for a total storage requirement of 134,000 acre-feet. In view of the long period of temperatures above 68°F in 1971 compared to the other years of records, it is considered that this would be the approximate maximum volume of 45°F cooling water required. Bathythermograph measurements showed that the required volume of 45°F water was available below 90 ft. of depth in Nechako reservoir near Kenney Dam.

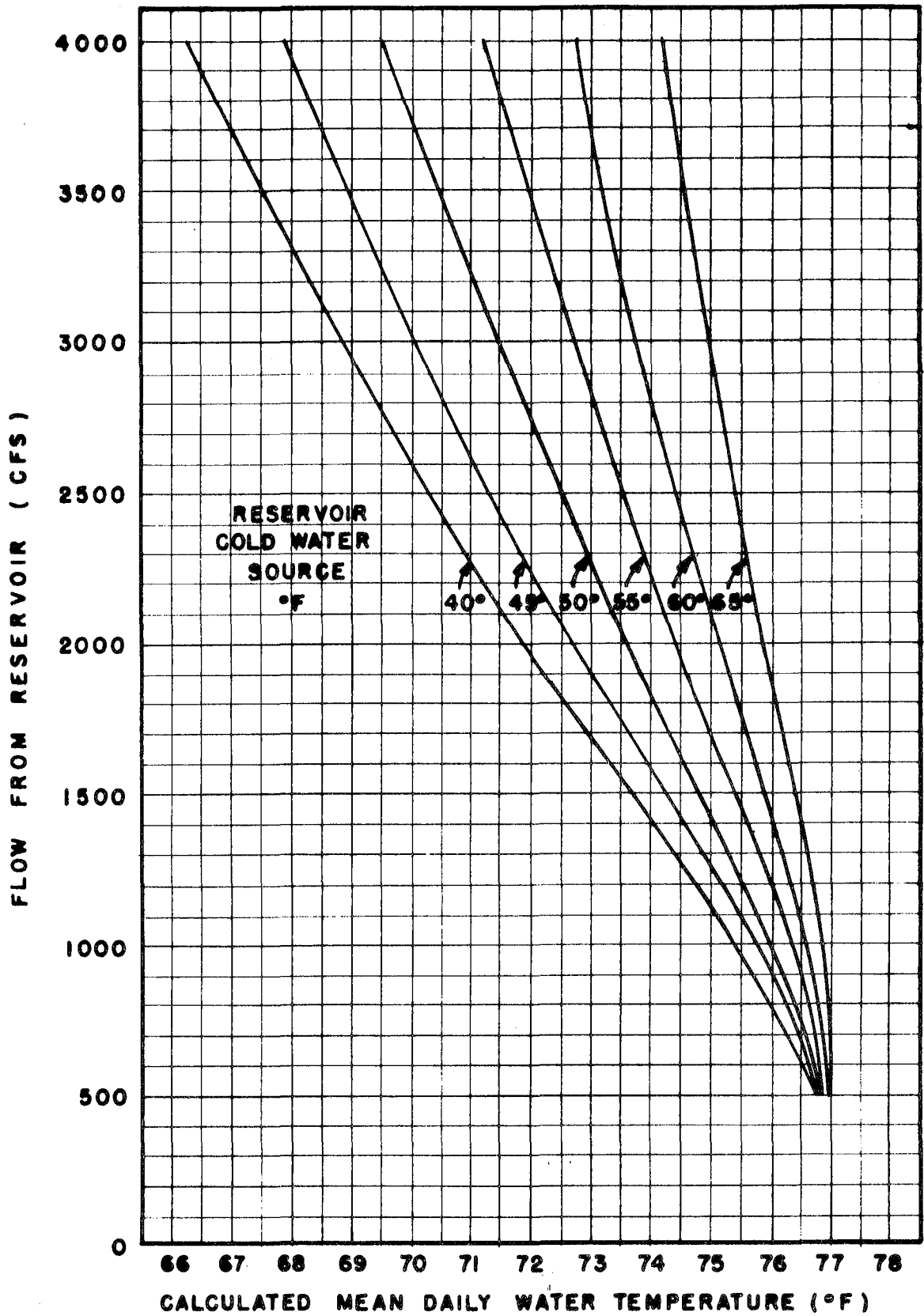


FIGURE 3. Effect of release of cooling water from Nechako reservoir on temperatures of the Nechako River above Stuart, July 31, 1960.

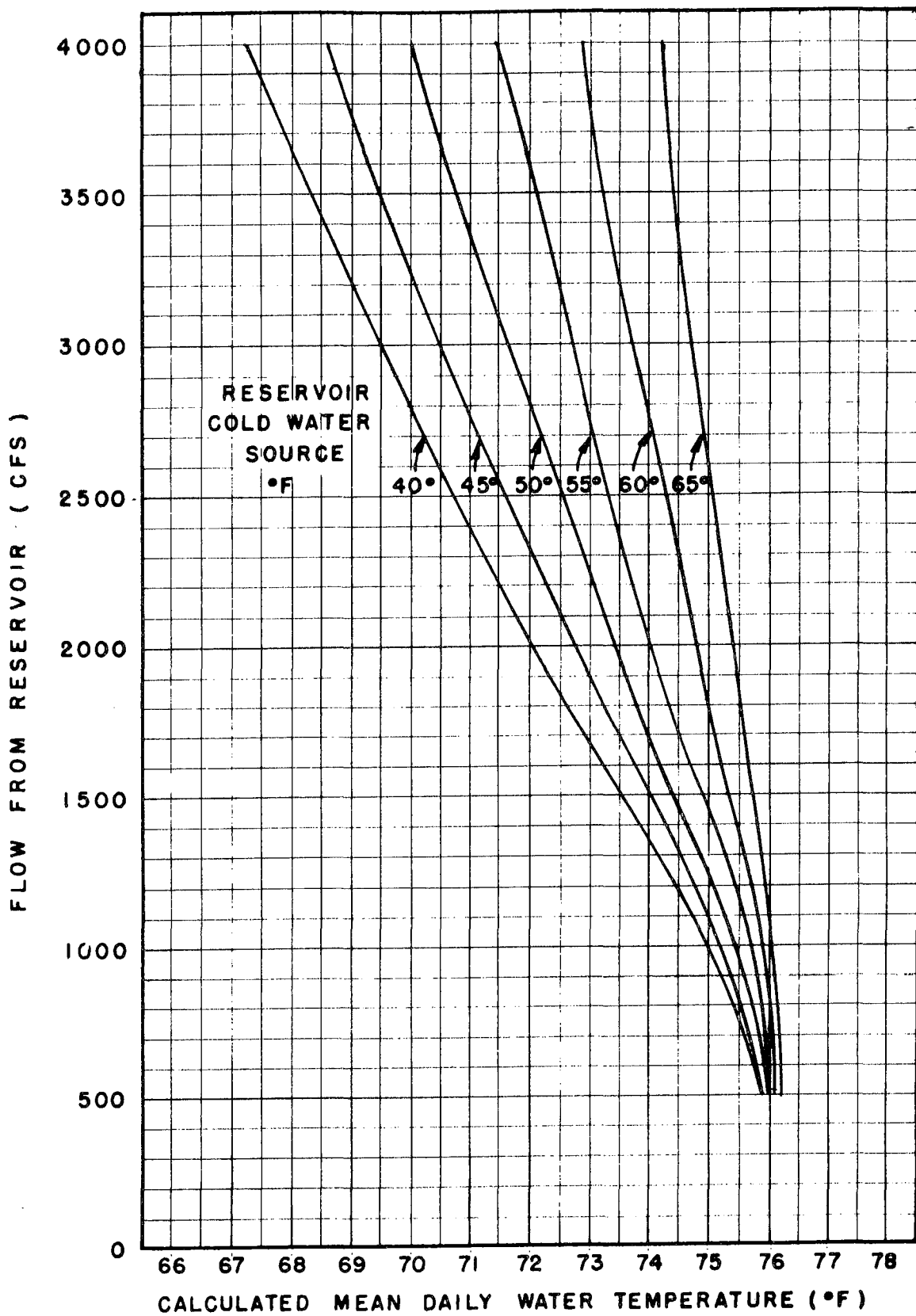


FIGURE 4. Effect of release of cooling water from Nechako reservoir on temperatures of the Nechako River above Stuart, July 31, 1971.

The duration of required cooling water releases was estimated on the basis of the sockeye migration period, weather conditions and the water travel time between the upper Nechako and the Stuart confluence. The earliest date that temperature control would be required is July 20. However, it would be necessary to gradually increase the cooling water flow in the upper Nechako to avoid scouring the river channel or adversely affecting chinook salmon and resident trout. For conditions similar to those occurring in 1971, a cooling water flow would have to begin about July 15.

Prior to the date when cooling water flows would be required, the flow in the upper Nechako should be 1,000 cfs for protection of rearing chinook salmon. This flow, which presumably would be routed through the Cheslatta system, would have to be replaced with 45°F cooling water when required. Calculations showed that it would be necessary to provide temperature control for the Nechako River above the Stuart confluence as late as September 6. Prior to August 30, the required cooling water discharge would be greater than the minimum flow required for protection of chinook salmon. From August 30 to September 6, the estimated maximum discharge of 45°F cooling water would gradually reduce from 1,200 cfs to 200 cfs with a concurrent increase in the Skins Lake releases to maintain a minimum river flow of 1,000 cfs for chinook spawning. If the total flow was 1,200 cfs, as indicated, no cooling water would be required after September 6.

The rates and total amount of cooling water calculated here apply to the Nechako River above the Stuart confluence. Computer calculations indicate slightly higher water temperature in the vicinity of Vanderhoof, which would require additional cooling water discharge. Records for 1974 also show increases in temperature between Stuart confluence

and Isle Pierre. Further study would be needed to determine the need for cooling water in the Stuart-to-Prince George reach and the additional quantity, if any, required.

3. Supersaturation Caused by Cooling Water

The concentration of dissolved gases in Nechako reservoir water near Kenney Dam was investigated during the 1974 and 1975 field surveys. Dissolved oxygen and nitrogen concentrations and saturation levels were determined at various depths in the Nechako reservoir near Kenney Dam and in the Nechako, Nautley and Stuart Rivers. There was increasing supersaturation of dissolved nitrogen in the Nechako reservoir at depths below 50 ft. to as much as 112% at 200 ft. depth. Conversely, there was increasing deficit of dissolved oxygen below saturation at depths below 50 ft. to as low as 57% at 200 ft. depth. In the Nechako River below the Cheslatta confluence, there was 112% saturation of nitrogen, which is attributable to the plunge basin in the Cheslatta River below Cheslatta Falls. As the water flowed downstream to Fort Fraser, the concentration of nitrogen decreased by 0.84 mg/l, indicating air equilibration. There was a slight supersaturation of oxygen below Cheslatta Falls, but the oxygen concentration stabilized downstream. Measurements in 1975 on August 13 and 14, at a time when water temperatures were increasing, showed supersaturation in the Nechako River at Fort Fraser and in the Nautley and Stuart Rivers.

If the Kemano II development was operated as proposed by the B.C. Energy Board, discharge in the Nechako River below Nautley would be almost the same as the discharge of the Nautley River, since there would be very little other inflow during critical summer periods. Calculations were made

to assess the magnitude of changes in dissolved gases that might be expected with near-extreme weather, using the Nautley River discharge and temperature on August 1, 1960 and 1971, and the dissolved gas concentration measured in the Nautley River on August 12, 1975. The calculations suggest that under these conditions, the total gas concentration would be approximately 108% of saturation (Table 7).

TABLE 7. Calculated Concentration of Dissolved Oxygen and Nitrogen in Nechako River above Stuart with only Nautley River Inflow and Assumed Near-Extreme Weather and Initial Saturation Levels

	<u>Percent Saturation</u>		Total
	Nitrogen	Oxygen	
August 1, 1960	105.0	117.7	107.4
August 1, 1971	104.7	119.9	107.7

Based on reaeration coefficients determined from measurements in 1974 and 1975, dissolved nitrogen and oxygen were calculated for a flow of 4,500 cfs of 45^oF water withdrawn from the Nechako reservoir. The results show that in the Nechako River above the Stuart, the concentration of both oxygen and nitrogen would be approximately 115% of saturation (Table 8). This level of supersaturation of nitrogen or total gas would not be sufficient to produce rapid mortality but would be sufficiently high to produce stress and/or impairment of some physiological processes, leading to increased susceptibility to disease. Resident fish would be affected as well as the migrating salmon.

If the cooling water was air-equilibrated at the point of release, the nitrogen supersaturation would be reduced only slightly above the Stuart, and oxygen supersaturation

would be increased (Table 9). The net effect would be a reduction of total gas supersaturation from 114.8% to 113.7%.

TABLE 8. Calculated Nitrogen and Oxygen Concentrations at Maximum Daily Water Temperature in a Cooling Water Flow of 4,500 cfs at 45° F from Nechako Reservoir under near-extreme Weather Conditions

Location	Temp. °C	OXYGEN		NITROGEN	
		mg/l	Percent Saturation	mg/l	Percent Saturation
Nechako Reservoir	7.2	9.49	87*	19.62	110*
at Cheslatta	7.2				
at Fort Fraser	16.3	9.64	107.6	18.21	119.8
Nautley River	22.8	10.09	128.2*	14.20	102.8*
Nechako below Nautley	18.1	9.77	112.8	17.06	114.9
Nechako above Stuart	21.3	9.40	115.2	16.32	114.9

* from records obtained in 1974 and 1975.

TABLE 9. Calculated Nitrogen and Oxygen Concentration at Maximum Daily Water Temperature in a Cooling Water Flow of 4,500 cfs of 45° F from Nechako Reservoir under near-extreme Weather Conditions with Aeration at Point of Release to Equilibrate with Air

Location	Temp. °C.	OXYGEN		NITROGEN	
		mg/l	Percent Saturation	mg/l	Percent Saturation
Nechako Reservoir	7.2	9.49	87*	19.62	110*
at Cheslatta	7.2	11.10	100	18.16	100
at Fort Fraser	16.3	10.53	117.5	17.38	114.0
above Stuart	21.3	9.82	120.3	15.93	112.2

* from records obtained in 1974 and 1975.

Further study of the supersaturated problem is recommended, including measurement of natural re-aeration factors in the river. It is also recommended that studies be made to assess possible effects of cooling water discharges, reduced summer temperatures in the upper Nechako, and increased nitrogen supersaturation on resident trout and both adult and juvenile chinooks in the Nechako River.

4. Downstream Effects of Flow Reduction

It was considered that the increased diversion of flow out of the Nechako system could have serious adverse effects on environmental conditions in the Fraser River and the estuary. Preliminary examination of available data indicate that if Kemano II were developed as recommended by the B.C. Energy Board, the smolt-to-adult survival rate would be reduced and as a consequence, it would be necessary to reduce the commercial fishery by about 6% to adjust for reduction in the number of returning adults. It was estimated that the combined effects of flow reduction due to Kemano I and II on survival of sockeye smolts would reduce the commercial fishery catch by about 9.6 percent. The reduced flow from Nechako River during summer months would cause higher temperatures in the Fraser River, which would increase the rate of prespawning mortality. Delay of adult sockeye in the estuary could also result from the reduction in discharge. Other possible environmental changes and the combined effect of other potential water-use projects, such as the McGregor-Peace diversion must be considered in evaluating overall adverse effects of Kemano II.

CHAPTER TWO

POTENTIAL EFFECTS ON SALMON IN THE
NANIKA - MORICE RIVER SYSTEM

Studies were conducted on the Nanika and Morice River systems during 1974 and 1975 by the Fisheries and Marine Service to determine the probable consequences of hydroelectric development on the salmon resources of the system. The studies included limnological investigations of Morice Lake to determine lake productivity and its response to an altered environment; documentation of the timing, distribution, abundance and population characteristics of each salmon species; potential effects of flow reduction on spawning, incubation, and rearing; and an analysis of the relationship between discharge and water temperature.

The studies presented in this chapter relate only to the salmon species which utilize the Nanika-Morice River system. Hydroelectric development is also expected to have an impact on resident fish stocks and steelhead trout. Studies on these fish species were undertaken by the Provincial Fish and Wildlife Branch.

1. Hydrology of the Bulkley River Drainage Basin

The Bulkley River drainage basin (Figure 5) can be divided into two major physiographic components: the Interior Plateau region which encompasses most of the 4,740 square miles of the drainage area, and the Coast Mountains bordering the western boundary of the basin. The Morice-Nanika watershed is located in the southwest portion of this basin and drains a

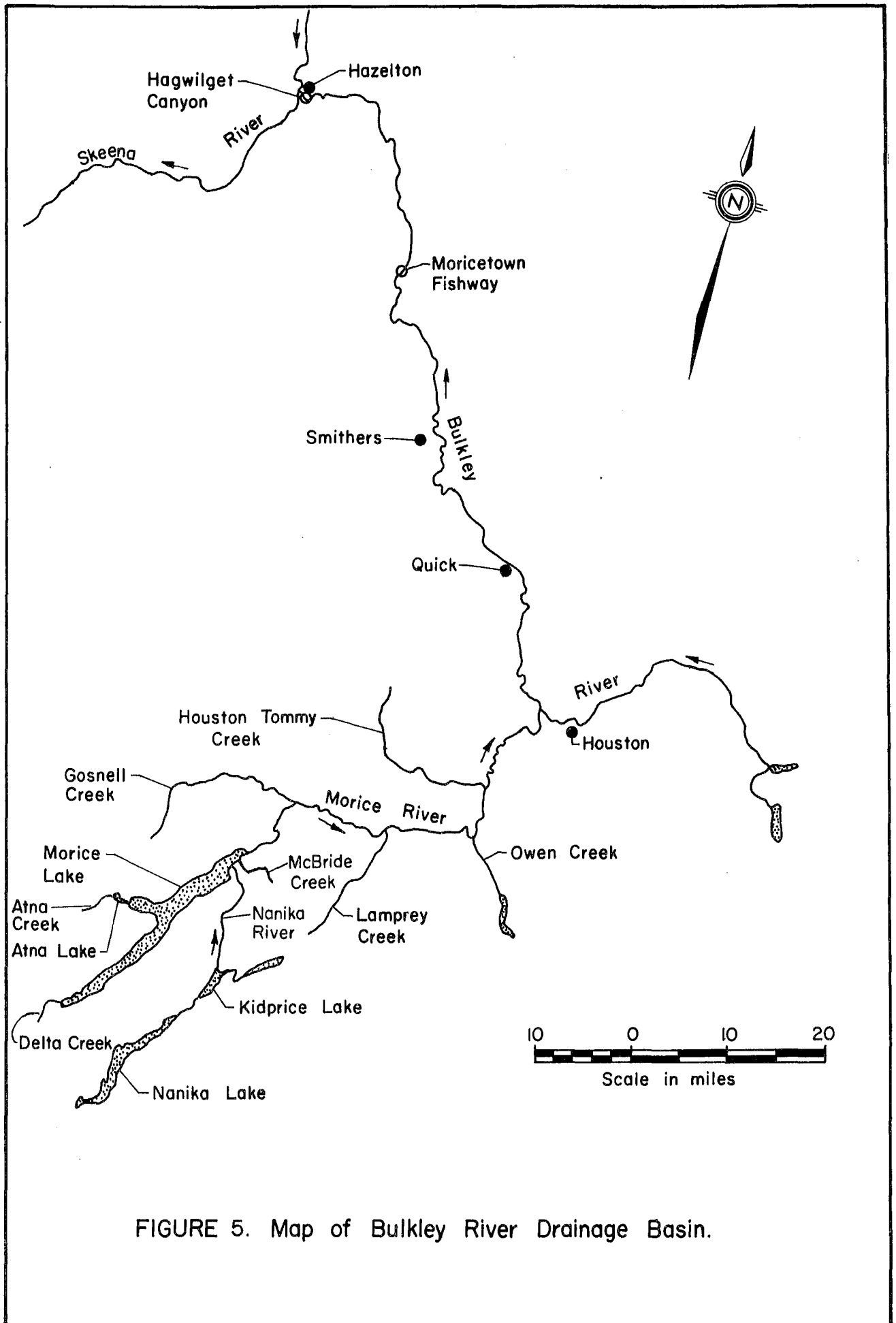


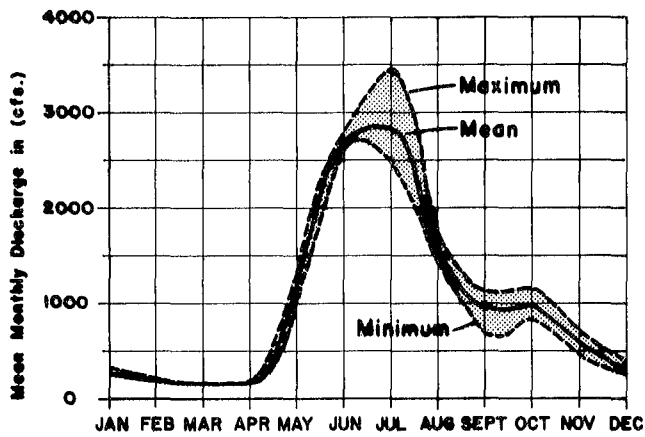
FIGURE 5. Map of Bulkley River Drainage Basin.

portion of the Tahtsa Range of the Coast Mountains. The watershed varies in elevation from 2,600 feet to 7,200 feet above sea level and is extensively glaciated. Approximately 15 percent of the entire Bulkley River drainage area lies upstream of the outlet of Morice Lake. Nanika, Kidprice and Morice Lakes provide almost all of the lake storage in the Bulkley River system.

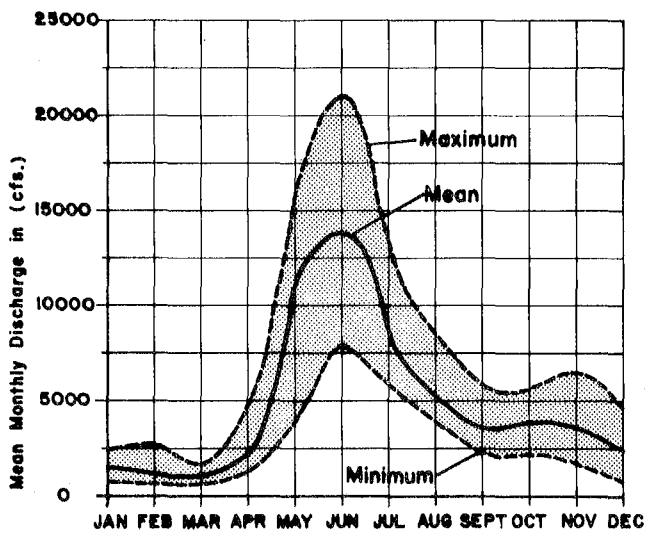
The average annual discharge in the Nanika River at the outlet of Kidprice Lake during 1973 and 1974 was 1,024 cfs. Over the period 1962 to 1974, inclusive, the average annual discharge at the outlet of Morice Lake was 2,744 cfs. During spring runoff periods the outflow from Morice Lake contributes as little as 20 percent of the flow in the Bulkley River at Quick (Figure 6). However, during the remainder of the year flow from Morice Lake may represent as much as 80 to 95 percent of the Bulkley flow at Quick.

2. Salmon Resources of the Nanika-Morice River System

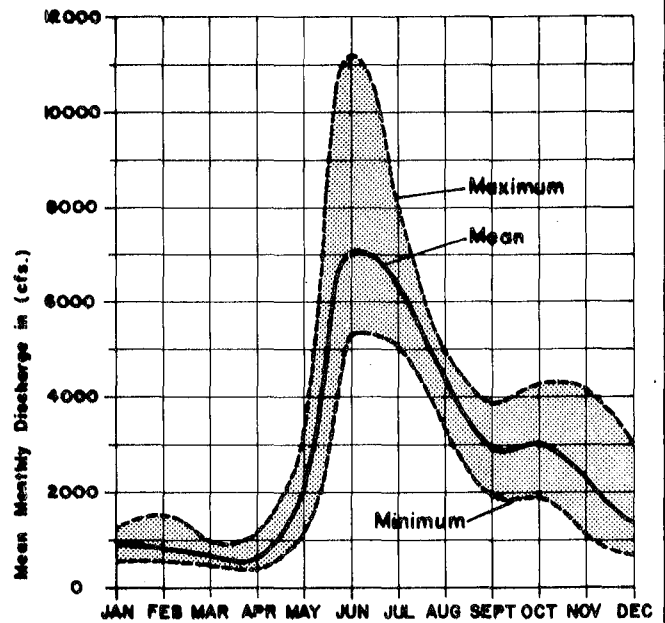
Adult and juvenile salmon were sampled in 1974 and 1975 in Nanika and Morice Rivers and several of their tributary streams using a variety of methods, including netting, trapping, electro-shocking, and observations by foot, boat, skindiving, and aircraft. The timing, distribution, abundance, and population characteristics of each species were deduced from these samples. Previous existing data were included where applicable. Juvenile fish were captured to determine the location of rearing and their habitat preferences.



Nanika River below Kidprice Lake
(1972-1974)



Bulkley River @ Quick
(1945-1973)



Morice River below Morice Lake
(1961-1974)

**FIGURE 6. Annual distribution of mean monthly discharges
Nanika, Morice, and Bulkley Rivers.**

2.1 Chinook Salmon:

Adult chinook salmon begin their migration into the Morice River system about mid-July and spawn during the period August 1 to October 30. Spawning occurs in the upper Morice River between the lake outlet and Lamprey Creek and in the Nanika River below Kidprice Lake. Most of the chinook spawning, however, occurs in the upper 3 miles of the Morice River (Figure 7). The capture of juvenile chinook in Gosnell Creek would also suggest the possibility of chinook spawning in this tributary.

Adult agings have indicated that 65 percent of the chinook salmon spend one year in freshwater after hatching (sub-2), while the balance spend less than one year (sub-1). However, very few sub-2 chinook were observed in the Morice River during the juvenile sampling period, which indicates that they leave the Morice system in late spring to rear during summer and winter in the Bulkley or Skeena Rivers. Fry were observed moving upstream into Morice Lake during the sampling period, but the total numbers were considered to be small.

2.2 Sockeye Salmon:

Adult sockeye migrate into the Morice River system after July 23 and spawn in the Nanika River below Kidprice Lake, on beaches near the south end of Morice Lake and in the Atna River above Atna Lake. Possible spawning areas, as determined by the presence of juveniles, also occur in Delta Creek at the south end of Morice Lake and in the Morice River near the lake outlet. However, the majority of the spawning population utilizes the Nanika River (Figure 8).

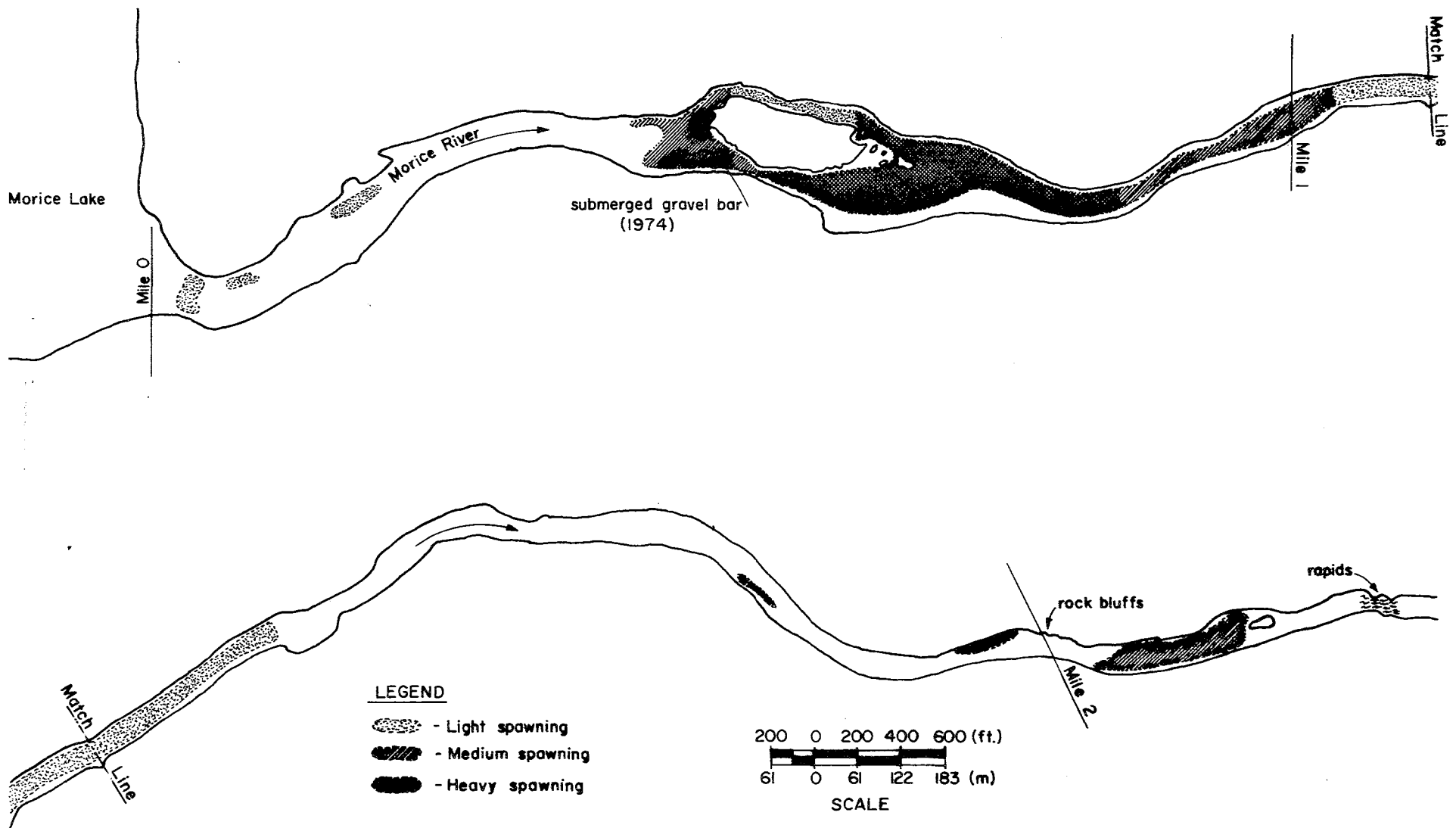


FIGURE 7. Chinook Spawning Areas in Upper Morice River in 1974

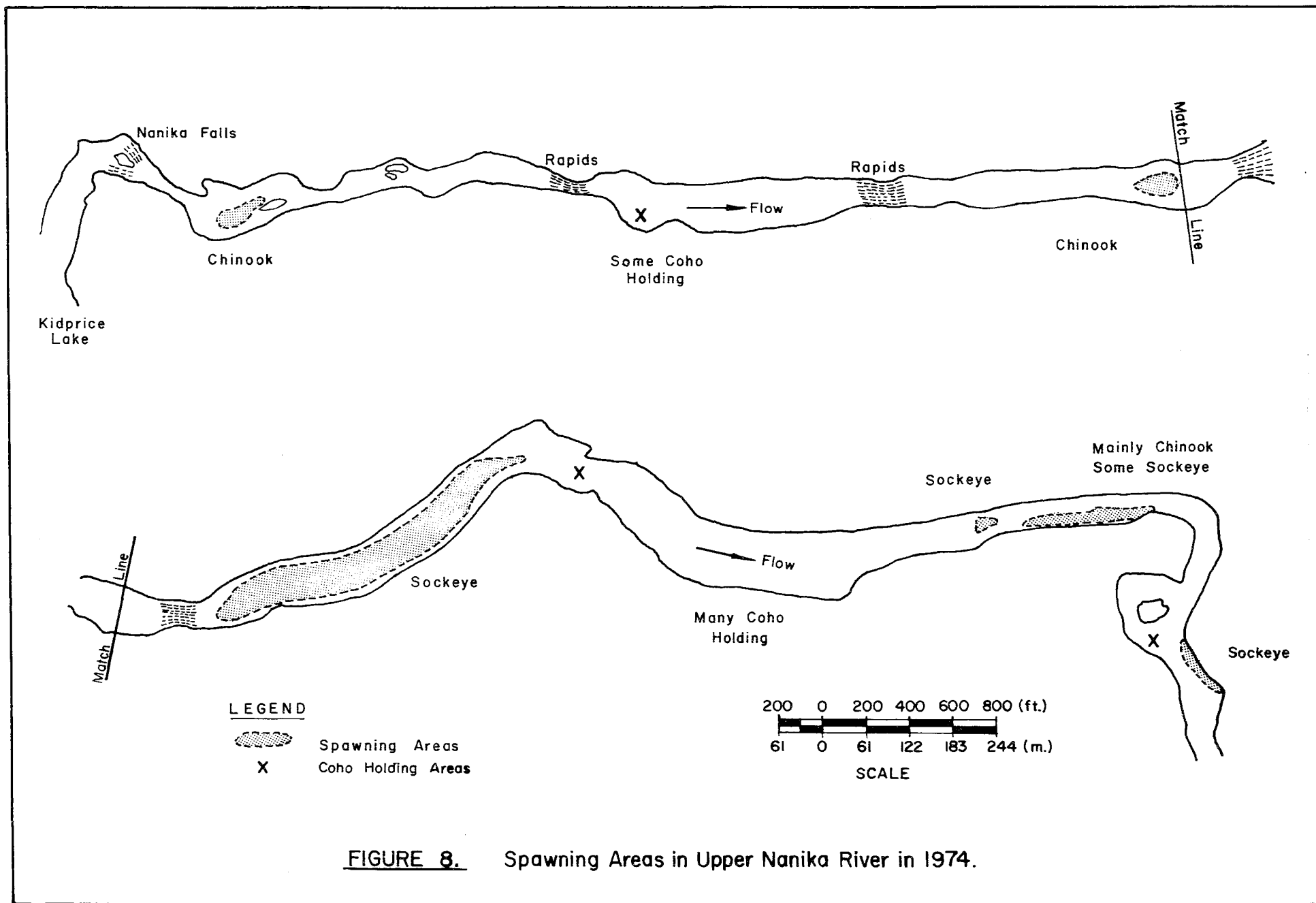


FIGURE 8. Spawning Areas in Upper Nanika River in 1974.

Sockeye juveniles migrate into Morice Lake after emergence in spring and remain in the lake for one to two years before migrating to sea as smolts in mid-May. The greatest rearing density within Morice Lake appeared to be in the northern part of the lake, although juveniles were observed throughout. Aging of adult sockeye salmon indicated that most sockeye juveniles spend two years in freshwater (sub-3), although equal numbers of sub-2 and sub-3 smolts are known to emigrate from Morice Lake. This likely reflects an increased smolt-to-adult survival of the larger sub-3 smolts.

2.3 Coho Salmon:

Adult coho salmon begin migrating into the Morice River in early August and spawn during the period August 15 to December 15. Due to the late timing of spawning and their wide distribution throughout tributary streams, it was difficult to adequately identify coho spawning areas. Documented spawning areas occur in all tributary streams of the Morice River, in the upper reaches of the Morice River between the lake outlet and Gosnell Creek, throughout the length of McBride Creek, and in the Nanika River below Kidprice Lake. Other possible spawning areas, as indicated by the presence of juveniles, include the lower reaches of Atna River and Delta Creek.

Coho juveniles rear for one to two years in the system. They were widely distributed throughout Morice Lake, Morice River and most of their tributary streams. The greatest coho rearing density during the sampling period occurred in McBride Creek and in Morice River between Gosnell and Owen Creeks. These areas, in addition to the lower reaches of the Nanika River, offered the best coho rearing potential in the system. During their stay in fresh water, coho juveniles preferred to rear in mainstream log jams during spring and side channels during summer. They

preferred habitat with velocities of less than 44 cm/sec, depths of 90 cm or more, silt substrate and cover of aquatic macrophytes or logs.

2.4 Pink Salmon:

Adult pink salmon migrate into the Morice River after August 1 and spawn until September 30. Since installation of fishways at Moricetown Falls on the Bulkley River in 1951, pink spawning has extended into the Morice River, and is believed to be continually expanding in terms of their numbers and upstream distribution. Scattered spawning occurs over the entire length of the Morice River and the lower reaches of Gosnell Creek, but the greatest spawning density occurs in Morice River between Gosnell and Owen Creeks. Pink salmon fry emigrate to sea directly upon emergence in spring.

2.5 Abundance of Salmon Stocks:

Escapement records for the period 1949 to 1975 for each salmon species in the Nanika-Morice system are presented in Table 10. The table does not include an average of 300 to 500 sockeye which spawn in Morice Lake. The relative contribution of all Morice-Nanika stocks to the total Skeena River escapements during the period 1965 to 1975 are shown on Table 11.

TABLE 10: Escapement Estimates for Morice and Nanika River Salmon Stocks, 1949-1976.

Year	MORICE RIVER				NANIKA RIVER		
	Chinook	Sockeye ¹	Coho	Pink	Chinook	Sockeye	Coho
1949	10000	300-500	6000	-	-	70000	-
1950	-	-	-	-	-	42000	-
1951	2000-5000	300-500	5000-10000	-	-	58800	-
1952	5000-10000	-	5000-10000	-	-	200+	-
1953	10000	700	5000-10000	2000-5000	-	35000	-
1954	11000	500-1000	10000	1000	-	-	-
1955	7000	-	10000	4000	-	4000	-
1956	10000-20000	-	10000-20000	-	-	6000	-
1957	10000-20000	-	2000-5000	-	-	1000	-
1958	10000-20000	-	2000-5000	few	-	150+	-
1959	10000-20000	-	2000-5000	2000-5000	50-100	500-1000	1-50
1960	2000-5000	-	5000-10000	-	100-300	2000-5000	-
1961	2000-5000	-	1000-2000	1000-2000	-	5000-10000	-
1962	2000-5000	-	1000-2000	-	-	3500	500
1963	7500	1000	1000	1000	-	1200	400
1964	5000	3000	1000	-	-	6000	500
1965	5000	200	1500	500	300	9700	-
1966	6000	100	1500	500	150	10700	300
1967	12000	-	2500	400	200	4100	300
1968	7000	-	2500	1000	100	3300	200
1969	5000	-	3000	2500	few	3400	300
1970	4600	-	2500	-	few	4700	300
1971	4200	-	3000	4500	1-50	4300	300
1972	8400	-	3500	1000	400	1100	200
1973	12000	-	4000	14000	400	1000	400
1974	9000	-	3000	1000	100	1200	150
1975	2500	400	-	50000	100	250	-

1. Morice sockeye were probably bound for the Nanika River or Morice Lake.

TABLE 11. Contribution of the Morice-Nanika Salmon Stocks to the Total Skeena River Escapements

<u>Year</u>	<u>Chinook</u>	<u>Sockeye</u>	<u>Coho</u>	<u>Pink</u>
1965-73	34.8%	0.8%	4.7%	0.2%
1974	31.0	0.2	8.6	0.1
1975	12.8	0.1	-	2.7

3. Limnology of Morice Lake

Juvenile sockeye and coho salmon rear for a period of one to two years in Morice Lake prior to migrating to the sea. During this period they feed on organisms produced within the lake or provided by inflowing streams. Environmental changes resulting from impoundment of water on Morice Lake may affect these organisms and hence the rearing populations. The more important limnological effects would occur at the land-water interface, due to flooding and/or lake drawdown. The new water level regime could either create or destroy habitat for existing species of fish and other organisms. Shoreline and bank erosion, altered flow regime and other physical changes could cause radical changes in lake productivity.

The basic indicators of lake productivity are water chemistry, phytoplankton, zooplankton and zoobenthos. Water chemistry influences the basic biological components of any natural waters thereby affecting the natural productivity. The water chemical budget of a reservoir usually depends upon the inflowing streams. However, during the formation period of a reservoir, the chemical nutrient supply will temporarily increase due to leaching of flooded soils and decomposition of submerged vegetation, which will modify the chemical

composition of the water. These chemical changes may result in several limnological modifications but the most obvious is usually a temporary increase in plankton biomass and lake productivity. Phytoplankton are the primary utilizers of nutrients and are the primary food organisms. These primary producers, by utilizing light and nutrients, initiate and sustain high trophic levels of the biological community. Algal production, as well as influencing the quantity of secondary production, may also affect the quality of the water and the fishery. The zooplankton are essentially the second (after phytoplankton) trophic level in most lakes. They graze on the phytoplankton and are consumed ultimately by the fish. They are therefore indicative of the general productivity of a lake and its capacity to produce fish. Zoobenthos are those invertebrates that inhabit the bottom sediments of aquatic systems. Since many benthic species are used as food for fish, the quantity and quality of zoobenthos are also good indicators of the general productivity of a water body.

In conducting the limnological studies, three sampling stations were located in both Nanika and Morice Lakes. Water chemistry, phytoplankton and zooplankton samples were collected at each of these stations intermittently throughout 1974 and 1975. Water chemistry stations were also located on ten rivers or streams flowing into Morice Lake and one station was located on Morice River near the lake outlet. Most of these stations were sampled monthly throughout summer and winter. Zoobenthos samples were collected on transects across Morice Lake at each sampling station during a one week period in June, 1975.

Morice Lake showed a high dissolved oxygen content (90 - 100%) and cool water temperatures. The maximum observed temperature was 12.7°C (55.3°F) on 6th August, 1974. The north end of the lake near Morice River was consistently

warmer than the south end of the lake. Most measured nutrient values (Nitrogen as NO_2 , NO_3 , NH_3 and Phosphorus as OPO_4 , T.P.) were generally lower than the sensitivity of our present analytical methods, silicon being the exception. Nanika River, which contributes about 50% of the total water inflow, was the only station to have a measurable phosphorus input into Morice Lake. Other parameters measured (total hardness, pH, conductivity, total residue) showed no significant spatial or temporal trends.

The total calculated phytoplankton biomass reached a maximum of 300 mg/m^3 , indicating a very low phytoplankton productivity in Morice Lake. This could be due to low water temperatures and low nutrient content. Observations also indicate a higher productivity towards the north end of the lake, which is likely due to the input of nutrients from Nanika River.

Zooplankton analysis showed that Morice Lake is low in the number of species and in total abundance. Eight species were identified with a maximum abundance of 8.96 individuals per litre. This limited amount of plankton is probably due to low temperatures, relatively high altitude, low total dissolved solids and a poor supply of nutrients.

The mean abundance of benthos in Morice Lake was 1,680 individuals per square meter, which is comparable to many other Canadian lakes of similar latitude and altitude. The littoral zone (0 - 10 meters depth) had an average abundance of benthic invertebrates of $3,366/\text{m}^2$. The dominant group was the non-biting midges which is indicative of a very cold lake with high oxygen saturation.

An ecosystem of a newly flooded reservoir normally reacts positively to increased nutrients from the newly flooded areas and therefore an increase in the total lake biomass, including fish, can be initially expected. This is due mainly to the increased nutrient input from newly flooded areas. Following stabilization, production within the lake will decrease and because of the Nanika River diversion this decrease is expected to be to a level that is less than the predevelopment period. The lower post impoundment production will affect all the food chain levels. The lower nutrient input entering the system will reduce the already low plankton component, which may cause a severe stress on present populations of plankton feeding fish in Morice Lake and Morice River. Likewise the total benthic community will be reduced causing a stress on fish utilizing this food source. The littoral benthos, the most productive of the zoobenthos surveyed, will be additionally affected due to the probable winter drawdown pattern, which will reduce all plants and animals inhabiting the littoral zone, as well as the fish utilizing this large food source. In addition, operation of a large capacity pump near the southern end of Morice Lake could result in changes in flow patterns and temperature regime within the lake, and possible changes in the overall lake productivity.

4. Potential Effects of Flow Reduction on Salmon Stocks

4.1 Adult Migration

Moricetown Falls has historically been a point of difficult passage for fish migrating up the Bulkley River. In 1951, vertical slot fishways were installed on each side of the falls to alleviate this problem. These were designed to operate over a range of 2,000 to 10,000 cfs. However, in the lower part of this range the fishway cannot accommodate

the large numbers of fish occurring during the peak of migration. Although additional investigations should be undertaken to determine the minimum acceptable discharge for the fishway operation, it is tentatively considered that not less than 3,500 cfs should be provided during the month of August. The estimated average natural flow at Moricetown Falls during August is 6,500 cfs.

The entire length of the Nanika River was inspected to ascertain whether migrational obstructions would occur with reduced flows. No obstructions were observed at a discharge of 155 cfs, although it was not determined at what lower discharge the river would become impassible for migrating salmon. The Morice River was inspected over its entire length when the discharge from Morice Lake was 1,460 cfs. No obstructions were observed, but certain rapids may present difficulties for migrants or cause a delay in their migration at any lesser discharge. Further observations would be required to confirm this.

It is well known that in natural situations low flow conditions will inhibit upstream migration. Consequently, flow reduction in the Nanika and Morice Rivers during the migrant period may result in blockage or delay of the run. While additional literature research should be undertaken to investigate flow requirements for migration, it is tentatively considered that discharge at least in the order of normal spawning discharges will be required in each river. This would represent approximately 1,000 cfs from July 23 in the Nanika River and 3,000 cfs from July 15 in the Morice River until spawning commences in each river.

4.2 Spawning

With a natural discharge in the order of 1,000 cfs, approximately 32,000 square yards of spawning gravel are available for sockeye in the upper Nanika River below Kidprice Lake. Surveys were conducted on two of the largest of these spawning areas, which together comprised approximately 22,000 square yards of spawning gravel. A greater water depth occurs over most of this spawning gravel and velocities are generally much lower than found in normal sockeye spawning areas. However, the entire spawning area remains wetted during low winter discharges and eggs are assured of ideal conditions during the incubation period.

On the basis of data collected during the spawning period, it was concluded that acceptable sockeye spawning conditions would be provided where silt-free spawning gravel occurred with water velocities in excess of 0.9 fps at 0.4 feet above the riverbed, and with a water depth in excess of one foot. Water depths and velocities were measured or computed within the spawning area at various discharges and on the basis of the above criteria, the relationship between discharge and available spawning area was determined. Potential spawning populations were then computed for each discharge on the premise that a pair of spawners require 2 square yards of spawning gravel. The results of this analysis are shown in Table 12.

A small number of chinook salmon also utilize the Nanika River spawning grounds at approximately the same time as sockeye salmon. Studies were not conducted to determine the effects of reduced discharges on their spawning area. However, it may be reasonable to assume that these chinook would suffer losses in proportion to those outlined above for sockeye salmon.

TABLE 12. Summary of Available Spawning Area and Potential Sockeye Spawning Populations in the Upper Nanika River

<u>Discharge (cfs)</u>	<u>Available Spawning Area, Sq. Yds.</u>	<u>Percent of Total Suitable Spawning Gravel</u>	<u>Potential Sockeye Spawning Population</u>
1,000	32,000	100%	32,000
800	30,300	95%	30,300
600	10,800	34%	10,800
400	1,600	5%	1,600
200	400	1%	400
150	0	0%	0

Studies were conducted in the Morice River on a densely populated chinook salmon spawning area located approximately one-half mile below the outlet of Morice Lake. Most of the riverbed within this area is characterized by a series of gravel dunes generally oriented perpendicular to the direction of flow. It is not known if the occurrence of these dunes is due to hydraulic conditions alone, to the spawning activity of the chinook salmon, or to some combination of both. The existence of the dunes is undoubtedly an important factor in the maintenance of the large runs of chinook salmon in the Morice River and additional studies should therefore be undertaken to determine how they were formed and the discharges necessary to ensure that they continue in their present form.

For purposes of quantifying chinook spawning area in the Morice River, suitable spawning habitat was defined as silt-free spawning gravel with a minimum water cover of one foot and a minimum velocity of one foot per second. A limit was not placed on the maximum velocity since all suitable spawning gravel within the study area was never subjected to excessive velocities within the range of discharges investigated. It was found that practically all suitable spawning gravel within the study area was available for spawning with a discharge of 2800 cfs. The percentage of suitable gravel available at other discharges is shown on Table 13.

TABLE 13. Percentage of Suitable Spawning Gravel Available for Spawning in the Morice River Study Area and Potential Chinook Spawning Populations in the Morice River for Various Discharges

Discharge (cfs)	Percent of Suitable Spawning Gravel Available for Spawning	Potential Chinook Spawning Population in Morice River
2800	100	12,000
2300	87	10,400
2000	68	8,200
1500	43	5,200
1000	28	3,300
460	19	2,300

Estimates of potential spawning populations within the Morice River are also provided in Table 13. These were computed assuming that the study area is representative of other chinook spawning areas in the river and that all suitable spawning gravel would be fully utilized by the maximum recorded escapement of 12,000 adults.

Studies were not conducted on pink salmon spawning areas in the lower Morice River. However, since the timing of pink spawning falls within the period of chinook spawning, it is considered that maintenance of adequate flows for chinook salmon will also be sufficient for pinks.

Coho spawning areas which have been documented in the lower reaches of McBride Creek would be inundated by the flooding of Morice Lake. It is possible that currently utilized spawning areas exist above the upstream limit of flooding. However, it is anticipated that inundation would result in an overall decline in the spawning populations of this stream.

The effect of increased water levels on sockeye beach spawning areas in Morice Lake is unknown. Beach spawning normally occurs in upwelling flows from a groundwater source and if this is the case in Morice Lake, raising the lake level would tend to decrease this flow. Furthermore, spawning success could decrease as a result of silt deposition from adjacent shoreline erosion.

4.3 Incubation

Low flows can affect egg incubation in a variety of ways aside from direct dewatering of spawning gravel. Any reduction in discharge can be expected to result in reduced sub-gravel flow which will reduce the flow of oxygen-rich water into the redd as well as the removal rate of toxic metabolic wastes. In addition, fines will settle and accumulate more at lower flows, resulting in further reductions in intragravel water velocities and oxygen levels. This can increase embryo mortality, delay hatching by retarding development and physically bar fry from emerging. Lowered winter flows can increase the frost depth in the gravel, which can cause death.

Alevins, however, are not entirely at the mercy of environmental conditions, as they are able to move within the gravel immediately after hatching and appear to be able to respond to lowered water levels by moving laterally or downward through the gravel. Aside from the need to maintain an adequate oxygen supply during the alevin stage, the most critical period with respect to reduced water levels is therefore in the egg stage prior to hatching.

The duration of time between egg fertilization and hatching is related to heat units of the water. It is generally accepted that chinook hatching requires 850 to 900 degree (fahrenheit) days, while sockeye hatching requires 950 degree days. On the basis of water temperature records obtained in the Nanika and Morice Rivers during the 1966 hatchery operation, egg hatching could be expected by the dates shown on Table 14.

TABLE 14. Probable Hatching Dates for Nanika River Sockeye Eggs and Morice River Chinook Eggs

	<u>Nanika River Sockeye</u>	<u>Morice River Chinook</u>
Earliest Hatching Date	November 6	October 15
Average Hatching Date	April 10	December 15
Latest Hatching Date	June 25	January 1

Most of the spawning area in the Nanika River is located in deep water and would not be dewatered with discharges as low as 100 cfs. However, spawning occurs almost to the shoreline in some areas, and such areas would be most critically affected by reduced flows. Studies have concluded that a minimum incubation discharge of 250 cfs would be required in the Nanika River if spawning were to occur at 800 cfs. Since 800 cfs is within the range of natural spawning discharge and

would result in very little loss of spawning habitat, it is recommended that 250 cfs be maintained from the end of the spawning period until such time that the discharge from Kidprice Lake would have naturally dropped below this level. Beyond this time on the falling stage of the hydrograph, outflow from Kidprice Lake should be regulated so as to closely simulate natural flows to a minimum of 100 cfs. This minimum discharge of 100 cfs should be provided during the spring freshet period until the end of June, except during such time when increased flows may be required for flushing of spawning gravel.

In determining incubation flow requirements for the Morice River, the pre-hatching and alevin stages were considered separately. It was assumed that the pre-hatching stage would continue until December 31. From 1962 to 1976 the average mean monthly flows in the Morice River during November and December were 1,380 and 2,360 cfs, respectively. Mean monthly flows fell below 1,000 cfs in only 3 cases throughout this 13 year period. Some of the spawning area along the shoreline and on the crests of dunes within the study area will be exposed at this discharge, although it was considered that very few eggs would be dewatered or frozen. Therefore, to ensure egg survival prior to hatching, it was concluded that the minimum incubation flow prior to December 31 should be 1,000 cfs.

Between January and the time of fry emergence, which could be as late as June, a lesser quantity of water is required as alevins have some mobility within the spawning gravel. During the period 1962 to 1974, the minimum mean monthly flows varied between 600 cfs in January and 390 cfs in April. An average of these discharges was considered to be adequate to ensure continued survival of alevins. It is therefore recommended that a minimum flow of 500 cfs be released between January 1

and April 30, except at such times when flows would naturally drop below this level. During this latter period of time, flow releases should be scheduled to coincide as closely as possible with the natural flows. Any reductions in discharge should be made gradually over a one or two day period. After April 30, flow requirements will be governed by rearing needs, as discussed below.

4.4 Juvenile Rearing

Studies were conducted on the Morice River upstream of Owen Creek during 1974 to document the habitat preferences of chinook and coho juveniles. It was found that the greatest rearing densities occurred in slack water areas along shorelines and in mainstream log jams. These two parameters were therefore selected as indices of rearing capacity and their relationship to discharge was subsequently established (Figure 9). The total number of wetted log jams was found to decrease linearly relative to discharge. Wetted shoreline was relatively constant at discharges above 1300 cfs. The river was not observed at discharges below 1300 cfs, but it was hypothesized that wetted shoreline would decrease markedly with decreasing discharge as most side channels would become dewatered.

Attempts were made to estimate potential losses of juvenile coho in the Morice River as a result of reductions in discharge below 3000 cfs. However, since data are not available to relate the rearing needs of present population levels to system capacity, it is considered that this information is not entirely valid. Additional field investigations would be required to provide this information and to determine rearing flow requirements. However, in order for these investigations

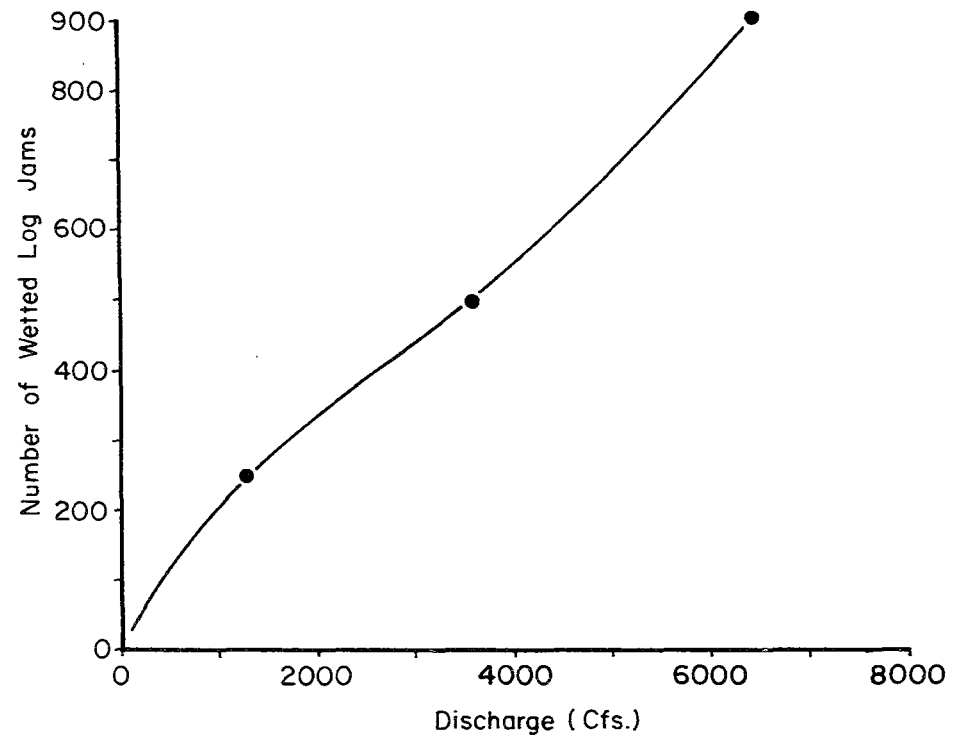
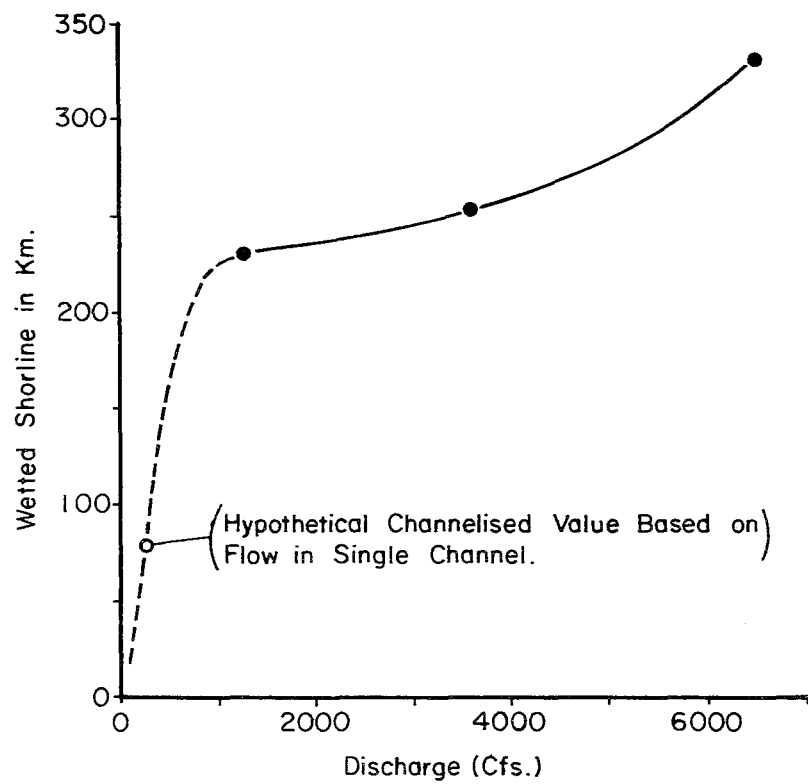


FIGURE 9. Relationship Between Discharge and Selected Rearing Indices in the Morice River.

to be successful, it may be necessary to provide some measure of flow control at the outlet of Morice Lake so that discharges in the Morice River can be temporarily regulated.

In the Nanika River, a reduction in summer flows may force chinook and coho juveniles to move downstream prematurely into Morice Lake and Morice River. This would probably only slightly increase rearing pressure on these downstream areas, as actual rearing densities in the lower Nanika reach appeared to be low.

Prime rearing areas in the lower reaches of the Nanika River and McBride Creek would be inundated and probably lost with the flooding of Morice Lake. New rearing habitat could become available within the littoral zone of the flooded area, but juveniles overwintering in these areas may be stranded and lost in low pools with lake drawdown.

Pumping of large quantity of water from any point on Morice Lake other than the lake outlet could alter flow patterns within the lake and attract juvenile salmon during their rearing period or downstream migration. Should this occur, it would be necessary to curtail or reduce the rate of pumping during the migration period, or to provide an effective means of screening and bypassing juveniles to the Morice River.

4.5 Water Temperatures

The effects of diversion on water temperatures were analyzed in the Nanika and Morice Rivers using a computer program developed by the International Pacific Salmon Fisheries Commission. The Morice River was analyzed in three segments - Morice Lake to Gosnell Creek, Gosnell Creek to Houston Tommy

Creek, and Houston Tommy Creek to the Bulkley River. The Nanika River was analyzed in a single segment from Kidprice Lake to Morice Lake.

The computer program was first verified for each river segment using recorded meteorological data and measured water temperatures. Computer runs were then carried out on each river segment using meteorological factors representative of a hot summer period. A series of runs were carried out for each selected discharge with initial water temperatures at the head of each segment ranging from 40°F to 70°F in increments of 5°. In each case the water temperature at the lower end of the river segment was computed. The probable maximum mean daily water temperatures computed for the Nanika and Morice Rivers are shown in Tables 15 and 16, respectively.

TABLE 15. Probable Maximum Mean Daily Water Temperatures in the Nanika River for Various Discharges

	<u>184 cfs</u>	<u>715 cfs</u>	<u>2040 cfs</u>
Nanika River at Kidprice Lake	60°F	60°F	60°F
Nanika River above Morice Lake	67.5°F	62.5°F	61°F

TABLE 16. Probably Maximum Mean Daily Water Temperatures in the Morice River for Various Morice Lake Outflows

	<u>500 cfs</u>	<u>1000 cfs</u>	<u>1500 cfs</u>	<u>2000 cfs</u>
Morice River at Morice Lake	63 ^o F	63 ^o F	63 ^o F	63 ^o F
Morice River above Gosnell Creek	66.2 ^o F	65.1 ^o F	64.5 ^o F	64.2 ^o F
Gosnell Creek above Morice River	55 ^o F	55 ^o F	55 ^o F	55 ^o F
Morice River below Gosnell Creek	63.8 ^o F	63.9 ^o F	63.7 ^o F	63.6 ^o F
Morice River above Houston Tommy Cr.	71.5 ^o F	69.0 ^o F	67.8 ^o F	67.2 ^o F
Houston Tommy Creek above Morice River	60 ^o F	60 ^o F	60 ^o F	60 ^o F
Morice River below Houston Tommy Cr.	68.8 ^o F	67.7 ^o F	67.0 ^o F	66.6 ^o F
Morice River above Bulkley River	71.3 ^o F	69.6 ^o F	68.5 ^o F	68.0 ^o F

It is concluded that within the range of discharges studied, the mean daily water temperatures in the Nanika and Morice Rivers should not approach levels which would result in direct fish kills. However, sub-lethal effects of temperature increases have been noted by other researchers to indirectly but significantly decrease salmon production in a variety of ways. It has been commonly observed that increases in juvenile disease and parasites occur at higher temperatures. In natural systems, increases in temperatures have resulted in less desirable species, such as suckers, being favoured over salmonids. For coho salmon, aggression rates have been found to increase with temperature,

which may result in lowered rearing capacities. Coho are likely to be most affected by temperature as they are year-round river residents during their juvenile stages. The complex and interactive nature of sub-lethal temperature effects does not allow quantitative prediction of juvenile losses at the present.

Adult sockeye have been blocked from entering other rivers with elevated water temperatures. However, if discharges from Morice Lake are maintained above 1,500 cfs during the adult migration period, it is unlikely that a thermal barrier would occur in the Morice River since mean daily temperature would seldom exceed 68^oF. It is important to note that the analysis was not extended to the Bulkley River below its confluence with the Morice River. Such an analysis may be necessary before minimum flow requirements can be finalized.

4.6 Downstream Salmon Rearing Areas

A brief downstream trapping survey of juvenile rearing was conducted by the Fisheries and Marine Service during September, 1976. The best habitat potential in the Bulkley River appeared to be between Telkwa and the Smithers airport and actual catches of chinook were highest in this area. The Skeena River between Kitwanga and Kwinitza offered the best rearing potential below the confluence of the Bulkley and Skeena Rivers. Chinook catches were highest in the reach between Kitwanga and Terrace, while coho catches were highest between Terrace and Kwinitza. Additional investigations should be undertaken to determine how diversion of the Nanika and Morice Rivers would affect these rearing areas, particularly in the Bulkley River. Potential problems include increased water temperatures, increased effluent concentrations from existing and future industrial and municipal sources, and decreased abundance of food for juvenile salmon and resident fish.

CHAPTER THREE

ECONOMIC AND SOCIAL IMPACT OF
REDUCTION IN THE FISHERIES RESOURCES

The economic and social importance of the commercial, Indian food and recreational fisheries likely to be affected by the Kemano II hydroelectric power project were assessed from three separate perspectives. The commercial fishery was assessed on the basis of its contribution to British Columbians and other Canadians. The value of the subsistence fishery was evaluated in terms of its contribution to the Indian people of British Columbia. The value of the sport fisheries was measured on the basis of the contribution that these sport fisheries make to people living in the north central area of British Columbia.

The various diversions, spillways and pumping schemes that are included within the Kemano II project cover an area of approximately 40,000 square miles. The project directly affects four major river systems: the Fraser, Skeena, Dean and Kemano. These four river systems produce roughly 40 percent of British Columbia's total salmon and steelhead commercial catch. It is estimated that the commercial production of salmon and steelhead attributable to that portion of each system which would be directly affected by Kemano II exceeds 1,098,000 pieces each year. The potential net economic yield generated by this annual harvest is \$7,851,000. The present discounted value of this stream of benefits over the period 1975 to 2024 is between a low of \$116,856,000 and a high of \$200,055,000. The best single estimate of value of this annual stream of benefits discounted at 9 percent per annum to the year 2024 is \$148,843,000.

Nearly one-half of the 52,000 registered Indians living in British Columbia reside in the areas adjacent to the Fraser and Skeena River Systems. Indians living in areas adjacent to the affected food fisheries catch at least 48,600 pieces of salmon and steelhead each year that are attributable to the affected waterways. The present discounted value of this annual salmon and steelhead catch, expressed in landed commercial terms, is between a low of \$2,251,000 and a high of \$3,311,000. The best single estimate of the value of this stream of benefits, calculated at 9 percent per annum to the year 2024, is \$2,659,000.

The additional percentage contribution to the income of Indians who actively participated in food fishing on the affected waterways during 1970 amounted to 6.3 percent. During that same year, the total Indian population living in the areas adjacent to the affected waterways enjoyed an average addition to their income of 2.4 percent because of participation in food fisheries affected by the Kemano II project.

The area where the impact of the Kemano II hydro-electric project is likely to be greatest, and where the focus of the sport fishing analysis was directed, is located in north central British Columbia where many of the province's most highly regarded sport fishing rivers are located. This north central portion of British Columbia has a resident population of approximately 113,200 persons who live in more than 20 different communities. Over one-third of the total resident population participate in 790,000 days of angling activity in this area each year. More than one-third of all this activity, or 293,900 angling days, takes place on waterways which are directly affected by the Kemano II project. These same waterways support 22,375 non-resident Canadian and

16,650 non-Canadian days of fishing activity each year. Non-resident fishing activity generates net economic benefits of \$209,900 and 48 full-time jobs, each year in the affected area. Conservative estimates of both resident and non-resident sport fishing activity that could be affected by the Kemano II project range from a discounted low value of \$147,392,000 to a high value of \$253,473,000. The most likely estimate of the present discounted value of all the sport fishing activity that takes place in the affected area each year is \$185,590,000.

The combined present discounted value of the commercial, Indian food and recreational fishing activity which is attributable to the waterways affected by Kemano II, discounted at 9 percent per annum to the year 2024, is \$337,092,000.

The Kemano II hydroelectric project is comprised of four different developments which have been identified as likely to have an adverse effect on British Columbia's fishery resources. However, only three of these developments, which together provide four different development options, are examined. These are:

- (1) the Nechako River diversion by itself,
- (2) the Nechako River diversion and the Nanika River diversion together,
- (3) the Nechako and the Morice Lake diversions together, and
- (4) the combination of the Nechako, Nanika and Morice diversions.

Information on the minimum flow conditions required to maintain optimum levels of anadromous fish production is identified for each of the developments. It is assumed that if these minimum flow conditions are maintained, the Kemano II project will have no detrimental effect on existing anadromous fish stocks and only a small effect on the fishing activity which is dependent on resident fish populations.

The economic costs of the Kemano II project's impact on the fishery resources are presented in terms of value loss estimates. These value loss estimates are based on four premises: (1) that it is reasonable to believe that a project as large as Kemano II, which is designed to alter the flow regimes of several major fish producing waterways, will cause some minimal amount of damage to the fishery resources, (2) that it is reasonable to believe that any damage to fish habitat is most likely to occur during the construction phases or during the early years of the project's operation, (3) that it is reasonable to expect that alterations to the aquatic environment may cause considerable harm to the affected waterways' fish production without being apparent or immediately detected by those responsible for protecting these resources, (4) that it seems probable that damage to the fisheries located in premium sport fishing areas, such as the area of concern in this analysis, will have an immediate and predictable effect on sport fishermen.

Two sets of value loss estimates are presented. The one set estimates the value of economic losses that could occur if serious damage is imposed on all the fisheries identified by the biological and engineering investigations as likely to be harmed by the proposed Nehcako, Nanika and Morice diversions. The other estimates the economic value losses should only one year class be destroyed or seriously damaged. Given the data on hand, the highest estimate of fishing value losses that could occur because of the development is \$273,395,000. The lowest estimate of fishery value losses that could occur if only comparatively small damage is imposed on the fisheries is \$64,594,000. These figures provide the range of estimate probability for the present analysis.

Even though the loss estimates presented in this volume are developed on the basis of the best biological, engineering and economic information that is available, there is always the possibility that the resulting damage could be greater and a great deal more costly than indicated here. This suggests that the impact of the Kemano II project could be assessed with greater precision if more detailed plans of the project were available or if further investigations were conducted on those waterways which are finally included in the project. This is particularly true of the Dean and Kemano Rivers where only minimal knowledge is currently available. Value loss estimates were not calculated for either the Dean or Kemano Rivers.

In order to give the reader a good appreciation of how sensitive the value calculations are to the discount rate, and to reflect the fact that the most appropriate discount rate may vary considerably over time, all streams of benefits are discounted at 7, 9 and 11 percent over the period 1975 to 2024. It is assumed that the best single estimate of the value of a stream of benefits is provided using the 9 percent discount rate. The 50 year time period, over which all streams of benefits were discounted, is consistent with the period chosen by most power authorities to estimate the value of electric energy. It could be argued that electrical facilities depreciate in value much faster than that of resources such as fisheries. However, it is only necessary for all to be aware that comparisons between the fishery's benefits identified here and other benefits will not be valid unless the value of other benefits are discounted at 9 percent per annum over the same period of time.

One final word of caution is necessary. Water from the Fraser, Skeena and Dean Rivers is used for a variety of purposes. For example, water from these rivers is used for human and animal consumption, domestic sewage, industrial waste, irrigation, transportation and recreation as well as for fish habitat. Although all of these uses provide benefits for British Columbians and Canadians, this study was concerned only with the economic costs imposed on society as a result of the Kemano II project's impact on the province's fisheries resources. A complete assessment of the total economic and social consequences of all the environmental damages imposed on society as a result of the Kemano II project would include a detailed examination of its impact on each of these other use activities.

CONCLUSIONS

A. Nechako River Salmon Stocks

1. For protection of sockeye and chinook salmon in the Nechako River, the following conditions should be obtained:

- a) A minimum flow of 1000 cfs at all times in the Nechako River downstream from its confluence with the Cheslatta River.
- b) Mean daily water temperatures not exceeding 68°F during adult migration;
- c) Total dissolved gasses not exceeding 110 percent of saturation during adult migrations.

Subject to further studies, additional flows may be required at certain times of the year for rearing of resident fish and juvenile chinook or for flushing of spawning gravel.

2. The maximum area of spawning gravel that could be utilized by chinook salmon in the upper Nechako River would be available at a discharge of 4,000 cfs. This is within the range of normal spawning discharge prior to construction of the Kenney Dam. However, spawning gravel is not considered to be a limiting factor in the propagation of Nechako River chinook stocks and it is concluded that historical population levels could be accommodated with a discharge of 1000 cfs.

3. Relatively stable flows are required during the spawning period, September 1 to October 15. Excessive discharge during this period would encourage adult chinook to deposit their eggs at higher riverbed levels, where they could, subsequently become dewatered or frozen. Flows during the incubation period should be equal to or greater than spawning flows.

4. In the years since 1952, when all or part of the Nechako River was diverted for the Alcan development, high temperatures have occurred in some years but because of fortuitous timing of the sockeye runs and the small numbers of fish present during periods of high temperature, losses of sockeye attributable to the high temperature appear to have been small. Mean daily temperatures as high as 77.3°F were recorded in the Nechako River above the Stuart confluence in 1971 and even higher temperatures would have occurred if the flow had been reduced as proposed by the B.C. Energy Board (160 cfs minimum flow, with no cooling water).

5. Discharges lower than 1,000 cfs in the Nechako River below the Nautley confluence would have occurred in 21 out of 26 years during the period July 20 to September 30, with the minimum flow of 160 cfs recommended by the B.C. Energy Board. Such discharges would not provide adequate river widths and depths for safe migration of salmon.

6. Mean daily water temperatures in the Nechako River above the Stuart confluence could be controlled to 68°F under near-extreme heating conditions by release of up to 4,500 cfs of 45°F water from the Nechako reservoir into the Nechako River near Cheslatta. A total volume of approximately 134,000 acre-feet would be required for a year such as 1971, and is considered to be near the maximum requirement. It is estimated that approximately 480,000 acre-feet at a temperature of 45°F or less could be obtained from the Nechako reservoir between Kenney Dam and the former Nataalkuz Lake.

7. This discharge of cooling water would result in a total dissolved gas concentration of approximately 115 percent of saturation when the water reached the confluence with the Stuart River. This amount of supersaturation would not result

in rapid mortality, but would stress the salmon and/or impair some physiological processes, which would increase susceptibility to disease. Air equilibration of the cooling water at point of release would reduce the supersaturation by about 1 percent. Consequently, the criterion that total dissolved gas concentration should not exceed 110 percent of saturation could not be fulfilled. Methods of reducing these supersaturation levels would therefore have to be developed.

8. The required minimum transportation flow of 1,000 cfs in the Nechako River below the Nautley confluence could be provided by release of water from the Nechako reservoir. The maximum quantity required would be approximately 30,000 acre-feet in addition to requirements for temperature control.

9. Without provision for temperature control, the reduction in flow in the Nechako River that would occur with the Kemano II development would result in higher water temperatures in the Nechako River which at times would be high enough to be lethal to sockeye and chinook, and at other times would impose an additional stress on the salmon which could result in death.

With provision of temperature control, the problems associated with temperatures would be alleviated, but the supersaturation of dissolved gases would reach levels that would impose a stress on the salmon which also could result in death.

Thus the proposed Kemano II development would have unavoidable adverse effects on the environment within the Nechako River which would result in increased probability of losses of sockeye and chinook salmon enroute to and on their spawning grounds in the Nechako River system. Such losses would reduce

the production of salmon from the current runs to the system and the large production potential known to be available in the rearing areas in the Nautley and Stuart tributary systems would also be reduced.

10. The effects of the Kemano II project on flows, water temperatures and dissolved gas levels in Nechako River above the Stuart confluence were studied in the present investigation since this portion of the river was considered to be the most critical, but these studies indicate that possible changes in Nechako River below the Stuart and in the Fraser River downstream from the Nechako should also be studied. The indicated cooling water discharges would limit the mean daily temperature to a maximum of 68°F above the Stuart confluence but higher discharges might be necessary for controlling temperatures below Stuart River.

11. The following additional studies are recommended:

- a) Further study of the supersaturation problem, including measurement of natural re-aeration factors in the Nechako River.
- b) Assessment of possible effects of cooling water discharges, reduced summer temperatures in the upper Nechako, and increased nitrogen supersaturation on resident trout and both adult and juvenile chinooks in the Nechako River.
- c) The effect of flow and temperatures (including flushing flows) on chinook rearing behavior, food availability, food consumption and cover.

- d) Survival of chinook fry during fluctuating discharges and the importance of predation and stranding.
- e) Competition between chinook fry and resident fish for food, space, etc., under reduced flow regimes.
- f) Timing of juvenile emigration to the marine environment and the effect of discharge on migration.
- g) Possible need for controlled freshet discharges for cleaning of spawning gravel.
- h) Effect of reduced flows on temperature and dissolved gas levels in Nechako River below the Stuart confluence and in Fraser River below the Nechako.
- i) Possible downstream effects of flow reduction due to Kemano II in combination with other Fraser River diversion projects on the survival of all Fraser River salmon populations.

B. Nanika-Morice Salmon Stocks

1. Adult salmon are present in the Nanika-Morice system from mid-July to mid-December. Chinook and sockeye salmon spawn from August 1 to October 31, pink salmon from August 11 to September 30 and coho salmon from August 15 to December 15.

2. Most of the chinook spawning occurs in the upper 1/3 of the Morice River, but the major spawning area is located just below Morice Lake. Limited numbers of chinook also spawn in the Nanika River. Most of the sockeye spawning occurs in the Nanika River below Kidprice Lake. Sockeye beach spawning also occurs near the south end of Morice Lake. Pink spawning occurs over the entire length of the Morice River but the major area is located between Gosnell and Owen Creeks. Coho spawning is widely distributed throughout the system, including the major tributaries of the Morice River.

3. Juvenile migrations consist mainly of downstream migration or displacement of fry upon emergence in spring in both Morice and Nanika Rivers. Upstream movements of Morice River chinook juveniles were recorded throughout the sampling period, but the numbers involved were considered to be minor. Most chinook appeared to leave the Morice system shortly after emergence. Sockeye juveniles remain in Morice Lake for one or two years, then migrate to sea as smolts in mid-May. Coho are widely distributed and rear for one to two years in the system. Pink salmon fry migrate to sea directly after emergence from the gravel.

4. Morice Lake was found to be an unproductive lake with most nutrient values so low that the sensitivity of present analytical methods did not allow them to be measured. Plankton biomass was less than in other Canadian lakes of similar elevation

and latitude although the abundance of benthic organisms was comparatively similar. The highest productivity was at the north end of the lake, likely as a result of the Nanika River nutrient input.

5. Diversion of the Nanika River will reduce the productivity of Morice Lake, particularly the more productive northerly end. At this time the levels of productivity subsequent to diversion cannot be quantitatively predicted. Flooding of Morice Lake will result in a temporary increase in lake productivity with leaching of nutrients from the newly flooded areas. However, productivity of littoral benthos is expected to eventually decline below current levels as a result of annual drawdown. This, in combination with the Nanika River diversion, could reduce overall lake productivity and the rearing potential for sockeye and coho fry within the lake.

6. A pumping scheme at the south end of Morice Lake would result in biological and physical changes within the lake which could affect lake productivity, alter the migration patterns of juvenile salmon, and cause extensive residualism.

7. Approximately 32,000 square yards of spawning gravel exists in the Nanika River below Kidprice Lake representing a total potential spawning population of 32,000 sockeye salmon. The discharge required to allow this number to successfully migrate and spawn is estimated to be 1,000 cfs during the period July 23 to October 31. The potential spawning populations corresponding to lower discharges would be 30,000 at 800 cfs; 10,800 at 600 cfs; 1,600 at 400 cfs; 400 at 200 cfs; and 0 and 150 cfs.

8. Studies conducted on a portion of the major chinook spawning area a short distance below Morice Lake have indicated that all suitable spawning gravel would be available for spawning at a discharge of 2,800 cfs. Assuming that the study area is representative of other chinook spawning areas in the river and that all suitable spawning gravel would be fully utilized by the maximum recorded escapement of 12,000 adults, the potential chinook population relative to discharge would be

12,000 at 2,800 cfs; 10,400 at 2,300 cfs; 8,200 at 2,000 cfs; 5,200 at 1,500 cfs; 3,300 at 1,000 cfs; and 2,300 at 460 cfs. Migration and spawning would extend over the period July 15 to October 31.

9. Flooding of Morice Lake to create storage for a pumping scheme would result in the loss of coho spawning grounds in the lower reaches of McBride Creek. Sockeye beach spawning areas in Morice Lake may also be adversely affected by increased water levels and shoreline erosion. It is estimated that 300 to 500 sockeye salmon utilize the beach spawning areas.

10. For purposes of egg incubation a flow of 250 cfs should be provided in the Nanika River after spawning has been completed. This should be maintained until such time that flows would naturally drop below this level. Beyond this time the minimum flow could be regulated so as to closely simulate the natural flow regime. At no time prior to the end of June should flows be less than 100 cfs.

11. An incubation flow of 1,000 cfs should be provided in the upper Morice River from the end of the spawning period to December 31. The flow could be reduced in stages to 500 cfs during the period January 1 to July 15, except when natural flows would drop below this level.

12. Decreases in the coho rearing capability of the Morice River from Morice Lake to Owen Creek were predicted by examining declines in the number of wetted log jams and the amount of braiding with reduced flows during the spring and summer. Of the rearing capacity available at 3,000 cfs, it was predicted that 19 percent would be lost by reducing the minimum summer discharge to 1,500 cfs, and 55 percent would be lost by reducing the discharge to 500 cfs.

13. Observations indicate that barriers to upstream salmon migration would not occur in the Nanika and Morice Rivers with flows reduced to 155 cfs and 1,460 cfs, respectively. However, it is tentatively considered that flows will have to be at least in the range of the normal spawning discharge to encourage migration. This would represent about 1,000 cfs in the Nanika River from July 23 and 3,000 cfs in the Morice River from July 15 until spawning commences in each river.

14. With discharges in excess of 184 cfs in the Nanika River and 1,000 cfs in the upper Morice River, water temperatures should not reach critical levels for juvenile and adult salmon during hot summer periods (July 15 to September 15). Lower discharges in either of these rivers could result in lethal temperature conditions.

15. Flushing flows may be required every few years in the Nanika and Morice Rivers for cleaning spawning gravel. The discharge requirements for flushing could not be determined as part of this study and it is therefore recommended that these be investigated.

16. Fishways installed at Moricetown Falls on the Bulkley River in 1951 by the Fisheries and Marine Service were designed to operate over a discharge range of 2,000 to 10,000 cfs. However, in the lower part of this range their capacity may not be sufficient to accommodate upstream migrants during the peak of the run without imposing unacceptable delay. It is therefore considered that the discharge should not be reduced below 3,500 cfs without extensive modification of the fishways.

17. Additional investigations should be undertaken to determine how diversion of the Nanika and Morice Rivers would affect rearing areas, particularly in the Bulkley River. Potential problems include increased water temperatures, increased effluent concentrations from existing and future industrial and municipal sources, and decreased abundance of food for juvenile salmon and resident fish. Increased water temperatures and effluent concentrations may also adversely affect adult salmon during their upstream migration.

C. Economic and Social Impacts

1. It is estimated that the commercial production of salmon and steelhead attributable to that portion of rivers affected by Kemano II exceeds 1,098,000 pieces each year. The net economic yield generated by this annual harvest is \$7,851,000. The present discounted value of this stream of benefits over the period 1975 to 2024 at a discount rate of 9 percent per annum is \$148,843,000.

2. It is estimated that Indians residing in areas adjacent to the Fraser and Skeena River systems catch at least 48,600 pieces of salmon and steelhead each year which originate in waterways affected by Kemano II. The present discounted value of this catch, expressed in equivalent commercial landed values, calculated to the year 2024, and discounted at 9 percent is \$2,659,000. In addition, reduction in fishing stocks utilized by Indian peoples would result in substantial social and cultural disruption.

3. Over one-third of the total resident population of 113,200 persons living in the north central portion of British Columbia participate in 790,000 days of angling activity in this area each year. More than one-third of all this activity, or 293,900 angling days, takes place on waterways which are directly affected by the Kemano II project. A conservative estimate of the present discounted value of both resident and non-resident sport fishing activity that is affected by the Kemano II project is estimated to be \$185,590,000, calculated to the year 2024, and discounted at 9 percent.

4. If it is assumed that the minimum flows and temperature provisions defined by the biological and engineering studies would cause no decrease in fish survival, the fisheries

resource would suffer no economic loss. However, it is estimated that fisheries value losses could range from \$64,594,000 by destruction of one year class of all fish stocks in each river to \$273,395,000 if serious damage was imposed on all year classes.

5. A complete assessment of total economic and social consequences of all the environmental damages imposed on society as a result of the Kemano II project would require further detailed examination of the impact on communities and resources in all of the affected river systems, and of the compensatory requirements of both local and non-local residents.